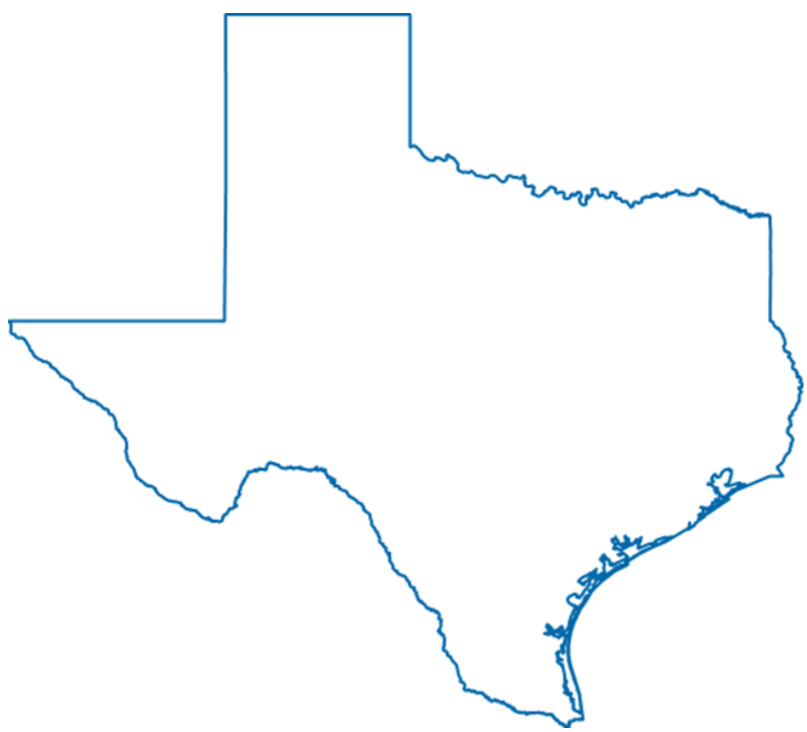
Public Utility Commission of Texas

Texas Technical Reference Manual

Version 4.0

Volume 2: Residential Measures

Program Year (PY) 2017



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Acknowledgments

The Technical Reference Manual is maintained by the Public Utility Commission of Texas' independent Evaluation, Monitoring and Verification (EM&V) team members—Tetra Tech, The Cadmus Group, Itron, and Johnson Consulting Group.

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 2001-2015 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2015 by Frontier Associates. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as 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 v4.0 serves as a centralized source of deemed savings values. Where appropriate, Measurement & Verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1-1 provides an overview of the residential measures contained within this TRM 4.0 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.

Table 1-1: Residential Deemed Savings by Measure Category

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	4.0 Update
Lighting	Standard Compact Fluorescent Lamps	–	–	X	–	–	Updated IEF values and useful life estimates.
	Specialty Compact Fluorescent Lamps	–	–	X	–	–	Updated IEF values and useful life estimates.
	ENERGY STAR® Omni-Directional LED Lamps	–	–	X	–	–	Updated IEF values and useful life estimates.
	ENERGY STAR® Specialty and Directional LED Lamps	–	–	X	–	–	Updated IEF values.
HVAC	Duct Efficiency Improvement	–	–	X	–	X	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.
	Central Air Conditioner	–	X	–	–	–	Added RUL value for units with an age of one year. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years.
	Ground Source Heat Pump	–	X	X	–	–	No revision.
	Central Heat Pump	–	X	–	–	–	Added RUL value for units with an age of one year. Added a default

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	4.0 Update
							RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years.
	Room Air Conditioner	–	–	X	–	–	Added RUL values for units with an age of one to three years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years.
Building Envelope	Air Infiltration	–	X	–	–	X	Updated energy and demand savings per new prototype energy simulation models. Introduced new protocols related to maximum CFM reduction percentage and its associated documentation requirements. Added a new example for calculating savings.
	Ceiling Insulation	–	X	–	–	–	Updated energy and demand savings per new prototype simulation models and introduced new protocols for baseline and post-retrofit R-values, their associated savings estimations and documentation requirements.
	Attic Encapsulation	–	X	–	–	–	TRM v4.0 origin.
	Wall Insulation	–	X	–	–	–	Updated energy and demand savings per new prototype energy simulation models. Added separate savings for 2x4 and 2x6 wall framing and for homes with central AC versus

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	4.0 Update
							evaporative cooling. Added a two-tier baseline definition of R-0 and R-4.
	Floor Insulation	–	X	–	–	–	Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. Disqualified homes with gas heating for adding floor insulation.
	ENERGY STAR® Windows	–	X	–	–	–	Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.
	Solar Screens	–	X	–	–	–	Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.
Domestic Water Heating	Faucet Aerators	–	–	X	–	–	Updated methodology to calculate energy and demand savings.
	Low-Flow Showerheads	–	–	X	–	–	Updated methodology to calculate energy and demand savings.
	Water Heater Pipe Insulation	–	–	X	–	–	No revision.
	Water Heater Tank Insulation	–	–	X	–	–	No revision.
	Water Heater Installation – Electric Tankless and Fuel Substitution	–	–	X	–	–	Updated HPWH baseline usage for gas storage water heaters larger than 55 gallons.
	Heat Pump Water Heater	–	X	–	–	–	Consolidated table formats.
	Water Heater Replacement–	–	X	–	–	–	No revision.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	4.0 Update
	Solar Water Heating						
Appliances	ENERGY STAR® Ceiling Fans	–	–	X	–	–	Updated IEF values.
	ENERGY STAR® Clothes Washer	–	X	–	–	–	No revision.
	ENERGY STAR® Dishwasher	–	X	–	–	–	No revision.
	ENERGY STAR® Refrigerator	–	–	X	–	X	No revision.
Renewable Energy Systems	Solar Photovoltaic (PV)	–	–	X	X	X	Moved to the M&V volume, Volume 4.
Load Management	Direct Load Control of Outdoor Compressor Units	X	–	–	–	–	Moved to the M&V volume.
	Direct Load Control of Swimming Pool Pump Motors	-	–	–	–	X	
Appliance Recycling	Refrigerator/ Freezer Recycling	X	–	X	–	–	No revision.

2 RESIDENTIAL MEASURES

2.1 RESIDENTIAL: LIGHTING

2.1.1 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

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure provides a method for calculating savings for replacement of an incandescent lamp with a 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 www.lightingfacts.com/Library/Content/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 indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

Baseline Condition

The baseline is assumed to be the Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2-21). Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen-per-watt efficacy standard. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[1] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

Table 2-1: ENERGY STAR® Standard CFLs – EISA Baselines[2]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (B_{ase})	2nd Tier EISA 2007 (B_{ase}) [3]	Effective Dates For 2nd Tier EISA 2007 Standards*
310	749	40	29	12	1/1/2020
750	1,049	60	43	20	1/1/2020
1,050	1,489	75	53	28	1/1/2020
1,490	2,600	100	72	45	1/1/2020

*While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

[1] This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

[2] 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.

[3] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

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 2-21) 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.

Energy Savings

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

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

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

Equation 1

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 2

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 http://lightingfacts.com/Library/Content/EISA

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[7]

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 2-21 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 2-2 for 1st Tier EISA 2007 default wattages).*

Table 2-2: ENERGY STAR® Standard CFLs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[8]	9–11 W	12–15 W	18–20 W	23–27 W
If Unknown: Default Installed CFL Wattage[9]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

$W_{base,ST}$ = *Second-tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in I Table 2-21under the column "Incandescent Equivalent 2nd Tier EISA 2007" (if unknown, see Table 2-2 for 2nd Tier EISA 2007 default wattages).*

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

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[10])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-3).*

[7] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

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

[9] 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.

[10] 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.

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* [11]

Table 2-3: ENERGY STAR® Standard CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[12]

	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[13]	0.87	1.03	1.08	1.12	1.01
Upstream Lighting[14]	0.89	1.03	1.07	1.10	1.01

* IEF for homes with no AC are 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. Annual summer or winter peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

[11] 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.

[12] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[13] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[14] Ibid.

For the first tier EISA baseline period:

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

Equation 3

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

Equation 4

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta \mathrm{kW}_{\mathrm{summer}} = \frac{(\mathrm{W}_{\mathrm{base,ST}} - \mathrm{W}_{\mathrm{post}})}{1000} \times \mathrm{CF}_{\mathrm{summer}} \times \mathrm{ISR} \times \mathrm{IEF}_{\mathrm{D,summer}}$$

Equation 5

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

Equation 6

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[15]

Where:

CF	=	*Coincidence Factor (see Table 2-4)*
IEF_D	=	*Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-5)*

Table 2-4: ENERGY STAR® Standard CFLs – Coincidence Factors[16]

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	0.277	0.232	0.199	0.267	0.357

[15] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[16] See Volume 1, Appendix B.

Table 2-5: ENERGY STAR® Standard CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[17]

$IEF_{D,summer}$					
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	1.27	1.28	1.19	1.23	1.37
Electric Resistance Heat with AC	1.07	1.27	1.07	1.23	1.36
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[18]	1.24	1.43	1.46	1.51	1.37
Upstream Lighting[19]	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
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[20]	0.75	0.80	0.83	0.85	0.81
Upstream Lighting[21]	0.78	0.83	0.85	0.86	0.83

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

[17] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[18] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[19] Ibid.

[20] Ibid.

[21] Ibid.

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

The average measure life is based upon 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. The algorithms below are designed to provide EISA Tier 1 and EISA Tier 2 measure lives, each to be applied to the appropriate tier of EISA savings.

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

Equation 7

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

Equation 8

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

Equation 9

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.[22]
DF	=	*0.85 degradation factor*[23]
HOU	=	*2.2 hours per day*[24]
2021	=	*One-year lag applied to year that EISA Tier 1 energy efficiency standard ends*

Table 2-6: ENERGY STAR® Standard CFLs – Estimated Useful Life

Range of Rated Measure Life (Hours)	Rated Measure Life Assumed (Hours)	Total Measure Life (Years)	EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
10,000–11,000	10,000	11	4	7
11,001–13,500	12,000	13	4	9
13,501–17,500	15,000	16	4	12
≥ 17,501	20,000	20*	4	16

* Measure life capped at 20 years.

Program Tracking Data & 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:

- 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)
- Program type (direct install, retail)

[22] 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.

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

[24] 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.

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 2-7: Residential Compact Fluorescent Lamp 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	March 2016	Updated summer and winter coincidence factors.
v4.0	10/10/2016	Updated IEF values and useful life estimates.

2.1.2 Specialty Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-SCF

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

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 indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

Baseline Condition

The baseline wattage will be determined based on the bulb shape of the installed lamp as outlined below.

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 2-10 through Table 2-12. 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 or Second Tier EISA baseline default wattage in table below.

Table 2-8: ENERGY STAR® CFLs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[25]	9–11 W	12–15 W	18–20 W	23–27 W
If Unknown: Default Installed CFL Wattage[26]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

- Non-Reflector Lamps, not affected by EISA 2007: 60 watts[27]
- Reflector Lamps affected by the DOE ruling in 2009 on IRLs: 60 watts[28]
- Reflector Lamps not affected by the DOE ruling in 2009 on IRLs: the appropriate default baseline may be determined using Table 2-9.

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

[26] 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.

[27] 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)

[28] Ibid.

Table 2-9: DOE-Ruling Exempt Reflectors – Default Wattages

Lamp Type	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[29]

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; and**
- **B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts.[30]**

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[31] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

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29 Ibid.

30 http://www.lightingfacts.com/Library/Content/EISA

31 This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year.
Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

Table 2-10: EISA-Affected Specialty CFL Baselines (Non-Reflectors)[32]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{Base,FT}$)	Incandescent Equivalent 2nd Tier EISA 2007 ($W_{Base,ST}$)[33]	Effective Dates For 2nd Tier EISA 2007 Standards*
• 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	310	749	29	12	1/1/2020
	750	1,049	43	20	1/1/2020
	1,050	1,489	53	28	1/1/2020
	1,490	2,600	72	45	1/1/2020

*While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

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; and**
- **B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less.**[34]

[32] Ibid.
[33] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.
[34] http://www.lightingfacts.com/Library/Content/EISA.

Table 2-11: EISA-Exempt Specialty CFL Baselines (Non-Reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	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.[35]		

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; and**
- **40-205 Watt incandescent PAR lamps.**[36]

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 2-12).

[35] 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)

[36] 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 2-12: DOE IRL Ruling-Affected Specialty CFL Baselines (Reflectors)[37,38]

Lamp Type	Lumen Range	B_{ase}
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

[37] 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.
GE Lighting catalog:
http://www.gelighting.com/LightingWeb/na/smartcatalogs/Lighting_and_Ballasts_Section_1_Incandescent_Lamps.pdf
Sylvania catalog: http://assets.sylvania.com/assets/documents/complete-catalog.b176dbb1-d6e0-40f0-ab92-e768e58f5dc1.pdf
Philips catalog: http://www.usa.lighting.philips.com/connect/tools_literature/downloads/sg100-2013.pdf
Illinois TRM 2014: http://www.ilsag.info/technical-reference-manual.html

[38] Table 2-12 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	B_{ase}
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
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; and**
- **R20 IRLs rated 45 watts or less.[39]**

Table 2-13: DOE-Ruling Exempt Reflectors

Lamp Type	B_{ase}
BR30 (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.
BR40 (65 watt)	
ER40 (65 watt)	
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)	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.
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	

[39] 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

High-Efficiency Condition

New CFLs must be ENERGY STAR® specialty CFLs as outlined in the latest ENERGY STAR® specification.[40] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps.

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.

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.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

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

Equation 10

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 11

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

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[41]

For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), annual energy (kWh) savings are not calculated using the two-tiered system. Instead, annual energy (kWh) savings are calculated using one algorithm.

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

Equation 12

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 2-10 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-10 under the column "Incandescent Equivalent 2nd Tier EISA 2007."*

W_{base} = *EISA-exempt specialty lamp or a DOE ruling-exempt reflector, use the nameplate wattage (see Table 2-12 and Table 2-13). If a DOE-ruling-affected IRL, use the wattages provided in Table 2-12.*

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

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[42])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-14).*

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*[43]

[41] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

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

[43] 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

Table 2-14: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[44]

Heating/Cooling Type*	IEF$_E$ Climate Zone 1	IEF$_E$ Climate Zone 2	IEF$_E$ Climate Zone 3	IEF$_E$ Climate Zone 4	IEF$_E$ 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[46]	0.87	1.03	1.08	1.12	1.01
Upstream Lighting[47]	0.89	1.03	1.07	1.10	1.01

* IEF for homes with no AC are 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. For EISA-affected specialty lamps only, peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

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

[44] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[45] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[46] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[47] Ibid.

For the first tier EISA baseline period:

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

Equation 13

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

Equation 14

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 15

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

Equation 16

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[48]

<u>For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected)</u>, 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.

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

Equation 17

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

Equation 18

Where:

CF = *Coincidence Factor (see Tabel 2-15)*

[48] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-16)*

Table 2-15: ENERGY STAR® CFLs – Coincidence Factors[49]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.277	0.232	0.199	0.267	0.357

Table 2-16: ENERGY STAR® CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[50]

$IEF_{D,summer}$					
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	1.27	1.28	1.19	1.23	1.37
Electric Resistance Heat with AC	1.07	1.27	1.07	1.23	1.36
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.45	1.33	1.68	1.23	1.44
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown[51]	1.24	1.43	1.46	1.51	1.37
Upstream Lighting[52]	1.20	1.36	1.39	1.43	1.31

49 See Volume 1, Appendix B.

50 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: $1 + HVAC_{savings}/Lighting_{savings}$.

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

52 Ibid.

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[53]	0.75	0.80	0.83	0.85	0.81
Upstream Lighting[54]	0.78	0.83	0.85	0.86	0.83

* IEF for homes with no AC are 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

The average measure life is based upon 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

[53] Ibid.
[54] Ibid.

blended usage for indoor/outdoor applications, and applies a 0.85 degradation factor to indoor/outdoor CFLs.

For an EISA-affected lamp, the following algorithms are designed to provide EISA Tier 1 and EISA Tier 2 measure lives, each to be applied to the appropriate tier of EISA savings.

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

Equation 19

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

Equation 20

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

Equation 21

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.*[55]
DF	=	*0.85 degradation factor*[56]
HOU	=	*2.2 hours per day*[57]
2021	=	*One-year lag applied to year that EISA Tier 1 energy efficiency standard ends*

For EISA-exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), use the following algorithm to calculate the measure life.

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

Equation 22

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[55] 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

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

[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.

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.*[58]
DF	=	*0.85 degradation factor*[59]
HOU	=	*2.2 hours per day*[60]

Table 2-17: ENERGY STAR® Specialty CFLs – Estimated Useful Life

Range of Rated Measure Life (Hours)	Rate Measure Life Assumed (Hours)	Total Measure Life (Years)	If Applicable:	
			EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
10,000–11,000	10,000	11	4	7
11,001–13,500	12,000	13	4	9
13,501–17,500	15,000	16	4	12
≥ 17,501	20,000	20*	4	16

* Measure life capped at 20 years.

Program Tracking Data & 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:

- 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)

[58] 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.

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

[60] 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.

- 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)

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 2-18: Residential Specialty Compact Fluorescent Lamp 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	March 2016	Updated summer and winter coincidence factors.
v4.0	10/10/ 2016	Updated IEF values and useful life estimates.

2.1.3 ENERGY STAR® Omni-Directional LED Lamps Measure Overview

TRM Measure ID: R-LT-OLED

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure provides a method for calculating savings for replacement of an incandescent lamp with an omni-directional LED[61] 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 indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

[61] 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%. At least 5% 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.

Baseline Condition

The baseline is assumed to be the EISA-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2-19). Baseline wattages should be adjusted as EISA regulations dictate higher efficiency baseline lamps. The second tier of EISA 2007 regulations go into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen per watt efficacy standard. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[62] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

Table 2-19: ENERGY STAR® Omni-Directional LEDs – EISA Baselines[63]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (B_{ase})	2nd Tier EISA 2007 (B_{ase}) [64]	Effective Dates For 2nd Tier EISA 2007 Standards*
310	749	40	29	12	1/1/2020
750	1,049	60	43	20	1/1/2020
1,050	1,489	75	53	28	1/1/2020
1,490	2,600	100	72	45	1/1/2020

* While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

High-Efficiency Condition

LEDs must be ENERGY STAR® -qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[65] 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.

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

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62 This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

63 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.

64 Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

65 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 2-19) 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.

Energy Savings

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

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

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

Equation 23

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 24

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[66]

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 2-19 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 2-20 for 1st Tier EISA 2007 default wattages).*

[66] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

Table 2-20: ENERGY STAR® Omni-Directional LEDs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[67]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[68]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-19 under the column "Incandescent Equivalent 2nd Tier EISA 2007" (if unknown, see Table 2-20 for 2nd Tier EISA 2007 default wattages).*

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

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[69])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-21).*

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*[70]

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

[68] 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.

[69] 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.

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

Table 2-21: ENERGY STAR® Omni-Directional LEDs Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[71]

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[72]	0.87	1.03	1.08	1.12	1.01
Upstream Lighting[73]	0.89	1.03	1.07	1.10	1.01

* IEF for homes with no AC are 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. Annual summer or winter peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

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

Equation 25

[71] 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 + $HVAC_{savings}/Lighting_{savings}$.

[72] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[73] Ibid.

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

Equation 26

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 27

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

Equation 28

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[74]

Where:

CF = *Coincidence Factor (see Table 2-22)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-23).*

Table 2-22: ENERGY STAR® LEDs – Coincidence Factors[75]

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	0.277	0.232	0.199	0.267	0.357

[74] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[75] See Volume 1, Appendix B.

Table 2-23: ENERGY STAR® Omni-directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[76]

$IEF_{D,summer}$					
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	1.27	1.28	1.19	1.23	1.37
Electric Resistance Heat with AC	1.07	1.27	1.07	1.23	1.36
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[77]	1.24	1.43	1.46	1.51	1.37
Upstream Lighting[78]	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
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[79]	0.75	0.80	0.83	0.85	0.81
Upstream Lighting[80]	0.78	0.83	0.85	0.86	0.83

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

[76] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[77] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[78] Ibid.

[79] Ibid.

[80] Ibid.

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

The measure life for indoor and outdoor LED omni-directional lamps is capped at 20 years.[81] Due to the EISA standards, the savings over the useful life will need to be adjusted to account for second tier EISA standards for all years as of 2021.

Table 2-24: ENERGY STAR® Omni-Directional LEDs – Estimated Useful Life

Total Measure Life (Years)	EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
20	4	16

Program Tracking Data & 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:

- Number of LEDs installed
- Wattage of each installed LED

[81] Mid-Atlantic Technical Reference Manual Version 5.0. Prepared by Shelter Analytics. Facilitated and Managed by the Northeast Energy Efficiency Partnerships (NEEP). June 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf.

- 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)

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 2-25: Residential Omni-Directional LED Lamp 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	March 2016	Updated summer and winter coincidence factors.
v4.0	10/10/2016	Updated IEF values and useful life estimates.

2.1.4 ENERGY STAR® Specialty and Directional LED Lamps Measure Overview

TRM Measure ID: R-LT-DLED

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

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.[82]

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 indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

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

Baseline Condition

The baseline wattage will be determined based on the bulb shape of the installed lamp as outlined below.

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 2-28 through Table 2-31 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 or Second Tier EISA baseline default wattage in Table 2-26.

Table 2-26: ENERGY STAR® Specialty LEDs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[83]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[84]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

- **Non-Reflector Lamps, not affected by EISA 2007: 60 watts**[85]
- **Reflector Lamps affected by the DOE ruling in 2009 on IRLs:** 60 watts[86]
- **Reflector Lamps not affected by the DOE ruling in 2009 on IRLs:** the appropriate default baseline may be determined using Table 2-27.

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

[84] 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.

[85] 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)

[86] Ibid.

Table 2-27: DOE-Ruling Exempt Reflectors – Default Wattages

Lamp Type	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[87]

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; and**
- **B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts.[88]**

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[89] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

87 Ibid.

88 http://www.lightingfacts.com/Library/Content/EISA.

89 This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

Table 2-28: EISA-Affected Specialty LED Baselines (Non-Reflectors)[90]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{Base,FT}$)	Incandescent Equivalent 2nd Tier EISA 2007 ($W_{Base,ST}$)[91]	Effective Dates For 2nd Tier EISA 2007 Standards*
• 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	310	749	29	12	1/1/2020
	750	1,049	43	20	1/1/2020
	1,050	1,489	53	28	1/1/2020
	1,490	2,600	72	45	1/1/2020

* While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

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; and**
- **B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less.[92]**

90 Ibid.

91 Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

92 http://www.lightingfacts.com/Library/Content/EISA.

Table 2-29: EISA-Exempt Specialty LED Baselines (Non-Reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	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.[93]		

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; and**
- **40-205 Watt incandescent PAR lamps.[94]**

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 2-20).

93 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)

94 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 2-30: DOE IRL Ruling-Affected Specialty LED Baselines (Reflectors)[95,96]

Lamp Type	Lumen Range	B_{ase}
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

95 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.
GE Lighting catalog: http://www.gelighting.com/LightingWeb/na/smartcatalogs/Lighting_and_Ballasts_Section_1_Incandescent_Lamps.pdf
Sylvania catalog: http://assets.sylvania.com/assets/documents/complete-catalog.b176dbb1-d6e0-40f0-ab92-e768e58f5dc1.pdf
Philips catalog: http://www.usa.lighting.philips.com/connect/tools_literature/downloads/sg100-2013.pdf
Illinois TRM 2014: http://www.ilsag.info/technical-reference-manual.html

96 Table 2-30 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	Base
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
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; and**
- **R20 IRLs rated 45 watts or less.**[97]

Table 2-31: DOE-Ruling Exempt Reflectors

Lamp Type	Base
BR30 (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.
BR40 (65 watt)	
ER40 (65 watt)	
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)	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.
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	

[97] 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.

High-Efficiency Condition

LEDs must be ENERGY STAR® -qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[98] 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.

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.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings must be calculated separately for two time periods:

- **First Tier EISA Baseline = 2021 – installation year = 5 years**
- **The remaining time in the EUL period**

For the first tier EISA baseline period:

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

Equation 29

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 30

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[99]

98 http://www.energystar.gov/products/certified-products/detail/light-bulbs

99 While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), annual energy (kWh) savings are not calculated using the two-tiered system. Instead, annual energy (kWh) savings are calculated using one algorithm.

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

Equation 31

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 2-28 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-28 under the column "Incandescent Equivalent 2nd Tier EISA 2007".*

W_{base} = *EISA-exempt specialty lamp or a DO E ruling-exempt reflector, use the nameplate wattage (see Table 2-29 and Table 2-31. If a DOE-ruling-affected IRL, use the wattages provided in Table 2-30.*

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

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[100])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-32).*

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*[101]

[100] 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.

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

Table 2-32: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[102]

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[103]	0.87	1.03	1.08	1.12	1.01
Upstream Lighting[104]	0.89	1.03	1.07	1.10	1.01

* IEF for homes with no AC are 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. For EISA-affected specialty lamps only, peak demand (kW) savings must be calculated separately for two time periods:

- **First Tier EISA Baseline = 2021 – installation year = 5 years**
- **The remaining time in the EUL period**

For the first tier EISA baseline period:

[102] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[103] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

[104] Ibid.

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

Equation 32

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

Equation 33

For the remaining time in the EUL period, use the second tier EISA baseline:

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

Equation 34

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

Equation 35

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[105]

<u>For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected)</u>, 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.

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

Equation 36

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

Equation 37

Where:

CF	=	*Coincidence Factor (Table 2-33)*
IEF_D	=	*Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-34).*

105 While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

Table 2-33: ENERGY STAR® LEDs – Coincidence Factors[106]

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	0.277	0.232	0.199	0.267	0.357

Table 2-34: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[107]

$IEF_{D,summer}$					
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	1.27	1.28	1.19	1.23	1.37
Electric Resistance Heat with AC	1.07	1.27	1.07	1.23	1.36
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[108]	1.24	1.43	1.46	1.51	1.37
Upstream Lighting[109]	1.20	1.36	1.39	1.43	1.31

106 See Volume 1, Appendix B.

107 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: $1 + HVAC_{savings}/Lighting_{savings}$.

108 Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

109 Ibid.

$IEF_{D,winter}$					
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[110]	0.75	0.80	0.83	0.85	0.81
Upstream Lighting[111]	0.78	0.83	0.85	0.86	0.83

* IEF for homes with no AC are 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.

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110 Ibid.

111 Ibid.

Measure Life and Lifetime Savings

The measure life for indoor and outdoor LED reflector and decorative lamps is capped at 20 years.[112]

Program Tracking Data & 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:

- Number of LEDs installed
- ANSI C79.1-2002 nomenclature of CFL 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)
- 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)

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

[112] Mid-Atlantic Technical Reference Manual Version 5.0. Prepared by Shelter Analytics. Facilitated and Managed by the Northeast Energy Efficiency Partnerships (NEEP). June 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf.

Document Revision History

Table 2-35: Residential Specialty and Directional LED Lamp 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	March 2016	Updated summer and winter coincidence factors.
v4.0	10/10/2016	Updated IEF values.

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

2.2.1 Air Conditioner or Heat Pump Tune-up Measure Overview

TRM Measure ID: To be determined

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 Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure applies to central air conditioners and heat pumps of any configuration as long as everything on the checklist below can be 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. In order 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[113]

- 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

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

- Inspect controls of the system to ensure proper and safe operation. Check the startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Clean evaporator and condenser coils
- 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 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:

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

Equation 38

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

Equation 39

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[114] HSPF. A 13 SEER is equivalent to approximately 11.2 EER[115] 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% due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[116]

Energy Savings Algorithms

Heating energy savings are only applicable to heat pumps.

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

Equation 40

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

Equation 41

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

[115] 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.

[116] 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 42

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 41 [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 42 [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 2-36: Equivalent full load cooling/heating hours[117]

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

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

Equation 43

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

Equation 44

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

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*[118] = *0.87*

DF_H = *Heating demand factor = 0.83 (heat pumps, default)*[119]

Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 2-37. Heating savings are only applicable for heat pumps.

Table 2-37: 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

Deemed Summer Demand Savings Tables

Applying the above algorithms results in the deemed summer demand savings per ton in Table 38.

Table 2-38:Deemed Summer Demand Savings per ton

Climate Zone	Summer Peak Demand kW Savings per Ton
All Zones	0.04680

118 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential air conditioners be sized at 115% 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.

119 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115% 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 Winter Demand Savings Tables

Applying the above algorithms results in the deemed winter demand savings per ton in Table 39. Winter peak demand savings are only applicable for heat pumps.

Table 2-39: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 5 years. [120]

According to the 2014 California Database for Energy Efficiency Resources (DEER), the estimated useful life of cleaning condenser and evaporator coils is 3 years [121], and the estimated useful life of refrigerant charge adjustment is 10 years.[122] The other parts of the tune-up checklist are not listed in DEER, therefore 5 years, as referenced by the Measure Life Report, is used as the best representation of the entire tune-up.

Program Tracking Data & 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:

- Manufacturer
- Model Number
- Cooling capacity of the installed unit (tons)
- Climate zone or county of the site
- Type of unit
    - Air conditioner

[120] 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.

[121] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/files/DEER2013codeUpdate/download/DEER2014-EUL-table-update_2014-02-05.xlsx.

[122] ibid

    - Air source heat pump
- Recommended:
    - Serial number
    - Refrigerant type
    - Target superheat or subcooling
    - Post tune-up superheat or subcooling
    - Amount of refrigerant added or removed
    - Static pressures before and after tune-up
    - Return and supply dry bulb and wet bulb temperatures
    - Before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment name plates are useful)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Document Revision History

Table 2-40: Residential Specialty and Directional LED Lamp Revision History

TRM Version	Date	Description of Change
v4.0	10/10/2015	TRM v4.0 origin

2.2.2 Duct Efficiency Improvement Measure Overview

TRM Measure ID: R-HV-DE

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: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Building Simulation Modeling

Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems of homes or converted residences with central air conditioning.

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.

Duct leakage should be assessed following Building Performance Institute (BPI) standards through testing. In some limited cases, where testing is not possible or unsafe (e.g. due to potential presence of asbestos), visual assessment may be satisfactory. The 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.[123]

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

[123] 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."*

Duct sealing is a residential retrofit measure.

Table 2-41: Duct Sealing – Applicability

Application Type	Applicable	Notes
Retrofit	Y	Leakage-to-outside testing is required
New Construction	N	

Baseline Condition

The savings calculation methods for this measure are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[124] 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.[125]

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

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 energy savings requires duct leakage-to-outside testing using a combination duct pressurization and house pressurization.

Duct Leakage Testing

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. For this measure, leakage-to-outside must be directly measured. The Project Sponsor shall use the Combination Duct Blaster™ (or equivalent) and Blower Door method. Prior to beginning any installations, the Project Sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician

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124 $Total\ Fan\ Flow = Cooling\ Capacity\ (tons) \times 400$

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

126 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).

Excellence (NATE) certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[127]

Energy and Demand Savings Methodology

The annual energy and summer and winter peak demand savings to be claimed 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 2-42 through Table 2-45 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

Savings Algorithms and Input Variables

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

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

Deemed Energy Savings Tables

Table 2-42 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:

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

Equation 45

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 2-42*

[127] 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.

$V_{E,H}$ = *Heating Energy Savings Coefficient in Table 2-42*

Table 2-42: 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

For program year 2017 only utilities may, at their discretion, calculate energy savings for this measure using the method described in TRM 3.1, and multiplying the result by the factor indicated in Table 2-43, corresponding to the appropriate weather zone and heating type.

Table 2-43: 2017 Energy Adjustment Factors

Heating Type	Region				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Gas	0.858	0.640	0.640	0.606	1.040
Electric Resistance	0.567	0.562	0.575	0.578	0.583
Heat Pump	0.561	0.566	0.585	0.583	0.601

Deemed Summer Demand Savings Tables

Table 2-44 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:

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

Equation 46

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 2-163*

Table 2-44: 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 2-45 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:

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

Equation 47

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 2-163*

Table 2-45: 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

For program year 2017 only utilities may, at their discretion, calculate demand reductions for this measure using the method described in TRM 3.1—which does not have separate summer and winter reductions--and multiplying the result by the factor indicated in Table 2-46, corresponding to the appropriate weather zone and heating type.

