Baseline Condition

This baseline applies to replace-on-burnout, early retirement, and new construction.

For most installations, the baseline condition is an electric storage water heater with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, which took effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 269).[321]

Table 269. Federal Standard for Residential Electric Storage Water Heaters

Rated storage volume	Draw pattern	First hour rating (FHR)[322][323]	Uniform energy factor (UEF)[324]
≥ 20 gal and ≤ 55 gal	Very Small Usage	0 ≤ FHR < 18	0.8808 − (0.0008 × V_r)
	Low Usage	18 ≤ FHR < 51	0.9254 − (0.0003 × V_r)
	Medium Usage	51 ≤ FHR < 75	0.9307 − (0.0002 × V_r)
	High Usage	75 ≤ FHR	0.9349 − (0.0001 × V_r)
> 55 gal and ≤ 120 gal	Very Small Usage	0 ≤ FHR < 18	1.9236 − (0.0011 × V_r)
	Low Usage	18 ≤ FHR < 51	2.0440 − (0.0011 × V_r)
	Medium Usage	51 ≤ FHR < 75	2.1171 − (0.0011 × V_r)
	High Usage	75 ≤ FHR	2.2418 − (0.0011 × V_r)

The new DOE efficiency standard effectively requires HPWHs (assuming electric water heating) for electric storage water heaters with tank size greater than 55 gallons. As such, electric water heaters with tanks greater than 55 gallons are not eligible for this measure. Instead, see the Heat Pump Water Heater measure. Furthermore, gas water heaters greater than 55 gallons must use HPWH baseline consumption to calculate savings.

For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source.

High-Efficiency Condition

For water heater replacement and fuel substitution, the new unit must meet the following federal minimum energy factor shown in Table 270~~Table 270~~. Water heaters must be installed in accordance with local code requirements.

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[321] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32. ~~Accessed August 2020~~

[322] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[323] Assume FHR equal to that of installed water heater.

[324] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Table 270. Water Heater Replacement—Efficiency Standards[325]

DHW type	Rated storage volume	Draw pattern	FHR	UEF[326]
Electric Tankless	< 2 gal	Very Small Usage	0 ≤ FHR < 18	0.91
		Low Usage	18 ≤ FHR < 51	0.91
		Medium Usage	51 ≤ FHR < 75	0.91
		High Usage	75 ≤ FHR	0.92
Gas Tankless	< 2 gal and > 50,000 Btuh	Very Small Usage	0 ≤ FHR < 18	0.80
		Low Usage	18 ≤ FHR < 51	0.81
		Medium Usage	51 ≤ FHR < 75	0.81
		High Usage	75 ≤ FHR	0.81
Gas Storage	≥ 20 gal and ≤ 55 gal	Very Small Usage	0 ≤ FHR < 18	0.3456 – (0.0020 x V_r)
		Low Usage	18 ≤ FHR < 51	0.5982 – (0.0019 x V_r)
		Medium Usage	51 ≤ FHR < 75	0.6483 – (0.0017 x V_r)
		High Usage	75 ≤ FHR	0.6920 – (0.0013 x V_r)
	> 55 gal and ≤ 100 gal	Very Small Usage	0 ≤ FHR < 18	0.6470 – (0.0006 x V_r)
		Low Usage	18 ≤ FHR < 51	0.7689 – (0.0005 x V_r)
		Medium Usage	51 ≤ FHR < 75	0.7897 – (0.0004 x V_r)
		High Usage	75 ≤ FHR	0.8072 – (0.0003 x V_r)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

Electric Tankless Water Heater

Energy Savings Algorithm

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

Equation 71

[325] 10 CFR Part 430.32 Energy and water conservation standards. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32. ~~Accessed August 2020.~~

[326] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Where:

ρ = *Water density (= 8.33 lbs/gallons)*

C_p = *Specific heat of water (= 1 Btu/lb·°F)*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 271)*

Table 271. Water Heater Consumption (Gal/Year)[327]

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

$T_{SetPoint}$ = *Water heater setpoint (= 120°F)*[328]

$T_{Supply,ann}$ = *Annual average mains temperature from Table 272*

UEF_{pre} = *Baseline uniform energy factor (calculate per* Table 270~~Table 270~~*)*[329]

UEF_{post} = *Uniform energy factor of new water heater (must exceed values from Table 270)*

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

[327] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[328] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

[329] Note that for efficient water heater installations in newly-constructed homes, the baseline energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

Table 272. Water Mains Temperature[330]

Climate zone		Water mains temperature (°F)		
		$T_{supply,annual}$	$T_{supply,seasonal}$	
			Summer	Winter
1	Panhandle	62.9	73.8	53.7
2	North	71.8	84.0	60.6
3	South	74.7	84.5	65.5
4	Valley	77.2	86.1	68.5
5	West	70.4	81.5	60.4

Demand Savings Algorithm

$$kW_{savings,summer} = CF_{Summer} \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412}$$

Equation 72

$$kW_{savings,winter} = CF_{Winter} \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,winter}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412}$$

Equation 73

Where:

CF = *Coincident peak demand factor, see Table 273~~Table 273~~.*

$T_{Supply,sum}$ = *Summer average water mains temperature (see Table 272)* — Field Code Changed

$T_{Supply,win}$ = *Winter average water mains temperature (see Table 272)* — Field Code Changed

[330] Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. https://nsrdb.nrel.gov/data-sets/archives.html. ~~Accessed August 2020.~~

Table 273. Coincident Peak Demand Factors[331]

Climate zone	Summer CF	Winter CF
1	0.042	0.067
2	0.039	0.068
3	0.041	0.070
4	0.041	0.065
5	0.036	0.067

Gas Storage or Tankless Water Heater (Fuel Substitution)

Energy and demand savings awarded for replacing an electric water heater with a gas storage or gas tankless water heater are equal to the consumption of the unit replaced.

For gas storage water heaters with a tank size greater than 55 gallons, or gas tankless water heaters replacing a unit greater than 55 gallons, the appropriate baseline is a HPWH. The baseline consumption values are calculated using the federal standard baseline condition specified in the Heat Pump Water Heater measure.

Energy Savings Algorithm for Units Less than 55 Gallons

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}}\right)}{3{,}412}$$

Equation 74

Demand Savings Algorithm for Units Less than 55 Gallons

$$SummerkW_{savings} = CF_{Summer} \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

Equation 75

$$WinterkW_{savings} = CF_{Winter} \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,winter}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

Equation 76

[331] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf. ~~Accessed August 2020.~~

Example Deemed Savings Calculation

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 a first-hour rating of 60 gal/hr and a uniform energy factor of 0.99.

$$kWh_{savings} = \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 71.8) \times \left(\frac{1}{0.9227} - \frac{1}{0.99}\right)\right]}{3{,}412} = 167\ kWh$$

$$kW_{savings,summer} = 0.042 - \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 84) \times \left(\frac{1}{0.9227} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.01\ kW$$

$$kW_{savings,winter} = 0.068 \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 60.6) \times \left(\frac{1}{0.9227} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.04\ kW$$

Example 2. An old 30-gallon electric water heater in a one-bedroom house in El Paso is replaced with a new gas storage water heater with a first-hour rating of 51 gal/hr and a uniform energy factor of 0.81.

$$kWh_{savings} = \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 70.4) \times \left(\frac{1}{0.9247}\right)\right]}{3{,}412} = 1{,}952\ kWh$$

$$kW_{savings,summer} = 0.036 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 81.5) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.15\ kW$$

$$kW_{savings,winter} = 0.067 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 60.4) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.43\ kW$$

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, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 20 years for a tankless water heater (gas or electric), as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Instant-Res.[332]

The EUL is 11 years for a high-efficiency gas water heater, as specified for EUL ID WtrHt-Res-Gas.~~The average EULs for installed equipment are: 20 years for a tankless water heater (gas or electric) and 11 years for a high-efficiency gas water heater.~~

~~These values are consistent with the EULs reported in the 2014 California DEER.~~[333]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Volume of the replacement water heater (gallons, zero if tankless)
- Volume of the existing water heater (gallons)
- First hour rating of replacement water heater (gal/hr)
- Uniform energy factor of the replacement water heater
- Number of bedrooms
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

[332] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[333] ~~2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.~~

Document Revision History

Table 274. Residential Water Heater Installations Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated measure to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. Updated to reflect that new construction permitted to claim savings subject to documentation requirements and that gas-fueled tankless water heaters are eligible for installation.
v3.0	04/10/2015	TRM v3.0 update. Amended fuel substitution savings to reflect the full consumption of the electric unit being replaced. Revised demand savings for installing an electric tankless unit to reflect daily usage patterns.
v3.1	11/05/2015	TRM v3.1 update. Clarified the baseline for water heaters greater than 55 gallons.
v4.0	10/10/2016	TRM v4.0 update. Updated HPWH baseline usage for gas storage water heaters larger than 55 gallons.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	11/2019	TRM v7.0 update. Implemented new baseline and high-efficiency standards.
v8.0	10/2020	TRM v8.0 update. Clarified HPWH baseline for tanks sizes over 55 gal. Updated algorithms to refer to UEF.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.

2.4.6 Heat Pump Water Heaters Measure Overview

TRM Measure ID: R-WH-HW

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up 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, first-hour rating, 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.[334]

These deemed savings are calculated using the amended federal standards for electric consumer water heaters effective April 16, 2015.

Eligibility Criteria

This measure applies to residential, electric, and storage-type heat pump water heaters. 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. New construction homes are also eligible to claim savings under this measure.~~

Baseline Condition

~~This baseline applies to replace-on-burnout, early retirement, and new construction.~~

[334] Interaction with space heating equipment only affects deemed savings for units below 55 gallons. This is because the measure assumes replace on burnout and 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. For these units any interaction with the space conditioning systems are essentially the same for base and change case systems, so they cancel each other out.

The baseline condition is an electric storage water heater (EWH) with baseline efficiency (UEF: uniform energy factor) determined by tank size and draw pattern – a proxy for first hour rating – 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.[335]

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline.

Table 275. Federal Standard for Residential Water Heaters

Rated storage volume	Draw pattern	First hour rating (FHR) [336]	Uniform energy factor[337]
≥ 20 gal and ≤ 55 gal	Very Small Usage	0 ≤ FHR < 18	0.8808 − (0.0008 × V_r)
	Low Usage	18 ≤ FHR < 51	0.9254 − (0.0003 × V_r)
	Medium Usage	51 ≤ FHR < 75	0.9307 − (0.0002 × V_r)
	High Usage	75 ≤ FHR	0.9349 − (0.0001 × V_r)
> 55 gal and ≤ 120 gal	Very Small Usage	0 ≤ FHR < 18	1.9236 − (0.0011 × V_r)
	Low Usage	18 ≤ FHR < 51	2.0440 − (0.0011 × V_r)
	Medium Usage	51 ≤ FHR < 75	2.1171 − (0.0011 × V_r)
	High Usage	75 ≤ FHR	2.2418 − (0.0011 × V_r)

Because 98% of all certified ENERGY STAR® water heaters are in the medium and high usage categories, the *very small usage* and *low usage* draw pattern categories are not included in this measure. Discarding these draw patterns and applying average tank volumes within four strata of storage tank sizes, the application of this equation provides the following baseline efficiency levels for residential electric storage water heaters.

Table 276. Heat Pump Water Heaters—Minimum Required Uniform Energy Factors

	Tank size (gallons)			
Usage rate	45	65	75	82
Medium Usage	0.922	2.046	2.035	N/A
High Usage	N/A	2.170	2.159	2.152

The DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank sizes 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.

[335] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. ~~Online. Available:~~ www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8. ~~Accessed August 2020~~.

