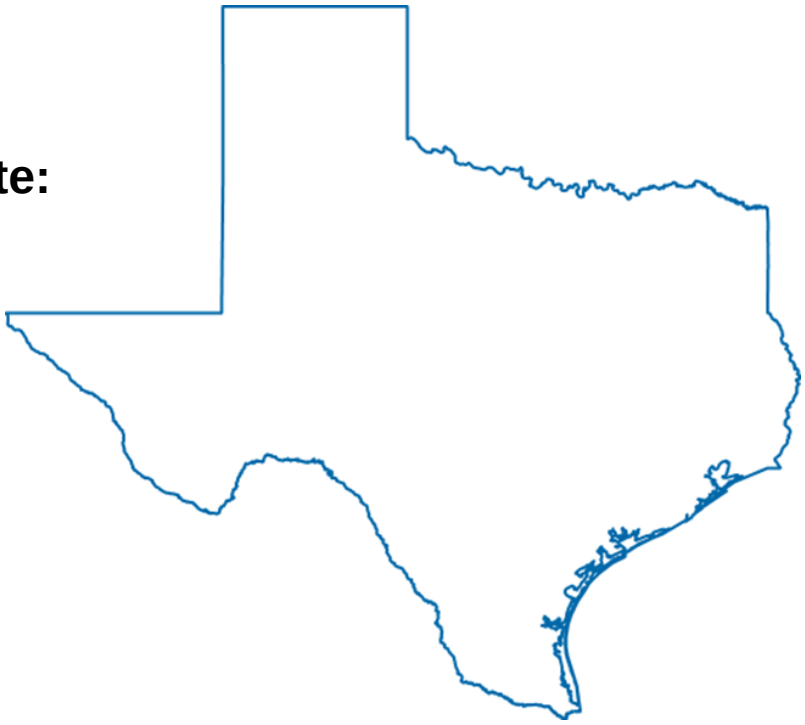
Public Utility Commission of Texas

Texas Technical Reference Manual

Version 2.1

Volume 2: Residential Measures

Guide for PY2015 Implementation



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Acknowledgments

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

This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Associates, ICF, CLEAResult and Nexant. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as consistent structure and level of information.

TRM Technical Support

Technical support and questions can be emailed to: TexasTRM@tetratech.com

1 INTRODUCTION

This volume of the TRM contains the deemed savings for residential measures that have been approved for use in Texas by the Public Utility Commission of Texas (PUCT). This volume includes instructions regarding various savings calculators and reference sources of the information. TRM 2.0 serves as a centralized source of deemed savings values. Where appropriate, Measurement & Verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1-1 provides an overview of the residential measures contained within this TRM 2.0 Volume 2 and the types of deemed savings estimates available for each one. There are five types of deemed savings estimates identified:

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

Table 1-1: Residential Deemed Savings by Measure Category

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	2.1 Update
Lighting	Compact Fluorescent Lamps	–	X	–	–	–	–
HVAC	Duct Efficiency Improvement	–	–	X	–	X	Addition of language referring contractors to program manuals for information regarding health and safety precautions.
	Central Air Conditioner	–	X	–	–	–	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.
	Ground Source Heat Pump	–	X	X	–	–	–
	Central Heat Pump	–	X	–	–	–	–
	Window Air Conditioner	–	–	X	–	–	–
Building Envelope	Air Infiltration	–	X	–	–	X	Addition of language referring contractors to program manuals for information regarding health and safety precautions.
	Ceiling Insulation	–	X	–	–	–	–
	Wall Insulation	–	X	–	–	–	–
	Floor Insulation	–	X	–	–	–	–
	ENERGY STAR® Windows	–	X	–	–	–	–
	Solar Screens	–	X	–	–	–	–
Domestic Water Heating	Faucet Aerators	–	–	X	–	–	–
	Low-Flow Showerheads	–	–	X	–	–	–

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calculator	M&V	2.1 Update
	Water Heater Pipe Insulation	–	–	X	–	–	–
	Water Heater Tank Insulation	–	–	X	–	–	–
	Water Heater Installation – Electric Tankless and Fuel Substitution	–	–	X	–	–	New construction permitted to claim savings subject to documentation requirements. Gas-fueled tankless water heaters made eligible for installation.
	Heat Pump Water Heater	–	X	–	–	–	–
	Water Heater Replacement– Solar Water Heating	–	X	–	–	–	–
Appliances	ENERGY STAR® Ceiling Fans	X	–	–	–	–	–
	ENERGY STAR® Clothes Washer	X	–	–	–	–	New ENERGY STAR standards incorporated.
	ENERGY STAR® Dishwasher	X	–	–	–	–	–
	ENERGY STAR® Refrigerator	–	–	X	–	–	New ENERGY STAR standards incorporated.
Whole House	New Homes	–	–	X	–	X	–
Renewable Energy Systems	Solar Photovoltaic (PV)	–	–	X	X	X	–
Load Management	Direct Load Control of Outdoor Compressor Units	X	–	–	–	–	–
	Direct Load Control of Swimming Pool Pump Motors	X	–	–	–	–	–
Appliance Recycling	Refrigerator/ Freezer Recycling	X	–	X	–	–	TRM v2.1 origin.

2 RESIDENTIAL MEASURES

2.1 RESIDENTIAL: LIGHTING

2.1.1 Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-CF

Market Sector: Residential

Measure Category: Lighting

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves the replacement of standard incandescent or halogen lamps with compact fluorescent lamps (CFLs). Deemed savings are calculated based on an average daily usage of 2.2 hours per day.

Eligibility Criteria

Eligibility to be awarded these deemed savings for installing CFLs varies based on the utility, program, and customer type. See program-specific manuals to determine customer eligibility.

Baseline Condition

Standard incandescent or halogen lamps are the baseline. As the Energy Independence and Security Act (EISA) of 2007 phases out the old standard allowed wattages of incandescent lamps, the new maximum wattages – which generally reflect standard wattages for halogen lamps – will become the baseline.

Table 2-1: EISA 2007 Revised Baselines

New Maximum Wattage	Old Standard Incandescent Wattage	Rated Lumens	Effective Date
29	40	310–749	1/1/2014
43	60	750 - 1049	1/1/2014
53	75	1050 - 1489	1/1/2013
72	100	1490 - 2600	1/1/2012

High-Efficiency Condition

In order to qualify for an incentive, the installed CFL must be an ENERGY STAR® -approved CFL.

The ENERGY STAR® CFL specification includes:

- Starting time of approximately one second
- Efficiency level for lamps of 15 watts or more is 60 lumens/watt
- Efficiency level for lamps of less than 15 watts is 45 lumens/watt

The fixture wattage rating dictates the maximum CFL wattage installed. If there is no fixture wattage rating shown on the fixture, the fixture wattage shall be assumed to be 43 watts. For example, when replacing an incandescent lamp in a fixture rated for 43W, the wattage of the CFL installed must be less than 16W as seen in Table 2-4 through Table 2-6.

“Hollywood-style” incandescent fixtures with four or more lamps may not be retrofitted with screw-in CFLs. These fixtures may be retrofitted with hard-wired fluorescent fixtures only. The addition of a disk device to a screw-in CFL to prevent its removal does not qualify it as a hard-wired fixture.

Energy and Demand Savings Methodology

The methodologies outlined below were used to derive the deemed energy and demand savings identified in Table 2-4through Table 2-6. Savings should be awarded according to the values outlined in these tables.

Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a standard baseline lamp, as defined by EISA 2007 (see Table 2-1), and the wattage of a comparable CFL. A comparable CFL wattage range is identified by lumen output, as defined by EISA 2007. Within this wattage range, a typical CFL wattage was established for each range based on market availability.

Energy savings are calculated based on an average daily usage of 2.2 hours per day,[1] resulting in an approximate annual usage of 803 hours. They are calculated as follows:

[1] Evaluation of 2008 Texas ‘Make Your Mark’ Statewide CFL Program Report. Frontier Associates. June 2009.

$$\Delta kWh = \frac{\left(Wattage_{Comparable\ Incandescent\ Light} - Wattage_{Measure\ CFL}\right)}{1000} \times 803 hours$$

Equation 1

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. These coincidence factors were determined by analyzing hourly data[2] to determine the percentage of time that CFLs were on during peak hours, resulting in a summer coincidence factor of 0.08 and a winter coincidence factor of 0.11 (see Table 2-2 and Table 2-3). The demand savings are calculated as follows:

$$\Delta kW = \frac{\left(Wattage_{Comparable\ Incandescent\ Light} - Wattage_{Measure\ CFL}\right)}{1000} \times Peak\ Demand\ Coincidence$$

Equation 2

Table 2-2: CFL – Summer Demand Coincidence Factor Month and Hour

Hour	June	July	Aug	Sept	Average
13	0.066	0.066	0.068	0.070	*0.07*
14	0.070	0.070	0.071	0.072	*0.07*
15	0.071	0.071	0.072	0.074	*0.07*
16	0.067	0.068	0.070	0.073	*0.07*
17	0.063	0.064	0.068	0.074	*0.07*
18	0.074	0.075	0.079	0.086	*0.08*
19	0.090	0.091	0.096	0.104	*0.10*
			TOTAL AVERAGE		***0.08***

Table 2-3: CFL – Winter Demand Coincidence Factor by Month and Hour

Hour	Dec	Jan	Feb	Average
6	0.073	0.073	0.072	*0.07*
7	0.077	0.077	0.076	*0.08*
8	0.081	0.081	0.078	*0.08*
9	0.08	0.079	0.077	*0.08*
18	0.1	0.099	0.094	*0.10*
19	0.12	0.119	0.114	*0.12*
20	0.156	0.154	0.147	*0.15*
21	0.188	0.187	0.182	*0.19*
		TOTAL AVERAGE		***0.11***

[2] DEER 2011 Update Documentation: "Support documents for the above summary of content, methods and parameters document." (updated May 16, 2012). http://www.deeresources.com/.

Deemed Energy Savings Tables

Table 2-4: CFL Energy Savings

Measure CFL (Watt)	Measure CFL (Range of Watts)	Comparable Incandescent Light (Watt)	Lumen Output	Daily Usage (Hrs/Day)	Annual Energy Savings (kWh)
11	9-11	29	310–749	2.2	14.5
13	12-16	43	750–1049	2.2	24.1
20	17-21	53	1050–1489	2.2	26.5
23	22-27	72	1490–2600	2.2	39.3

Deemed Summer Demand Savings Tables

Table 2-5: CFL Summer Peak Demand Savings

Measure CFL (Watt)	Measure CFL (Range of Watts)	Comparable Incandescent Light (Watt)	Lumen Output	Daily Usage (Hrs/Day)	Demand Savings (kW)
11	9-11	29	310–749	2.2	0.001
13	12-16	43	750–1049	2.2	0.002
20	17-21	53	1050–1489	2.2	0.003
23	22-27	72	1490–2600	2.2	0.004

Deemed Winter Demand Savings Tables

Table 2-6: CFL Winter Peak Demand Savings

Measure CFL (Watt)	Measure CFL (Range of Watts)	Comparable Incandescent Light (Watt)	Lumen Output	Daily Usage (Hrs/Day)	Demand Savings (kW)
11	9-11	29	310–749	2.2	0.002
13	12-16	43	750–1049	2.2	0.003
20	17-21	53	1050–1489	2.2	0.004
23	22-27	72	1490–2600	2.2	0.005

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of an indoor screw-in CFL is established at 7.7 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER)[3], under the assumption of an 8,000-hour manufacturer rated life.

Program Tracking Data & Evaluation Requirements

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

- Number of CFLs installed
- Wattage of each installed CFL

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

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

[3] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

Document Revision History

Table 2-7: Residential Compact Fluorescent Lamp Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor corrections due to phase-in of EISA regulations, updated EUL from DEER 2014. Legacy EISA tables removed.

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

2.2.1 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 Estimates

Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems of homes or converted residences with either central air conditioning or a ducted heating system. Eligibility Criteria

All residential customers with refrigerated air cooling are eligible for this measure.

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.[4]

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

Duct sealing is a residential retrofit measure.

[4] 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."*

Table 2-8: Duct Sealing – Applicability

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

Baseline Condition

For residential and hard-to-reach standard offer programs, the savings calculation methods for this measure are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[5] 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.[6]

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[7] 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 Excellence (NATE)

[5] $Total\ Fan\ Flow = Cooling\ Capacity\ (tons) \times 400$

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

[7] 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).

certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[8]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Cooling Energy Savings (Electric)

$$kWh_{savings,C} = \frac{(DL_{pre} - DL_{post}) \times EFLH_C \times (h_{out}\rho_{out} - h_{in}\rho_{in}) \times 60}{1,000 \times SEER}$$

Equation 3

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)*

$EFLH_C$ = *Equivalent full load cooling hours (Table 2-9)*[9]

h = *Outdoor/Indoor seasonal specific enthalpy (Table 2-10) (Btu/lb)*[10]

ρ_{out} = *Density of outdoor air (Table 2-11) (lb/cu. ft.)*[11]

Table 2-9: Equivalent Full Load Cooling Hours

Climate Zone	$EFLH_C$
Climate Zone 1: Panhandle	1,142
Climate Zone 2: North	1,926
Climate Zone 3: South	2,209
Climate Zone 4: Valley	2,958
Climate Zone 5: West	1,524

Table 2-10: Seasonal Specific Enthalpy (Btu/lb)

Climate Zone	h_{out}	h_{in}
Climate Zone 1: Panhandle	32	28
Climate Zone 2: North	36	29
Climate Zone 3: South	37	30
Climate Zone 4: Valley	39	31
Climate Zone 5: West	29	26

[8] 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.

[9] ENERGY STAR Central A/C Savings Calculator http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CA .

[10] ANSI/ASHRAE Standard 152-2004, Table 6.3b.

[11] ASHRAE Fundamentals 2009, Chapter 1: Psychometrics, Equation 11, Equation 41, Table 2.

Table 2-11: Density of Outdoor Air (lb/cu. ft.)

Climate Zone	Temp. (°F)[12]	ρ_{out}
Climate Zone 1: Panhandle	95	0.0740
Climate Zone 2: North	99	0.0738
Climate Zone 3: South	94	0.0741
Climate Zone 4: Valley	94	0.0741
Climate Zone 5: West	98	0.0738

ρ_{in} = *Density of conditioned air at 75°F (lb/cu. ft.) = 0.0756 (default)*[13]

60 = *Constant to convert from minutes to hours*

1,000 = *Constant to convert from W to kW*

SEER = *Seasonal Energy Efficiency Ratio of existing system (Btu/W·hr) = 13 (default)*[14]

Heating Energy Savings (Heat Pump)

$$kWh_{savings,H} = \frac{(DL_{pre} - DL_{post}) \times 60 \times 0.77 \times HDD \times 24 \times 0.018}{1,000 \times HSPF}$$

Equation 4

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)*

60 = *Constant to convert from minutes to hours*

0.77 = *Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[15]

HDD = *Heating degree days (Table 2-12)*[16]

[12] Manual J, Volume 7, Table 1.
[13] ASHRAE Fundamentals 2009, Chapter 1: Psychometrics, Equation 11, Equation 41, Table 2.
[14] The DOE minimum allowed SEER for new air conditioners after January 23, 2006 and before January 1, 2015 is 13.0 SEER. While minimum air conditioner efficiency standards increase in 2015, the previous standard is used here to reflect typical efficiency of installed units.
[15] Manual J, Volume 7: Appendix A-4.
[16] National Climatic Data Center: http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.html.

Table 2-12: Heating Degree Days

Climate Zone	HDD
Climate Zone 1: Panhandle	4,318
Climate Zone 2: North	2,370
Climate Zone 3: South	1,525
Climate Zone 4: Valley	950
Climate Zone 5: West	2,543

24 = *Constant to convert from days to hours*

0.018 = *Volumetric heat capacity of air (Btu/cu. ft.°F)*

1,000 = *Constant to convert from W to kW*

HSPF = *Heating Seasonal Performance Factor of existing system (Btu/W·hr)*

= *7.7 (default)*[17]

Heating Energy Savings (Electric Resistance)

$$kWh_{savings,H} = \frac{(DL_{pre} - DL_{post}) \times 60 \times 0.77 \times HDD \times 24 \times 0.018}{3,412}$$

Equation 5

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)*

60 = *Constant to convert from minutes to hours*

0.77 = *Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[18]

HDD = *Heating degree days (Table 2-12)*[19]

24 = *Constant to convert from days to hours*

0.018 = *Volumetric heat capacity of air (Btu/cu. ft.°F)*

3,412 = *Constant to convert from Btu to kWh*

[17] The DOE minimum allowed HSPF for new heat pumps after January 23, 2006 and before January 1, 2015 is 7.7 HSPF. While minimum heat pump efficiency standards increase in 2015, the previous standard is used here to reflect typical efficiency of installed units.

[18] Manual J, Volume 7: Appendix A-4.

[19] National Climatic Data Center: http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.html.

Cooling Demand Savings (Electric)

$$kW_{savings,C} = \frac{kWh_{savings,C}}{EFLH_C} \times 1.163 \times CF$$

Equation 6

Where:

$\mathrm{kWh}_{\mathrm{savings,C}}$	=	*Calculated kWh savings for cooling*
$\mathrm{EFLH}_{\mathrm{C}}$	=	*Equivalent full load cooling hours[20] (Table 2-9)*
1.163	=	*Constant to convert efficiency from SEER to EER[21]*
CF	=	*Coincidence factor[22] = 0.87*

Heating Demand Savings (Electric Resistance and Heat Pump)

$$kW_{savings,H} = \frac{kWh_{savings,H}}{0.77 \times HDD \times 24} \times CF$$

Equation 7

Where:

$\mathrm{kWh}_{\mathrm{savings,H}}$	=	*Calculated kWh savings for heating*
0.77	=	*Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)[23]*
HDD	=	*Heating degree days (Table 2-12)[24]*
24	=	*Constant to convert from days to hours*
CF	=	*Coincidence factor = 0.83 (heat pumps, default)[25]*
	=	*1.00 (electric resistance, default)[26]*

[20] ENERGY STAR® Central A/C Savings Calculator http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CA.

[21] Department of Energy: Building America House Simulation Protocols, p.7 (revised October 2010). Approximation: $EER = 1.12 \times SEER - 0.02 \times SEER^2$

[22] 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.

[23] Manual J, Volume 7: Appendix A-4.

[24] National Climatic Data Center: http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.html.

[25] 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 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

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).[27]

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

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[26] Standard assumption.

[27] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-13: 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.

2.2.2 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 (Low-Income Customers[28] Only)

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.

[28] 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).

This measure uses baseline and efficient conditions corresponding with federal standards effective January 1, 2015,[29] but excludes the Department of Energy's enhanced regional standards for Texas. A settlement with the American Public Gas Association permits distributors and retailers to sell central air conditioners that do not meet regional standards without penalty until July 1, 2016. [30]

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.

Only participants of low-income programs[28] are eligible for early retirement deemed savings associated with installation of a new central air conditioning system. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal. For the early retirement of a central air conditioning system other than through a low-income program, replace-on-burnout savings may be awarded.

Baseline Condition

New construction baseline efficiency values for air conditioners are compliant with the current federal standard,[31] effective January 1, 2015, which requires a minimum AHRI-listed Seasonal Energy Efficiency Ratio (SEER) rating of 13.0 for split-system air conditioning units.

For replace-on-burnout installations, the baseline is assumed to be 12.44 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 condensing unit and evaporator coil.

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER.

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

[30] "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.

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

Table 2-14: Central Air Conditioner Baseline Efficiencies

Project Type	Cooling Mode[32]
New Construction	13.00 SEER
Replace-on-Burnout	12.44 SEER
Early Retirement	10.00 SEER

High-Efficiency Condition

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.

The central air conditioning equipment must meet the following standard:

- Minimum AHRI-listed SEER rating of 14.00
- Minimum AHRI-listed Energy Efficiency Rating (EER) of 11.5

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction and Replace-on-Burnout

In reviewing data on the relationship between efficiency and outdoor air temperature, the Frontier research team concluded that actual unit performance data, if it could be obtained from the major manufacturers, should be used to develop performance curves for units in each of the following SEER ranges:

- 13.0 – 13.9
- 14.0 – 14.9
- 15.0 – 15.9
- 16.0 – 16.9
- 17.0 – 17.9
- 18 and above

[32] 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.

Performance data for residential heat pumps and air conditioners was requested from each of the four largest manufacturers, Carrier, Goodman/Amana, Lennox, and American Standard/Trane. Collectively these manufacturers account for a 71% national market share. Each of the manufacturers provided performance data, allowing the research team to develop performance curves for each size and SEER range. For some individual units in certain higher SEER ranges, performance data was interpolated from other sizes in that same SEER range. This was necessary because the manufacturers do not produce units in all SEER ranges and capacities. For example, some higher-SEER units may not be available in 1.5, 2.5, 3.5 or 5-ton sizes.

The availability of this data allowed the research team to directly assess the performance of typical units currently being installed in Texas residences. By using actual performance data in conjunction with hourly weather conditions in each of the four weather zones, the research team avoided the need to weather-adjust SEER and EER values, and provided a potentially more accurate estimate of annual cooling energy use. This approach also allowed the research team to incorporate the cyclic degradation factor into the seasonal energy use calculation.

For the air conditioner deemed savings, unit performance data was selected for units in each of the seven sizes and six SEER ranges, for a total of forty-two product types. For each of the product types in the 13 and 14 SEER ranges, data was available from at least three manufacturers. One manufacturer supplied product data for selected condenser/coil combinations in each product line. The others provided data on all their residential products. In selecting an appropriate condenser/coil combination, the research team generally used the following criteria:

1. *SEER value at or near low end of the SEER range, e.g., 14.00*
2. *All units had to have a minimum 11.5 EER*
3. *The specific condenser/coil combination that was tested by the manufacturer*
4. *Highest sales volume combination*

In some cases, the research team selected a condenser/coil combination that didn't meet the above criteria, typically if required to find a sufficient number of units with a particular SEER value to produce a robust analysis. Selecting units with SEER values at or near the low end of the SEER range addresses the concern raised by the auditors about using the mid-point of the SEER range rather, than the median SEER value of all units within this range.

The performance data is not reported in a consistent manner by all manufacturers. For example, some manufacturers don't report performance data for 65 degree ambient. In these cases, performance data was extrapolated.

The data from each manufacturer was weighted based on national market share information. Weighted average performance curves were thus developed for each of the forty-two product types.

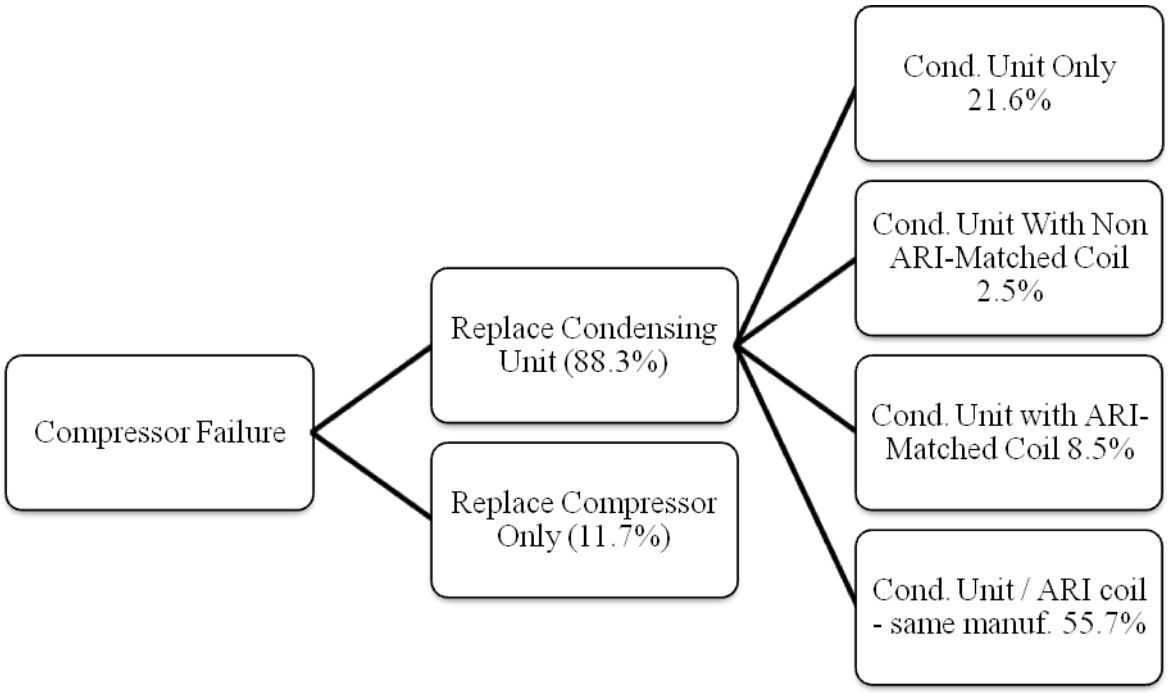
Using the unit performance data compiled as outlined above, the kW demand and Btuh capacity of the units was calculated at each temperature point between 65 and 115 degrees ambient. An oversize factor of 115% was assumed, as was a cyclic degradation factor 0.25 (ASHRAE default value). Separate calculation models were developed for single-speed and two-speed units. For peak demand, the average peak hour kW value corresponding to the 99% design temperature for the representative cities in each of the four weather zones was calculated. For the units in the 14.5 SEER category, data was interpolated from the 14 SEER and 15 SEER units. This separate category was developed for central air conditioners and heat pumps so utilities running programs

that require ENERGY STAR® qualified units can accurately determine savings once the ENERGY STAR® specification goes to 14.5 SEER in 2009.

To determine annual cooling energy consumption, hourly weather data for each of the four weather zones was used. The performance of the unit at the midpoint of each temperature bin (e.g. 77.5 degrees for the 75-80 degree bin) was determined. Using manufacturer values for input kW and capacity, coupled with cooling load, and number of hours in each of the temperature bins, we produced the seasonal performance of each of the forty-two product types. Comparison with the performance of the baseline unit in each size range provided estimates of peak demand reduction and annual cooling energy savings.

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:

Figure 2-1: Unit Replacement Percentages upon Compressor Failure



Source: Docket No. 36780

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

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

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

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

In new construction, there is no possibility of a partial system (e.g. condensing unit-only) changeout, so the 12.44 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government's minimum efficiency standard of 13 SEER.

Climate Zone. These deemed savings values were developed using data from a study of performance at different ambient temperatures across a range of HVAC manufacturers. To calculate energy savings, performance data were weighted by the number of hours at each temperature point; to calculate demand savings performance data at the ASHRAE design temperature was used, as in Project No. 27647.[33]

Early Retirement

In order to calculate the energy (kWh) and demand (kW) savings associated with the installation of a new central air conditioning system in a home through a low-income program, the savings must be weighted by the age of the unit to be replaced.

The following equations may be used to calculate the deemed energy and demand savings awarded to a newly-installed central air conditioner:

[33] Energy Efficiency Program Implementation Docket, P.U.C. SUBST R. §25.181 (n) Energy Implementation Project, Project No. 27647.

$$\textbf{Annual kWh Savings} = \left(\frac{\textbf{AC Age}}{\textbf{AC Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kWh Savings}_{\textbf{Replace on Burnout}} + \left(\frac{\textbf{Remaining Useful Life}}{\textbf{AC Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kWh Savings}_{\textbf{Early Retirement}}$$

Equation 8

$$\textbf{Annual kW Savings} = \left(\frac{\textbf{AC Age}}{\textbf{AC Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kW Savings}_{\textbf{Replace on Burnout}} + \left(\frac{\textbf{Remaining Useful Life}}{\textbf{AC Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kW Savings}_{\textbf{Early Retirement}}$$

Equation 9

Remaining useful life is dependent upon the age of the replaced central air conditioner. The remaining useful life can be found in Table 2-15.

Table 2-15: Remaining Useful Life of Replaced Unit

Age of Replaced Unit	Remaining Useful Life	Age of Replaced Unit	Remaining Useful Life
1	18	13	7..5
2	17	14	7
3	16	15	5.5
4	15	16	5
5	14	17	4.5
6	13	18	3.5
7	12	19	3
8	11.5	20	2.5
9	10.5	21	1.5
10	9	22	1.5
11	8.5	23	1
12	8	24	0

Deemed Energy Savings Tables

Table 2-16 through Table 2-20 present the energy savings (kWh) associated with central air conditioners installed in new homes. Table 2-21 through Table 2-25 present energy savings associated with replace-on-burnout of central air conditioners. Table 2-26 through Table 2-30 present energy savings associated with early retirement of central air conditioners.

