Table 287 presents the deemed energy savings tables for high usage HPWHs for the five Texas climate zones.

**Table 287: 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 288 presents the deemed summer demand savings for medium usage heat pump water heaters across the five Texas climate zones.

**Table 288: 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 |
| | | 80+ | 0.07 | 0.07 |
| 2 | North | <55 | 0.24 | 0.20 |
| | | 55-69 | 0.05 | 0.04 |
| | | 70-79 | 0.05 | 0.04 |
| | | 80+ | 0.05 | 0.04 |
| 3 | South | <55 | 0.24 | 0.20 |
| | | 55-69 | 0.05 | 0.04 |
| | | 70-79 | 0.05 | 0.04 |
| | | 80+ | 0.05 | 0.04 |
| 4 | Valley | <55 | 0.23 | 0.19 |
| | | 55-69 | 0.05 | 0.04 |
| | | 70-79 | 0.05 | 0.04 |
| | | 80+ | 0.05 | 0.04 |
| 5 | West | <55 | 0.26 | 0.22 |
| | | 55-69 | 0.05 | 0.05 |
| | | 70-79 | 0.06 | 0.05 |
| | | 80+ | 0.06 | 0.05 |

Table 289 presents the deemed summer demand savings for medium usage heat pump water heaters across the five Texas climate zones.

**Table 289: 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 290 presents the deemed winter demand savings for medium usage heat pump water heaters across the five Texas climate zones.

**Table 290: 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 |
| | | 80+ | 0.17 | 0.17 | 0.17 | 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 |
| | | 80+ | 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 |
| | | 80+ | 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 |
| | | 80+ | 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 |
| | | 80+ | 0.15 | 0.15 | 0.15 | 0.16 |

Table 291 presents the deemed winter demand savings for high usage heat pump water heaters across the five Texas climate zones.

**Table 291: 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life for this measure is 13 years. This EUL is consistent with the judgment of the American Council for an Energy-Efficient Economy as listed on its website.[276]

[276] Water Heating. American Council for an Energy Efficient Economy. Online. Available: http://www.aceee.org/consumer/water-heating. Accessed: September 2011.

## 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
- Baseline uniform energy factor (UEF)
- UEF of the replacement water heater
- First-hour rating (FHR) of the replacement water heater
- Water heater type (e.g., heat pump, electric resistance)
- Installed location (i.e., 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

This section is not applicable.

### Relevant Standards and Reference Sources

This section is not applicable.

## Document Revision History

**Table 292: 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 Associates, March 2014, based on new federal standards. |
| v2.1 | 01/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 04/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Consolidated table formats. |
| 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. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

## Eligibility Criteria

These deemed savings are for solar water heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes. However, savings are calculated under the assumption of replace-on-burnout.

## Baseline Condition

This section is not applicable.

## High-efficiency Condition

Only solar water heaters meeting the SRCC OG-300 standard (based on tank size and final Solar Energy Factor-SEF) qualify for these deemed savings estimates.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Solar water heating values are on a per-unit basis. Deemed savings variables include tank volume and installed unit solar energy factor (SEF) as rated in the Solar Rating and Certification

Corporation (SRCC) "Summary of SRCC Certified Solar Collector and Water Heating System Ratings." The Solar Energy Factor (SEF) is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed as a means to compare solar water heating systems with conventional water heating systems rated with an Energy Factor (EF) and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both EF and SEF are based on the same environmental and hot water use conditions used in the DOE Test Procedures for Water Heaters. The only significant difference is that the DOE test does not specify solar radiation. So SRCC uses a 1500 Btu/sq.ft./day solar radiation profile—a value typical of Sunbelt states (note - the annual average solar radiation for Dallas is 1533 Btu/sq.ft./day. (Information on the SRCC can be found at http://www.solar-rating.org/.)

### *Examples*

A passive Sun Earth CP-40 with a SEF of 1.4 would consume 2,133 kWh (2987/1.4), saving 1,323 kWh compared to a baseline 50-gallon water heater that consumes 3458 kWh (values based on Frontier data).

An active Heliotype HP 410 G 80 with a SEF of 2.0 would consume 1,494 kWh (2987/2), saving 1,965 kWh compared to the baseline 50-gallon water heater.

### *Use SRCC OG-300 Test to Obtain SEF*

SRCC = Solar Rating and Certification Corporation

OG-300 = test standard for SWH systems

SEF = Solar Energy Factor

### *Calculate kWh Savings*

$$kWh\ savings = standard\ load \times \left(1 - \frac{EF}{SEF}\right) = (3{,}458) \times \left(1 - \frac{0.864}{2}\right) = 1{,}965kWh$$

## Deemed Energy Savings Tables

The following table presents the energy savings for solar water heaters based on tank size and final Solar Energy Factor (SEF).

**Table 293: Solar Water Heating Energy Savings (kWh)**

| Water Heating Replacements—Solar Water Heating Energy Savings | | | |
|---|---|---|---|
| **Approximate Volume (gal)** | **80** | **50** | **30** |
| **Baseline (DOE Standard) EF** | **0.82** | **0.86** | **0.89** |
| **SRCC OG-300 Solar Energy Factor** | **Energy Savings (kWh)** | | |
| 1.0 | 637 | 471 | 368 |
| 1.1 | 909 | 743 | 640 |