[336] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[337] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

High-Efficiency Condition

The efficient condition is a heat pump water heater certified by ENERGY STAR® with uniform energy factor (UEF) greater than 2.3.[338] A complete list of certified ENERGY STAR® heat pump water heaters can be accessed via the ENERGY STAR® program website.[339]

Heat pump water heaters depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces in where 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.[340]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Deemed savings are estimated using a model that applies a similar algorithm to that used in the Water Heater Installations measure, based on gallons per year, temperature difference, and efficiency (UEF). ~~The average uniform energy factor (UEF) of~~ ENERGY STAR® certified systems with UEF > 2.3 by storage tank size strata and first-hour rating/usage draw pattern according to the list of certified products available in August 2021~~2018~~.[341] Consumption in gallons per year us estimated using data from Building America Performance Analysis Procedures for Existing Homes.[342] Temperature data are based on TMY3 dataset.[343]

[338] ENERGY STAR® Requirements (as of April 2015): HPWH must have nominal input of 75,000 BTU/h or less, 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 for units ≤ 55 gal, EF ≥ 2.20 for units > 55 gal, first-hour rating (FHR) ≥ 50 gallons/hour, Warranty ≥ 6 years on sealed systems, Safety UL 174 and UL 1995.~~.~~ See: https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.

[339] ENERGY STAR Certified Water Heaters qualified product listing. ~~Online. Available:~~ https://www.energystar.gov/productfinder/product/certified-water-heaters/?scrollTo=721.5999755859375&search_text=&fuel_filter=Electric&type_filter=Heat+Pump&brand_name_isopen=&input_rate_thousand_btu_per_hour_isopen=&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=uniform_energy_factor_uef&sort_direction=asc&currentZipCode=1871&page_number=0&lastpage=0

[340] Heat Pump Water Heaters. Department of Energy, May 2012. ~~Online. Available:~~ http://energy.gov/energysaver/articles/heat-pump-water-heaters ~~http://energy.gov/energysaver/articles/heat-pump-water-heaters. Accessed: August 2020.~~.

[341] As of August 2021~~0~~, the ENERGY STAR® products list includes 2330~~5~~ residential heat pump water heaters with UEF >2.3.

[342] Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf. ~~Accessed August 2020~~.

[343] TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. https://nsrdb.nrel.gov/data-sets/archives.html. ~~Accessed August 2020~~.

Deemed Energy Savings Tables

Deemed savings are developed for heat pump water heaters in four size ranges: less than or equal to 55 gallons, 56-69 gallons, 70-79 gallons, and 80 gallons or more. These sizes correspond to the four basic sizes of HPWHs commercially available at the time these deemed savings were developed, according to a review of manufacturer data provided on the ENERGY STAR® and AHRI websites. Table 277~~Table 277~~ presents the deemed energy savings tables for medium usage HPWHs for the five Texas climate zones. This table assumes a replace-on-burnout scenario but may be used for early retirement and new construction projects.

Table 277. Medium Usage Residential HPWH Deemed Annual Energy Savings (kWh)

Climate zone		HPWH tank size range (gallons)	Conditioned space			Unconditioned space
			Gas heat	Electric resistance	Heat pump	
1	Panhandle	<55	2,244	1,450	1,899	2,102
		55-69	592	592	592	616
		70-79	600	600	600	623
2	North	<55	1,985	1424	1,741	1,825
		55-69	496	496	496	500
		70-79	502	502	502	506
3	South	<55	1,897	1342	1,656	1,729
		55-69	465	465	465	457
		70-79	470	470	470	462
4	Valley	<55	1,840	1,510	1,696	1,649
		55-69	434	434	434	425
		70-79	439	439	439	430
5	West	<55	2,001	1,440	1,758	1,865
		55-69	511	511	511	515
		70-79	517	517	517	521

Table 278~~Table 278~~ presents the deemed energy savings tables for high usage HPWHs for the five Texas climate zones.

Table 278. High Usage Residential HPWH Deemed Annual Energy Savings (kWh)

Climate zone		HPWH tank size range (gallons)	Conditioned space			Unconditioned space
			Gas heat	Electric resistance	Heat pump	
1	Panhandle	55-69	652	652	652	677
		70-79	769	769	769	799
		80+	478	478	478	497
2	North	55-69	546	546	546	550
		70-79	644	644	644	649
		80+	401	401	401	404
3	South	55-69	511	511	511	502
		70-79	603	603	603	593
		80+	375	375	375	369
4	Valley	55-69	477	477	477	467
		70-79	563	563	563	551
		80+	351	351	351	343
5	West	55-69	562	562	562	566
		70-79	663	663	663	668
		80+	412	412	412	416

Deemed Summer Demand Savings Tables

Table 279~~Table 279~~ presents the deemed summer demand savings for medium usage heat pump water heaters across the five Texas climate zones.

Table 279. Medium Usage Residential HPWH Deemed Summer Demand Savings (kW)

Climate zone		HPWH tank size range (gallons)	Conditioned space	Unconditioned space
1	Panhandle	<55	0.31	0.27
		55-69	0.07	0.06
		70-79	0.07	0.06
2	North	<55	0.24	0.20
		55-69	0.05	0.04
		70-79	0.05	0.04
3	South	<55	0.24	0.20
		55-69	0.05	0.04
		70-79	0.05	0.04
4	Valley	<55	0.23	0.19
		55-69	0.05	0.04
		70-79	0.05	0.04
5	West	<55	0.26	0.22
		55-69	0.05	0.05
		70-79	0.06	0.05

Table 280~~Table 280~~ presents the deemed summer demand savings for medium usage heat pump water heaters across the five Texas climate zones.

Table 280. High Usage Residential HPWH Deemed Summer Demand Savings (kW)

Climate zone		HPWH tank size range (gallons)	Conditioned space	Unconditioned space
1	Panhandle	55-69	0.07	0.07
		70-79	0.09	0.08
		80+	0.05	0.05
2	North	55-69	0.05	0.05
		70-79	0.06	0.06
		80+	0.04	0.03
3	South	55-69	0.05	0.05
		70-79	0.06	0.06
		80+	0.04	0.04
4	Valley	55-69	0.05	0.05
		70-79	0.06	0.05
		80+	0.04	0.03
5	West	55-69	0.06	0.05
		70-79	0.07	0.06
		80+	0.04	0.04

Deemed Winter Demand Savings Tables

Table 281~~Table 281~~ presents the deemed winter demand savings for medium usage heat pump water heaters across the five Texas climate zones.

Table 281. Medium Usage Residential HPWH Deemed Winter Demand Savings (kW)

Climate zone		HPWH tank size range (gallons)	Conditioned space			Unconditioned space
			Gas heat	Electric resistance	Heat pump	
1	Panhandle	<55	0.57	0.00	0.44	0.54
		55-69	0.16	0.16	0.16	0.18
		70-79	0.16	0.16	0.16	0.18
2	North	<55	0.53	0.00	0.40	0.51
		55-69	0.15	0.15	0.15	0.16
		70-79	0.15	0.15	0.15	0.17
3	South	<55	0.48	0.00	0.36	0.47
		55-69	0.14	0.14	0.14	0.15
		70-79	0.14	0.14	0.14	0.15
4	Valley	<55	0.46	0.00	0.33	0.45
		55-69	0.13	0.13	0.13	0.14
		70-79	0.13	0.13	0.13	0.14
5	West	<55	0.52	0.00	0.39	0.51
		55-69	0.15	0.15	0.15	0.16
		70-79	0.15	0.15	0.15	0.16

Table 282~~Table 282~~ presents the deemed winter demand savings for high usage heat pump water heaters across the five Texas climate zones.

Table 282: High Usage Residential HPWH Deemed Winter Demand Savings (kW)

Climate zone		HPWH tank size range (gallons)	Conditioned space			Unconditioned space
			Gas heat	Electric resistance	Heat pump	
1	Panhandle	55-69	0.18	0.18	0.18	0.20
		70-79	0.21	0.21	0.21	0.23
		80+	0.13	0.13	0.13	0.15
2	North	55-69	0.17	0.17	0.17	0.18
		70-79	0.20	0.20	0.20	0.21
		80+	0.12	0.12	0.12	0.13
3	South	55-69	0.15	0.15	0.15	0.16
		70-79	0.18	0.18	0.18	0.19
		80+	0.11	0.11	0.11	0.12
4	Valley	55-69	0.14	0.14	0.14	0.15
		70-79	0.17	0.17	0.17	0.18
		80+	0.11	0.11	0.11	0.11
5	West	55-69	0.16	0.16	0.16	0.18
		70-79	0.19	0.19	0.19	0.21
		80+	0.12	0.12	0.12	0.13

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 13 years.[344]

[344] 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, "Heat Pump Water Heaters and American Homes: A Good Fit?" p 9-74. https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf. ~~Accessed August 2020.~~

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Approximate volume of the replacement heat pump water heater tank in gallons
- Replacement water heater UEF
- First-hour rating (FHR) of the replacement water heater
- Existing water heater type (heat pump, electric resistance)
- Installed location (conditioned, unconditioned space)
- For heat pump water heater installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 283. Residential Heat Pump Water Heaters Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	01/30/2015	TRM v2.1 update. No revision.
v3.0	04/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. Consolidated table formats.
v5.0	10/2017	TRM v5.0 update. No revision.

TRM version	Date	Description of change
v6.0	11/2018	TRM v6.0 update. Implementation of new baseline and update to the efficiency of qualifying HPWHs.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Added new construction eligibility
v9.0	10/2021	TRM v9.0 update. Clarified baseline condition. Confirmed ENERGY STAR® qualified product listing still does not contain a significant number of products with low or very small usage patterns.

2.4.7 Solar Water Heaters Measure Overview

TRM Measure ID: R-WH-SW

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves installing a new solar water heater in place of an electric storage water heater. 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 and in new construction homes. However, savings are calculated under the assumption of replace-on-burnout.

Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, which took effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 279).[345] This baseline applies to replace-on-burnout, early retirement, and new construction applications.

[345] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32. ~~Accessed August 2020.~~

Table 284. -Federal Standard for Residential Electric Storage Water Heaters

Rated storage volume	Draw pattern	First hour rating (FHR)[346,347]	Uniform energy factor (UEF)[348]
≥ 20 gal and ≤ 55 gal	Very Small Usage	0 ≤ FHR < 18	0.8808 − (0.0008 × V_r)
	Low Usage	18 ≤ FHR < 51	0.9254 − (0.0003 × V_r)
	Medium Usage	51 ≤ FHR < 75	0.9307 − (0.0002 × V_r)
	High Usage	75 ≤ FHR	0.9349 − (0.0001 × V_r)
> 55 gal and ≤ 120 gal	Very Small Usage	0 ≤ FHR < 18	1.9236 − (0.0011 × V_r)
	Low Usage	18 ≤ FHR < 51	2.0440 − (0.0011 × V_r)
	Medium Usage	51 ≤ FHR < 75	2.1171 − (0.0011 × V_r)
	High Usage	75 ≤ FHR	2.2418 − (0.0011 × V_r)

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 savings 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/.~~)~~

[346] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf. ~~Accessed August 2020.~~

[347] Assume FHR equal to that of installed water heater.

[348] Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

Energy Savings Algorithm

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SEF_{post}}\right)}{3{,}412}$$

Equation 77

Where:

ρ = *Water density (= 8.33 lbs/gallons)*

C_p = *Specific heat of water (= 1 Btu/lb·°F)*

GPY = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see* Table 285*)*

Table 285. Water Heater Consumption (Gal/Year) [349]

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

$T_{SetPoint}$ = *Water heater setpoint = 120°F*[350]

$T_{Supply,ann}$ = *Annual average mains temperature from* Table 286

EF_{pre} = *Baseline uniform energy factor (calculate per* Table 284*)*[351]

[349] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[350] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

[351] Note that for efficient water heater installations in ~~newly-constructed~~new construction homes, the baseline energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

EF_{post} = *Solar energy factor of new water heater*

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

Table 286. Water Mains Temperature[352]

Climate zone		Water mains temperature (°F)		
		$T_{supply,annual}$	$T_{supply,seasonal}$	
			Summer	Winter
1	Panhandle	62.9	73.8	53.7
2	North	71.8	84.0	60.6
3	South	74.7	84.5	65.5
4	Valley	77.2	86.1	68.5
5	West	70.4	81.5	60.4

Demand Savings Algorithm

$$kW_{savings} = CF \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SEF_{post}}\right)}{365 \times 3{,}412}$$

Equation 78

Where:

$Ratio_{dailygal}^{Sumpeakgal}$ = *Coincident peak demand factor (see* Table 287*)*

$T_{Supply,sum}$ = *Summer/winter average water mains temperature (see* Table 286*)*

[352] Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. https://nsrdb.nrel.gov/data-sets/archives.html. ~~Accessed August 2020.~~

Table 287. Coincident Peak Demand Factors[353]

Climate Zone	Summer CF	Winter CF
1	0.042	0.067
2	0.039	0.068
3	0.041	0.070
4	0.041	0.065
5	0.036	0.067

Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-SWH.[354] ~~of a solar water heater is established at 15 years.~~

[353] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf. ~~Accessed August 2020.~~

[354] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

~~This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).~~[355]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Number of bedrooms
- The approximate volume of the replacement water heater in gallons
- First hour rating of baseline water heater
- SRCC OG-300 Solar Energy Factor of the replacement unit
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy 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

Not applicable.