New Construction

Table 2-16 through Table 2-20 present the energy savings (kWh) associated with central air conditioners installed in new homes (13 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-16: Energy Savings (kWh) for 13.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	218	301	384	456	615	657
2.0	291	401	512	608	820	875
2.5	364	502	639	760	1,025	1,094
3.0	437	602	767	913	1,230	1,313
3.5	510	702	895	1,065	1,434	1,532
4.0	582	803	1,023	1,217	1,639	1,751
5.0	728	1,003	1,279	1,521	2,049	2,188

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

Table 2-17: Energy Savings (kWh) for 13.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	319	441	562	667	910	968
2.0	426	587	749	889	1,214	1,291
2.5	532	734	936	1,111	1,517	1,613
3.0	639	881	1,124	1,334	1,821	1,936
3.5	745	1,028	1,311	1,556	2,124	2,259
4.0	852	1,175	1,498	1,778	2,427	2,581
5.0	1,065	1,469	1,873	2,223	3,034	3,227

Climate Zone 3: South Region, Houston Weather Data

Table 2-18: Energy Savings (kWh) for 13.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	361	506	650	758	1,042	1,118
2.0	481	674	867	1,011	1,389	1,490
2.5	601	843	1,084	1,264	1,737	1,863
3.0	722	1,011	1,301	1,517	2,084	2,235
3.5	842	1,180	1,518	1,770	2,431	2,608
4.0	962	1,348	1,734	2,023	2,778	2,980
5.0	1,203	1,685	2,168	2,528	3,473	3,725

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-19: Energy Savings (kWh) for 13.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	426	596	766	896	1,234	1,321
2.0	568	795	1,021	1,195	1,645	1,761
2.5	710	993	1,277	1,494	2,056	2,202
3.0	852	1,192	1,532	1,793	2,468	2,642
3.5	994	1,391	1,787	2,092	2,879	3,082
4.0	1,136	1,589	2,043	2,390	3,290	3,522
5.0	1,420	1,987	2,553	2,988	4,113	4,403

Climate Zone 5: West Region El Paso Weather Data

Table 2-20: Energy Savings (kWh) for 13.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	268	373	477	559	769	820
2.0	357	497	636	745	1,025	1,094
2.5	447	621	795	931	1,281	1,367
3.0	536	745	954	1,118	1,538	1,641
3.5	625	869	1,114	1,304	1,794	1,914
4.0	714	994	1,273	1,490	2,050	2,187
5.0	893	1,242	1,591	1,863	2,563	2,734

Replace-on-Burnout

Table 2-21 through Table 2-25 present the energy savings (kWh) associated with central air conditioners installed in replace-on-burnout homes (12.44 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-21: Energy Savings (kWh) for 12.44 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	323	405	488	560	719	761
2.0	430	540	650	747	959	1,014
2.5	538	675	813	934	1,198	1,268
3.0	645	810	976	1,121	1,438	1,521
3.5	753	945	1,138	1,308	1,677	1,775
4.0	860	1,081	1,301	1,494	1,917	2,029
5.0	1,075	1,351	1,626	1,868	2,396	2,536

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

Table 2-22: Energy Savings (kWh) for 12.44 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	472	594	715	820	1,063	1,121
2.0	630	791	953	1,093	1,418	1,495
2.5	787	989	1,191	1,366	1,772	1,868
3.0	945	1,187	1,430	1,640	2,126	2,242
3.5	1,102	1,385	1,668	1,913	2,481	2,616
4.0	1,259	1,583	1,906	2,186	2,835	2,989
5.0	1,574	1,978	2,383	2,733	3,544	3,736

Climate Zone 3: South Region, Houston Weather Data

Table 2-23: Energy Savings (kWh) for 12.44 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	522	667	811	919	1,203	1,278
2.0	696	889	1,082	1,226	1,604	1,705
2.5	870	1,111	1,352	1,532	2,005	2,131
3.0	1,043	1,333	1,623	1,839	2,406	2,557
3.5	1,217	1,555	1,893	2,145	2,807	2,983
4.0	1,391	1,777	2,163	2,452	3,208	3,409
5.0	1,739	2,222	2,704	3,065	4,009	4,261

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-24: Energy Savings (kWh) for 12.44 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	618	788	958	1,089	1,426	1,513
2.0	824	1,051	1,277	1,451	1,901	2,017
2.5	1,030	1,313	1,597	1,814	2,377	2,522
3.0	1,236	1,576	1,916	2,177	2,852	3,026
3.5	1,442	1,839	2,236	2,540	3,327	3,530
4.0	1,648	2,102	2,555	2,903	3,803	4,035
5.0	2,060	2,627	3,194	3,628	4,753	5,043

Climate Zone 5: West Region El Paso Weather Data

Table 2-25: Energy Savings (kWh) for 12.44 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	391	495	600	682	891	943
2.0	521	660	800	909	1,189	1,257
2.5	651	826	1,000	1,136	1,486	1,572
3.0	781	991	1,200	1,363	1,783	1,886
3.5	912	1,156	1,400	1,590	2,080	2,200
4.0	1,042	1,321	1,600	1,818	2,377	2,515
5.0	1,302	1,651	2,000	2,272	2,972	3,143

Early Retirement

Table 2-26 through Table 2-30 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 in Equation 8 with the replace-on-burnout energy savings in Table 2-21 through Table 2-25 to calculate annual savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-26: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	913	1,150
2.0	1,217	1,534
2.5	1,521	1,917
3.0	1,825	2,301
3.5	2,129	2,684
4.0	2,434	3,068
5.0	3,042	3,835

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

Table 2-27: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	1,339	1,686
2.0	1,785	2,248
2.5	2,231	2,810
3.0	2,677	3,372
3.5	3,123	3,934
4.0	3,570	4,496
5.0	4,462	5,620

Climate Zone 3: South Region, Houston Weather Data

Table 2-28: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	1,433	1,831
2.0	1,911	2,441
2.5	2,389	3,052
3.0	2,867	3,662
3.5	3,344	4,272
4.0	3,822	4,883
5.0	4,778	6,103

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-29: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	1,706	2,177
2.0	2,275	2,902
2.5	2,844	3,628
3.0	3,412	4,353
3.5	3,981	5,079
4.0	4,550	5,804
5.0	5,687	7,255

Climate Zone 5: West Region El Paso Weather Data

Table 2-30: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 5*

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	1,339	1,686
2.0	1,785	2,248
2.5	2,231	2,810
3.0	2,677	3,372
3.5	3,123	3,934
4.0	3,570	4,496
5.0	4,462	5,620
* Early retirement savings are not available for Climate Zone 5. Savings for Climate Zone 2 are used instead.		

Deemed Summer Demand Savings Tables

New Construction

Table 2-31 through Table 2-35 present the summer demand savings (kW) associated with central air conditioners installed in new homes (13.0 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-31: Demand Savings (kW) for 13.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.13	0.15	0.18	0.23	0.30	0.31
2.0	0.17	0.21	0.24	0.31	0.41	0.42
2.5	0.21	0.26	0.30	0.39	0.51	0.52
3.0	0.25	0.31	0.36	0.46	0.61	0.63
3.5	0.30	0.36	0.42	0.54	0.71	0.73
4.0	0.34	0.41	0.48	0.62	0.81	0.83
5.0	0.42	0.51	0.60	0.77	1.01	1.04

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

Table 2-32: Demand Savings (kW) for 13.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.12	0.14	0.17	0.23	0.28	0.28
2.0	0.16	0.19	0.22	0.30	0.37	0.37
2.5	0.20	0.24	0.28	0.38	0.46	0.47
3.0	0.24	0.28	0.33	0.45	0.55	0.56
3.5	0.28	0.33	0.39	0.53	0.64	0.65
4.0	0.32	0.38	0.44	0.60	0.73	0.75
5.0	0.39	0.47	0.55	0.75	0.92	0.93

Climate Zone 3: South Region, Houston Weather Data

Table 2-33: Demand Savings (kW) for 13.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.13	0.15	0.17	0.23	0.29	0.30
2.0	0.17	0.20	0.23	0.30	0.39	0.41
2.5	0.21	0.25	0.29	0.38	0.49	0.51

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
3.0	0.25	0.30	0.35	0.46	0.58	0.61
3.5	0.30	0.35	0.41	0.53	0.68	0.71
4.0	0.34	0.40	0.46	0.61	0.78	0.81
5.0	0.42	0.50	0.58	0.76	0.97	1.02

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-34: Demand Savings (kW) for 13.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.13	0.15	0.18	0.23	0.30	0.31
2.0	0.17	0.20	0.24	0.31	0.40	0.41
2.5	0.21	0.25	0.30	0.38	0.50	0.52
3.0	0.25	0.30	0.36	0.46	0.60	0.62
3.5	0.30	0.36	0.42	0.54	0.70	0.72
4.0	0.34	0.41	0.47	0.61	0.80	0.82
5.0	0.42	0.51	0.59	0.77	1.00	1.03

Climate Zone 5: West Region El Paso Weather Data

Table 2-35: Demand Savings (kW) for 14.0 SEER New Construction Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.12	0.14	0.17	0.23	0.28	0.28
2.0	0.16	0.19	0.22	0.30	0.37	0.37
2.5	0.20	0.24	0.28	0.38	0.46	0.47
3.0	0.24	0.28	0.33	0.45	0.55	0.56
3.5	0.28	0.33	0.39	0.53	0.64	0.65
4.0	0.32	0.38	0.44	0.60	0.73	0.75
5.0	0.39	0.47	0.55	0.75	0.92	0.93

Replace-on-Burnout

Table 2-36 through Table 2-40 present the summer demand savings (kW) associated with central air conditioners installed in replace-on-burnout homes (12.44 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-36: Demand Savings (kW) for 12.44 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.19	0.22	0.25	0.30	0.37	0.38
2.0	0.26	0.29	0.33	0.40	0.49	0.51
2.5	0.32	0.37	0.41	0.50	0.62	0.63
3.0	0.38	0.44	0.49	0.60	0.74	0.76
3.5	0.45	0.51	0.58	0.70	0.86	0.88
4.0	0.51	0.59	0.66	0.79	0.99	1.01
5.0	0.64	0.73	0.82	0.99	1.23	1.26

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

Table 2-37: Demand Savings (kW) for 12.44 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.19	0.21	0.24	0.30	0.34	0.35
2.0	0.25	0.28	0.31	0.39	0.46	0.47
2.5	0.31	0.35	0.39	0.49	0.57	0.58
3.0	0.38	0.42	0.47	0.59	0.69	0.70
3.5	0.44	0.49	0.55	0.69	0.80	0.82
4.0	0.50	0.56	0.63	0.79	0.92	0.93
5.0	0.63	0.70	0.78	0.98	1.15	1.17

Climate Zone 3: South Region, Houston Weather Data

Table 2-38: Demand Savings (kW) for 12.44 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.19	0.22	0.24	0.29	0.36	0.37
2.0	0.26	0.29	0.32	0.39	0.48	0.50
2.5	0.32	0.36	0.40	0.49	0.60	0.62
3.0	0.39	0.44	0.48	0.59	0.72	0.74
3.5	0.45	0.51	0.56	0.69	0.84	0.87
4.0	0.52	0.58	0.64	0.79	0.96	0.99
5.0	0.65	0.73	0.80	0.98	1.20	1.24

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-39: Demand Savings (kW) for 12.44 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.19	0.22	0.24	0.30	0.37	0.38
2.0	0.26	0.29	0.33	0.40	0.49	0.50
2.5	0.32	0.36	0.41	0.49	0.61	0.63
3.0	0.39	0.44	0.49	0.59	0.73	0.75
3.5	0.45	0.51	0.57	0.69	0.85	0.88
4.0	0.52	0.58	0.65	0.79	0.97	1.00
5.0	0.64	0.73	0.82	0.99	1.22	1.25

Climate Zone 5: West Region El Paso Weather Data

Table 2-40: Demand Savings (kW) for 12.44 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.0–14.4	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18+
1.5	0.19	0.21	0.24	0.30	0.34	0.35
2.0	0.25	0.28	0.31	0.39	0.46	0.47
2.5	0.31	0.35	0.39	0.49	0.57	0.58
3.0	0.38	0.42	0.47	0.59	0.69	0.70
3.5	0.44	0.49	0.55	0.69	0.80	0.82
4.0	0.50	0.56	0.63	0.79	0.92	0.93
5.0	0.63	0.70	0.78	0.98	1.15	1.17

Early Retirement

Table 2-41 through Table 2-45 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 in Equation 9 with the replace-on-burnout energy savings in Table 2-36 through Table 2-40 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-41: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	0.19	0.30
2.0	0.26	0.40
2.5	0.32	0.50
3.0	0.38	0.60
3.5	0.45	0.70
4.0	0.51	0.79
5.0	0.64	0.99

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

Table 2-42: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	0.19	0.30
2.0	0.25	0.39
2.5	0.31	0.49
3.0	0.38	0.59
3.5	0.44	0.69
4.0	0.50	0.79
5.0	0.63	0.98

Climate Zone 3: South Region, Houston Weather Data

Table 2-43: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	0.19	0.29
2.0	0.26	0.39
2.5	0.32	0.49
3.0	0.39	0.59
3.5	0.45	0.69
4.0	0.52	0.79
5.0	0.65	0.98

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-44: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	0.19	0.30
2.0	0.26	0.40
2.5	0.32	0.49
3.0	0.39	0.59
3.5	0.45	0.69
4.0	0.52	0.79
5.0	0.64	0.99

Climate Zone 5: West Region El Paso Weather Data

Table 2-45: Demand Savings (kW) for Early Retirement Baseline – Zone 5

Size (tons)	SEER Range	
	14.0–15.9	16.0+
1.5	0.19	0.30
2.0	0.25	0.39
2.5	0.31	0.49
3.0	0.38	0.59
3.5	0.44	0.69
4.0	0.50	0.79
5.0	0.63	0.98

* Early retirement savings are not available for Climate Zone 5. Savings for Climate Zone 2 are used instead.

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 19 years.

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Air Conditioners.[34]

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)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[35]

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

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

Document Revision History

Table 2-46: 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.

2.2.3 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,[36] effective January 1, 2015.

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

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

replacements that do not include the installation of an AHRI-matched system.[37] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 2-47: Ground Source Heat Pump Baseline Efficiencies

Project Type	Cooling Mode[38]	Heating Mode[39]
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 2-48 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 2-48: 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:[40]

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

[37] 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.

[38] 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.

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

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

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.[41] 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.[42]

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 2-50 and Table 2-51, respectively.

[41] 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.

[42] 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 10

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

Equation 11

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

Equation 12

Where:

$kWh_{desuperheater}$ = *Energy savings (kWh) associated with installation of a desuperheater (see Table 2-50). 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 2-50)*

$SEER_{Base}$ = *Seasonal Energy Efficiency Ratio of the baseline cooling equipment (Table 2-47)*

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

$HSPF_{Base}$ = *Heating Seasonal Performance Factor of the baseline heating equipment (Table 2-47)*

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

Table 2-49: Equivalent full load cooling/heating hours[43]

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 13

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

Equation 14

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 2-47)*

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

COP_{Base} = *Coefficient of Performance of the baseline heating equipment (Table 2-47)*

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

CF_C = *Coincidence Factor = 0.87 (default)*[44]

[43] ENERGY STAR Central AC/HP Savings Calculator. http://www.energystar.gov/certified-products/detail/heat_pumps_air_source.

[44] 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.

CF_H = *Coincidence Factor = 0.83 (default)*[45]

$kW_{desuperheater}$ = *Summer demand savings (kW) associated with installation of a desuperheater (see Table 2-51). These savings should only be added if a desuperheater is installed.*

Deemed Energy Savings Tables

Table 2-50: 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 2-51: 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.

[45] 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

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.[46]

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.

[46] 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 2-52: 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.

2.2.4 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 (Low-Income Customers[47] Only)

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.

Only participants of low-income programs[47] are eligible for early retirement deemed savings associated with installation of a new central heat pump. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal. For installation of a

[47] 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).

central heat pump as an early retirement project not conducted through a low-income program, replace-on-burnout savings may be awarded.

Baseline Condition

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

New construction baseline efficiency values for heat pumps are compliant with the current federal minimum standard,[48] 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.[49]

With the exception of early retirement 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).[50]

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.[51] 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.

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. Early retirement projects do not commonly replace HVAC units without an electric resistance furnace.

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

[49] 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.

[50] *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.

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

Table 2-53: 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	10 SEER	8.2 HSPF*
Early Retirement, Electric Resistance Furnace		3.41 HSPF

* It is rare for early retirement projects to replace a pre-existing heat pump. For these measures, heating savings for the replace-on-burnout of a heat pump shall be used instead.

High-Efficiency Condition

Table 2-54 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 2-54: 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[52] 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

[52] 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 – 16.9 SEER units were assumed to be single stage. 17.0 and above SEER units were assumed to be multi-stage.

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. In heating mode, predicted HVAC operation was limited to meeting 77 percent of load, using a factor applied in Manual J to correlate design load hours to equivalent full load hours under actual operating conditions, taking into account that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings are estimated according to expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Heating mode capacity was related to rated cooling capacity using the rated capacity in cooling and heating mode of the residential market heat pump products of four major manufacturers according to data exported from AHRI. Data were exported from the AHRI directory and the average ratio for each equipment size (1 ton, 1.5 ton, 2 ton, etc.) of heating capacity to cooling capacity was multiplied by the rated (cooling side) capacity to estimate the heat pump capacity. Heat pump system output was then compared to its loading under design conditions.

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

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

Table 2-55: Heat Pump Capacity Curve Coefficients

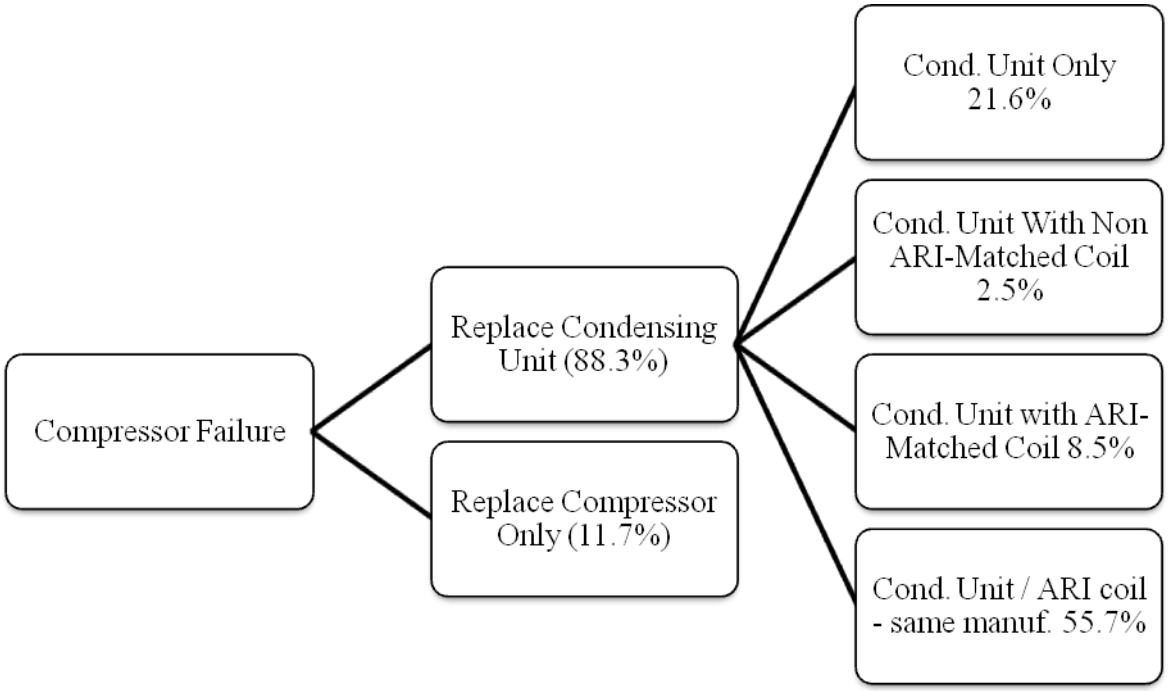
Coefficient	Cooling			Heating
	Single Stage	Multi-Stage/Speed		Single Stage
		Low	High	
a	3.68637657	3.998418659	3.466810106	0.566333415
b	-0.098352478	-0.108728222	-0.091476056	-0.000744164
c	0.000956357	0.001056818	0.000901205	-0.0000103
d	0.005838141	0.007512314	0.004163355	0.009414634
e	-0.0000127	-0.0000139	-0.00000919	0.0000506
f	-0.000131702	-0.000164716	-0.000110829	-0.00000675

Table 2-56: Heat Pump EIR Curve Coefficients

Coefficient	Cooling			Heating
	Single Stage	Multi-Stage/Speed		Single Stage
		Low	High	
a	-3.437356399	-4.282911381	-3.557757517	0.718398423
b	0.136656399	0.181023691	0.112737397	0.003498178
c	-0.001049231	-0.001357391	-0.000731381	0.000142202
d	-0.0079378	-0.026310378	0.01384877	-0.005724331
e	0.000185435	0.000333282	0.000132645	0.00014085
f	-0.0001441	-0.000197405	-0.000338716	-0.000215321

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:

Figure 2-2: Unit Replacement Percentages upon Compressor Failure



Source: Docket No. 36780

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

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

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

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

Adjusting for the increased 14 SEER baseline:

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

In new construction, there is no possibility of a partial system (e.g. condensing unit-only) changeout, 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

In order to calculate the energy (kWh) and demand (kW) savings associated with the installation of a new central heat pump system in a home through a low-income program, the savings must be weighted by the age of the unit to be replaced.

The following equations may be used to calculate the deemed energy and demand savings awarded to a newly-installed central heat pump:

$$\begin{aligned} &\textbf{Annual kWh Savings} \\ &= \left(\frac{\textbf{HP Age}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kWh Savings}_{\textbf{Replace on Burnout}} \\ &+ \left(\frac{\textbf{Remaining Useful Life}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Annual kWh Savings}_{\textbf{EarlyRetirement}} \end{aligned}$$

Equation 15

$$\begin{aligned} &\textbf{Summer kW Savings} \\ &= \left(\frac{\textbf{HP Age}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Summer kW Savings}_{\textbf{Replace on Burnout}} \\ &+ \left(\frac{\textbf{Remaining Useful Life}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Summer kW Savings}_{\textbf{Early Retirement}} \end{aligned}$$

Equation 16

$$\begin{aligned} &\textbf{Winter kW Savings} \\ &= \left(\frac{\textbf{HP Age}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Winter kW Savings}_{\textbf{Replace on Burnout}} \\ &+ \left(\frac{\textbf{Remaining Useful Life}}{\textbf{HP Age} + \textbf{Remaining Useful Life}}\right) \times \textbf{Winter kW Savings}_{\textbf{Early Retirement}} \end{aligned}$$

Equation 17

The annual kW will be the larger of the summer or winter demand savings as calculated in Equation 16 and Equation 17, respectively. Remaining useful life is dependent upon the age of the replaced heat pump. The remaining useful life can be found in Table 2-57.

Table 2-57: Remaining Useful Life of Replaced Unit

Age of Replaced Unit	Remaining Useful Life	Age of Replaced Unit	Remaining Useful Life
1	18	13	7..5
2	17	14	7
3	16	15	5.5
4	15	16	5
5	14	17	4.5
6	13	18	3.5
7	12	19	3
8	11.5	20	2.5
9	10.5	21	1.5

Age of Replaced Unit	Remaining Useful Life	Age of Replaced Unit	Remaining Useful Life
10	9	22	1.5
11	8.5	23	1
12	8	24	0

The deemed demand savings awarded for the installation of a new central heat pump unit are provided in the lookup tables below.

Deemed Energy Savings Tables

Cooling, New Construction

Table 2-58 through Table 2-62 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 2-58: 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	178	278	447	527	712
2.0	104	237	370	596	703	949
2.5	130	296	463	745	879	1,186
3.0	156	356	556	894	1,055	1,423
3.5	181	415	648	1,043	1,230	1,661
4.0	207	474	741	1,192	1,406	1,898
5.0	259	593	926	1,490	1,758	2,372

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

Table 2-59: 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	269	421	704	823	1,107
2.0	157	359	561	938	1,097	1,477
2.5	196	449	702	1,173	1,372	1,846
3.0	236	539	842	1,407	1,646	2,215
3.5	275	629	982	1,642	1,920	2,584
4.0	314	718	1,122	1,876	2,195	2,953
5.0	393	898	1,403	2,345	2,743	3,691

Climate Zone 3: South Region, Houston Weather Data

Table 2-60: 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	125	285	446	784	907	1,211
2.0	166	380	594	1,045	1,210	1,614
2.5	208	475	743	1,306	1,512	2,018
3.0	249	570	891	1,567	1,814	2,421
3.5	291	665	1,040	1,828	2,117	2,825
4.0	333	760	1,188	2,089	2,419	3,228
5.0	416	950	1,485	2,612	3,024	4,035

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-61: 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	145	331	518	904	1,048	1,402
2.0	193	442	690	1,205	1,397	1,869
2.5	242	552	863	1,506	1,746	2,336
3.0	290	663	1,035	1,807	2,095	2,804
3.5	338	773	1,208	2,108	2,444	3,271
4.0	387	884	1,381	2,409	2,793	3,738
5.0	483	1,105	1,726	3,012	3,492	4,673

Climate Zone 5: West Region El Paso Weather Data

Table 2-62: 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	101	232	362	622	723	969
2.0	135	309	483	829	965	1,292
2.5	169	386	603	1,037	1,206	1,615
3.0	203	463	724	1,244	1,447	1,939
3.5	236	540	844	1,451	1,688	2,262
4.0	270	618	965	1,659	1,929	2,585
5.0	338	772	1,206	2,073	2,412	3,231

Cooling, Replace-on-Burnout

Table 2-63 through Table 2-67 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 2-63: 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	215	315	415	584	664	849
2.0	286	419	553	779	885	1,131
2.5	358	524	691	973	1,107	1,414
3.0	429	629	829	1,168	1,328	1,697
3.5	501	734	967	1,362	1,550	1,980
4.0	572	839	1,106	1,557	1,771	2,263
5.0	715	1,049	1,382	1,946	2,214	2,828

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

Table 2-64: 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	325	477	628	911	1,030	1,315
2.0	433	636	838	1,214	1,374	1,753
2.5	542	794	1,047	1,518	1,717	2,191
3.0	650	953	1,256	1,822	2,060	2,629
3.5	759	1,112	1,466	2,125	2,404	3,068
4.0	867	1,271	1,675	2,429	2,747	3,506
5.0	1,084	1,589	2,094	3,036	3,434	4,382

Climate Zone 3: South Region, Houston Weather Data

Table 2-65: 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	344	504	665	1,003	1,127	1,430
2.0	459	673	886	1,337	1,502	1,906
2.5	573	841	1,108	1,671	1,878	2,383
3.0	688	1,009	1,330	2,006	2,253	2,860
3.5	803	1,177	1,551	2,340	2,629	3,336
4.0	918	1,345	1,773	2,674	3,004	3,813
5.0	1,147	1,682	2,216	3,343	3,755	4,766

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-66: 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	400	586	773	1,158	1,302	1,657
2.0	533	782	1,030	1,545	1,737	2,209
2.5	666	977	1,288	1,931	2,171	2,761
3.0	800	1,173	1,545	2,317	2,605	3,314
3.5	933	1,368	1,803	2,703	3,039	3,866
4.0	1,066	1,563	2,060	3,089	3,473	4,418
5.0	1,333	1,954	2,576	3,861	4,342	5,523

Climate Zone 5: West Region El Paso Weather Data

Table 2-67: 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	280	410	540	800	902	1,147
2.0	373	546	720	1,067	1,202	1,530
2.5	466	683	900	1,334	1,503	1,912
3.0	559	820	1,080	1,600	1,803	2,295
3.5	652	956	1,260	1,867	2,104	2,677
4.0	745	1,093	1,440	2,134	2,404	3,060
5.0	932	1,366	1,800	2,667	3,006	3,825

Cooling, Early Retirement

Table 2-68 through Table 2-72 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 in Equation 15 with the replace-on-burnout energy savings in Table 2-63 through Table 2-67 to calculate annual cooling savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-68: 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+
1.5	861	961	1,062
2.0	1,147	1,282	1,416
2.5	1,434	1,602	1,770
3.0	1,721	1,922	2,124
3.5	2,008	2,243	2,477
4.0	2,295	2,563	2,831
5.0	2,869	3,204	3,539

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

Table 2-69: 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+
1.5	1,303	1,455	1,608
2.0	1,738	1,941	2,144
2.5	2,172	2,426	2,680
3.0	2,606	2,911	3,216
3.5	3,041	3,396	3,752
4.0	3,475	3,881	4,287
5.0	4,344	4,852	5,359

Climate Zone 3: South Region, Houston Weather Data

Table 2-70: 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+
1.5	1,382	1,544	1,705
2.0	1,843	2,058	2,274
2.5	2,304	2,573	2,842
3.0	2,764	3,087	3,411
3.5	3,225	3,602	3,979
4.0	3,686	4,117	4,547
5.0	4,607	5,146	5,684

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-71: 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+
1.5	1,606	1,794	1,982
2.0	2,142	2,392	2,643
2.5	2,677	2,990	3,303
3.0	3,213	3,588	3,964
3.5	3,748	4,186	4,624
4.0	4,284	4,784	5,285
5.0	5,355	5,980	6,606

Climate Zone 5: West Region El Paso Weather Data

Table 2-72: 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+
1.5	1,121	1,252	1,383
2.0	1,495	1,669	1,844
2.5	1,868	2,087	2,305
3.0	2,242	2,504	2,766
3.5	2,616	2,921	3,227
4.0	2,989	3,339	3,688
5.0	3,737	4,173	4,610

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

Table 2-73 through Table 2-77 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 2-73: 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 2-74: 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 2-75: 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 2-76: 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 2-77: 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 2-78 through Table 2-82 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 2-78: 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	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	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	15,591	15,788	16,151	16,477	16,628	16,772
5	19,489	19,735	20,188	20,596	20,785	20,965

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

Table 2-79: 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	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	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	9,096	9,209	9,417	9,604	9,691	9,773
5	11,370	11,511	11,771	12,005	12,113	12,217

Climate Zone 3: South Region, Houston Weather Data

Table 2-80: 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	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	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	4,874	4,934	5,045	5,144	5,191	5,235
5	6,092	6,167	6,306	6,431	6,488	6,543

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-81: 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	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	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	3,760	3,806	3,892	3,969	4,004	4,038
5	4,700	4,758	4,865	4,961	5,005	5,048

Climate Zone 5: West Region El Paso Weather Data

Table 2-82: 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	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	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	9,185	9,299	9,509	9,697	9,785	9,868
5	11,482	11,624	11,886	12,122	12,231	12,335

Heating, Early Retirement – Replacement of a Heat Pump

See Table 2-73 through Table 2-77 for the energy savings (kWh) per heating load type associated with a central heat pump replacing another heat pump for all five Texas climate zones. As early retirement of a central heat pump is rare, replace-on-burnout heating savings are awarded for this measure.