| Water Heating Replacements—Solar Water Heating Energy Savings | | | |
|---|---|---|---|
| **Approximate Volume (gal)** | **80** | **50** | **30** |
| **Baseline (DOE Standard) EF** | **0.82** | **0.86** | **0.89** |
| **SRCC OG-300 Solar Energy Factor** | **Energy Savings (kWh)** | | |
| 1.2 | 1,135 | 969 | 866 |
| 1.3 | 1,326 | 1,160 | 1,057 |
| 1.4 | 1,490 | 1,324 | 1,221 |
| 1.5 | 1,633 | 1,467 | 1,364 |
| 1.6 | 1,757 | 1,591 | 1,488 |
| 1.7 | 1,867 | 1,701 | 1,598 |
| 1.8 | 1,965 | 1,799 | 1,696 |
| 1.9 | 2,052 | 1,886 | 1,783 |
| 2.0 | 2,131 | 1,965 | 1,862 |
| 2.1 | 2,202 | 2,036 | 1,933 |
| 2.2 | 2,266 | 2,100 | 1,997 |
| 2.3 | 2,325 | 2,159 | 2,056 |
| 2.4 | 2,379 | 2,213 | 2,110 |
| 2.5 | 2,429 | 2,263 | 2,160 |
| 2.6 | 2,475 | 2,309 | 2,206 |
| 2.7 | 2,518 | 2,352 | 2,249 |
| 2.8 | 2,557 | 2,391 | 2,288 |
| 2.9 | 2,594 | 2,428 | 2,325 |
| 3.0 | 2,628 | 2,462 | 2,359 |
| 3.1 | 2,660 | 2,494 | 2,391 |
| 3.2 | 2,691 | 2,525 | 2,422 |
| 3.3 | 2,719 | 2,553 | 2,450 |
| 3.4 | 2,745 | 2,579 | 2,476 |
| 3.5 | 2,771 | 2,605 | 2,502 |
| 3.6 | 2,794 | 2,628 | 2,525 |
| 3.7 | 2,817 | 2,651 | 2,548 |
| 3.8 | 2,838 | 2,672 | 2,569 |
| 3.9 | 2,858 | 2,692 | 2,589 |
| 4.0 | 2,877 | 2,711 | 2,608 |
| 4.1 | 2,895 | 2,729 | 2,626 |

| Water Heating Replacements—Solar Water Heating Energy Savings | | | |
|---|---|---|---|
| **Approximate Volume (gal)** | **80** | **50** | **30** |
| **Baseline (DOE Standard) EF** | **0.82** | **0.86** | **0.89** |
| **SRCC OG-300 Solar Energy Factor** | **Energy Savings (kWh)** | | |
| 4.2 | 2,913 | 2,747 | 2,644 |
| 4.3 | 2,929 | 2,763 | 2,660 |
| 4.4 | 2,945 | 2,779 | 2,676 |
| 4.5 | 2,960 | 2,794 | 2,691 |
| 4.6 | 2,975 | 2,809 | 2,706 |
| 4.7 | 2,988 | 2,822 | 2,719 |
| 4.8 | 3,002 | 2,836 | 2,733 |
| 4.9 | 3,014 | 2,848 | 2,745 |
| 5.0 | 3,027 | 2,861 | 2,758 |

Source: Tim Kerrigan, National Renewable Energy Laboratory (2001).

## Deemed Summer Demand Savings Tables

The following table presents the demand savings for solar water heaters.

**Table 294: Solar Water Heating Demand Savings (kW)**

| Solar Water Heating Demand Savings kW |
|---|
| 0.42 |

- Diversified value fully displaced during solar peak.
- This value is consistent with the University of Texas study (0.4).

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar water heater is established at 15 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[277]

## 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:

- The approximate volume of the replacement water heater in gallons
- 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 Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003, Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

This section is not applicable.

[277] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer-versions/deer2013-update-for-2014-codes.

## Document Revision History

**Table 295: 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 |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |

## 2.4.8 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, duplex, and triplex; 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)[278] between the existing shower arm and showerhead. The valve will restrict 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

The incentive is for the installment of a temperature sensitive restrictor valve between the existing shower arm and showerhead.

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in existing homes. In order 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.

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

## High-efficiency Condition

To qualify for temperature sensitive restrictor valve deemed savings, the installed equipment must be 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.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Estimated Hot Water Usage Reduction*

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[279,280,281]

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 93**

*Where:*

| | | |
|---|---|---|
| *SHFR* | = | *Showerhead flow rate, gallons per minute (gpm) (see Table 296)* |
| *BW*$C_P$ | = | *Behavioral waste, minutes per shower (see Table 296)* |
| $n_S C_P$ | = | *Number of showers per person per day (see Table 296)* |
| *365*$C_P$ | = | *Constant to convert days to years (see Table 296)* |
| $n_O C_P$ | = | *Number of occupants per home (see Table 296)* |
| $n_{SH} C_P$ | = | *Number of showerheads per home (see Table 296)* |

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

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

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

Applying the formula to the values used for Texas from Table 296 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM): 2.5 \times\ 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68} = 854\ gal$$

$$Showerhead\ (2.0\ GPM): 2.0 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68} = 683\ gal$$

$$Showerhead\ (1.75\ GPM): 1.75 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68} = 598\ gal$$

$$Showerhead\ (1.5\ GPM): 1.5 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68} = 513\ gal$$

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 296.

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

**Equation 94**

*Where:*

*HW%* = *Hot water percentage (see Table 296)*

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 854 \times\ 0.825 = 705\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 683 \times\ 0.825 = 563\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 598 \times\ 0.825 = 493\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 513 \times\ 0.825 = 423\ gal$$

**Table 296: Estimated Showerhead with TSRV Hot Water Usage Reduction**

| Description | 2.5 gpm | 2.0 gpm | 1.75 gpm | 1.5 gpm |
|---|---|---|---|---|
| Average behavioral waste (minutes per shower)[282] | 0.783 | 0.783 | 0.783 | 0.783 |
| Showers/person/day[283] | 0.72 | 0.72 | 0.72 | 0.72 |
| Occupants per home[284] | 2.79 | 2.79 | 2.79 | 2.79 |
| Showerheads per home[285] | 1.68 | 1.68 | 1.68 | 1.68 |
| Gallons behavioral waste per showerhead per year | 1,018 | 814 | 713 | 611 |

[282] 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.