Document Revision History

Table 288. Residential Solar Water Heaters Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	4/18/2014	TRM v2.0 update. Minor edits to language.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v4.0	10/10/2016	TRM v4.0 update. No revision

[355] ~~2014 California Database for Energy Efficiency Resources. http://www.deeresources.com~~

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated algorithms and coincidence factors.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.

2.4.8 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: R-WH-SV

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, multifamily; manufactured

Fuels Affected: Electricity~~, gas~~

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)[356] between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95˚F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

Eligibility Criteria

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in residential applications. Buildings must have electrically fueled hot water to be eligible for this measure.~~To use deemed savings, the fuel type of the water heater must be electricity or gas.~~

Baseline Condition

The baseline condition is the residential shower arm and standard (2.5 gpm) showerhead without a temperature sensitive restrictor valve installed.

High-Efficiency Condition

The high-efficiency condition is a temperature sensitive restrictor valve installed on a residential shower arm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-flow Showerheads measure and claim additional savings as outlined in that measure.

[356] A temperature sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

Equation 79

Where:

SHFR	=	*Showerhead flow rate, gallons per minute (gpm) (see Table 289)*
BWC$_P$	=	*Behavioral waste, minutes per shower (see Table 289)*
n_S	=	*Number of showers per person per day (see Table 289)*
365	=	*Constant to convert days to years (see Table 289)*
n_O	=	*Number of occupants per home (see Table 289)*
n_{SH}	=	*Number of showerheads per home (see Table 289)*

Applying the formula to the values from Table 289~~Table 289~~ returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM)\text{: } 2.5 \times\ 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 713\ gal$$

$$Showerhead\ (2.0\ GPM)\text{: } 2.0 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 570\ gal$$

$$Showerhead\ (1.75\ GPM)\text{: } 1.75 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 499\ gal$$

$$Showerhead\ (1.5\ GPM)\text{: } 1.5 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 428\ gal$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 289~~Table 289~~.

$$Gallons\ of\ hot\ water\ saved\ per\ year = Annual\ Behavioral\ Waste \times HW\%$$

Equation 80

Where:

HW% = *Hot water percentage (see Table 289)*

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 713 \times\ 0.825 = 588\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 570 \times\ 0.825 = 470\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 499 \times\ 0.825 = 412\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 428 \times\ 0.825 = 353\ gal$$

Table 289. Showerhead TSRVs – Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower)[357]	0.783			
Showers/person/day[358]	0.6			
Occupants per home[359]	2.86			
Showerheads/home[360]	1.72			
Behavioral waste/showerhead/year (gal)	713	570	499	428
Percent hot water[361]	80-85%, or 82.5% on average			
Hot water saved/year (gal)	588	470	412	353

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times \sout{Conversion\ Factor}3{,}412}$$

Equation 81

[357] "Disaggregating Residential Shower Warm-Up Waste", Sherman, Troy. August 2014. Derived by dividing average behavioral waste time (47 seconds) by 60 seconds.

[358] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group. June 2013.

[359] Occupants per home for Texas from US Census Bureau, "Persons per household, 2014-2018". ~~Accessed August 2020.~~ https://www.census.gov/quickfacts/TX.

[360] Showerheads per home assumed to be equal to the number of full bathrooms per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS) Table HC2.8 Structural and geographic characteristics of homes in the West South Central region. https://www.eia.gov/consumption/residential/data/2015/#structural.

[361] "Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV", Sherman, Troy. Evolve Technologies. December 15, 2015.

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 289)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [362]

T_{Supply} = *Average supply water temperature (see Table 290)*

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, or 0.8 for gas hot water heaters.* [363]

~~ConversionFactor~~*3,412* = *Constant to convert from Btu to kWh ~~3,412 Btu/kWh for electric or 100,000 Btu/therm for gas~~*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{Supply,Seasonal})}{RE \times \sout{Conversion\ Factor}3{,}412 \times 365} \times CF$$

Equation 82

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 290)*

CF = *Peak coincidence factor (seeTable 291)*

[362] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

[363] ~~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.~~

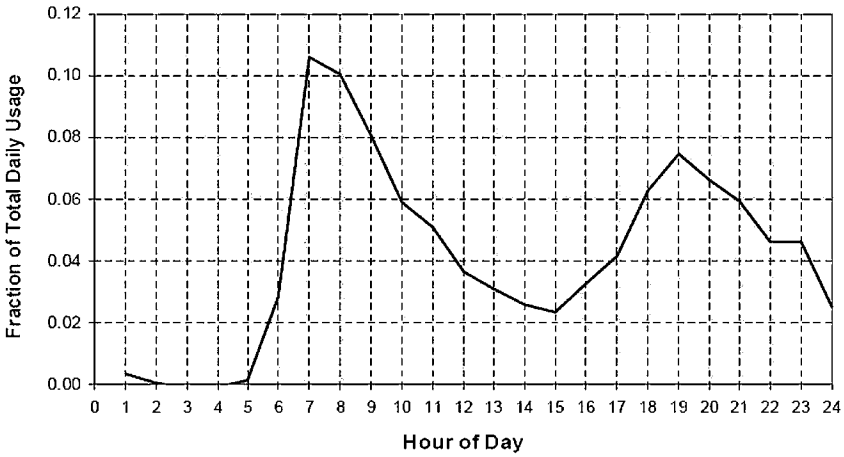
Table 290. Showerhead TSRVs – Water Mains Temperatures

Climate zone	Water Mains Temperature (°F)[364]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		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

Table 291. Water Fixture Peak Demand Ratios

Climate Zones	Summer	Winter
Climate Zone 1: Panhandle	0.039	0.073
Climate Zone 2: North	0.035	0.075
Climate Zone 3: South	0.038	0.080
Climate Zone 4: Valley	0.038	0.068
Climate Zone 5: West	0.028	0.069

Figure 10. Showerhead TSRVs – Shower, Bath, and Sink Hot Water Use Profile[365]



Source: Building America Performance Analysis Procedures for Existing Homes.

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

[365] 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, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[366] ~~for this measure is established at 10 years.~~

~~This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).~~[367]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- DHW 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)

[366] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.
[367] ~~2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.~~

Document Revision History

Table 292. Residential Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated coincidence factors.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference and restricted measure to electric DHW.

2.4.9 Tub Spout and Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: R-WH-TV

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity~~, gas~~

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of replacing existing tub spouts and showerheads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV) [368] between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95˚F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

Eligibility Criteria

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in existing homes. Buildings must have electrically fueled hot water to be eligible for this measure.~~To use these deemed savings, the fuel type of the water heater must be electricity or gas.~~

Baseline Condition

The baseline condition is the residential tub spout with a standard diverter and a standard (2.5 gpm) showerhead.

[368] A temperature sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a residential shower arm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-flow Showerheads measure and claim additional savings as outlined in that measure.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage.

Part 1: To determine baseline gallons of behavioral waste per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = \%WUE_{SH} \times SHFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

Equation 83

$$Annual\ Tub\ Spout\ Behavioral\ Waste = \%WUE_{TS} \times TSFR \times BW \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

Equation 84

Where:

$\%WUE_{SH}$	=	*Showerhead percentage of warm-up events (see Table 293~~Table 293~~)*
$\%WUE_{TS}$	=	*Tub spout percentage of warm-up events (see Table 293~~Table 293~~)*
SHFR	=	*Showerhead flow rate, gallons per minute (gpm) (see Table 293~~Table 293~~)*
TSFR	=	*Tub spout flow rate, gallons per minute (gpm) (see Table 293~~Table 293~~)*
BW	=	*Behavioral waste, minutes per shower (see Table 293~~Table 293~~)*
n_S	=	*Number of showers per person per day (see Table 293~~Table 293~~)*
365	=	*Constant to convert days to years (see Table 293~~Table 293~~)*

n_O = *Number of occupants per home (see Table 293~~Table 293~~)*

n_{SH} = *Number of showerheads per home (see Table 293~~Table 293~~)*

Applying the formula to the values from Table 293~~Table 293~~ returns the following values:

$$Showerhead\ (1.5\ GPM)\text{: } 0.6 \times \left(1.5 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 257$$

$$Showerhead\ (1.75\ GPM)\text{: } 0.6 \times \left(1.75 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 299$$

$$Showerhead\ (2.0\ GPM)\text{: } 0.6 \times \left(2.0 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 342$$

$$Showerhead\ (2.5\ GPM)\text{: } 0.6 \times \left(2.5 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 428$$

$$Tub\ Spout\ (5.0\ GPM)\text{: } 0.4 \times \left(5.0 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 570$$

Part 2: To determine baseline gallons of diverter leakage per year, the following formula was used:

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

Equation 85

Where:

DLR = *Diverter leakage rate (gpm) (see Table 293~~Table 293~~)*

t_S = *Shower time (min/shower) (see Table 293~~Table 293~~)*

Applying the formula to the values from Table 293~~Table 293~~ returns the following values:

$$Diverter\ (0.8\ GPM)\text{: } 0.8 \times 7.8 \times 0.60 \times 365 \times \frac{2.86}{1.72} = 2{,}272$$

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percent of hot water from Table 293~~Table 293~~.

$$Gallons\ of\ hot\ water\ saved = (SHBW + TSBW) \times HW\%_{SH,TS} + DW \times HW\%_D$$

Equation 86

Where:

SHBW = *Showerhead behavioral waste (gal)*

TSBW = *Tub spout behavioral waste (gal)*

DW = *Diverter waste (gal)*

$HW\%_{SH,TS}$ = *Showerheads and tub spout hot water percentage (see Table 293~~Table 293~~)*

$HW\%_{D}$ = *Diverter hot water percentage (see Table 293~~Table 293~~)*

Applying the formula to the values from Table 293~~Table 293~~ returns the following values:

$$Total\ Annual\ Waste\ (1.5\ gpm): (257 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}357$$

$$Total\ Annual\ Waste\ (1.75\ gpm): (299 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}392$$

$$Total\ Annual\ Waste\ (2.0\ gpm): (342 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}427$$

$$Total\ Annual\ Waste\ (2.5\ gpm): (428 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}498$$

Table 293. Tub Spout/Showerhead TSRVs – Hot Water Usage Reduction

Description	Part 1—Behavioral Waste		Part 2—Diverter Leakage	Part 3—Total
	Showerhead Warm-up	Tub spout Warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			N/A
Tub spout flow rate (gpm)[369]	N/A	5.0		N/A
Percent of warm-up events[370]	60%	40%		N/A
Average behavioral waste (minutes per shower)[371]		0.783		N/A
Average diverter leakage rate (gpm)[372]		N/A	0.80	N/A
Average shower time (minutes per shower)[373]		N/A	7.8	N/A
Showers/person/day[374]				0.60
Occupants/home[375]				2.86

[369] Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.
[370] Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).
[371] Average behavioral waste from Lutz (2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and Sherman (2014) Disaggregating Residential Shower Warm-Up Waste. Derived by dividing 47 seconds by 60 seconds.
[372] Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.
[373] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.
[374] Derivation of value for showers per person per day defined in the Low Flow Showerhead measure.
[375] 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.

