- 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.

[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	310	749	29	12	1/1/2020
	750	1,049	43	20	1/1/2020
• T-shape lamps greater than 40 watts or a length of 10 inches or less	1,050	1,489	53	28	1/1/2020
• B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts	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	B_{ase}
• 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]

	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[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]

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

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

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.

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

Equation 19

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

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.

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

Equation 22

[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)

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[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:

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

Equation 23

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

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

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:

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

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.

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

Equation 26

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

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

Equation 27

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

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	B_{ase}
BR30 (65 W)	
BR40 (65 W)	65 W
ER40 (65 W)	
R20 (≤ 45 W)	45 W
BR30 (≤ 50 W)	
BR40 (≤ 50 watt)	50 W
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	
Indeterminate	60 W[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.

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[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	B_{ase}
• 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	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.**[97]

Table 2-31: DOE-Ruling Exempt Reflectors

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

[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]

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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]

	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[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]

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

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

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.

Heating/Cooling Type	$IEF_{D,winter}$				
	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.

[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:

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

Equation 38

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

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.

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

Equation 40

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

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."

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

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

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

Equation 43

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

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.

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[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

[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™ (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:

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

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

	Region				
Heating Type	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)

[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

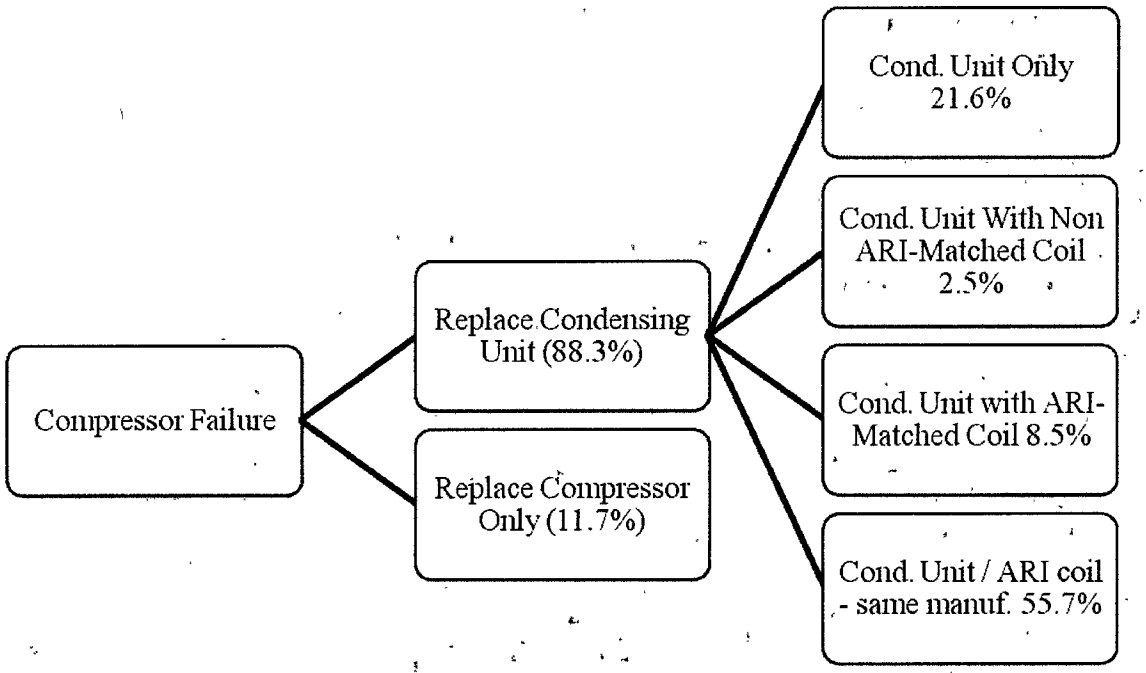
Coefficient	Single Stage	Multi-Stage/Speed	
		Low	High
a	3.670270705	3.940185508	3.109456535
b	-0.098652414	-0.104723455	-0.085520461
c	0.000955906	0.001019298	0.000863238
d	0.006552414	0.006471171	0.00863049
e	-0.0000156	-0.00000953	-0.000021
f	-0.000131877	-0.000161658	-0.000140186

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:

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

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.

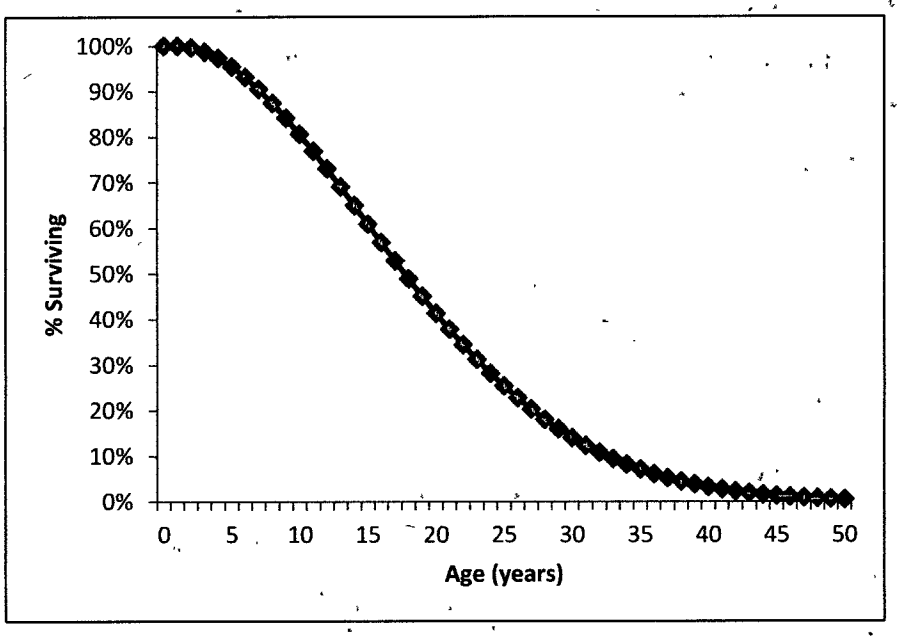


Figure 2-2: Survival Function for Central Air Conditioners[138]