[283] 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.

[284] Derivation of value for showers per person per day defined in the Low Flow Showerhead measure.

[285] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

| Description | 2.5 gpm | 2.0 gpm | 1.75 gpm | 1.5 gpm |
|---|---|---|---|---|
| Percent hot water[286] | 82.5% | 82.5% | 82.5% | 82.5% |
| Gallons hot water saved per year | 705 | 563 | 493 | 423 |

## Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

**Equation 95**

*Where:*

$\rho$ = *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 296)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [287]

$T_{Supply}$ = *Average supply water temperature (see Table 297)*

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, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.* [288]

ConversionFactor = *3,412 Btu/kWh for electric or 100,000 Btu/therm for gas*

[286] Average percent hot water 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.

[287] 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.

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

## Demand Savings Algorithms

Demand savings will be calculated using the following formula:

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

**Equation 96**

*Where:*

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 297)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 298)*

**Table 297: Water Mains Temperature**

| Climate Zone | Water Mains Temperature (°F)[289] | | |
|---|---|---|---|
| | $T_{SupplyAverage}$ | $T_{SupplySeasonal}$ | |
| | | 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 298: Water Fixture Peak Demand Ratios**

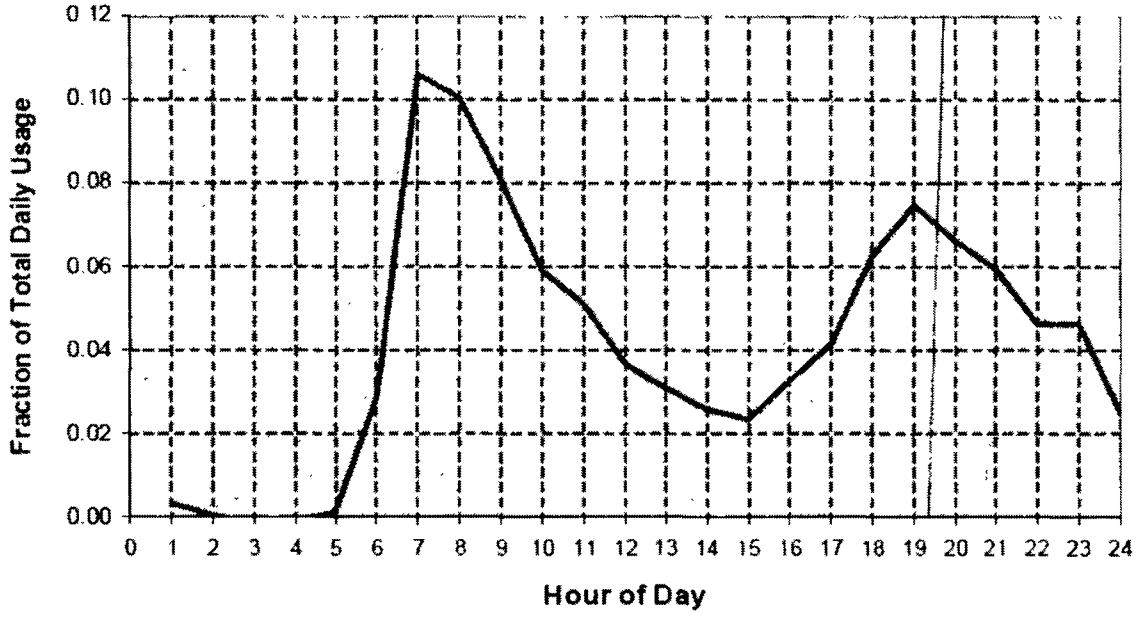
| Peak Demand Ratios[290] | |
|---|---|
| Summer | Winter |
| 0.000110 | 0.000274 |

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

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

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

**Figure 10: Shower, Bath, and Sink Hot Water Use Profile**




Source: Building America Performance Analysis Procedures for Existing Homes.

## Deemed Energy Savings Tables

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

## Deemed Summer Demand Savings Tables

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

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) 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).[291]

## 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
- 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)

## Document Revision History

**Table 299: 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. |

[291] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

## 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, duplex, and triplex; 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) [292] 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

The incentive is for the installment of an automatically diverting tub spout and showerhead system with temperature sensitive restrictor technology.

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. In order 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.

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

## High-efficiency Condition

To qualify for tub spout and showerhead system with temperature sensitive restrictor technology deemed savings, the installed equipment must be 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*

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[293,294,295]

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 97**

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

**Equation 98**

*Where:*

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 300)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 300)*

---

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

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

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

| | | |
|---|---|---|
| *SHFR* | = | *Showerhead flow rate, gallons per minute (gpm) (see Table 300)* |
| *TSFR* | = | *Tub spout flow rate, gallons per minute (gpm) (see Table 300)* |
| $BWC_P$ | = | *Behavioral waste, minutes per shower (see Table 300)* |
| $n_SC_P$ | = | *Number of showers per person per day (see Table 300)* |
| $365C_P$ | = | *Constant to convert days to years (see Table 300)* |
| $n_OC_P$ | = | *Number of occupants per home (see Table 300)* |
| $n_{SH}C_P$ | = | *Number of showerheads per home (see Table 300)* |

Applying the formula to the values used for Texas from Table 300 returns the following values:

$$Showerhead\ (1.5\ GPM)\text{: } 0.6 \times \left(1.5 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68}\right) = 308$$

$$Showerhead\ (1.75\ GPM)\text{: } 0.6 \times \left(1.75 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68}\right) = 359$$

$$Showerhead\ (2.0\ GPM)\text{: } 0.6 \times \left(2.0 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68}\right) = 410$$

$$Showerhead\ (2.5\ GPM)\text{: } 0.6 \times \left(2.5 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68}\right) = 513$$

$$Tub\ Spout\ (5.0\ GPM)\text{: } 0.4 \times \left(5.0 \times 0.783 \times 0.72 \times 365 \times \frac{2.79}{1.68}\right) = 683$$