Description	Part 1—Behavioral Waste		Part 2—Diverter Leakage	Part 3—Total
	Showerhead Warm-up	Tub spout Warm-up		
Showerheads/home[376]				1.72
Gallons behavioral waste. per tub spout/showerhead per year (1.5 gpm)	257	570	2,272	3,099
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	299			3,142
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	342			3,185
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	428			3,270
Percent hot water[377]	80-85%, or 82.5% average		73.7%	N/A
Gallons hot water saved per year (1.5 gpm)			N/A	2,357
Gallons hot water saved per year (1.75 gpm)			N/A	2,392
Gallons hot water saved per year (2.0 gpm)			N/A	2,427
Gallons hot water saved per year (2.5 gpm)			N/A	2,498

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage})}{RE \times \sout{Conversion\ Factor}3{,}412}$$

Equation 87

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 293~~Table 293~~)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [378]

Field Code Changed

Field Code Changed

[376] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2015 RECS, Table HC2.8. https://www.eia.gov/consumption/residential/data/2015/#structural.

[377] Average percent hot water for warm up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[378] 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.

T_{Supply} = *Average supply water temperature (see Table 294)*

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, or 0.8 for gas hot water heaters.*[379]

~~ConversionFactor~~*3,412* = *Constant to convert from Btu to kWh ~~3,412 Btu/kWh for electric or 100,000 Btu/therm for gas~~*

Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Demand\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{Supply,Seasonal})}{RE \times \text{~~Conversion Factor~~}3{,}412 \times 365} \times CF$$

Equation 88

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 294)*

CF = *Peak coincidence factor (see Table 295)*

Table 294. Tub Spout/Showerhead TSRVs – Water Mains Temperature

Climate zone	Water mains temperature (°F)[380]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	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

Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

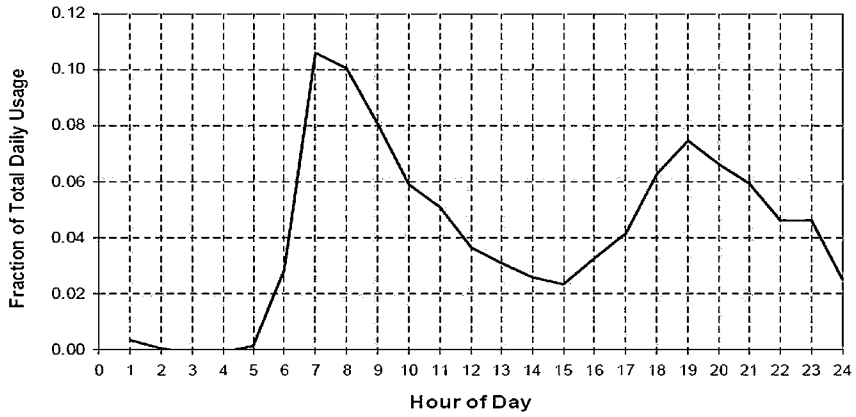
~~[379] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH.~~

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

Table 295. Tub Spout/Showerhead TSRVs – Peak Coincidence Factors

Climate Zones	Summer	Winter
Climate Zone 1: Panhandle	0.039	0.073
Climate Zone 2: North	0.035	0.075
Climate Zone 3: South	0.038	0.080
Climate Zone 4: Valley	0.038	0.068
Climate Zone 5: West	0.028	0.069

Figure 11. Tub Spout/Showerhead TSRVs – Shower, Bath, and Sink Hot Water Use Profile[381]



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.

[381] Building America performance analysis procedures for existing homes.

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[382] ~~for this measure is established at 10 years.~~

~~This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[383]~~

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (~~e.g.,~~ heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available

Document Revision History

Table 296. Residential Tub Spout and Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 origin.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Updated coincidence factors.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference and restricted measure to electric DHW.

[382] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

~~[383] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com.~~

2.5 RESIDENTIAL: APPLIANCES

2.5.1 ENERGY STAR® Ceiling Fans Measure Overview

TRM Measure ID: R-AP-CF

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® ceiling fan and light kit. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

Savings values in this measure are based on indoor usage patterns and are not applicable to outdoor applications.

Baseline Condition

The baseline is a conventional non-ENERGY STAR® labeled ceiling fan and light kit.

High-Efficiency Condition

Table 297~~Table 297~~ displays the ENERGY STAR® requirements for eligible ceiling fans as of June 16, 2018. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® specification.[384]

[384] ENERGY STAR® Ceiling Fan Specification: https://www.energystar.gov/products/lighting_fans/ceiling_fans/ceiling_fans_key_product_criteria.

Table 297. ENERGY STAR® Ceiling Fan Definitions

Fan type	Description
Ceiling fan	A non-portable device designed for home use that is suspended from the ceiling for circulating air via the rotation of fan blades; for which the lowest point on fan blades is greater than 10 inches from the ceiling.
Hugger ceiling fan	A ceiling fan for which the lowest point on the fan blades is less than or equal to 10 inches from the ceiling. Hugger ceiling fans can be safely installed on low ceilings, and some are sold with ceiling fan light kits.

Table 298. ENERGY STAR® Ceiling Fan Efficiency Requirements

Type	Diameter (inches)	Minimum efficiency (cfm/W)	Minimum high speed airflow (cfm)
Ceiling fan	D ≤ 36	≥ 0.72 x D + 41.93	≥ 1,767
	36 < D < 78	≥ 2.63 x D – 26.83	≥ 250 x π x $(D/24)^2$
	D ≥ 78		≥ 8,296
Hugger ceiling fan	D ≤ 36	≥ 0.31 x D + 36.84	≥ 1,414
	36 < D < 78	≥ 1.75 x D – 15	≥ 200 x π x $(D/24)^2$
	D ≥ 78		≥ 6,637

Table 299. ENERGY STAR® Ceiling Fan Light Kit Efficacy Requirements

Type	Minimum efficacy (lumens/W)	Minimum light output (lumens)
Shipped with ENERGY STAR certified light bulbs	65.0	N/A
Separable light source	65.0	800
Integrated light source	70.0	

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings were calculated using the ENERGY STAR® Ceiling Fan Savings Calculator found on the ENERGY STAR® website.[385] Default values were taken directly from the ENERGY STAR® Ceiling Fan Savings Calculator, unless otherwise specified.

[385] ENERGY STAR® Ceiling Fan Savings Calculator (updated September 2013). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

$$kWh_{savings} = (kWh_{baseline} - kWh_{ES})_{fan} + (kWh_{baseline} - kWh_{ES})_{lgt} \times IEF_E$$

Equation 89

$$kWh_{baseline,Fan} = \frac{W_{Fan,baseline} \times AOH_{Fan}}{1{,}000}$$

Equation 90

$$kWh_{ES,Fan} = \frac{W_{Fan,ES} \times AOH_{Fan}}{1{,}000}$$

Equation 91

$$W_{Fan} = (W_{LS} \times OP_{LS}) + (W_{MS} \times OP_{MS}) + (W_{HS} \times OP_{HS})$$

Equation 92

$$kWh_{baseline,Lgt} = \frac{W_{Lgt,baseline} \times AOH_{Lgt}}{1{,}000}$$

Equation 93

$$kWh_{ES,Lgt} = \frac{W_{Lgt,ES} \times AOH_{Lgt}}{1{,}000}$$

Equation 94

Where:

$kWh_{baseline}$	=	*Non-ENERGY STAR® baseline energy usage*
kWh_{ES}	=	*ENERGY STAR® average energy usage*
IEF_E	=	*Energy Interactive Effects Factor from Table 300 assuming heating/cooling unknown*[386]
$W_{Lgt,baseline}$	=	*Conventional lighting total wattage = 115 W (160 W default value from ENERGY STAR® calculator reduced to comply with EISA 2007 baseline wattages)*[387]
$W_{Lgt,ES}$	=	*Actual wattage of installed ENERGY STAR® lighting; assume one high-efficiency 32 W lamp*
$W_{Fan,baseline}$	=	*Conventional fan motor wattage*
$W_{Fan,ES}$	=	*ENERGY STAR® fan motor wattage*
$W_{LS,MS,HS}$	=	*Fan motor wattage at low, medium, and high speed; see Table 301*

[386] The assumed energy interactive effects factors are taken from the residential lighting measure.
[387] Assumes a mix of 40 and 60 W incandescent lamps. EISA 2007 baseline wattages are approximately 72 percent of standard incandescent wattages.

$OP_{LS,MS,HS}$	=	*Fan operating percentage at low, medium, and high speed; see Table 302* ~~*Table 302*~~
AOH_{Lgt}	=	*Annual lighting operating hours = 803 hours/year (assuming 2.2 hours/day and 365 days/year operation)*[388]
AOH_{Fan}	=	*Annual fan operating hours = 1,095 hours/year (assuming 3.0 hours/day and 365 days/year operation)*[389]
1,000	=	*Constant to convert from W to kW*

Table 300. ENERGY STAR® Ceiling Fans—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[390]

	IEF_E				
Heating/cooling type	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Heating/Cooling Unknown[391]	0.88	0.98	1.04	1.07	0.95

Table 301. Ceiling Fan Motor Wattages

Fan type	Fan speed	Fan motor wattage (W)
Conventional	Low	15
	Medium	34
	High	67
ENERGY STAR®	Low	6
	Medium	23
	High	56

[388] The assumed annual operating hours are taken from the residential lighting measure.

[389] The assumed annual operating hours are taken from the ENERGY STAR® Light Fixture and Ceiling Fan Calculator. https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

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

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

Table 302. Ceiling Fan Operating Percentages

Fan speed	Operating percentage (OP)
Low	40%
Medium	40%
High	20%

Demand Savings Algorithms

Peak demand savings were calculated using separate coincidence factors for the lighting and the fan motor portion of the ceiling fan savings. For lighting the coincidence factor varies based on climate zone. For the fan motor a coincidence factor of 0.446 was applied (derived from the EnergyGauge software ceiling fan profiles).

$$kW_{savings} = kW_{Fan} + kW_{Lgt}$$

Equation 95

$$kW_{Fan} = \frac{W_{Fan,baseline} - W_{Fan,ES}}{1{,}000} \times CF_{Fan}$$

Equation 96

$$kW_{Lgt} = \frac{W_{Lgt,baseline} - W_{Lgt,ES}}{1{,}000} \times CF_{Lgt} \times IEF_{D}$$

Equation 97

Where:

kW_{Fan} = *Fan demand savings*

CF_{Fan} = *Fan motor coincidence factor = 0.446*

kW_{Lgt} = *Lighting demand savings*

CF_{Lgt} = *Lighting coincidence factor (Table 303)*

IEF_{D} = *Demand Interactive Effects Factor from* <u>*Table* 304</u> ~~*Table* 304~~ *assuming heating/cooling unknown*[392]

[392] The assumed demand interactive effects factors are taken from the residential lighting measure.

Table 303. ENERGY STAR® Ceiling Fans—Lighting Coincidence Factors[393]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.275	0.232	0.199	0.263	0.358

Table 304. ENERGY STAR® Ceiling Fans—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[394]

$IEF_{D,summer}$					
Heating/cooling type	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Heating/cooling unknown[395]	1.39	1.28	1.58	1.20	1.38
$IEF_{D,winter}$					
Heating/cooling type	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Heating/cooling unknown[396]	0.76	0.72	0.73	0.75	0.80

Deemed Energy Savings Tables

Table 305. Ceiling Fans Deemed Energy Savings

Deemed energy ~~svings~~savings (kWh/Year)				
Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
69.8	76.5	80.5	82.5	74.5

[393] See Volume 1, Section 4.

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

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

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

Deemed Summer Demand Savings Tables

Table 306. Ceiling Fans Deemed Demand Savings - Summer

Deemed summer demand savings (kW)				
Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
0.011	0.010	0.013	0.010	0.008

Deemed Winter Demand Savings Tables

Table 307. Ceiling Fans Deemed Demand Savings - Winter

Deemed winter demand savings (kW)				
Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
0.022	0.018	0.017	0.021	0.028

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 10 years according to the ENERGY STAR® Ceiling Fan Savings Calculator.