Table 2-46: 2017 Demand Adjustment Factors

Heating Type	Region				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Gas	0.921	0.709	0.759	0.642	1.007
Electric Resistance	0.913	0.741	0.755	0.639	0.997
Heat Pump	0.909	0.703	0.752	0.638	0.991

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. 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}.

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

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

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

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

$$Summer\ kW\ savings = 1.06x10^{-3} \times 390 = 0.41\ \text{kW}$$

$$Winter\ kW\ savings = 8.60x10^{-6} \times 390 = 0.003\ \text{kW}$$

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).[128]

Program Tracking Data & 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:

- The climate zone
- Heating type (gas, resistance heat, heat pump)
- Cooling capacity of home HVAC units (tons)
- Pre-improvement duct leakage at 25 Pa (cu. ft./min)

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[128] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

- Post-improvement duct leakage at 25 Pa (cu. ft./min)

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 2-47: Duct Efficiency Improvement 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.

2.2.3 Central Air Conditioner Measure Overview

TRM Measure ID: R-HV-AC

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Residential replacement of an existing central air conditioning system with a new central air conditioning system in an existing building, or the installation of a new central air conditioning system in a new residential construction. A new central air conditioning system includes an entire packaged unit, or a split system consisting of an indoor unit with a matching remote condensing unit.

Prior to July 1, 2016, utilities may, at their discretion, claim savings according to TRM v2.1. A settlement between the U.S. Department of Energy and the American Public Gas Association permits distributors and retailers to sell split-system central air conditioners that do not meet regional standards without penalty until July 1, 2016, provided they comply with federal standards and were manufactured before January 1, 2015.[129] After July 1, 2016, the Department of Energy's enhanced regional standards for Texas[130] will determine the baseline and efficient conditions, as provided below.

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[129] "Due to the uncertainty created by the litigation and in an exercise of its enforcement discretion, DOE will not seek civil penalties for violations of the regional standards applicable to central air conditioners that occur prior to July 1, 2016, provided that the violations are related to the distribution in commerce (including sales by retailers and installation) of units manufactured prior to January 1, 2015. DOE will continue to enforce the base national standard for central air conditioners and central air conditioning heat pumps."
American Public Gas Association v. United States Department of Energy, et al. "JOINT MOTION OF ALL PARTIES AND INTERVENORS TO VACATE IN PART AND REMAND FOR FURTHER RULEMAKING." USCA Case No. 11-1485. http://causeofaction.org/assets/uploads/2014/03/Joint-Motion.pdf. Filed March 11, 2014.

[130] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

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.

Air conditioning equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.

Manufacturer data sheets on installed air conditioning equipment or AHRI reference numbers must be provided.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[131] when designing programs that permit savings to be claimed for early retirement. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 24 years.

Replacement of an evaporative cooler with a central air conditioner is eligible where the decision to change equipment types predates or is independent of the decision to install efficient equipment.

Baseline Condition

New construction baseline efficiency values for air conditioners are compliant with the current federal standard,[132] effective January 1, 2015. The baseline is assumed to be a new air conditioner system with an AHRI-listed SEER rating of 14.0.

For replace-on-burnout (ROB) projects, the baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current non-program replacements that do not include the installation of an AHRI-matched system.[133]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 12.44[134] SEER at that time.

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131 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.

132 DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

133 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.

134 Refer to Texas TRM 2.1 for savings using 12.44 SEER baseline.

Table 2-48: Central Air Conditioner Baseline Efficiencies

Project Type	Cooling Mode
New Construction	14.00 SEER
Replace-on-Burnout	13.08 SEER
Early Retirement (as of 1/23/2006)	12.44 SEER
Early Retirement (before 1/23/2006)	10.00 SEER

High-Efficiency Condition

Table 2-49 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 1 air conditioners as of January 1, 2009. Energy efficiency service providers are expected to comply with the latest CEE Tier 1 requirements.

Table 2-49: Central Air Conditioner CEE Tier 1 Requirements

SEER	EER
14.5	12.0

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction and Replace-on-Burnout

Energy and summer demand savings were estimated using air conditioner performance curves developed by the National Renewable Energy Laboratory[135] for typical units in each of the following SEER ranges:

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

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

[135] 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.

These performance curves provide the capacity and efficiency of the air conditioners 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.

Summer demand savings are estimated according to 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). Air conditioner system output was then compared to its loading under design conditions.

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

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

Equation 48

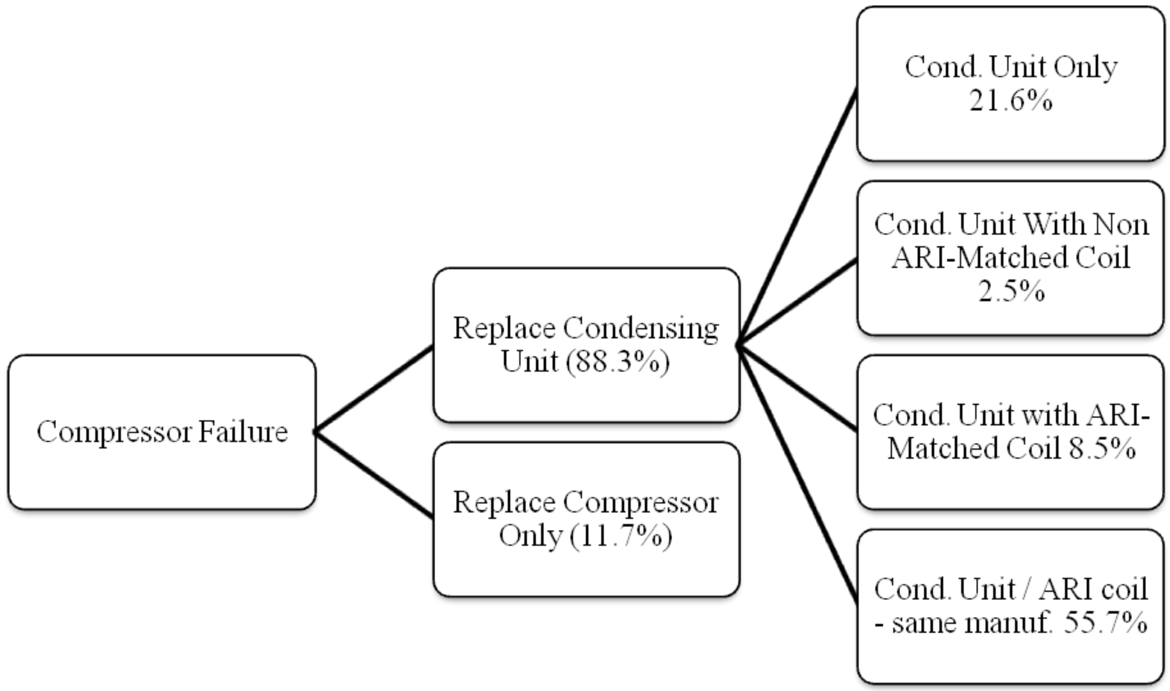
Table 2-50: Air Conditioner Capacity Curve Coefficients

Coefficient	Single Stage	Multi-Stage/Speed	
		Low	High
a	3.670270705	3.940185508	3.109456535
b	-0.098652414	-0.104723455	-0.085520461
c	0.000955906	0.001019298	0.000863238
d	0.006552414	0.006471171	0.00863049
e	-0.0000156	-0.00000953	-0.000021
f	-0.000131877	-0.000161658	-0.000140186

Table 2-51: Air Conditioner EIR Curve Coefficients

Coefficient	Single Stage	Multi-Stage/Speed	
		Low	High
a	-3.302695861	-3.87752688	-1.990708931
b	0.137871531	0.164566276	0.093969249
c	-0.001056996	-0.001272755	-0.00073335
d	-0.012573945	-0.019956043	-0.009062553
e	0.000214638	0.000256512	0.000165099
f	-0.000145054	-0.000133539	-0.0000997

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% of the time, and replaced the condensing unit 88.3% 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:



Source: Docket No. 36780

Figure 2-1: Unit Replacement Percentages upon Compressor Failure

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% 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:

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

Equation 49

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 (18 – 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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-52); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 7.0 years*

EUL = *Estimated Useful Life = 18 years*

Table 2-52: Remaining Useful Life of Replaced Unit

Age of Replaced Unit (years)	Remaining Useful Life (years)	Age of Replaced Unit (years)	Remaining Useful Life (years)
1	16.8	14	8.6
2	15.8	15	8.2
3	14.9	16	7.9
4	14.1	17	7.6
5	13.3	18	7.0
6	12.6	19	6.0
7	11.9	20	5.0
8	11.3	21	4.0
9	10.8	22	3.0
10	10.3	23	2.0
11	9.8	24	1.0
12	9.4	25[136,137]	0.0
13	9.0		

136 RULs are capped at the 75th percentile of equipment age, 25 years, as determined based on DOE survival curves (see Figure 2-2). 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.

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

Derivation of RULs

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

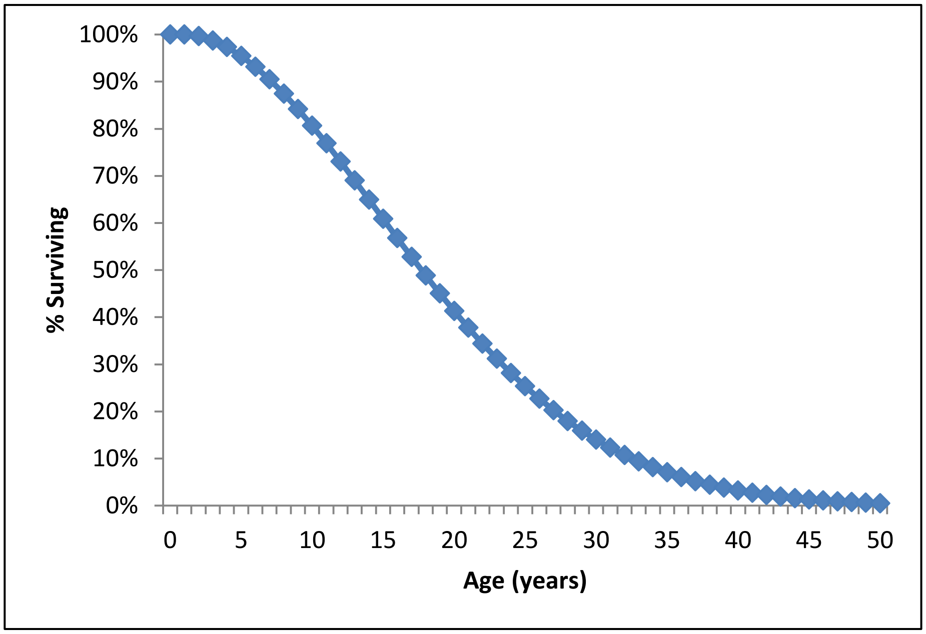


Figure 2-2: Survival Function for Central Air Conditioners[138]

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 2-2. The age of the central air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving air conditioners 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

Table 2-53 through Table 2-57 present the energy savings (kWh) associated with central air conditioners installed in new homes. Table 2-58 through Table 2-62 present energy savings associated with replace-on-burnout of central air conditioners. Table 2-63 through Table 2-67 present energy savings associated with early retirement of central air conditioners.

[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.

New Construction

Table 2-53 through Table 2-57 present the energy savings (kWh) associated with central air conditioners installed in new homes (14 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-53: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	78	150	278	447	527	712
2.0	104	199	370	596	703	949
2.5	130	249	463	745	879	1,186
3.0	156	299	556	894	1,055	1,423
3.5	181	349	648	1,043	1,230	1,661
4.0	207	399	741	1,192	1,406	1,898
5.0	259	499	926	1,490	1,758	2,372

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-54: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	118	227	421	704	823	1,107
2.0	157	302	561	938	1,097	1,477
2.5	196	378	702	1,173	1,372	1,846
3.0	236	453	842	1,407	1,646	2,215
3.5	275	529	982	1,642	1,920	2,584
4.0	314	604	1,122	1,876	2,195	2,953
5.0	393	756	1,403	2,345	2,743	3,691

Climate Zone 3: South Region, Houston Weather Data

Table 2-55: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	125	240	446	784	907	1,211
2.0	166	320	594	1,045	1,210	1,614
2.5	208	400	743	1,306	1,512	2,018
3.0	249	480	891	1,567	1,814	2,421
3.5	291	560	1,040	1,828	2,117	2,825
4.0	333	640	1,188	2,089	2,419	3,228
5.0	416	800	1,485	2,612	3,024	4,035

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-56: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	145	279	518	904	1,048	1,402
2.0	193	372	690	1,205	1,397	1,869
2.5	242	465	863	1,506	1,746	2,336
3.0	290	558	1,035	1,807	2,095	2,804
3.5	338	651	1,208	2,108	2,444	3,271
4.0	387	743	1,381	2,409	2,793	3,738
5.0	483	929	1,726	3,012	3,492	4,673

Climate Zone 5: West Region El Paso Weather Data

Table 2-57: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	101	195	362	622	723	969
2.0	135	260	483	829	965	1,292
2.5	169	325	603	1,037	1,206	1,615
3.0	203	390	724	1,244	1,447	1,939
3.5	236	455	844	1,451	1,688	2,262
4.0	270	520	965	1,659	1,929	2,585
5.0	338	650	1,206	2,073	2,412	3,231

Replace-on-Burnout

Table 2-58 through Table 2-62 present the energy savings (kWh) associated with central air conditioners installed in replace-on-burnout homes (13.08 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-58: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	215	286	415	584	664	849
2.0	286	382	553	779	885	1,131
2.5	358	477	691	973	1,107	1,414
3.0	429	573	829	1,168	1,328	1,697
3.5	501	668	967	1,362	1,550	1,980
4.0	572	764	1,106	1,557	1,771	2,263
5.0	715	955	1,382	1,712	1,991	2,638

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-59: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	325	434	628	911	1,030	1,315
2.0	433	579	838	1,214	1,374	1,753
2.5	542	723	1,047	1,518	1,717	2,191
3.0	650	868	1,256	1,822	2,060	2,629
3.5	759	1,012	1,466	2,125	2,404	3,068
4.0	867	1,157	1,675	2,429	2,747	3,506
5.0	1,084	1,446	2,094	3,036	3,434	4,382

Climate Zone 3: South Region, Houston Weather Data

Table 2-60: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	344	459	665	1,003	1,127	1,430
2.0	459	612	886	1,337	1,502	1,906
2.5	573	765	1,108	1,671	1,878	2,383
3.0	688	918	1,330	2,006	2,253	2,860
3.5	803	1,072	1,551	2,340	2,629	3,336
4.0	918	1,225	1,773	2,674	3,004	3,813
5.0	1,147	1,531	2,216	3,343	3,755	4,766

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-61: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	400	534	773	1,158	1,302	1,657
2.0	533	712	1,030	1,545	1,737	2,209
2.5	666	890	1,288	1,931	2,171	2,761
3.0	800	1,067	1,545	2,317	2,605	3,314
3.5	933	1,245	1,803	2,703	3,039	3,866
4.0	1,066	1,423	2,060	3,089	3,473	4,418
5.0	1,333	1,779	2,576	3,861	4,342	5,523

Climate Zone 5: West Region El Paso Weather Data

Table 2-62: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	280	373	540	800	902	1,147
2.0	373	497	720	1,067	1,202	1,530
2.5	466	622	900	1,334	1,503	1,912
3.0	559	746	1,080	1,600	1,803	2,295
3.5	652	870	1,260	1,867	2,104	2,677
4.0	745	995	1,440	2,134	2,404	3,060
5.0	932	1,244	1,800	2,667	3,006	3,825

Early Retirement

Table 2-63 through Table 2-67 present the early retirement energy savings (kWh) associated with central air conditioners installed in homes for the five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-58 through Table 2-62 to calculate annual savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-63: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	856	927	1,056	1,225	1,305	1,490
2.0	1,141	1,237	1,408	1,633	1,740	1,986
2.5	1,426	1,546	1,759	2,042	2,175	2,483
3.0	1,711	1,855	2,111	2,450	2,610	2,979
3.5	1,996	2,164	2,463	2,858	3,045	3,476
4.0	2,282	2,473	2,815	3,267	3,480	3,972
5.0	2,852	3,091	3,519	4,083	4,351	4,965

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-64: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,296	1,405	1,600	1,882	2,002	2,286
2.0	1,729	1,874	2,133	2,510	2,669	3,048
2.5	2,161	2,342	2,666	3,137	3,336	3,810
3.0	2,593	2,811	3,199	3,764	4,003	4,572
3.5	3,025	3,279	3,732	4,392	4,670	5,334
4.0	3,457	3,747	4,265	5,019	5,337	6,096
5.0	4,322	4,684	5,332	6,274	6,672	7,620

Climate Zone 3: South Region, Houston Weather Data

Table 2-65: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,372	1,487	1,693	2,031	2,155	2,458
2.0	1,830	1,983	2,257	2,708	2,873	3,277
2.5	2,287	2,479	2,822	3,385	3,591	4,097
3.0	2,744	2,975	3,386	4,062	4,309	4,916
3.5	3,202	3,470	3,950	4,739	5,027	5,735
4.0	3,659	3,966	4,514	5,416	5,746	6,554
5.0	4,574	4,958	5,643	6,770	7,182	8,193

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-66: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,595	1,728	1,967	2,353	2,497	2,852
2.0	2,126	2,305	2,623	3,138	3,330	3,802
2.5	2,658	2,881	3,279	3,922	4,162	4,753
3.0	3,189	3,457	3,935	4,706	4,994	5,703
3.5	3,721	4,033	4,591	5,491	5,827	6,654
4.0	4,252	4,609	5,247	6,275	6,659	7,604
5.0	5,316	5,762	6,558	7,844	8,324	9,505

Climate Zone 5: West Region El Paso Weather Data

Table 2-67: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,115	1,208	1,375	1,635	1,737	1,983
2.0	1,486	1,611	1,834	2,180	2,316	2,643
2.5	1,858	2,014	2,292	2,726	2,895	3,304
3.0	2,229	2,416	2,751	3,271	3,474	3,965
3.5	2,601	2,819	3,209	3,816	4,053	4,626
4.0	2,973	3,222	3,667	4,361	4,632	5,287
5.0	3,716	4,027	4,584	5,451	5,789	6,609

Deemed Summer Demand Savings Tables

New Construction

Table 2-68 through Table 2-72 present the summer demand savings (kW) associated with central air conditioners installed in new homes (14.0 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-68: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.19	0.26	0.38
2.0	0.07	0.14	0.25	0.26	0.34	0.51
2.5	0.09	0.17	0.32	0.32	0.43	0.63
3.0	0.11	0.21	0.38	0.39	0.51	0.76
3.5	0.12	0.24	0.44	0.45	0.60	0.89
4.0	0.14	0.27	0.51	0.52	0.69	1.02
5.0	0.18	0.34	0.64	0.65	0.86	1.27

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-69: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.20	0.27	0.39
2.0	0.08	0.15	0.27	0.26	0.35	0.52
2.5	0.10	0.18	0.34	0.33	0.44	0.66
3.0	0.11	0.22	0.41	0.39	0.53	0.79
3.5	0.13	0.26	0.48	0.46	0.62	0.92
4.0	0.15	0.29	0.54	0.53	0.71	1.05
5.0	0.19	0.37	0.68	0.66	0.88	1.31

Climate Zone 3: South Region, Houston Weather Data

Table 2-70: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.19	0.26	0.38
2.0	0.07	0.14	0.25	0.26	0.34	0.51
2.5	0.09	0.17	0.32	0.32	0.43	0.63
3.0	0.11	0.21	0.38	0.39	0.51	0.76
3.5	0.12	0.24	0.44	0.45	0.60	0.89
4.0	0.14	0.27	0.51	0.52	0.69	1.02
5.0	0.18	0.34	0.64	0.65	0.86	1.27

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-71: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.19	0.26	0.38
2.0	0.07	0.14	0.25	0.26	0.34	0.51
2.5	0.09	0.17	0.32	0.32	0.43	0.63
3.0	0.11	0.21	0.38	0.39	0.51	0.76
3.5	0.12	0.24	0.44	0.45	0.60	0.89
4.0	0.14	0.27	0.51	0.52	0.69	1.02
5.0	0.18	0.34	0.64	0.65	0.86	1.27

Climate Zone 5: West Region El Paso Weather Data

Table 2-72: Summer Demand Savings for 14.0 SEER New Construction Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.20	0.27	0.39
2.0	0.08	0.15	0.27	0.26	0.35	0.52
2.5	0.10	0.18	0.34	0.33	0.44	0.66
3.0	0.11	0.22	0.41	0.39	0.53	0.79
3.5	0.13	0.26	0.48	0.46	0.62	0.92
4.0	0.15	0.29	0.54	0.53	0.71	1.05
5.0	0.19	0.37	0.68	0.66	0.88	1.31

Replace-on-Burnout

Table 2-73 through Table 2-77 present the summer demand savings (kW) associated with central air conditioners installed in replace-on-burnout homes (13.08 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-73: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.20	0.28	0.29	0.35	0.47
2.0	0.20	0.26	0.38	0.38	0.47	0.63
2.5	0.25	0.33	0.47	0.48	0.58	0.79
3.0	0.29	0.39	0.57	0.58	0.70	0.95
3.5	0.34	0.46	0.66	0.67	0.82	1.11
4.0	0.39	0.52	0.76	0.77	0.94	1.27
5.0	0.49	0.66	0.95	0.96	1.17	1.58

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-74: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.30	0.37	0.49
2.0	0.21	0.28	0.41	0.40	0.49	0.66
2.5	0.26	0.35	0.51	0.50	0.61	0.82
3.0	0.31	0.42	0.61	0.60	0.73	0.99
3.5	0.37	0.49	0.71	0.69	0.85	1.15
4.0	0.42	0.56	0.81	0.79	0.98	1.32
5.0	0.52	0.70	1.01	0.99	1.22	1.65

Climate Zone 3: South Region, Houston Weather Data

Table 2-75: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.20	0.28	0.29	0.35	0.47
2.0	0.20	0.26	0.38	0.38	0.47	0.63
2.5	0.25	0.33	0.47	0.48	0.58	0.79
3.0	0.29	0.39	0.57	0.58	0.70	0.95
3.5	0.34	0.46	0.66	0.67	0.82	1.11
4.0	0.39	0.52	0.76	0.77	0.94	1.27
5.0	0.49	0.66	0.95	0.96	1.17	1.58

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-76: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.20	0.28	0.29	0.35	0.47
2.0	0.20	0.26	0.38	0.38	0.47	0.63
2.5	0.25	0.33	0.47	0.48	0.58	0.79
3.0	0.29	0.39	0.57	0.58	0.70	0.95
3.5	0.34	0.46	0.66	0.67	0.82	1.11
4.0	0.39	0.52	0.76	0.77	0.94	1.27
5.0	0.49	0.66	0.95	0.96	1.17	1.58

Climate Zone 5: West Region El Paso Weather Data

Table 2-77: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.30	0.37	0.49
2.0	0.21	0.28	0.41	0.40	0.49	0.66
2.5	0.26	0.35	0.51	0.50	0.61	0.82
3.0	0.31	0.42	0.61	0.60	0.73	0.99
3.5	0.37	0.49	0.71	0.69	0.85	1.15
4.0	0.42	0.56	0.81	0.79	0.98	1.32
5.0	0.52	0.70	1.01	0.99	1.22	1.65

Early Retirement

Table 2-78 through Table 2-82 present the early retirement summer demand savings (kW) associated with central air conditioners installed in homes for the five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-73 through Table 2-77 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-78: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.64	0.72	0.73	0.79	0.91
2.0	0.78	0.85	0.97	0.97	1.05	1.22
2.5	0.98	1.06	1.21	1.21	1.32	1.52
3.0	1.17	1.27	1.45	1.46	1.58	1.83
3.5	1.37	1.49	1.69	1.70	1.85	2.13
4.0	1.57	1.70	1.93	1.94	2.11	2.44
5.0	1.96	2.12	2.41	2.43	2.64	3.05

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-79: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.77	0.84	0.96
2.0	0.84	0.91	1.03	1.02	1.11	1.28
2.5	1.05	1.13	1.29	1.28	1.39	1.61
3.0	1.26	1.36	1.55	1.54	1.67	1.93
3.5	1.46	1.59	1.81	1.79	1.95	2.25
4.0	1.67	1.81	2.06	2.05	2.23	2.57
5.0	2.09	2.27	2.58	2.56	2.79	3.21

Climate Zone 3: South Region, Houston Weather Data

Table 2-80: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.64	0.72	0.73	0.79	0.91
2.0	0.78	0.85	0.97	0.97	1.05	1.22
2.5	0.98	1.06	1.21	1.21	1.32	1.52
3.0	1.17	1.27	1.45	1.46	1.58	1.83
3.5	1.37	1.49	1.69	1.70	1.85	2.13
4.0	1.57	1.70	1.93	1.94	2.11	2.44
5.0	1.96	2.12	2.41	2.43	2.64	3.05

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-81: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.64	0.72	0.73	0.79	0.91
2.0	0.78	0.85	0.97	0.97	1.05	1.22
2.5	0.98	1.06	1.21	1.21	1.32	1.52
3.0	1.17	1.27	1.45	1.46	1.58	1.83
3.5	1.37	1.49	1.69	1.70	1.85	2.13
4.0	1.57	1.70	1.93	1.94	2.11	2.44
5.0	1.96	2.12	2.41	2.43	2.64	3.05

Climate Zone 5: West Region El Paso Weather Data

Table 2-82: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.77	0.84	0.96
2.0	0.84	0.91	1.03	1.02	1.11	1.28
2.5	1.05	1.13	1.29	1.28	1.39	1.61
3.0	1.26	1.36	1.55	1.54	1.67	1.93
3.5	1.46	1.59	1.81	1.79	1.95	2.25
4.0	1.67	1.81	2.06	2.05	2.23	2.57
5.0	2.09	2.27	2.58	2.56	2.79	3.21

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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a central air conditioning unit is 18 years based on the current DOE Final Rule standards for central air conditioners.[139]

Program Tracking Data & 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:

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (tons)
- Seasonal Energy Efficiency Ratio (SEER) of the installed unit
- Climate zone of the site
- Age of replaced unit (Early Retirement only)
- Recommended: retired unit model number, serial number, and manufacturer (Early Retirement only)
- Recommended: photograph of retired unit nameplate (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

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139 Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. Accessed 10/21/2014. 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.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[140]

Document Revision History

Table 2-83: Residential Central Air Conditioner Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as "Early Retirement" option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. Reversion to TRM v1.0 savings tables to reflect deferred enforcement of new regional standards. A court-ordered settlement allows SEER 13 split-system units to be sold without penalty until July 1, 2016.
v3.0	4/10/2015	TRM v3.0 update. Savings values incorporated corresponding with federal and regional standards effective January 1, 2015. Early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated.
v3.1	11/05/2015	TRM v3.1 update. Removal of legacy language around baseline. Extension of Early Retirement savings tables to higher SEER values.
v4.0	10/10/2016	TRM v4.0 update. Added RUL value for units with an age of one year. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years. Updated savings for 15.0-15.9 SEER range.

140 https://www.acca.org/store/product.php?pid=172.

2.2.4 Ground Source Heat Pump 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 Values and Calculations

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,[141] effective January 1, 2015.

[141] DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

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

Table 2-84: Ground Source Heat Pump Baseline Efficiencies

Project Type	Cooling Mode[143]	Heating Mode[144]
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		1 COP (3.41 HSPF)

High-Efficiency Condition

Table 2-85 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 2-85: 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

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[145]

- $\boldsymbol{EER = (highest\ rated\ capacity\ EER + lowest\ rated\ capacity\ EER) \div 2}$

Equation 50

[142] 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.

[143] 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.

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

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

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

Equation 51

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.[146] 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 replacement of air source heat pumps with ground source heat pumps. These estimates were found to be within 5% of actual post-retrofit savings. Building models were developed using TRNSYS.[147]

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.

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 2-87 and Table 2-88, respectively.

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[146] 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. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf.

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

Energy Savings Algorithms

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

Equation 52

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

Equation 53

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

Equation 54

Where:

$kWh_{desuperheater}$	=	*Energy savings (kWh) associated with installation of a desuperheater (see Table 2-87). 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 2-86)*
$SEER_{Base}$	=	*Seasonal Energy Efficiency Ratio of the baseline cooling equipment (Table 2-84)*
EER_{GSHP}	=	*Energy Efficiency Ratio of the installed GSHP*
$HSPF_{Base}$	=	*Heating Seasonal Performance Factor of the baseline heating equipment (Table 2-84)*
COP_{GSHP}	=	*Coefficient of Performance of the installed GSHP*

Table 2-86: Equivalent full load cooling/heating hours[148]

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 55

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

Equation 56

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 2-84)*

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

COP_{Base} = *Coefficient of Performance of the baseline heating equipment (Table 2-84)*

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

CF_C = *Coincidence Factor = 0.87 (default)*[149]

CF_H = *Coincidence Factor = 0.83 (default)*[150]

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148 ENERGY STAR® Central AC/HP Savings Calculator. http://www.energystar.gov/certified-products/detail/heat_pumps_air_source.

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

150 Air Conditioning Contractors of America (ACCA) Manual S allows residential heat pumps to be sized at 115% of the maximum cooling requirement of the house (for cooling dominated climates). Based on AHRI data for 1.5 to 5 ton heat pump 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 of 4 to 5 PM, the guideline leads to a winter coincidence factor for residential HVAC measures of 0.96/1.15 = 0.83

$kW_{desuperheater}$ = *Summer demand savings (kW) associated with installation of a desuperheater (see Table 2-88). These savings should only be added if a desuperheater is installed.*

Deemed Energy Savings Tables

Table 2-87: 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 2-88: 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.

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.[151]

Program Tracking Data & 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:

- 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
- Climate zone of the site
- Whether a desuperheater was also installed or present

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. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf
- The applicable version of ENERGY STAR®'s specifications and requirements addressing residential ground source heat pumps.

[151] 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 2-89: Ground Source Heat Pump 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.

2.2.5 Central Heat Pump Measure Overview

TRM Measure ID: R-HV-HP

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new central air-source heat pump in an existing building, or the installation of a new central heat pump in a new residential construction. A new central heat pump includes an entire packaged unit, or a split system consisting of an indoor unit with a matching remote condensing unit.

All measure installation standards and baseline data from the central air conditioner measure shall apply to the heat pump measure.

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 data sheets on installed heat pump equipment or AHRI reference numbers must be provided.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[152] when designing programs that permit savings to be claimed for early

[152] 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.

retirement. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 20 years.

Baseline Condition

New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source Heat Pump

New construction baseline efficiency values for heat pumps are compliant with the current federal minimum standard,[153] effective January 1, 2015. The baseline is assumed to be a new heat pump system with an AHRI-listed SEER rating of 14.0.

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.[154]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 12.44[155] SEER at that time.

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, or 8.0 for packaged systems. This baseline reflects updates to federal standards that take effect January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[156] For ER projects, 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.[157]

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.[158] Projects in which an electric resistance furnace is replaced, either in replace-on-burnout or early retirement scenarios, use this baseline for heating-side savings.

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153 DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

154 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.

155 Refer to Texas TRM 2.1 for savings using 12.44 SEER baseline.

156 *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.

157 Ibid.

158 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.

For ROB projects, cooling savings are the same as for new construction and ROB of an air-source heat pump. For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 13 SEER at that time. There is no significant difference between the 13 SEER ER and 13.08 ROB baseline efficiencies. Early retirement projects do not commonly replace HVAC units without an electric resistance furnace.

Table 2-90: Central Heat Pump 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	8.2 HSPF
Early Retirement, Electric Resistance Furnace (as of 1/23/2006)		3.41 HSPF
Early Retirement, Heat Pump (before 1/23/2006)	10 SEER	7.7 HSPF
Early Retirement, Electric Resistance Furnace (before 1/23/2006)		3.41 HSPF

High-Efficiency Condition

Table 2-91 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.