**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 99**

*Where:*

| | | |
|---|---|---|
| DLR | = | *Diverter leakage rate (gpm) (see Table 300)* |
| $t_S$ | = | *Shower time (min/shower) (see Table 300)* |

Applying the formula to the values used for Texas from Table 300 returns the following values:

$$Diverter\ (0.8\ GPM)\text{: } 0.8 \times 5.68 \times 0.72 \times 365 \times \frac{2.79}{1.68} = 1{,}983$$

**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 300.

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

**Equation 100**

*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 300)*

$HW\%_{D}$ = *Diverter hot water percentage (see Table 300)*

Applying the formula to the values used for Texas from Table 300 returns the following values:

$$Total\ Annual\ Waste\ (1.5\ gpm): (308 + 683) \times 0.825 + 1{,}983 \times 0.737 = 2{,}279$$

$$Total\ Annual\ Waste\ (1.75\ gpm): (359 + 683) \times 0.825 + 1{,}983 \times 0.737 = 2{,}321$$

$$Total\ Annual\ Waste\ (2.0\ gpm): (410 + 683) \times 0.825 + 1{,}983 \times 0.737 = 2{,}363$$

$$Total\ Annual\ Waste\ (2.5\ gpm): (513 + 683) \times 0.825 + 1{,}983 \times 0.737 = 2{,}448$$

**Table 300: Estimated Tub Spout/Showerhead System with TSRV 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)[296] | N/A | 5.0 | N/A | |
| Percent of warm-up events[297] | 60 | 40 | N/A | |
| Average behavioral waste (minutes per shower)[298] | 0.783 | 0.783 | N/A | |
| Average diverter leak rate (gpm)[299] | N/A | | 0.80 | N/A |

[296] Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[297] Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

[298] 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.

[299] Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.

| Description | Part 1- Behavioral Waste | | Part 2— Diverter Leakage | Part 3— Total |
|---|---|---|---|---|
| | Showerhead Warm-up | Tub spout Warm-up | | |
| Average shower time (minutes)[300] | N/A | | 5.68 | N/A |
| Showers/person/day[301] | 0.72 | 0.72 | 0.72 | 0.72 |
| Occupants per home[302] | 2.79 | 2.79 | 2.79 | 2.79 |
| Showerheads per home[303] | 1.68 | 1.68 | 1.68 | 1.68 |
| Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm) | 308 | 683 | 1,983 | 2,974 |
| Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm) | 359 | 683 | 1,983 | 3,025 |
| Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm) | 410 | 683 | 1,983 | 3,076 |
| Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm) | 513 | 683 | 1,983 | 3,179 |
| Percent hot water[304] | 82.5% | 82.5% | 73.7% | N/A |
| Gallons hot water saved per year (1.5 gpm) | N/A | N/A | N/A | 2,279 |
| Gallons hot water saved per year (1.75 gpm) | N/A | N/A | N/A | 2,321 |
| Gallons hot water saved per year (2.0 gpm) | N/A | N/A | N/A | 2,363 |
| Gallons hot water saved per year (2.5 gpm) | N/A | N/A | N/A | 2,448 |

## Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

**Equation 101**

*Where:*

ρ = *Water density, 8.33 lbs/gallon*

[300] Average shower time from (REUWS 1999) Residential End Uses of Water Study and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

[301] Derivation of value for showers per person per day defined in the Low Flow Showerhead measure.

[302] 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.

[303] Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

[304] 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.

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

V = *Gallons of hot water saved per year per showerhead (see Table 300)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [305]

$T_{Supply}$ = *Average supply water temperature (see Table 301)*

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, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.* [306]

ConversionFactor = *3,412 Btu/kWh for electric or 100,000 Btu/therm for gas*

## Demand Savings Algorithms

Demand savings will be calculated using the following formula:

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

**Equation 102**

*Where:*

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 301)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 302)*

[305] 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.

[306] 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 301: Water Mains Temperature**

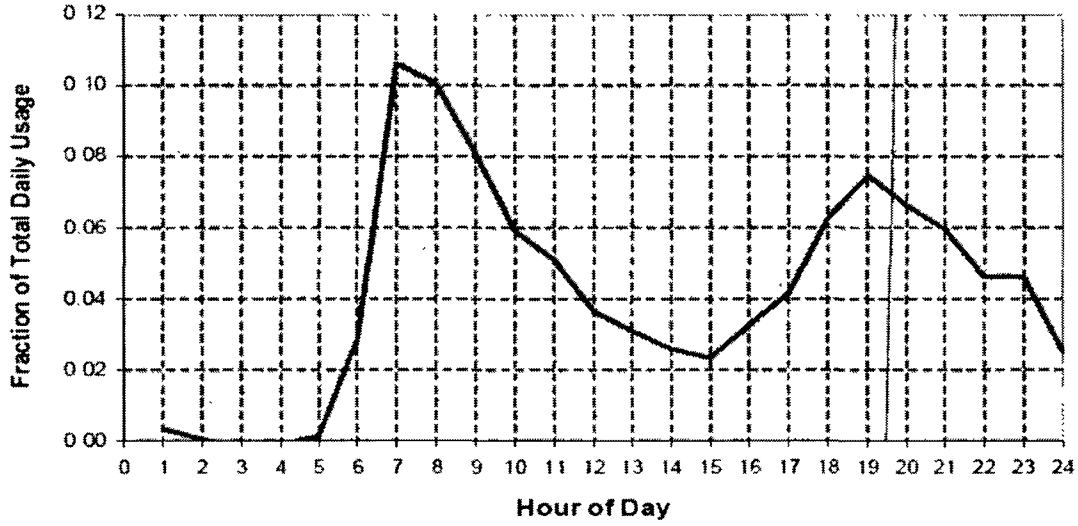
| Climate Zone | Water Mains Temperature (°F)[307] | | |
|---|---|---|---|
| | $T_{SupplyAverage}$ | $T_{SupplySeasonal}$ | |
| | | Summer | Winter |
| Climate Zone 1: Panhandle | 62.9 | 73.8 | 53.7 |
| Climate Zone 2: North | 71.8 | 84.0 | 60.6 |
| Climate Zone 3: South | 74.7 | 84.5 | 65.5 |
| Climate Zone 4: Valley | 77.2 | 86.1 | 68.5 |
| Climate Zone 5: West | 70.4 | 81.5 | 60.4 |