This EUL is consistent with Docket No. 38025 approved in 2010.[397]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- ~~The number~~Quantity of installed ENERGY STAR® ceiling fan and light kits
- Manufacturer and model number

[397] 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.

- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

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 308. Residential ENERGY STAR® Ceiling Fans 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 the ENERGY STAR® specification table.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2014	TRM v3.0 update. Explanation of methodology and alignment with ENERGY STAR® calculator. Introduction of interactive effects factors and in-service rates. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. Revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types.
v3.1	3/28/2016	TRM v3.1 March revision. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated interactive effect values using building energy simulation.
v5.0	10/2017	TRM v5.0 update. Updated footnote reference to ENERGY STAR® calculator.
v6.0	11/2018	TRM v6.0 update. Updated interactive effect values.
v7.0	11/2019	TRM v7.0 update. Established deemed savings approach.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. No revision.

2.5.2 ENERGY STAR® Clothes Washers Measure Overview

TRM Measure ID: R-AP-CW

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

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 January 1, 2018.

Eligibility Criteria

Not applicable.

Baseline Condition

Effective January 1, 2018, the baseline is the Department of Energy (DOE) minimum efficiency standard[398] 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 based on customers having the option to install a top-loading clothes washer. Therefore, savings are calculated using the lower top-loading baseline condition. ~~consistent with the ENERGY STAR® appliance calculator.~~

[398] DOE minimum efficiency standard for residential clothes washers. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Table 309. Federal Standard for Clothes Washers

Product type	Current criteria as of January 1, 2018
Top-loading, Standard (1.6 ft^3 or greater capacity)	IMEF ≥ 1.57 IWF≤ 6.5
Top-loading, Compact (less than 1.6 ft^3 capacity)	IMEF ≥ 1.15 IWF≤ 12.0

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 8.~~0~~1 requirements for eligible clothes washers effective February 5, 2018~~, with early certification available starting May 5, 2017~~.[399] 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 310. ENERGY STAR® Specifications for Residential Clothes Washers

Product type	Current criteria as of February 5, 2018
ENERGY STAR® Residential Front-loading (> 2.5 ft^3)	IMEF ≥ 2.76 IWF≤ 3.2
ENERGY STAR® Residential Top-loading (> 2.5 ft^3)	IMEF ≥ 2.06 IWF ≤ 4.3
ENERGY STAR® Residential Small or Compact (< 2.5 ft^3)	IMEF ≥ 2.07 IWF ≤ 4.2

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Appliance Savings Calculator found on the ENERGY STAR® website.[400] This document will be updated regularly to apply the values provided in the latest available ENERGY STAR® appliance calculator. The most recent TRM version should be referenced to determine the savings for this measure.

[399] Available for download at: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf.

[400] ENERGY STAR® Appliance Savings Calculator (updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 98

Baseline Unit

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH} + kWh_{conv,dryer} + kWh_{conv,LPM}$$

Equation 99

$$kWh_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 100

$$kWh_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

Equation 101

$$kWh_{conv,LPM} = kW_{conv,LPM} \times (8{,}760 - LPY)$$

Equation 102

$$kWh_{conv,dryer} = \left[\left(\frac{CAP_{conv}}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right) - kWh_{conv,LPM}\right] \times \frac{DU_{DW}}{DUF}$$

Equation 103

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage*

$kWh_{conv,machine}$ = *Conventional machine energy*

$kWh_{conv,WH}$ = *Conventional water heater energy*

$kWh_{conv,dryer}$ = *Conventional dryer energy*

$kWh_{conv,LPM}$ = *Conventional combined low-power mode energy*

$RUEC_{conv}$ = *Conventional rated unit electricity consumption = 381 kWh/year (top-loading, standard)*[401], 163 kWh/year top-loading, compact)

LPY = *Loads per year = 295*

RLPY = *Reference loads per year = 392*

$kW_{conv,LPM}$ = *Combined low-power mode wattage of conventional unit = 0.00115 kW (top-loading, standard), 0.00144 kW (top-loading, compact)*

[401] This value is taken from the ENERGY STAR® appliance calculator and corresponds with the federal standard after March 7, 2015.

CAP_{conv} = *Average machine capacity = 4.5 ft³ (top-loading, standard), 2.1 ft³ (top-loading, compact)*

$IMEF_{FS}$ = *Federal standard integrated modified energy factor (Table 309)*

MCF = *Machine consumption factor = 20%*

WHCF = *Water heater consumption factor = 80%*

DU_{DW} = *Dryer usage in households with both a washer and a dryer = 95%*

DUF = *Dryer use factor (percentage of washer loads dried in machine) = 91%*

ENERGY STAR® Unit

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH} + kWh_{ES,dryer} + kWh_{ES,LPM}$$

Equation 104

$$kWh_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

Equation 105

$$kWh_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

Equation 106

$$kWh_{ES,LPM} = kW_{ES,LPM} \times (8{,}760 - LPY)$$

Equation 107

$$kWh_{ES,dryer} = \left[\left(\frac{CAP_{ES}}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right) - kWh_{ES,LPM}\right] \times \frac{DU_{DW,ES}}{DUF}$$

Equation 108

Where:

kWh_{ES} = *ENERGY STAR® average energy usage*

$kWh_{ES,machine}$ = *ENERGY STAR® machine energy*

$kWh_{ES,WH}$ = *ENERGY STAR® water heater energy*

$kWh_{ES,dryer}$ = *ENERGY STAR® dryer energy*

$kWh_{ES,LPM}$ = *ENERGY STAR® combined low-power mode energy*

$RUEC_{ES}$ = *ENERGY STAR® rated unit electricity consumption (see Table 311)*

$kW_{ES,LPM}$ = *Combined low-power mode wattage of ENERGY STAR® unit (see Table 311)*

$IMEF_{ES}$ = *ENERGY STAR® integrated modified energy factor (Table 310)*

CAP_{ES} = *Average machine capacity (see Table 311)*

Table 311. ENERGY STAR® Clothes Washer Characteristics[402]

Product type	ENERGY STAR® rated unit electricity consumption (kWh)	Average capacity (ft^3)	Combined low-power mode wattage (kW)
Residential front-loading (> 2.5 ft^3)	127	4.0	0.00160
Residential top-loading (> 2.5 ft^3)	230	4.5	0.00115
Residential small or compact (< 2.5 ft^3)	1089	2.1	0.00144

Summer Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Equation 109

$$AOH = LPY \times d$$

Equation 110

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor (Table 312)*

LPY = *Loads per year = 295*

d = *Average wash cycle duration = 1 hour*[403,404]

[402] This value is taken from the ENERGY STAR® appliance calculator and corresponds with the ENERGY STAR® specification after March 7, 2015.

[403] Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers.

[404] Consumer Reports. "Top-loading washers remain more popular with Americans". April 13, 2010. Weighted average of 75 percent Top-Loading Clothes Washers and 25 percent Front-Loading Clothes Washers.

Table 312. ENERGY STAR® Clothes Washer Coincidence Factors[405]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.040	0.040	0.040	0.041	0.041
Winter	0.043	0.043	0.043	0.044	0.039

Deemed Energy Savings Tables

Table 313. 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 ft³	Electric	Electric	428~~394~~
		Gas	187
	Gas	Electric	275~~241~~
		Gas	34
Top-loading > 2.5 ft³	Electric	Electric	205~~193~~
		Gas	114
	Gas	Electric	114~~102~~
		Gas	23
All ≤ 2.5 ft³	Electric	Electric	248~~222~~
		Gas	41
	Gas	Electric	215~~189~~
		Gas	8

[405] See Volume 1, Section 4.

Deemed Summer Demand Savings Tables

Table 314. ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW)

ENERGY STAR® clothes washer — summer demand savings							
Washer type	Fuel type		Summer demand savings (kW)				
	Water heater	Dryer	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Front-loading > 2.5 ft³	Electric	Electric	0.058~~0.053~~	0.058~~0.053~~	0.058~~0.053~~	0.060~~0.055~~	0.060~~0.055~~
		Gas	0.025	0.025	0.025	0.026	0.026
	Gas	Electric	0.037~~0.033~~	0.037~~0.033~~	0.037~~0.033~~	0.038~~0.033~~	0.038~~0.033~~
		Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft³	Electric	Electric	0.028~~0.026~~	0.028~~0.026~~	0.028~~0.026~~	0.028~~0.027~~	0.028~~0.027~~
		Gas	0.015	0.015	0.015	0.016	0.016
	Gas	Electric	0.015~~0.014~~	0.015~~0.014~~	0.015~~0.014~~	0.016~~0.014~~	0.016~~0.014~~
		Gas	0.003	0.003	0.003	0.003	0.003
All ≤ 2.5 ft³	Electric	Electric	0.034~~0.030~~	0.034~~0.030~~	0.034~~0.030~~	0.034~~0.031~~	0.034~~0.031~~
		Gas	0.006	0.006	0.006	0.006	0.006
	Gas	Electric	0.029~~0.026~~	0.029~~0.026~~	0.029~~0.026~~	0.030~~0.026~~	0.030~~0.026~~
		Gas	0.001	0.001	0.001	0.001	0.001

Deemed Winter Demand Savings Tables

Table 315. All Climate Zones—ENERGY STAR® Clothes Washer Winter Demand Savings (kW)

ENERGY STAR® clothes washer—winter demand savings							
Washer type	Fuel type		Winter demand savings (kW)				
	Water heater	Dryer	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Front-loading > 2.5 ft³	Electric	Electric	0.062~~0.057~~	0.062~~0.057~~	0.062~~0.057~~	0.064~~0.059~~	0.057~~0.052~~
		Gas	0.027	0.027	0.027	0.028	0.025
	Gas	Electric	0.040~~0.035~~	0.040~~0.035~~	0.040~~0.035~~	0.041~~0.036~~	0.036~~0.032~~
		Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft³	Electric	Electric	0.030~~0.028~~	0.030~~0.028~~	0.030~~0.028~~	0.031~~0.029~~	0.027~~0.026~~
		Gas	0.017	0.017	0.017	0.017	0.015
	Gas	Electric	0.017~~0.015~~	0.017~~0.015~~	0.017~~0.015~~	0.017~~0.015~~	0.015~~0.014~~
		Gas	0.003	0.003	0.003	0.003	0.003
All ≤ 2.5 ft³	Electric	Electric	0.036~~0.032~~	0.036~~0.032~~	0.036~~0.032~~	0.037~~0.033~~	0.033~~0.029~~
		Gas	0.006	0.006	0.006	0.006	0.005
	Gas	Electric	0.031~~0.028~~	0.031~~0.028~~	0.031~~0.028~~	0.032~~0.028~~	0.028~~0.025~~
		Gas	0.001	0.001	0.001	0.001	0.001

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of an ENERGY STAR® clothes washer is established at 11 years based on the Technical Support Document for the current DOE Final Rule standards for residential clothes washers.[406]

[406] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 32308 (May 31, 2012) and associated Technical Support Document. ~~Accessed 08/15/2019.~~ https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=68&action=viewlive. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047.

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Unit quantity~~Number of units installed~~
- Manufacturer and model number
- Type of unit (top-loading, front-loading, or compact)
- DHW fFuel type~~ of water heater~~ (gas or electric)
- DHW fFuel type ~~of dryer~~ (gas or electric)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for clothes washers.

Document Revision History

Table 316. Residential ENERGY STAR® Clothes Washers 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 Energy, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.
v3.0	4/10/2015	TRM v3.0 update. Updated EUL to align with median lifetime. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. New ENERGY STAR® algorithms and default assumptions incorporated.
v3.1	3/28/2016	TRM v3.1 March revision. Updated winter coincidence factors and winter and summer demand savings tables.
v4.0	10/10/2016	TRM v4.0 update. No revision.

TRM version	Date	Description of change
v5.0	10/2017	TRM v5.0 update. Updated baseline IMEF to reflect changes in Federal Standard. Updated Front Load Washer IMEF to reflect changes in ENERGY STAR Specification. Added baseline for compact units to reflect Federal Standard for compact washers.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	11/2019	TRM v7.0 update. Updated links and dates.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated deemed savings tables to match savings algorithms and ENERGY STAR® calculator.