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]

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

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:

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

Equation 57

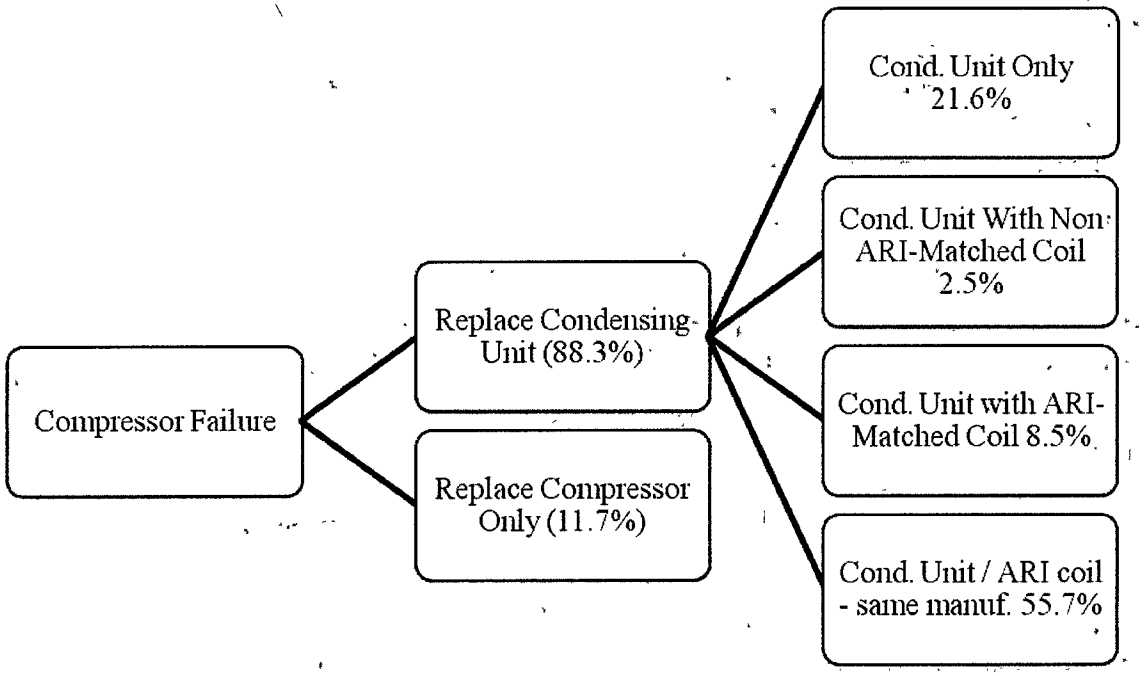
Table 2-92: Heat Pump Capacity Curve Coefficients

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:

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

Equation 58

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

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

Adjusting for the increased 14 SEER baseline:

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

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

Early Retirement

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

1. **The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and**

2. **The remaining time in the EUL period (15 – RUL)**

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

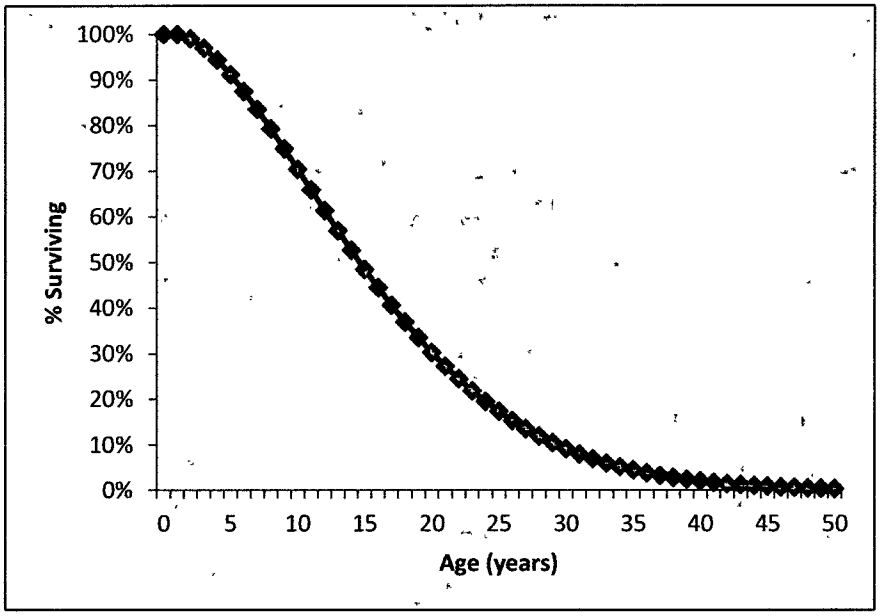


Figure 2-4: Survival Function for Central Heat Pumps[162]

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