**Table 302: Water Fixture Peak Demand Ratios**

| Peak Demand Ratios[308] | |
|---|---|
| Summer | Winter |
| 0.000110 | 0.000274 |

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

**Figure 11: Shower, Bath, and Sink Hot Water Use Profile**




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

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

Source: Building America Performance Analysis Procedures for Existing Homes.

## Deemed Energy Savings Tables

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

## Deemed Summer Demand Savings Tables

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

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) 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).[309]

## 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
- 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)

[309] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

## Document Revision History

**Table 303: 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. |

# 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This 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 304 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.[310]

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

**Table 304: 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 305: ENERGY STAR® Ceiling Fan Efficiency Requirements**

| Type | Diameter (inches) | Minimum Efficiency (cfm/W) | Minimum High Speed Airflow (cfm) |
|---|---|---|---|
| Ceiling fan | $D \leq 36$ | $\geq 0.72 \times D + 41.93$ | $\geq 1{,}767$ |
| | $36 < D < 78$ | $\geq 2.63 \times D - 26.83$ | $\geq 250 \times \pi \times (D/24)^2$ |
| | $D \geq 78$ | | $\geq 8{,}296$ |
| Hugger ceiling fan | $D \leq 36$ | $\geq 0.31 \times D + 36.84$ | $\geq 1{,}414$ |
| | $36 < D < 78$ | $\geq 1.75 \times D - 15$ | $\geq 200 \times \pi \times (D/24)^2$ |
| | $D \geq 78$ | | $\geq 6{,}637$ |

**Table 306: 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.[311] Default values were taken directly from the ENERGY STAR® Ceiling Fan Savings Calculator, unless otherwise specified.

[311] 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 103**

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

**Equation 104**

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

**Equation 105**

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

**Equation 106**

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

**Equation 107**

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

**Equation 108**

*Where*:

| | | |
|---|---|---|
| $kWh_{baseline}$ | = | *Non-ENERGY STAR® baseline energy usage* |
| $kWh_{ES}$ | = | *ENERGY STAR® average energy usage* |
| $IEF_E$ | = | *Energy Interactive Effects Factor from Table 307 assuming heating/cooling unknown*[312] |
| $W_{Lgt,baseline}$ | = | *Conventional lighting total wattage = 115 W (160 W default value from ENERGY STAR® calculator reduced to comply with EISA 2007 baseline wattages)*[313] |
| $W_{Lgt,ES}$ | = | *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 308* |

[312] The assumed energy interactive effects factors are taken from the residential lighting measure.
[313] 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 309* |
| $AOH_{Lgt}$ | = | *Annual lighting operating hours = 803 hours/year (assuming 2.2 hours/day and 365 days/year operation)*[314] |
| $AOH_{Fan}$ | = | *Annual fan operating hours = 1,095 hours/year (assuming 3.0 hours/day and 365 days/year operation)*[315] |
| 1,000 | = | *Constant to convert from W to kW* |

**Table 307: ENERGY STAR® Ceiling Fans—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties**[316]

| | $IEF_E$ | | | | |
|---|---|---|---|---|---|
| Heating/Cooling Type* | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
| Heating/Cooling Unknown[317] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

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

[315] 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.

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

[317] 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 308: 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 |

**Table 309: 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 109**

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

**Equation 110**

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

**Equation 111**

*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 310)*

$IEF_D$ = *Demand Interactive Effects Factor from Table 311 assuming heating/cooling unknown*[318]

**Table 310 ENERGY STAR® Ceiling Fans—Lighting Coincidence Factors**[319]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.060 | 0.053 | 0.063 | 0.059 | 0.032 |
| Winter | 0.277 | 0.232 | 0.199 | 0.267 | 0.357 |

**Table 311: ENERGY STAR® Ceiling Fans—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties**[320]

| $IEF_{D,summer}$ | | | | | |
|---|---|---|---|---|---|
| Heating/Cooling Type* | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
| Heating/cooling unknown[321] | 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[322] | 0.76 | 0.72 | 0.73 | 0.75 | 0.80 |

## Deemed Energy Savings Tables

**Table 312: Ceiling Fans Deemed Energy Savings**

| Deemed Energy 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 |

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

[319] See Volume 1, Appendix B.

[320] 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: $1 + HVAC_{savings}/Lighting_{savings}$.

[321] 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.

[322] 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 313: 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 314: 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

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

This EUL is consistent with Docket No. 38025 approved in 2010.[323]

## 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 of installed ENERGY STAR® ceiling fan and light kits
- Proof of purchase – with date of purchase and quantity

[323] 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.

- 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 315: 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. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** 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

This section is not applicable.

### Baseline Condition

Effective January 1, 2018, the baseline is the Department of Energy (DOE) minimum efficiency standard[324] for top-loading clothes washers. While the DOE provides criteria for both top- and front-loading washers, only the standards for top-loading washers are listed below, as a top-loading unit is assumed to be the baseline equipment. This approach is consistent with the ENERGY STAR® appliance calculator.