2.5.3 ENERGY STAR® Clothes Dryers Measure Overview

TRM Measure ID: R-AP-CD

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® electric clothes dryer. 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

Gas dryers are ineligible to claim savings under this measure. Savings may be claimed for the replacement of gas dryers if the decision to switch fuels predates the decision to install efficient equipment.

Baseline Condition

Effective January 1, 2015, the baseline is the Department of Energy (DOE) minimum federal efficiency standard[407], adjusted to reflect recent Combined Energy Factor (CEF) definition updates for vented and ventless clothes dryers. These adjusted baselines consider calculated differences between CEF values under original clothes dryer testing procedures of 10 CFR 430, Subpart B, Appendix D1, and those amended procedures outlined in Appendix D2; a change indicated in detail in the September 5, 2013, ENERGY STAR® stakeholder webinar[408]. These values are consistent with the current ENERGY STAR® Appliance Savings Calculator.

[407] DOE minimum efficiency standard for residential clothes dryers. https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0050.

[408] Available for download at: https://www.energystar.gov/sites/default/files/specs/Clothes%20Dryers%20Draft%202%20V1%200%20Stakeholder%20Webinar%20Final.pdf.

Table 317. Federal Standard for Residential Clothes Dryers

Product type	Average capacity (ft^3)	Amended minimum CEF: calculations	Minimum CEF levels (lbs/kWh)
Vented Electric, Standard	≥ 4.4	3.73 – (3.73 x 0.166)	3.11
Vented Electric, Compact (120 V)	< 4.4	3.61 – (3.61 x 0.166)	3.01
Vented Electric, Compact (240 V)	< 4.4	3.27 – (3.27 x 0.166)	2.73
Ventless Electric, Compact (240 V)	< 4.4	2.55 – (2.55 x 0.166)	2.13

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 1.1 requirements for eligible clothes dryers effective January 1, 2015.[409] 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 318. ENERGY STAR® Specifications for Residential Clothes Dryers

Product type	Average Capacity (ft^3)	Minimum CEF levels (lbs/kWh)
ENERGY STAR® Ventless or Vented Electric, Standard	≥ 4.4	3.93
ENERGY STAR® Ventless or Vented Electric, Compact (120V)	< 4.4	3.80
ENERGY STAR® Vented Electric, Compact (240 V)	< 4.4	3.45
ENERGY STAR® Ventless Electric, Compact (240 V)	< 4.4	2.68

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.[410] This document will be updated regularly to apply the values provided in the latest available ENERGY STAR® appliance calculator. The most recent TRM version should be referenced to determine the savings for this measure.

[409] Available for download at: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Program%20Commitment%20Criteria%20and%20Eligibility%20Criteria.pdf.

[410] ENERGY STAR® Appliance Savings Calculator (updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

Table 319. Default Average Load for Clothes Dryers in Pounds

Product type	Average load (lbs)
Vented Electric, Standard	8.45
Vented Electric, Compact (120 V)	3.00
Vented Electric, Compact (240 V)	3.00
Ventless Electric, Compact (240 V)	3.00

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 111

Baseline Unit

$$kWh_{baseline} = \frac{AvgLoad \times LPY}{CEF_{baseline}}$$

Equation 112

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage*

$AvgLoad$ = *Average load in lbs (Table 319)*

LPY = *Loads per year = 283*

$CEF_{baseline}$ = *Amended Baseline Combined Energy Factor (See* Table 317*)*

ENERGY STAR® Unit

$$kWh_{ES} = \frac{AvgLoad \times LPY}{CEF_{ES}}$$

Equation 113

Where:

kWh_{ES} = *ENERGY STAR® average energy usage*

$AvgLoad$ = *Average load in lbs (See Table 319)*

LPY = *Loads per Year = 283*

CEF_{ES} = *ENERGY STAR® Minimum Combined Energy Factor (See* Table 318*)*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Equation 114

Where:

AOH = *Annual operating hours = (8760 – 8463) = 297 hours*[411]

CF = *Coincidence factor (Table 320)*

Table 320. ENERGY STAR® Clothes Dryer Coincidence Factors[412]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.041	0.041	0.041	0.041	0.042
Winter	0.045	0.045	0.041	0.048	0.047

Deemed Energy Savings Tables

Table 321. ENERGY STAR® Clothes Dryer Energy Savings (kWh/Year)

~~ENERGY STAR® clothes dryer—annual energy savings~~		
Product type	Average capacity (ft^3)	Energy savings (kWh)
Ventless or Vented Electric, Standard	≥ 4.4	160
Ventless or Vented Electric, Compact (120V)	< 4.4	59
Vented Electric, Compact (240 V)	< 4.4	65
Ventless Electric, Compact (240 V)	< 4.4	82

[411] Concerning annual operating hours: Minute-by-minute field data shows "96.6% ± 0.5% idle time, or about 8463 hours." Hannas, Benjamin and Gilman, Lucinda. *Dryer Field Study*, 39. Available for download at ~~(last accessed August 29, 2019)~~: https://neea.org/img/uploads/neea-clothes-dryer-field-study.pdf.

[412] See Volume 1, Section 4.

Deemed Summer Demand Savings Tables

Table 322. ENERGY STAR® Clothes Dryer Summer Peak Demand Savings (kW)

ENERGY STAR® clothes dryer—summer demand savings						
Product type	Average capacity (ft^3)	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Ventless or Vented Electric, Standard	≥ 4.4	0.022	0.022	0.022	0.022	0.023
Ventless or Vented Electric, Compact (120V)	< 4.4	0.008	0.008	0.008	0.008	0.008
Vented Electric, Compact (240 V)	< 4.4	0.009	0.009	0.009	0.009	0.009
Ventless Electric, Compact (240 V)	< 4.4	0.011	0.011	0.011	0.011	0.012

Deemed Winter Demand Savings Tables

Table 323. ENERGY STAR® Clothes Dryer Winter Demand Savings (kW)

ENERGY STAR® clothes dryer—winter demand savings						
Product type	Average capacity (ft^3)	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Ventless or Vented Electric, Standard	≥ 4.4	0.024	0.024	0.022	0.026	0.025
Ventless or Vented Electric, Compact (120V)	< 4.4	0.009	0.009	0.008	0.009	0.009
Vented Electric, Compact (240 V)	< 4.4	0.010	0.010	0.009	0.011	0.010
Ventless Electric, Compact (240 V)	< 4.4	0.012	0.013	0.011	0.013	0.013

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of an ENERGY STAR® clothes dryer is established at 16 years based on the current DOE Final Rule standards for clothes dryers.[413]

[413] Technical Support Document (April 2011) ~~accessed 09/03/2019~~. See "Appendix 8C.Lifetime Distributions": https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- ~~Number of units installed~~Unit quantity
- Manufacturer and model number
- Type of unit (vented or ventless)
- Capacity (≥ 4.4 ft^3/standard or < 4.4 ft^3/compact)
- Proof of purchase – including date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for clothes washers.

Document Revision History

Table 324. Residential ENERGY STAR® Clothes Dryers Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. No revision.

2.5.4 ENERGY STAR® Dishwashers Measure Overview

TRM Measure ID: R-AP-DW

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR® dishwasher. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

Eligibility Criteria

This measure applies to both standard and compact dishwasher types.

Baseline Condition

Effective May 30, 2013, the baseline is the Department of Energy (DOE) minimum efficiency standard[414] for dishwashers.

Table 325. 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

[414] DOE minimum efficiency standard for residential dishwashers. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive.

High-Efficiency Condition

The following table displays the ENERGY STAR® Final Version 6.0 requirements for eligible dishwashers effective January 29, 2016.[415] 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 326. ENERGY STAR® Specifications for Dishwashers

Product type	Estimated annual energy use (kWh/year)	Water consumption (gallons/cycle)
Standard (≥ 8 place settings + 6 serving pieces)	≤ 270	≤ 3.5
Compact (< 8 place settings + 6 serving pieces)	≤ 203	≤ 3.1

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Appliance Savings Calculator found on the ENERGY STAR® website and the revised ENERGY STAR® specification in Table 326~~Table 326~~.[416] Default values were taken directly from the ENERGY STAR® calculator. This document will be updated regularly to apply the values provided in the latest available ENERGY STAR® specification and appliance calculator. The most recent TRM version should be referenced to determine measure savings for this measure.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 115

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH}$$

Equation 116

$$kWh_{conv,machine} = RUEC_{conv} \times MCF$$

Equation 117

$$kWh_{conv,WH} = RUEC_{conv} \times WHCF$$

Equation 118

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH}$$

Equation 119

[415] Available for download at: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf.

[416] ENERGY STAR® Appliance Savings Calculator (updated October 2016). https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

$$kWh_{ES,machine} = RUEC_{ES} \times MCF$$

Equation 120

$$kWh_{ES,WH} = RUEC_{ES} \times WHCF$$

Equation 121

Where:

$kWh_{baseline}$	=	*Federal standard baseline energy usage*
kWh_{ES}	=	*ENERGY STAR® average energy usage*
$kWh_{conv,machine}$	=	*Conventional machine energy*
$kWh_{conv,WH}$	=	*Conventional water heater energy*
$kWh_{ES,machine}$	=	*ENERGY STAR® machine energy*
$kWh_{ES,WH}$	=	*ENERGY STAR® water heater energy*
$RUEC_{conv}$	=	*Conventional rated use electricity consumption = 307 kWh/year for standard and 222 kWh/year for compact (Table 325)*
$RUEC_{ES}$	=	*ENERGY STAR® rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact (Table 326)*
MCF	=	*Machine consumption factor = 44%*
WHCF	=	*Water heater consumption factor = 56%*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

Equation 122

$$AOH = CPY \times d$$

Equation 123

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor = (Table 327)*

CPY = *Cycles per year = 215*

d = *Average wash cycle duration = 2.1 hours*[417]

Table 327. ENERGY STAR® Dishwasher Coincidence Factors[418]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	0.042	0.041	0.042	0.041	0.042
Winter	0.106	0.104	0.090	0.112	0.129

Deemed Energy Savings Tables

Table 328. ENERGY STAR® Dishwasher Energy Savings

ENERGY STAR® dishwasher—energy savings (kWh)		
Product type	**Electric water heating**	**Gas water heating**
Standard	37	16
Compact	19	8

Deemed Summer Demand Savings Tables

Table 329. ENERGY STAR® Dishwasher Summer Peak Demand Savings (kW)

ENERGY STAR® dishwasher—summer demand savings (kW)						
Dishwasher type	**Water heating fuel/DHW fuel**	**Climate zone 1**	**Climate zone 2**	**Climate zone 3**	**Climate zone 4**	**Climate zone 5**
Standard	Electric	0.003	0.003	0.003	0.003	0.003
	Gas	0.002	0.001	0.002	0.001	0.002
Compact	Electric	0.002	0.002	0.002	0.002	0.002
	Gas	0.001	0.001	0.001	0.001	0.001

[417] Average of Consumer Reports Cycle Times for Dishwashers.
[418] See Volume 1, Section 4.

Deemed Winter Demand Savings Tables

Table 330. ENERGY STAR® Dishwasher Winter Peak Demand Savings (kW)

ENERGY STAR® Dishwasher—Winter Demand Savings (kW)						
Dishwasher type	Water heating fuelDHW fuel	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5
Standard	Electric	0.009	0.009	0.007	0.009	0.011
	Gas	0.004	0.004	0.003	0.004	0.005
Compact	Electric	0.004	0.004	0.004	0.005	0.005
	Gas	0.002	0.002	0.002	0.002	0.002

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 15 years based on the Technical Support Document for the current DOE Final Rule standards for residential dishwashers.[419]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- ~~Number of units installed~~Unit quantity
- Manufacturer and model number
- Type of dishwasher (standard or compact)
- Fuel type of water heater (gas or electric)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

[419] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 31918 (May 30, 2012) and associated Technical Support Document. ~~Accessed 08/15/2019.~~ https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive.

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for dishwashers.