Table 2-91: Central Heat Pump 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 heat pump performance curves developed by the National Renewable Energy Laboratory[159] for typical units in each of the following SEER ranges:

- Baseline units

[159] 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

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

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

These performance curves provide the capacity and efficiency of 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, taking into account that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings are estimated according to 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 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 (1 ton, 1.5 ton, 2 ton, etc.) 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 uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

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

Equation 57

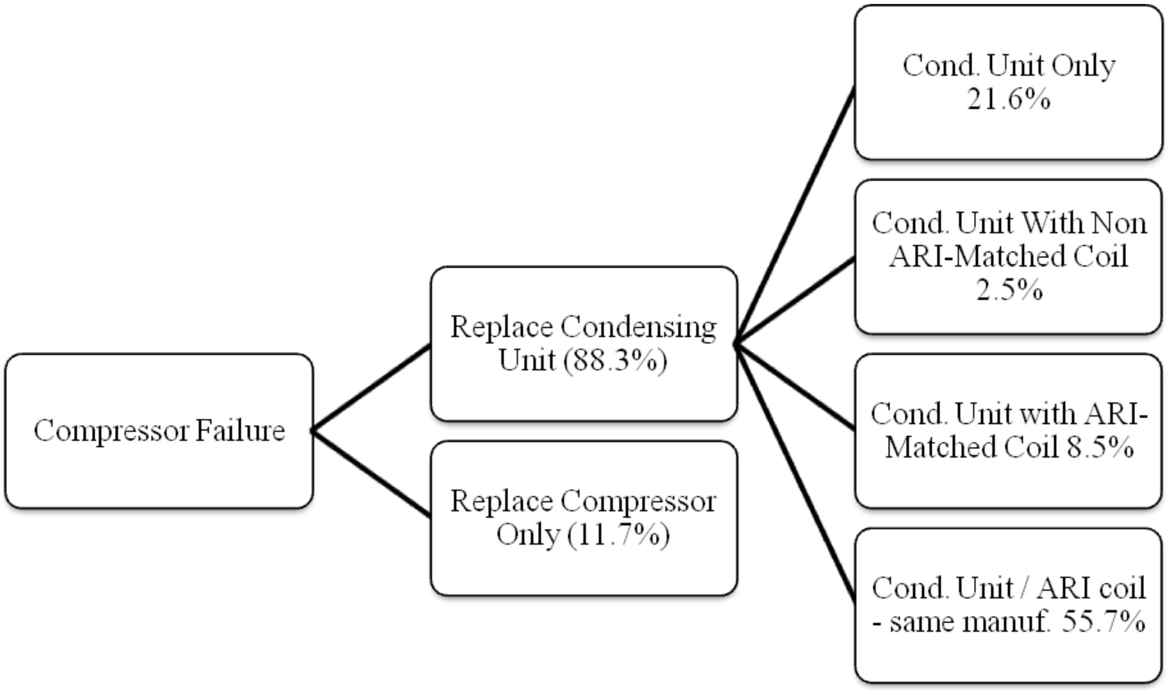
Table 2-92: Heat Pump Capacity Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	High		Low	High
a	3.68637657	3.998418659	3.466810106	0.566333415	0.335690634	0.306358843
b	-0.098352478	-0.108728222	-0.091476056	-0.000744164	0.002405123	0.005376987
c	0.000956357	0.001056818	0.000901205	-0.0000103	-0.0000464	-0.0000579
d	0.005838141	0.007512314	0.004163355	0.009414634	0.013498735	0.011645092
e	-0.0000127	-0.0000139	-0.00000919	0.0000506	0.0000499	0.0000591
f	-0.000131702	-0.000164716	-0.000110829	-0.00000675	-0.00000725	-0.0000203

Table 2-93: Heat Pump EIR Curve Coefficients

Coeff.	Cooling			Heating		
	Single Stage	Multi-Stage/Speed		Single Stage	Multi-Stage/Speed	
		Low	High		Low	High
a	-3.437356399	-4.282911381	-3.557757517	0.718398423	0.36338171	0.981100941
b	0.136656399	0.181023691	0.112737397	0.003498178	0.013523725	-0.005158493
c	-0.001049231	-0.001357391	-0.000731381	0.000142202	0.000258872	0.000243416
d	-0.0079378	-0.026310378	0.01384877	-0.005724331	-0.009450269	-0.005274352
e	0.000185435	0.000333282	0.000132645	0.00014085	0.000439519	0.000230742
f	-0.0001441	-0.000197405	-0.000338716	-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% of the time, and replaced the condensing unit 88.3% 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:



Source: Docket No. 36780

Figure 2-3: Unit Replacement Percentages upon Compressor Failure

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% 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:

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

Equation 58

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

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

Adjusting for the increased 14 SEER baseline:

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

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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-88); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 6.0 years*

EUL = *Estimated Useful Life = 15 years*

Table 2-94: Remaining Useful Life of Replaced Unit

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[160,161]	0.0
11	8.2		

160 RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (Figure 2-4). 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.

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

Derivation of RULs

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 heat pumps installed in a given year will no longer be in service, as described by the survival function in Figure 2-4.

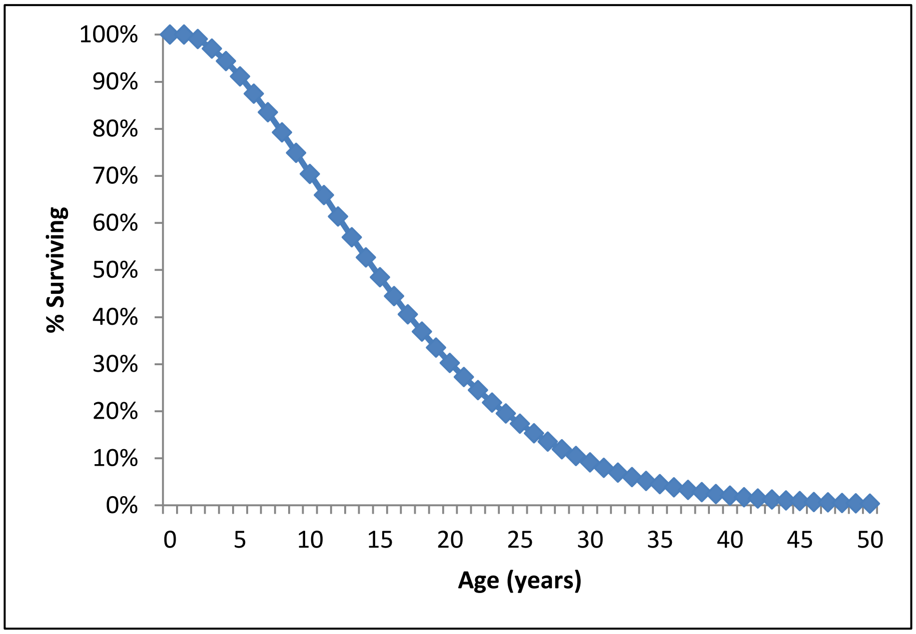


Figure 2-4: Survival Function for Central Heat Pumps[162]

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 2-4. The age of the central heat pump being replaced is found on the horizontal axis, and the corresponding percentage of surviving heat pumps 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.

[162] 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.

Deemed Energy Savings Tables

Cooling, New Construction

Table 2-95 through Table 2-99 present the energy savings (kWh) for cooling load types associated with a central heat pump being installed during new construction for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-95: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	78	150	279	427	509	697
2.0	104	201	373	570	679	930
2.5	130	251	466	712	849	1,162
3.0	156	301	559	855	1,019	1,394
3.5	183	351	652	997	1,188	1,627
4.0	209	401	745	1,140	1,358	1,859
5.0	261	502	931	1,425	1,698	2,324

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-96: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	118	228	423	673	795	1,085
2.0	158	304	564	897	1,060	1,447
2.5	197	380	705	1,122	1,325	1,808
3.0	237	456	846	1,346	1,590	2,170
3.5	276	532	987	1,571	1,855	2,531
4.0	316	608	1,128	1,795	2,120	2,893
5.0	395	759	1,410	2,244	2,650	3,616

Climate Zone 3: South Region, Houston Weather Data

Table 2-97: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	126	242	449	771	896	1,204
2.0	168	322	598	1,027	1,195	1,605
2.5	209	403	748	1,284	1,494	2,007
3.0	251	483	898	1,541	1,792	2,408
3.5	293	564	1,047	1,798	2,091	2,809
4.0	335	644	1,197	2,055	2,390	3,211
5.0	419	805	1,496	2,568	2,987	4,014

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-98: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	146	281	522	897	1,043	1,401
2.0	195	374	695	1,196	1,390	1,868
2.5	243	468	869	1,495	1,738	2,336
3.0	292	562	1,043	1,794	2,085	2,803
3.5	341	655	1,217	2,093	2,433	3,270
4.0	389	749	1,391	2,392	2,780	3,737
5.0	487	936	1,738	2,989	3,475	4,671

Climate Zone 5: West Region El Paso Weather Data

Table 2-99: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	102	196	364	596	700	951
2.0	136	261	485	795	933	1,268
2.5	170	327	607	994	1,166	1,585
3.0	204	392	728	1,193	1,400	1,901
3.5	238	457	849	1,391	1,633	2,218
4.0	272	523	971	1,590	1,866	2,535
5.0	340	653	1,213	1,988	2,333	3,169

Cooling, Replace-on-Burnout

Table 2-100 through Table 2-104 present the energy savings (kWh) for cooling load types associated with a central heat pump replacing on burnout an HVAC system for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-100: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	216	288	417	565	647	835
2.0	288	384	556	753	862	1,113
2.5	360	480	695	942	1,078	1,391
3.0	432	576	834	1,130	1,294	1,670
3.5	504	672	973	1,318	1,509	1,948
4.0	575	768	1,112	1,507	1,725	2,226
5.0	719	960	1,390	1,883	2,156	2,783

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-101: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	327	436	631	881	1,003	1,293
2.0	436	582	842	1,175	1,338	1,724
2.5	545	727	1,052	1,469	1,672	2,155
3.0	654	872	1,263	1,763	2,007	2,586
3.5	762	1,018	1,473	2,057	2,341	3,018
4.0	871	1,163	1,684	2,350	2,675	3,449
5.0	1,089	1,454	2,105	2,938	3,344	4,311

Climate Zone 3: South Region, Houston Weather Data

Table 2-102: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	347	463	670	991	1,117	1,425
2.0	462	617	893	1,322	1,489	1,900
2.5	578	771	1,116	1,652	1,862	2,375
3.0	693	925	1,339	1,983	2,234	2,850
3.5	809	1,079	1,563	2,313	2,606	3,325
4.0	924	1,234	1,786	2,644	2,979	3,800
5.0	1,155	1,542	2,232	3,305	3,724	4,750

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-103: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	403	538	778	1,154	1,299	1,658
2.0	537	717	1,038	1,538	1,733	2,211
2.5	671	896	1,297	1,923	2,166	2,764
3.0	806	1,075	1,557	2,307	2,599	3,316
3.5	940	1,254	1,816	2,692	3,032	3,869
4.0	1,074	1,434	2,076	3,076	3,465	4,422
5.0	1,343	1,792	2,594	3,845	4,331	5,527

Climate Zone 5: West Region El Paso Weather Data

Table 2-104: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	281	375	543	775	879	1,130
2.0	375	500	724	1,034	1,172	1,507
2.5	469	625	905	1,292	1,465	1,883
3.0	562	750	1,086	1,551	1,758	2,260
23.5	656	875	1,267	1,809	2,051	2,636
4.0	750	1,000	1,448	2,068	2,344	3,013
5.0	937	1,251	1,811	2,585	2,930	3,766

Cooling, Early Retirement

Table 105 through Table 109 present the cooling energy savings (kWh) associated with the installation of a central heat pump following the early retirement of an HVAC system for all five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 100 through Table 104 to calculate annual cooling savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-105: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	861	933	1,062	1,210	1,292	1,480
2.0	1,147	1,244	1,416	1,613	1,722	1,973
2.5	1,434	1,555	1,770	2,016	2,153	2,466
3.0	1,721	1,866	2,124	2,420	2,583	2,959
3.5	2,008	2,177	2,477	2,823	3,014	3,452
4.0	2,295	2,487	2,831	3,226	3,444	3,946
5.0	2,869	3,109	3,539	4,033	4,305	4,932

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-106: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,303	1,413	1,608	1,858	1,980	2,270
2.0	1,738	1,883	2,144	2,477	2,639	3,026
2.5	2,172	2,354	2,680	3,096	3,299	3,783
3.0	2,606	2,825	3,216	3,716	3,959	4,539
3.5	3,041	3,296	3,752	4,335	4,619	5,296
4.0	3,475	3,767	4,287	4,954	5,279	6,052
5.0	4,344	4,708	5,359	6,193	6,599	7,565

Climate Zone 3: South Region, Houston Weather Data

Table 2-107: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,382	1,498	1,705	2,027	2,153	2,461
2.0	1,843	1,998	2,274	2,703	2,870	3,281
2.5	2,304	2,497	2,842	3,378	3,588	4,101
3.0	2,764	2,996	3,411	4,054	4,305	4,921
3.5	3,225	3,496	3,979	4,730	5,023	5,741
4.0	3,686	3,995	4,547	5,406	5,740	6,562
5.0	4,607	4,994	5,684	6,757	7,176	8,202

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-108: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,606	1,741	1,982	2,357	2,503	2,862
2.0	2,142	2,322	2,643	3,143	3,337	3,816
2.5	2,677	2,902	3,303	3,929	4,172	4,770
3.0	3,213	3,482	3,964	4,714	5,006	5,723
3.5	3,748	4,063	4,624	5,500	5,840	6,677
4.0	4,284	4,643	5,285	6,286	6,675	7,631
5.0	5,355	5,804	6,606	7,857	8,343	9,539

Climate Zone 5: West Region El Paso Weather Data

Table 2-109: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,121	1,215	1,383	1,615	1,719	1,970
2.0	1,495	1,620	1,844	2,154	2,292	2,626
2.5	1,868	2,025	2,305	2,692	2,865	3,283
3.0	2,242	2,430	2,766	3,231	3,438	3,940
3.5	2,616	2,835	3,227	3,769	4,011	4,596
4.0	2,989	3,240	3,688	4,308	4,584	5,253
5.0	3,737	4,050	4,610	5,385	5,730	6,566

Heating, New Construction or Replace-on-Burnout of a Heat Pump

Table 2-110 through Table 2-114 present the energy savings (kWh) for heating load types associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-110: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	119	193	329	451	508	562
2.0	159	257	438	601	677	749
2.5	198	321	548	752	846	936
3.0	238	385	657	902	1,015	1,123
3.5	278	450	767	1,052	1,185	1,311
4.0	317	514	876	1,203	1,354	1,498
5.0	397	642	1,096	1,503	1,692	1,872

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-111: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	68	111	188	259	291	322
2.0	91	147	251	345	388	429
2.5	114	184	314	431	485	537
3.0	136	221	377	517	582	644
3.5	159	258	440	603	679	752
4.0	182	295	503	690	776	859
5.0	227	368	628	862	970	1,074

Climate Zone 3: South Region, Houston Weather Data

Table 2-112: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	36	59	101	138	155	172
2.0	49	79	134	184	207	229
2.5	61	98	168	230	259	286
3.0	73	118	201	276	311	344
3.5	85	138	235	322	362	401
4.0	97	157	268	368	414	458
5.0	121	197	335	460	518	573

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-113: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	28	45	77	106	120	132
2.0	37	61	103	142	160	177
2.5	47	76	129	177	199	221
3.0	56	91	155	213	239	265
3.5	65	106	181	248	279	309
4.0	75	121	207	284	319	353
5.0	93	151	258	354	399	441

Climate Zone 5: West Region El Paso Weather Data

Table 2-114: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	69	111	190	261	294	325
2.0	92	149	253	348	391	433
2.5	115	186	317	435	489	541
3.0	138	223	380	522	587	650
3.5	161	260	444	609	685	758
4.0	183	297	507	696	783	866
5.0	229	372	634	869	979	1,083

Heating, Replace-on-Burnout – Replacement of an Electric Resistance Furnace

Table 2-115through Table 2-119 present the energy savings (kWh) per heating load type associated with a central heat pump replacing on burnout an electric resistance furnace for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-115: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	5,847	5,921	6,057	6,179	6,236	6,290
2.0	7,796	7,894	8,075	8,238	8,314	8,386
2.5	9,745	9,868	10,094	10,298	10,393	10,483
3.0	11,694	11,841	12,113	12,358	12,471	12,579
3.5	13,643	13,815	14,132	14,417	14,550	14,676
4.0	15,591	15,788	16,151	16,477	16,628	16,772
5.0	19,489	19,735	20,188	20,596	20,785	20,965

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-116: Energy Savings (Heating kWh Only) for 3.41HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	3,411	3,453	3,531	3,601	3,634	3,665
2.0	4,548	4,605	4,708	4,802	4,845	4,887
2.5	5,685	5,756	5,886	6,002	6,057	6,108
3.0	6,822	6,907	7,063	7,203	7,268	7,330
3.5	7,959	8,058	8,240	8,403	8,479	8,552
4.0	9,096	9,209	9,417	9,604	9,691	9,773
5.0	11,370	11,511	11,771	12,005	12,113	12,217

Climate Zone 3: South Region, Houston Weather Data

Table 2-117: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1,828	1,850	1,892	1,929	1,947	1,963
2.0	2,437	2,467	2,522	2,572	2,595	2,617
2.5	3,046	3,084	3,153	3,215	3,244	3,272
3.0	3,655	3,700	3,783	3,858	3,893	3,926
3.5	4,264	4,317	4,414	4,501	4,542	4,580
4.0	4,874	4,934	5,045	5,144	5,191	5,235
5.0	6,092	6,167	6,306	6,431	6,488	6,543

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-118: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1,410	1,427	1,459	1,488	1,502	1,514
2.0	1,880	1,903	1,946	1,984	2,002	2,019
2.5	2,350	2,379	2,432	2,480	2,503	2,524
3.0	2,820	2,855	2,919	2,977	3,003	3,029
3.5	3,290	3,331	3,405	3,473	3,504	3,533
4.0	3,760	3,806	3,892	3,969	4,004	4,038
5.0	4,700	4,758	4,865	4,961	5,005	5,048

Climate Zone 5: West Region El Paso Weather Data

Table 2-119: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	3,444	3,487	3,566	3,636	3,669	3,701
2.0	4,593	4,650	4,754	4,849	4,892	4,934
2.5	5,741	5,812	5,943	6,061	6,115	6,168
3.0	6,889	6,974	7,131	7,273	7,339	7,401
3.5	8,037	8,137	8,320	8,485	8,562	8,635
4.0	9,185	9,299	9,509	9,697	9,785	9,868
5.0	11,482	11,624	11,886	12,122	12,231	12,335

Heating, Early Retirement – Replacement of a Heat Pump

See Table 2-120 through Table 2-124 for the energy savings (kWh) per heating load type associated with a central heat pump replacing another heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-120: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	392	466	602	724	781	835
2.0	523	621	802	965	1,041	1,113
2.5	653	776	1,003	1,207	1,301	1,391
3.0	784	931	1,203	1,448	1,561	1,669
3.5	915	1,087	1,404	1,689	1,822	1,948
4.0	1,045	1,242	1,604	1,931	2,082	2,226
5.0	1,307	1,552	2,006	2,413	2,602	2,782

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-121: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	225	267	345	415	448	479
2.0	300	356	460	554	597	638
2.5	375	445	575	692	746	798
3.0	450	534	690	830	895	957
3.5	524	623	805	969	1,045	1,117
4.0	599	712	920	1,107	1,194	1,276
5.0	749	890	1,150	1,384	1,492	1,596

Climate Zone 3: South Region, Houston Weather Data

Table 2-122: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	120	142	184	222	239	255
2.0	160	190	245	295	318	341
2.5	200	237	307	369	398	426
3.0	240	285	368	443	478	511
3.5	280	332	430	517	557	596
4.0	320	380	491	591	637	681
5.0	400	475	614	738	796	851

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-123: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	92	110	142	171	184	197
2.0	123	146	189	228	245	262
2.5	154	183	236	284	307	328
3.0	185	220	284	341	368	394
3.5	216	256	331	398	429	459
4.0	246	293	378	455	491	525
5.0	308	366	473	569	613	656

Climate Zone 5: West Region El Paso Weather Data

Table 2-124: Energy Savings (Heating kWh) for 7.7 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	227	269	348	419	451	483
2.0	302	359	464	558	602	644
2.5	378	449	580	698	752	805
3.0	453	539	696	837	903	965
3.5	529	628	812	977	1,053	1,126
4.0	604	718	928	1,117	1,204	1,287
5.0	756	898	1,160	1,396	1,505	1,609

Heating, Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-125 through Table 2-129 for the energy savings (kWh) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones.

Deemed Summer Demand Savings Tables

New Construction

Table 2-114 through Table 2-118 present the summer demand savings (kW) associated with a central heat pump being installed during new construction for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-125: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-126: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.15	0.22	0.35
2.0	0.08	0.15	0.27	0.20	0.29	0.47
2.5	0.09	0.18	0.34	0.25	0.36	0.59
3.0	0.11	0.22	0.41	0.30	0.44	0.70
3.5	0.13	0.26	0.47	0.35	0.51	0.82
4.0	0.15	0.29	0.54	0.40	0.58	0.94
5.0	0.19	0.37	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-127: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-128: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.10	0.19	0.17	0.23	0.36
2.0	0.07	0.14	0.25	0.22	0.31	0.48
2.5	0.09	0.17	0.32	0.28	0.38	0.60
3.0	0.11	0.21	0.38	0.33	0.46	0.72
3.5	0.12	0.24	0.45	0.39	0.54	0.84
4.0	0.14	0.27	0.51	0.44	0.62	0.96
5.0	0.18	0.34	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-129: Summer Demand Savings for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.11	0.20	0.15	0.22	0.35
2.0	0.08	0.15	0.27	0.20	0.29	0.47
2.5	0.09	0.18	0.34	0.25	0.36	0.59
3.0	0.11	0.22	0.41	0.30	0.44	0.70
3.5	0.13	0.26	0.47	0.35	0.51	0.82
4.0	0.15	0.29	0.54	0.40	0.58	0.94
5.0	0.19	0.37	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Replace-on-Burnout

Table 2-130 through Table 2-134 present the summer demand savings (kW) associated with a central heat pump replacing on burnout an HVAC system for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-130: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-131: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.25	0.32	0.45
2.0	0.21	0.28	0.40	0.33	0.43	0.60
2.5	0.26	0.35	0.51	0.41	0.53	0.75
3.0	0.31	0.42	0.61	0.50	0.64	0.90
3.5	0.37	0.49	0.71	0.58	0.74	1.05
4.0	0.42	0.56	0.81	0.66	0.85	1.21
5.0	0.52	0.70	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-132: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-133: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.20	0.29	0.26	0.32	0.45
2.0	0.20	0.26	0.38	0.35	0.43	0.60
2.5	0.25	0.33	0.48	0.43	0.54	0.75
3.0	0.30	0.39	0.57	0.52	0.65	0.90
3.5	0.34	0.46	0.67	0.61	0.76	1.06
4.0	0.39	0.53	0.76	0.69	0.87	1.21
5.0	0.49	0.66	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-134: Summer Demand Savings for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.21	0.30	0.25	0.32	0.45
2.0	0.21	0.28	0.40	0.33	0.43	0.60
2.5	0.26	0.35	0.51	0.41	0.53	0.75
3.0	0.31	0.42	0.61	0.50	0.64	0.90
3.5	0.37	0.49	0.71	0.58	0.74	1.05
4.0	0.42	0.56	0.81	0.66	0.85	1.21
5.0	0.52	0.70	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Early Retirement

Table 2-135 through Table 2-139 present the summer demand savings (kW) associated with a central heat pump replacing an HVAC system for all five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-130 through Table 2-134 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-135: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-136: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.72	0.79	0.92
2.0	0.84	0.91	1.03	0.96	1.05	1.23
2.5	1.04	1.13	1.29	1.20	1.31	1.54
3.0	1.25	1.36	1.55	1.44	1.58	1.84
3.5	1.46	1.58	1.80	1.68	1.84	2.15
4.0	1.67	1.81	2.06	1.91	2.10	2.46
5.0	2.09	2.26	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-137: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-138: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.64	0.73	0.70	0.77	0.89
2.0	0.78	0.85	0.97	0.94	1.02	1.19
2.5	0.98	1.06	1.21	1.17	1.28	1.49
3.0	1.18	1.28	1.45	1.40	1.53	1.79
3.5	1.37	1.49	1.69	1.64	1.79	2.08
4.0	1.57	1.70	1.94	1.87	2.04	2.38
5.0	1.96	2.13	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-139: Summer Demand Savings for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.68	0.77	0.72	0.79	0.92
2.0	0.84	0.91	1.03	0.96	1.05	1.23
2.5	1.04	1.13	1.29	1.20	1.31	1.54
3.0	1.25	1.36	1.55	1.44	1.58	1.84
3.5	1.46	1.58	1.80	1.68	1.84	2.15
4.0	1.67	1.81	2.06	1.91	2.10	2.46
5.0	2.09	2.26	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Deemed Winter Demand Savings Tables

New Construction or Replace-on-Burnout of a Heat Pump

Table 2-140 through Table 2-144 present the winter demand savings (kW) associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-140: Winter Demand Savings for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.14	0.19	0.21
2.0	0.07	0.11	0.11	0.18	0.25	0.29
2.5	0.08	0.14	0.14	0.23	0.32	0.36
3.0	0.10	0.16	0.16	0.28	0.38	0.43
3.5	0.12	0.19	0.19	0.32	0.44	0.50
4.0	0.13	0.22	0.22	0.37	0.51	0.57
5.0	0.17	0.27	0.27	0.46	0.63	0.71

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-141: Winter Demand Savings for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.21
2.0	0.06	0.10	0.10	0.18	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.34
3.0	0.10	0.16	0.16	0.27	0.37	0.41
3.5	0.11	0.18	0.18	0.31	0.43	0.48
4.0	0.13	0.21	0.21	0.36	0.49	0.55
5.0	0.16	0.26	0.26	0.44	0.61	0.69

Climate Zone 3: South Region, Houston Weather Data

Table 2-142: Winter Demand Savings for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.04	0.06	0.06	0.11	0.15	0.17
2.0	0.05	0.09	0.09	0.15	0.20	0.22
2.5	0.07	0.11	0.11	0.18	0.25	0.28
3.0	0.08	0.13	0.13	0.22	0.30	0.34
3.5	0.09	0.15	0.15	0.25	0.35	0.39
4.0	0.11	0.17	0.17	0.29	0.40	0.45
5.0	0.13	0.21	0.21	0.36	0.50	0.56

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-143: Winter Demand Savings for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.03	0.05	0.05	0.09	0.13	0.14
2.0	0.04	0.07	0.07	0.12	0.17	0.19
2.5	0.06	0.09	0.09	0.15	0.21	0.24
3.0	0.07	0.11	0.11	0.18	0.25	0.28
3.5	0.08	0.13	0.13	0.21	0.29	0.33
4.0	0.09	0.14	0.14	0.25	0.34	0.38
5.0	0.11	0.18	0.18	0.31	0.42	0.47

Climate Zone 5: West Region El Paso Weather Data

Table 2-144: Winter Demand Savings for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.20
2.0	0.06	0.10	0.10	0.17	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.33
3.0	0.09	0.15	0.15	0.26	0.36	0.40
3.5	0.11	0.18	0.18	0.30	0.42	0.47
4.0	0.13	0.20	0.20	0.35	0.47	0.53
5.0	0.16	0.25	0.25	0.43	0.59	0.67

Replace-on-Burnout – Replacement of Electric Resistance Furnace

Table 2-145 through Table 2-149 present the winter demand savings (kW) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-145: Winter Demand Savings for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.05	2.08	2.14	2.19	2.21	2.24
2.0	2.73	2.78	2.85	2.92	2.95	2.98
2.5	3.42	3.47	3.57	3.65	3.69	3.73
3.0	4.10	4.16	4.28	4.38	4.43	4.47
3.5	4.79	4.86	4.99	5.11	5.17	5.22
4.0	5.47	5.55	5.70	5.84	5.91	5.97
5.0	6.84	6.94	7.13	7.30	7.38	7.46

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-146: Winter Demand Savings for 3.41 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.33	2.36	2.41	2.46	2.49	2.51
2.0	3.11	3.15	3.22	3.29	3.32	3.35
2.5	3.88	3.93	4.02	4.11	4.15	4.18
3.0	4.66	4.72	4.83	4.93	4.97	5.02
3.5	5.44	5.51	5.63	5.75	5.80	5.85
4.0	6.21	6.29	6.44	6.57	6.63	6.69
5.0	7.77	7.87	8.05	8.21	8.29	8.36

Climate Zone 3: South Region, Houston Weather Data

Table 2-147: Winter Demand Savings for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.94	1.97	2.01	2.05	2.07	2.09
2.0	2.59	2.62	2.68	2.74	2.76	2.79
2.5	3.24	3.28	3.35	3.42	3.45	3.48
3.0	3.89	3.94	4.03	4.11	4.14	4.18
3.5	4.53	4.59	4.70	4.79	4.84	4.88
4.0	5.18	5.25	5.37	5.48	5.53	5.57
5.0	6.48	6.56	6.71	6.84	6.91	6.97

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-148: Winter Demand Savings for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.66	1.69	1.72	1.76	1.77	1.79
2.0	2.22	2.25	2.30	2.34	2.36	2.38
2.5	2.77	2.81	2.87	2.93	2.96	2.98
3.0	3.33	3.37	3.45	3.52	3.55	3.58
3.5	3.88	3.93	4.02	4.10	4.14	4.17
4.0	4.44	4.49	4.60	4.69	4.73	4.77
5.0	5.55	5.62	5.74	5.86	5.91	5.96

Climate Zone 5: West Region El Paso Weather Data

Table 2-149: Winter Demand Savings for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.27	2.30	2.36	2.41	2.43	2.45
2.0	3.03	3.07	3.14	3.21	3.24	3.27
2.5	3.79	3.84	3.93	4.01	4.05	4.08
3.0	4.55	4.61	4.72	4.81	4.86	4.90
3.5	5.31	5.38	5.50	5.61	5.67	5.72
4.0	6.07	6.14	6.29	6.42	6.48	6.53
5.0	7.58	7.68	7.86	8.02	8.09	8.17

Early Retirement – Replacement of a Heat Pump

See Table 2-150 through Table 2-154 for the winter demand savings (kW) associated with a central heat pump replacing another heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-150: Winter Demand Savings for 7.7 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.17	0.20	0.25	0.31	0.33	0.35
2.0	0.22	0.26	0.34	0.41	0.44	0.47
2.5	0.28	0.33	0.42	0.51	0.55	0.59
3.0	0.33	0.39	0.51	0.61	0.66	0.70
3.5	0.39	0.46	0.59	0.71	0.77	0.82
4.0	0.44	0.52	0.68	0.81	0.88	0.94
5.0	0.55	0.65	0.84	1.02	1.10	1.17

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-151: Winter Demand Savings for 7.7 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.16	0.19	0.24	0.29	0.32	0.34
2.0	0.21	0.25	0.32	0.39	0.42	0.45
2.5	0.26	0.31	0.41	0.49	0.53	0.56
3.0	0.32	0.38	0.49	0.59	0.63	0.68
3.5	0.37	0.44	0.57	0.68	0.74	0.79
4.0	0.42	0.50	0.65	0.78	0.84	0.90
5.0	0.53	0.63	0.81	0.98	1.05	1.13

Climate Zone 3: South Region, Houston Weather Data

Table 2-152: Winter Demand Savings for 7.7 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.13	0.15	0.20	0.24	0.26	0.28
2.0	0.17	0.21	0.27	0.32	0.35	0.37
2.5	0.22	0.26	0.33	0.40	0.43	0.46
3.0	0.26	0.31	0.40	0.48	0.52	0.55
3.5	0.30	0.36	0.47	0.56	0.60	0.65
4.0	0.35	0.41	0.53	0.64	0.69	0.74
5.0	0.43	0.51	0.67	0.80	0.86	0.92

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-153: Winter Demand Savings for 7.7 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.11	0.13	0.17	0.20	0.22	0.23
2.0	0.15	0.17	0.22	0.27	0.29	0.31
2.5	0.18	0.22	0.28	0.34	0.36	0.39
3.0	0.22	0.26	0.34	0.41	0.44	0.47
3.5	0.26	0.30	0.39	0.47	0.51	0.55
4.0	0.29	0.35	0.45	0.54	0.58	0.62
5.0	0.37	0.44	0.56	0.68	0.73	0.78

Climate Zone 5: West Region El Paso Weather Data

Table 2-154: Winter Demand Savings for 7.7 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.15	0.18	0.24	0.29	0.31	0.33
2.0	0.21	0.24	0.32	0.38	0.41	0.44
2.5	0.26	0.31	0.40	0.48	0.51	0.55
3.0	0.31	0.37	0.47	0.57	0.62	0.66
3.5	0.36	0.43	0.55	0.67	0.72	0.77
4.0	0.41	0.49	0.63	0.76	0.82	0.88
5.0	0.52	0.61	0.79	0.95	1.03	1.10

Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-150 through Table 2-154 for the winter demand savings (kW) associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones

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) of a central heat pump unit is 15 years based on the current DOE Final Rule standards for central heat pumps.[163]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Heat Pumps.[164]

Program Tracking Data & 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:

[163] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. Accessed 10/21/2014. 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.