Heating, Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-78 through Table 2-82 for the energy savings (kWh) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones.

Deemed Summer Demand Savings Tables

New Construction

Table 2-83 through Table 2-87 present the summer demand savings (kW) associated with a central heat pump being installed during new construction for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-83: Demand Savings (Summer kW) 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	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

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

Table 2-84: Demand Savings (Summer kW) 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	0.13	0.20	0.20	0.27	0.39
2.0	0.08	0.17	0.27	0.26	0.35	0.52
2.5	0.10	0.22	0.34	0.33	0.44	0.66
3.0	0.11	0.26	0.41	0.39	0.53	0.79
3.5	0.13	0.30	0.48	0.46	0.62	0.92
4.0	0.15	0.35	0.54	0.53	0.71	1.05
5.0	0.19	0.43	0.68	0.66	0.88	1.31

Climate Zone 3: South Region, Houston Weather Data

Table 2-85: Demand Savings (Summer kW) 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	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-86: Demand Savings (Summer kW) 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	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

Climate Zone 5: West Region El Paso Weather Data

Table 2-87: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.06	0.13	0.20	0.20	0.27	0.39
2.0	0.08	0.17	0.27	0.26	0.35	0.52
2.5	0.10	0.22	0.34	0.33	0.44	0.66
3.0	0.11	0.26	0.41	0.39	0.53	0.79
3.5	0.13	0.30	0.48	0.46	0.62	0.92
4.0	0.15	0.35	0.54	0.53	0.71	1.05
5.0	0.19	0.43	0.68	0.66	0.88	1.31

Replace-on-Burnout

Table 2-88 through Table 2-92 present the summer demand savings (kW) associated with a central heat pump replacing on burnout an HVAC system for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-88: Demand Savings (Summer kW) 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	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

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

Table 2-89: Demand Savings (Summer kW) 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	0.23	0.30	0.30	0.37	0.49
2.0	0.21	0.31	0.41	0.40	0.49	0.66
2.5	0.26	0.38	0.51	0.50	0.61	0.82
3.0	0.31	0.46	0.61	0.60	0.73	0.99
3.5	0.37	0.54	0.71	0.69	0.85	1.15
4.0	0.42	0.62	0.81	0.79	0.98	1.32
5.0	0.52	0.77	1.01	0.99	1.22	1.65

Climate Zone 3: South Region, Houston Weather Data

Table 2-90: Demand Savings (Summer kW) 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	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-91: Demand Savings (Summer kW) 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	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

Climate Zone 5: West Region El Paso Weather Data

Table 2-92: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.16	0.23	0.30	0.30	0.37	0.49
2.0	0.21	0.31	0.41	0.40	0.49	0.66
2.5	0.26	0.38	0.51	0.50	0.61	0.82
3.0	0.31	0.46	0.61	0.60	0.73	0.99
3.5	0.37	0.54	0.71	0.69	0.85	1.15
4.0	0.42	0.62	0.81	0.79	0.98	1.32
5.0	0.52	0.77	1.01	0.99	1.22	1.65

Early Retirement

Table 2-93 through Table 2-97 present the summer demand savings (kW) associated with a central heat pump replacing an HVAC system for all five Texas climate zones. These savings can be used in Equation 16 with the replace-on-burnout energy savings in Table 2-88 through Table 2-92 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-93: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range		
	14.5–14.9	15.0–15.9	16.0+
1.5	0.59	0.66	0.73
2.0	0.78	0.88	0.97
2.5	0.98	1.10	1.21
3.0	1.18	1.31	1.45
3.5	1.37	1.53	1.69
4.0	1.57	1.75	1.94
5.0	1.96	2.19	2.42

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

Table 2-94: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range		
	14.5–14.9	15.0–15.9	16.0+
1.5	0.63	0.70	0.77
2.0	0.84	0.93	1.03
2.5	1.04	1.17	1.29
3.0	1.25	1.40	1.55
3.5	1.46	1.63	1.80
4.0	1.67	1.87	2.06
5.0	2.09	2.33	2.58

Climate Zone 3: South Region, Houston Weather Data

Table 2-95: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range		
	14.5–14.9	15.0–15.9	16.0+
1.5	0.59	0.66	0.73
2.0	0.78	0.88	0.97
2.5	0.98	1.10	1.21
3.0	1.18	1.31	1.45
3.5	1.37	1.53	1.69
4.0	1.57	1.75	1.94
5.0	1.96	2.19	2.42

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-96: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range		
	14.5–14.9	15.0–15.9	16.0+
1.5	0.59	0.66	0.73
2.0	0.78	0.88	0.97
2.5	0.98	1.10	1.21
3.0	1.18	1.31	1.45
3.5	1.37	1.53	1.69
4.0	1.57	1.75	1.94
5.0	1.96	2.19	2.42

Climate Zone 5: West Region El Paso Weather Data

Table 2-97: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range		
	14.5–14.9	15.0–15.9	16.0+
1.5	0.63	0.70	0.77
2.0	0.84	0.93	1.03
2.5	1.04	1.17	1.29
3.0	1.25	1.40	1.55
3.5	1.46	1.63	1.80
4.0	1.67	1.87	2.06
5.0	2.09	2.33	2.58

Deemed Winter Demand Savings Tables

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

Table 2-98 through Table 2-102 present the winter demand savings (kW) associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-98: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.14	0.19	0.21
2	0.07	0.11	0.11	0.18	0.25	0.29
2.5	0.08	0.14	0.14	0.23	0.32	0.36
3	0.10	0.16	0.16	0.28	0.38	0.43
3.5	0.12	0.19	0.19	0.32	0.44	0.50
4	0.13	0.22	0.22	0.37	0.51	0.57
5	0.17	0.27	0.27	0.46	0.63	0.71

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

Table 2-99: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.21
2	0.06	0.10	0.10	0.18	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.34
3	0.10	0.16	0.16	0.27	0.37	0.41
3.5	0.11	0.18	0.18	0.31	0.43	0.48
4	0.13	0.21	0.21	0.36	0.49	0.55
5	0.16	0.26	0.26	0.44	0.61	0.69

Climate Zone 3: South Region, Houston Weather Data

Table 2-100: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.04	0.06	0.06	0.11	0.15	0.17
2	0.05	0.09	0.09	0.15	0.20	0.22
2.5	0.07	0.11	0.11	0.18	0.25	0.28
3	0.08	0.13	0.13	0.22	0.30	0.34
3.5	0.09	0.15	0.15	0.25	0.35	0.39
4	0.11	0.17	0.17	0.29	0.40	0.45
5	0.13	0.21	0.21	0.36	0.50	0.56

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-101: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.03	0.05	0.05	0.09	0.13	0.14
2	0.04	0.07	0.07	0.12	0.17	0.19
2.5	0.06	0.09	0.09	0.15	0.21	0.24
3	0.07	0.11	0.11	0.18	0.25	0.28
3.5	0.08	0.13	0.13	0.21	0.29	0.33
4	0.09	0.14	0.14	0.25	0.34	0.38
5	0.11	0.18	0.18	0.31	0.42	0.47

Climate Zone 5: West Region El Paso Weather Data

Table 2-102: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.20
2	0.06	0.10	0.10	0.17	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.33
3	0.09	0.15	0.15	0.26	0.36	0.40
3.5	0.11	0.18	0.18	0.30	0.42	0.47
4	0.13	0.20	0.20	0.35	0.47	0.53
5	0.16	0.25	0.25	0.43	0.59	0.67

Replace-on-Burnout – Replacement of Electric Resistance Furnace

Table 2-103 through Table 2-107 present the winter demand savings (kW) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-103: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.05	2.08	2.14	2.19	2.21	2.24
2	2.73	2.78	2.85	2.92	2.95	2.98
2.5	3.42	3.47	3.57	3.65	3.69	3.73
3	4.10	4.16	4.28	4.38	4.43	4.47
3.5	4.79	4.86	4.99	5.11	5.17	5.22
4	5.47	5.55	5.70	5.84	5.91	5.97
5	6.84	6.94	7.13	7.30	7.38	7.46

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

Table 2-104: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.33	2.36	2.41	2.46	2.49	2.51
2	3.11	3.15	3.22	3.29	3.32	3.35
2.5	3.88	3.93	4.02	4.11	4.15	4.18
3	4.66	4.72	4.83	4.93	4.97	5.02
3.5	5.44	5.51	5.63	5.75	5.80	5.85
4	6.21	6.29	6.44	6.57	6.63	6.69
5	7.77	7.87	8.05	8.21	8.29	8.36

Climate Zone 3: South Region, Houston Weather Data

Table 2-105: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.94	1.97	2.01	2.05	2.07	2.09
2	2.59	2.62	2.68	2.74	2.76	2.79
2.5	3.24	3.28	3.35	3.42	3.45	3.48
3	3.89	3.94	4.03	4.11	4.14	4.18
3.5	4.53	4.59	4.70	4.79	4.84	4.88
4	5.18	5.25	5.37	5.48	5.53	5.57
5	6.48	6.56	6.71	6.84	6.91	6.97

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-106: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.66	1.69	1.72	1.76	1.77	1.79
2	2.22	2.25	2.30	2.34	2.36	2.38
2.5	2.77	2.81	2.87	2.93	2.96	2.98
3	3.33	3.37	3.45	3.52	3.55	3.58
3.5	3.88	3.93	4.02	4.10	4.14	4.17
4	4.44	4.49	4.60	4.69	4.73	4.77
5	5.55	5.62	5.74	5.86	5.91	5.96

Climate Zone 5: West Region El Paso Weather Data

Table 2-107: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.27	2.30	2.36	2.41	2.43	2.45
2	3.03	3.07	3.14	3.21	3.24	3.27
2.5	3.79	3.84	3.93	4.01	4.05	4.08
3	4.55	4.61	4.72	4.81	4.86	4.90
3.5	5.31	5.38	5.50	5.61	5.67	5.72
4	6.07	6.14	6.29	6.42	6.48	6.53
5	7.58	7.68	7.86	8.02	8.09	8.17

Early Retirement – Replacement of a Heat Pump

See Table 2-98 through Table 2-102 for the winter demand savings (kW) associated with a central heat pump replacing another heat pump for all five Texas climate zones. As early retirement of a central heat pump is rare, replace-on-burnout winter peak demand savings are awarded for this measure.

Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-103 through Table 2-107 for the winter demand savings (kW) associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a central heat pump unit is 16 years.

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Heat Pumps.[53]

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
- Heating Seasonal Performance Factor (HSPF) of the installed unit
- Climate zone of the site
- Type of unit replaced (e.g., electric resistance furnace, air source heat pump)
- Age of the replaced unit (early retirement only)

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

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[54]

Document Revision History

Table 2-108: Central Heat Pump Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as "Early Retirement" option. Updated by Frontier Associates, March 2014, based on new federal standards.

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

2.2.5 Window Air Conditioner Measure Overview

TRM Measure ID: R-HV-WA

Market Sector: Residential

Measure Category: HVAC

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, Early Retirement (Low-Income Participants Only[55])

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The following deemed savings values are applicable in calculating an incentive for a room air conditioner replaced with a higher efficiency room air conditioner in a dwelling occupied by a residential energy consumer.

Eligibility Criteria

The deemed savings apply only to a window air conditioner replaced with a higher efficiency window air conditioner.

Only participants of targeted low-income programs[55] are eligible for deemed savings associated with early retirement of a window air conditioning unit. In order to be awarded early retirement savings, the unit to be replaced must be functioning at the time of removal.

Baseline Condition

Baseline is assumed to be a new window air conditioning unit with an EER rating that is compliant with the current federal standard,[56] effective June 1, 2014. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

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[55] 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).

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

Table 2-109: Window Air Conditioner Baseline Efficiencies

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Baseline CEER
No	Yes	< 8,000	11.0
		≥ 8,000 and < 14,000	10.9
		≥ 14,000 and < 20,000	10.7
		≥ 20,000 and < 25,000	9.4
		≥ 25,000	9.0
No	No	< 8,000	10.0
		≥ 8,000 and < 11,000	9.6
		≥ 11,000 and < 14,000	9.5
		≥ 14,000 and < 20,000	9.3
		≥ 20,000	9.4
Yes	Yes	< 20,000	9.8
		≥ 20,000	9.3
Yes	No	< 14,000	9.3
		≥ 14,000	8.7
Casement-only		All capacities	9.5
Casement-slider		All capacities	10.4

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

Table 2-110: Window Air Conditioner Baseline Efficiencies for Replace-on-Burnout and Early Retirement

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

High-Efficiency Condition

The table below displays the ENERGY STAR® requirements for eligible window air conditioners, effective October 1, 2013. This specification is 15 percent above the federal standard in place prior to June 1, 2014. After June 1, 2014, the efficient condition is anticipated to be 15 percent above the new federal standard, as presented in Table 2-111. Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-111: Window Air Conditioner Efficient Condition Specifications

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	ENERGY STAR® Minimum EER prior to June 1, 2014	Anticipated Minimum CEER on or after June 1, 2014*
No	Yes	< 8,000	11.2	12.7
		≥ 8,000 and < 14,000	11.3	12.5
		≥ 14,000 and < 20,000	11.2	12.3
		≥ 20,000 and < 25,000	9.8	10.8
		≥ 25,000	9.8	10.4
No	No	< 8,000	10.4	11.5
		≥ 8,000 and < 11,000	9.8	11.0
		≥ 11,000 and < 14,000	9.8	10.9
		≥ 14,000 and < 20,000	9.8	10.7
		≥ 20,000	9.8	10.8
Yes	Yes	< 20,000	10.4	11.3
		≥ 20,000	9.8	10.7
Yes	No	< 14,000	9.8	10.7
		≥ 14,000	9.2	10.0
Casement-only		All capacities	10.0	10.9
Casement-slider		All capacities	10.9	12.0

* ENERGY STAR® specifications effective October 1, 2013, require that ENERGY STAR® rated window air conditioning units have an EER 15% above the federal standard. The anticipated minimum CEER reflects 15% above the federal standards taking effect June 1, 2014.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{Savings,C} = CAP \times \frac{1\ kW}{1,000\ W} \times EFLH_C \times RAF \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{WAC}}\right)$$

Equation 18

Where:

CAP	=	*Rated equipment cooling capacity of the installed window air conditioner (Btu/hr)*
$EFLH_C$	=	*Equivalent full load hours for cooling (Table 2-112)*
RAF	=	*Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[57] *= 0.77*[58]
EER_{Base}	=	*Energy Efficiency Ratio of the baseline cooling equipment (Table 2-110)*
EER_{WAC}	=	*Energy Efficiency Ratio of the installed window air conditioner*

Table 2-112: Window Air Conditioner Equivalent Full Load Cooling Hours[59]

Climate Zone	$EFLH_C$
Climate Zone 1: Panhandle	1,142
Climate Zone 2: North	1,926
Climate Zone 3: South	2,209
Climate Zone 4: Valley	2,958
Climate Zone 5: West	1,524

Demand Savings Algorithms

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

Equation 19

Where:

CAP	=	*Rated equipment cooling capacity of the installed window air conditioner (Btu/hr)*
EER_{Base}	=	*Energy Efficiency Ratio of the baseline cooling equipment (Table 2-110)*
EER_{WAC}	=	*Energy Efficiency Ratio of the installed window air conditioner*
CF	=	*Coincidence Factor = 0.87 (default)*[60]

[57] Manual J, Volume 7: Appendix A-4.
[58] The EFLH presented in Table 2-115 reflect the values currently available in the ENERGY STAR room air conditioner savings calculator, which are adopted from the ENERGY STAR central air conditioner EFLH. If values specific to window air conditioners are released by ENERGY STAR, this technical reference manual will be updated to reflect these changes; the RAF would then be set to 1.
[59] ENERGY STAR Room AC Savings Calculator. http://www.energystar.gov/certified-products/detail/air_conditioning_room.

Early Retirement

In order to calculate the summer peak demand (kW) and energy (kWh) savings associated with the installation of a new window air conditioner in a home following the early retirement of a functioning window air conditioner, the savings must be weighted by the age of the unit to be replaced. It is assumed that replacement units meet the ENERGY STAR® standard of 15% above the baseline federal standard.

The following equations may be used to calculate the deemed energy savings awarded to a newly-installed window air conditioner under early retirement conditions. Annual operating hours of window AC units vary by climate zone (see Table 2-112).

$$\boldsymbol{Annual\ kWh\ Savings_{Early\ Retirement} = CAP \times \frac{1\ kW}{1,000\ W} \times RAF \times EFLH_C \times \left(\frac{1}{EER_{ER}} - \frac{1}{EER_{WAC}}\right)}$$

Equation 20

$$\boldsymbol{Annual\ kWh\ Savings_{Replace\ on\ Burnout} = CAP \times \frac{1\ kW}{1,000\ W} \times RAF \times EFLH_C \times \left(\frac{1}{EER_{ROB}} - \frac{1}{EER_{WAC}}\right)}$$

Equation 21

Where:

CAP	=	*Rated equipment cooling capacity of the installed window air conditioner (Btu/hr)*
$EFLH_C$	=	*Equivalent full load hours for cooling (Table 2-112)*
RAF	=	*Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[61] *= 0.77*
EER_{ROB}	=	*Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 2-110)*
EER_{ER}	=	*Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 2-110)*
EER_{WAC}	=	*Energy Efficiency Ratio of the installed window air conditioner*

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

[61] Manual J, Volume 7: Appendix A-4.

$$\boldsymbol{Annual\ kWh\ Savings} = \left(\frac{\boldsymbol{Window\ AC\ Age}}{\boldsymbol{Window\ AC\ Age + Remaining\ Useful\ Life}}\right) \times \boldsymbol{Annual\ kWh\ Savings_{Replace\ on\ Burnout}} + \left(\frac{\boldsymbol{Remaining\ Useful\ Life}}{\boldsymbol{Window\ AC\ Age + Remaining\ Useful\ Life}}\right) \times \boldsymbol{Annual\ kWh\ Savings_{Early\ Retirement}}$$

Equation 22

Remaining useful life is equal to the unit lifetime, 11 years, minus the age of the window air conditioner replaced:

$$\boldsymbol{Remaining\ Service\ Life = Lifetime - Window\ AC\ Age, Lifetime = 11\ years}$$

Equation 23

Deemed summer peak demand savings may be calculated for the early retirement of a window air conditioner as follows:

$$\boldsymbol{Annual\ kW\ Savings} = \left(\frac{\boldsymbol{Window\ AC\ Age}}{\boldsymbol{Window\ AC\ Age + Remaining\ Useful\ Life}}\right) \times \frac{\boldsymbol{Annual\ kWh\ Savings_{Replace\ on\ Burnout}}}{\boldsymbol{EFLH_C}} + \left(\frac{\boldsymbol{Remaining\ Useful\ Life}}{\boldsymbol{Window\ AC\ Age + Remaining\ Useful\ Life}}\right) \times \frac{\boldsymbol{Annual\ kWh\ Savings_{Early\ Retirement}}}{\boldsymbol{EFLH_C}}$$

Equation 24

Federal standards for a unit replaced on burnout and baseline efficiencies for early retirement can be found in Table 2-110.

Deemed Energy Savings Tables

Replace-on-Burnout

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

Early Retirement

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

Deemed Summer Demand Savings Tables

Replace-on-Burnout

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

Early Retirement

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a window air conditioning unit is 11 years.

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 52852 Technical Support Document for Energy Conservation Standards for Room Air Conditioners.[62]

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)
- Cooling capacity of the installed unit (Btu/hr)
- Energy Efficiency Ratio (EER) of the unit installed
- Climate zone of the site
- Age of the replaced unit (Early Retirement only)

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

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

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

Document Revision History

Table 2-113: Window 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.

2.3 RESIDENTIAL: BUILDING ENVELOPE

2.3.1 Air Infiltration Measure Overview

TRM Measure ID: R-BE-AI

Market Sector: Residential

Measure Category: Building Envelope

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithm and Estimates

Measure Description

This measure reduces air infiltration into the residence, using pre- and post-treatment blower door air pressure readings to confirm air leakage reduction. Homes treated for air infiltration reduction must have electric air conditioning to qualify for these deemed savings values.

Eligibility Criteria

There is an upper limit of 4.00 CFM_{50} per square foot of house floor area for the pre-retrofit infiltration rate on eligible projects. At their utility's discretion, this cap may not apply to homes implementing the measure under low-income programs.[63]

Air 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 air 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.[64]

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[63] 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).

[64] 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**

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

Only structures with electric refrigerated air conditioning systems are eligible.

Baseline Condition

For residential dwellings, the winter/summer air change per hour (ACH) differential was derived from ESPRE model weather data for the Panhandle (Amarillo weather), North (Dallas weather), South (Houston weather), and Valley (Corpus Christi weather) climate zones. Electric air conditioning was assumed for all homes, with gas, electric or heat pump heating.

Table 2-114: Baseline Seasonal ACH by Climate Zone

Air Infiltration Values (ACH)		
Region	**Winter ACH**	**Summer ACH**
Climate Zone 1: Panhandle	1.25	0.96
Climate Zone 2: North	0.94	0.49
Climate Zone 3: South	0.86	0.54
Climate Zone 4: Valley	0.95	0.94
Climate Zone 5: West	0.94	0.49

High-Efficiency Condition

To qualify for an incentive, a minimum air leakage reduction of 10 percent of the pre-installation reading is required. Utilities may require competency testing of personnel who will perform the blower door tests.

Blower door air pressure measurements will also be used to ensure that air infiltration in a residence shall not be less than the standards set forth in the following table:

Table 2-115: Minimum Final Ventilation Rate*

Shielding	Number of Stories		
	Single Story	Two Story	3 or More Stories
Well shielded	1.18	0.95	0.83
Normal	0.99	0.79	0.69
Exposed	0.89	0.71	0.62

* Measured in cubic feet per minute at 50 Pascal per square foot of conditioned area.

Well shielded is defined as urban areas with high buildings or sheltered areas, and building surrounded by trees, bermed earth, or higher terrain.

Normal is defined as buildings in a residential neighborhood or subdivision setting, with yard space between buildings. 80 percent to 90 percent of houses fall in this category.

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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."*

Exposed is defined as buildings in an open setting with few buildings or trees around and buildings on top of a hill or ocean front, exposed to winds.

As an example, the minimum post-installation air exchange rate for an 1800 square foot, one-story home with normal shielding is 1782 CFM_{50} (1800 x 0.99). In order to qualify for the air infiltration control deemed savings, there must be a minimum 10 percent reduction between the pre- and post-installation ventilation rate. Therefore, the pre-installation ventilation rate must be at least 1980 CFM_{50} (1782 ÷ 0.9) in order to be considered for air infiltration control measures.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

For climate zones 1 through 4, building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was based on the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for climate zone 5 were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home.[65] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the air infiltration reduction. Next, change-case models were run to calculate energy use after steps had been taken to reduce air infiltration in the home.

[65] For a list of input values used in these models refer to Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

For climate zone 5, summer peak savings were calculated by taking the difference in demand at the hour when the summer peak is likely to occur. The day of the peak was determined based on TMY3 weather data: the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

In order to develop winter peak savings values for all climate zones, a whole home simulation model was developed using EnergyGauge. Prototypical home characteristics were selected using available data on the construction, occupancy, and equipment characteristics of Texas homes.[66] The predicted annual energy consumption of the model was benchmarked using data from the Energy Information Administration's Residential Energy Consumption Survey (RECS) for homes of similar heating types and floor area. Base and change case models were run using parameters matching the baseline and efficiency conditions of the measure. From the hourly output for each run, a winter peak load factor representing the relationship between energy savings and winter peak savings was calculated as follows:

$$\boldsymbol{Winter\ Peak\ Load\ Factor} = \frac{\boldsymbol{Modeled\ Annual\ Energy\ Savings}}{\boldsymbol{8760 \times Modeled\ Winter\ Peak\ Demand\ Savings}}$$

The winter peak load factor was then applied to the existing deemed savings to derive a value for the winter peak demand savings as follows:

$$\boldsymbol{Winter\ Peak\ Demand\ Savings} = \frac{\boldsymbol{Existing\ Annual\ Energy\ Savings}}{\boldsymbol{8760 \times Winter\ Peak\ Load\ Factor}}$$

Deemed Energy Savings Tables

Table 2-119 presents the energy savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

$$\boldsymbol{Deemed\ Energy\ Savings} = \boldsymbol{CFM_{50} \times V_E}$$

Equation 25

Where:

CFM_{50}	=	*Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*
V_E	=	*Corresponding value in Table* 2-119

[66] For a list of input values used in these models refer to 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.

Table 2-116: Energy Savings V_E per CFM_{50} Reduction

Region	kWh Impact per CFM_{50} Reduction		
	Gas Heat	Resistance Heat	Heat Pump Heat
Climate Zone 1: Panhandle	0.1262	1.6673	0.7933
Climate Zone 2: North	0.1929	1.0565	0.5046
Climate Zone 3: South	0.2694	0.7945	0.4438
Climate Zone 4: Valley	0.6268	0.9732	0.7368
Climate Zone 5: West	0.1212	0.8096	N/A

Deemed Summer Demand Savings Tables

Table 2-117 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed summer demand savings for air infiltration improvements.

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

Equation 26

Where:

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

V_S = *Corresponding value in Table 2-117*

Table 2-117: Peak Summer Demand Savings V_S per CFM_{50} Reduction

Region	Summer kW Impact per CFM_{50} Reduction
Climate Zone 1: Panhandle	0.00024
Climate Zone 2: North	0.00019
Climate Zone 3: South	0.00026
Climate Zone 4: Valley	0.00043
Climate Zone 5: West	0.000207

Deemed Winter Demand Savings Tables

Table 2-118 presents the summer peak demand savings per CFM_{50} reduction for a residential air sealing project. The following formula shall be used to calculate deemed winter demand savings for air infiltration improvement:

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

Equation 27

Where:

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

V_W = *Corresponding value in Table 2-118*

Table 2-118: Peak Winter Demand Savings V_W per CFM_{50} Reduction

Region	Winter kW Impact per CFM_{50} Reduction	
	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	0.000842	0.000553
Climate Zone 2: North	0.000616	0.000261
Climate Zone 3: South	0.000486	0.000221
Climate Zone 4: Valley	0.000528	0.000305
Climate Zone 5: West	0.000534	N/A

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

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

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Heating type (gas, resistance heat, heat pump)
- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of stories

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-119: Air Infiltration Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics.
v2.1	1/30/2015	TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions.