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

**Table 316: 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<br>IWF≤ 6.5 |
| Top-loading, Compact (less than 1.6 $ft^3$ capacity) | IMEF ≥ 1.15<br>IWF≤ 12.0 |

## High-efficiency Condition

The table below displays the ENERGY STAR® Final Version 8.0 requirements for eligible clothes washers effective February 5, 2018, with early certification available starting May 5, 2017.[325] 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 317: 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<br>IWF≤ 3.2 |
| ENERGY STAR® Residential Top-loading (> 2.5 $ft^3$) | IMEF ≥ 2.06<br>IWF ≤ 4.3 |
| ENERGY STAR® Residential Small or Compact (< 2.5 $ft^3$) | IMEF ≥ 2.07<br>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.[326] 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.

[325] 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.

[326] 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 112**

## Baseline Unit

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

**Equation 113**

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

**Equation 114**

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

**Equation 115**

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

**Equation 116**

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

**Equation 117**

*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)* [327], 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)*

[327] 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 316)* |
| *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 118**

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

**Equation 119**

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

**Equation 120**

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

**Equation 121**

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

**Equation 122**

*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 318)* |

$kW_{ES,LPM}$ = *Combined low-power mode wattage of ENERGY STAR® unit (see Table 318)*

$IMEF_{ES}$ = *ENERGY STAR® integrated modified energy factor (Table 317)*

$CAP_{ES}$ = *Average machine capacity (see Table 318)*

**Table 318: ENERGY STAR® Clothes Washer Characteristics[328]**

| Product Type | ENERGY STAR® Rated Unit Electricity Consumption (kWh) | Average Capacity ($ft^3$) | Combined Low-Power Mode Wattage (kW) |
|---|---|---|---|
| Residential front-loading (> 2.5 $ft^3$) | 127 | 4.0 | 0.00160 |
| Residential top-loading (> 2.5 $ft^3$) | 230 | 4.5 | 0.00115 |
| Residential small or compact (< 2.5 $ft^3$) | 109 | 2.1 | 0.00144 |

## *Summer Demand Savings Algorithms*

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

**Equation 123**

$$AOH = LPY \times d$$

**Equation 124**

*Where*:

*AOH* = *Annual operating hours*

*CF* = *Coincidence factor (Table 319)*

*LPY* = *Loads per year = 295*

*d* = *Average wash cycle duration = 1 hour*[329,330]

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

[329] Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers. Top: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/top-loading-washing-machine-ratings/ratings-overview.htm. Front: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/front-loading-washing-machine-ratings/ratings-overview.htm.

[330] 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. http://news.consumerreports.org/home/2010/04/best-front-loaders-top-loaders-which-is-more-popular-mold-vibration-washing-machine-reviews.html. This publication is available for purchase only.

**Table 319: ENERGY STAR® Clothes Washer Coincidence Factors[331]**

| 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 320: ENERGY STAR® Clothes Washer Energy Savings (kWh)**

| ENERGY STAR® Clothes Washer—Annual Energy Savings | | | |
|---|---|---|---|
| Type | Water Heater Fuel Type | Dryer Fuel Type | kWh Savings |
| Front-loading > 2.5 $ft^3$ | Electric | Electric | 394 |
| | | Gas | 187 |
| | Gas | Electric | 241 |
| | | Gas | 34 |
| Top-loading > 2.5 $ft^3$ | Electric | Electric | 193 |
| | | Gas | 114 |
| | Gas | Electric | 102 |
| | | Gas | 23 |
| All $\leq$ 2.5 $ft^3$ | Electric | Electric | 222 |
| | | Gas | 41 |
| | Gas | Electric | 189 |
| | | Gas | 8 |

[331] See Volume 1, Appendix B.

## Deemed Summer Demand Savings Tables

**Table 321: ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW)**

| ENERGY STAR® Clothes Washer—Summer Demand Savings | | | | | | | |
|---|---|---|---|---|---|---|---|
| Washer Type | Fuel Type | | Summer Demand Savings (kW) | | | | |
| | Water Heater | Dryer | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
| Front-loading > 2.5 ft$^3$ | Electric | Electric | 0.053 | 0.053 | 0.053 | 0.055 | 0.055 |
| | | Gas | 0.025 | 0.025 | 0.025 | 0.026 | 0.026 |
| | Gas | Electric | 0.033 | 0.033 | 0.033 | 0.033 | 0.033 |
| | | Gas | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| Top-loading > 2.5 ft$^3$ | Electric | Electric | 0.026 | 0.026 | 0.026 | 0.027 | 0.027 |
| | | Gas | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 |
| | Gas | Electric | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 |
| | | Gas | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| All ≤ 2.5 ft$^3$ | Electric | Electric | 0.030 | 0.030 | 0.030 | 0.031 | 0.031 |
| | | Gas | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | Gas | Electric | 0.026 | 0.026 | 0.026 | 0.026 | 0.026 |
| | | Gas | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

## Deemed Winter Demand Savings Tables

**Table 322: 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 | 0.057 | 0.057 | 0.057 | 0.059 | 0.052 |
| | | Gas | 0.027 | 0.027 | 0.027 | 0.028 | 0.025 |
| | Gas | Electric | 0.035 | 0.035 | 0.035 | 0.036 | 0.032 |
| | | Gas | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| Top-loading > 2.5 ft³ | Electric | Electric | 0.028 | 0.028 | 0.028 | 0.029 | 0.026 |
| | | Gas | 0.017 | 0.017 | 0.017 | 0.017 | 0.015 |
| | Gas | Electric | 0.015 | 0.015 | 0.015 | 0.015 | 0.014 |
| | | Gas | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| All ≤ 2.5 ft³ | Electric | Electric | 0.032 | 0.032 | 0.032 | 0.033 | 0.029 |
| | | Gas | 0.006 | 0.006 | 0.006 | 0.006 | 0.005 |
| | Gas | Electric | 0.028 | 0.028 | 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) of an ENERGY STAR® clothes washer is established at 11 years based on the Technical Support Document for the current DOE Final Rule standards for residential clothes washers.[332]

[332] 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=viewliveDownload 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
- Number of units installed
- Type of unit (top-loading, front-loading, or compact)
- Fuel type of water heater (gas or electric)
- Fuel type of dryer (gas or electric)
- 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

This section is not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 323: 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 Associates, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. New ENERGY STAR® standards incorporated. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Updated EUL to align with median lifetime. New peak savings calculated according to revised peak definition. |
| v3.1 | 11/05/2015 | TRM v3.1 update. New ENERGY STAR® algorithms and default assumptions incorporated. |
| v3.1 | 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. |
| 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 |

| TRM Version | Date | Description of Change |
|---|---|---|
| | | 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. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** 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[333], 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[334]. These values are consistent with the current ENERGY STAR® Appliance Savings Calculator.