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

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (tons)
- Seasonal Energy Efficiency Ratio (SEER) of the installed unit
- Heating Seasonal Performance Factor (HSPF) of the installed unit
- Climate zone of the site
- Type of unit replaced (e.g., electric resistance furnace, air source heat pump)
- Age of the replaced unit (Early Retirement only)
- Recommended: retired unit model number, serial number, and manufacturer (Early Retirement only)
- Recommended: photograph of retired unit nameplate (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[165]

[165] https://www.acca.org/store/product.php?pid=172.

Document Revision History

Table 2-155: Central Heat Pump Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as "Early Retirement" option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated.
v3.1	11/05/2015	TRM v3.1 update. Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of Early Retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.
v4.0	10/10/2016	TRM v4.0 update. Added RUL value for units with an age of one year. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years. Updated savings for 15.0-15.9 SEER range.

2.2.6 Room Air Conditioner Measure Overview

TRM Measure ID: R-HV-WA

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

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The following deemed savings values are applicable in calculating an incentive for the installation of a high-efficiency room air conditioner in a newly-constructed home or a room air conditioner replaced with a higher efficiency room air conditioner in a dwelling occupied by a residential energy consumer.

Eligibility Criteria

Installed room air conditioners must be compliant with the current ENERGY STAR® specification for room air conditioners.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[166] when designing programs that permit savings to be claimed for early retirement. In order to be awarded early retirement savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 12 years.

Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit with a CEER rating that is compliant with the current federal standard,[167]

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166 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.

167 DOE minimum efficiency standard for residential room air conditioners. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

effective June 1, 2014. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

For early retirement, the baseline efficiency is assumed to match the minimum federal standard efficiencies in place prior to June 1, 2014.

Table 2-156: Room Air Conditioner Baseline Efficiencies for New Construction, Replace-on-Burnout, and Early Retirement

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr.)	Federal Standard prior to June 1, 2014	Federal Standard as of June 1, 2014
			ER Baseline EER	NC/ROB Baseline CEER
No	Yes	< 8,000	9.7	11.0
		> 8,000 and < 14,000	9.8	10.9
		> 14,000 and < 20,000	9.7	10.7
		> 20,000 and < 25,000	8.5	9.4
		> 25,000	8.5	9.0
No	No	< 8,000	9.0	10.0
		> 8,000 and < 11,000	8.5	9.6
		> 11,000 and < 14,000	8.5	9.5
		> 14,000 and < 20,000	8.5	9.3
		> 20,000	8.5	9.4
Yes	Yes	< 20,000	9.0	9.8
		> 20,000	8.5	9.3
Yes	No	< 14,000	8.5	9.3
		> 14,000	8.0	8.7
Casement-only		All capacities	8.7	9.5
Casement-slider		All capacities	9.5	10.4

High-Efficiency Condition

ENERGY STAR® specifications effective October 30, 2015 are provided in Table 2-157 as the efficient condition.[168] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

168 ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners: Eligibility Criteria Version 4.0. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.0%20Room%20Air%20Conditioners%20Specification.pdf. February 20, 2015.

Table 2-157: Room Air Conditioner Efficient Condition Specifications

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr.)	Minimum CEER as of October 30, 2015
No	Yes	< 8,000	12.1
		≥ 8,000 and < 14,000	12.0
		≥ 14,000 and < 20,000	11.8
		≥ 20,000 and < 25,000	10.3
		≥ 25,000	9.9
No	No	< 8,000	11.0
		≥ 8,000 and < 11,000	10.6
		≥ 11,000 and < 14,000	10.5
		≥ 14,000 and < 20,000	10.2
		≥ 20,000	10.3
Yes	Yes	< 20,000	10.8
		≥ 20,000	10.2
Yes	No	< 14,000	10.2
		≥ 14,000	9.6
Casement-only		All capacities	10.5
Casement-slider		All capacities	11.4

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Peak demand and annual energy savings for room air conditioners should be calculated as shown next.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{Savings,C} = CAP \times \frac{1\ kW}{1,000\ W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 59

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*
AOH_C	=	*Annual operating hours for cooling (Table 2-158)*
$CEER_{Base}$	=	*Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-157)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed room air conditioner*

Table 2-158: Room Air Conditioner Annual Operating Hours for Cooling[169]

Climate Zone	AOH_C
Climate Zone 1: Panhandle	820
Climate Zone 2: North	1,374
Climate Zone 3: South	1,308
Climate Zone 4: Valley	2,150
Climate Zone 5: West	1,204

Demand Savings Algorithms

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

Equation 60

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*
$CEER_{Base}$	=	*Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-157)*

169 Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator. http://www.cooloff.org/sub_cool.html.

$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed room air conditioner*
CF	=	*Coincidence Factor = 0.87 (default)*[170]

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 (8 – RUL)**

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

Where:

RUL	=	*Remaining Useful Life (seeTable 2-159); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years*
EUL	=	*Estimated Useful Life = 8 years*

Table 2-159: Remaining Useful Life (RUL) of Replaced Room Air Conditioner

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
1	8.2	8	5.0
2	7.2	9	4.0
3	6.2	10	3.0
4	5.2	11	2.0
5	5.2	12	1.0
6	5.2	13[171,172]	0.0
7	5.2		

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

171 RULs are capped at the 75th percentile of equipment age, 13 years, based on DOE survival curves. Systems older than 13 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

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

Derivation of RULs

Room air conditioners have an estimated useful life of 8 years. This estimate is consistent with the age at which approximately 50 percent of the room air conditioners installed in a given year will no longer be in service, as described by the survival function in Figure 2-5.

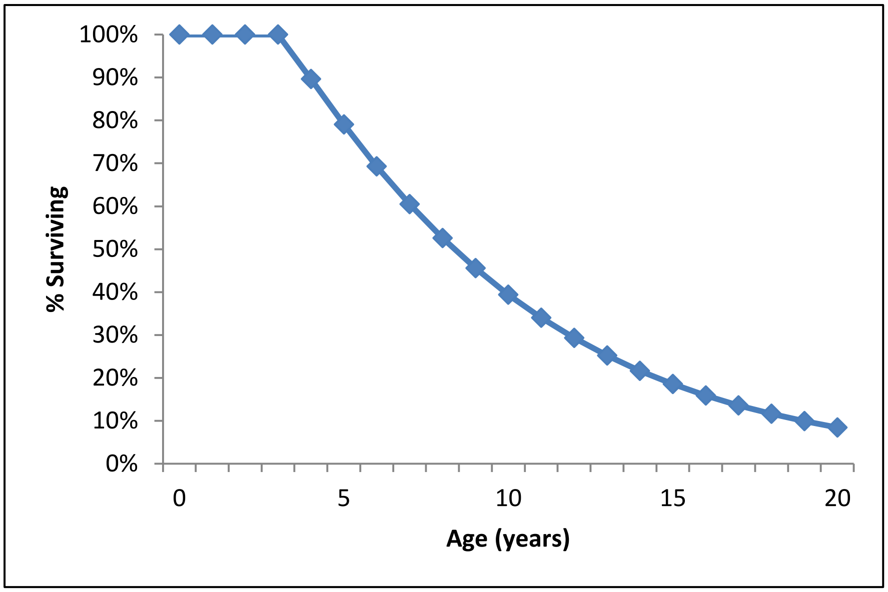

Figure 2-5: Survival Function for Room Air Conditioners[173]

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 2-5. The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving room air conditioners is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

Energy Savings Algorithms

For the RUL time period:

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

Equation 61

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

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

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

Equation 62

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr.)*
AOH_C	=	*Annual operating hours for cooling (Table 2-158)*
$CEER_{ROB}$	=	*Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 2-157)*
EER_{ER}	=	*Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 2-157)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed room air conditioner*

Summer Demand Savings Algorithms

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

For the RUL time period:

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

Equation 63

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

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

Equation 64

Deemed Energy Savings Tables

Replace-on-Burnout

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

Early Retirement

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

Replace-on-Burnout

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

Early Retirement

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

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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a room air conditioning unit is 8 years based on the Technical Support Document for the current DOE Final Rule standards for room air conditioners.[174]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 52852 Technical Support Document for Energy Conservation Standards for Room Air Conditioners.[175]

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[174] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 76 FR 22454 (April 21, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

[175] Department of Energy, Federal Register, 76 FR 52852, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

Program Tracking Data & 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:

- Decision/action type (Early Retirement, Replace-on-Burnout, New Construction)
- Cooling capacity of the installed unit (Btu/hr.)
- Combined Energy Efficiency Ratio (CEER) of the unit installed
- Climate zone of the site
- Age of the replaced unit (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for room air conditioners.
- Code of Federal Regulations, 10 CFR 430.32(b)

Document Revision History

Table 2-160: Room Air Conditioner Revision History

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

2.3 RESIDENTIAL: BUILDING ENVELOPE

2.3.1 Air Infiltration Measure Overview

TRM Measure ID: R-BE-AI

Market Sector: Residential

Measure Category: Building Envelope

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling and Engineering Algorithms

Measure Description

This measure involves implementation of interventions to reduce the rate of air infiltration into residences with central air cooling and/or heating systems. Pre- and post-treatment blower door air pressure readings are required to confirm air leakage reduction.

Eligibility Criteria

Homes treated for air infiltration reduction must be centrally cooled with electric refrigerated air conditioning to claim cooling savings; to claim heating savings, homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump.

There is an upper limit of 5.2 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate on eligible projects. For homes where the pre-retrofit leakage exceeds this limit, savings will be awarded against the leakage cap. At the utility's discretion, this cap may not apply to homes implementing the measure under low-income programs.[176] Utilities may require certification or competency testing of personnel who will perform the blower door tests.

Air leakage should be assessed through testing following Building Performance Institute (BPI) standards. In some limited cases, where testing is not possible or unsafe (e.g. due to potential presence of asbestos), visual assessment may be satisfactory. The air leakage testing should

[176] 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).

not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[177]

Utilities' program manuals should be consulted for health and safety considerations related to implementation of air sealing measures.

Only structures with electric refrigerated air conditioning systems are eligible.

Baseline Condition

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

Baseline assumptions used in the development of these deemed savings are based on a 2013 Lawrence Berkeley National Laboratory (LBNL) analysis of air leakage measurements of US houses.[178] The LBNL study showed that approximately 95 percent of the home infiltration rates were below a normalized leakage rate of 2.0. Normalized leakage can be converted to CFM_{50}/ft^2 using Equation 65 through Equation 67.

$$NL = 1,000 \times \frac{ELA_4}{A \times 0.3048^2} \times \left(\frac{H \times 0.3048}{2.5\,m}\right)^{0.3}$$

Equation 65

$$Q_{50} = ELA_4 \Big/ \left(\sqrt{\frac{\rho}{2(4\,Pa)}} \times \left(\frac{4\,Pa}{50\,Pa}\right)^{0.65}\right)$$

Equation 66

$$CFM_{50,pre}/ft^2 = \frac{Q_{50} \times 60 \times 35.3147}{A}$$

Equation 67

Where:

NL = *Normalized Leakage = 2.0 from LBNL study*

[177] 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."*

[178] Chan, W.R., Joh, J., and Sherman, M. H. Analysis of air leakage measurements of US houses. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory (LBNL), p. 616-625.

ELA_4	=	*Area of an orifice that would result in the same air-flow through the building envelope at a pressure difference of 4 Pa (m^2)*
A	=	*Average area of a home in Texas from RECS 2009 (ft^2) = 1,757 ft^2*
H	=	*Ceiling height (ft.) = 8.5 (default)* [179]
0.3048	=	*Constant to convert from feet to meters*
Q_{50}	=	*Leakage rate at 50 Pa (m^3/s)*
ρ	=	*1.2 kg/m^3 from LBNL study*
$CFM_{50,\,pre}/ft^2$	=	*Maximum per-square-foot pre-installation infiltration rate*
60	=	*Constant to convert from minutes to seconds*
35.3147	=	*Constant to convert from cubic meters to cubic feet*

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 5.2 CFM_{50}/ft^2. Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or where blower door tests were improperly conducted, these savings should only be applied starting at a baseline CFM_{50}/ft^2 of 5.2 or lower.

High-Efficiency Condition

Blower door air pressure measurements must also be used to ensure that post-treatment air infiltration rates are not less than those set forth by the standard in Equation 68, based on floor area and number of bedrooms.[180] These calculated minimum CFM_{50} values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. Where higher occupant densities are known, the minimum rate shall be increased by 7.5 CFM_{Nat} for each additional person. A CFM_{Nat} value can be converted to CFM_{50} by multiplying by the appropriate N factor (Table 2-161).

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

Equation 68

Where:

$Min\ CFM_{50}$	=	*Minimum final ventilation rate (CFM_{50})*
A_{Floor}	=	*Floor area (ft^2)*
OCC	=	*BR + 1, where BR is the number of bedrooms; if number of home occupants is known to exceed BR + 1, occupancy should be used instead*

179 Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

180 ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

$N \quad = \quad N\ factor\ (Table\ 2\text{-}161)$

Table 2-161: N Factors[181]

Shielding	Number of Stories		
	Single Story	Two Story	3 or More Stories
Well shielded	22.2	17.8	15.5
Normal	18.5	14.8	13.0
Exposed	16.7	13.3	11.7

The maximum CFM reduction percentage[182] is capped at 40% for RSOP homes. It is important to note that the minimum ventilation rate specified earlier in this section still applies for cases where the maximum 40% CFM reduction cannot be achieved due to the post CFM value being limited by the minimum allowable post CFM value provisioned for safety reasons.

The TRM stipulates an upper limit of 5.2 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate as part of eligibility criteria. For homes where the pre-retrofit leakage exceeds this limit, energy and demand savings must be calculated using the pre-measure-installation leakage cap. Therefore, when the pre-retrofit leakage is capped, energy and demand savings can only be claimed for a 40% reduction in CFM compared to the capped pre-CFM value. When the pre-retrofit leakage is not capped, energy and demand savings can only be claimed for a 40% reduction in CFM compared to the tested, actual pre-retrofit infiltration rate of the home.

The TRM requires all contractors to provide sufficient evidence such as pictures capturing the scope/type of retrofit implemented and blower door test readings for all RSOP homes that reach a CFM reduction percentage within the range of 30-40%. In the absence of any evidence, the TRM places a cap of 30% CFM reduction for calculating energy and demand savings.

At the utility's discretion, the cap of 40% CFM reduction and the ceiling of 5.2 CFM_{50} for pre-retrofit infiltration rate may not apply to homes implementing the measure under low-income programs.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the leakage reduction achieved (in CFM_{50}).[183] 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

[181] Krigger, J. and Dorsi, C.,"Residential Energy: Cost Savings and Comfort for Existing Buildings". A-11 Building Tightness Limits, p. 284. Use Zone 2 for Texas climate. http://www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf.

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

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

climate zone were modified as follows: the base case air infiltration rate was set to 20 ACH_{50}. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 3 ACH_{50}.

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

Deemed Energy Savings Tables

Table 2-162 presents the energy savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

$$\boldsymbol{Deemed\ Energy\ Savings = \Delta CFM_{50} \times \left(V_{E,C} + V_{E,H}\right)}$$

Equation 69

Where:

ΔCFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

$V_{E,C}$ = *Corresponding cooling savings value in Table 2-162*

$V_{E,H}$ = *Corresponding heating savings value in Table 2-162*

Table 2-162: Energy Savings V_E per CFM_{50} Reduction

Climate Zone	$V_{E,C}$: Cooling Savings	$V_{E,H}$: Heating Savings		
	Refrigerated Air	Gas Heat	Electric Resistance	Heat Pump
Zone 1: Panhandle	0.12	0.09	1.92	0.78
Zone 2: North	0.27	0.04	1.10	0.45
Zone 3: South	0.22	0.02	0.63	0.25
Zone 4: Valley	0.39	0.02	0.55	0.21
Zone 5: West*	0.07	0.03	0.88	0.34

Deemed Summer Demand Savings Tables

Table 2-163 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed summer demand savings for air infiltration improvements.

$$\textbf{Deemed Summer Demand Savings} = \Delta CFM_{50} \times V_S$$

Equation 70

Where:

ΔCFM_{50}	=	*Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*
V_S	=	*Corresponding value in Table 2-163*

Table 2-163: Peak Summer Demand Savings V_S per CFM_{50} Reduction

Region	Summer kW Impact per CFM_{50} Reduction
Climate Zone 1: Panhandle	1.64E-04
Climate Zone 2: North	2.10E-04
Climate Zone 3: South	1.90E-04
Climate Zone 4: Valley	2.24E-04
Climate Zone 5: West	9.40E-05

Deemed Winter Demand Savings Tables

Table 2-164 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed winter demand savings for air infiltration improvement:

$$\textbf{Deemed Winter Demand Savings} = \Delta CFM_{50} \times V_W$$

Equation 71

Where:

ΔCFM_{50}	=	*Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*
V_W	=	*Corresponding value in Table 2-164*

Table 2-164: Peak Winter Demand Savings V_W per CFM_{50} Reduction

Region	Winter kW Impact per CFM_{50} Reduction	
	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	9.42E-04	5.48E-04
Climate Zone 2: North	1.25E-03	6.93E-04
Climate Zone 3: South	8.61E-04	4.41E-04
Climate Zone 4: Valley	7.81E-04	3.60E-04
Climate Zone 5: West	2.92E-04	1.19E-04

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

$$Max\ Initial\ Leakage\ Rate\ = 5.2 * 2{,}200 = 11{,}440\ CFM_{50}$$

$$Reported\ Initial\ Leakage\ = Min(12{,}000, 11{,}400) = 11{,}440\ CFM_{50}$$

$$Capped\ Post\ Retrofit\ Leakage\ = 11{,}400\ \mathrm{x}\ (1 - 0.4) = 6{,}864\ CFM_{50}$$

$$Reported\ Post\ Retrofit\ Leakage\ = Max(8{,}000, 6{,}864) = 8{,}000\ CFM_{50}$$

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

$$\Delta CFM_{50} = (11{,}440 - 8{,}000) = 3{,}440$$

$$kWh\ savings = (0.39 + 0.21) \times 3{,}440 = 2{,}064\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 2.24x10^{-4} \times 3{,}440 = 0.77\ \mathrm{kW}$$

$$Winter\ kW\ savings = 3.60x10^{-4} \times 3{,}440 = 1.24\ \mathrm{kW}$$

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the DEER Final Report December 2008, the estimated useful life is 11 years for air infiltration reduction.

Program Tracking Data & 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:

- The climate zone
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Heating type (gas, resistance heat, heat pump)

- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories
- Number of occupants
- For RSOP homes that achieve a CFM reduction percentage of 30-40%: pictures capturing the scope/type of retrofit implemented and blower door test readings showing pre- and post-retrofit condition of the treated spot such as newly added door strip, caulking around window frame and recessed lighting fixtures.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-165: Air Infiltration Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.
v3.0	4/10/2015	TRM v3.0 update. Revision of minimum ventilation requirements, pre-retrofit cap on infiltration levels, Climate Zone 5 savings values for homes with heat pumps, and tracking number of bedrooms and occupants in a house.
v3.1	11/05/2015	TRM v3.1 update. Provided clarification around effects of occupancy on minimum final ventilation.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Introduced new protocols related to maximum CFM reduction percentage and its associated documentation requirements. Added a new example for calculating savings.

2.3.2 Ceiling Insulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Savings are estimated for insulation improvements to the ceiling area above a conditioned space in residences with central air cooling and/or heating systems.

Eligibility Criteria

Cooling savings in this measure apply to customers with electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings.

Baseline Condition

Ceiling insulation levels encountered in existing homes can vary significantly, depending on factors such as the age of the home, type of insulation installed, and level of attic use (equipment, storage, etc.). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The current average ceiling insulation level at participating homes is to be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

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

For any reported pre-retrofit R-value that falls below R-5, the TRM requires all contractors to provide sufficient evidence including two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation. In the absence of evidence demonstrating pre-retrofit ceiling insulation below R-5, the lowest level of pre-retrofit ceiling insulation that can be claimed is the R-5 to R-8 range.

High-Efficiency Condition

A ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation: contractors should estimate post-retrofit R-value according to the average insulation depth achieved across the area treated and the R-per-inch of the insulation material installed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22. These modifications are shown in Table 2-166.

The model runs are used to estimate peak demand and energy use in the modeled home at each of the base case ceiling insulation levels. The change-case models were run with the ceiling insulated to R-30.

Table 2-166: Residential Ceiling Insulation – Prototypical Home Characteristics

Shell Characteristic	Value	Source
Base Ceiling Insulation	R-0 R1-R4 R5-R8 R9-R14 R15-R22	Existing insulation level
Change Ceiling Insulation	R-30	Efficiency measure – R-30 retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas

Deemed Energy Savings Tables

Table 2-167 through Table 2-171 present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Climate Zone 1: Panhandle Region

Table 2-167: Climate Zone 1: Panhandle Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft)

Ceiling Insulation Base R-value	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	0.75	0.22	0.21	5.48	2.35
R-1 to R-4	0.62	0.18	0.18	4.60	1.97
R-5 to R-8	0.28	0.08	0.08	2.16	0.92
R-9 to R-14	0.15	0.04	0.05	1.17	0.50
R-15 to R-22	0.06	0.02	0.02	0.51	0.22

Climate Zone 2: North Region

Table 2-168: Climate Zone 2: North Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.23	0.12	3.40	1.41
R-1 to R-4	1.01	0.10	2.87	1.18
R-5 to R-8	0.46	0.05	1.34	0.55
R-9 to R-14	0.25	0.03	0.72	0.30
R-15 to R-22	0.11	0.01	0.32	0.13

Climate Zone 3: South Region

Table 2-169: Climate Zone 3: South Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.27	0.09	2.30	0.93
R-1 to R-4	1.04	0.07	1.96	0.79
R-5 to R-8	0.46	0.03	0.92	0.37
R-9 to R-14	0.24	0.02	0.50	0.20
R-15 to R-22	0.10	0.01	0.22	0.09

Climate Zone 4: Valley Region

Table 2-170: Climate Zone 4: Valley Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.))

Ceiling Insulation Base R-value	Cooling Savings	Heating Savings		
		Gas Heat	Electric Resistance	Heat Pump
R-0	1.00	0.04	1.60	0.62
R-1 to R-4	0.78	0.04	1.35	0.52
R-5 to R-8	0.35	0.02	0.62	0.24
R-9 to R-14	0.18	0.01	0.33	0.13
R-15 to R-22	0.08	0.00	0.14	0.06

Climate Zone 5: West Region

Table 2-171: Climate Zone 5: West Region – Deemed Annual Energy Savings for Residential Ceiling Insulation to R-30 (kWh/sq. ft.)

Ceiling Insulation Base R-value	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	1.17	0.38	0.12	3.44	1.43
R-1 to R-4	0.96	0.32	0.10	2.95	1.22
R-5 to R-8	0.43	0.15	0.05	1.40	0.57
R-9 to R-14	0.23	0.08	0.03	0.75	0.31
R-15 to R-22	0.10	0.03	0.01	0.33	0.13

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

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

$$\boldsymbol{Energy\ Savings\ (kWh) = \{R30\ Savings/ft^2 + [S_{D/U} \times (R_{Achieved} - 30)]\} \times A}$$

Equation 72

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 2-172 through Table 2-173*

$S_{D/U}$	=	*Project-appropriate scale-down or scale-up factor from either Table 2-172 or Table 2-173.*
$R_{Achieved}$	=	*Achieved R-value of installed insulation (e.g. for R-28,* $R_{Achieved} = 28$*)*
A	=	*Treated area* (ft^2)

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

Table 2-172: Energy Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02
2	6.66E-03	n/a	7.11E-04	2.00E-02	8.20E-03
3	6.22E-03	n/a	4.67E-04	1.38E-02	5.47E-03
4	4.92E-03	n/a	2.44E-04	9.04E-03	3.47E-03
5	4.00E-03	1.16E-03	1.27E-03	3.26E-02	1.38E-02

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

Table 2-173: Energy Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
1	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03
2	4.45E-03	n/a	4.82E-04	1.33E-02	5.47E-03
3	4.00E-03	n/a	2.97E-04	9.19E-03	3.66E-03
4	3.24E-03	n/a	1.62E-04	5.99E-03	2.30E-03
5	2.66E-03	7.63E-04	8.45E-04	2.18E-02	9.18E-03

Deemed Summer Demand Savings Tables

Table 2-174 through Table 178 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-174: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Refrigerated Air	Evaporative Cooling
R-0	1.15E-03	3.44E-04
R-1 to R-4	9.78E-04	3.04E-04
R-5 to R-8	4.50E-04	1.47E-04
R-9 to R-14	2.33E-04	7.16E-05
R-15 to R-22	1.02E-04	2.87E-05

Climate Zone 2: North Region

Table 2-175: Climate Zone 2: North Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	1.27E-03
R-1 to R-4	1.10E-03
R-5 to R-8	5.17E-04
R-9 to R-14	2.67E-04
R-15 to R-22	1.15E-04

Climate Zone 3: South Region

Table 2-176: Climate Zone 3: South Region – Residential Ceiling Insulation to R-30 Conditioning Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	1.44E-03
R-1 to R-4	1.21E-03
R-5 to R-8	5.51E-04
R-9 to R-14	2.87E-04
R-15 to R-22	1.22E-04

Climate Zone 4: Valley Region

Table 2-177: Climate Zone 4: Valley Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Demand Savings (kW/sq. ft.)
R-0	8.70E-04
R-1 to R-4	7.16E-04
R-5 to R-8	3.40E-04
R-9 to R-14	1.79E-04
R-15 to R-22	7.95E-05

Climate Zone 5: West Region

Table 2-178: Climate Zone 5: West Region – Residential Ceiling Insulation to R-30 Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	Refrigerated Air	Evaporative Cooling
R-0	1.18E-03	3.33E-04
R-1 to R-4	1.01E-03	3.25E-04
R-5 to R-8	4.72E-04	1.53E-04
R-9 to R-14	2.38E-04	6.25E-05
R-15 to R-22	1.03E-04	2.09E-05

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

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

Table 2-179: Summer Peak Demand Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Refrigerated Air	Evaporative Cooling
1	6.41E-06	1.97E-06
2	7.30E-06	n/a
3	7.91E-06	n/a
4	5.20E-06	n/a
5	6.41E-06	1.97E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

Table 2-180: Summer Peak Demand Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Refrigerated Air	Evaporative Cooling
1	4.22E-06	1.89E-06
2	4.92E-06	n/a
3	5.92E-06	n/a
4	3.47E-06	n/a
5	4.22E-06	1.89E-06

Deemed Winter Demand Savings Tables

Table 2-181 through Table 2-185 present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-181: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	7.83E-05	2.25E-03	1.15E-03
R-1 to R-4	6.35E-05	1.90E-03	9.84E-04
R-5 to R-8	2.51E-05	8.74E-04	4.53E-04
R-9 to R-14	1.37E-05	4.56E-04	2.38E-04
R-15 to R-22	4.72E-06	1.95E-04	1.01E-04

Climate Zone 2: North Region

Table 2-182: Climate Zone 2: North Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	6.02E-05	2.49E-03	1.62E-03
R-1 to R-4	5.35E-05	2.11E-03	1.41E-03
R-5 to R-8	2.79E-05	9.84E-04	6.60E-04
R-9 to R-14	1.45E-05	5.13E-04	3.51E-04
R-15 to R-22	6.42E-06	2.23E-04	1.52E-04

Climate Zone 3: South Region

Table 2-183: Climate Zone 3: South Region - Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	8.08E-05	1.96E-03	1.08E-03
R-1 to R-4	6.85E-05	1.65E-03	9.43E-04
R-5 to R-8	2.91E-05	7.71E-04	4.49E-04
R-9 to R-14	1.39E-05	4.01E-04	2.35E-04
R-15 to R-22	5.36E-06	1.74E-04	1.03E-04

Climate Zone 4: Valley Region

Table 2-184: Climate Zone 4: Valley Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	5.28E-05	1.60E-03	7.50E-04
R-1 to R-4	4.48E-05	1.36E-03	6.47E-04
R-5 to R-8	2.18E-05	6.31E-04	3.03E-04
R-9 to R-14	1.13E-05	3.28E-04	1.57E-04
R-15 to R-22	5.71E-06	1.44E-04	6.95E-05

Climate Zone 5: West Region

Table 2-185: Climate Zone 5: West Region – Residential Ceiling Insulation to R-30 Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	Gas	Electric Resistance	Heat Pump
R-0	3.28E-05	9.12E-04	3.91E-04
R-1 to R-4	2.56E-05	8.13E-04	3.45E-04
R-5 to R-8	1.14E-05	3.72E-04	1.57E-04
R-9 to R-14	5.38E-06	1.79E-04	7.54E-05
R-15 to R-22	2.26E-06	7.41E-05	3.11E-05

Scale Down/Up Factors for Demand Reduction: Insulation to Below or Above R-30

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

$$\boldsymbol{Demand\ Savings\ (kW) = \{R30\ Savings/ft^2 + [S_{D/U} \times (R_{Achieved} - 30)]\} \times A}$$

Equation 73

Where:

R30 Savings/ft² = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 2-172 and Table 2-173*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 2-172 or Table 2-173*

$R_{Achieved}$ = *Achieved R-value of installed insulation (e.g. for R-28, $R_{Achieved}$ = 28)*

A = *Treated area (ft²)*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings per square foot of treated ceiling area.

Table 2-186: Winter Peak Demand Scale Down Factors: Ceiling Insulation to less than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
1	4.29E-07	1.21E-05	6.30E-06
2	3.97E-07	1.40E-05	9.55E-06
3	3.05E-07	1.10E-05	6.53E-06
4	3.19E-07	9.18E-06	4.32E-06
5	4.29E-07	1.21E-05	6.30E-06

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

Table 2-187: Winter Peak Demand Scale Up Factors: Ceiling Insulation to greater than R-30 (kWh/sq. ft./ΔR)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
1	2.76E-07	7.85E-06	4.19E-06
2	2.57E-07	8.33E-06	4.80E-06
3	2.19E-07	7.33E-06	4.46E-06
4	1.72E-07	5.79E-06	2.72E-06
5	2.76E-07	7.85E-06	4.19E-06

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 (Scale Up). A home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 400 square feet from a baseline of R-1 to an efficient condition of R-38.

$$cooling\ energy\ savings\ per\ sq.ft. = 0.32 + 7.63x10^{-4} \times (38-30) = 0.33\ kWh/sq.ft.$$

$$heating\ energy\ savings\ per\ sq.ft. = 2.95 + 2.18x10^{-2} \times (38-30) = 3.12\ kWh/sq.ft.$$

$$kWh\ savings = (0.33 + 3.12) \times 400 = 1{,}381\ kWh$$

$$summer\ demand\ savings\ per\ sq.ft. = 3.25x10^{-4} + 1.89x10^{-6} \times (38-30) = 3.41x10^{-4}\ kW/sq.ft.$$

$$Summer\ kW\ savings = 3.41x10^{-4} \times 400 = 0.14\ \mathrm{kW}$$

$$winter\ demand\ savings\ per\ sq.ft = 8.13x10^{-4} + 7.85x10^{-5} \times (38-30) = 8.76x10^{-4}\ kW/sq.ft.$$

$$Winter\ kW\ savings = 8.76x10^{-4} \times 400 = 0.35\ \mathrm{kW}$$

Example 2 (Scale Down). A home in Climate Zone 3 with an air-source heat pump insulates 550 square feet from a baseline of R-5 to an efficient condition of R-28.

$$cooling\ energy\ savings\ per\ sq.ft. = 0.46 + 5.47x10^{-3} \times (28-30) = 0.45\ kWh/sq.ft.$$

$$heating\ energy\ savings\ per\ sq.ft. = 0.37 + 3.66x10^{-3} \times (28-30) = 0.36\ kWh/sq.ft.$$

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

$$summer\ demand\ savings\ per\ sq.ft. = 5.51x10^{-4} + 7.91x10^{-6} \times (28-30) = 5.35x10^{-4}\ kW/sq.ft.$$

$$Summer\ kW\ savings = 5.35x10^{-4} \times 550 = 0.29\ kW$$

$$winter\ demand\ savings\ per\ sq.ft. = 4.49x10^{-4} + 6.53x10^{-6} \times (28-30) = 4.36x10^{-4}\ kW/sq.ft.$$

$$Winter\ kW\ savings = 4.36x10^{-4} \times 550 = 0.24\ kW$$

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[184] the Estimated Useful Life is 25 years for ceiling insulation.