2.3.2 Ceiling Insulation Measure Overview

TRM Measure ID: R-BE-CI

Market Sector: Residential

Measure Category: Building Envelope

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Ceiling insulation savings are calculated per square foot of treated ceiling area above a conditioned space. To qualify for these deemed savings values, ceiling insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

In existing construction, ceiling insulation levels vary greatly depending on the age of the home, type of insulation, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings tables are based on the current level of ceiling insulation in the home from R-0 to R-22. The current insulation level of each home will be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing insulation is or has been removed, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

High-Efficiency Condition

A ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. The combined R-values of the existing insulation and the insulation being added will total at least R-30. The R-value of the existing insulation can be no greater than R-22.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

For climate zones 1 through 4, building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was based on the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for climate zone 5 were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models may have been modified from those shown in Table 2-120.[67] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of the ceiling insulation measure. Next, change-case models were run to calculate energy use with the ceiling insulation measure in place.

For climate zone 5, summer peak savings were calculated by taking the difference in demand at the hour when the summer peak is likely to occur. The day of the peak was determined based on

[67] For a list of input values used in these models refer to Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

TMY3 weather data: the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

In order to develop winter peak savings values for all climate zones, a whole home simulation model was developed using EnergyGauge. Prototypical home characteristics (which may diverge from those outlined in Table 2-120) were selected using available data on the construction, occupancy, and equipment characteristics of Texas homes.[68] The predicted annual energy consumption of the model was benchmarked using data from the Energy Information Administration's Residential Energy Consumption Survey (RECS) for homes of similar heating types and floor area. Base and change case models were run using parameters matching the baseline and efficiency conditions of the measure. From the hourly output for each run, a winter peak load factor representing the relationship between energy savings and winter peak savings was calculated as follows:

$$\boldsymbol{Winter\ Peak\ Load\ Factor} = \frac{\boldsymbol{Modeled\ Annual\ Energy\ Savings}}{\boldsymbol{8760 \times Modeled\ Winter\ Peak\ Demand\ Savings}}$$

The winter peak load factor was then applied to the existing deemed savings to derive a value for the winter peak demand savings as follows:

$$\boldsymbol{Winter\ Peak\ Demand\ Savings} = \frac{\boldsymbol{Existing\ Annual\ Energy\ Savings}}{\boldsymbol{8760 \times Winter\ Peak\ Load\ Factor}}$$

Table 2-120: Residential Ceiling Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade, no edge insulation	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model
Base Ceiling Insulation	R-0 to R-22	Existing insulation level

[68] For a list of input values used in these models refer to 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.

Shell Characteristic	Value	Source
Change Ceiling Insulation	R-30	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas
Wall Insulation	R-10.26	ESPRE default based on wood frame, 4" wall stud, sheathing, siding or brick, R-11 insulation with ½" gypsum, SPS Baseline data for 1998 IRP average wall insulation R-10.94
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU's Residential MARS database; U-0.72 represents a mix of single and double pane windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units, NAECA standard is 10.0
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2 HSPF	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

Deemed Energy Savings Tables

Table 2-121 through Table 2-125 present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones.

Table 2-121: Climate Zone 1: Panhandle Region –
Residential Ceiling Insulation Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.86	9.99	5.04
R-1 to R-4	0.52	6.43	3.14
R-5 to R-8	0.24	3.19	1.48
R-9 to R-14	0.11	1.67	0.76
R-15 to R-22	0.05	0.71	0.31

Table 2-122: Climate Zone 2: North Region –
Residential Ceiling Insulation Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	1.22	6.71	3.16
R-1 to R-4	0.79	4.32	2.07
R-5 to R-8	0.40	2.15	1.04
R-9 to R-14	0.21	1.13	0.54
R-15 to R-22	0.09	0.47	0.23

Table 2-123: Climate Zone 3: South Region –
Residential Ceiling Insulation Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	1.00	4.40	2.14
R-1 to R-4	0.64	2.81	1.40
R-5 to R-8	0.32	1.38	0.70
R-9 to R-14	0.17	0.72	0.36
R-15 to R-22	0.07	0.30	0.15

Table 2-124: Climate Zone 4: Valley Region –
Residential Ceiling Insulation Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	1.30	3.64	2.10
R-1 to R-4	0.85	2.33	1.39
R-5 to R-8	0.44	1.15	0.70
R-9 to R-14	0.23	0.60	0.37
R-15 to R-22	0.10	0.25	0.15

Table 2-125: Climate Zone 5: West Region –
Residential Ceiling Insulation Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)*
R-0	2.59	5.66	N/A
R-1 to R-4	1.56	3.48	N/A
R-5 to R-8	1.12	2.28	N/A
R-9 to R-14	0.74	1.54	N/A
R-15 to R-22	0.51	1.10	N/A

* Savings for heat pump are not provided for El Paso.

Deemed Summer Demand Savings Tables

Table 2-126 through Table 2-130 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones.

Table 2-126: Climate Zone 1: Panhandle Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.000973	0.000973
R-1 to R-4	0.000608	0.000622
R-5 to R-8	0.000297	0.000311
R-9 to R-14	0.000153	0.000153
R-15 to R-22	0.000068	0.000074

Table 2-127: Climate Zone 2: North Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.001027	0.001027
R-1 to R-4	0.000622	0.000662
R-5 to R-8	0.000297	0.000311
R-9 to R-14	0.000153	0.000162
R-15 to R-22	0.000074	0.000074

Table 2-128: Climate Zone 3: South Region – Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.000973	0.000973
R-1 to R-4	0.000608	0.000622
R-5 to R-8	0.000297	0.000297
R-9 to R-14	0.000153	0.000153
R-15 to R-22	0.000074	0.000074

Table 2-129: Climate Zone 4: Valley Region – Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.001027	0.001027
R-1 to R-4	0.000622	0.000649
R-5 to R-8	0.000284	0.000297
R-9 to R-14	0.000135	0.000153
R-15 to R-22	0.000068	0.000074

Table 2-130: Climate Zone 5: West Region – Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)*
R-0	0.002053	N/A
R-1 to R-4	0.001200	N/A
R-5 to R-8	0.000860	N/A
R-9 to R-14	0.000531	N/A
R-15 to R-22	0.000275	N/A

* Savings for heat pump are not provided for El Paso.

Deemed Winter Demand Savings Tables

Table 2-131 through Table 2-135 present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

Table 2-131: Climate Zone 1: Panhandle Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.003988	0.001239
R-1 to R-4	0.002468	0.000672
R-5 to R-8	0.001062	0.000300
R-9 to R-14	0.000584	0.000249
R-15 to R-22	0.000268	0.000125

Table 2-132: Climate Zone 2: North Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.002992	0.001053
R-1 to R-4	0.001869	0.000661
R-5 to R-8	0.000796	0.000272
R-9 to R-14	0.000459	0.000150
R-15 to R-22	0.000208	0.000089

Table 2-133: Climate Zone 3: South Region -
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.002192	0.000766
R-1 to R-4	0.001355	0.000492
R-5 to R-8	0.000565	0.000195
R-9 to R-14	0.000329	0.000118
R-15 to R-22	0.000151	0.000067

Table 2-134: Climate Zone 4: Valley Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
R-0	0.001802	0.000748
R-1 to R-4	0.001120	0.000488
R-5 to R-8	0.000483	0.000196
R-9 to R-14	0.000275	0.000114
R-15 to R-22	0.000123	0.000059

Table 2-135: Climate Zone 5: West Region –
Residential Ceiling Insulation Deemed Demand Savings (kW)

Ceiling Insulation Base R-value	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)*
R-0	0.002348	N/A
R-1 to R-4	0.001410	N/A
R-5 to R-8	0.000775	N/A
R-9 to R-14	0.000571	N/A
R-15 to R-22	0.000458	N/A

* Savings for Heat Pump are not provided for El Paso due to the minimal prevalence of homes heated with heat pumps in this region.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[69] the Estimated Useful Life is 25 years for ceiling insulation.

[69] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space heating system type (gas, electric, heat pump) Square footage of ceiling insulation installed above a conditioned space

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-136: Ceiling Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.

2.3.3 Wall Insulation Measure Overview

TRM Measure ID: R-BE-WI

Market Sector: Residential

Measure Category: Building Envelope

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Wall insulation savings are per square foot of treated wall area (gross wall area less window and door area), and are based on R-0 increased to R-13. To qualify for these deemed savings values, wall insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

The baseline is considered to be a house with no wall insulation in the 4 inches wall cavity.

High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by United States Department of Energy (DOE) and Texas Department of Housing & Community Affairs (TDHCA) programs. To qualify for the incentive, there must be no existing wall insulation.

Under the Hard-To-Reach Standard Offer template, wall insulation reduces the ventilation rate in the home and therefore a post-installation blower door test must be conducted. Results must comply with the Minimum Final Ventilation Rate table (Table 2-115) found in the Air Infiltration section of this document.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-137.[70] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of the wall insulation measure. Next, change-case models were run to calculate energy use with the wall insulation in place.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

[70] For a list of input values used in these models refer to Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas and Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

Table 2-137: Residential Wall Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade, no edge insulation	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model
Ceiling Insulation	R-19	Average insulation level in an existing home used in model; SPS Baseline data for 1998 IRP, residential AC replacement programs average ceiling insulation level for existing homes R-20.51 of 1,010 homes in efficiency programs
Base Wall Insulation	R-2.84	ESPRE default based on wood frame, 4" wall stud, sheathing, siding or brick, no insulation with ½" gypsum
Change Wall Insulation	R-13	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU's Residential MARS database; U-0.72 represents a mix of single and double pane windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric-Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2 HSPF	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

Deemed Energy Savings Tables

Table 2-138 through Table 2-142 present the deemed energy savings values for all five Texas climate zones.

Table 2-138: Climate Zone 1: Panhandle Region –
Residential Wall Insulation Deemed Annual Energy Savings (kWh)

Electric A/C,Gas Heat (per sq. ft.)	Electric A/C, Electric Heat (per sq. ft.)	Electric A/C, Heat Pump (per sq. ft.)
0.33586	11.014	6.496

Table 2-139: Climate Zone 2: North Region –
Residential Wall Insulation Deemed Annual Energy Savings (kWh)

Electric A/C, Gas Heat (per sq. ft.)	Electric A/C, Electric Heat (per sq. ft.)	Electric A/C, Heat Pump (per sq. ft.)
0.45875	7.043	2.990

Table 2-140: Climate Zone 3: South Region –
Residential Wall Insulation Deemed Annual Energy Savings (kWh)

Electric A/C, Gas Heat (per sq. ft.)	Electric A/C, Electric Heat (per sq. ft.)	Electric A/C, Heat Pump (per sq. ft.)
0.24242	4.529	1.726

Table 2-141: Climate Zone 4: Valley Region –
Residential Wall Insulation Deemed Annual Energy Savings (kWh)

Electric A/C, Gas Heat (per sq. ft.)	Electric A/C, Electric Heat (per sq. ft.)	Electric A/C, Heat Pump (per sq. ft.)
0.28199	3.273	1.310

Table 2-142: Climate Zone 5: West Region –
Residential Wall Insulation Deemed Annual Energy Savings (kWh)

Electric A/C, Gas Heat (per sq. ft.)	Electric A/C, Electric Heat (per sq. ft.)	Electric A/C, Heat Pump (per sq. ft.)
0.996655	4.214643	N/A

* Savings for heat pump are not provided for El Paso.

Deemed Summer Demand Savings Tables

Table 2-143 through Table 2-147 present the deemed summer demand savings tables for all five Texas climate zones.

Table 2-143: Climate Zone 1: Panhandle Region – Residential Wall Insulation Deemed Demand Savings (kW)

Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
0.0005892	0.0005892

Table 2-144: Climate Zone 2: North Region – Residential Wall Insulation Deemed Demand Savings (kW)

Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
0.0007576	0.0008418

Table 2-145: Climate Zone 3: South Region – Residential Wall Insulation Deemed Demand Savings (kW)

Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
0.0006734	0.0006734

Table 2-146: Climate Zone 4: Valley Region – Residential Wall Insulation Deemed Demand Savings (kW)

Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
0.0007576	0.0007576

Table 2-147: Climate Zone 5: West Region – Residential Wall Insulation Deemed Demand Savings (kW)

Gas Heat & Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
0.000695	N/A

* Savings for heat pump are not provided for El Paso.

Deemed Winter Demand Savings

Table 2-148 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-148: Deemed Winter Peak Demand Savings (kW) – Residential Wall Insulation

Climate Zone	Winter Peak Avg. kW Savings Electric Heat (per sq. ft.)
Zone 1	N/A
Zone 2	N/A
Zone 3	N/A
Zone 4	N/A
Zone 5	0.001218

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for wall insulation.

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Space heating system type (gas, electric, heat pump)
- Cooling system type
- Square footage of retrofitted wall area (gross wall area excluding window and door area)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-149: Wall Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.

2.3.4 Floor Insulation Measure Overview

TRM Measure ID: R-BE-FI

Market Sector: Residential

Measure Category: Building Envelope

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Floor insulation savings are per square foot of treated floor area above a non-conditioned space. To qualify for these deemed savings values, floor insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

The baseline is considered to be a house with pier and beam construction and no floor insulation against the floor of conditioned area.

High-Efficiency Condition

A floor insulation level of R-19 is recommended for site-built homes throughout Texas as prescribed by DOE and Texas Department of Housing & Community Affairs (TDHCA) programs. To qualify for the incentive, there must be no existing floor insulation. Batt insulation is recommended in most cases, and must have the vapor barrier installed facing up and against the floor or conditioned area. Insulation should be attached or secured so that it remains in place for at least 10 years.

Typical floor construction depth of manufactured homes usually does not allow R-19 batt to be installed within the floor joists so R-15 loose-fill insulation is recommended by TDHCA.

A minimum of 24 inches clearance from bottom of the insulation to the ground is required by Occupational Safety and Health Association (OSHA).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy). The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-150[71]. The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of the floor insulation measure. Next, change-case models were run to calculate energy use with the floor insulation measure in place.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is

[71] For a list of input values used in these models refer to Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas and Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

Table 2-150: Residential Floor Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area (site-built)	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Conditioned Area (manufactured home)	1,504 square feet	Average square footage of homes sold since 1983 (1.045 million) from The Manufactured Housing Industry in Texas, 1999 Report. Information in report received from the Texas Department of Housing Community Affairs and Texas Manufactured Housing Association member manufacturers and retailers. Percent of sales of new & used manufactured homes to total sales of new & used single family homes for metropolitan statistical areas is 34.3%.
Foundation	Pier and Beam	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model. Skirting around perimeter is assumed insulated and vented. Ground under home is assumed to be bare, without any type of moisture barrier.
Base Floor Insulation	R-2.36	ESPRE default based on hardwood floor without carpet or other type of covering
Change Floor Insulation	R-19 (except for manufactured housing, R-15)	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas. Due to the typical floor joists depths found in manufactured housing, TDHCA recommends an R-15 loose-fill insulation for manufactured housing and other non-site-built homes.
Ceiling Insulation	R-19	Average insulation level in an existing home used in model; SPS Baseline data for 1998 IRP, residential AC replacement programs average ceiling insulation level for existing homes R-20.51 of 1,010 homes in efficiency programs
Wall Insulation	R-10.26	ESPRE default based on wood frame, 4” wall stud, sheathing, siding or brick, R-11 insulation with ½” gypsum, SPS Baseline data for 1998 IRP average wall insulation R-10.94
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU’s Residential MARS database; U-0.72 represents a mix of single and double pane

Shell Characteristic	Value	Source
		windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units, NAECA standard is 10.0
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2 HSPF	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

Deemed Energy Savings Tables

Table 2-151 through Table 2-155 present the energy savings (kWh) for all five Texas climate zones.

Table 2-151: Climate Zone 1: Panhandle Region –
Residential Floor Insulation Deemed Annual Energy Savings (kWh)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	No Savings[72]	No Savings
Electric Heat	5.00054	4.98271
Heat Pump	2.59838	2.51197

[72] No savings: Some models showed a slight increase in total annual electricity use for adding floor insulation with gas heating. The cooler, bare ground underneath the house acts as a heat sink and draws heat from the house when no insulation is present. With the addition of floor insulation, cooling consumption increased slightly due to the insulation blocking the advantage of the bare ground.

Table 2-152: Climate Zone 2: North Region –
Residential Floor Insulation Deemed Annual Energy Savings (kWh)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.06486	0.03457
Electric Heat	2.93189	2.90027
Heat Pump	1.11730	1.09707

Table 2-153: Climate Zone 3: South Region –
Residential Floor Insulation Deemed Annual Energy Savings (kWh)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	No Savings	No Savings
Electric Heat	1.70757	1.65891
Heat Pump	0.58324	0.55718

Table 2-154: Climate Zone 4: Valley Region –
Residential Floor Insulation Deemed Annual Energy Savings (kWh)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.02378	No Savings
Electric Heat	1.16649	1.12832
Heat Pump	0.42757	0.40359

Table 2-155: Climate Zone 5: West Region –
Residential Floor Insulation Deemed Annual Energy Savings (kWh)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.313416	0.810602
Electric Heat	3.878664	2.594086
Heat Pump	N/A	N/A

* Savings for Heat Pump are not provided for El Paso due to the minimal prevalence of homes heated with heat pumps in this region.

Deemed Summer Demand Savings Tables

Table 2-156 through Table 2-160 present the deemed summer demand savings (kW) for all five Texas climate zones.

Table 2-156: Climate Zone 1: Panhandle Region –
Residential Floor Insulation Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000216	0.000199
Electric Heat	0.000216	0.000199
Heat Pump	0.000216	0.000266

Table 2-157: Climate Zone 2: North Region –
Residential Floor Insulation Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000270	0.000266
Electric Heat	0.000270	0.000266
Heat Pump	0.000270	0.000266

Table 2-158: Climate Zone 3: South Region –
Residential Floor Insulation Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000216	0.000266
Electric Heat	0.000216	0.000266
Heat Pump	0.000216	0.000266

Table 2-159: Climate Zone 4: Valley Region –
Residential Floor Insulation Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000270	0.000266
Electric Heat	0.000270	0.000266
Heat Pump	0.000270	0.000266

Table 2-160: Climate Zone 5: West Region –
Residential Floor Insulation Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000505	0.000003
Electric Heat	0.000505	0.000003
Heat Pump	N/A	N/A

* Savings for heat pump are not provided for El Paso.

Deemed Winter Demand Savings Tables

Table 2-161 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-161: Climate Zone 5: West Region –
Residential Floor Insulation Deemed Winter Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0	0
Electric Heat	0.001577	0.001278
Heat Pump	N/A	N/A

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for floor insulation.

Program Tracking Data & Evaluation Requirements

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

- Space heating system type (gas, electric, heat pump)
- Home type (site built or manufactured)
- Square footage of installed insulation

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-162: Floor Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics.

2.3.5 ENERGY STAR® Windows Measure Overview

TRM Measure ID: R-BE-EW

Market Sector: Residential

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

Measure Category: Building Envelope

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

ENERGY STAR® windows savings are calculated on per square foot of window basis, inclusive of frame and sash. To qualify for these deemed savings values, ENERGY STAR® windows may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline

The baseline is a double-glazed (i.e., double-pane), clear window with an aluminum frame, with a U-factor of 0.87, a solar heat gain coefficient (SHGC) of 0.66, and air infiltration of 1 CFM/sq. ft.

High-Efficiency Condition

For a window to qualify for these deemed savings, it must meet the relevant ENERGY STAR® criteria anywhere in the state. Table 2-163 lists the ENERGY STAR® specifications for windows as of January 2010. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-163: ENERGY STAR® Windows Specifications, January 2010

U.S. Region, ENERGY STAR®	U-Factor Btu/(h·ft²·°F)	Solar Heat Gain Coefficient (SHGC)
North-Central	≤ 0.32	≤ 0.40
South-Central	≤ 0.35	≤ 0.30
Southern	≤ 0.60	≤ 0.27

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

To develop the recommended deemed savings values, we relied on information contained in the NFRC 900 database.[73] To develop deemed savings estimates from the NFRC 900 database, the following steps were taken:

- The difference in energy consumption and electrical demand between a home with base case and change case[74] windows was calculated from the database for the prototypes in Brownsville (Valley Region), San Antonio (South Region), Fort Worth (North Region) and Oklahoma City (a proxy for the Panhandle region).
- The heating fuel energy use reported in the NFRC 900 database was converted into electricity requirements and natural gas requirements, depending upon three alternative assumptions regarding the type of HVAC equipment present in the home (heat pumps, electric resistance heating, or natural gas heating).
- The "per-home" estimates were divided by the total assumed window area (231 sq. ft.) to derive "per-square foot of window" estimates.

Deemed Energy Savings Tables

Table 2-164 through Table 2-167 present the energy savings (kWh) for four Texas climate zones (1, 2, 3 and 4).

[73] The National Fenestration Rating Council has developed a database of the annual energy impacts for various types of windows installed in a typical new, single family, single story residence in various U.S. cities. This database, called NFRC 900, contains results for four Texas cities: Brownsville, El Paso, Fort Worth and San Antonio. Here we will assume the results for Oklahoma City will serve as a reasonable proxy for the energy savings and demand reduction achievable in the Texas Panhandle. The NFRC 900 database was developed by LBNL.

[74] The change case window assumed in the NFRC 900 database exceeds the minimum requirements (U-factor = 0.30, SHGC = 0.29, CFM/ft² = 0.15), and is more representative of higher-end windows, such as those manufactured by Andersen, Pella, or Marvin.

Table 2-164: Climate Zone 1: Panhandle Region –
Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)

Heating Type	kWh Savings (per sq. ft.)
Installed in home with non-electric heating	2.68
Installed in home with electric resistance heating	9.50
Installed in home with heat pump	6.85

Table 2-165: Climate Zone 2: North Region –
Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)

Heating Type	kWh Savings (per sq. ft.)
Installed in home with non-electric heating	3.46
Installed in home with electric resistance heating	6.88
Installed in home with heat pump	5.27

Table 2-166: Climate Zone 3: South Region –
Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)

Heating Type	kWh Savings (per sq. ft.)
Installed in home with non-electric heating	3.81
Installed in home with electric resistance heating	6.48
Installed in home with heat pump	5.26

Table 2-167: Climate Zone 4: Valley Region –
Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)

Heating Type	kWh Savings (per sq. ft.)
Installed in home with non-electric heating	4.72
Installed in home with electric resistance heating	6.06
Installed in home with heat pump	5.35

Deemed Summer Demand Savings Tables

Table 2-168 through Table 2-171 present the summer demand savings tables for four Texas climate zones (1, 2, 3 and 4).

Table 2-168: Climate Zone 1: Panhandle Region – Residential ENERGY STAR® Windows Deemed Demand Savings (kW)

Heating Type	kW Savings (per sq. ft.)
Installed in home with non-electric heating	0.0033
Installed in home with electric resistance heating	0.0033
Installed in home with heat pump	0.0033

Table 2-169: Climate Zone 2: North Region – Residential ENERGY STAR® Windows Deemed Demand Savings (kW)

Heating Type	kW Savings (per sq. ft.)
Installed in home with non-electric heating	0.0028
Installed in home with electric resistance heating	0.0028
Installed in home with heat pump	0.0028

Table 2-170: Climate Zone 3: South Region – Residential ENERGY STAR® Windows Deemed Demand Savings (kW)

Heating Type	kW Savings (per sq. ft.)
Installed in home with non-electric heating	0.0024
Installed in home with electric resistance heating	0.0024
Installed in home with heat pump	0.0024

Table 2-171: Climate Zone 4: Valley Region – Residential ENERGY STAR® Windows Deemed Demand Savings (kW)

Heating Type	kW Savings (per sq. ft.)
Installed in home with non-electric heating	0.0027
Installed in home with electric resistance heating	0.0027
Installed in home with heat pump	0.0027

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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for ENERGY STAR windows.

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Space heating system type (non-electric, electric resistance, heat pump)
- Area of ENERGY STAR® windows installed

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 48. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-172: ENERGY STAR® Windows Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

2.3.6 Solar Screens Measure Overview

TRM Measure ID: R-BE-SC

Market Sector: Residential

Measure Category: Building Envelope

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

To qualify for these deemed savings values, solar screens may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs. Deemed savings are calculated per square foot of window or door opening.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Solar screens must be installed on windows that face east, west, or south, and that receive significant direct sun exposure. Solar screens must block at least 65 percent of the solar heat gain to qualify for deemed savings.

Baseline Condition

The baseline is a single pane, clear glass, unshaded, east, west, or south facing window with a solar heat gain coefficient of 0.75. Baseline window area is assumed to be 10.2 percent of the floor area.

High-Efficiency Condition

To qualify for solar screen deemed savings, windows must be facing predominately east, west, or south, and receive significant direct sun exposure. Solar screen material must reduce solar heat gain by at least 65 percent. Solar screens are not recommended for homes with electric heat.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The RESFEN 3.1 model was developed by LBNL to calculate a prototype home's energy consumption and electrical demand under alternative assumptions regarding the home's windows. This software was used for deemed savings for the solar screen measure since this software was specifically developed to calculate the load attributed to windows.

The results from the RESFEN models were compared to models conducted with ESPRE hourly load simulation software as used for other deemed savings envelope measures. Extensive modeling was conducted in an effort to compare the two modeling software programs. When variables were equalized to the extent possible, the results were similar. The RESFEN software was used for deemed savings for the solar screen measure since it was specifically developed to calculate the load attributed to windows.

The weather regions used in the RESFEN modeling matched previous deemed savings models to the extent possible. Weather data corresponds as follows:

- *Climate Zone 1: Panhandle Region (Oklahoma City, OK weather data)*
- *Climate Zone 2: North Region (Fort Worth weather data)*
- *Climate Zone 3: South Region (San Antonio weather data)*
- *Climate Zone 4: Valley Region (Brownsville weather data)*

The RESFEN software is limited in allowing change for most envelope characteristics, however, an effort was made to match the deemed savings "prototype" house used in other deemed savings models.

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-173.[75] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of solar screens. Next, change-case models were run to calculate energy use with the solar screens in place.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and

[75] For a list of input values used in these models refer to Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

Table 2-173: Residential Solar Screens – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade	
Slab Insulation	Climate Zone 1: R-2	
	All Other Zones: R-0	
Ceiling Insulation	Climate Zone 1: R-38	
	Climate Zone 2: R-30	
	Climate Zone 3: R-26	
	Climate Zone 4: R-19	
Wall Insulation	Climate Zone 1: R-19	
	Climate Zone 2: R-14	
	Climate Zone 3: R-11	
	Climate Zone 4: R-13	
Window Area	10.2% of floor area (~14% of wall area)	
Window U-Value	1.27	Average single pane, clear glass window with aluminum frame. This is the average of 1.25 as documented in the RESFEN Manual and 1.30 as documented in the NFRC 900 database for this type window.
Window SHGC	0.75	Represents the average from RESFEN (0.76) and the NFRC 900 (0.74) database for a single pane, clear glass window with an aluminum frame.
Air Leakage	0.30 CFM/ft^2	
Window Overhang/Shading	Typical	To represent statistically average solar gain reduction for a generic house, option includes: • *Interior shades (Seasonal SHGC multiplier, summer = 0.80, winter = 0.90);* • *1' overhang;* • *and 67% transmitting same-height obstruction 20' away intended to represent adjacent buildings.* To account for other sources of solar heat gain reduction (insect screens, trees, dirt on glass pane, building and window

Shell Characteristic	Value	Source
		self-shading), the SHGC multiplier was further reduced by 0.1. This results in a final winter SHGC multiplier of 0.80 and a final summer SHGC multiplier of 0.70.
Air Infiltration	0.58 ACH	
Air Conditioning or Heat Pump	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency

The model assumes the "average" solar screen installed blocks 80% of the solar heat gain attributed to the east, south and west facing windows. Performance data was available with sun angles at 30, 45 and 75 degrees to the window for a solar screen of this type. A 45° incident angle for direct radiation is typically chosen to represent average conditions.[76] Thus, the average shading coefficient for 1/8" and ¼" clear glass and different screen colors at 45 degrees is 0.305.[77]

Even though it is recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, often they are not removed seasonally. This may be due to solar screens serving as an insect screen in addition to blocking the sun or simply that they're installed in difficult-to-reach areas such as second floor windows. In these deemed savings models, it's assumed the screens remain in place year round.

Thermal Performance Improvement

Manual J and other studies researched indicate a thermal improvement to a window with a solar screen due to reduced air infiltration. The National Certified Testing Laboratories provided a report stating a 15% improvement in the thermal transmittance of a single pane, ¼" clear glass window with a solar screen added to the exterior.