---

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

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

**Table 324: 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.[335] 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 325: 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.[336] 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.

[335] 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.

[336] 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 326: 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 125**

## Baseline Unit

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

**Equation 126**

*Where*:

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

$AvgLoad$ = *Average load in lbs (Table 326)*

$LPY$ = *Loads per year = 283*

$CEF_{baseline}$ = *Amended Baseline Combined Energy Factor (See* Table 324*)*

## ENERGY STAR® Unit

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

**Equation 127**

*Where*:

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

$AvgLoad$ = *Average load in lbs (See Table 326)*

$LPY$ = *Loads per Year = 283*

$CEF_{ES}$ = *ENERGY STAR® Minimum Combined Energy Factor (See* Table 325*)*

## Demand Savings Algorithms

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

**Equation 128**

*Where*:

*AOH* = *Annual operating hours = (8760 – 8463) = 297 hours*[337]

*CF* = *Coincidence factor (*Table 327*)*

**Table 327: ENERGY STAR® Clothes Dryer Coincidence Factors**[338]

| 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 |

[337] 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

[338] See Volume 1, Appendix B.

## Deemed Energy Savings Tables

**Table 328: 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 |

## Deemed Summer Demand Savings Tables

**Table 329: 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 330: 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) of an ENERGY STAR® clothes dryer is established at 16 years based on the current DOE Final Rule standards for clothes dryers[339].

## 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
- 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

This section is not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 331: Residential ENERGY STAR® Clothes Dryers Revision History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |

[339] 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

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** 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[340] for dishwashers.

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

**Table 332 Federal Standard for Dishwashers**

| Product Type | Estimated Annual Energy Use (kWh/year) | Water Consumption (gallons/cycle) |
|---|---|---|
| Standard (≥ 8 place settings) | ≤ 307 | ≤ 5.0 |
| Compact (< 8 place settings) | ≤ 222 | ≤ 3.5 |

## High-efficiency Condition

The following table displays the ENERGY STAR® Final Version 6.0 requirements for eligible dishwashers effective January 29, 2016.[341] 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 333 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 333.[342] 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.

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

[342] 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 129**

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

**Equation 130**

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

**Equation 131**

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

**Equation 132**

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

**Equation 133**

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

**Equation 134**

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

**Equation 135**

*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 332)*

$RUEC_{ES}$ = *ENERGY STAR® rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact (Table 333)*

*MCF* = *Machine consumption factor = 44%*

*WHCF* = *Water heater consumption factor = 56%*

### *Demand Savings Algorithms*

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

**Equation 136**

$$AOH = CPY \times d$$

**Equation 137**

*Where*:

*AOH* = *Annual operating hours*

*CF* = *Coincidence factor = (Table 334)*

*CPY* = *Cycles per year = 215*

*d* = *Average wash cycle duration = 2.1 hours*[343]

**Table 334: ENERGY STAR® Dishwasher Coincidence Factors**[344]

| 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 335: 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 |

[343] Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/appliances/kitchen-appliances/dishwashers/dishwasher-ratings/ratings-overview.htm.

[344] See Volume 1, Appendix B.

## Deemed Summer Demand Savings Tables

**Table 336: ENERGY STAR® Dishwasher Summer Peak Demand Savings (kW)**

| ENERGY STAR® Dishwasher—Summer Demand Savings (kW) | | | | | | |
|---|---|---|---|---|---|---|
| Dishwasher Type | Water Heating Fuel | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
| Standard | Electric | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | Gas | 0.002 | 0.001 | 0.002 | 0.001 | 0.002 |
| Compact | Electric | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | Gas | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

## Deemed Winter Demand Savings Tables

**Table 337: ENERGY STAR® Dishwasher Winter Peak Demand Savings (kW)**

| ENERGY STAR® Dishwasher—Winter Demand Savings (kW) | | | | | | |
|---|---|---|---|---|---|---|
| Dishwasher Type | Water Heating Fuel | Climate Zone 1 | Climate Zone 2 | Climate Zone 3 | Climate Zone 4 | Climate Zone 5 |
| Standard | Electric | 0.009 | 0.009 | 0.007 | 0.009 | 0.011 |
| | Gas | 0.004 | 0.004 | 0.003 | 0.004 | 0.005 |
| Compact | Electric | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 |
| | Gas | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 15 years based on the Technical Support Document for the current DOE Final Rule standards for residential dishwashers.[345]

[345] 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.

## 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
- 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

## References and Efficiency Standards

### Petitions and Rulings

This section is not applicable.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 338: 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 Associates, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. New ENERGY STAR® specifications incorporated into 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. |

| TRM Version | Date | Description of Change |
|---|---|---|
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated links and dates. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings 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 342. All retired refrigerators must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly installed refrigerators must meet current ENERGY STAR® efficiency levels.

### Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[346] 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

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

the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[347]

## High-efficiency Condition

Table 339 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 339: 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 340) |

[347] 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.