Program Tracking Data & 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:

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Space heating system type (gas, electric, heat pump)
- Square footage of ceiling insulation installed above a conditioned space
- Only for homes with a reported baseline R-value that is less than R-5:

  Two pictures: 1) a picture showing the entire attic floor, and 2) a close-up picture of a ruler that shows the measurement of the depth of the insulation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

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[184] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

Document Revision History

Table 2-188: Ceiling Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRV v3.0 update. Provided savings tables for installation of insulation up to R-38. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air conditioning. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Clarified that no heating demand savings are to be claimed for homes with a gas furnace.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype simulation models and introduced new protocols for baseline and post-retrofit R-values, their associated savings estimations and documentation requirements.

2.3.3 Attic Encapsulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Savings are estimated for bringing the attic into conditioned space by insulating and sealing the attic walls and roofs, eliminating leakage (to outside), and removing ceiling insulation, if present, to enhance air flow between the attic and the conditioned space directly below.

Eligibility Criteria

Cooling savings in this measure apply to customers with electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings.

Baseline Condition

The baseline condition is a vented, unfinished attic with some level of ceiling insulation. Ceiling insulation levels in existing construction can vary significantly, depending on the age of the home, type of insulation installed, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from no insulation material (R-0) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The average ceiling insulation level prior to the retrofit for at participating homes is to be determined and documented by the contractor. Degradation due to age and density of the existing insulation should be taken into account.

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

High-Efficiency Condition

Attic walls and roof deck are insulated to either R-19 or R-38. Closed cell spray foam is recommended. Vents are sealed, as are obvious leaks. Ceiling insulation between the attic and the conditioned space is removed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22 to establish baseline energy use prior to encapsulation of the attic. These modifications are shown in Table 2-189.

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

Table 2-189: **Residential Attic Encapsulation – Prototypical Home Characteristics, Climate Zones 1-4**

Shell Characteristic	Value	Source
Base Attic Encapsulation	Vented Attic R-0 R1-R4 R5-R8 R9-R14 R15-R22	Typical construction practice throughout the state
Change Attic Encapsulation	Sealed attic with no ceiling insulation and either R-39 or R-38 roof deck insulation	Typical construction practice throughout the state

Deemed Energy Savings Tables

Table 2-190 through Table 2-194 present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-190: Climate Zone 1: Panhandle Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	R				
		Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.56	0.21	0.19	4.21	1.80
R-1 to R-4	R-19	0.44	0.18	0.16	3.43	1.46
R-5 to R-8	R-19	0.14	0.09	0.08	1.24	0.52
R-9 to R-14	R-19	0.02	0.05	0.04	0.36	0.14
R-15 to R-22	R-19	-0.06	0.03	0.02	-0.23	-0.11
R-0	R-38	0.63	0.23	0.21	4.54	1.94
R-1 to R-4	R-38	0.52	0.20	0.18	3.76	1.60
R-5 to R-8	R-38	0.22	0.11	0.09	1.57	0.66
R-9 to R-14	R-38	0.10	0.08	0.06	0.69	0.28
R-15 to R-22	R-38	0.02	0.06	0.04	0.10	0.03

Climate Zone 2: North Region

Table 2-191: Climate Zone 2: North Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.91	0.10	2.63	1.09
R-1 to R-4	R-19	0.71	0.08	2.15	0.88
R-5 to R-8	R-19	0.22	0.04	0.78	0.32
R-9 to R-14	R-19	0.03	0.02	0.23	0.09
R-15 to R-22	R-19	-0.10	0.01	-0.13	-0.06
R-0	R-38	1.04	0.11	2.83	1.17
R-1 to R-4	R-38	0.84	0.09	2.35	0.97
R-5 to R-8	R-38	0.35	0.05	0.98	0.40
R-9 to R-14	R-38	0.16	0.03	0.43	0.17
R-15 to R-22	R-38	0.04	0.01	0.07	0.02

Climate Zone 3: South Region

Table 2-192: Climate Zone 3: South Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.96	0.08	1.81	0.73
R-1 to R-4	R-19	0.76	0.06	1.51	0.60
R-5 to R-8	R-19	0.24	0.03	0.58	0.23
R-9 to R-14	R-19	0.04	0.01	0.20	0.07
R-15 to R-22	R-19	-0.08	0.00	-0.05	-0.03
R-0	R-38	1.09	0.08	1.94	0.78
R-1 to R-4	R-38	0.88	0.07	1.64	0.65
R-5 to R-8	R-38	0.36	0.03	0.71	0.28
R-9 to R-14	R-38	0.17	0.02	0.33	0.13
R-15 to R-22	R-38	0.04	0.01	0.08	0.03

Climate Zone 4: Valley Region

Table 2-193: Climate Zone 4: Valley Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings	Heating Savings		
			Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.67	0.03	1.26	0.48
R-1 to R-4	R-19	0.48	0.03	1.04	0.40
R-5 to R-8	R-19	0.09	0.01	0.39	0.15
R-9 to R-14	R-19	-0.05	0.00	0.13	0.05
R-15 to R-22	R-19	-0.15	0.00	-0.04	-0.02
R-0	R-38	0.77	0.04	1.34	0.52
R-1 to R-4	R-38	0.58	0.03	1.12	0.43
R-5 to R-8	R-38	0.19	0.01	0.47	0.18
R-9 to R-14	R-38	0.05	0.01	0.21	0.08
R-15 to R-22	R-38	-0.05	0.00	0.04	0.01

Climate Zone 5: West Region

Table 2-194: Climate Zone 5: West Region – Deemed Annual Energy Savings for Residential Attic Encapsulation (kWh/sq. ft.)

Ceiling Insulation Base R-value	Change Case Roof Deck Insulation R-value	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
R-0	R-19	0.90	0.37	0.10	2.71	1.13
R-1 to R-4	R-19	0.72	0.32	0.09	2.27	0.93
R-5 to R-8	R-19	0.25	0.16	0.04	0.89	0.36
R-9 to R-14	R-19	0.06	0.10	0.02	0.30	0.12
R-15 to R-22	R-19	-0.06	0.06	0.01	-0.07	-0.04
R-0	R-38	1.02	0.42	0.11	2.90	1.20
R-1 to R-4	R-38	0.84	0.36	0.10	2.46	1.01
R-5 to R-8	R-38	0.37	0.21	0.05	1.07	0.44
R-9 to R-14	R-38	0.19	0.15	0.03	0.49	0.20
R-15 to R-22	R-38	0.07	0.11	0.02	0.12	0.04

Deemed Summer Demand Savings Tables

Table 2-195 through Table 2-199 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-195: Climate Zone 1: Panhandle Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	9.70E-04	4.01E-04	1.04E-03	4.04E-04
R-1 to R-4	8.16E-04	3.66E-04	8.83E-04	3.69E-04
R-5 to R-8	3.44E-04	2.25E-04	4.11E-04	2.28E-04
R-9 to R-14	1.50E-04	1.57E-04	2.16E-04	1.61E-04
R-15 to R-22	3.29E-05	1.19E-04	9.93E-05	1.23E-04

Climate Zone 2: North Region

Table 2-196: Climate Zone 2: North Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.06E-03	-	1.14E-03	-
R-1 to R-4	9.08E-04		9.89E-04	
R-5 to R-8	3.86E-04		4.68E-04	
R-9 to R-14	1.62E-04		2.44E-04	
R-15 to R-22	2.63E-05		1.08E-04	

Climate Zone 3: South Region

Table 2-197: Climate Zone 3: South Region – Residential Attic Encapsulation Conditioning Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.26E-03	-	1.35E-03	-
R-1 to R-4	1.06E-03		1.14E-03	
R-5 to R-8	4.65E-04		5.51E-04	
R-9 to R-14	2.29E-04		3.15E-04	
R-15 to R-22	8.20E-05		1.68E-04	

Climate Zone 4: Valley Region

Table 2-198: Climate Zone 4: Valley Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	7.44E-04	-	7.99E-04	-
R-1 to R-4	6.06E-04		6.61E-04	
R-5 to R-8	2.69E-04		3.25E-04	
R-9 to R-14	1.25E-04		1.81E-04	
R-15 to R-22	3.67E-05		9.19E-05	

Climate Zone 5: West Region

Table 2-199: Climate Zone 5: West Region – Residential Attic Encapsulation Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-19 Installed)		R-38 Installed	
	Refrigerated Air	Evaporative Cooling	Refrigerated Air	Evaporative Cooling
R-0	1.01E-03	3.22E-04	1.08E-03	3.44E-04
R-1 to R-4	8.58E-04	3.15E-04	9.32E-04	3.38E-04
R-5 to R-8	3.74E-04	1.62E-04	4.48E-04	1.84E-04
R-9 to R-14	1.64E-04	8.02E-05	2.38E-04	1.02E-04
R-15 to R-22	4.29E-05	4.29E-05	1.17E-04	6.52E-05

Deemed Winter Demand Savings Tables

Table 2-200 through Table 2-204 present the winter demand savings associated with ceiling insulation for the five Texas climate zones. Savings are per square foot of installed insulation.

Climate Zone 1: Panhandle Region

Table 2-200: Climate Zone 1: Panhandle Region – Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	7.75E-05	1.70E-03	8.70E-04	8.67E-05	1.82E-03	9.35E-04
R-1 to R-4	6.43E-05	1.39E-03	7.22E-04	7.34E-05	1.51E-03	7.87E-04
R-5 to R-8	2.99E-05	4.74E-04	2.47E-04	3.90E-05	5.94E-04	3.12E-04
R-9 to R-14	1.98E-05	1.00E-04	5.48E-05	2.89E-05	2.20E-04	1.20E-04
R-15 to R-22	1.17E-05	-1.34E-04	-6.79E-05	2.09E-05	-1.38E-05	-2.63E-06

Climate Zone 2: North Region

Table 2-201: Climate Zone 2: North Region – Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	4.97E-05	1.88E-03	1.21E-03	6.17E-05	2.01E-03	1.32E-03
R-1 to R-4	4.37E-05	1.55E-03	1.02E-03	5.57E-05	1.68E-03	1.13E-03
R-5 to R-8	2.08E-05	5.42E-04	3.55E-04	3.28E-05	6.70E-04	4.64E-04
R-9 to R-14	8.86E-06	1.21E-04	7.86E-05	2.09E-05	2.50E-04	1.87E-04
R-15 to R-22	1.59E-06	-1.39E-04	-9.90E-05	1.36E-05	-1.02E-05	9.55E-06

Climate Zone 3: South Region

Table 2-202: Climate Zone 3: South Region - Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	8.71E-05	1.59E-03	8.78E-04	9.55E-05	1.68E-03	9.34E-04
R-1 to R-4	7.61E-05	1.32E-03	7.58E-04	8.46E-05	1.41E-03	8.14E-04
R-5 to R-8	4.08E-05	5.29E-04	3.16E-04	4.93E-05	6.20E-04	3.72E-04
R-9 to R-14	2.73E-05	1.98E-04	1.25E-04	3.57E-05	2.89E-04	1.81E-04
R-15 to R-22	1.96E-05	-4.36E-06	6.84E-06	2.81E-05	8.67E-05	6.31E-05

Climate Zone 4: Valley Region

Table 2-203: Climate Zone 4: Valley Region – Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	4.67E-05	1.31E-03	6.23E-04	4.94E-05	1.38E-03	6.55E-04
R-1 to R-4	3.95E-05	1.10E-03	5.31E-04	4.21E-05	1.16E-03	5.63E-04
R-5 to R-8	1.90E-05	4.40E-04	2.24E-04	2.16E-05	5.08E-04	2.56E-04
R-9 to R-14	9.58E-06	1.69E-04	9.26E-05	1.22E-05	2.37E-04	1.25E-04
R-15 to R-22	4.57E-06	4.16E-06	1.43E-05	7.20E-06	7.22E-05	4.64E-05

Climate Zone 5: West Region

Table 2-204: Climate Zone 5: West Region – Residential Attic Encapsulation Deemed Winter Demand Savings (kW/sq. ft.)

Ceiling Insulation Base R-value	R-19 Installed			R-38 Installed		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	2.57E-05	6.66E-04	2.83E-04	3.08E-05	6.87E-04	2.92E-04
R-1 to R-4	1.93E-05	5.77E-04	2.42E-04	2.44E-05	5.98E-04	2.51E-04
R-5 to R-8	6.56E-06	1.83E-04	7.34E-05	1.17E-05	2.04E-04	8.31E-05
R-9 to R-14	1.18E-06	9.88E-06	5.10E-08	6.30E-06	3.09E-05	9.74E-06
R-15 to R-22	-1.60E-06	-8.35E-05	-3.96E-05	3.51E-06	-6.25E-05	-2.99E-05

Examples

Example 1. A contractor seals the attic and adds 900 square feet of R-38 insulation to the underside of the roof to a home in Climate Zone 3 with refrigerated air and a gas furnace, which has existing ceiling insulation estimated at R-7.

$$kWh\ savings = (0.36 + \ 0.03) \times 900 = 356.4\ \text{kWh}$$

$$Summer\ kW\ savings = 5.51x10^{-4} \times 900 = 0.50\ \text{kW}$$

$$Winter\ kW\ savings = 4.93x10^{-5} \times 900 = 0.04\ \text{kW}$$

Example 2. A contractor seals the attic and adds 1,200 square feet of R-38 insulation to the underside of the roof to a home in Climate Zone 4 with an air-source heat pump in which existing ceiling insulation is demonstrated to be only R-4.

$$kWh\ savings = (0.58 + \ 0.43) \times 1{,}200 = 1{,}207.2\ \text{kWh}$$

$$Summer\ kW\ savings = 6.61x10^{-4} \times 1{,}200 = 0.79\ \text{kW}$$

$$Winter\ kW\ savings = 5.63x10^{-4} \times 1{,}200 = 0.68\ \text{kW}$$

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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[185] the Estimated Useful Life is 25 years for ceiling insulation.

Program Tracking Data & 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:

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Space heating system type (gas, electric, heat pump)
- Square footage of ceiling insulation installed above a conditioned space

References and Efficiency Standards

Petitions and Rulings

- TBD

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-205: Ceiling Insulation Revision History

TRM Version	Date	Description of Change
v4.0	10/10/2016	TRM v4.0 origin.

185 GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

2.3.4 Wall Insulation Measure Overview

TRM Measure ID: R-BE-WI

Market Sector: Residential

Measure Category: Building Envelope

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling and Engineering Estimates

Measure Description

Wall insulation is added to the walls surrounding conditioned space in existing homes, either by removing wall enclosures and applying batt or spray insulation, or by otherwise filling (e.g. blowing loose insulation into) the cavity space between studs in the walls of existing homes. Walls may be either 2x4 or 2x6 construction. Savings are estimated for filling the wall cavities of 2x4 or 2x6 walls with either fiberglass batts or closed-cell spray foam, and are presented per square foot of treated wall area (gross wall area less window and door area).

Eligibility Criteria

To qualify for these deemed savings values, wall insulation may be added for customers with electric, central air conditioning or for customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Refer to the Baseline Condition section below for eligibility criteria regarding pre-retrofit level of wall insulation.

Baseline Condition

The baseline is considered to be a house with little or no wall insulation in the wall cavity. For those homes for which a minimal level of insulation is encountered, baseline is established at R-4. This baseline should be used to represent homes for which installed insulation covers a very limited amount of the wall area to be treated, is significantly degraded, and/or is less than an inch thick. Homes with more than this base level of insulation are not eligible for the measure.

Baseline homes may have either 2x4 or 2x6 construction.

High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by United States Department of Energy (DOE) and Texas Department of Housing & Community Affairs (TDHCA) programs. The standard is achieved by filling a 2x4 wall cavity with fiberglass batt insulation, which typically provides an R-value per inch (thickness) of between 3 and 4 hr·ft^2·°F/BTU. Other wall insulation materials may be used, such as closed-cell spray foam, which approximately provides an R-value of 6 per inch.

As such, deemed savings are provided for insulating 2x4 and 2x6 walls to the levels presented in Table 2-206:

Table 2-206: High-Efficiency Condition R-Values for 2x4 and 2x6 Walls

Insulation Material	2x4 Wall	2x6 Wall
Fiberglass Batt	R-13	R-17
Closed-cell Spray Foam	R-21	R-33

Wall insulation reduces the ventilation rate in the home and therefore a post-installation blower door test must be conducted. Results must comply with the Minimum Final Ventilation Rate discussed in the High-Efficiency Condition section found in the Air Infiltration section of this document. This requirement applies to retrofits implemented under the HTR and RSOP programs.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-11 insulation was reduced to either R-0 or R-4.

The model runs calculated energy use for the prototypical home prior to the installation of the wall insulation measure. Next, change-case models were run to calculate energy use with the wall insulation measure in place.

Table 2-207: Residential Wall Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Base Wall Insulation	R-0 R-4	BEopt estimates wall assembly R-value for uninsulated walls to be 3.6 for 2x4 construction and 3.7 for 2x6 construction. Assembly R-values for R-4 walls are 6.7 and 7.1 for 2x4 and 2x6 construction, respectively. Listed base levels are for the insulation material only.
Change Wall Insulation 2x4 wall	R-13 R-21	For retrofit with fiberglass batt and closed-cell spray foam, respectively.
Change Wall Insulation 2x6 wall	R-17 R-33	EF or retrofit with fiberglass batt and closed-cell spray foam, respectively.

Deemed Energy Savings Tables

Savings are presented separately for insulating 2x4 wall construction and homes with 2x6 walls. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

2x4 Walls

Table 2-209 presents the deemed energy savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-208: Deemed Annual Energy Savings, Insulation of 2x4 Walls to R- 13 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.50	0.17	0.18	3.96	1.67
Climate Zone 2: North		0.85	N/A	0.09	2.44	0.99
Climate Zone 3: South		0.90	N/A	0.07	1.67	0.66
Climate Zone 4: Valley		0.53	N/A	0.04	1.19	0.45
Climate Zone 5: West		0.76	0.29	0.09	2.40	0.98
Climate Zone 1: Panhandle	R-4	0.18	0.06	0.07	1.52	0.64
Climate Zone 2: North		0.32	N/A	0.04	0.93	0.38
Climate Zone 3: South		0.33	N/A	0.03	0.64	0.25
Climate Zone 4: Valley		0.19	N/A	0.01	0.45	0.17
Climate Zone 5: West		0.28	0.11	0.03	0.92	0.37

Table 2-209 presents the deemed energy savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

Table 2-209: Deemed Annual Energy Savings, Insulation of 2x4 Walls to R-21 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.56	0.18	0.20	4.44	1.87
Climate Zone 2: North		0.95	N/A	0.10	2.73	1.11
Climate Zone 3: South		1.01	N/A	0.08	1.88	0.74
Climate Zone 4: Valley		0.59	N/A	0.04	1.33	0.50
Climate Zone 5: West		0.85	0.33	0.10	2.69	1.09
Climate Zone 1: Panhandle	R-4	0.24	0.08	0.09	2.00	0.84
Climate Zone 2: North		0.42	N/A	0.05	1.23	0.50
Climate Zone 3: South		0.43	N/A	0.03	0.84	0.33
Climate Zone 4: Valley		0.26	N/A	0.02	0.59	0.22
Climate Zone 5: West		0.37	0.14	0.05	1.20	0.49

2x6 Walls

Table 2-210 presents the deemed energy savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-210: Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-17 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.53	0.18	0.19	4.27	1.80
Climate Zone 2: North		0.91	N/A	0.10	2.63	1.07
Climate Zone 3: South		0.97	N/A	0.08	1.81	0.71
Climate Zone 4: Valley		0.56	N/A	0.04	1.27	0.48
Climate Zone 5: West		0.81	0.31	0.10	2.58	1.05
Climate Zone 1: Panhandle	R-4	0.22	0.07	0.08	1.81	0.76
Climate Zone 2: North		0.38	N/A	0.04	1.11	0.45
Climate Zone 3: South		0.39	N/A	0.03	0.76	0.30
Climate Zone 4: Valley		0.23	N/A	0.02	0.53	0.20
Climate Zone 5: West		0.33	0.13	0.04	1.08	0.44

Table 2-211 presents the deemed energy savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-211: Deemed Annual Energy Savings, Insulation of 2x6 Walls to R-33 (kWh/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Savings		Heating Savings		
		Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	0.59	0.20	0.22	4.79	2.01
Climate Zone 2: North		1.01	N/A	0.11	2.94	1.20
Climate Zone 3: South		1.07	N/A	0.09	2.02	0.80
Climate Zone 4: Valley		0.62	N/A	0.04	1.42	0.54
Climate Zone 5: West		0.90	0.35	0.11	2.88	1.17
Climate Zone 1: Panhandle	R-4	0.28	0.09	0.11	2.33	0.98
Climate Zone 2: North		0.48	N/A	0.05	1.42	0.58
Climate Zone 3: South		0.49	N/A	0.04	0.98	0.38
Climate Zone 4: Valley		0.29	N/A	0.02	0.67	0.25
Climate Zone 5: West		0.42	0.16	0.05	1.38	0.56

Deemed Summer Demand Savings Tables

2x4 Walls

Table 2-212 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-212: Deemed Summer Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	6.41E-04	2.40E-04
Climate Zone 2: North		7.32E-04	N/A
Climate Zone 3: South		8.50E-04	N/A
Climate Zone 4: Valley		4.17E-04	N/A
Climate Zone 5: West		6.52E-04	2.00E-04
Climate Zone 1: Panhandle	R-4	2.35E-04	9.16E-05
Climate Zone 2: North		2.70E-04	N/A
Climate Zone 3: South		3.02E-04	N/A
Climate Zone 4: Valley		1.55E-04	N/A
Climate Zone 5: West		2.43E-04	7.40E-05

Table 2-213 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-213: Deemed Summer Demand Savings, Insulation of 2x4 Walls to R-21 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.34E-04	2.66E-04
Climate Zone 2: North		8.16E-04	N/A
Climate Zone 3: South		9.55E-04	N/A
Climate Zone 4: Valley		4.69E-04	N/A
Climate Zone 5: West		7.32E-04	2.23E-04
Climate Zone 1: Panhandle	R-4	3.29E-04	1.18E-04
Climate Zone 2: North		3.55E-04	N/A
Climate Zone 3: South		4.08E-04	N/A
Climate Zone 4: Valley		2.07E-04	N/A
Climate Zone 5: West		3.24E-04	9.68E-05

2x6 Walls

Table 2-214 presents the deemed summer demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-214: Deemed Summer Demand Savings, Insulation of 2x6 Walls to R-17 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.00E-04	2.59E-04
Climate Zone 2: North		7.87E-04	N/A
Climate Zone 3: South		9.20E-04	N/A
Climate Zone 4: Valley		4.56E-04	N/A
Climate Zone 5: West		7.06E-04	2.14E-04
Climate Zone 1: Panhandle	R-4	2.88E-04	1.06E-04
Climate Zone 2: North		3.19E-04	N/A
Climate Zone 3: South		3.67E-04	N/A
Climate Zone 4: Valley		1.88E-04	N/A
Climate Zone 5: West		2.91E-04	8.44E-05

Table 2-215 presents the deemed summer demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-215: Deemed Summer Demand Savings, Insulation of 2x6 Walls to R-33 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Cooling Type	
		Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	Uninsulated	7.76E-04	2.83E-04
Climate Zone 2: North		8.77E-04	N/A
Climate Zone 3: South		1.02E-03	N/A
Climate Zone 4: Valley		5.08E-04	N/A
Climate Zone 5: West		7.80E-04	2.38E-04
Climate Zone 1: Panhandle	R-4	3.64E-04	1.30E-04
Climate Zone 2: North		4.09E-04	N/A
Climate Zone 3: South		4.64E-04	N/A
Climate Zone 4: Valley		2.40E-04	N/A
Climate Zone 5: West		3.65E-04	1.08E-04

Deemed Winter Demand Savings

2x4 Walls

Table 2-216 presents the deemed winter demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

Table 2-216: Deemed Winter Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	6.93E-05	1.71E-03	8.78E-04
Climate Zone 2: North		6.66E-05	1.96E-03	1.30E-03
Climate Zone 3: South		7.49E-05	1.48E-03	8.39E-04
Climate Zone 4: Valley		4.28E-05	1.22E-03	5.78E-04
Climate Zone 5: West		2.06E-05	6.78E-04	2.84E-04
Climate Zone 1: Panhandle	R-4	2.58E-05	6.20E-04	3.19E-04
Climate Zone 2: North		2.46E-05	7.32E-04	4.94E-04
Climate Zone 3: South		2.61E-05	5.50E-04	3.20E-04
Climate Zone 4: Valley		1.61E-05	4.51E-04	2.13E-04
Climate Zone 5: West		6.23E-06	2.23E-04	9.39E-05

Table 2-217 presents the deemed winter demand savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

Table 2-217: Deemed Winter Demand Savings, Insulation of 2x4 Walls to R-13 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	7.69E-05	1.89E-03	9.75E-04
Climate Zone 2: North		7.41E-05	2.18E-03	1.46E-03
Climate Zone 3: South		8.19E-05	1.65E-03	9.40E-04
Climate Zone 4: Valley		4.78E-05	1.36E-03	6.41E-04
Climate Zone 5: West		2.24E-05	7.37E-04	3.10E-04
Climate Zone 1: Panhandle	R-4	3.34E-05	8.06E-04	4.16E-04
Climate Zone 2: North		3.20E-05	9.57E-04	6.50E-04
Climate Zone 3: South		3.31E-05	7.19E-04	4.21E-04
Climate Zone 4: Valley		2.11E-05	5.88E-04	2.77E-04
Climate Zone 5: West		8.01E-06	2.83E-04	1.20E-04

2x6 Walls

Table 2-218 presents the deemed winter demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

Table 2-218: Deemed Winter Demand Savings, Insulation of 2x6 Walls to R-17 (kW/sq. ft.)

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	6.99E-05	1.76E-03	9.09E-04
Climate Zone 2: North		7.01E-05	2.07E-03	1.40E-03
Climate Zone 3: South		7.86E-05	1.57E-03	9.10E-04
Climate Zone 4: Valley		4.58E-05	1.29E-03	6.08E-04
Climate Zone 5: West		1.84E-05	6.24E-04	2.64E-04
Climate Zone 1: Panhandle	R-4	2.68E-05	6.93E-04	3.58E-04
Climate Zone 2: North		2.84E-05	8.49E-04	5.84E-04
Climate Zone 3: South		2.96E-05	6.40E-04	3.82E-04
Climate Zone 4: Valley		1.90E-05	5.19E-04	2.41E-04
Climate Zone 5: West		5.59E-06	2.06E-04	8.81E-05

Table 2-219 presents the deemed winter demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

Table 2-219: **Deemed Winter Demand Savings, Insulation of 2x6 Walls to R-33 (kW/sq. ft.)**

Climate Zone	Base Case Wall Insulation	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	Uninsulated	7.66E-05	1.95E-03	1.00E-03
Climate Zone 2: North		7.77E-05	2.31E-03	1.56E-03
Climate Zone 3: South		8.62E-05	1.75E-03	1.02E-03
Climate Zone 4: Valley		5.11E-05	1.43E-03	6.73E-04
Climate Zone 5: West		1.96E-05	6.66E-04	2.82E-04
Climate Zone 1: Panhandle	R-4	3.35E-05	8.76E-04	4.53E-04
Climate Zone 2: North		3.60E-05	1.08E-03	7.44E-04
Climate Zone 3: South		3.72E-05	8.17E-04	4.92E-04
Climate Zone 4: Valley		2.43E-05	6.59E-04	3.06E-04
Climate Zone 5: West		6.87E-06	2.48E-04	1.06E-04

Examples

Example 1. A home with uninsulated 2x4 walls in Climate Zone 1 with evaporative cooling and an electric resistance furnace insulates 750 square feet to R-13 with fiberglass batt insulation.

$$kWh\ savings = (0.17 + 3.96) \times 750 = 3{,}091.5\ \text{kWh}$$

$$Summer\ kW\ savings = 2.40x10^{-4} \times 750 = 0.18\ \text{kW}$$

$$Winter\ kW\ savings = 1.71x10^{-3} \times 750 = 1.28\ \text{kW}$$

Example 2. A home in Climate Zone 4 with uninsulated 2x6 walls with a central air conditioning unit and a gas furnace insulates 500 square feet to R-17 with closed-cell spray foam.

$$kWh\ savings = (0.56 + 0.04) \times 500 = 300.0\ \text{kWh}$$

$$Summer\ kW\ savings = 4.56x10^{-4} \times 500 = 0.23\ \text{kW}$$

$$Winter\ kW\ savings = 4.58x10^{-5} \times 500 = 0.02\ \text{kW}$$

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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for wall insulation.

Program Tracking Data & 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:

- The climate zone
- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Square footage of retrofitted wall area (gross wall area excluding window and door area)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-220: Wall Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	August 31, 2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for 2x4 an 2x6 wall framing and for homes with central AC versus evaporative cooling. Added a two-tier baseline definition of R-0 and R-4.

2.3.5 Floor Insulation Measure Overview

TRM Measure ID: R-BE-FI

Market Sector: Residential

Measure Category: Building Envelope

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

Floor insulation is installed on the underside of floor areas sitting below conditioned space. Typically, it is installed in ventilated crawlspaces. Savings are presented per square foot of treated floor area.

Eligibility Criteria

To qualify for these deemed savings values, floor insulation may be added for customers with electric air conditioning or for customers in TRM climate zones 1 and 5 who have evaporative cooling systems in their homes. Homes with gas heating are disqualified for adding floor insulation since this may result in an energy penalty due to floors not getting cooled from the ground during summer.

Baseline Condition

The baseline is considered to be a house with pier and beam construction and no floor insulation against the floor of conditioned area.

High-Efficiency Condition

A floor insulation level of R-19 is recommended for site-built homes throughout Texas as prescribed by DOE and Texas Department of Housing & Community Affairs (TDHCA) programs. Batt insulation is recommended in most cases, and must have the vapor barrier installed facing up and against the floor or conditioned area. Insulation should be attached or secured so that it can reasonably be expected to remain in place for at least 10 years.

Typical floor construction depth of manufactured homes usually does not allow R-19 batt to be installed within the floor joists so R-15 loose-fill insulation is recommended by TDHCA.

A minimum of 24-inch clearance from bottom of the insulation to the ground is required by Occupational Safety and Health Association (OSHA).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values.

Savings values for the deemed savings estimates for this measure were developed using demand and energy savings calculated using BEopt 2.6, running Energy Plus 8.1 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: slab foundation was replaced with a crawlspace. A 5/8" thick wood floor is also specified.

The model runs calculated energy use for the prototypical home prior to the installation of the floor insulation measure. Next, change-case models were run to calculate energy use with the floor insulation measure in place.

Table 2-221: Residential Floor Insulation – Modifications to the Prototype Home Characteristics

Shell Characteristic	Value	Source
Foundation	Crawlspace	Skirting around perimeter is assumed uninsulated and vented. Ground under home is assumed to be bare, without any type of moisture barrier.
Base Floor Insulation	R-3.1	BEopt default for floor assembly, assuming 5/8" thick hardwood floor without carpet or other type of covering.
Change Floor Insulation	R-19 (except for manufactured housing, R-15)	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas. Due to the typical floor joists depths found in manufactured housing, TDHCA recommends an R-15 loose-fill insulation for manufactured housing and other non-site-built homes.

Deemed Energy Savings Tables

Table 2-222 through Table 2-226 present energy savings on a kWh per square foot of insulation installed basis for all five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-222: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.13	-0.07	1.72	0.68
Manufactured Home	-0.11	-0.06	1.52	0.60

Table 2-223: Climate Zone 2: North Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.12	-	0.96	0.38
Manufactured Home	-0.10	-	0.85	0.33

Table 2-224: Climate Zone 3: South Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.12	-	0.63	0.24
Manufactured Home	-0.10	-	0.56	0.21

Table 2-225: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.07	-	0.40	0.15
Manufactured Home	-0.06	-	0.35	0.13

Table 2-226: Climate Zone 5: West Region – Residential Floor Insulation Deemed Annual Energy Savings (kWh/sq. ft.)