Another study that was conducted for NFRC indicated between a 22% and 4% improvement to the U-value of a window with a solar screen. A single pane, clear window has a 22% improvement with the addition of a solar screen, whereas a double pane, spectrally selective low-E window may only have a 4% improvement. The deemed savings models assume an average 10% improvement in thermal performance with the addition of a solar screen.

Window Frame

The window frame accounts for 10-30%[78] of the window area and since it's opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15% frame area was incorporated into the performance of the window.

[76] "Effect of Shading Devices of Residential Energy Use in Austin, Texas" by the Center of Energy Studies, University of Texas at Austin, June 1988.
[77] Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80% of solar heat gain.
[78] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.

Deemed Energy Savings Tables

Table 2-174 presents the deemed energy savings value per square foot of solar screen installed.

Table 2-174: Deemed Energy (kWh) Savings per Square Foot of Solar Screen

Climate Zone	Gas Heat (per sq. ft.)	Electric Heat (per sq. ft.)	Heat Pump (per sq. ft.)
Climate Zone 1: Panhandle	4.22938	0.45208	1.91859
Climate Zone 2: North	5.18338	2.08937	3.54039
Climate Zone 3: South	5.82998	3.78803	4.72758
Climate Zone 4: Valley	7.03837	6.23033	6.65677
Climate Zone 5: West	7.967266	-0.856480	N/A

Deemed Summer Demand Savings Tables

Table 2-175 presents the deemed summer peak demand savings value per square foot of solar screen installed.

Table 2-175: Deemed Summer Peak Demand (kW) Savings per Square Foot of Solar Screen

Climate Zone	Summer Peak Average kW Savings (per sq. ft.)
Climate Zone 1: Panhandle	0.000954
Climate Zone 2: North	0.002438
Climate Zone 3: South	0.001590
Climate Zone 4: Valley	0.002756
Climate Zone 5: West	0.003412

Deemed Winter Demand Savings Tables

Table 2-176 presents the deemed winter peak demand savings value per square foot of solar screen installed for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-176: Deemed Winter Peak Demand (kW) Savings per Square Foot of Solar Screen

Climate Zone	Winter Peak Average kW Savings (per sq. ft.)
Climate Zone 1: Panhandle	N/A
Climate Zone 2: North	N/A
Climate Zone 3: South	N/A
Climate Zone 4: Valley	N/A
Climate Zone 5: West	-0.004275

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of solar screens is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[79]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Space heating system type (gas, electric, heat pump)
- Square footage of windows or door openings treated

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

[79] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-177: Solar Screens Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Added detail on methodology and model characteristics. Savings awarded for south-facing windows, in addition to east- and west-facing windows.

2.4 RESIDENTIAL: WATER HEATING

2.4.1 Faucet Aerators Measure Overview

TRM Measure ID: R-WH-FA

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves installing aerators on kitchen and bathroom water faucets as a retrofit measure.

Eligibility Criteria

The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable.

These deemed savings are for residential, retrofit-only installation of kitchen and bathroom faucet aerators. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-178: Faucet Aerators – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Energy Policy Act of 1992 (EPAct 92). The deemed savings assume that the existing faucet aerators have a minimum flow rate of 2.2 GPM. The US EPA WaterSense specification for faucet aerators is 1.5 GPM.[80]

Table 2-179: Faucet Aerators – Baseline and Efficiency Standard

Baseline	Efficiency Standard
2.2 GPM minimum	1.5 GPM maximum

High-Efficiency Condition

Aerators that have been defaced so as to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[81,82,83] See Table 2-180 for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\boldsymbol{Faucet\ use\ (gallons) per\ person\ per\ day} \times \boldsymbol{Occupants\ per\ home} \times \frac{\boldsymbol{365 \frac{days}{year}}}{\boldsymbol{Faucets\ per\ home}}$$

Equation 28

[80] http://www.epa.gov/watersense/partners/faucets_final.html.

[81] Seattle Home Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." December 2000. http://allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=856.

[82] Residential Indoor Water Conservation Study: "Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July 2003. http://www.ebmud.com/sites/default/files/pdfs/residential_indoor_wc_study_0.pdf.

[83] Tampa Water Department Residential Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." January 8, 2004. www.cuwcc.org/WorkArea/downloadasset.aspx?id=12162.

Applying the formula to the values used for Texas from Table 2-180 returns the following values for baseline and post water consumption.

$$\boldsymbol{Baseline}: \mathbf{9.7} \times \mathbf{2.79} \times {}^{\mathbf{365}}/_{\mathbf{3.93}} = \mathbf{2,513}$$

Equation 29

$$\boldsymbol{Post}\ (\mathbf{1.5}\ \boldsymbol{GPM}): \mathbf{8.2} \times \mathbf{2.79} \times {}^{\mathbf{365}}/_{\mathbf{3.93}} = \mathbf{2,125}$$

Equation 30

$$\boldsymbol{Post}\ (\mathbf{1.0}\ \boldsymbol{GPM}): \mathbf{7.2} \times \mathbf{2.79} \times {}^{\mathbf{365}}/_{\mathbf{3.93}} = \mathbf{1,866}$$

Equation 31

Gallons of hot water saved per year can be found by subtracting the post consumption in gallons per year per aerator from the baseline consumption, and then multiplying the result by the percent hot water.

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year}\ (\mathbf{1.5}\ \boldsymbol{GPM}): (\mathbf{2,513} - \mathbf{2,125}) \times \mathbf{0.669} = \mathbf{260}$$

Equation 32

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year}\ (\mathbf{1.0}\ \boldsymbol{GPM}): (\mathbf{2,513} - \mathbf{1,866}) \times \mathbf{0.669} = \mathbf{433}$$

Equation 33

Table 2-180: Estimated Aerator Hot Water Usage Reduction

	Sample Studies			Average	Value used for Texas
	Seattle	Tampa	East Bay		
Faucet use gallons/person/day (baseline)	9.2	9.4	10.5	9.7	**9.7**
Faucet use gallons/person/day (1.5 GPM)	8.0	6.2	10.5	8.2	**8.2**
Faucet use gallons/person/day (1.0 GPM)*	N/A				**7.2**
Occupants per home**	2.54	2.92	2.56	2.67	**2.79**
Faucets per home***	N/A				**3.93**
Gallons/year/faucet (baseline)	N/A				**2,513**
Gallons/year /faucet (1.5 GPM)	N/A				**2,125**
Gallons/year /faucet (1.0 GPM)	N/A				**1,866**
Percent hot water	76.1%	not listed	57.6%	66.9%	**66.9%**
DHW gallons saved/year/faucet for 1.5 GPM	N/A				**260**
DHW gallons saved/year/faucet for 1.0 GPM	N/A				**433**

Notes:

*This value is a linear extrapolation of gallons per person per day from the baseline (2.2 GPM) and the 1.5 GPM case.

** Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2007-2011." Accessed January 2013 http://quickfacts.census.gov/qfd/states/48000.html.

*** Faucets per home assumed to be equal to one plus the number of half bathrooms and full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Energy Savings Algorithms

The deemed savings, for any faucet aerator change case using aerators with flow rates of 1.5 GPM or lower, are calculated as follows:

$$\boldsymbol{Energy\ Savings} = \frac{\boldsymbol{\rho \times C_P \times V \times \left(T_{SetPoint} - T_{SupplyAverage}\right) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}}$$

Equation 34

Where:

ρ	=	*Water density, 8.33 lbs./gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
V	=	*Gallons of hot water saved per year per faucet (see Table 2-180)*
$T_{SetPoint}$	=	*Water heater setpoint (default value 120°F)*[84]
$T_{SupplyAverage}$	=	*Average supply water temperature (see Table 2-181)*
RE	=	*Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[85]
ConversionFactor	=	*3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings} = \frac{\boldsymbol{\rho \times C_P \times V \times \left(T_{SetPoint} - T_{SupplySeasonal}\right) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}} \times \boldsymbol{Ratio}_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 35

Where:

$T_{SupplySeasonal}$	=	*Seasonal supply water temperature (Table 2-181)*
$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$	=	*Ratio of peak seasonal kW to annual kWh savings (Table 2-182)*

[84] Note that the temperature of the water at faucet is likely to be lower, due to thermal losses in the water pipe system within the home, and tempering of the water temperature by the user.

[85] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Table 2-181: Water Mains Temperature

Climate Zone	Water Mains Temperature °F*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

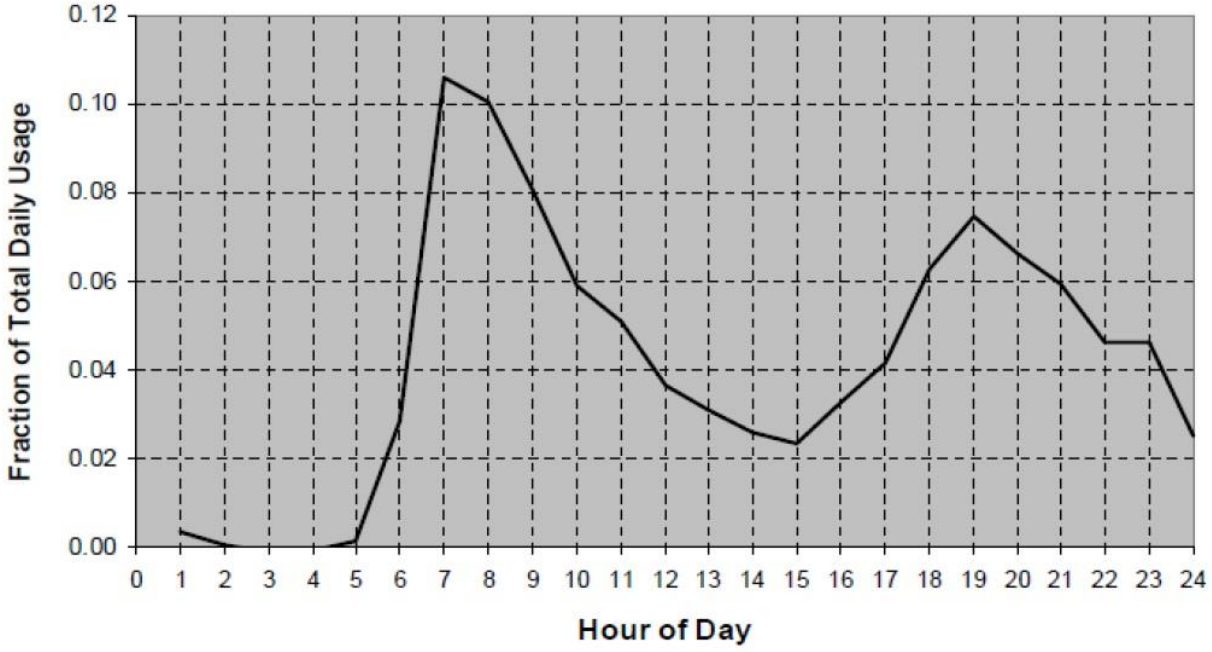
Table 2-182: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	**Winter**
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5PM, winter: 7-8AM) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.

Figure 2-3: Shower, Bath, and Sink Hot Water Use Profile



Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a faucet aerator is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[86]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of faucet installed
- Water heater type (e.g., heat pump, electric resistance)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-183: Faucet Aerators Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

[86] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.2 Low-Flow Showerheads Measure Overview

TRM Measure ID: R-WH-SH

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences.

Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at 2.0, 1.7, or 1.5 gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit measure in existing homes. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-184: Low-Flow Showerheads – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[87] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[88]

[87] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37

Table 2-185: Low-Flow Showerhead – Baseline and Efficiency Standards

Existing Showerhead Baseline Flow Rate	New Showerhead Flow Rate*
2.5 GPM maximum	1.5 GPM, 1.75 GPM or 2.0 GPM maximum

* All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

High-Efficiency Condition

In addition to the meeting the baseline requirements above, existing showerheads that have been defaced so as to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[89,90,91] See for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\boldsymbol{Gallons\ per\ shower} \times \boldsymbol{Showers\ per\ person\ per\ day} \times \mathbf{365}\ \frac{\boldsymbol{days}}{\boldsymbol{year}} \times \frac{\boldsymbol{Occupants\ per\ home}}{\boldsymbol{Showerheads\ per\ home}}$$

Equation 36

Applying the formula to the values used for Texas from Table 2-186 returns the following values for baseline and post water consumption:

$$\boldsymbol{Baseline}\ (\mathbf{2.5}\ \boldsymbol{GPM})\mathbf{: 20.7 \times 0.69 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 8,658}$$

[88] http://www.epa.gov/watersense/products/showerheads.html
[89] Seattle Home Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." December 2000. http://allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=856.
[90] Residential Indoor Water Conservation Study: "Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July 2003. http://www.ebmud.com/sites/default/files/pdfs/residential_indoor_wc_study_0.pdf.
[91] Tampa Water Department Residential Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." January 8, 2004. www.cuwcc.org/WorkArea/downloadasset.aspx?id=12162.

$$\textbf{\textit{Post-retrofit}}\ (\mathbf{2.0\ GPM}): \mathbf{16.5 \times 0.72 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 7,201}$$

$$\textbf{\textit{Post-retrofit}}\ (\mathbf{1.5\ GPM}): \mathbf{12.4 \times 0.72 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 5,412}$$

Equation 37

Although the referenced studies do not provide data on 1.75 GPM showerheads, the consumption values for 2.5, 2.0, and 1.5 GPM roughly follow a linear pattern. Taking a simple average of the consumption for 2.0 and 1.5 GPM showerheads returns a value for a 1.75 GPM showerhead:

$$\textbf{\textit{Post-retrofit}}\ (\mathbf{1.75\ GPM}): (\mathbf{7,201 + 5,412})/\mathbf{2 = 6,306}$$

Equation 38

Gallons of hot water saved per year can be found by subtracting the post consumption in gallons per year per showerhead from the baseline consumption, and then multiplying the result by the percent hot water.

$$\textbf{\textit{Gallons of hot water saved per year}}\ (\mathbf{2.0\ GPM}): (\mathbf{8,658 - 7,201}) \times \mathbf{0.737 = 1,074}$$

$$\textbf{\textit{Gallons of hot water saved per year}}\ (\mathbf{1.75\ GPM}): (\mathbf{8,658 - 6,306}) \times \mathbf{0.737 = 1,733}$$

$$\textbf{\textit{Gallons of hot water saved per year}}\ (\mathbf{1.5\ GPM}): (\mathbf{8,658 - 5,412}) \times \mathbf{0.737 = 2,392}$$

Equation 39

Table 2-186: Estimated Showerhead Hot Water Usage Reduction

	Sample Studies			Average	Value used for Texas
	Seattle	Tampa	East Bay		
Gallons/shower @ 2.5 GPM (baseline)	19.8	20	22.3	20.7	**20.7**
Gallons/shower @ 2.0 GPM	15.8	16	17.8	16.5	**16.5**
Gallons/shower @ 1.5 GPM	11.9	12	13.4	12.4	**12.4**
Showers/person/day (baseline)	0.51	0.92	0.65	0.69	**0.69**
Showers/person/day (post)	0.59	0.82	0.74	0.72	**0.72**
Occupants per home*	2.54	2.92	2.56	2.67	**2.79**
Showerheads per home**	N/A				**1.68**
Gallons/year/showerhead @ 2.5 GPM (baseline)	N/A				**8,658**
Gallons/year /showerhead @ 2.0 GPM	N/A				**7,201**
Gallons/year /showerhead @ 1.75 GPM	N/A				**6,306**
Gallons/year /showerhead @ 1.5 GPM	N/A				**5,412**

	Sample Studies			Average	Value used for Texas
	Seattle	Tampa	East Bay		
Percent hot water	75.50%	not listed	71.90%	73.70%	**73.70%**
2.0 gpm showerhead DHW gallons saved /year	N/A				**1,074**
1.75 gpm showerhead DHW gallons saved /year	N/A				**1,733**
1.5 gpm showerhead DHW gallons saved /year	N/A				**2,392**

Notes:
* Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2007-2011." Accessed January 2013 http://quickfacts.census.gov/qfd/states/48000.html.
** Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage}) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}}$$

Equation 40

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

V = *Gallons of hot water saved per year per showerhead (see Table 2-186)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F*[92]

T_{Supply} = *Average supply water temperature (see Table 2-187)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water* heaters.[93]

$ConversionFactor$ = *3,412 Btu/kWh*

[92] Hot water consumption accounts for thermal losses delivering hot water to the showerhead, and tempering to typical shower temperature.
[93] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$Demand\ Savings = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal}) \times \left(\frac{1}{RE}\right)}{Conversion\ Factor} \times Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 41

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 2-187)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 2-188)*

Table 2-187: Water Mains Temperature

Climate Zone	Water Mains Temperature (°F)*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

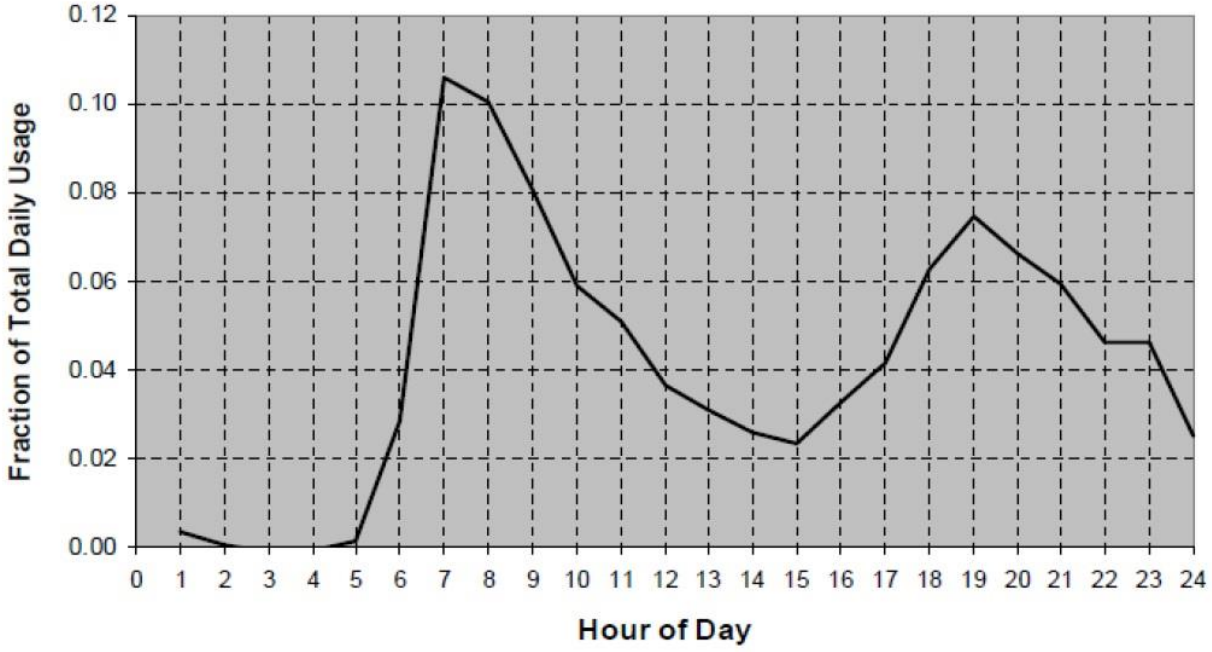
Table 2-188: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	Winter
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5pm, winter: 7-8am) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.

Figure 2-4: Shower, Bath, and Sink Hot Water Use Profile



Source: Building America Performance Analysis Procedures for Existing Homes

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a low-flow showerhead is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[94]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (e.g., heat pump, electric resistance)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-189: Low-Flow Showerheads Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

[94] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.3 Water Heater Pipe Insulation Measure Overview

TRM Measure ID: R-WH-PI

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of pipe insulation on un-insulated water heater pipes that are served by an electric water heater.

Eligibility Criteria

Water heaters plumbed with heat traps are not eligible to receive incentives for this measure. It is recommended that the installer (or contractor) checks to see if the water heater heat trap works properly before declaring the water heater ineligible.

Water heater pipe insulation is a residential retrofit measure. New construction and retrofits involving the installation of new water heaters are not eligible for this measure, because they must meet current code requirements. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-190: Water Heater Pipe Insulation – Applicability

Application Type	Applicable	Notes
Retrofit	Y	Savings cannot be claimed in conjunction with the installation of a new water heater.
New Construction	N	

Baseline Condition

The baseline is assumed to be a typical electric water heater with no heat traps and no insulation on water heater pipes.

Table 2-191: Water Heater Pipe Insulation – Baseline Standard

Baseline
Un-insulated hot water pipes

High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3. The International Residential Code (IRC) 2009 section N1103.3: Mechanical system piping insulation requires R-3 insulation.

Table 2-192: Water Heater Pipe Insulation – Efficiency Standard

Efficiency Standard
Minimum insulation of R-3

All visible hot water piping must be insulated. Savings are based on a maximum allowable insulation length of 6 feet of piping.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Hot water pipe insulation energy savings are calculated using the following formula:

$$\boldsymbol{Energy\ savings\ per\ year} = \left(\boldsymbol{U_{pre} - U_{post}}\right) \times \boldsymbol{A} \times \left(\boldsymbol{T_{pipe} - T_{ambient\ annual}}\right) \times \left(\frac{\boldsymbol{1}}{\boldsymbol{RE}}\right) \times \frac{\boldsymbol{Hours_{Total}}}{\boldsymbol{conversion\ factor}}$$

Equation 42

Where:

U_{pre}[95] = $\frac{1}{2.03} = 0.49\ {}^{Btu}/_{hr \cdot sq.ft. \cdot °F}$

U_{post} = $\frac{1}{2.03 + R_{Insulation}}$

$R_{Insulation}$ = *R-value of installed insulation*

A = *Pipe surface area insulated in square feet* (πDL) *with L (length) and D (pipe diameter) in feet. The maximum length allowable for insulation is 6 feet. If the pipe area is unknown, use the following table:*

[95] 2.03 is the R-value representing the film coefficients between water and the inside of the pipe, and between the surface and air. Mark's Standard Handbook for Mechanical Engineers, 8th edition.

Table 2-193: Estimated Pipe Surface Area

Pipe Diameter (inches)	Pipe Surface Area (square feet)[96]
0.5	0.16 x required input "Pipe Length insulated (feet)"
0.75	0.23 x required input "Pipe Length insulated (feet)"
1.0	0.29 x required input "Pipe Length insulated (feet)"

$T_{pipe}(°F)$ = *120°F*[97]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-194)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[98]

$Hours_{Total}$ = *8,760 hr per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textbf{Pipe Insulation Demand Savings } (kW) = (U_{pre} - U_{post}) \times A \times (T_{Pipe} - T_{ambient\ seasonal}) \times \left(\frac{1}{RE}\right) \times \frac{1}{conversion\ factor}$$

Equation 43

Where:

$T_{ambientseasonal}(°F)$ = *Ambient seasonal temperature (see Table 2-194)*

[96] Factors used in the calculation for pipe area were determined by using the outside diameter of the pipe in inches, converting it to feet, and multiplying by π.

Nominal Diameter (inches)	Outside Diameter (inches)	Factor to Calculate Pipe Area
0.5	0.625	0.16
0.75	0.875	0.23
1.0	1.125	0.29

[97] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 102.

[98] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Table 2-194: Ambient Temperatures per Climate Zone

Climate Zone		Ambient Temperature (°F)					
		Water Heater Location: Unconditioned Space*			Water Heater Location: Conditioned Space**		
		Annual	Peak Seasonal		Annual	Peak Seasonal	
			Summer	Winter		Summer	Winter
1	Panhandle	65.5	106	32	72.7	75.1	69.3
2	North	73.1	108.1	42			
3	South	76.3	108.2	46			
4	Valley	78.4	103	55			
5	West	71.8	108	41.1			

* Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of water heater pipe insulation installed for an electric water heater is established at 13 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[99]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- The R-value of the installed insulation
- Recovery Efficiency (RE) or COP, if available
- Pipe length insulated (feet)
- The pipe surface area insulated in square feet (at least the pipe diameter in inches)

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-195: Water Heater Pipe Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

[99] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.4 Water Heater Tank Insulation Measure Overview

TRM Measure ID: R-WH-WJ

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of tank insulation on un-insulated water heater tanks that are served by an electric water heater.

Eligibility Criteria

Water heaters meeting the National Appliance Energy Conservation Act standards with respect to insulation and standby loss requirements are not eligible for this measure. To ensure compliance, the contractor shall inspect the build date listed on the existing water heater label and verify that the listed build date is before 1991.

Water heater pipe insulation is a residential retrofit measure. New construction and water heater replacements are not eligible for this measure, because they must meet current code requirements. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-196: Water Heater Tank Insulation – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation.

High-Efficiency Condition

There is no minimum insulation requirement. Manufacturer's instructions on the water heater jacket and the water heater itself should be followed. Thermostat and heating element access panels must be left uncovered.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Hot water tank insulation energy savings are calculated using the following formula:

$$\boldsymbol{Energy\ savings\ per\ year} = \left(\boldsymbol{U_{pre} - U_{post}}\right) \times \boldsymbol{A} \times \left(\boldsymbol{T_{tank} - T_{ambient\ annual}}\right) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\boldsymbol{Hours_{Total}}}{\boldsymbol{conversion\ factor}}$$

Equation 44

Where:

U_{pre} = *1/(5) Btu/hr sq.ft. °F*

U_{post} = *1/(5+*$R_{Insulation}$*)*

$R_{Insulation}$ = *R-value of installed insulation*

A = *Tank surface area insulated in square feet* (πDL) *with L (length) and D (tank diameter) in feet. If the tank area is not known, use .*

Table 2-197: Estimated Tank Area

Volume (gal)	A (sf.)*
30	17.45
40	21.81
50	22.63
60	26.94
80	30.36
120	38.73

* Tank area was obtained from a survey of electric water heater manufacturer data. Dimensions for each tank size were collected and averaged to determine a typical square footage of each size water heater. Accessed April 2013: http://www.hotwater.com/water-heaters/residential/conventional/electric/promax/standard/. Accessed April 2013: http://www.whirlpoolwaterheaters.com/products/electric-water-heaters/es40r92-45d/.

$T_{tank}(°F)$ = *Average temperature of the tank, default use 120°F* [100]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-198)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[101]

$Hours_{Total}$ = *8,760 hours per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textbf{Tank Insulation Demand Savings (kW)} = (U_{pre} - U_{post}) \times A \times (T_{Tank} - T_{ambient\ seasonal}) \times \frac{1}{RE} \times \frac{1}{conversion\ factor}$$

Equation 45

Where:

$T_{ambientseasonal}(°F)$ = *Ambient seasonal temperature (see Table 2-227)*

Table 2-198: Ambient Temperatures per Climate Zone

Climate Zone		Ambient Temperature (°F)					
		Water Heater Location: Unconditioned Space			Water Heater Location: Conditioned Space		
		Annual	Peak Seasonal		Annual	Peak Seasonal	
			Summer	Winter		Summer	Winter
1	Panhandle	65.5	106	32	72.7	75.1	69.3
2	North	73.1	108.1	42			
3	South	76.3	108.2	46			
4	Valley	78.4	103	55			
5	West	71.8	108	41.1			

* Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[100] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
[101] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for storage water heater tank insulation is established at 7 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[102]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- Recovery Efficiency (RE) or COP, if available
- The R-value of the installed insulation
- Tank surface area insulated in square feet (πDL) with L (length) and D (tank diameter) in feet; if unable to determine tank area, tank volume must be recorded.

[102] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-199: Water Heater Tank Insulation Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

2.4.5 Water Heater Installation – Electric Tankless and Fuel Substitution Measure Overview[103]

TRM Measure ID: R-WH-WH

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves the installation of a new electric tankless or gas-fueled water heater (storage or tankless) in place of an electric storage water heater.

These deemed savings are calculated using the federal standards effective April 16, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).

Eligibility Criteria

This measure involves the installation of a gas storage, gas tankless (instantaneous), or electric tankless water heater in place of an electric storage water heater, as long as the new unit meets all other requirements described below. Heat pump water heaters are not eligible for installation through this measure (see separate heat pump water heater measure). Currently, there are no conventional, electrically-fueled storage units that sufficiently exceed the new federal standard to merit inclusion as an efficient condition in these deemed savings; therefore, deemed savings are only calculated for new gas storage, gas tankless, and electric tankless systems. Electric tankless water heaters may only replace systems with tanks less than 55 gallons.

[103] Previous versions of this measure included an incentive for installation of high efficiency conventional (electric resistance) storage water heaters. Increments to the federal standard for electric storage water heaters set to go into effect April 16, 2015, eliminate the feasibility of continuing to provide deemed savings for these units.