Document Revision History

Table 331. Residential ENERGY STAR® Dishwashers 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 Energy, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10/2015	TRM v3.0 update. New ENERGY STAR® specifications incorporated into the measure. New peak savings calculated according to revised peak definition.
v3.1	11/05/2015	TRM v3.1 update. Final ENERGY STAR® specification incorporated into the measure. Consolidated table formats.
v3.1	3/28/2016	TRM 3.1 March revision. Updated summer and winter coincidence factors and demand savings tables.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. Updated footnote reference to ENERGY STAR® calculator.
v6.0	11/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Updated links and dates.
v8.0	10/2020	TRM v8.0 update. No revision.
v9.0	10/2021	TRM v9.0 update. No revision.

2.5.5 ENERGY STAR® Refrigerators Measure Overview

TRM Measure ID: R-AP-RF

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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 unit with a maximum age of 20 years. To determine the remaining useful life of an existing unit, see Table 335. 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. 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[420] for refrigerators, effective September 15, 2014.

For early retirement, the baseline for refrigerators is the annual unit energy consumption of an assumed refrigerator's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[421] Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

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[420] DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

[421] Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. http://www.kouba-cavallo.com/refmods.htm.

High-Efficiency Condition

Table 332 displays the ENERGY STAR® requirements for eligible refrigerators, which went into effect on 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 332. ENERGY STAR® Specifications for Refrigerators

ENERGY STAR® refrigerator		
Product type	Volume	Criteria as of September 15, 2014
Full-size Refrigerators and Refrigerator-Freezers	7.75 cubic feet or greater	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 333)

Table 333. Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume[422]

Product number	Product class	Baseline energy usage federal standard as of September 15, 2014 (kWh/year)[423]	Average ENERGY STAR® energy usage (kWh/year)[424]	Adjusted volume[425] (cubic feet)	Baseline energy usage (kWh/year)	ENERGY STAR® energy usage (kWh/year)
3	Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.26 × AV + 210.3	16.9	370.1	333.0
5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.97 × AV + 285.3	18.6	481.5	433.5
5A	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.25 × AV + 475.4	8.33 × AV + 436.3	32.1	772.1	703.5
7	Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	8.54 × AV + 432.8	7.69 × AV + 397.9	30.4	692.1	631.4

[422] 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.
[423] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[424] Approximately 10 percent more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.
[425] AV is calculated as a simple average across all refrigerators in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 124

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 333)*

kWh_{ES} = *ENERGY STAR® average energy usage (see Table 333)*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760\ hrs} \times LSAF$$

Equation 125

Where:

LSAF = *Load Shape Adjustment Factor (see Table 334~~Table 334~~)*

Table 334. ENERGY STAR® Refrigerator Load Shape Adjustment Factors[426]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	1.112	1.099	1.108	1.100	1.081
Winter	0.929	0.966	0.924	0.941	0.966

Early Retirement

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

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

[426] See Volume 1, Section 4.

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

Where:

RUL = *Remaining useful life (see Table 335); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years*

EUL = *Estimated useful life = 16 years*

Table 335. Remaining Useful Life (RUL) of Replaced Refrigerator[427]

Age of replaced refrigerator (years)	RUL (years)	Age of replaced refrigerator (years)	RUL (years)
1	15.2	12	7.0
2	14.2	13	6.6
3	13.2	14	6.3
4	12.2	15	6.0
5	11.2	16	5.0
6	10.3	17	4.0
7	9.6	18	3.0
8	8.9	19	2.0
9	8.3	20	1.0
10	7.8	21[428,429]	0.0
11	7.4		

Derivation of RULs

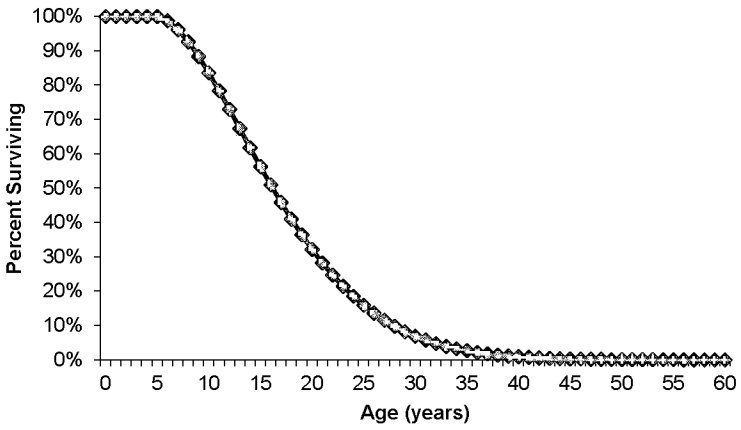
ENERGY STAR® refrigerators have an estimated useful life of 16 years. This estimate is consistent with the age at which approximately 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 12.

[427] Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[428] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see Figure 12~~Figure 12~~). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

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

Figure 12. Survival Function for ENERGY STAR® Refrigerators[430]



The method to estimate the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 12. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a refrigerator being replaced is 15 years old. The corresponding percent surviving value is 56 percent. Half of 56 percent is 28 percent. The age corresponding to 28 percent on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21–15) = 6 years.

Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

Equation 126

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

$$kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}$$

Equation 127

[430] 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.

Where:

kWh_{manf} = *968 kWh/Year*[431]

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 333)*

kWh_{ES} = *ENERGY STAR® average energy usage (see Table 333)*

Demand Savings Algorithms

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

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8{,}760\ hrs} \times LSAF$$

Equation 128

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

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8{,}760\ hrs} \times LSAF$$

Equation 129

Where:

LSAF = *Load shape adjustment factor (Table 334~~Table 334~~)*

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

[431] This is the weighted average of Adjusted annual unit energy consumption, derived from the MwEPA Refrigerator and Freezer Energy Rating Database (or from metering). Weights are calculated from the millions-of-households measurements obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of refrigerators greater than 15 years old (specifically, 15-to-19-years-old and 20-or-more-years-old). Data in which refrigerators' model years were older than 1975 were excluded.

Where:

RUL = *Remaining useful life (see Table 335)*

EUL = *Estimated useful life = 16 years*[432]

Deemed Energy Savings Tables

Table 336. ENERGY STAR® Refrigerators Energy Savings (kWh) by Refrigerator Type

Through-the-door ice?	Door type	Product class	ROB savings (kWh/year)	ER savings (kWh/year)
No	Top Freezer	3: Refrigerator freezers—automatic defrost with a top-mounted freezer without an automatic icemaker	37	224
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with a bottom-mounted freezer without an automatic icemaker	48	200
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	69	147
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	61	130
Unknown or Average Refrigerator[433]			44	205

[432] 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. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

[433] An "Unknown or Average" refrigerator's savings are calculated as the difference between the weighted average of baseline energy usage ratings and the weighted average of ENERGY STAR® energy usage ratings for the four selected refrigerator categories, with weights ascertained from averages of refrigerators in 10-14 year-old, 5-9 year-old, and 2-4 year-old age groups. The data used to calculate weights is hosted by Natural Resources Canada (NRCAN) at the following link which contains a table of the distribution of refrigerator types in households by year: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CM&sector=aaa&juris=ca&rn=3&page=1. Weights were similarly calculated utilizing data from RECS (data which is summarized, i.e. not yearly, and located here: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php). While the reported distribution of refrigerator types between the two sets of data varies, we prefer the year-level granularity of the data from NRCAN considering that the differences between both sets of weighted average baseline energy usage and weighted average ENERGY STAR® energy usage were nearly identical. Hence, we elect to utilize the more detailed weightings derived from the data hosted by NRCAN.

Deemed Summer Demand Savings Tables

Table 337. ENERGY STAR® Refrigerators Replace-on-Burnout Summer Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	Replace-on-burnout savings (kW—summer)				
			Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
No	Top Freezer	3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	0.0047	0.0047	0.0047	0.0047	0.0046
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	0.0061	0.0060	0.0061	0.0060	0.0059
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.0087	0.0086	0.0087	0.0086	0.0085
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.0077	0.0076	0.0077	0.0076	0.0075
Unknown or Average Refrigerator			0.0056	0.0056	0.0056	0.0056	0.0055

Table 338. ENERGY STAR® Refrigerators Early Retirement Summer Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	Early-Retirement Savings (kW —summer)				
			Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
No	Top Freezer	3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	0.028	0.028	0.028	0.028	0.028
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	0.025	0.025	0.025	0.025	0.025
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.016	0.016	0.016	0.016	0.016
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.019	0.018	0.019	0.018	0.018
Unknown or Average Refrigerator			0.026	0.026	0.026	0.026	0.025

Deemed Winter Demand Savings Tables

Table 339. ENERGY STAR® Refrigerators Replace-on-burnout Winter Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	Replace-on-burnout savings (kW—winter)				
			Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
No	Top Freezer	3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	0.0039	0.0041	0.0039	0.0040	0.0041
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	0.0051	0.0053	0.0051	0.0052	0.0053
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.0073	0.0076	0.0072	0.0074	0.0076
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.0064	0.0067	0.0064	0.0065	0.0067
Unknown or Average Refrigerator			0.0047	0.0049	0.0047	0.0048	0.0049

Table 340. ENERGY STAR® Refrigerators Early Retirement Winter Demand Savings (kW) by Refrigerator Type

Through-the-door ice?	Door type	Product class	Early-retirement savings (kW —winter)				
			Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
No	Top Freezer	3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	0.024	0.025	0.024	0.024	0.025
	Bottom Freezer	5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	0.021	0.022	0.021	0.021	0.022
Yes	Bottom Freezer	5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	0.014	0.014	0.014	0.014	0.014
	Side-by-Side	7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	0.016	0.016	0.015	0.016	0.016
Unknown or Average Refrigerator			0.022	0.023	0.022	0.022	0.023

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 16 years based on the current DOE Final Rule standards for residential refrigerators.[434]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- ~~Number of units installed~~Unit quantity
- ~~The project~~Baseline type ~~of the installation~~ (new construction, replace-on-burnout, or early retirement)
- Manufacturer and ~~Installed refrigerator~~ model number
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Document proper disposal of the existing refrigerator (early retirement only)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

References and Efficiency Standards

Petitions and Rulings

Not applicable.

[434] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. ~~Accessed 10/10/2014.~~ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for refrigerators.

Document Revision History

Table 341. Residential ENERGY STAR® Refrigerators 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 the main measure as "early retirement" option. Updated by Frontier Energy, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New ENERGY STAR® standards incorporated.
v3.0	4/10/2015	TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with the EM&V team's memo, "Considerations for early replacement of residential equipment." Remaining useful lifetimes updated. LSAF updated to align with new peak demand methodology.
v3.1	11/05/2015	TRM v3.1 update. Correction to legacy LSAF. Revision to align with ENERGY STAR® calculator and specification.
v3.1	3/28/2016	TRM v3.1 March revision. Updated summer and winter coincidence factors.
v4.0	10/10/2016	TRM v4.0 update. Updated RUL value for units with the age of seven years and added RUL values for units with an age of one to five years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have an age of minimum of five years.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	11/2018	TRM v6.0 update. Updated database reference.
v7.0	10/2019	TRM v7.0 update. Established deemed savings approach.
v8.0	10/2020	TRM v8.0 update. Updated early retirement age eligibility
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility

2.5.6 ENERGY STAR® Freezers Measure Overview

TRM Measure ID: R-AP-FZ

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure applies to all ENERGY STAR® freezers 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 unit with a maximum age of 27 years. To determine the remaining useful life of an existing unit, see Table 345. All retired freezers 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 freezers. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly-installed freezers 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[435] for freezers, effective September 15, 2014.

For early retirement, the baseline for freezers is the annual unit energy consumption of a freezer's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[436] Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

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[435] DOE minimum efficiency standard for residential refrigerators and freezers. https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8.

[436] Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. http://www.kouba-cavallo.com/refmods.htm.