Home Type	Cooling Savings		Heating Savings	
	Refrigerated Air	Evaporative Cooling	Electric Resistance	Heat Pump
Site-Built Home	-0.16	-0.07	1.10	0.43
Manufactured Home	-0.13	-0.06	0.97	0.38

Deemed Summer Demand Savings Tables

Table 2-227 through Table 2-231 present the deemed summer demand savings (kW) for all five Texas climate zones.

Table 2-227: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	6.17E-06	-1.52E-05
Manufactured Home	5.48E-06	-1.30E-05

Table 2-228: Climate Zone 2: North Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.10E-05	-
Manufactured Home	2.75E-05	-

Table 2-229: Climate Zone 3: South Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.36E-05	-
Manufactured Home	2.77E-05	-

Table 2-230: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	3.58E-05	-
Manufactured Home	3.07E-05	-

Table 2-231: Climate Zone 5: West Region – Residential Floor Insulation Deemed Summer Demand Savings (kW/sq. ft.)

Home Type	Refrigerated Air	Evaporative Cooling
Site-Built Home	6.29E-06	-1.34E-06
Manufactured Home	8.30E-07	1.85E-07

Deemed Winter Demand Savings Tables

Table 2-232 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-232: Climate Zone 1: Panhandle Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	5.23E-04	2.55E-04
Manufactured Home	4.62E-04	2.25E-04

Table 2-233: Climate Zone 2: North Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	5.19E-04	2.88E-04
Manufactured Home	4.56E-04	2.50E-04

Table 2-234: Climate Zone 3: South Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	4.22E-04	2.03E-04
Manufactured Home	3.64E-04	1.74E-04

Table 2-235: Climate Zone 4: Valley Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	3.51E-04	1.53E-04
Manufactured Home	3.02E-04	1.31E-04

Table 2-236: Climate Zone 5: West Region – Residential Floor Insulation Deemed Winter Demand Savings (kW/sq. ft.)

Home Type	Electric Resistance	Heat Pump
Site-Built Home	3.54E-04	1.44E-04
Manufactured Home	3.19E-04	1.30E-04

Examples

Example 1. A manufactured home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 500 square feet.

$$kWh\ savings = (-0.06 + \ 0.97) \times 500 = 457.0\ \text{kWh}$$

$$Summer\ kW\ savings = 1.85x10^{-7} \times 500 = 0.00\ \text{kW}$$

$$Winter\ kW\ savings = 3.19x10^{-4} \times 500 = 0.16\ \text{kW}$$

Example 2. A site-built home in Climate Zone 2 with an air-source heat pump insulates 825 square feet.

$$kWh\ savings = (-0.12 + 0.38) \times 825 = 212.0\ \text{kWh}$$

$$Summer\ kW\ savings = 3.10x10^{-5} \times 825 = 0.03\ \text{kW}$$

$$Winter\ kW\ savings = 2.88x10^{-4} \times 825 = 0.24\ \text{kW}$$

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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for floor insulation.

Program Tracking Data & 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: The climate zone

- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- Home type (site built or manufactured)
- Square footage of installed insulation

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-237: Floor Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. Disqualified homes with gas heating for adding floor insulation.

2.3.6 ENERGY STAR® Windows Measure Overview

TRM Measure ID: R-BE-EW

Market Sector: Residential

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Measure Category: Building Envelope

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

ENERGY STAR® windows savings are calculated on per square foot of window basis, inclusive of frame and sash. To qualify for these deemed savings values, ENERGY STAR® windows may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline

Two base cases are contemplated: single-pane and double-pane windows. In both cases a metal frame is specified. Estimated U-Values and SHGCs for baseline windows are presented in **Table 2-238**.

Table 2-238: Baseline Windows

Number of Panes	U-Factor Btu/(h·ft²·°F)	Solar Heat Gain Coefficient (SHGC)
1	1.16	0.76
2	0.76	0.67

High-Efficiency Condition

For a window to qualify for these deemed savings, it must meet the relevant ENERGY STAR® criteria for the location in the state where the window is to be installed. Table 2-239 lists the ENERGY STAR® specifications for windows as of January 1, 2015. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-239: ENERGY STAR® Windows Specifications effective January 2015

U.S. Region, ENERGY STAR®	U-Factor Btu/(h·ft²·°F)	Solar Heat Gain Coefficient (SHGC)
North-Central	≤ 0.30	≤ 0.40
South-Central	≤ 0.30	≤ 0.25
Southern	≤ 0.40	≤ 0.25

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Base case homes were fitted with single-pane and double-pane windows: change case homes were equipped with windows meeting the appropriate ENERGY STAR window specification for the location in which the window was to be installed. The Climate Zones in the Energy Star Windows specification were mapped to the Texas TRM Climate Zones as shown in Table 2-240:

Table 2-240. TRM Climate Zones and ENERGY STAR® Windows Climate Zones

Texas TRM Climate Zones	U.S. Region, ENERGY STAR® Windows
Climate Zone 1: Panhandle	North-Central
Climate Zone 2: North	South-Central
Climate Zone 3: South	Southern
Climate Zone 4: Valley	Southern
Climate Zone 5: West	South-Central

Deemed Energy Savings Tables

Table 2-241 presents the energy savings (kWh) for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-241: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Annual Energy Savings (kWh/sq. ft.)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.83	0.98	0.29	6.70	3.16
Climate Zone 2: North	5.42	-	0.10	3.09	1.45
Climate Zone 3: South	5.32	-	0.02	0.77	0.41
Climate Zone 4: Valley	5.97	-	0.02	0.82	0.34
Climate Zone 5: West	5.67	1.90	0.00	0.99	0.69

Table 2-242: ENERGY STAR® Windows Replacing Double-Pane Windows Deemed Annual Energy Savings (kWh/sq. ft.)

Climate Zone	Cooling Savings		Heating Savings		
	Refrigerated Air	Evaporative Cooling	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.03	0.72	0.18	4.15	2.00
Climate Zone 2: North	4.11	-	0.04	1.47	0.76
Climate Zone 3: South	3.96	-	-0.01	-0.21	0.01
Climate Zone 4: Valley	4.45	-	0.00	-0.01	0.02
Climate Zone 5: West	4.24	1.46	-0.03	-0.18	0.16

Deemed Summer Demand Savings Tables

Table 2-242 presents the summer demand savings tables for the five Texas climate zones.

Table 2-243: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Summer Demand Savings (kW/sq. ft.)

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	3.09E-03	1.16E-03
Climate Zone 2: North	3.89E-03	-
Climate Zone 3: South	3.51E-03	-
Climate Zone 4: Valley	2.99E-03	-
Climate Zone 5: West	3.86E-03	1.05E-03

Table 2-244: ENERGY STAR® Windows Replacing Double-Pane Windows, Deemed Summer Demand Savings (kW/sq. ft.)

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	2.08E-03	8.36E-04
Climate Zone 2: North	2.80E-03	-
Climate Zone 3: South	2.40E-03	-
Climate Zone 4: Valley	2.15E-03	-
Climate Zone 5: West	2.76E-03	8.09E-04

Deemed Winter Demand Savings Tables

Table 2-244 presents the winter demand savings tables for the five Texas climate zones.

Table 2-245: ENERGY STAR® Windows Replacing Single-Pane Windows, Deemed Winter Demand Savings by Heat Type (kW/sq. ft.)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.01E-04	4.98E-03	2.43E-03
Climate Zone 2: North	1.77E-04	4.73E-03	2.74E-03
Climate Zone 3: South	6.89E-05	1.78E-03	3.11E-04
Climate Zone 4: Valley	4.78E-05	1.65E-03	6.68E-04
Climate Zone 5: West	2.83E-05	1.10E-03	5.00E-04

Table 2-246: ENERGY STAR® Windows Replacing Double-Pane Windows, Deemed Winter Demand Savings by Heat Type (kW/sq. ft.)

Climate Zone	Gas Heat	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	1.32E-04	3.30E-03	1.64E-03
Climate Zone 2: North	1.12E-04	3.16E-03	1.89E-03
Climate Zone 3: South	2.33E-05	6.68E-04	3.58E-06
Climate Zone 4: Valley	1.53E-05	5.62E-04	2.34E-04
Climate Zone 5: West	1.31E-05	5.84E-04	2.76E-04

Examples

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

$$kWh\ savings = (0.98\ +\ 6.70) \times 125 = 960\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 1.16x10^{-3} \times 125 = 0.15\ \mathrm{kW}$$

$$Winter\ kW\ savings = 4.98x10^{-3} \times 125 = 0.62\ \mathrm{kW}$$

Example 2. A home in Climate Zone 5 with a central air conditioning unit and a gas furnace replaces 250 square feet of double-pane windows with ENERGY STAR® windows.

$$kWh\ savings = \left(4.24 +\ (-0.03)\right) \times 250 = 1{,}052.5\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 2.76x10^{-3} \times 250 = 0.69\ \mathrm{kW}$$

$$Winter\ kW\ savings = 1.31x10^{-5} \times 250 = 0.00\ kW$$

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

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

Program Tracking Data & 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:

- The climate zone
- Space heating system type (non-electric, electric resistance, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- Area of ENERGY STAR® windows installed

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 48. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-247: ENERGY STAR® Windows Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations. Consolidated table formats.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.

2.3.7 Solar Screens Measure Overview

TRM Measure ID: R-BE-SC

Market Sector: Residential

Measure Category: Building Envelope

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: Deemed Savings Values (Lookup Tables)

Savings Methodology: Building Simulation Modeling

Measure Description

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

Eligibility Criteria

To qualify for these deemed savings values, solar screens may be installed for customers with electric refrigerated air conditioning or evaporative cooling systems in their homes.

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. A single modification was made to the prototype models for the various climate zone-HVAC type combinations to create the base case models for estimating savings for the solar screens measure. Windows facing all directions are assumed to be single-pane windows with U-Values of 1.16 BTU/h-ft^2-R and Solar Heat Gain Coefficients (SHGC) of 0.76.

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

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

The model assumes the average solar screen installed blocks 80% of the solar heat gain attributed to the south and west facing windows based on performance data from solar screens analyzed at sun angles of 30, 45 and 75 degrees to the window. [186]

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

Thermal Performance Improvement

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

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

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

Window Frame

The window frame accounts for 10-30 percent[187] of the window area and since it is opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15% frame area was incorporated into the performance of the window.

Example Calculation

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

$$kWh\ savings = \left(6.09 + \ (-3.21)\right) \times 75 = 216\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 3.17x10^{-3} \times 75 = 0.24\ \mathrm{kW}$$

$$Winter\ kW\ savings = -2.32x10^{-3} \times 75 = -0.17\ \mathrm{kW}$$

Deemed Energy Savings Tables

Table 2-247 presents the deemed energy savings value per square foot of solar screen installed. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-248: Deemed Energy (kWh) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Cooling Savings (kWh/sq. ft.)		Heating Savings (kWh/sq. ft.)		
	Refrigerated Air	Evaporative Cooling	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	3.67	1.34	-0.62	-12.81	-4.54
Climate Zone 2: North	5.38	-	-0.29	-7.14	-2.56
Climate Zone 3: South	5.33	-	-0.16	-4.69	-1.69
Climate Zone 4: Valley	6.09	-	-0.09	-3.21	-1.16
Climate Zone 5: West	5.62	1.99	-0.44	-10.48	-3.81

Deemed Summer Demand Savings Tables

Table 2-248 presents the deemed summer peak demand savings value per square foot of solar screen installed.

Table 2-249: Deemed Summer Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Refrigerated Air	Evaporative Cooling
Climate Zone 1: Panhandle	2.89E-03	1.35E-03
Climate Zone 2: North	3.42E-03	-

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

Climate Zone 3: South	3.29E-03	-
Climate Zone 4: Valley	3.17E-03	-
Climate Zone 5: West	3.12E-03	1.07E-03

Deemed Winter Demand Savings Tables

Table 2-249 presents the deemed winter peak demand savings value per square foot of solar screen installed. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-250: Deemed Winter Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	-1.16E-04	-1.73E-03	-9.45E-04
Climate Zone 2: North	-5.20E-05	-1.32E-03	-7.96E-04
Climate Zone 3: South	-1.07E-04	-2.65E-03	-1.71E-03
Climate Zone 4: Valley	-7.68E-05	-2.32E-03	-1.08E-03
Climate Zone 5: West	-1.45E-04	-3.34E-03	-1.30E-03

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) of solar screens is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[188]

Program Tracking Data & 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:

- The climate zone
- Space cooling system type (evaporative cooling, refrigerated air conditioning)

[188] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

- Space heating system type (gas, electric, heat pump)
- Square footage of windows or door openings treated

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-251: Solar Screens Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics. Savings awarded for south-facing windows, in addition to east- and west-facing windows.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps.
v3.1	11/05/2015	TRM v3.1 update. Provided example savings calculations.
v4.0	10/10/2016	TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling.

2.4 RESIDENTIAL: WATER HEATING

2.4.1 Faucet Aerators Measure Overview

TRM Measure ID: R-WH-FA

Market Sector: Residential

Measure Category: Water Heating

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 Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

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

Eligibility Criteria

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

These deemed savings are for residential, retrofit-only installation of kitchen and bathroom faucet aerators. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-252: Faucet Aerators – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Energy Policy Act of 1992 (EPAct 92). The deemed savings assume that the existing faucet aerators have a minimum flow rate of 2.2 GPM. The US EPA WaterSense specification for faucet aerators is 1.5 GPM.[189]

Table 2-253: Faucet Aerators – Baseline and Efficiency Standard

Baseline	Efficiency Standard
2.2 GPM minimum	1.5 GPM maximum

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

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

$$\boldsymbol{Energy\ Savings\ (per\ aerator)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times \left(T_{FaucetAvg} - T_{SupplyAvg}\right)}{FPH \times RE \times Conversion\ Factor}$$

Equation 74

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

GPM_{Base} = *Average baseline flow rate of aerator = 2.2 gallons per minute*

GPM_{Low} = *Post-installation flow rate of aerator, typically 1.5, 1.0, or 0.5 gallons per minute; if unknown, assume 1.5 gallons per minute*

N = *Average number of persons per household = 2.82 persons*[190]

189 http://www.epa.gov/watersense/partners/faucets_final.html.

190 Occupants per home for Texas from US Census Bureau, "Persons per household, 2009-2013". Accessed December 2015. http://quickfacts.census.gov/qfd/states/48000.html.

t	=	*Average time in minutes of hot water usage per person per day; default = 2.34 min/person/day*[191]
$T_{SetPoint}$	=	*Average faucet temperature = 88°F*[192]
$T_{SupplyAverage}$	=	*Average supply water temperature (seeTable 2-253)*
FPH	=	*Average number of faucets per household = 3.93 faucets*[193]
RE	=	*Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[194]
ConversionFactor	=	*3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings\ (per\ aerator)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times \left(T_{FaucetAvg} - T_{SupplySeasonal}\right)}{FPH \times RE \times Conversion\ Factor} \times Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 75

Where:

$T_{SupplySeasonal}$	=	*Seasonal supply water temperature (Table2-253)*
$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$	=	*Ratio of peak seasonal kW to annual kWh savings (Table 2-254)*

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

192 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average temperature for kitchens (93 °F) and bathrooms (86 °F) assuming 1 kitchen aerator and 2.93 bathrooms.

Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

193 Faucets per home assumed to be equal to one (kitchen) plus number of half bathrooms and full bathrooms per home as specified in the 2009 Residential Energy Consumption Survey (RECS), Table HC2.10.

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

Table 2-254: Water Mains Temperature

Climate Zone	Water Mains Temperature °F*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 2-255: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	**Winter**
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5PM, winter: 7-8AM) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.

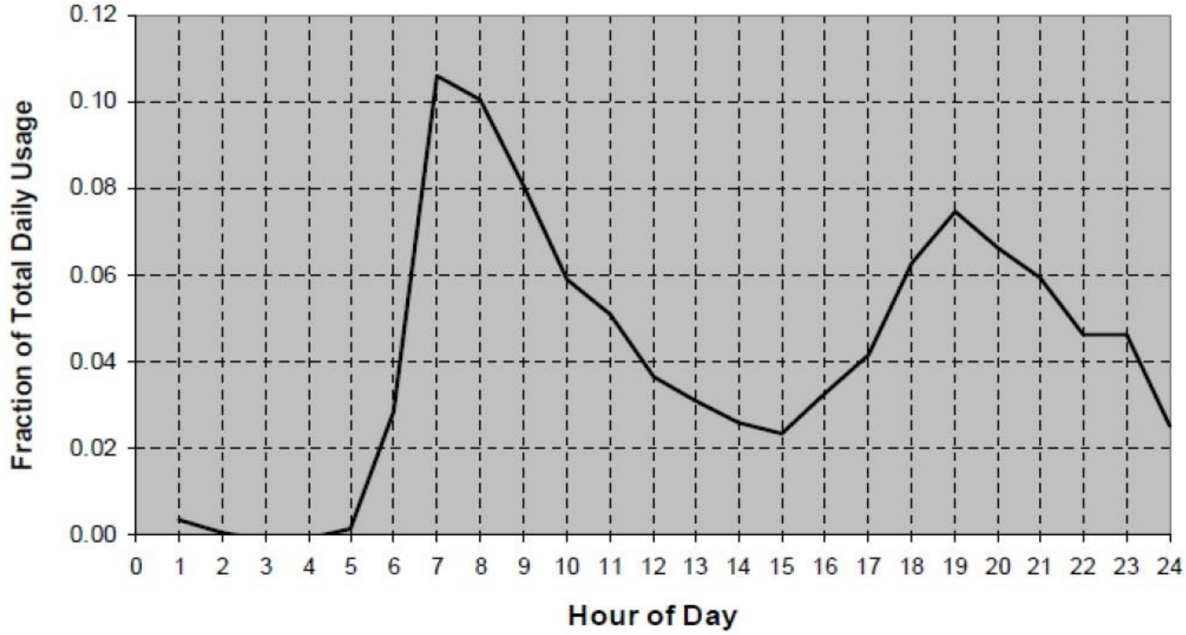


Figure 2-6: Shower, Bath, and Sink Hot Water Use Profile

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

The estimated useful life (EUL) of a faucet aerator is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[195]

Program Tracking Data & 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:

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-256: Faucet Aerators Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	10/30/2015	TRM v3.1 update. Supplemented reference for water heater set point temperature.
v4.0	10/10/2016	Updated methodology to calculate energy and demand savings.

[195] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.2 Low-Flow Showerheads Measure Overview

TRM Measure ID: R-WH-SH

Market Sector: Residential

Measure Category: Water Heating

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 Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

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

Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at 2.0, 1.7, or 1.5 gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit measure in existing homes. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-257: Low-Flow Showerheads – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[196] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[197]

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

Table 2-258: Low-Flow Showerhead – Baseline and Efficiency Standards

Existing Showerhead Baseline Flow Rate	New Showerhead Flow Rate*
2.5 GPM maximum	1.5 GPM, 1.75 GPM or 2.0 GPM maximum

* All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings\ (per\ showerhead)} = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{ShowerAvg} - T_{SupplyAverage})}{SPH \times RE \times Conversion\ Factor}$$

Equation 76

Where:

ρ	=	*Water density, 8.33 lbs/gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
GPM_{Base}	=	*Average baseline flow rate of aerator = 2.5 gallons per minute*
GPM_{Low}	=	*Post-installation flow rate of aerator, typically 2.0, 1.75, or 1.5 gallons per minute; if unknown, assume 2.0 gallons per minute*
N	=	*Average number of persons per household = 2.82 persons*[198]
t	=	*Average time in minutes of hot water usage per person per day; default = 7.8 min/person/day*[199]

[198] Occupants per home for Texas from US Census Bureau, "Persons per household, 2009-2013". Accessed December 2015. http://quickfacts.census.gov/qfd/states/48000.html.

[199] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.

$T_{SetPoint}$ = *Average shower temperature = 101°F* [200]

T_{Supply} = *Average supply water temperature (see Table 2-253*

SPH = *Average number of showerheads per household = 1.68 showerheads*[201]

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water* heaters.[202]

ConversionFactor = *3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings\ (per\ showerhead)} = \frac{\boldsymbol{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{ShowerAvg} - T_{SupplySeasonal})}}{\boldsymbol{SPH \times RE \times Conversion\ Factor}} \times \boldsymbol{Ratio_{annual\ kWh}^{Peak_{seasonal}kW}}$$

Equation 77

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 2-259)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 2-260)*

[200] Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[201] Showerheads per home assumed to be equal to the number of full bathrooms per home as specified in the 2009 Residential Energy Consumption Survey (RECS), Table HC2.10.

[202] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Table 2-259: Water Mains Temperature

Climate Zone	Water Mains Temperature (°F) *		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

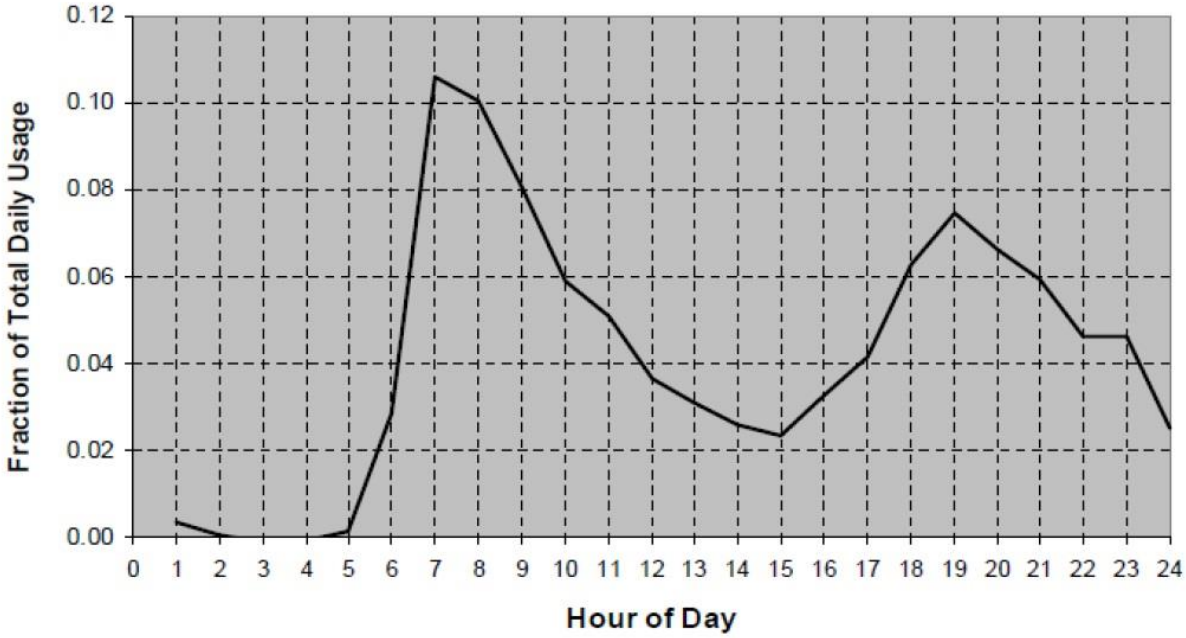
* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 2-260: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	Winter
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5pm, winter: 7-8am) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.



Source: Building America Performance Analysis Procedures for Existing Homes

Figure 2-7: Shower, Bath, and Sink Hot Water Use Profile

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

The estimated useful life (EUL) of a low-flow showerhead is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[203]

Program Tracking Data & 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:

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

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

[203] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

Document Revision History

Table 2-261: Low-Flow Showerheads Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Provided clarification that savings are to be awarded per showerhead. Supplemented reference for water heater set point temperature.
v4.0	10/10/2016	Updated methodology to calculate energy and demand savings.

2.4.3 Water Heater Pipe Insulation Measure Overview

TRM Measure ID: R-WH-PI

Market Sector: Residential

Measure Category: Water Heating

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 Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of pipe insulation on un-insulated water heater pipes that are served by an electric water heater.

Eligibility Criteria

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

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

Table 2-262: Water Heater Pipe Insulation – Applicability

Application Type	Applicable	Notes
Retrofit	Y	Savings cannot be claimed in conjunction with the installation of a new water heater.
New Construction	N	

Baseline Condition

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

Table 2-263: Water Heater Pipe Insulation – Baseline Standard

Baseline
Un-insulated hot water pipes

High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3. The International Residential Code (IRC) 2009 section N1103.3: Mechanical system piping insulation requires R-3 insulation.

Table 2-264: Water Heater Pipe Insulation – Efficiency Standard

Efficiency Standard
Minimum insulation of R-3

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

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

$$\boldsymbol{Energy\ savings\ per\ year} = \left(\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}\right) \times \boldsymbol{A} \times \left(\boldsymbol{T_{pipe}} - \boldsymbol{T_{ambient\ annual}}\right) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\boldsymbol{Hours_{Total}}}{\boldsymbol{conversion\ factor}}$$

Equation 78

Where:

U_{pre}[204] = $\frac{1}{2.03} = 0.49\ {}^{Btu}/_{hr \cdot sq.ft. \cdot {}^{\circ}F}$

U_{post} = $\frac{1}{2.03 + R_{Insulation}}$

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

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

[204] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe, and between the surface and air. Mark's Standard Handbook for Mechanical Engineers, 8th edition.

Table 2-265: Estimated Pipe Surface Area

Pipe Diameter (inches)	Pipe Surface Area (square feet)[205]
0.5	0.16 x required input “Pipe Length insulated (feet)”
0.75	0.23 x required input “Pipe Length insulated (feet)”
1.0	0.29 x required input “Pipe Length insulated (feet)”

T_{pipe} *(°F)* = *120°F*[206]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-266)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[207]

$Hours_{Total}$ = *8,760 hr. per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textbf{\textit{Pipe Insulation Demand Savings}}\ (\boldsymbol{kW}) = (\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}) \times \boldsymbol{A} \times (\boldsymbol{T_{Pipe}} - \boldsymbol{T_{ambient\ seasonal}}) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\mathbf{1}}{\boldsymbol{conversion\ factor}}$$

Equation 79

Where:

$T_{ambientseasonal}$ *(°F)* = *Ambient seasonal temperature (see Table 2-266)*

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

Nominal Diameter (inches)	Outside Diameter (inches)	Factor to Calculate Pipe Area
0.5	0.625	0.16
0.75	0.875	0.23
1.0	1.125	0.29

[206] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs” October 2010, page 102.

Data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

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

Table 2-266: Ambient Temperatures per Climate Zone

Climate Zone		Ambient Temperature (°F)					
		Water Heater Location: Unconditioned Space*			Water Heater Location: Conditioned Space**		
		Annual	Peak Seasonal		Annual	Peak Seasonal	
			Summer	Winter		Summer	Winter
1	Panhandle	65.5	106	32	72.7	75.1	69.3
2	North	73.1	108.1	42			
3	South	76.3	108.2	46			
4	Valley	78.4	103	55			
5	West	71.8	108	41.1			

* Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat set points from RECS. Times associated with these set points are assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

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

The estimated useful life (EUL) of water heater pipe insulation installed for an electric water heater is established at 13 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[208]

Program Tracking Data & 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:

- The climate zone
- The R-value of the installed insulation
- Recovery Efficiency (RE) or COP, if available
- Pipe length insulated (feet)
- The pipe surface area insulated in square feet (at least the pipe diameter in inches)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-267: Water Heater Pipe Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Supplemented reference for water heater set point temperature.
v4.0	10/10/2016	TRM v4.0 update: No revision

[208] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.4 Water Heater Tank Insulation Measure Overview

TRM Measure ID: R-WH-WJ

Market Sector: Residential

Measure Category: Water Heating

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 Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of tank insulation on un-insulated water heater tanks that are served by an electric water heater.

Eligibility Criteria

Water heaters meeting the National Appliance Energy Conservation Act standards with respect to insulation and standby loss requirements are not eligible for this measure. To ensure compliance, the contractor shall inspect the build date listed on the existing water heater label and verify that the listed build date is before 1991.

Water heater pipe insulation is a residential retrofit measure. New construction and water heater replacements are not eligible for this measure, because they must meet current code requirements. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-268: Water Heater Tank Insulation – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation.

High-Efficiency Condition

There is no minimum insulation requirement. Manufacturer's instructions on the water heater jacket and the water heater itself should be followed. Thermostat and heating element access panels must be left uncovered.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

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

$$\textit{Energy savings per year} = (U_{pre} - U_{post}) \times A \times (T_{tank} - T_{ambient\ annual}) \times \left(\frac{1}{RE}\right) \times \frac{Hours_{Total}}{conversion\ factor}$$

Equation 80

Where:

U_{pre} = *1/ (5) Btu/hr. sq.ft. °F*

U_{post} = *1/ (5+*$R_{Insulation}$*)*

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

A = *Tank surface area insulated in square feet* (πDL) *with L (length) and D (tank diameter) in feet. If the tank area is not known, use Table 2-269.*

Table 2-269: Estimated Tank Area

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

* Tank area was obtained from a survey of electric water heater manufacturer data. Dimensions for each tank size were collected and averaged to determine a typical square footage of each size water heater. Accessed April 2013: http://www.hotwater.com/water-heaters/residential/conventional/electric/promax/standard/. Accessed April 2013: http://www.whirlpoolwaterheaters.com/products/electric-water-heaters/es40r92-45d/.

T_{tank} *(°F)* = *Average temperature of the tank, default use 120°F* [209]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-270)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.* [210]

$Hours_{Total}$ = *8,760 hours per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textit{Tank Insulation Demand Savings } (kW) = (U_{pre} - U_{post}) \times A \times (T_{Tank} - T_{ambient\ seasonal}) \times \frac{1}{RE} \times \frac{1}{conversion\ factor}$$

Equation 81

Where:

$T_{ambientseasonal}$ *(°F)* = *Ambient seasonal temperature (see Table 2-270)*

Table 2-270: Ambient Temperatures per Climate Zone

Climate Zone		Ambient Temperature (°F)					
		Water Heater Location: Unconditioned Space			Water Heater Location: Conditioned Space		
		Annual	Peak Seasonal		Annual	Peak Seasonal	
			Summer	Winter		Summer	Winter
1	Panhandle	65.5	106	32	72.7	75.1	69.3
2	North	73.1	108.1	42			
3	South	76.3	108.2	46			
4	Valley	78.4	103	55			
5	West	71.8	108	41.1			

* Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat set points from RECS. Times associated with these set points assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[209] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs” October 2010, page 99.

Data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

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

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

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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for storage water heater tank insulation is established at 7 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[211]

Program Tracking Data & 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:

- The climate zone
- Recovery Efficiency (RE) or COP, if available
- The R-value of the installed insulation
- Tank surface area insulated in square feet (πDL) with L (length) and D (tank diameter) in feet; if unable to determine tank area, tank volume must be recorded.

[211] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

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 2-271: Water Heater Tank Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. Supplemented reference for water heater set point temperature.

2.4.5 Water Heater Installation – Electric Tankless and Fuel Substitution Measure Overview

TRM Measure ID: R-WH-WH

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout, Early Retirement, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves installing a new electric tankless or gas-fueled water heater (storage or tankless) in place of an electric storage water heater.[212]

Eligibility Criteria

This measure involves installing a gas storage, gas tankless (instantaneous), or electric tankless water heater in place of an electric storage water heater, and which meets all the additional requirements described below. HPWHs are not eligible for installation through this measure (see separate Heat Pump Water Heater measure). Currently, there are no conventional, electrically fueled storage units that sufficiently exceed the new federal standard to merit inclusion as an efficient condition in these deemed savings; therefore, deemed savings are only calculated for new gas storage, gas tankless, and electric tankless systems. Electric tankless water heaters may only replace systems with tanks less than 55 gallons. For the installation of an electric water heater with a tank size greater than 55 gallons, please refer to the Heat Pump Water Heater measure.

These deemed savings are for water heater replacements installed as a replace-on-burnout, new construction, or early retirement measure. However, savings are calculated under the assumption of replace-on-burnout or new construction. Savings may be awarded for installations in newly constructed homes where customer and utility representatives provide

[212] Previous versions of this measure included an incentive for installing high-efficiency conventional (electric resistance) storage water heaters. Increments to the federal standard for electric storage water heaters went into effect on April 16, 2015, eliminating the feasibility of continuing to provide deemed savings for these units.

written indication that an electric storage water heater would otherwise have been installed, along with relevant design documentation showing an electric storage water heater.

Table 2-272: Water Heater Replacement – Applicability

Application Type	Applicable
Replace-on-Burnout	Y
Early Retirement	Y
New Construction	Y*

* Subject to documentation requirements described above.