These deemed savings are for water heater replacements installed as a replace-on-burnout/new construction measure or as an early retirement measure. However, savings are calculated under the assumption of replace-on-burnout/new construction. Savings may be awarded for installations in newly-constructed homes where customer and utility representatives provide written indication that an electric storage water heater would otherwise have been installed. Relevant design documentation showing an electric storage water heater should also be provided.

Table 2-200: Water Heater Replacement – Applicability

Application Type	Applicable
Replace-on-Burnout	Y
Early Retirement	Y
New Construction	Y*

* Subject to documentation requirements described above.

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes 20 – 120 gallons, which take effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register:[104]

Table 2-201: Water Heater Replacement – Baseline

Rated Storage Volume	Energy Factor
≥ 20 gal and ≤ 55 gal	$0.960 – (0.0003*V_s)$
> 55 gal and ≤ 120 gal	$2.057 – (0.00113*V_s)$

where V_s is the volume of the water heater's storage tank. Water heaters above 55 gal in volume are presumed to be heat pump water heaters. This baseline assumes a replace-on-burnout scenario.

High-Efficiency Condition

For fuel substitution, the unit must meet the federal minimum energy factor (EF) for a gas water heater. Water heaters must be installed in accordance with local code requirements.

Table 2-202: Water Heater Replacement – Efficiency Standards

Energy Source	Tank Volume (unit being replaced)	Standard EF
Electric Tankless	≥ 20 gal and ≤ 55 gal	EF = 0.98*
	> 55 gal	N/A
Gas Tankless	≥ 20 gal	$EF = 0.82 – 0.0019 * V_s$

[104] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

Gas Storage	≥ 20 gal and ≤ 55 gal	EF = 0.675 – 0.0015 * V_s
	> 55 gal	EF = 0.8012 – 0.00078 * V_s

* The lowest energy factor (EF) associated with an electric tankless water heater in the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database is 0.98 as of March 2014. http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

** V_s is the rated storage volume of the new water heater.

Note that some installations may result in negative energy savings but positive demand savings.

Table 2-203: Storage Water Heater Energy Factors for Common Tank Volumes (not exhaustive)

Fuel Type	Tank Volume (Gallons)			
	30	40	50	80
Baseline – Electric Storage	0.951	0.948	0.945	1.967
Efficiency Standard – Gas Storage	0.630	0.615	0.600	0.739

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout/new construction scenario, but may be used to award savings for early retirement projects.

Electric Tankless Water Heater

Energy Savings Algorithm

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,ann}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{3,412 Btu/kWh}$$

Equation 46

Where:

ρ = *Water density, 8.33 lbs/gallons*

C_p = *Specific heat of water, 1 Btu/lb·°F*

GPY = *Estimated annual hot water use (gal/year), specified by number of bedrooms in the home in Table 2-204.*

Table 2-204: Water Heater Consumption (gal/year)*

Climate Zone		Number of Bedrooms			
		1	2	3	4
1	Panhandle	15,476	20,171	24,866	29,561
2	North	14,778	19,244	23,710	28,177
3	South	14,492	18,864	23,236	27,608
4	Valley	14,213	18,494	22,775	27,056
5	West	14,905	19,412	23,920	28,427

* Building America Research Benchmark Definition, December 2009 (http://www.nrel.gov/docs/fy10osti/47246.pdf).

$T_{SetPoint}$ = *Water heater setpoint = 120°F*

$T_{Supply,ann}$ = *Annual average mains temperature from Table 2-234*

EF_{pre} = *Baseline value from Table 2-203, or calculated per Table 2-201*[105]

EF_{post} = *Energy Factor of new water heater*

Conversion Factor = $3{,}412\ Btu/kWh$

Table 2-205: Water Mains Temperature

Climate Zone		Water Mains Temperature °F		
		T Supply Average	T Supply Seasonal	
			Summer	Winter
1	Panhandle	62.9	73.8	53.7
2	North	71.8	84.0	60.6
3	South	74.7	84.5	65.5
4	Valley	77.2	86.1	68.5
5	West	70.4	81.5	60.4

Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

[105] Note that for efficient water heater installations in newly-constructed homes, the baseline efficiency EF_{pre} is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

Demand Savings Algorithm

$$\boldsymbol{SummerkW_{savings}} = \frac{\mathbf{1}}{\mathbf{24}} \times \frac{\boldsymbol{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,sum}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}}{\mathbf{365 \times 3,412 \frac{Btu}{kWh}}}$$

Equation 47

$$\boldsymbol{WinterkW_{savings}} = \frac{\mathbf{1}}{\mathbf{24}} \times \frac{\boldsymbol{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,win}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}}{\mathbf{365 \times 3,412 \frac{Btu}{kWh}}}$$

Equation 48

Where:

$\frac{1}{24}$	=	*Conversion from daily energy use to hourly. Because electric-electric replacement savings are driven entirely by reduction in storage losses, storage losses are assumed to be evenly spread throughout the day, rather than consumption driven.*
GPY	=	*Estimated annual hot water use (gal/year), specified by number of bedrooms in the home in Table 2-204*
$T_{Supply,sum}$	=	*Summer average water mains temperature from Table 2-205*
$T_{Supply,win}$	=	*Winter average water mains temperature from Table 2-205*

Gas Storage or Tankless Water Heater (Fuel Substitution)

Energy Savings Algorithm

$$\boldsymbol{kWh_{savings}} = \frac{\boldsymbol{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,ann}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{2.46 \times EF_{post}}\right)}}{\mathbf{3,412 \frac{Btu}{kWh}}}$$

Equation 49

Where:

2.46	=	*Site-to-source conversion to convert Therms into kWh equivalent based on the ERCOT fuel mix-weighted average heat rate*[106]

Demand Savings Algorithm

$$\boldsymbol{SummerkW_{savings} = Ratio_{daily\ gal}^{Sum\ peak\ gal} \times \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,sum}) \times \left(\frac{1}{EF_{pre}}\right)}{365 \times 3,412 \frac{Btu}{kWh}}}$$

Equation 50

$$\boldsymbol{WinterkW_{savings} = Ratio_{daily\ gal}^{Win\ peak\ gal} \times \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,win}) \times \left(\frac{1}{EF_{pre}}\right)}{365 \times 3,412 \frac{Btu}{kWh}}}$$

Equation 51

Where:

$\text{Ratio}_{\text{dailygal}}^{\text{Sumpeakgal}}$	=	*Ratio of hot water use during the typical summer peak hour (4-5pm) to daily hot water use = 0.0436. Because savings are consumption-driven for electric-gas replacement, the portion of water consumption is used rather than assuming savings are evenly distributed throughout the day.*
$\text{Ratio}_{\text{dailygal}}^{\text{Winpeakgal}}$	=	*Ratio of average hot water use during the winter peak hour (8am) to daily hot water use = 0.0794*

Examples

Example 1. An old 40 gallon electric water heater in a two bedroom home in Dallas is replaced with a new, tankless electric water heater with an EF of 0.99

$$\boldsymbol{kWh\ savings = \frac{[8.33 \times 1 \times 19,244 \times (120 - 71.8) \times (\frac{1}{0.948} - \frac{1}{0.99})]}{3,412} = 101.3\ kWh}$$

$$\boldsymbol{Summer\ kW\ savings = \frac{1}{24} \times \frac{[8.33 \times 1 \times 19,244 \times (120 - 84) \times (\frac{1}{0.948} - \frac{1}{0.99})]}{365 \times 3,412} = 0.009\ kW}$$

$$\boldsymbol{Winter\ kW\ savings = \frac{1}{24} \times \frac{[8.33 \times 1 \times 19,244 \times (120 - 60.6) \times (\frac{1}{0.948} - \frac{1}{0.99})]}{365 \times 3,412} = 0.014\ kW}$$

[106] ERCOT's fuel mix in 2012 was 44.6% natural gas, 33.8% coal, 11.8% nuclear, 9.2% wind, and 0.6% hydro/other (http://www.ercot.com/news/press_releases/show/26382). Per DOE the average heat rate is 8,185 Btu/kWh for natural gas, 10,415 for coal, and 10,452 for nuclear. (http://www.eia.gov/electricity/annual/pdf/table5.3.pdf). For wind, hydro, and other a heat rate of 0 is assumed, i.e., that electricity is produced without the marginal use of source fuel. The result is an average heat rate of 8,404 Btu/kWh, or 2.46 source Btu per generated Btu.

Example 2. An old 30 gallon electric water heater in a one bedroom house in El Paso is replaced with a new gas storage water heater with an EF of 0.65

$$kWh\ savings = \frac{[8.33 \times 1 \times 14,905 \times (120 - 70.4) \times (\frac{1}{0.951} - \frac{1}{2.46 \times 0.65})]}{3,412} = 769.1\ \text{kWh}$$

$$Summer\ kW\ savings = 0.0436 \times \frac{[8.33 \times 1 \times 14,905 \times (120 - 81.5) \times (\frac{1}{0.951})]}{365 \times 3,412} = 0.176\ \text{kW}$$

$$Winter\ kW\ savings = 0.0794 \times \frac{[8.33 \times 1 \times 14,905 \times (120 - 60.4) \times (\frac{1}{0.951})]}{365 \times 3,412} = 0.496\ \text{kW}$$

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 Estimated Useful Lives for equipment installed in this measure are: 20 years for a tankless water heater (gas or electric), or 11 years for a high efficiency gas water heater.

These values are consistent with the EULs reported in the 2014 California Database for Energy Efficiency Resources (DEER).[107]

[107] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

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
- Volume of the replacement water heater in gallons (zero if tankless)
- Volume of the existing water heater in gallons
- Energy factor (EF) of the existing water heater
- EF of the replacement water heater
- Number of bedrooms
- Form signed by customer and utility representative indicating planned electric storage water heater installation (New Construction only)
- Design documents indicating planned electric storage water heater installation (New Construction only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-206: Water Heater Installation – Electric Tankless and Fuel Substitution Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Measure updated to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New construction permitted to claim savings subject to documentation requirements. Gas-fueled tankless water heaters made eligible for installation.

2.4.6 Heat Pump Water Heater Measure Overview

TRM Measure ID: R-WH-HW

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The residential heat pump water heater (HPWH) measure involves the installation of an integrated or "drop-in" ENERGY STAR® HPWH. Deemed savings values are presented on a per-unit basis. Deemed savings variables include storage tank volume and HPWH installation location (in conditioned or unconditioned space). In addition, this measure accounts for the interactive air-conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.[108]

These deemed savings are calculated using the federal standards effective April 16, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).

Eligibility Criteria

This measure applies to residential, electric, storage-type water heaters with storage capacities between 40 and 80 gallons. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

These deemed savings are for Heat Pump Water Heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes. However, savings are calculated under the assumption of replace-on-burnout.

[108] Because the latest manufacturer standards effectively require heat pump water heaters (assuming electric water heating) for residential units with storage tank size greater than 55 gallons. As such, interactive effects are essentially the same for base and change case systems, so they are ignored.

Table 2-207: Heat Pump Water Heaters – Applicability

Application Type	Applicable	Notes
Replace-on-Burnout	Y	For replacement of electric storage water heater
Early Retirement	Y	Awarded savings calculated for replace-on-burnout
New Construction	N	

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency determined by tank size based on the amended federal energy efficiency standards for residential water heaters with tank sizes 20 – 120 gallons, as published in 10 CFR Part 430.32 of the Federal Register:[109]

Table 2-208: Federal Standard for Residential Water Heaters

Rated Storage Volume	Energy Factor
≥ 20 gal and ≤ 55 gal	$0.960 – (0.0003*V_s)$
> 55 gal and ≤ 120 gal	$2.057 – (0.00113*V_s)$

Application of this equation provides the following baseline efficiency levels for electric storage water heaters.

Table 2-209: Heat Pump Water Heaters –
Minimum Required Energy Factors for Post-2004 Water Heaters

Tank Size (Gallons)			
40	**50**	**60**	**80**
0.948	0.945	1.989	1.967

The new DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank size greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source. This baseline assumes a replace-on-burnout scenario.

[109] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

High-Efficiency Condition

The efficient condition (i.e., equipment eligible to receive an incentive through a program) is a heat pump water heater that meets ENERGY STAR® qualifications.[110] Heat pump water heaters depend on adequate ventilation for proper functioning, including adequate space for both inlet and outlet air flow, and should be installed in spaces in which temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round, and provide a minimum of 1,000 cubic feet of air space around the water heater.[111]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Four basic variables specify the appropriate deemed demand and energy savings values for a given project:

- The climate zone
- The HPWH tank size
- The HPWH installed location (Conditioned vs. Unconditioned Space)
- For HPWH installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

Deemed savings are estimated using an energy factor (EF) of 2.4. This EF is the average efficiency of ENERGY STAR® HPWHs as of February 2014.[112]

Deemed Energy Savings Tables

Deemed savings are developed for heat pump water heaters in four size ranges: 40-49 gallon, 50-59 gallons, 60-79 gallons, and 80 or more gallon sizes. These sizes correspond to the four basic sizes of HPWHs commercially available at the time these deemed savings were developed, according to review of manufacturer data provided on the ENERGY STAR® and AHRI websites. Table 2-210 through Table 2-214 present the deemed saving tables for five Texas climate zones. These tables assume a replace-on-burnout scenario, but may be used to award savings for early retirement projects.

[110] ENERGY STAR® Requirements (as of February 2014): HPWH must have a maximum current rating of 24 amperes, voltage no greater than 250 volts, and a transfer of thermal energy from one temperature to a higher temperature level for the purpose of heating water. Unit must have "integrated" or "drop-in" configuration. EF ≥ 2.0, first-hour rating (FHR) ≥ 50 gallons/hour, Warranty ≥ 6 years on sealed systems, Safety UL 174 & UL 1995.

[111] Heat Pump Water Heaters. Department of Energy, May 2012. Online. Available: http://energy.gov/energysaver/articles/heat-pump-water-heaters. Accessed: February 22, 2013.

[112] As of February 2014, the ENERGY STAR® products list includes thirty residential heat pump water heaters with energy factors ranging from 2.2 to 2.75.

Table 2-210: Climate Zone 1: Amarillo, TX –
Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,805	2,084	308	394
	Heat Pump	1,464	1,737	308	394
	Elec. Resistance	1,020	1,284	308	394
Unconditioned Space	N/A	1,645	1,916	320	409

Table 2-211: Climate Zone 2: Dallas, TX –
Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,533	1,759	243	310
	Heat Pump	1,294	1,516	243	310
	Elec. Resistance	982	1,199	243	310
Unconditioned Space	N/A	1,362	1,585	245	313

Table 2-212: Climate Zone 3: Houston, TX –
Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,449	1,657	223	285
	Heat Pump	1,213	1,417	223	285
	Elec. Resistance	906	1,105	223	285
Unconditioned Space	N/A	1,273	1,481	219	280

Table 2-213: Climate Zone 4: Corpus Christi, TX –
Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,393	1,587	204	260
	Heat Pump	1,253	1,445	204	260
	Elec. Resistance	1,070	1,260	204	260
Unconditioned Space	N/A	1,193	1,387	199	255

Table 2-214: Climate Zone 5: El Paso, TX –
Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,554	1,788	253	324
	Heat Pump	1,315	1,544	253	324
	Elec. Resistance	1,003	1,227	253	324
Unconditioned Space	N/A	1,409	1,639	255	326

Deemed Summer Demand Savings Tables

Table 2-215 through Table 2-219 present the deemed summer demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-215: Climate Zone 1: Amarillo, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.26	0.30	0.04	0.04
Unconditioned Space	N/A	0.22	0.25	0.03	0.04

Table 2-216: Climate Zone 2: Dallas, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.20	0.22	0.02	0.03
Unconditioned Space	N/A	0.16	0.18	0.02	0.03

Table 2-217: Climate Zone 3: Houston, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.19	0.22	0.02	0.03
Unconditioned Space	N/A	0.15	0.18	0.02	0.03

Table 2-218: Climate Zone 4: Corpus Christi, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.18	0.21	0.02	0.03
Unconditioned Space	N/A	0.14	0.17	0.02	0.02

Table 2-219: Climate Zone 5: El Paso, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.21	0.24	0.03	0.03
Unconditioned Space	N/A	0.17	0.20	0.02	0.03

Deemed Winter Demand Savings Tables

Table 2-223 through Table 2-224 present the deemed winter demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-220: Climate Zone 1: Amarillo, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.45	0.52	0.08	0.11
	Heat Pump	0.32	0.39	0.08	0.11
	Elec. Resistance	0.00	0.22	0.08	0.11
Unconditioned Space	N/A	0.41	0.48	0.09	0.12

Table 2-221: Climate Zone 2: Dallas, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.39	0.46	0.07	0.09
	Heat Pump	0.27	0.33	0.07	0.09
	Elec. Resistance	0.00	0.16	0.07	0.09
Unconditioned Space	N/A	0.37	0.43	0.08	0.10

Table 2-222: Climate Zone 3: Houston, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.35	0.41	0.07	0.08
	Heat Pump	0.23	0.28	0.07	0.08
	Elec. Resistance	0.00	0.12	0.07	0.08
Unconditioned Space	N/A	0.34	0.39	0.07	0.09

Table 2-223: Climate Zone 4: Corpus Christi, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.33	0.38	0.06	0.08
	Heat Pump	0.20	0.25	0.06	0.08
	Elec. Resistance	0.00	0.09	0.06	0.08
Unconditioned Space	N/A	0.32	0.37	0.06	0.08

Table 2-224: Climate Zone 5: El Paso, TX –
Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.39	0.46	0.07	0.09
	Heat Pump	0.27	0.33	0.07	0.09
	Elec. Resistance	0.00	0.16	0.07	0.09
Unconditioned Space	N/A	0.37	0.43	0.08	0.10

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The Estimated Useful Life for this measure is 13 years. This EUL is consistent with the judgment of the American Council for an Energy-Efficient Economy as listed on its website.[113]

Program Tracking Data & Evaluation Requirements

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

- The climate zone
- The approximate volume of the replacement heat pump water heater tank in gallons
- The baseline energy factor (EF)
- The EF of the replacement water heater
- Water heater type (e.g., heat pump, electric resistance)
- The installed location (conditioned vs. unconditioned space)
- For heat pump water heater installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

[113] Water Heating. American Council for an Energy Efficient Economy. Online. Available: http://www.aceee.org/consumer/water-heating. Accessed: September 2011.

Document Revision History

Table 2-225: Heat Pump Water Heater 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.

2.4.7 Water Heater Replacement – Solar Water Heating Measure Overview

TRM Measure ID: R-WH-WS

Market Sector: Residential

Measure Category: Water Heating

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

Eligibility Criteria

These deemed savings are for solar water heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes. However, savings are calculated under the assumption of replace-on-burnout.

Baseline Condition

This section is not applicable.

High-Efficiency Condition

Only solar water heaters meeting the SRCC OG-300 standard (based on tank size and final Solar Energy Factor-SEF) qualify for these deemed savings estimates.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Solar water heating values are on a per-unit basis. Deemed savings variables include tank volume and installed-unit Solar Energy Factor (SEF) as rated in the Solar Rating and Certification

Corporation (SRCC) “Summary of SRCC Certified Solar Collector and Water Heating System Ratings.” The Solar Energy Factor (SEF) is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed as a means to compare solar water heating systems with conventional water heating systems rated with an Energy Factor (EF) and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both EF and SEF are based on the same environmental and hot water use conditions used in the DOE Test Procedures for Water Heaters. The only significant difference is that the DOE test does not specify solar radiation. So SRCC uses a 1500 Btu/sq.ft./day solar radiation profile – a value typical of Sunbelt states (note - the annual average solar radiation for Dallas is 1533 Btu/sq.ft./day. (Information on the SRCC can be found at http://www.solar-rating.org/.)

Examples

A passive SunEarth CP-40 with a SEF of 1.4 would consume 2133 kWh (2987/1.4), saving 1323 kWh compared to a baseline 50 gallon water heater that consumes 3458 kWh (values based on Frontier data).

An active Heliodyne HP 410 G 80 with a SEF of 2.0 would consume 1494 kWh (2987/2), saving 1965 kWh compared to the baseline 50 gallon water heater.

Use SRCC OG-300 Test to obtain SEF

SRCC = Solar Rating and Certification Corporation

OG-300 = test standard for SWH systems

SEF = Solar Energy Factor

Calculate kWh Savings

$$kWh\ savings = standard\ load \times \left(1 - \frac{EF}{SEF}\right) = (3{,}458) \times \left(1 - \frac{0.864}{2}\right) = 1{,}965kWh$$

Deemed Energy Savings Tables

The following table presents the energy savings for solar water heaters based on tank size and final Solar Energy Factor (SEF).

Table 2-226: Solar Water Heating Energy Savings (kWh)

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
1.0	637	471	368
1.1	909	743	640
1.2	1,135	969	866
1.3	1,326	1,160	1,057
1.4	1,490	1,324	1,221
1.5	1,633	1,467	1,364
1.6	1,757	1,591	1,488
1.7	1,867	1,701	1,598
1.8	1,965	1,799	1,696
1.9	2,052	1,886	1,783
2.0	2,131	1,965	1,862
2.1	2,202	2,036	1,933
2.2	2,266	2,100	1,997
2.3	2,325	2,159	2,056
2.4	2,379	2,213	2,110
2.5	2,429	2,263	2,160
2.6	2,475	2,309	2,206
2.7	2,518	2,352	2,249
2.8	2,557	2,391	2,288
2.9	2,594	2,428	2,325
3.0	2,628	2,462	2,359
3.1	2,660	2,494	2,391
3.2	2,691	2,525	2,422
3.3	2,719	2,553	2,450
3.4	2,745	2,579	2,476
3.5	2,771	2,605	2,502
3.6	2,794	2,628	2,525
3.7	2,817	2,651	2,548
3.8	2,838	2,672	2,569
3.9	2,858	2,692	2,589
4.0	2,877	2,711	2,608
4.1	2,895	2,729	2,626
4.2	2,913	2,747	2,644
4.3	2,929	2,763	2,660
4.4	2,945	2,779	2,676

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
4.5	2,960	2,794	2,691
4.6	2,975	2,809	2,706
4.7	2,988	2,822	2,719
4.8	3,002	2,836	2,733
4.9	3,014	2,848	2,745
5.0	3,027	2,861	2,758

Source: Tim Merrigan, National Renewable Energy Laboratory (2001)

Deemed Summer Demand Savings Tables

The following table presents the energy savings for solar water heaters based on tank size and final Solar Energy Factor (SEF).

Table 2-227: Solar Water Heating Demand Savings (kW)

Solar Water Heating Demand Savings kW
0.42

Diversified value fully displaced during solar peak.

This value is consistent with Univ. of Texas study (0.4)

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar water heater is established at 15 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[114]

Program Tracking Data & Evaluation Requirements

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

- The approximate volume of the replacement water heater in gallons
- SRCC OG-300 Solar Energy Factor of the replacement unit

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003 Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-228: Water Heater Replacement – Solar Water Heating Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.

[114] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.5 RESIDENTIAL: APPLIANCES

2.5.1 ENERGY STAR® Ceiling Fans Measure Overview

TRM Measure ID: R-AP-FN

Market Sector: Residential

Measure Category: Appliances

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® ceiling fan and light kit. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

This section is not applicable.

Baseline Condition

The baseline is a conventional non-ENERGY STAR® labeled ceiling fan and light kit.

High-Efficiency Condition

Table 2-229 displays the ENERGY STAR® requirements for eligible ceiling fans as of April 2012. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-229: ENERGY STAR® Specifications for Ceiling Fans

ENERGY STAR® Specifications for Ceiling Fans
1. Specification defines residential ceiling fan airflow efficiency on a performance basis: CFM of airflow per watt of power consumed by the motor and controls. Efficiency is measured on each of three speeds (low/medium/high).
2. At low speed, fans must have a minimum airflow of 1,250 CFM and an efficiency of 155 CFM/Watt
3. At medium speed, fans must have a minimum airflow of 3,000 CFM and an efficiency of 100 CFM/W.
4. At high speed, fans must have a minimum airflow of 5,000 CFM and an efficiency of 75 CFM/Watt
5. Qualifying ceiling fan models must come with a minimum 30-year motor warranty; one-year component(s) warranty; and light kit warranty specified in "ENERGY STAR® Program Requirements for Luminaires" document.[115]
6. Integral or attachable lighting, including separately sold ceiling fan light kits, must meet requirements provided in the "ENERGY STAR® Program Requirements for Luminaires" specification.[115]
7. Qualifying products must permit convenient consumer adjustment of fan speed, by means of one or more wall-mounted switch(es), a remote control, or readily accessible pull chains.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy savings were calculated using the ENERGY STAR® Ceiling Fan Savings Calculator found on the ENERGY STAR® website. Peak demand savings were calculated using separate coincidence factors for the lighting and the fan motor portion of the ceiling fan savings. For lighting a coincidence factor of 0.08 was applied (referenced from the CFL METERING STUDY FINAL REPORT, Prepared for: Pacific Gas & Electric Company, San Diego Gas & Electric Company, Southern California Edison Company, 2005). For the fan motor a coincidence factor of 0.446 was applied (derived from the EnergyGauge software ceiling fan profiles).

[115] ENERGY STAR® Program Requirements for Luminaires. http://www.energystar.gov/ia/partners/product_specs/program_reqs/Final_Luminaires_V1_2.pdf?6d42-c7e4.

Deemed Energy Savings Tables

Table 2-230: ENERGY STAR® Ceiling Fan Energy Savings

ENERGY STAR® Ceiling Fan
Energy Savings (kWh)
141

Deemed Summer Demand Savings Tables

Table 2-231: ENERGY STAR® Ceiling Fan Summer Peak Demand Savings

ENERGY STAR® Ceiling Fan
Summer Peak Savings (kW)
0.011

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 10 years.

This EUL is consistent with Docket No. 38025 approved in 2010.[116]

Program Tracking Data & Evaluation Requirements

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

- The number of installed ENERGY STAR® ceiling fan and light kits.

[116] Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR® Appliance Measures. Public Utility Commission of Texas.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR® Appliance Measures. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for ceiling fans.

Document Revision History

Table 2-232: ENERGY STAR® Ceiling Fan Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language and updates to ENERGY STAR® specification table.

2.5.2 ENERGY STAR® Clothes Washer Measure Overview

TRM Measure ID: R-AP-CW

Market Sector: Residential

Measure Category: Appliances

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® clothes washer. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

These deemed savings are calculated using the federal standards effective March 7, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).[117]

Eligibility Criteria

This section is not applicable.

Baseline Condition

Effective March 7, 2015, the baseline is the Department of Energy (DOE) minimum efficiency standard[118] for top-loading clothes washers. While the DOE provides criteria for both top- and front-loading washers, only the standards for top-loading washers are listed below, as a top-loading unit is assumed to be the baseline equipment. This approach is consistent with the ENERGY STAR® appliance calculator. This baseline is schedule to change again on January 1, 2018.

[117] If savings are claimed based on the federal standards in place prior to March 7, 2015, the measure installation date must be tracked.

[118] DOE minimum efficiency standard for residential clothes washers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Table 2-233: Federal Standard for Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)	Proposed Changes for January 1, 2018
Top-loading, Standard (1.6 ft^3 or greater capacity)	IMEF ≥ 1.29 IWF≤ 8.4	IMEF ≥ 1.57 IWF≤ 6.5

IMEF = Integrated Modified Energy Factor (ft^3/kWh/cycle)

IWF = Integrated Water Factor (gallons/cycle/ft^3)

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 7.0 requirements for eligible clothes washers effective March 7, 2015. [119]These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-234: ENERGY STAR® and CEE Specifications for Residential Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)
ENERGY STAR® Residential Front-loading (> 2.5 ft^3)	IMEF ≥ 2.38 IWF≤ 3.7
ENERGY STAR® Residential Top-loading, (> 2.5 ft^3)	IMEF ≥ 2.06 IWF ≤ 4.3
ENERGY STAR® Residential (< 2.5 ft^3)	IMEF ≥ 2.07 IWF ≤ 4.2

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Appliance Savings Calculator found on the ENERGY STAR® website.[120] Default values were taken directly from the ENERGY STAR® appliance calculator. When a new ENERGY STAR® appliance calculator becomes available, the most recent values provided should be substituted as appropriate.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 52

[119] Available for download at: http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf.