Alternatively, the baseline annual energy usage of the freezer being replaced may be estimated by metering for a period of at least two hours using the measurement protocol specified in the DOE report, "Incorporating Refrigerator Replacement into the Weatherization Assistance Program."[437]

To determine annual kWh of the freezer being replaced, use the following formula:

$$Annual\ kWh\ Usage = \frac{WH \times 8{,}760}{h \times 1{,}000}$$

Equation 130

Where:

WH	=	*Watt-hours metered during a time period*
h	=	*Measurement time period (hours)*
8,760	=	*Hours in a year*
1,000 Watt-hours	=	*1 kWh*

High-Efficiency Condition

Table 342 displays the ENERGY STAR® requirements for eligible freezers, which went into effect on 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 342. ENERGY STAR® Specifications for Freezers[438]

ENERGY STAR® freezer		
Product type	Volume	Criteria as of September 15, 2014
Freezers	7.75 cubic feet or greater	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 333)
Compact Freezers	Less than 7.75 cubic feet	Approximately 10 percent more energy efficient than the minimum federal standard (see Table 333)

[437] Alex Moore, DandR International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel2_Paper16.pdf.

[438] https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria.

Table 343. Formulas to Calculate the ENERGY STAR® Criteria for Select Freezer Product Categories by Adjusted Volume[439]

Product number	Full product name[440]	Product class	Baseline energy usage federal standard (kWh/year)[441]	Average ENERGY STAR® energy usage (kWh/year)[442]	Adjusted volume[443] (cubic feet)	Baseline energy usage (kWh/year)	ENERGY STAR® energy usage (kWh/year)
8	Upright freezers with manual defrost	Upright (Manual Defrost)	5.57 × AV + 193.7	5.01 × AV + 174.3	16.12	283.5	255.1
9	Upright freezers with automatic defrost without an automatic icemaker	Upright (Auto Defrost)	8.62 × AV + 228.3	7.76 × AV + 205.5	29.96	486.6	438.0
10	Chest freezers and all other freezers except compact freezers	Chest	7.29 × AV + 107.8	6.56 × AV + 97	25.25	291.8	262.6
16	Compact upright freezers with manual defrost	Compact Upright (Manual Defrost)	8.65 × AV + 225.7	7.79 × AV + 203.1	5.34	271.9	244.7
17	Compact upright freezers with automatic defrost	Compact Upright (Auto Defrost)	10.17 × AV + 351.9	9.15 × AV + 316.7	7.95	432.7	389.4
18	Compact chest freezers	Compact Chest	9.25 × AV + 136.8	8.33 × AV + 123.1	9.06	220.6	198.6

[439] 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.

[440] Note that when calculating deemed savings for upright freezers, we calculated a weighted average of adjusted energy usage of manual versus automatic defrost upright freezers, with weights based on the number of millions-of-households which contain these types of freezers, obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php), thus eliminating this input from consideration.

[441] https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8.

[442] Approximately 10 percent more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

[443] AV is calculated as a simple average per selected freezer product type in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-freezers/results.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 131

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see* Table 343*)*

kWh_{ES} = *ENERGY STAR® average energy usage (see* Table 343*)*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{8{,}760\ hrs} \times LSAF$$

Equation 132

Where:

LSAF = *Load Shape Adjustment Factor (see* Table 344*)*

Table 344. ENERGY STAR® Freezer Load Shape Adjustment Factors[444]

Season	Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Summer	1.112	1.099	1.108	1.100	1.081
Winter	0.929	0.966	0.924	0.941	0.966

Early Retirement

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

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

[444] See Volume 1, Section 4.

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

Where:

RUL = *Remaining useful life (see* Table 343*); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years.*

EUL = *Estimated useful life = 22 years*

Table 345. Remaining Useful Life (RUL) of Replaced Freezer[445]

Age of replaced freezer (years)	RUL (years)	Age of replaced Freezer (years)	RUL (years)	Age of replaced Freezer (years)	RUL (years)
1	20.7	10	12.1	19	6.6
2	19.7	11	11.3	20	6.2
3	18.7	12	10.6	21	5.9
4	17.7	13	9.9	22	5.0
5	16.7	14	9.2	23	4.0
6	15.7	15	8.6	24	3.0
7	14.8	16	8.1	25	2.0
8	13.8	17	7.5	26	1.0
9	13.0	18	7.1	27[446,447]	0.0

[445] Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[446] RULs are capped at the 75th percentile of equipment age, 27 years, as determined based on DOE survival curves (see Figure 12~~Figure 12~~). Systems older than 27 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

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

Derivation of RULs

ENERGY STAR® freezers have an estimated useful life of 22 years. This estimate is consistent with the age at which approximately 50 percent of the freezers installed in a given year will no longer be in service, as described by the survival function in Figure 13.

Figure 13. Survival Function for ENERGY STAR® Freezers[448]

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 13. The age of the freezer being replaced is found on the horizontal axis, and the corresponding percentage of surviving freezers is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a freezer being replaced is 22 years old (the estimated useful life). The corresponding percent surviving value is approximately 50 percent. Half of 50 percent is 25 percent. The age corresponding to 25 percent on the chart is approximately 27 years. Therefore, the RUL of the freezer being replaced is 27-22 = 5 years.

[448] 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.

Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

Equation 133

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

$$kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}$$

Equation 134

Where:

kWh_{manf} = *841 kWh/Year*[449]

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 343)*

kWh_{ES} = *ENERGY STAR® average energy usage (see Table 343)*

Demand Savings Algorithms

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

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8{,}760\ hrs} \times LSAF$$

Equation 135

[449] This is the weighted average of adjusted annual unit energy consumption, a metric obtained from the MwEPA Refrigerator and Freezer Energy Rating Database (if from metering, substitute recorded value in lieu of this weighted average). Weights are calculated from the millions-of-households measurements obtained from RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of freezers greater than 15 years old (specifically, 15-to-19-years-old and 20-or-more-years-old). The oldest freezers for which we had data were from 1979.

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

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8{,}760\ hrs} \times LSAF$$

Equation 136

Where:

LSAF = *Load shape adjustment factor (Table 344)*

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

Where:

RUL = *Remaining Useful Life (see Table 335)*

EUL = *Estimated Useful Life = 22 years*[450]

Deemed Energy Savings Tables

Table 346. ENERGY STAR® Freezers Energy Savings (kWh) by Freezer Type

Freezer type	Size	ROB savings (kWh/year)	ER savings (kWh/year)
Chest	Standard (≥ 7.75 ft^3)	29	154
	Compact (< 7.75 ft^3)	22	163
Upright	Standard (≥ 7.75 ft^3)	48	130
	Compact (< 7.75 ft^3)	32	151

[450] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

Deemed Summer Demand Savings Tables

Table 347. ENERGY STAR® Freezers Replace-on-Burnout Summer Demand Savings (kW) by Freezer Type

Freezer type	Product class	Replace-on-burnout savings (kW—summer)				
		Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Chest	Standard (≥ 7.75 ft^3)	0.004	0.004	0.004	0.004	0.004
	Compact (< 7.75 ft^3)	0.003	0.003	0.003	0.003	0.003
Upright	Standard (≥ 7.75 ft^3)	0.006	0.006	0.006	0.006	0.006
	Compact (< 7.75 ft^3)	0.004	0.004	0.004	0.004	0.004

Table 348. ENERGY STAR® Freezers Early Retirement Summer Demand Savings (kW) by Freezer Type

Freezer type	Product class	Early-retirement savings (kW—summer)				
		Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Chest	Standard (≥ 7.75 ft^3)	0.020	0.019	0.019	0.019	0.019
	Compact (< 7.75 ft^3)	0.021	0.020	0.021	0.020	0.020
Upright	Standard (≥ 7.75 ft^3)	0.017	0.016	0.016	0.016	0.016
	Compact (< 7.75 ft^3)	0.019	0.019	0.019	0.019	0.019

Deemed Winter Demand Savings Tables

Table 349. ENERGY STAR® Freezers Replace-on-Burnout Winter Demand Savings (kW) by Freezer Type

Freezer type	Product class	Replace-on-burnout savings (kW—winter)				
		Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Chest	Standard (≥ 7.75 ft^3)	0.003	0.003	0.003	0.003	0.003
	Compact (< 7.75 ft^3)	0.002	0.002	0.002	0.002	0.002
Upright	Standard (≥ 7.75 ft^3)	0.005	0.005	0.005	0.005	0.005
	Compact (< 7.75 ft^3)	0.003	0.003	0.003	0.003	0.003

Table 350. ENERGY STAR® Freezers Early Retirement Winter Demand Savings (kW) by Freezer Type

Freezer type	Product class	Early-retirement savings (kW—winter)				
		Climate zone 1: Amarillo	Climate zone 2: Dallas	Climate zone 3: Houston	Climate zone 4: Corpus Christi	Climate zone 5: El Paso
Chest	Standard (≥ 7.75 ft^3)	0.016	0.017	0.016	0.017	0.017
	Compact (< 7.75 ft^3)	0.017	0.018	0.017	0.018	0.018
Upright	Standard (≥ 7.75 ft^3)	0.014	0.014	0.014	0.014	0.014
	Compact (< 7.75 ft^3)	0.016	0.017	0.016	0.016	0.017

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 22 years based on the current DOE Final Rule standards for residential freezers.[451]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Unit quantity~~Number of units installed~~
- ~~The project type of the installation~~Baseline type (new construction, replace-on-burnout, or early retirement)
- Manufacturer and model number
- ~~Installed f~~Freezer type (upright or chest)
- ~~Installed f~~Freezer size (standard, i.e., ≥ 7.75 ft^3, or compact, i.e., < 7.75 ft^3)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- The installer will provide documentation of proper disposal of freezers in accordance with applicable federal, state, and local regulations. (early retirement only)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

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[451] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. ~~Accessed 09/03/2019.~~ https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for freezers.

Document Revision History

Table 351. Residential ENERGY STAR® Clothes Dryers Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. Updated early retirement age eligibility.
v9.0	10/2021	TRM v9.0 update. Updated early retirement age eligibility.

2.5.7 ENERGY STAR® Pool Pumps Measure Overview

TRM Measure ID: R-AP-PP

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, multifamily, manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR® certified variable-speed or multi-speed pool pump.

Eligibility Criteria

This measure applies to all residential applications of in-ground pools or above-ground pools. Pools that serve multiple tenants in a common area are not eligible for this measure. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa.[452]

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[453] Therefore, multi-speed pumps must have a high-speed override capability to revert back to low speed after a period not to exceed 24 hours.

Baseline Condition

The baseline condition is a 1 to 3 horsepower (hp) standard efficiency[454] single-speed pool pump.

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[452] These product types are excluded by the ENERGY STAR® specifications. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%203.0%20Pool%20Pumps%20Specification.pdf. ~~Accessed July 2020.~~

[453] Hunt, A. and Easley, S., 2012, "*Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings.*" Building America Retrofit Alliance (BARA), U.S. U.S. DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf. ~~Accessed July 2020.~~

[454] The U.S. DOE passed minimum efficiency standards for pool pumps effective July 19, 2021. These new baseline standards will be incorporated into TRM 10.0 to allow for sell down of existing inventory.

High-Efficiency Condition

The high-efficiency condition is a 1 to 3 hp ENERGY STAR® certified variable speed pump (VSP) or ENERGY STAR® certified multi-speed pool pump.

Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR® Pool Pump Savings Calculator.

Savings Algorithms and Input Variables

Energy Savings Algorithms

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator with Texas selected as the applicable location, so Texas-specific assumptions were used.[455]

$$kWh_{Savings} = kWh_{conv} - kWh_{ES}$$

Equation 137

Where:

kWh_{conv} = *Conventional single-speed pool pump energy (kWh)*

kWh_{ES} = *ENERGY STAR® variable speed pool pump energy (kWh)*

Algorithms to calculate the above parameters are defined as:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times hours \times days}{EF_{conv} \times 1000}$$

Equation 138

$$kWh_{ES} = \frac{gal \times turn_{day} \times days}{EF_{ES} \times 1000}$$

Equation 139

Where:

hours = *Pump daily operating hours (Table 352)*

days = *Operating days per year = 365 days (default)*

PFRconv = *Conventional single-speed pump flow rate [gal/min] (Table 352)*

[455] The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: https://www.energystar.gov/products/certified-products/detail/pool-pumps.