Baseline Condition

For most installations, the baseline condition is an electric storage water heater with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, which took effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (seeTable 2-272).[213]

Table 2-273: Water Heater Replacement – Baseline

Rated Storage Volume	Energy Factor*
≥ 20 gal and ≤ 55 gal	$0.960 – (0.0003*V_S)$
> 55 gal and ≤ 120 gal	$2.057 – (0.00113*V_S)$

*V_S is the volume of the water heater storage tank.

The new DOE efficiency standard effectively requires HPWHs (assuming electric water heating) for electric storage water heaters with tank size greater than 55 gallons. As such, electric water heaters with tanks greater than 55 gallons are not eligible for this measure. Instead, see the Heat Pump Water Heater measure. Furthermore, gas water heaters greater than 55 gallons must use HPWH baseline consumption to calculate savings, as shown in the deemed savings provided at the end of this measure.

For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source. This baseline assumes a replace-on-burnout scenario.

High-Efficiency Condition

For water heater replacement and fuel substitution, the new unit must meet the following federal minimum energy factor shown in Table 2-274. Water heaters must be installed in accordance with local code requirements.

Table 2-274 shows storage water heater energy factors for common tank volumes.

[213] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Accessed February 2014. Available online: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

Table 2-274: Water Heater Replacement – Efficiency Standards

Energy Source	Tank Volume (unit being replaced)	Standard Energy Factor
Electric Tankless	≥ 20 gal and ≤ 55 gal	0.98*
	> 55 gal	N/A
Gas Tankless	≥ 20 gal	$0.82 - 0.0019 \times V_s$
Gas Storage	≥ 20 gal and ≤ 55 gal	$0.675 - 0.0015 \times V_s$
	> 55 gal	$0.8012 - 0.00078 \times V_s$

* The lowest energy factor associated with an electric tankless water heater in the AHRI database was 0.98 as of March 2014. http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

** V_s is the rated storage volume of the new water heater.

Table 2-275: Storage Water Heater Energy Factors for Common Tank Volumes (not exhaustive)

Fuel Type	Tank Volume (Gallons)			
	30	40	50	80
Baseline – Electric Storage	0.951	0.948	0.945	1.967*
Efficiency Standard – Gas Storage	0.630	0.615	0.600	0.739

* Baseline value from the Heat Pump Water Heater measure.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Electric Tankless Water Heater

Energy Savings Algorithm

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{3{,}412}$$

Equation 82

Where:

ρ = Water density (= 8.33 lbs/gallons)

C_p = Specific heat of water (= 1 Btu/lb·°F)

GPY = Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 2-275)

Table 2-276: Water Heater Consumption (gal/year)*

Climate Zone		Number of Bedrooms			
		1	2	3	4
1	Panhandle	15,476	20,171	24,866	29,561
2	North	14,778	19,244	23,710	28,177
3	South	14,492	18,864	23,236	27,608
4	Valley	14,213	18,494	22,775	27,056
5	West	14,905	19,412	23,920	28,427

* Building America Research Benchmark Definition. December 2009. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

$T_{SetPoint}$ = Water heater set point (= 120°F)[214]

$T_{Supply,ann}$ = Annual average mains temperature from Table 2-276

EF_{pre} = Baseline energy factor (see Table 2-275 or calculate per Table 2-273)[215]

EF_{post} = Energy factor of new water heater

3,412 = Constant to convert from Btu to kWh

Table 2-277: Water Mains Temperature*

Climate Zone		Water Mains Temperature (°F)		
		$T_{supply,annual}$	$T_{supply,seasonal}$	
			Summer	Winter
1	Panhandle	62.9	73.8	53.7
2	North	71.8	84.0	60.6
3	South	74.7	84.5	65.5
4	Valley	77.2	86.1	68.5
5	West	70.4	81.5	60.4

* Based on TMY3 dataset: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

214 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

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

Demand Savings Algorithm

$$\mathrm{kW_{savings,summer}} = \mathrm{Ratio}_{\text{daily gal}}^{\text{summer peak gal}} \frac{\rho \times C_p \times \mathrm{GPY} \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{365 \times 3{,}412}$$

Equation 83

$$\mathrm{kW_{savings,winter}} = \mathrm{Ratio}_{\text{daily gal}}^{\text{winter peak gal}} \frac{\rho \times C_p \times \mathrm{GPY} \times (T_{setpoint} - T_{supply,winter}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{365 \times 3{,}412}$$

Equation 84

Where:

$\mathrm{Ratio}_{dailygal}^{Sumpeakgal}$ = Ratio of hot water use during the typical summer peak hour (4:00 p.m. to 5:00 p.m.) to daily hot water use (= 0.0436)

$\mathrm{Ratio}_{dailygal}^{Winpeakgal}$ = Ratio of average hot water use during the winter peak hour (7:00 a.m. to 8:00 a.m.) to daily hot water use (= 0.0794)

$T_{Supply,sum}$ = Summer average water mains temperature (see Table 2-276)

$T_{Supply,win}$ = Winter average water mains temperature (see Table 2-276)

Gas Storage or Tankless Water Heater (Fuel Substitution)

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

For gas storage water heaters with a tank size greater than 55 gallons, or gas tankless water heaters replacing a unit greater than 55 gallons, the appropriate baseline is a HPWH. The baseline consumption values are calculated using the federal standard baseline condition specified in the Heat Pump Water Heater measure. Savings for gas water heaters larger than 55 gallons are shown in Table 2-278 through Table 2-281.

Energy Savings Algorithm for Units Less than 55 Gallons

$$\mathrm{kWh_{savings}} = \frac{\rho \times C_p \times \mathrm{GPY} \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{EF_{pre}}\right)}{3{,}412}$$

Equation 85

Demand Savings Algorithm for Units Less than 55 Gallons

$$\text{SummerkW}_{\text{savings}} = \text{Ratio}_{\text{daily gal}}^{\text{summer peak gal}} \times \frac{\rho \times C_p \times \text{GPY} \times (T_{\text{setpoint}} - T_{\text{supply,summer}}) \times \left(\frac{1}{EF_{\text{pre}}}\right)}{365 \times 3{,}412}$$

Equation 86

$$\text{WinterkW}_{\text{savings}} = \text{Ratio}_{\text{daily gal}}^{\text{winter peak gal}} \times \frac{\rho \times C_p \times \text{GPY} \times (T_{\text{setpoint}} - T_{\text{supply,winter}}) \times \left(\frac{1}{EF_{\text{pre}}}\right)}{365 \times 3{,}412}$$

Equation 87

Examples

Example 1. An old 40-gallon electric water heater in a two-bedroom home in Dallas is replaced with a new, tankless electric water heater with an energy factor of 0.99.

$$\text{kWh}_{\text{savings}} = \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 71.8) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{3{,}412} = 101\ \text{kWh}$$

$$\text{kW}_{\text{savings,summer}} = 0.0436 \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 84) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.01\ \text{kW}$$

$$\text{kW}_{\text{savings,winter}} = 0.0794 \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 60.6) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.03\ \text{kW}$$

Example 2. An old 30-gallon electric water heater in a one-bedroom house in El Paso is replaced with a new gas storage water heater with an energy factor of 0.65.

$$\text{kWh}_{\text{savings}} = \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 70.4) \times \left(\frac{1}{0.951}\right)\right]}{3{,}412} = 1{,}898\ \text{kWh}$$

$$\text{kW}_{\text{savings,summer}} = 0.0436 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 81.5) \times \left(\frac{1}{0.951}\right)\right]}{365 \times 3{,}412} = 0.18\ \text{kW}$$

$$\text{kW}_{\text{savings,winter}} = 0.0794 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 60.4) \times \left(\frac{1}{0.951}\right)\right]}{365 \times 3{,}412} = 0.50\ \text{kW}$$

Example 3. An old electric water heater in a two-bedroom house in Corpus Christi is replaced with a new 65-gallon gas storage water heater in a home with gas heat.

$$\text{kWh}_{\text{savings}} = 1{,}246\ \text{kWh}$$

$$\text{kW}_{\text{savings,summer}} = 0.19\ \text{kW}$$

$$\text{kW}_{\text{savings,winter}} = 0.38\ \text{kW}$$

Deemed Energy Savings Tables

Energy savings for gas water heaters with tanks greater than 55 gallons (or gas tankless units replacing a unit greater than 55 gallons) are provided in Table 2-278.

Table 2-278: HPWH Baseline Energy Consumption (kWh) for Gas Water Heaters with > 55 Gallon Tanks

Climate Zone	Tank Size (Gal)	Water Heater Location/Heat Type			
		Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
1	55 - 64	1,873	1,059	1,520	1,830
	65 - 74	2,137	1,303	1,775	2,102
	75 +	2,403	1,550	2,033	2,378
2	55 - 64	1,553	984	1,306	1,396
	65 - 74	1,762	1,180	1,509	1,604
	75 +	1,973	1,378	1,715	1,814
3	55 - 64	1,467	906	1,223	1,249
	65 - 74	1,659	1,087	1,411	1,435
	75 +	1,853	1,270	1,600	1,623
4	55 - 64	1,382	1,050	1,238	1,135
	65 - 74	1,558	1,219	1,411	1,304
	75 +	1,736	1,390	1,586	1,474
5	55 - 64	1,585	1,015	1,338	1,457
	65 - 74	1,803	1,219	1,549	1,674
	75 +	2,022	1,426	1,763	1,893

Deemed Summer Demand Savings Tables

Summer demand savings for gas water heaters with tanks greater than 55 gallons (or gas tankless units replacing a unit greater than 55 gallons) are provided in Table 2-279.

Table 2-279: HPWH Baseline Summer Demand (kW) for Gas Heaters with > 55 Gallon Tanks

Climate Zone	Tank Size (gal)	Water Heater Location	
		Conditioned Space	Unconditioned Space
1	55 - 64	0.19	0.14
	65 - 74	0.21	0.16
	75 +	0.23	0.18
2	55 - 64	0.13	0.08
	65 - 74	0.14	0.09
	75 +	0.16	0.1
3	55 - 64	0.13	0.08
	65 - 74	0.15	0.1
	75 +	0.16	0.11
4	55 - 64	0.12	0.08
	65 - 74	0.14	0.09
	75 +	0.15	0.1
5	55 - 64	0.13	0.09
	65 - 74	0.14	0.1
	75 +	0.16	0.11

Deemed Winter Demand Savings Tables

Winter demand savings for gas water heaters with tanks greater than 55 gallons (or gas tankless units replacing a unit greater than 55 gallons) are provided in Table 2-280.

Table 2-280: HPWH Baseline Winter Demand (kW) for Gas Water Heaters with > 55 Gallon Tanks

Climate Zone	Tank Size (gal)	Water Heater Location/Heat Type			
		Conditioned Space			Unconditioned Space
		Gas	Electric Resistance	Heat Pump	
1	55 - 64	0.40	0.13	0.28	0.44
	65 - 74	0.46	0.19	0.34	0.51
	75 +	0.52	0.24	0.40	0.57
2	55 - 64	0.36	0.1	0.25	0.38
	65 - 74	0.41	0.15	0.30	0.44
	75 +	0.47	0.2	0.35	0.50
3	55 - 64	0.33	0.07	0.22	0.38
	65 - 74	0.38	0.11	0.26	0.44
	75 +	0.43	0.16	0.31	0.50
4	55 - 64	0.28	0.04	0.18	0.38
	65 - 74	0.33	0.08	0.22	0.44
	75 +	0.37	0.12	0.26	0.50
5	55 - 64	0.33	0.08	0.22	0.38
	65 - 74	0.38	0.12	0.27	0.44
	75 +	0.43	0.16	0.31	0.50

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 average EULs for installed equipment are: 20 years for a tankless water heater (gas or electric) and 11 years for a high efficiency gas water heater.

These values are consistent with the EULs reported in the 2014 California DEER.[216]

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 at the site
- Volume of the replacement water heater (gallons, zero if tankless)
- Volume of the existing water heater (gallons)
- Energy factor of the replacement water heater
- Number of bedrooms
- Form signed by customer and utility representative indicating planned electric storage water heater installation (New Construction only)
- Design documents indicating planned electric storage water heater installation (New Construction only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

[216] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer-versions/deer2013-update-for-2014-codes.

Document Revision History

Table 2-281: Water Heater Installation – Electric Tankless and Fuel Substitution Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	TRM v2.0 update. Updated measure to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. Updated to reflect that new construction permitted to claim savings subject to documentation requirements, and that gas-fueled tankless water heaters are eligible for installation.
v3.0	04/10/2015	TRM v3.0 update. Amended fuel substitution savings to reflect the full consumption of the electric unit being replaced. Revised demand savings for installing an electric tankless unit to reflect daily usage patterns.
v3.1	11/05/2015	TRM v3.1 update. Clarified baseline for water heaters greater than 55 gallons.
v4.0	10/10/2016	TRM v4.0 update. Updated HPWH baseline usage for gas storage water heaters larger than 55 gallons.

2.4.6 Heat Pump Water Heater Measure Overview

TRM Measure ID: R-WH-HW

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The residential heat pump water heater (HPWH) measure involves the installation of an integrated or "drop-in" ENERGY STAR® HPWH. Deemed savings values are presented on a per-unit basis. Deemed savings variables include storage tank volume and HPWH installation location (in conditioned or unconditioned space). In addition, this measure accounts for the interactive air-conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.[217]

These deemed savings are calculated using the federal standards effective April 16, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).

Eligibility Criteria

This measure applies to residential, electric, storage-type water heaters with storage capacities between 40 and 80 gallons. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

These deemed savings are for Heat Pump Water Heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes. However, savings are calculated under the assumption of replace-on-burnout.

[217] Because the latest manufacturer standards effectively require heat pump water heaters (assuming electric water heating) for residential units with storage tank size greater than 55 gallons. As such, interactive effects are essentially the same for base and change case systems, so they are ignored.

Table 2-282: Heat Pump Water Heaters – Applicability

Application Type	Applicable	Notes
Replace-on-Burnout	Y	For replacement of electric storage water heater
Early Retirement	Y	Awarded savings calculated for replace-on-burnout
New Construction	N	

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency determined by tank size based on the amended federal energy efficiency standards for residential water heaters with tank sizes 20 – 120 gallons, as published in 10 CFR Part 430.32 of the Federal Register:[218]

Table 2-283: Federal Standard for Residential Water Heaters

Rated Storage Volume	Energy Factor
≥ 20 gal and ≤ 55 gal	$0.960 - (0.0003 * V_s)$
> 55 gal and ≤ 120 gal	$2.057 - (0.00113 * V_s)$

Application of this equation provides the following baseline efficiency levels for electric storage water heaters.

Table 2-284: Heat Pump Water Heaters –
Minimum Required Energy Factors for Post-2004 Water Heaters

Tank Size (Gallons)			
40	50	60	80
0.948	0.945	1.989	1.967

The new DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank size greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source. This baseline assumes a replace-on-burnout scenario.

[218] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

High-Efficiency Condition

The efficient condition (i.e., equipment eligible to receive an incentive through a program) is a heat pump water heater that meets ENERGY STAR® qualifications.[219] Heat pump water heaters depend on adequate ventilation for proper functioning, including adequate space for both inlet and outlet air flow, and should be installed in spaces in which temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round, and provide a minimum of 1,000 cubic feet of air space around the water heater.[220]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Four basic variables specify the appropriate deemed demand and energy savings values for a given project:

- The climate zone
- The HPWH tank size
- The HPWH installed location (Conditioned vs. Unconditioned Space)
- For HPWH installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

Deemed savings are estimated using an energy factor (EF) of 2.4. This EF is the average efficiency of ENERGY STAR® HPWHs as of February 2014.[221]

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[219] ENERGY STAR® Requirements (as of February 2014): HPWH must have a maximum current rating of 24 amperes, voltage no greater than 250 volts, and a transfer of thermal energy from one temperature to a higher temperature level for the purpose of heating water. Unit must have "integrated" or "drop-in" configuration. EF ≥ 2.0, first-hour rating (FHR) ≥ 50 gallons/hour, Warranty ≥ 6 years on sealed systems, Safety UL 174 & UL 1995.

[220] Heat Pump Water Heaters. Department of Energy, May 2012. Online. Available: http://energy.gov/energysaver/articles/heat-pump-water-heaters. Accessed: February 22, 2013.

[221] As of February 2014, the ENERGY STAR® products list includes thirty residential heat pump water heaters with energy factors ranging from 2.2 to 2.75.

Deemed Energy Savings Tables

Deemed savings are developed for heat pump water heaters in four size ranges: 40-49 gallon, 50-59 gallons, 60-79 gallons, and 80 or more gallon sizes. These sizes correspond to the four basic sizes of HPWHs commercially available at the time these deemed savings were developed, according to review of manufacturer data provided on the ENERGY STAR® and AHRI websites. Table 2-285 presents the deemed saving tables for five Texas climate zones. This table assumes a replace-on-burnout scenario, but may be used to award savings for early retirement projects.

Table 2-285: Residential HPWH Deemed Annual Energy Savings (kWh)

Climate Zone		HPWH Tank Size Range (Gallons)	Conditioned Space			Unconditioned Space
			Gas	Heat Pump	Elec. Resistance	
1	Panhandle	40-49	1,805	1,464	1,020	1,645
		50-59	2,084	1,737	1,284	1,916
		60-79	308	308	308	320
		80+	394	394	394	409
2	North	40-49	1,533	1,294	982	1,362
		50-59	1,759	1,516	1,199	1,585
		60-79	243	243	243	245
		80+	310	310	310	313
3	South	40-49	1,449	1,213	906	1,273
		50-59	1,657	1,417	1,105	1,481
		60-79	223	223	223	219
		80+	285	285	285	280
4	Valley	40-49	1,393	1,253	1,070	1,193
		50-59	1,587	1,445	1,260	1,387
		60-79	204	204	204	199
		80+	260	260	260	255
5	West	40-49	1,554	1,315	1,003	1,409
		50-59	1,788	1,544	1,227	1,639
		60-79	253	253	253	255
		80+	324	324	324	326

Deemed Summer Demand Savings Tables

Table 2-286 presents the deemed summer demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-286: Residential HPWH Deemed Summer Demand Savings (kW)

Climate Zone		HPWH Tank Size Range (Gallons)	Conditioned Space	Unconditioned Space
1	Panhandle	40-49	0.26	0.22
		50-59	0.30	0.25
		60-79	0.04	0.03
		80+	0.04	0.04
2	North	40-49	0.20	0.16
		50-59	0.22	0.18
		60-79	0.02	0.02
		80+	0.03	0.03
3	South	40-49	0.19	0.15
		50-59	0.22	0.18
		60-79	0.02	0.02
		80+	0.03	0.03
4	Valley	40-49	0.18	0.14
		50-59	0.21	0.17
		60-79	0.02	0.02
		80+	0.03	0.02
5	West	40-49	0.21	0.17
		50-59	0.24	0.20
		60-79	0.03	0.02
		80+	0.03	0.03

Deemed Winter Demand Savings Tables

Table 2-287 presents the deemed winter demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-287: Residential HPWH Deemed Winter Demand Savings (kW)

Climate Zone		HPWH Tank Size Range (Gallons)	Conditioned Space			Unconditioned Space
			Gas	Heat Pump	Electric Resistance	
1	Panhandle	40-49	0.45	0.32	0.00	0.41
		50-59	0.52	0.39	0.22	0.48
		60-79	0.08	0.08	0.08	0.09
		80+	0.11	0.11	0.11	0.12
2	North	40-49	0.39	0.27	0.00	0.37
		50-59	0.46	0.33	0.16	0.43
		60-79	0.07	0.07	0.07	0.08
		80+	0.09	0.09	0.09	0.10
3	South	40-49	0.35	0.23	0.00	0.34
		50-59	0.41	0.28	0.12	0.39
		60-79	0.07	0.07	0.07	0.07
		80+	0.08	0.08	0.08	0.09
4	Valley	40-49	0.33	0.20	0.00	0.32
		50-59	0.38	0.25	0.09	0.37
		60-79	0.06	0.06	0.06	0.06
		80+	0.08	0.08	0.08	0.08
5	West	40-49	0.39	0.27	0.00	0.37
		50-59	0.46	0.33	0.16	0.43
		60-79	0.07	0.07	0.07	0.08
		80+	0.09	0.09	0.09	0.10

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 for this measure is 13 years. This EUL is consistent with the judgment of the American Council for an Energy-Efficient Economy as listed on its website.[222]

Program Tracking Data & 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:

- The climate zone
- The approximate volume of the replacement heat pump water heater tank in gallons
- The baseline energy factor (EF)
- The EF of the replacement water heater
- Water heater type (e.g., heat pump, electric resistance)
- The installed location (conditioned vs. unconditioned space)
- For heat pump water heater installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

[222] Water Heating. American Council for an Energy Efficient Economy. Online. Available: http://www.aceee.org/consumer/water-heating. Accessed: September 2011.

Document Revision History

Table 2-288: Heat Pump Water Heater Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	04/18/2014	TRM v2.0 update. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Consolidated table formats.

2.4.7 Water Heater Replacement – Solar Water Heating Measure Overview

TRM Measure ID: R-WH-WS

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

Eligibility Criteria

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

Baseline Condition

This section is not applicable.

High-Efficiency Condition

Only solar water heaters meeting the SRCC OG-300 standard (based on tank size and final Solar Energy Factor-SEF) qualify for these deemed savings estimates.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Solar water heating values are on a per-unit basis. Deemed savings variables include tank volume and installed-unit Solar Energy Factor (SEF) as rated in the Solar Rating and Certification Corporation (SRCC) “Summary of SRCC Certified Solar Collector and Water Heating System Ratings.” The Solar Energy Factor (SEF) is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed as a means to compare solar water heating systems with conventional water heating systems rated with an Energy Factor (EF) and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

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

Examples

A passive Sun Earth CP-40 with a SEF of 1.4 would consume 2133 kWh (2987/1.4), saving 1323 kWh compared to a baseline 50-gallon water heater that consumes 3458 kWh (values based on Frontier data).

An active Heliotype HP 410 G 80 with a SEF of 2.0 would consume 1494 kWh (2987/2), saving 1965 kWh compared to the baseline 50-gallon water heater.

Use SRCC OG-300 Test to obtain SEF

SRCC = Solar Rating and Certification Corporation

OG-300 = test standard for SWH systems

SEF = Solar Energy Factor

Calculate kWh Savings

$$kWh\ savings = standard\ load \times \left(1 - \frac{EF}{SEF}\right) = (3{,}458) \times \left(1 - \frac{0.864}{2}\right) = 1{,}965 kWh$$

Deemed Energy Savings Tables

The following table presents the energy savings for solar water heaters based on tank size and final Solar Energy Factor (SEF).

Table 2-289: Solar Water Heating Energy Savings (kWh)

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
1.0	637	471	368
1.1	909	743	640
1.2	1,135	969	866
1.3	1,326	1,160	1,057
1.4	1,490	1,324	1,221
1.5	1,633	1,467	1,364
1.6	1,757	1,591	1,488
1.7	1,867	1,701	1,598
1.8	1,965	1,799	1,696
1.9	2,052	1,886	1,783
2.0	2,131	1,965	1,862
2.1	2,202	2,036	1,933
2.2	2,266	2,100	1,997
2.3	2,325	2,159	2,056
2.4	2,379	2,213	2,110
2.5	2,429	2,263	2,160
2.6	2,475	2,309	2,206
2.7	2,518	2,352	2,249
2.8	2,557	2,391	2,288
2.9	2,594	2,428	2,325
3.0	2,628	2,462	2,359
3.1	2,660	2,494	2,391
3.2	2,691	2,525	2,422
3.3	2,719	2,553	2,450
3.4	2,745	2,579	2,476
3.5	2,771	2,605	2,502
3.6	2,794	2,628	2,525
3.7	2,817	2,651	2,548
3.8	2,838	2,672	2,569
3.9	2,858	2,692	2,589
4.0	2,877	2,711	2,608
4.1	2,895	2,729	2,626
4.2	2,913	2,747	2,644
4.3	2,929	2,763	2,660
4.4	2,945	2,779	2,676

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
4.5	2,960	2,794	2,691
4.6	2,975	2,809	2,706
4.7	2,988	2,822	2,719
4.8	3,002	2,836	2,733
4.9	3,014	2,848	2,745
5.0	3,027	2,861	2,758

Source: Tim Kerrigan, National Renewable Energy Laboratory (2001)

Deemed Summer Demand Savings Tables

The following table presents the demand savings for solar water heaters.

Table 2-290: Solar Water Heating Demand Savings (kW)

Solar Water Heating Demand Savings kW
0.42

Diversified value fully displaced during solar peak.

This value is consistent with Univ. of Texas study (0.4)

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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar water heater is established at 15 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[223]

Program Tracking Data & 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:

- The approximate volume of the replacement water heater in gallons
- SRCC OG-300 Solar Energy Factor of the replacement unit

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-291: Water Heater Replacement – Solar Water Heating Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
V4.0	10/10/2016	TRM v4.0 update. No revision

[223] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer-versions/deer2013-update-for-2014-codes.

2.5 RESIDENTIAL: APPLIANCES

2.5.1 ENERGY STAR® Ceiling Fans Measure Overview

TRM Measure ID: R-AP-FN

Market Sector: Residential

Measure Category: Appliances

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 Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® ceiling fan and light kit. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

This section is not applicable.

Baseline Condition

The baseline is a conventional non-ENERGY STAR® labeled ceiling fan and light kit.

High-Efficiency Condition

Table 2-291 displays the ENERGY STAR® requirements for eligible ceiling fans as of April 1, 2012. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-292: ENERGY STAR® Specifications for Ceiling Fans

ENERGY STAR® Specifications for Ceiling Fans
1. Specification defines residential ceiling fan airflow efficiency on a performance basis: CFM of airflow per watt of power consumed by the motor and controls. Efficiency is measured on each of three speeds (low/medium/high).
2. At low speed, fans must have a minimum airflow of 1,250 CFM and an efficiency of 155 CFM/Watt
3. At medium speed, fans must have a minimum airflow of 3,000 CFM and an efficiency of 100 CFM/W.
4. At high speed, fans must have a minimum airflow of 5,000 CFM and an efficiency of 75 CFM/Watt
5. Qualifying ceiling fan models must come with a minimum 30-year motor warranty; one-year component(s) warranty; and light kit warranty specified in "ENERGY STAR® Program Requirements for Luminaires" document.[224]
6. Integral or attachable lighting, including separately sold ceiling fan light kits, must meet requirements provided in the "ENERGY STAR® Program Requirements for Luminaires" specification. [225]
7. Qualifying products must permit convenient consumer adjustment of fan speed, by means of one or more wall-mounted switch(es), a remote control, or readily accessible pull chains.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings were calculated using the ENERGY STAR® Ceiling Fan Savings Calculator found on the ENERGY STAR® website.226 Default values were taken directly from the ENERGY STAR® Ceiling Fan Savings Calculator, unless otherwise specified.

$$kWh_{savings} = (kWh_{baseline} - kWh_{ES})_{fan} + (kWh_{baseline} - kWh_{ES})_{lgt} \times IEF_E$$

Equation 88

$$kWh_{baseline,Fan} = \frac{W_{Fan,baseline} \times AOH_{Fan}}{1,000}$$

Equation 89

[224] ENERGY STAR® Program Requirements for Luminaires. http://www.energystar.gov/ia/partners/product_specs/program_reqs/Final_Luminaires_V1_2.pdf?6d42-c7e4.

[225] Ibid.

[226] ENERGY STAR® Ceiling Fan Savings Calculator (updated September 2013). http://www.energystar.gov/products/certified-products/detail/ceiling-fans.

$$\boldsymbol{kWh_{ES,Fan} = \frac{W_{Fan,ES} \times AOH_{Fan}}{1,000}}$$

Equation 90

$$\boldsymbol{W_{Fan} = (W_{LS} \times OP_{LS}) + (W_{MS} \times OP_{MS}) + (W_{HS} \times OP_{HS})}$$

Equation 91

$$\boldsymbol{kWh_{baseline,Lgt} = \frac{W_{Lgt,baseline} \times AOH_{Lgt}}{1,000}}$$

Equation 92

$$\boldsymbol{kWh_{ES,Lgt} = \frac{W_{Lgt,ES} \times AOH_{Lgt}}{1,000}}$$

Equation 93

Where:

$kWh_{baseline}$	=	*Non-ENERGY STAR® baseline energy usage*
kWh_{ES}	=	*ENERGY STAR® average energy usage*
IEF_E	=	*Energy Interactive Effects Factor (Table 2-292)* [227]
$W_{Lgt,baseline}$	=	*Conventional lighting total wattage = 115 W (160 W default value from ENERGY STAR® calculator reduced to comply with EISA 2007 baseline wattages)*[228]
$W_{Lgt,ES}$	=	*Actual wattage of installed ENERGY STAR® lighting; if unknown, assume one high-efficiency 32 W lamp*
$W_{Fan,baseline}$	=	*Conventional fan motor wattage*
$W_{Fan,ES}$	=	*ENERGY STAR® fan motor wattage*
$W_{LS,MS,HS}$	=	*Fan motor wattage at low, medium, and high speed; see Table 2-293*
$OP_{LS,MS,HS}$	=	*Fan operating percentage at low, medium, and high speed; see Table 2-294*
AOH_{Lgt}	=	*Annual lighting operating hours = 803 hours/year (assuming 2.2 hours/day and 365 days/year operation)*[229]
AOH_{Fan}	=	*Annual fan operating hours = 1,095 hours/year (assuming 3.0 hours/day and 365 days/year operation)*
1,000	=	*Constant to convert from W to kW*

[227] The assumed energy interactive effects factors are taken from the residential lighting measure.
[228] EISA 2007 baseline wattages are approximately 72% of standard incandescent wattages.
[229] The assumed annual operating hours are taken from the residential lighting measure.

Table 2-293: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[230]

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[231]	0.87	1.03	1.08	1.12	1.01
Upstream Lighting[232]	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

Table 2-294: Ceiling Fan Motor Wattages

Fan Type	Fan Speed	Fan Motor Wattage (W)
Conventional	Low	15
	Medium	34
	High	67
ENERGY STAR®	Low	6
	Medium	23
	High	56

230 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: $1 + HVAC_{savings}/Lighting_{savings}$.

231 Calculated using IEFs from Cadmus report and weighted using TMY CDD and HDD for Texas. 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.

232 Ibid.

Table 2-295: Ceiling Fan Operating Percentages

Fan Speed	Operating Percentage (OP)
Low	40%
Medium	40%
High	20%

Demand Savings Algorithms

Peak demand savings were calculated using separate coincidence factors for the lighting and the fan motor portion of the ceiling fan savings. For lighting the coincidence factor varies based on climate zone. For the fan motor a coincidence factor of 0.446 was applied (derived from the EnergyGauge software ceiling fan profiles).

$$kW_{savings} = kW_{Fan} + kW_{Lgt}$$

Equation 94

$$kW_{Fan} = \frac{W_{Fan,baseline} - W_{Fan,ES}}{1,000} \times CF_{Fan}$$

Equation 95

$$kW_{Lgt} = \frac{W_{Lgt,baseline} - W_{Lgt,ES}}{1,000} \times CF_{Lgt} \times IEF_D$$

Equation 96

Where:

kW_{Fan} = *Fan demand savings*

CF_{Fan} = *Fan motor coincidence factor = 0.446*

kW_{Lgt} = *Lighting demand savings*

CF_{Lgt} = *Lighting coincidence factor (Table 2-319)*

IEF_D = *Demand Interactive Effects Factor (Table 2-296)*[233]

Table 2-296 ENERGY STAR® Ceiling Fans – Lighting Coincidence Factors[234]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.277	0.232	0.199	0.267	0.357

233 The assumed demand interactive effects factors are taken from the residential lighting measure.
234 See Volume 1, Appendix B.

Table 2-297: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[235]

$IEF_{D,summer}$					
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	1.27	1.28	1.19	1.23	1.37
Electric Resistance Heat with AC	1.07	1.27	1.07	1.23	1.36
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[236]	1.24	1.43	1.46	1.51	1.37
Upstream Lighting[237]	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
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[238]	0.75	0.80	0.83	0.85	0.81
Upstream Lighting[239]	0.78	0.83	0.85	0.86	0.83

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

[235] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[236] Calculated using IEFs from Cadmus report and weighted using TMY CDD and HDD for Texas. 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.

[237] Ibid.

[238] Ibid.

[239] Ibid.

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

The estimated useful life (EUL) is established at 10 years according to the ENERGY STAR® Ceiling Fan Savings Calculator.

This EUL is consistent with Docket No. 38025 approved in 2010.[240]

Program Tracking Data & 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:

- The number of installed ENERGY STAR® ceiling fan and light kits.
- Wattage of installed lighting

[240] Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR® Appliance Measures. Public Utility Commission of Texas.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR® Appliance Measures. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for ceiling fans.