[120] ENERGY STAR® Appliance Savings Calculator (updated May 2014). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

$$kWh_{baseline} = E_{conv,machine} + E_{conv,WH} + E_{conv,dryer}$$

Equation 53

$$E_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

$$E_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

$$E_{conv,dryer} = \left[\left(\frac{CAP}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right)\right] \times DUF$$

Equation 54

$$kWh_{ES} = E_{ES,machine} + E_{ES,WH} + E_{ES,dryer}$$

Equation 55

$$E_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

$$E_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

$$E_{ES,dryer} = \left[\left(\frac{CAP}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right)\right] \times DUF$$

Equation 56

Where:

$kWh_{baseline}$	=	*Federal standard baseline energy usage*
kWh_{ES}	=	*ENERGY STAR® average energy usage*
$E_{conv,machine}$	=	*Conventional machine energy*
$E_{conv,WH}$	=	*Conventional water heater energy*
$E_{conv,dryer}$	=	*Conventional dryer energy*
$E_{ES,machine}$	=	*ENERGY STAR® machine energy*
$E_{ES,WH}$	=	*ENERGY STAR® water heater energy*
$E_{ES,dryer}$	=	*ENERGY STAR® dryer energy*
$RUEC_{conv}$	=	*Conventional rated unit electricity consumption = 417 kWh/year (top-loading)* [121]

[121] This value is taken from the ENERGY STAR® appliance calculator available February 2013, and corresponds with the federal standard prior to March 7, 2015.

$RUEC_{ES}$	=	*ENERGY STAR® rated unit electricity consumption = 186 kWh/year*[122]
LPY	=	*Loads per year = 295*
$RLPY$	=	*Reference loads per year = 392*
CAP	=	*Average machine capacity = 3.1 ft³*
$IMEF_{FS}$	=	*Federal standard integrated modified energy factor (Table 2-233)*
$IMEF_{ES}$	=	*ENERGY STAR® integrated modified energy factor (Table 2-234)*
MCF	=	*Machine consumption factor = 20%*
$WHCF$	=	*Water heater consumption factor = 80%*
DUF	=	*Dryer use factor (percentage of washer loads dried in machine) = 100%*

Summer Demand Savings Algorithms

$$\boldsymbol{kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF}$$

$$\boldsymbol{AOH = LPY \times d}$$

Equation 57

Where:

AOH	=	*Annual operating hours*
CF	=	*Coincidence factor = 0.05*[123]
LPY	=	*Loads per year = 295*
d	=	*Average wash cycle duration = 1 hour*[124,125]

[122] This value is taken from the ENERGY STAR® appliance calculator available February 2013, and corresponds with the ENERGY STAR® specification prior to March 7, 2015.

[123] Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory (NREL). "Building America Research Benchmark Definition: Updated December 2009." Department of Energy. January 2010. p. 14 (peak hour of 4 PM applied). http://www.nrel.gov/docs/fy10osti/47246.pdf

[124] Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers. Top: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/top-loading-washing-machine-ratings/ratings-overview.htm. Front: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/front-loading-washing-machine-ratings/ratings-overview.htm.

[125] Consumer Reports. "Top-loading washers remain more popular with Americans". April 13, 2010. Weighted average of 75% Top-Loading Clothes Washers and 25% Front-Loading Clothes Washers. http://news.consumerreports.org/home/2010/04/best-front-loaders-top-loaders-which-is-more-popular-mold-vibration-washing-machine-reviews.html. This publication is available for purchase only.

Deemed Energy Savings Tables

Table 2-235: ENERGY STAR® Clothes Washer Energy Savings (kWh)

ENERGY STAR® Clothes Washer – Annual Energy Savings			
Type	**Water Heater Fuel Type**	**Dryer Fuel Type**	**kWh Savings**
Front-loading > 2.5 ft^3	Electric	Electric	325
	Electric	Gas	174
	Gas	Electric	186
	Gas	Gas	35
Top-loading > 2.5 ft^3	Electric	Electric	265
	Electric	Gas	174
	Gas	Electric	126
	Gas	Gas	35
All ≤ 2.5 ft^3	Electric	Electric	267
	Electric	Gas	174
	Gas	Electric	128
	Gas	Gas	35

Deemed Summer Demand Savings Tables

Table 2-236: ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW)

ENERGY STAR® Clothes Washer – Summer Demand Savings			
Type	**Water Heater Fuel Type**	**Dryer Fuel Type**	**kW Savings**
Front-loading > 2.5 ft^3	Electric	Electric	0.055
	Electric	Gas	0.029
	Gas	Electric	0.031
	Gas	Gas	0.006
Top-loading > 2.5 ft^3	Electric	Electric	0.045
	Electric	Gas	0.029
	Gas	Electric	0.021
	Gas	Gas	0.006
All ≤ 2.5 ft^3	Electric	Electric	0.045
	Electric	Gas	0.029
	Gas	Electric	0.022
	Gas	Gas	0.006

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 an ENERGY STAR® clothes washer is established at 14 years.

This value is consistent with the EUL reported in the Department of Energy 77 Final Rule 59719 Technical Support Document.[126]

Program Tracking Data & Evaluation Requirements

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

- Number of units installed
- Type of unit (top-loading, front-loading, or compact)
- Fuel type of water heater (gas or electric)
- Fuel type of dryer (gas or electric)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for clothes washers.

[126] Department of Energy, Federal Register, 77 FR 59719, Technical Support Document: 8.2.3 Product Lifetimes. April 2012. http://www.regulations.gov/contentStreamer?objectId=090000648106e7a7&disposition=attachment&contentType=pdf. Accessed February 2014.

Document Revision History

Table 2-237: ENERGY STAR® Clothes Washer Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.

2.5.3 ENERGY STAR® Dishwasher Measure Overview

TRM Measure ID: R-AP-DW

Market Sector: Residential

Measure Category: Appliances

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® dishwasher. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

Residential compact dishwashers are not eligible for this measure because the ENERGY STAR® criteria are equivalent to the federal standard criteria. Once the ENERGY STAR® criteria for compact dishwashers are updated, their eligibility will be reassessed. There is no scheduled update for ENERGY STAR® criteria at this time.

Baseline Condition

Effective May 30, 2013, the baseline is the Department of Energy (DOE) minimum efficiency standard[127] for dishwashers.

[127] DOE minimum efficiency standard for residential dishwashers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67.

Table 2-238 Federal Standard for Dishwashers

Product Type	Estimated Annual Energy Use (kWh/year)	Water Consumption (gallons/cycle)
Standard (≥ 8 place settings)	≤ 307	≤ 5.0
Compact (< 8 place settings)	≤ 222	≤ 3.5

High-Efficiency Condition

The following table displays the ENERGY STAR® requirements for eligible dishwashers effective since January 2012. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-239 ENERGY STAR® Specifications for Dishwashers

Product Type	Estimated Annual Energy Use (kWh/year) (as of May 30, 2013)	Water Consumption (gallons/cycle) (as of May 30, 2013)
Standard (≥ 8 place settings + 6 serving pieces)	≤ 295	≤ 4.25
Compact[128] (< 8 place settings + 6 serving pieces)	≤ 222	≤ 3.50

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® appliance calculator. Default values were taken directly from the ENERGY STAR® appliance calculator.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 58

$$kWh_{baseline} = E_{conv,machine} + E_{conv,WH}$$

$$E_{conv,machine} = RUEC_{conv} \times MCF$$

$$E_{conv,WH} = RUEC_{conv} \times WHCF$$

Equation 59

$$kWh_{ES} = E_{ES,machine} + E_{ES,WH}$$

[128] ENERGY STAR® specifications for residential compact dishwashers have not been updated to reflect the May 30, 2013 federal standard update.

$$E_{ES,machine} = RUEC_{ES} \times MCF$$

$$E_{ES,WH} = RUEC_{ES} \times WHCF$$

Equation 60

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage*

kWh_{ES} = *ENERGY STAR® average energy usage*

$E_{conv,machine}$ = *Conventional machine energy*

$E_{conv,WH}$ = *Conventional water heater energy*

$E_{ES,machine}$ = *ENERGY STAR® machine energy*

$E_{ES,WH}$ = *ENERGY STAR® water heater energy*

$RUEC_{conv}$ = *Conventional rated use electricity consumption = 307 kWh/year (Table 2-238)*

$RUEC_{ES}$ = *ENERGY STAR® rated use electricity consumption = 295 kWh/year (Table 2-239)*

MCF = *Machine consumption factor = 44%*

$WHCF$ = *Water heater consumption factor = 56%*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

$$AOH = CPY \times d$$

Equation 61

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor = 0.04*[129]

CPY = *Cycles per year = 215*

[129] Robert Hendron and Cheryn Engebrecht, National Renewable Energy Laboratory (NREL). "Building America Research Benchmark Definition: Updated December 2009." Department of Energy. January 2010. p. 14 (peak hour of 4 PM was applied). http://www.nrel.gov/docs/fy10osti/47246.pdf.

d = *Average wash cycle duration = 2.1 hours*[130]

Deemed Energy Savings Tables

Table 2-240: ENERGY STAR® Dishwasher Energy Savings

ENERGY STAR® Dishwasher Savings	
Energy kWh Savings	
With Electric Water Heating	**Without Electric Water Heating**
12	5

Deemed Summer Demand Savings Table

Table 2-241: ENERGY STAR® Dishwasher Summer Peak Demand Savings

ENERGY STAR® Dishwasher Savings	
Summer Peak kW Savings	
With Electric Water Heating	**Without Electric Water Heating**
0.0011	0.0005

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 15 years. This value is consistent with the EUL reported in the Department of Energy 77 Final Rule 31918 Technical Support Document.[131]

[130] Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/appliances/kitchen-appliances/dishwashers/dishwasher-ratings/ratings-overview.htm.

[131] Department of Energy, Federal Register, 77 FR 31918, Technical Support Document: 8.2.3 Product Lifetimes. May 2012.

Program Tracking Data & Evaluation Requirements

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

- Number of units installed
- Fuel type of water heater (gas or electric)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for dishwashers.

Document Revision History

Table 2-242: ENERGY STAR® Dishwasher Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Updated by Frontier Associates, March 2014, based on new federal standards.

2.5.4 ENERGY STAR® Refrigerator Measure Overview

TRM Measure ID: R-AP-RF

Market Sector: Residential

Measure Category: Appliances

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

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement (Low-Income Customers Only[132])

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure applies to all ENERGY STAR® refrigerators that meet the criteria for the ENERGY STAR® label specified below.

Eligibility Criteria

To qualify for early retirement, the ENERGY STAR® unit must replace an existing, full-size, working unit with a remaining useful life of five years or more. To determine the remaining useful life of an existing unit, see Table 2-245. All retired refrigerators must be dismantled in an environmentally-safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators.

Only low-income customers[132] are eligible for deemed savings associated with early retirement of refrigerators. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly-installed refrigerators must meet current ENERGY STAR® efficiency levels.

Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[133] for refrigerators, effective September 15, 2014.

[132] 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).

For early retirement, the baseline for refrigerators is assumed to be the annual unit energy consumption of the refrigerator being replaced, as reported by the Association of Home Appliance Manufacturers (AHAM) refrigerator database[134] and adjusted for age according to the formula in the Energy and Demand Savings Methodology section. AHAM energy use data includes the average manufacturer reported annual kWh usage by year of production dating back to the 1970s.

Alternatively, the baseline annual energy usage of the refrigerator being replaced may be estimated by metering for a period of at least one hour using the measurement protocol specified in the DOE report, "Incorporating Refrigerator Replacement into the Weatherization Assistance Program".[135]

To determine annual kWh of the refrigerator being replaced, use the following formula:

$$\boldsymbol{Annual\ kWh\ Usage = \frac{WH \times 8,760}{h \times 1,000}}$$

Equation 62

Where:

WH = *Watt-hours metered during a time period*

h = *Measurement time period (hours)*

$8,760$ = *Hours in a year*

$1,000\ Watt\text{-}hours$ = $1\ kWh$

High-Efficiency Condition

Table 2-244 displays the ENERGY STAR® requirements for eligible refrigerators, which went into effect September 15, 2014. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-243: ENERGY STAR® Specifications for Refrigerators

ENERGY STAR® Refrigerator		
Product Type	**Volume**	**Criteria as of September 15. 2014**
Full-Size Refrigerators and Refrigerator-Freezers	7.75 cubic feet or greater	At least 10% more energy efficient than the minimum federal government standard

[133] DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[134] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

[135] Alex Moore, D&R International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. http://www.waptac.org/data/files/Website_Docs/technical_tools/toolkit07.pdf.

Table 2-244: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume[136]

Product Class	Baseline Energy Usage Federal Standard as of Sept 14, 2014 (kWh/year)[137]	Average ENERGY STAR® Energy Usage (kWh/year)[138]	Configuration(s)	Ice (Y/N)	Defrost
Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	(8.07 × AV + 233.7) × 0.9	TF	N	A
Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	9.15 × AV + 264.9	(9.15 × AV + 264.9) × 0.9	TF	N	A
Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	8.07 × AV + 317.7	(8.07 × AV + 317.7) × 0.9	TF	Y	A
Built-in refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	9.15 × AV + 348.9	(9.15 × AV + 348.9) × 0.9	TF	Y	A
Refrigerator-only—automatic defrost	7.07 × AV + 201.6	(7.07 × AV + 201.6) × 0.9	SD	Y, N	A
Built-in refrigerator-only—automatic defrost	8.02 × AV + 228.5	(8.02 × AV + 228.5) × 0.9	SD	Y, N	A
Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	8.51 × AV + 297.8	(8.51 × AV + 297.8) × 0.9	SS	N	A

[136] Available for download at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Select product classes excluded.

[137] The refrigerator baseline is set to change effective September 14, 2014. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Once the ENERGY STAR appliance calculator is updated to reflect the code update, baseline values will need to be updated for consistency.

[138] 20% more efficient than baseline, as specified in the ENERGY STAR appliance calculator; available for download at http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=RF.

Product Class	Baseline Energy Usage Federal Standard as of Sept 14, 2014 (kWh/year)[137]	Average ENERGY STAR® Energy Usage (kWh/year)[138]	Configuration(s)	Ice (Y/N)	Defrost
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	(10.22 × AV + 357.4) × 0.9	SS	N	A
Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	(8.51 × AV + 381.8) × 0.9	SS	Y	A
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	(10.22 × AV + 441.4) × 0.9	SS	Y	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	(8.85 × AV + 317.0) × 0.9	BF	N	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	(9.40 × AV + 336.9) × 0.9	BF	N	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	(8.85 × AV + 401.0) × 0.9	BF	Y	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	9.40 × AV + 420.9	(9.40 × AV + 420.9) × 0.9	BF	Y	A
Refrigerator-freezers—automatic defrost with bottom-mounted freezer with TTD ice service	9.25 × AV + 475.4	(9.25 × AV + 475.4) × 0.9	BF	Y	A
Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with TTD ice service	9.83 × AV + 499.9	(9.83 × AV + 499.9) × 0.9	BF	Y	A
Refrigerator-freezers—automatic defrost with top-mounted freezer with TTD ice service	8.40 × AV + 385.4	(8.40 × AV + 385.4) × 0.9	TF	Y	A

Product Class	Baseline Energy Usage Federal Standard as of Sept 14, 2014 (kWh/year)[137]	Average ENERGY STAR® Energy Usage (kWh/year)[138]	Configuration(s)	Ice (Y/N)	Defrost
Refrigerator-freezers—automatic defrost with side-mounted freezer with TTD ice service	8.54 × AV + 432.8	(8.54 × AV + 432.8) × 0.9	SS	Y	A
Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with TTD ice service	10.25 × AV + 502.6	(10.25 × AV + 502.6) × 0.9	SS	Y	A

Configuration Codes:
BF: Bottom Freezer
SD: Refrigerator Only – Single Door
SS: Side-by-Side
TF: Top Freezer
TTD: Through the Door (Ice Maker)

A: Automatic Defrost
M: Manual Defrost
P: Partial Automatic Defrost
AV = Adjusted Volume (ft^3) = Refrigerator Volume + (1.63 × Freezer Volume)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 63

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 2-244)*

kWh_{ES} = *ENERGY STAR average energy usage (see Table 2-244)*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760\ hrs}\ x\ TAF \times LSAF$$

Equation 64

Where:

TAF = *Temperature Adjustment Factor*[139] *= 1.188*

$LSAF$ = *Load Shape Adjustment Factor*[140] *= 1.074*

Early Retirement

Energy Savings Algorithms

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***

[139] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29, 2004. Factor to adjust for varying temperature based on site conditions, p. 47.

[140] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29, 2004. Used load shape adjustment for "hot days" during the 4PM hour, p. 45-48.

2. The remaining time in the EUL period (17 – RUL)

For the RUL time period:

$$\boldsymbol{kWh_{savings,ER} = kWh_{manf} - kWh_{ES}}$$

Equation 65

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

$$\boldsymbol{kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}}$$

Equation 66

Where:

kWh_{manf} = *Annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database*[141] *(or from metering)*

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 2-244)*

kWh_{ES} = *ENERGY STAR® average energy usage (see Table 2-244)*

To find the annual energy (kWh) savings, the early retirement and replace-on-burnout savings are weighted by the remaining useful life of the unit and the remainder of the EUL period.

$$\boldsymbol{Annual\ kWh\ Savings = \left(\frac{EUL - RUL}{EUL}\right) \times kWh_{savings,ROB} + \left(\frac{RUL}{EUL}\right) \times kWh_{savings,ER}}$$

Equation 67

Where:

RUL = *Remaining Useful Life (see Table 2-245)*

EUL = *Estimated Useful Life = 17 years*[142]

[141] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

[142] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Table 2-245: Remaining Useful Life (RUL) of Replaced Refrigerator

Age of Replaced Refrigerator (years)	RUL (years)	Age of Replaced Refrigerator (years)	RUL (years)
6	10.3	13	6.6
7	9.6	14	6.3
8	8.9	15	6.0
9	8.3	16	5.8
10	7.8	17	5.5
11	7.4	18	5.3
12	7.0	19	5.1

Demand Savings Algorithms

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

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8,760\ hrs}\ x\ TAF \times LSAF$$

Equation 68

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

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8,760\ hrs}\ x\ TAF \times LSAF$$

Equation 69

Where:

TAF = *Temperature Adjustment Factor*[143] = 1.188

$LSAF$ = *Load Shape Adjustment Factor*[144] = 1.074

[143] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29, 2004. Factor to adjust for varying temperature based on site conditions, p. 47.

[144] Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report – 2003-2004 Metering Study". July 29, 2004. Used load shape adjustment for "hot days" during the 4PM hour, p. 45-48.

Annual deemed summer peak demand savings may be calculated for the early retirement of an ENERGY STAR® refrigerator as follows:

$$\boldsymbol{Annual\ kW\ Savings} = \left(\frac{\boldsymbol{EUL - RUL}}{\boldsymbol{EUL}}\right) \times \boldsymbol{kW_{savings,ROB}} + \left(\frac{\boldsymbol{RUL}}{\boldsymbol{EUL}}\right) \times \boldsymbol{kW_{savings,ER}}$$

Equation 70

Where:

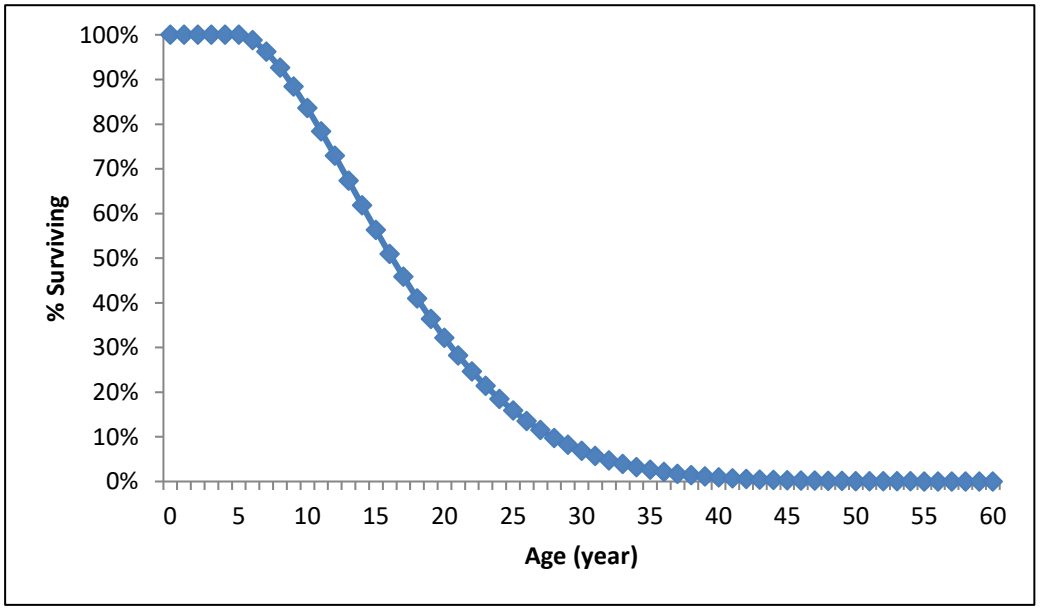
RUL = *Remaining Useful Life (see Table 2-245)*

EUL = *Estimated Useful Life = 17 years*[145]

Derivation of RULs

ENERGY STAR® refrigerators have an estimated useful life of 17 years. This estimate is consistent with the age at which 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 2-5.

Figure 2-5: Survival Function for ENERGY STAR® Refrigerators[146]



[145] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[146] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 2-5. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced. For example, assume a refrigerator being replaced is 15 years old. The corresponding % surviving value is 56%. Half of 56% is 28%. The age corresponding to 28% on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21 – 15) = 6 years.

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 17 years.

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 57516 Technical Support Document.[147]

[147] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

Program Tracking Data & Evaluation Requirements

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

- Number of units installed
- The project type of the installation (New Construction, Replace-on-Burnout, or Early Retirement)
- Installed refrigerator model number
- Product class (see Table 2-244)
- Refrigerator volume
- Freezer volume
- Retired refrigerator model number (Early Retirement only)
- Retired refrigerator annual energy usage (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for refrigerators.

Document Revision History

Table 2-246: ENERGY STAR® Refrigerator Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Low-income and Hard-to-Reach Market Transformation section merged with main measure as “Early Retirement” option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.

2.6 RESIDENTIAL: WHOLE HOUSE

2.6.1 New Homes Measure Overview

TRM Measure ID: R-HS-NH

Market Sector: Residential

Measure Category: Whole-House

Applicable Building Types: Single-Family; Manufactured

Fuels Affected: Electricity and Gas

Decision/Action Type(s): New Construction

Program Delivery Type(s): Custom

Deemed Savings Type: For this measure, savings are not deemed and are estimated based on each house's specific characteristics and parameters.

Savings Methodology: EM&V and Whole-House Simulation Modeling

Measure Description

The New Homes program promotes a holistic approach to achieving energy efficient homes, including a combination of envelope and equipment-based improvements to reduce home energy use. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating home.

Eligibility Criteria

This measure does not apply to existing construction. Only new construction homes are eligible.

Baseline Condition[148]

For a list of baseline parameters and input values, see Table 2-247. When a new statewide energy code is adopted by the State Energy Conservation Office (SECO), the baseline parameters for residential whole-house measures must be updated to reflect this change on the date the new energy code becomes effective in those jurisdictions required to meet or exceed the statewide energy code.

If a baseline study has been conducted since the adoption of the current statewide code that demonstrates standard practice less than the statewide energy code, the researched baseline may be used as the baseline from which to claim savings for the researched jurisdiction(s).

[148] Baseline parameters are subject to change with updates to the relevant energy code.

Ideally, the relevant energy code will be tracked in the program tracking system. Alternatively, it may be tracked as part of project documentation made available to evaluators upon request

Table 2-247: New Home – Baseline Characteristics

Baseline Home Parameters and Characteristics	Baseline Specification / Value
House Envelope	
Unit Type	Single- Family Detached
Number of Stories Above Grade 1	Same as As-Built
Foundation Type	Same as As-Built
Number of Bedrooms	Same as As-Built
Total Conditioned Floor Area	Same as As-Built
Total Conditioned Volume	Same as As-Built
Wall Height Per Floor	Same as As-Built
Window Distribution (N,S,E,W)	Same as As-Built
Percentage Window to Floor Area	Same as As-Built
Front Door Orientation	Same as As-Built
Aspect Ratio (Length / Width)	Use the same estimated average aspect ratio for both baseline and as-built. However, it is recommended to use actual aspect ratio when actual house footprint dimensions are available.
Roof Solar Absorptivity	Same as As-Built. When as-built data is not available, use 0.75.
Attic Insulation R-Value	See IECC 2009, Table 402.1.1
Cathedral Ceiling Insulation R-Value	R-19
Percentage Cathedral Ceilings	Same as As-Built
Wall Construction	2x4-16 inch on center spacing
Wall Framing Fraction	23%
Wall Insulation	See IECC 2009, Table 402.1.1
Wall Sheathing	Plywood
Wall Insulation Grade	3
Door R-Value	Same as As-Built.
Floor Insulation	See IECC 2009, Table 402.1.1
Rim Joist	Same as wall insulation
Window U Factor	See IECC 2009, Table 402.1.1
Window SHGC	See IECC 2009, Table 402.1.1
Air Infiltration	7 ACH50
Mechanical Ventilation	None
Slab Edge Insulation	See IECC 2009, Table 402.1.1
HVAC Equipment	
HVAC Equipment Type	Same as As-Built
Cooling Capacity	Same as As-Built
Heating Capacity	Same as As-Built

Baseline Home Parameters and Characteristics	Baseline Specification / Value
Cooling Efficiency (SEER)	14
Heating Efficiency (AFUE)	80
Heating Efficiency (HSPF) – Heat Pump	8.2
Duct Location	100% Attic
Duct R-Value	R-6
Duct Leakage to Outside	8 CFM per 100 ft² of Conditioned Floor Area
Thermostat Type	Same as As-Built
Heating Setpoint	68°F
Cooling Setpoint	78°F
Water Heating System	
DHW Fuel Type	Same as As-Built
DHW Capacity (Gallons)	Same as As-Built for Storage. Assume a 50-gallon storage water heater when as-built water heater is instantaneous.
Energy Factor (EF)	Water heater efficiency based on updates to federal standards (10 CFR Part 430.32[149]) as of April 16, 2015
DHW Temperature	120°F
DHW Pipe Insulation	None
Low Flow Shower Heads	None

High-Efficiency Condition

The high-efficiency conditions are according to the as-built home's parameters and characteristics.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

House Simulation Modeling and Input Variables

Two house simulation models should be developed for each home utilizing an appropriate residential modeling package software. The first model simulates the baseline home's annual energy use and demand, while the second simulates the as-built home. The energy and demand savings are the difference in annual energy use between the as-built home and the baseline home.

[149] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

Energy Savings Methodology

Energy savings are estimated utilizing whole-house simulation modeling based on on-site data collection.

Summer Demand Savings Methodology

Summer peak demand savings are estimated utilizing whole-house simulation modeling based on on-site data collection and load shape profiles for the specific climate zone.

Winter Demand Savings Methodology

Winter peak demand savings are estimated utilizing whole-house simulation modeling based on on-site data collection and load shape profiles for the specific climate zone.

Deemed Energy Savings Tables

There are no lookup tables available for this measure. See methodology 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 methodology 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 methodology 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

Appropriate residential modeling package software should be used to simulate the baseline and as-built home's annual energy use and demand.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a new home measure is established at 23.0 years.

Program Tracking Data & Evaluation Requirements

The following primary inputs and contextual data should be specified and tracked to inform the evaluation and apply the savings properly. While they do not need to be tracked in the program database, they must be in a format easily made available to evaluators.

- Relevant Energy Code under which the House was Built – especially in cases where the local jurisdiction has adopted an energy code more stringent than the statewide code.
- House Envelope
    - Dwelling Unit Type
    - House Footprint Dimensions
    - Number of Stories Above Grade 1
    - Foundation Type
    - Number of Bedrooms
    - Total Conditioned Floor Area
    - Total Conditioned Volume
    - Wall Height Per Floor
    - Window Distribution (N,S,E,W)
    - Front Door Orientation
    - Aspect Ratio (Length / Width) – when available
    - Roof Solar Absorptivity – when available
    - Attic Insulation R-Value
    - Cathedral Ceiling Insulation R-Value
    - Percentage Cathedral Ceilings
    - Ceiling Insulation Grade
    - Wall Construction
    - Wall Framing Fraction
    - Wall Insulation (R-Value)
    - Wall Insulation Grade
    - Door Material (Wood, Metal, Vinyl, and whether Solid Core or Hollow) – when available
    - Rim Joist
    - Window U Factor
    - Window SHGC
    - Air Infiltration
    - Mechanical Ventilation
    - Slab Edge Insulation – only for houses located in IECC climate zone 4
- HVAC Equipment
    - HVAC Equipment Type
    - AHRI Number of Installed HVAC Equipment – in the absence of an AHRI number, manufacturers' cut sheets and/or make and model numbers should be provided instead.
    - Cooling Capacity
    - Heating Capacity
    - Cooling Efficiency (SEER)

        - Heating Efficiency (AFUE), and HSPF for Heat Pumps
        - Duct Location
        - Duct Insulation R-Value
        - Duct Leakage to Outside (CFA)
        - Heating Set-Point Temperature (°F)
        - Cooling Set-Point Temperature (°F)
        - Thermostat Type (Setback or No Setback)
- Water Heating System
        - Water Heating Systems
        - AHRI Number of Installed Water Heating Equipment – in the absence of an AHRI number, manufacturers' cut sheets and/or make and model numbers should be provided instead
        - DHW Fuel Type
        - DHW Capacity (Gallons)
        - Energy Factor
        - DHW Set-Point Temperature
        - DHW Pipe Insulation
        - Number of Low Flow Shower Heads

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-248: Water Heater Jacket 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 baseline conditions due to federal standard updates for HVAC and water heating equipment. Modified program tracking requirements and requirements surrounding the relevant baseline code.