Document Revision History

Table 2-298: ENERGY STAR® Ceiling Fan Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language and updates to ENERGY STAR® specification table.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2014	TRM v3.0 update. Explanation of methodology and alignment with ENERGY STAR® calculator. Introduction of interactive effects factors and in-service rates. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. Revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types.
v3.1	March 2016	TRM v3.1 March Revision update. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated interactive effect values using building energy simulation.

2.5.2 ENERGY STAR® Clothes Washer Measure Overview

TRM Measure ID: R-AP-CW

Market Sector: Residential

Measure Category: Appliances

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 Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® clothes washer. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

These deemed savings are calculated using the federal standards effective March 7, 2015.

Eligibility Criteria

This section is not applicable.

Baseline Condition

Effective March 7, 2015, the baseline is the Department of Energy (DOE) minimum efficiency standard[241] for top-loading clothes washers. While the DOE provides criteria for both top- and front-loading washers, only the standards for top-loading washers are listed below, as a top-loading unit is assumed to be the baseline equipment. This approach is consistent with the ENERGY STAR® appliance calculator. This baseline is schedule to change again on January 1, 2018.

[241] DOE minimum efficiency standard for residential clothes washers. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Table 2-299: Federal Standard for Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)	Proposed Changes for January 1, 2018
Top-loading, Standard (1.6 ft^3 or greater capacity)	IMEF ≥ 1.29 IWF≤ 8.4	IMEF ≥ 1.57 IWF≤ 6.5

IMEF = Integrated Modified Energy Factor (ft^3/kWh/cycle)

IWF = Integrated Water Factor (gallons/cycle/ft^3)

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 7.0 requirements for eligible clothes washers effective March 7, 2015.[242] These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-300: ENERGY STAR® Specifications for Residential Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)
ENERGY STAR® Residential Front-loading (> 2.5 ft^3)	IMEF ≥ 2.38 IWF≤ 3.7
ENERGY STAR® Residential Top-loading (> 2.5 ft^3)	IMEF ≥ 2.06 IWF ≤ 4.3
ENERGY STAR® Residential Small or Compact (< 2.5 ft^3)	IMEF ≥ 2.07 IWF ≤ 4.2

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Appliance Savings Calculator found on the ENERGY STAR® website.[243] Default values were taken directly from the ENERGY STAR® calculator. This document will be updated regularly to apply the values provided in the latest available ENERGY STAR® appliance calculator. The most recent TRM version should be referenced to determine the savings for this measure.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 97

[242] Available for download at: http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf.

[243] ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Baseline Unit

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH} + kWh_{conv,dryer} + kWh_{conv,LPM}$$

Equation 98

$$kWh_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 99

$$kWh_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 100

$$kWh_{conv,LPM} = kW_{conv,LPM} \times (8,760 - LPY)$$

Equation 101

$$kWh_{conv,dryer} = \left[\left(\frac{CAP_{conv}}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right) - kWh_{conv,LPM}\right] \times \frac{DU_{DW}}{DUF}$$

Equation 102

Where:

$kWh_{baseline}$	=	*Federal standard baseline energy usage*
$kWh_{conv,machine}$	=	*Conventional machine energy*
$kWh_{conv,WH}$	=	*Conventional water heater energy*
$kWh_{conv,dryer}$	=	*Conventional dryer energy*
$kWh_{conv,LPM}$	=	*Conventional combined low-power mode energy*
$RUEC_{conv}$	=	*Conventional rated unit electricity consumption = 381 kWh/year (top-loading)* [244]
LPY	=	*Loads per year = 295*
$RLPY$	=	*Reference loads per year = 392*
$kW_{conv,LPM}$	=	*Combined low-power mode wattage of conventional unit = 0.00115 kW*
CAP_{conv}	=	*Average machine capacity = 4.5 ft^3 (top-loading)*

[244] This value is taken from the ENERGY STAR® appliance calculator available September 2015, and corresponds with the federal standard after March 7, 2015.

$IMEF_{FS}$	=	*Federal standard integrated modified energy factor (Table 2-299)*
MCF	=	*Machine consumption factor = 20%*
$WHCF$	=	*Water heater consumption factor = 80%*
DU_{DW}	=	*Dryer usage in households with both a washer and a dryer = 95%*
DUF	=	*Dryer use factor (percentage of washer loads dried in machine) = 91%*

ENERGY STAR® Unit

$$\boldsymbol{kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH} + kWh_{ES,dryer} + kWh_{ES,LPM}}$$

Equation 103

$$\boldsymbol{kWh_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}}$$

Equation 104

$$\boldsymbol{kWh_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}}$$

Equation 105

$$\boldsymbol{kWh_{ES,LPM} = kW_{ES,LPM} \times (8,760 - LPY)}$$

Equation 106

$$\boldsymbol{kWh_{ES,dryer} = \left[\left(\frac{CAP_{ES}}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right) - kWh_{ES,LPM}\right] \times \frac{DU_{DW,ES}}{DUF}}$$

Equation 107

Where:

kWh_{ES}	=	*ENERGY STAR® average energy usage*
$kWh_{ES,machine}$	=	*ENERGY STAR® machine energy*
$kWh_{ES,WH}$	=	*ENERGY STAR® water heater energy*
$kWh_{ES,dryer}$	=	*ENERGY STAR® dryer energy*
$kWh_{ES,LPM}$	=	*ENERGY STAR® combined low-power mode energy*
$RUEC_{ES}$	=	*ENERGY STAR® rated unit electricity consumption (see Table 2-301)*
$kW_{ES,LPM}$	=	*Combined low-power mode wattage of ENERGY STAR® unit (see Table 2-301)*

$IMEF_{ES}$ = *ENERGY STAR® integrated modified energy factor (Table 2-300)*

CAP_{ES} = *Average machine capacity (see Table 2-301)*

Table 2-301: ENERGY STAR® Clothes Washer Characteristics[245]

Product Type	ENERGY STAR® Rated Unit Electricity Consumption (kWh)	Average Capacity (ft^3)	Combined Low-Power Mode Wattage (kW)
Residential Front-loading (> 2.5 ft^3)	127	4.0	0.00160
Residential Top-loading (> 2.5 ft^3)	230	4.5	0.00115
Residential Small or Compact (< 2.5 ft^3)	109	2.1	0.00144

Summer Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

$$AOH = LPY \times d$$

Equation 108

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor (Table 2-302)*

LPY = *Loads per year = 295*

d = *Average wash cycle duration = 1 hour*[246,247]

Table 2-302: ENERGY STAR® Clothes Washer Coincidence Factors[248]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.040	0.040	0.040	0.041	0.041
Winter	0.043	0.043	0.043	0.044	0.039

245 This value is taken from the ENERGY STAR® appliance calculator available September 2015, and corresponds with the ENERGY STAR® specification after March 7, 2015.

246 Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers. Top: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/top-loading-washing-machine-ratings/ratings-overview.htm. Front: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/front-loading-washing-machine-ratings/ratings-overview.htm.

247 Consumer Reports. "Top-loading washers remain more popular with Americans". April 13, 2010. Weighted average of 75% Top-Loading Clothes Washers and 25% Front-Loading Clothes Washers. http://news.consumerreports.org/home/2010/04/best-front-loaders-top-loaders-which-is-more-popular-mold-vibration-washing-machine-reviews.html. This publication is available for purchase only.

248 See Volume 1, Appendix B.

Deemed Energy Savings Tables

Table 2-303: ENERGY STAR® Clothes Washer Energy Savings (kWh)

ENERGY STAR® Clothes Washer – Annual Energy Savings			
Type	Water Heater Fuel Type	Dryer Fuel Type	kWh Savings
Front-loading > 2.5 ft^3	Electric	Electric	548
	Electric	Gas	187
	Gas	Electric	396
	Gas	Gas	34
Top-loading > 2.5 ft^3	Electric	Electric	397
	Electric	Gas	114
	Gas	Electric	306
	Gas	Gas	23
All $\leq$ 2.5 ft^3	Electric	Electric	753
	Electric	Gas	203
	Gas	Electric	589
	Gas	Gas	39

Deemed Summer Demand Savings Tables

Table 2-304: ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW)

ENERGY STAR® Clothes Washer – Summer Demand Savings							
Washer Type	Fuel Type		Summer Demand Savings (kW)				
	Water Heater	Dryer	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Front-loading > 2.5 ft^3	Electric	Electric	0.075	0.074	0.075	0.076	0.076
	Electric	Gas	0.026	0.025	0.026	0.026	0.026
	Gas	Electric	0.054	0.054	0.054	0.055	0.055
	Gas	Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft^3	Electric	Electric	0.054	0.054	0.054	0.055	0.055
	Electric	Gas	0.016	0.015	0.016	0.016	0.016
	Gas	Electric	0.042	0.041	0.042	0.042	0.043
	Gas	Gas	0.003	0.003	0.003	0.003	0.003
All $\leq$ 2.5 ft^3	Electric	Electric	0.103	0.102	0.103	0.105	0.105
	Electric	Gas	0.028	0.028	0.028	0.028	0.028
	Gas	Electric	0.081	0.080	0.080	0.081	0.082
	Gas	Gas	0.005	0.005	0.005	0.005	0.005

Deemed Winter Demand Savings Tables

Table 2-305: All Climate Zones – ENERGY STAR® Clothes Washer Winter Demand Savings (kW)

ENERGY STAR® Clothes Washer – Winter Demand Savings							
Washer Type	Fuel Type		Winter Demand Savings (kW)				
	Water Heater	Dryer	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Front-loading > 2.5 ft^3	Electric	Electric	0.079	0.080	0.080	0.083	0.072
	Electric	Gas	0.027	0.027	0.027	0.028	0.025
	Gas	Electric	0.057	0.058	0.058	0.060	0.052
	Gas	Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft^3	Electric	Electric	0.057	0.058	0.058	0.060	0.052
	Electric	Gas	0.016	0.017	0.017	0.017	0.015
	Gas	Electric	0.044	0.045	0.045	0.046	0.040
	Gas	Gas	0.003	0.003	0.003	0.003	0.003
All $\leq$ 2.5 ft^3	Electric	Electric	0.108	0.110	0.110	0.113	0.099
	Electric	Gas	0.029	0.030	0.030	0.031	0.027
	Gas	Electric	0.085	0.086	0.086	0.089	0.078
	Gas	Gas	0.006	0.006	0.006	0.006	0.005

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) of an ENERGY STAR® clothes washer is established at 11 years based on the Technical Support Document for the current DOE Final Rule standards for residential clothes washers.[249]

[249] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 32308 (May 31, 2012) and associated Technical Support Document. Accessed 10/07/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047.

Program Tracking Data & 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:

- Number of units installed
- Type of unit (top-loading, front-loading, or compact)
- Fuel type of water heater (gas or electric)
- Fuel type of dryer (gas or electric)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for clothes washers.

Document Revision History

Table 2-306: ENERGY STAR® Clothes Washer 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.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.
v3.0	4/10/2015	TRM v3.0 update. Updated EUL to align with median lifetime. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. New ENERGY STAR® algorithms and default assumptions incorporated.
v3.1	March 2016	Updated winter coincidence factors and winter and summer demand savings tables.
v4.0	10/10/2016	TRM v4.0 update. No revision.

2.5.3 ENERGY STAR® Dishwasher Measure Overview

TRM Measure ID: R-AP-DW

Market Sector: Residential

Measure Category: Appliances

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 Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® dishwasher. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

This measure applies to both standard and compact dishwasher types.

Baseline Condition

Effective May 30, 2013, the baseline is the Department of Energy (DOE) minimum efficiency standard[250] for dishwashers.

[250] DOE minimum efficiency standard for residential dishwashers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67.

Table 2-307 Federal Standard for Dishwashers

Product Type	Estimated Annual Energy Use (kWh/year)	Water Consumption (gallons/cycle)
Standard (≥ 8 place settings)	≤ 307	≤ 5.0
Compact (< 8 place settings)	≤ 222	≤ 3.5

High-Efficiency Condition

The following table displays the ENERGY STAR® Final Version 6.0 requirements for eligible dishwashers effective January 29, 2016.[251] These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-308 ENERGY STAR® Specifications for Dishwashers

Product Type	Estimated Annual Energy Use (kWh/year)	Water Consumption (gallons/cycle)
Standard (≥ 8 place settings + 6 serving pieces)	≤ 270	≤ 3.5
Compact (< 8 place settings + 6 serving pieces)	≤ 203	≤ 3.1

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Appliance Savings Calculator found on the ENERGY STAR® website and the revised ENERGY STAR® specification in Table 2-308.[252] Default values were taken directly from the ENERGY STAR® calculator. This document will be updated regularly to apply the values provided in the latest available ENERGY STAR® specification and appliance calculator. The most recent TRM version should be referenced to determine measure savings for this measure.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 109

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH}$$

Equation 110

[251] Available for download at: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf.

[252] ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

$$\boldsymbol{kWh_{conv,machine} = RUEC_{conv} \times MCF}$$

Equation 111

$$\boldsymbol{kWh_{conv,WH} = RUEC_{conv} \times WHCF}$$

Equation 112

$$\boldsymbol{kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH}}$$

Equation 113

$$\boldsymbol{kWh_{ES,machine} = RUEC_{ES} \times MCF}$$

Equation 114

$$\boldsymbol{kWh_{ES,WH} = RUEC_{ES} \times WHCF}$$

Equation 115

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage*

kWh_{ES} = *ENERGY STAR® average energy usage*

$kWh_{conv,machine}$ = *Conventional machine energy*

$kWh_{conv,WH}$ = *Conventional water heater energy*

$kWh_{ES,machine}$ = *ENERGY STAR® machine energy*

$kWh_{ES,WH}$ = *ENERGY STAR® water heater energy*

$RUEC_{conv}$ = *Conventional rated use electricity consumption = 307 kWh/year for standard and 222 kWh/year for compact (Table 2-307)*

$RUEC_{ES}$ = *ENERGY STAR® rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact (Table 2-308)*

MCF = *Machine consumption factor = 44%*

$WHCF$ = *Water heater consumption factor = 56%*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Equation 116

$$AOH = CPY \times d$$

Equation 117

Where:

AOH	=	*Annual operating hours*
CF	=	*Coincidence factor = (Table 2-309)*
CPY	=	*Cycles per year = 215*
d	=	*Average wash cycle duration = 2.1 hours*[253]

Table 2-309: ENERGY STAR® Dishwasher Coincidence Factors[254]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	0.042	0.041	0.042	0.041	0.042
Winter	0.106	0.104	0.090	0.112	0.129

Deemed Energy Savings Tables

Table 2-310: ENERGY STAR® Dishwasher Energy Savings

ENERGY STAR® Dishwasher – Energy Savings (kWh)		
Product Type	**Electric Water Heating**	**Gas Water Heating**
Standard	37	16
Compact	19	8

[253] Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/appliances/kitchen-appliances/dishwashers/dishwasher-ratings/ratings-overview.htm.

[254] See Volume 1, Appendix B.

Deemed Summer Demand Savings Table

Table 2-311: ENERGY STAR® Dishwasher Summer Peak Demand Savings (kW)

ENERGY STAR® Dishwasher – Summer Demand Savings (kW)						
Dishwasher Type	Water Heating Fuel	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Standard	Electric	0.003	0.003	0.003	0.003	0.003
	Gas	0.002	0.001	0.002	0.001	0.002
Compact	Electric	0.002	0.002	0.002	0.002	0.002
	Gas	0.001	0.001	0.001	0.001	0.001

Deemed Winter Demand Savings Tables

Table 2-312: ENERGY STAR® Dishwasher Winter Peak Demand Savings (kW)

ENERGY STAR® Dishwasher – Winter Demand Savings (kW)						
Dishwasher Type	Water Heating Fuel	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Standard	Electric	0.009	0.009	0.007	0.009	0.011
	Gas	0.004	0.004	0.003	0.004	0.005
Compact	Electric	0.004	0.004	0.004	0.005	0.005
	Gas	0.002	0.002	0.002	0.002	0.002

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) is established at 15 years based on the Technical Support Document for the current DOE Final Rule standards for residential dishwashers.[255]

[255] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 31918 (May 30, 2012) and associated Technical Support Document. Accessed 10/07/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0007.

Program Tracking Data & 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:

- Number of units installed
- Type of dishwasher (standard or compact)
- Fuel type of water heater (gas or electric)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for dishwashers.

Document Revision History

Table 2-313: ENERGY STAR® Dishwasher 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.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. New ENERGY STAR® specifications incorporated into measure. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. Final ENERGY STAR® specification incorporated into measure. Consolidated table formats.
v3.1	March 2016	Updated summer and winter coincidence factors and demand savings tables.
v4.0	10/10/2016	TRM v4.0 update. No revision.

2.5.4 ENERGY STAR® Refrigerator Measure Overview

TRM Measure ID: R-AP-RF

Market Sector: Residential

Measure Category: Appliances

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

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure applies to all ENERGY STAR® refrigerators that meet the criteria for the ENERGY STAR® label specified below.

Eligibility Criteria

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[256] when designing programs that permit savings to be claimed for early retirement. To qualify for early retirement, the ENERGY STAR® unit must replace an existing, full-size unit with a maximum age of 20 years. To determine the remaining useful life of an existing unit, see Table 2-314. All retired refrigerators must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly-installed refrigerators must meet current ENERGY STAR® efficiency levels.

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

Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[257] for refrigerators, effective September 15, 2014.

For early retirement, the baseline for refrigerators is assumed to be the annual unit energy consumption of the refrigerator being replaced, as reported by the Association of Home Appliance Manufacturers (AHAM) refrigerator database[258] and adjusted for age according to the formula in the Energy and Demand Savings Methodology section of this measure. AHAM energy use data includes the average manufacturer reported annual kWh usage by year of production dating back to the 1970s.

Alternatively, the baseline annual energy usage of the refrigerator being replaced may be estimated by metering for a period of at least two hours using the measurement protocol specified in the DOE report, "Incorporating Refrigerator Replacement into the Weatherization Assistance Program".[259]

To determine annual kWh of the refrigerator being replaced, use the following formula:

$$\boldsymbol{Annual\ kWh\ Usage} = \frac{\boldsymbol{WH \times 8,760}}{\boldsymbol{h \times 1,000}}$$

Equation 118

Where:

WH	=	*Watt-hours metered during a time period*
h	=	*Measurement time period (hours)*
8,760	=	*Hours in a year*
1,000 Watt-hours	=	*1 kWh*

High-Efficiency Condition

Table 2-313 displays the ENERGY STAR® requirements for eligible refrigerators, which went into effect September 15, 2014. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

257 DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

258 AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

259 Alex Moore, D&R International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. http://www.waptac.org/data/files/Website_Docs/technical_tools/toolkit07.pdf.

Table 2-314: ENERGY STAR® Specifications for Refrigerators

ENERGY STAR® Refrigerator		
Product Type	**Volume**	**Criteria as of September 15. 2014**
Full-Size Refrigerators and Refrigerator-Freezers	7.75 cubic feet or greater	Approximately 10% more energy efficient than the minimum federal standard (see Table 2-313)

Configuration Codes (for Table 2-315):

BF: Bottom Freezer
SD: Refrigerator Only – Single Door
SR: Refrigerator/Freezer – Single Door
SS: Side-by-Side
TF: Top Freezer

TTD: Through the Door (Ice Maker)

A: Automatic Defrost
M: Manual Defrost
P: Partial Automatic Defrost

AV = Adjusted Volume = Fresh Volume + 1.63 x Freezer Volume (ft^3)

Table 2-315: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume[260]

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[261]	Average ENERGY STAR® Energy Usage (kWh/year)[262]	Configuration(s)	Ice (Y/N)	Defrost
1, 2	Refrigerator-freezers—manual or partial automatic defrost	7.99 × AV + 225.0	7.19 × AV + 202.5	SS, TF, BF, SR	Y, N	M, P
1A	Refrigerator-only—manual defrost	6.79 × AV + 193.6	6.11 × AV + 174.2	SD	Y, N	M
3	Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.26 × AV + 210.3	TF	N	A
3-BI	Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	9.15 × AV + 264.9	8.24 × AV + 238.4	TF	N	A
3I	Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	8.07 × AV + 317.7	7.26 × AV + 294.3	TF	N	A
3I-BI	Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic ice maker with TTD ice service	9.15 × AV + 348.9	8.24 × AV + 322.4	TF	N	A
3A	Refrigerator-only—automatic defrost	7.07 × AV + 201.6	6.36 × AV + 181.4	SD	Y, N	A

[260] Available for download at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Select product classes excluded.
[261] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[262] Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[263]	Average ENERGY STAR® Energy Usage (kWh/year)[264]	Configuration(s)	Ice (Y/N)	Defrost
3A-BI	Built-in refrigerator-only—automatic defrost	8.02 × AV + 228.5	7.22 × AV + 205.7	SD	Y, N	A
4	Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	8.51 × AV + 297.8	7.66 × AV + 268.0	SS	N	A
4-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	9.20 × AV + 321.7	SS	N	A
4I	Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	7.66 × AV + 352.0	SS	N	A
4I-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	9.20 × AV + 405.7	SS	N	A
5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.97 × AV + 285.3	BF	N	A
5-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	8.46 × AV + 303.2	BF	N	A
5I	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	7.97 × AV + 369.3	BF	N	A

263 http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

264 Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[265]	Average ENERGY STAR® Energy Usage (kWh/year)[266]	Configuration(s)	Ice (Y/N)	Defrost
5I-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	9.40 × AV + 420.9	8.46 × AV + 387.2	BF	N	A
5A	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.25 × AV + 475.4	8.33 × AV + 436.3	BF	Y	A
5A-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.83 × AV + 499.9	8.85 × AV + 458.3	BF	Y	A
6	Refrigerator-freezers—automatic defrost with top-mounted freezer with TTD ice service	8.40 × AV + 385.4	7.56 × AV + 355.3	TF	Y	A
7	Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.69 × AV + 397.9	SS	Y	A
7-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	10.25 × AV + 502.6	9.23 × AV + 460.7	SS	Y	A

265 http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

266 Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$\boldsymbol{kWh_{savings} = kWh_{baseline} - kWh_{ES}}$$

Equation 119

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 2-314)*

kWh_{ES} = *ENERGY STAR average energy usage (see (see Table 2-314)*

Demand Savings Algorithms

$$\boldsymbol{kW_{savings} = \frac{kWh_{savings}}{8,760\ hrs} \times LSAF}$$

Equation 120

Where:

$LSAF$ = *Load Shape Adjustment Factor (see Table 2-315)*

Table 2-316: ENERGY STAR® Refrigerator Load Shape Adjustment Factors[267]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	1.112	1.099	1.108	1.100	1.081
Winter	0.929	0.966	0.924	0.941	0.966

Early Retirement

Annual energy (kWh) and 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 (16 – RUL)

[267] See Volume 1, Appendix B.

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

Where:

RUL	=	*Remaining Useful Life (seeTable 2-316); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years*
EUL	=	*Estimated Useful Life = 16 years*

Table 2-317: Remaining Useful Life (RUL) of Replaced Refrigerator

Age of Replaced Refrigerator (years)	RUL (years)	Age of Replaced Refrigerator (years)	RUL (years)
1	15.2	12	7.0
2	14.2	13	6.6
3	13.2	14	6.3
4	12.2	15	6.0
5	11.2	16	5.0
6	10.3	17	4.0
7	9.6	18	3.0
8	8.9	19	2.0
9	8.3	20	1.0
10	7.8	21[268,269]	0.0
11	7.4		

Derivation of RULs

ENERGY STAR® refrigerators have an estimated useful life of 16 years. This estimate is consistent with the age at which approximately 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Table 2-316.

[268] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see Figure 2-8). 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.

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

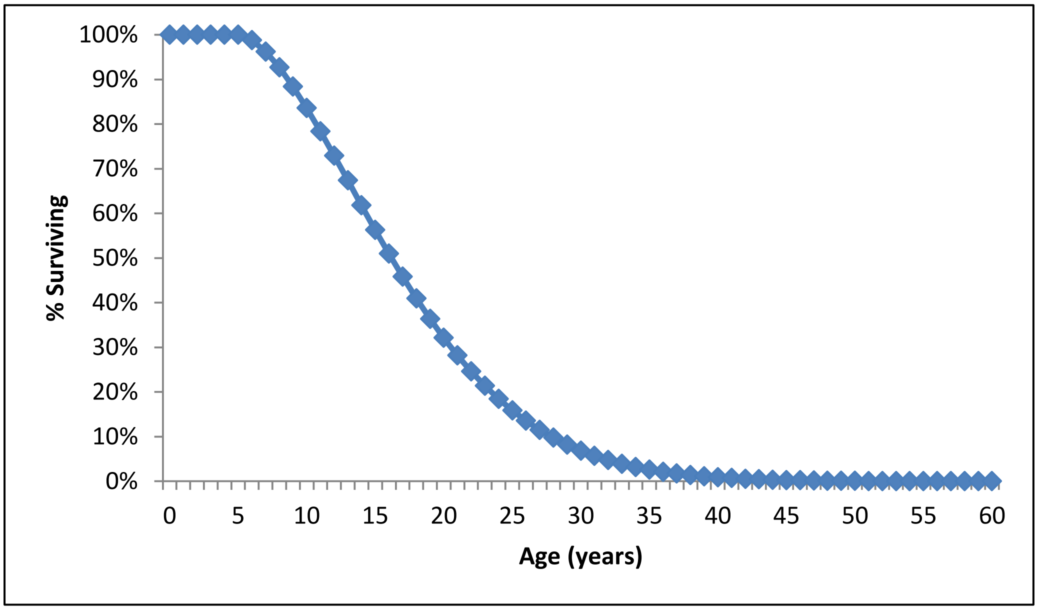

Figure 2-8: Survival Function for ENERGY STAR® Refrigerators[270]

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 2-8. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators 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. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a refrigerator being replaced is 15 years old. The corresponding % surviving value is 56%. Half of 56% is 28%. The age corresponding to 28% on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21 – 15) = 6 years.

Energy Savings Algorithms

For the RUL time period:

$$\boldsymbol{kWh_{savings,ER} = kWh_{manf} - kWh_{ES}}$$

Equation 121

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

[270] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

$$kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}$$

Equation 122

Where:

kWh_{manf}	=	*Annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database*[271] *(or from metering)*
$kWh_{baseline}$	=	*Federal standard baseline energy usage (see Table 2-314)*
kWh_{ES}	=	*ENERGY STAR® average energy usage (see Table 2-314)*

Demand Savings Algorithms

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

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8,760\ hrs} \times LSAF$$

Equation 123

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

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8,760\ hrs} \times LSAF$$

Equation 124

Where:

$LSAF$	=	*Load Shape Adjustment Factor (Table 2-315)*

Annual deemed 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 Volume 3, Appendix D of this document.

Where:

RUL	=	*Remaining Useful Life (seeTable 2-316)*
EUL	=	*Estimated Useful Life = 16 years*[272]

[271] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

[272] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011.

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

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.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 16 years based on the current DOE Final Rule standards for residential refrigerators.[273]

Program Tracking Data & 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:

- Number of units installed
- The project type of the installation (New Construction, Replace-on-Burnout, or Early Retirement)
- Installed refrigerator model number
- Product class (see Table 2-315)
- Refrigerator volume

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http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

273 Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. Accessed 10/10/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

- Freezer volume
- Retired refrigerator model number (Early Retirement only)
- Retired refrigerator annual energy usage (Early Retirement only)
- Age of retired refrigerator (Early Retirement only)
- Recommended: internal temperature(s) in retired refrigerator and, if present, freezer (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for refrigerators.

Document Revision History

Table 2-318: ENERGY STAR® Refrigerator Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as “Early Retirement” option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.
v3.0	4/10/2015	TRM v3.0 update. Early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team’s memo, “Considerations for early replacement of residential equipment.” Remaining useful lifetimes updated. LSAF updated to align with new peak demand methodology.
v3.1	11/05/2015	TRM v3.1 update. Correction to legacy LSAF. Revision to align with ENERGY STAR® calculator and specification.
v3.1	March 2016	TRM v3.1, March Revision. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated RUL value for units with the age of seven years and added RUL values for units with an age of one to five years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have an age of minimum five years.

2.6 RESIDENTIAL: APPLIANCE RECYCLING

2.6.1 Refrigerator/Freezer Recycling Measure Overview

TRM Measure ID: R-AP-RR

Market Sector: Residential

Measure Category: Appliance Recycling

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves early retirement and recycling of an existing, full-size (7.75 ft^3 or greater) refrigerator/freezer in a residential application. Savings represent the entire estimated energy consumption of the existing unit and are applicable over the estimated remaining life of the existing unit.

Eligibility Criteria

This measure applies to operable primary and secondary retired refrigerators/freezers. Recycling savings for this measure are limited to the removal of a working refrigerator/freezer from the electrical grid, and differ from the savings specified in the ENERGY STAR® Refrigerator replacement measure. The latter, which pertain to the direct replacement of a refrigerator and reflect the difference in energy consumption between new ENERGY STAR® qualifying and standard efficiency models, may be claimed for the recycling of primary refrigerators/freezers that have been replaced, provided that savings for that replacement were not already claimed in another energy efficiency program. To qualify, the customer must release the existing unit to the utility or utility representative in order to ensure proper disposal in accordance with applicable federal, state, and local regulations.

Baseline Condition

Without program intervention, the recycled refrigerator or freezer would have remained operable on the electrical grid. As a result, the baseline condition for early retirement programs is the status quo (continued operation) and the basis for estimating energy savings is the annual energy consumption of the refrigerator or freezer being retired (as specified in the “Energy and Demand Savings Methodology” section).

High-Efficiency Condition

There is no efficiency standard for a recycling measure because the energy efficient action is the removal of an operable appliance, not—as with most demand side management programs—the installation of a higher efficiency model.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

Energy savings are calculated as follows:

$$\begin{aligned} \boldsymbol{kWh_{savings}} &= \boldsymbol{kWh_{existing} \times ISAF \times PUF} \\ &= \mathbf{1,308 \times 0.942 \times 0.915} \\ &= \mathbf{1,128\ \boldsymbol{kWh}} \end{aligned}$$

Equation 125

Where:

$kWh_{existing}$ = *Average annual energy consumption*[274] *= 1,308 kWh*

$ISAF$ = *In Situ Adjustment Factor*[275] *= 0.942*

PUF = *Part Use Factor*[276] *= 0.915*

[274] The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report". Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Average of DOE-Based Full-Year Unit Energy Consumption (weighted by representative utility survey participation).

[275] Ibid. Factor to account for variation between site conditions and controlled DOE testing conditions (90 °F test chamber, empty refrigerator and freezer cabinets, and no door openings). Appliances in warmer climate zones use more energy than those in cooler climate zones; utilized SCE data (highest percentage of warm climate projects) to best approximate Texas climate, p. 139-140.

[276] Ibid. Factor to account for the number of refrigerators that were running, running part time, or not running at the time of recycling, p. 142-143 (weighted by representative utility survey participation, p. 117).

Demand Savings

Summer peak demand savings are calculated as follows:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times LSAF$$

Equation 126

Where:

AOH = *Annual Operating Hours = 8,760 hours*

$LSAF$ = *Load Shape Adjustment Factor (Table 2-319)*

Table 2-319: Load Shape Adjustment Factors[277]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Summer	1.112	1.099	1.108	1.100	1.081
Winter	0.929	0.966	0.924	0.941	0.966

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.

277 See Volume 1, Appendix B.

Measure Life and Lifetime Savings

Based on the KEMA Residential Refrigerator Recycling Ninth Year Retention Study,[278] the Estimated Useful Life of Refrigerator Recycling is 8 years, representing the assumed remaining useful life of the retired unit.

Program Tracking Data & 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:

- Number of refrigerators/freezers replaced
- Age of removed unit
- Size (in cubic feet)
- Configuration (top freezer, bottom freezer, side-by-side, or single-door)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 42212. Petition of El Paso Electric Company to Approve Revisions to the Deemed Savings for the Appliance Recycling Market Transformation program. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 2-320: Residential Refrigerator/Freezer Recycling Revision History

TRM Version	Date	Description of Change
v2.1	1/30/2015	TRM v2.1 origin
v3.0	4/10/2015	TRM v3.0 update. LSAF updated to align with new peak demand methodology.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v3.1	March 2016	Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. No revision.

[278] KEMA, Inc. "Residential Refrigerator Recycling Ninth Year Retention Study." Prepared for Southern California Edison Company. July 22, 2004.