2.7 RESIDENTIAL: RENEWABLE ENERGY SYSTEMS

2.7.1 Solar Photovoltaic (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

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

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations or Simulation Software

Savings Methodology: Algorithms, Model-Calculator (PVWatts™)

Measure Description

This section summarizes the savings calculations of the Solar Photovoltaic Standard Offer, Market Transformation, and Pilot programs. The primary objective of these programs is to achieve cost-effective reduction in energy savings and peak demand savings. Participation in the Solar Photovoltaic program involves the installation of a solar photovoltaic system. There are two primary methods used to estimate savings. The deemed method uses deemed algorithms, and the M&V method uses a simulation tool: the National Renewable Energy Laboratory's (NREL) PVWatts™.

Eligibility Criteria

Only photovoltaic systems that result in net reductions of the customer's purchased energy and peak demand qualify for these deemed savings estimates.

The installation must also meet the following requirements in order to be eligible for these deemed savings values:

- The system shall be installed by a licensed electrical contractor or, in the case of a residential installation by the homeowner, with the approval of the electrical inspector in accordance with the National Electric Code (NEC 690, "Solar Photovoltaic Systems") or local building codes.
- If the system is utility interactive the inverter shall be listed by national testing laboratory (see, for example, UL 1741, "Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems") and meet the requirements of the Institute of Electrical

and Electronics Engineers (IEEE) Standard 929-2000 “Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.”

- The estimated annual energy generation from the PV system shall not exceed the customer’s annual energy consumption.
- **Standard Installation:** The array azimuth shall be within +/- 20 degrees of south; the tilt angle shall be between 0 (horizontal) and latitude + 15 degrees to use the deemed savings factors.
- **Non-Standard Installation:** PUCT Docket No. 40885 allows for alternative means for estimating deemed savings for solar PV systems for non-standard installations, allowing residential customers around the state access to utility incentives for systems installed on roofs – or portions of roofs – that are not within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site specific considerations. The proposed alternative would also facilitate the installation of single-axis or two-axis tracking systems. For those solar PV installations that do not conform to the installation standards of the existing deemed savings, the deemed demand and energy savings should be established by modeling the performance of the system using PVWatts™ Version 1.

Each utility may have additional program eligibility requirements, which are listed here. These requirements are provided for reference purposes only, and are not listed in any PUCT-approved petition. Therefore, these utility-specific eligibility requirements may be subject to change.

- **American Electric Power and El Paso Electric:** The estimated annual electrical energy output of a solar electric system, as modeled by National Renewable Energy Laboratory’s (NREL) PVWatts™[150] and considering an appropriate factor for shading, must be at least 80% of the estimated annual energy output for an optimally-sited, un-shaded system of the same DC capacity.

Baseline Condition

PV system not currently installed (typical), or production capacity of an existing system is less than any utility requirements, so that additional panels can be added.

High-Efficiency Condition

PV systems must meet the eligibility criteria shown above to be eligible for incentives.

Energy and Demand Savings Methodology

Depending on whether a solar PV system qualifies as a “standard” or “non-standard” installation, separate savings methodologies may be used to calculate savings as outlined in the following sections. Non-standard systems are those installed on roofs – or portions of roofs – that are not

[150] Optimally-sited system is determined by selecting an appropriate location, entering system capacity in kWdc, and accepting default parameters for tilt (latitude tilt), orientation (due south), and derating factor (0.77) into the PVWatts calculator.

within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site-specific considerations.

Savings Algorithms and Input Variables

Standard Installation

The following formula calculates the energy savings for solar electric photovoltaic energy systems based on the rated watts DC_{STC}.

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = 1.60 \times Watts\ DC_{STC}\ installed}$$

Equation 71

Non-Standard Installation

PUCT Docket No. 40885 allows for alternative means for estimating deemed savings for solar PV systems for non-standard installations, permitting both residential and commercial customers around the state access to utility incentives for systems installed on roofs – or portions of roofs – that are not within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site specific considerations. The proposed alternative would also facilitate the installation of single-axis or two-axis tracking systems.

For those solar PV installations that do not conform to the installation standards of the existing deemed savings, the deemed demand and energy savings be established by modeling the performance of the system using PVWatts™ Version 1.[151]

Summer Demand Savings Methodology

The following formula calculates the demand savings for solar electric photovoltaic energy systems based on the rated watts DC_{STC}.

$$\boldsymbol{Deemed\ Demand\ Savings\ (kW) = 0.83 \times kW\ DC_{STC}\ installed}$$

Equation 72

Winter Demand Savings Methodology

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

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.

[151] A. P. Dobos. PVWatts Version 1 Technical Reference. National Renewable Energy Laboratory. NREL/TP-6A20-60272. October 2013. http://www.nrel.gov/docs/fy14osti/60272.pdf. PVWatts™ v.1 calculator available at: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/.

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

For non-standard installation PV systems, PVWatts™ should be used to model the performance of the system and to estimate energy and demand savings.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of photovoltaic system is established at 30.0 years.

This value is consistent with the Frontier Associates' engineering estimate based on manufacturers' warranties.

Program Tracking Data & Evaluation Requirements

The following information will be required to be collected to determine the project eligibility.

- Project location (city)
- DC rating for the system
- Standard or non-standard system
- Savings approach type: deemed algorithm or PVWatts™
- System latitude
- System tilt
- System azimuth

References and Efficiency Standards

Petitions and Rulings

- Docket No. 40885. 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 Revise Deemed Savings Values for Commercial HVAC and Solar Photovoltaic Measures. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

- National Electric Code (NEC) 690, "Solar Photovoltaic Systems" or local building codes.
- Institute of Electrical and Electronics Engineers (IEEE) Standard 929-2000 "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems." http://standards.ieee.org/findstds/standard/929-2000.html.
- A. P. Dobos. PVWatts Version 1 Technical Reference. National Renewable Energy Laboratory. NREL/TP-6A20-60272. October 2013. http://www.nrel.gov/docs/fy14osti/60272.pdf. PVWattsTM v.1 calculator available at: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/.

Document Revision History

Table 2-249: Residential Solar Electric (Photovoltaic) Energy Systems Revision History

TRM Version	Date	Description of Change
v1.0	11/25/2013	TRM v1.0 origin
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language and structure.

2.8 RESIDENTIAL: LOAD MANAGEMENT

2.8.1 Direct Load Control of Outdoor Compressor Units Measure Overview

TRM Measure ID: R-LM-OC

Market Sector: Residential

Measure Category: Load Management

Applicable Building Types: Single-family

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Estimates and M&V

Measure Description

These deemed savings values will provide a benchmark for estimating the annual summer peak demand savings associated with the curtailment of residential air conditioning energy usage during periods of high demand via direct load control switches or certain programmable communicating thermostats installed to control the outdoor compressor units of split unitary HVAC systems in detached single-family homes in CenterPoint Houston's service territory. The deemed savings values are on a per-home basis, predicated on basic considerations related to the design and implementation of a residential demand response program.

Eligibility Criteria

The home must be an occupied, single-family detached home that participates in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to all outdoor units (compressors) of the unitary split central air conditioning systems installed at a home

Baseline Condition

This section is not applicable.

High-Efficiency Condition

This section is not applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

CenterPoint Houston undertook` a multi-year research project evaluating the potential for a residential demand response program allowing residential customers in single-family, detached homes to provide summer peak demand savings by participating in load curtailment events with remotely-controllable, major electric energy end use equipment in their homes.

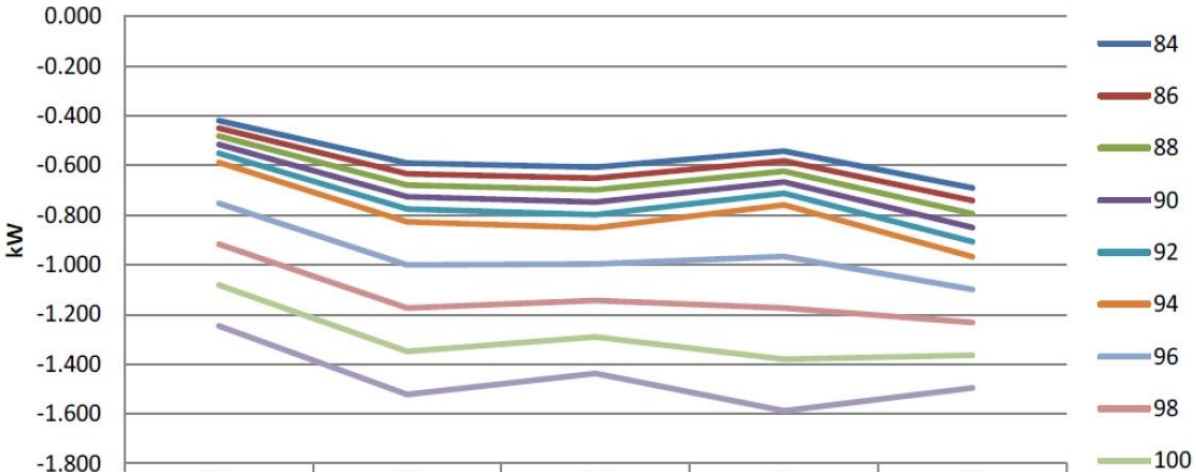
The 2011 pilot involved installation of 74 direct load control (DLC) switches on outdoor compressor units at the homes of test group participants in the CenterPoint Smart Partners program. Measurement and verification was performed using data from 30 homes (in which 35 switches were installed) randomly selected from among the participants.

The 2012 pilot involved installation of 1,379 DLC switches at 1,026 homes in the CenterPoint Houston service territory. A total of 314 customers were randomly selected for this M&V study. Sub metering devices were installed on 458 air conditioner compressors and 18 pool pumps at these 314 premises. Participating homes were self-selected from among the customers of two Retail Electric Providers who agreed to participate in the program.

Load control events were called during the summers of 2011 and 2012. Events were two to four hours in duration (though only 3 and 4 hour events were included in the analysis presented herein), and began at either 2 p.m. or 3 p.m. (ending at either 6 p.m. or 7 p.m.; no three-hour events were begun at 2 p.m. to avoid “bounce back” in the peak hour, which frequently occurs between 5 p.m. and 6 p.m.). The general criterion for events was a daily high temperature above 94 degrees, but events were called with a range of temperatures occurring across the duration of events. Furthermore, operating conditions affecting residential demand for cooling vary across these hours (on average, occupancy is lower earlier in the afternoon and demand for cooling is further lowered for those homes employing afternoon setups via programmable thermostats until the evening program is engaged). As such, estimates of hourly load shed for HVAC compressors were developed by hour and by temperature.

Hourly compressor load shed estimates were developed by the implementing contractor using regression analysis on hourly loads estimated from on/off runtime monitoring of the controlled compressor units. They are reproduced in Figure 2-6, which shows load reduction between 2 p.m. and 7 p.m. (the values on the horizontal axis are the hour ending values, so 15 represents 15:00, or the hour from 2:00–3:00 p.m.). The load reduction in any single hour ranges from 0.42 kW at 84 degrees in the 2 p.m. hour to just under 1.6 kW at 102 degrees in the 6 p.m. hour.

Figure 2-6: Primary Load Reductions (kW/Household), DLC Switch on Residential HVAC Compressor Unit



	15	16	17	18	19
84	-0.419	-0.590	-0.607	-0.542	-0.691
86	-0.450	-0.633	-0.652	-0.582	-0.741
88	-0.482	-0.679	-0.698	-0.623	-0.794
90	-0.515	-0.726	-0.747	-0.666	-0.849
92	-0.551	-0.775	-0.798	-0.712	-0.907
94	-0.587	-0.827	-0.851	-0.759	-0.968
96	-0.752	-1.001	-0.997	-0.966	-1.100
98	-0.917	-1.175	-1.144	-1.174	-1.232
100	-1.082	-1.348	-1.290	-1.381	-1.364
102	-1.247	-1.522	-1.437	-1.588	-1.496

Development of the proposed deemed savings value based on this information takes into account two factors: (1) the expected design of the measure for which the proposed deemed savings value will be used, and (2) the weather conditions that can be expected in a summer peak demand period, when CenterPoint Houston will want to deploy the residential demand response to maximize capacity. Specifically, the proposed deemed savings values were developed based on the following parameters:

- Curtailment events will be four hours in duration, lasting either from 2 p.m. to 6 p.m. or 3 p.m. to 7 p.m., and will only be called on weekdays.
- Cycling will be accomplished by deploying a 50 percent cycling strategy (taken as a percentage of time) or an equivalent strategy.
- Participating customers will be asked to provide demand response services for up to 40 total hours per summer peak demand period (10 events, based on the above four hours per event).
- Curtailment events will be initiated on days when system demand is expected to be at its highest, which, in turn, will generally correlate with high temperatures.

Given these program considerations, an analysis of typical meteorological year data for CenterPoint Houston's service territory was undertaken, using Typical Meteorological Year (TMY3) data for Houston's Bush Intercontinental Airport. In a Typical Meteorological Year, there are twenty days with high temperatures of 96 degrees or above. Given that 2 of every 7 days are likely to be weekends, approximately 14 of these 20 days would be weekdays, on which events could be initiated. As such, it is reasonable to expect that the ten events called each summer peak demand season will occur on days for which conditions in these twenty peak days are representative. Using the average temperature in each hour between 2PM and 7 PM for those twenty days, typical load reductions for each hour can be constructed from the data provided in Figure 2-6.

Table 2-250: Typical Hourly Load Reductions, Compressor Units on Residential HVAC Systems

Hour	Temperature (°F)	Typical Load Reduction (kW)
2 p.m.–3 p.m.	97.1	0.84
3 p.m.–4 p.m.	97.2	1.00
4 p.m.–5 p.m.	95.1	0.93
5 p.m.–6 p.m.	92.5	0.72
6 p.m.–7 p.m.	89.1	0.82
Average Hourly Load Reduction		**0.86**

Assuming an even distribution of events that run from 2 p.m. to 6 p.m. and events that run from 3 p.m. to 7 p.m., an average hourly load reduction of 0.86 kW per home is estimated.

Programmable communicating thermostats may receive the same deemed savings so long as they follow the same parameters outlined above.

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

Occupied, single-family detached homes that participate in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to all outdoor units (compressors) of the unitary split central air conditioning systems installed at a home are granted a deemed savings value of 0.86 kW per home per summer peak demand period.

Table 2-251: Direct Load Control of Outdoor Compressor Units
Summer Peak Demand Savings

DLC for Outdoor Compressor Units
Summer Peak Savings (kW)
0.86

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 measure life for the residential demand response measure for which these deemed savings values are granted is one year.

Program Tracking Data & Evaluation Requirements

No primary inputs or contextual data must be specified or tracked by the program database to inform the evaluation and apply the savings properly, beyond evidence of participation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41413. Petition of CenterPoint Energy Houston Electric, LLC to Establish Deemed Savings Values for Residential Demand Response with Direct Load Control Switches Installed on Outdoor Compressor Units. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-252: Residential Direct Load Control of Outdoor Compressor Units 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. Modified to allow for thermostat-regulated direct load control. Minor edits to language.

2.8.2 Direct Load Control of Swimming Pool Pump Motors Measure Overview

TRM Measure ID: R-LM-SP

Market Sector: Residential

Measure Category: Load Management

Applicable Building Types: Single-family

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Estimates and M&V

Measure Description

These deemed savings values will provide a benchmark for estimating the annual summer peak demand savings associated with the curtailment of swimming pool filtration system energy usage during periods of high demand via direct load control switches or certain programmable communicating thermostats installed to control the electrical supplies to pool pump motors in detached single-family homes in CenterPoint Houston's service territory. The deemed savings values are on a per-home basis, predicated on basic considerations related to the design and implementation of a residential demand response program.

Eligibility Criteria

Pool pump motors must be installed in an occupied, single-family detached home that participates in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to the motor(s) driving the pump(s) of a swimming pool filtration system.

Baseline Condition

This section is not applicable.

High-Efficiency Condition

This section is not applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

CenterPoint Houston undertook a multi-year research project evaluating the potential for a residential demand response program allowing residential customers in single-family, detached homes to provide summer peak demand savings by participating in load curtailment events with remotely-controllable, major electric energy end use equipment in their homes.

The 2011 pilot involved installation of 74 direct load control (DLC) switches on outdoor compressor units at the homes of test group participants in the CenterPoint Smart Partners program. Measurement and verification was performed using data from 30 homes (in which 35 switches were installed) randomly selected from among the participants.

The 2012 pilot involved installation of 1,379 DLC switches at 1,026 homes in the CenterPoint Houston service territory. A total of 314 customers were randomly selected for this M&V study. Sub metering devices were installed on 458 air conditioner compressors and 18 pool pumps at these 314 premises. Participating homes were self-selected from among the customers of two Retail Electric Providers who agreed to participate in the program.

Load control events were called during the summers of 2011 and 2012. Events were two to four hours in duration (though only 3 and 4 hour events were included in the analysis presented herein), and began at either 2 p.m. or 3 p.m. (ending at either 6 p.m. or 7 p.m.; no three-hour events were begun at 2 p.m. to avoid “bounce back” in the peak hour, which frequently occurs between 5 and 6 p.m.). The general criterion for events was a daily high temperature above 94 degrees, but events were called with a range of temperatures occurring across the duration of events. Furthermore, operating conditions affecting residential demand for cooling vary across these hours (on average, occupancy is lower earlier in the afternoon and demand for cooling is further lowered for those homes employing afternoon setups via programmable thermostats until the evening program is engaged). As such, estimates of hourly load shed for HVAC compressors were developed by hour and by temperature.

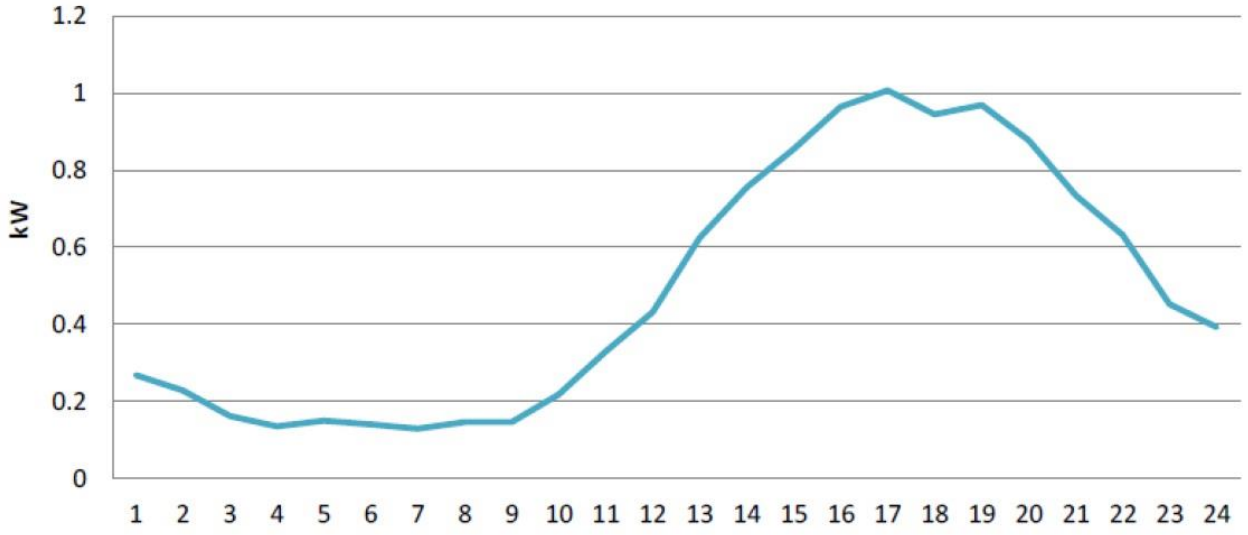
Development of the proposed deemed savings value based on this information takes into account two factors: (1) the expected design of the measure for which the proposed deemed savings value will be used, and (2) the weather conditions that can be expected in a summer peak demand period, when CenterPoint Houston will want to deploy the residential demand response to maximize capacity. Specifically, the proposed deemed savings values were developed based on the following parameters:

- Curtailment events will be four hours in duration, lasting either from 2 p.m. to 6 p.m. or 3 p.m. to 7 p.m., and will only be called on weekdays.
- Cycling will be accomplished by deploying a 100 percent cycling strategy (taken as a percentage of time) or an equivalent strategy.
- Participating customers will be asked to provide demand response services for up to 40 total hours per summer peak demand period (10 events, based on the above four hours per event).
- Curtailment events will be initiated on days when system demand is expected to be at its highest, which, in turn, will generally correlate with high temperatures.

Given these program considerations, an analysis of typical meteorological year data for CenterPoint Houston's service territory was undertaken, using Typical Meteorological Year (TMY3) data for Houston's Bush Intercontinental Airport. In a Typical Meteorological Year, there are twenty days with high temperatures of 96 degrees or above. Given that 2 of every 7 days are likely to be weekends, approximately 14 of these 20 days would be weekdays, on which events could be initiated. As such, it is reasonable to expect that the ten events called each summer peak demand season will occur on days for which conditions in these twenty peak days are representative.

The variables of interest in estimating pool pump demand savings are the typical energy draw of swimming pool pumps, and their aggregated load shape. Figure 2-7 presents the observed load shape from on-off monitoring and nameplate data collection for pool pumps observed in the 2012 pilot in Houston.

Figure 2-7: Average Hourly Pool Pump Demand



On average, the observed demand pattern is consistent with pumping systems that draw 1.5 kW for 8 hours per day; however, the curve provides relatively high coincidence, with average demand of 0.95 kW for the five hours between 2 p.m. and 7 p.m. during which the 4-hour events are likely to be called. As such, the proposed deemed demand savings for swimming pool pumps is 0.95 kW.

Programmable communicating thermostats may receive the same deemed savings so long as they follow the same parameters outlined above.

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

Occupied, single-family detached homes that participate in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to the motor(s) driving the pump(s) of a swimming pool filtration system are granted a deemed savings value of 0.95 kW per home per summer peak demand period.

Table 2-253: Direct Load Control of Swimming Pool Pump Motors
Summer Peak Demand Savings

DLC for Pool Pump Motors
Summer Peak Savings (kW)
0.95

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 measure life for the residential demand response measure for which these deemed savings values are granted is one year.

Program Tracking Data & Evaluation Requirements

No primary inputs or contextual data must be specified or tracked by the program database to inform the evaluation and apply the savings properly, beyond evidence of participation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41413. Petition of CenterPoint Energy Houston Electric, LLC to Establish Deemed Savings Values for Residential Demand Response with Direct Load Control Switches Installed on Outdoor Compressor Units. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-254: Residential Direct Load Control of Swimming Pool Pump Motors 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. Modified to allow for thermostat-regulated direct load control. Minor edits to language.

2.9 RESIDENTIAL: APPLIANCE RECYCLING

2.9.1 Refrigerator/Freezer Recycling Measure Overview

TRM Measure ID: R-AP-RR

Market Sector: Residential

Measure Category: Appliance Recycling

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

Fuels Affected: Electricity

Decision/Action Type(s): Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves early retirement and recycling of an existing, full-size (7.75 ft^3 or greater) refrigerator/freezer in a residential application. Savings represent the entire estimated energy consumption of the existing unit and are applicable over the estimated remaining life of the existing unit.

Eligibility Criteria

This measure applies to operable primary and secondary retired refrigerators/freezers. Recycling savings for this measure are limited to the removal of a working refrigerator/freezer from the electrical grid, and differ from the savings specified in the ENERGY STAR® Refrigerator replacement measure. The latter, which pertain to the direct replacement of a refrigerator and reflect the difference in energy consumption between new ENERGY STAR®-qualifying and standard efficiency models, may be claimed for the recycling of primary refrigerators/freezers that have been replaced, provided that savings for that replacement were not already claimed in another energy efficiency program. To qualify, the customer must release the existing unit to the utility or utility representative in order to ensure proper disposal in accordance with applicable federal, state, and local regulations.

Baseline Condition

Without program intervention, the recycled refrigerator or freezer would have remained operable on the electrical grid. As a result, the baseline condition for early retirement programs is the status quo (continued operation) and the basis for estimating energy savings is the annual energy

consumption of the refrigerator or freezer being retired (as specified in the “Energy and Demand Savings Methodology” section).

High-Efficiency Condition

There is no efficiency standard for a recycling measure because the energy efficient action is the removal of an operable appliance, not—as with most demand side management programs—the installation of a higher efficiency model.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

Energy savings are calculated as follows:

$$\begin{aligned} \boldsymbol{kWh_{savings}} &= \boldsymbol{kWh_{existing}} \times \boldsymbol{ISAF} \times \boldsymbol{PUF} \\ &= \mathbf{1,308} \times \mathbf{0.942} \times \mathbf{0.915} \\ &= \mathbf{1,128}\ \boldsymbol{kWh} \end{aligned}$$

Equation 73

Where:

$kWh_{existing}$	=	*Average annual energy consumption[152] = 1,308 kWh*
$ISAF$	=	*In Situ Adjustment Factor[153] = 0.942*
PUF	=	*Part Use Factor[154] = 0.915*

[152] The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report". Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Average of DOE-Based Full-Year Unit Energy Consumption (weighted by representative utility survey participation).

[153] Ibid. Factor to account for variation between site conditions and controlled DOE testing conditions (90 °F test chamber, empty refrigerator and freezer cabinets, and no door openings). Appliances in warmer climate zones use more energy than those in cooler climate zones; utilized SCE data (highest percentage of warm climate projects) to best approximate Texas climate, p. 139-140.

[154] Ibid. Factor to account for the number of refrigerators that were running, running part time, or not running at the time of recycling, p. 142-143 (weighted by representative utility survey participation, p. 117).

Demand Savings

Summer peak demand savings are calculated as follows:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times TAF \times LSAF$$
$$= \frac{1,128}{8760} \times 1.249 \times 1.074$$
$$= 0.173\ kW$$

Equation 74

Where:

AOH	=	*Annual Operating Hours = 8,760 hours*
TAF	=	*Temperature Adjustment Factor*[155,156] *= 1.249*
$LSAF$	=	*Load Shape Adjustment Factor*[157] *= 1.074*

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.

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155 Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report - 2003-2004 Metering Study". July 29, 2004. Factor to adjust for varying temperature based on site conditions (conditioned vs. unconditioned space), p. 47.

156 The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report". Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Assuming 62% primary refrigerators/conditioned space and 36% secondary refrigerators/unconditioned space, p.137 (weighted by representative utility survey participation, p. 117).

157 Proctor Engineering Group, Michael Blasnik & Associates, and Conservation Services Group. "Measurement & Verification of Residential Refrigerator Energy Use: Final Report - 2003-2004 Metering Study". July 29, 2004. Used load shape adjustment for "hot days" during the 4PM hour, p. 45-48.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

Based on the KEMA Residential Refrigerator Recycling Ninth Year Retention Study,[158] the Estimated Useful Life of Refrigerator Recycling is 8 years, representing the assumed remaining useful life of the retired unit.

Program Tracking Data & Evaluation Requirements

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

- Number of refrigerators/freezers replaced
- Age of removed unit
- Size (in cubic feet)
- Configuration (top freezer, bottom freezer, side-by-side, or single-door)

References and Efficiency Standards

Petitions and Rulings

- Docket No. 42212. Petition of El Paso Electric Company to Approve Revisions to the Deemed Savings for the Appliance Recycling Market Transformation program. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 2-255: Residential Refrigerator/Freezer Recycling Revision History

TRM Version	Date	Description of Change
v2.1	1/30/2015	TRM v2.1 origin

[158] KEMA, Inc. “Residential Refrigerator Recycling Ninth Year Retention Study.” Prepared for Southern California Edison Company. July 22, 2004.