**Table 340: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume[348]**

| Product Number | Product Class | Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[349] | Average ENERGY STAR® Energy Usage (kWh/year)[350] | Adjusted Volume[351] (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 | 9.25 × AV + 475.4 | 8.33 × AV + 436.3 | 32.1 | 772.1 | 703.5 |

[348] 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.

[349] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[350] 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.

[351] 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

| | | | | | | |
|---|---|---|---|---|---|---|
| | freezer with an automatic icemaker with TTD ice service | | | | | |
| 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 |

## 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 138**

*Where*:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 340)*

$kWh_{ES}$ = *ENERGY STAR average energy usage (see (see Table 340)*

*Demand Savings Algorithms*

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

**Equation 139**

*Where*:

*LSAF* = *Load Shape Adjustment Factor (see Table 341)*

**Table 341: ENERGY STAR® Refrigerator Load Shape Adjustment Factors[352]**

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

### *Early Retirement*

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

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (16—RUL)

[352] See Volume 1, Appendix B.

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

*Where*:

*RUL* = *Remaining useful life (see Table 342); 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 342: Remaining Useful Life (RUL) of Replaced Refrigerator**

| Age of Replaced Refrigerator (years) | RUL (years) | Age of Replaced Refrigerator (years) | RUL (years) |
|---|---|---|---|
| 1 | 15.2 | 12 | 7.0 |
| 2 | 14.2 | 13 | 6.6 |
| 3 | 13.2 | 14 | 6.3 |
| 4 | 12.2 | 15 | 6.0 |
| 5 | 11.2 | 16 | 5.0 |
| 6 | 10.3 | 17 | 4.0 |
| 7 | 9.6 | 18 | 3.0 |
| 8 | 8.9 | 19 | 2.0 |
| 9 | 8.3 | 20 | 1.0 |
| 10 | 7.8 | 21[353,354] | 0.0 |
| 11 | 7.4 | | |

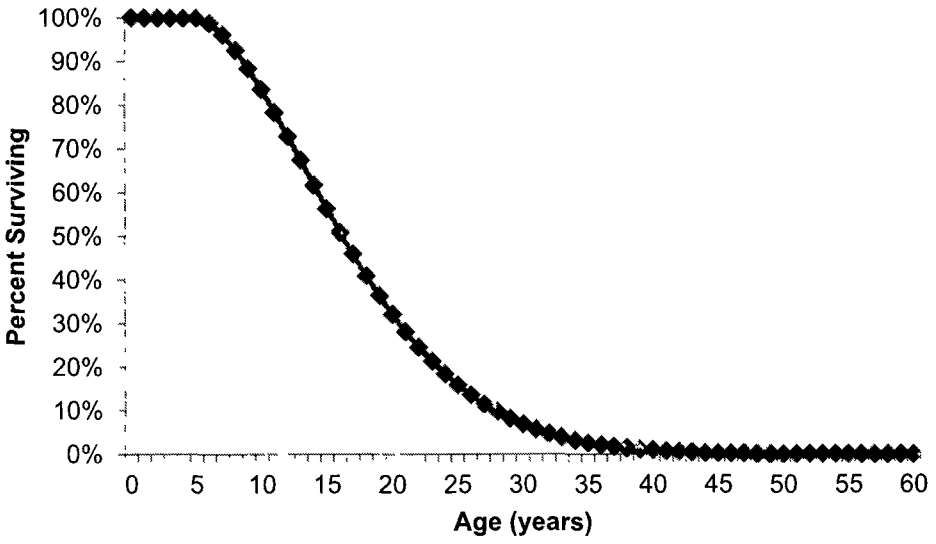
## *Derivation of RULs*

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.

[353] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see 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.

[354] 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[355]**




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 140**

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

[355] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

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

**Equation 141**

*Where*:

$kWh_{manf}$ = *968 kWh/Year*[356]

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 340)*

$kWh_{ES}$ = *ENERGY STAR® average energy usage (see Table 340)*

## *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 142**

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 143**

*Where*:

*LSAF* = *Load shape adjustment factor (Table 341)*

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.

[356] 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 342)* |
| *EUL* | = | *Estimated useful life = 16 years*[357] |

[357] 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.

## Deemed Energy Savings Tables

**Table 343: 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[358] | | | 44 | 205 |

[358] 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

## Deemed Summer Demand Savings Tables

**Table 344: 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 |

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.

**Table 345: 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 346: 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 347: 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 |

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 16 years based on the current DOE Final Rule standards for residential refrigerators.[359]

# 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
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- 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

This section is not applicable.

---

[359] 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 348: 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 Associates, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. New ENERGY STAR® standards incorporated. |
| v3.0 | 4/10/2015 | TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with 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. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings 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 352. 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[360] for freezers, effective September 15, 2014.

[360] 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.

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.[361]

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."[362]

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 144**

*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 349 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 349: ENERGY STAR® Specifications for Freezers[363]**

| 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 340) |
| Compact Freezers | Less than 7.75 cubic feet | Approximately 10 percent more energy efficient than the minimum federal standard (see Table 340) |

[361] 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.

[362] 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.

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

**Table 350: Formulas to Calculate the ENERGY STAR® Criteria for Select Freezer Product Categories by Adjusted Volume[364]**

| Product Number | Full Product Name[365] | Product Class | Baseline Energy Usage Federal Standard (kWh/year) | Average ENERGY STAR® Energy Usage (kWh/year)[367] | Adjusted Volume[368] (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 |

[364] 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.

[365] 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

[366] https //www ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10 3 430_132&rgn=div8

[367] 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

[368] 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 145**

*Where*:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see* Table 350*)*

$kWh_{ES}$ = *ENERGY STAR® average energy usage (see* Table 350*)*

*Demand Savings Algorithms*

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

**Equation 146**

*Where*:

*LSAF* = *Load Shape Adjustment Factor (see* Table 351*)*

**Table 351: ENERGY STAR® Freezer Load Shape Adjustment Factors[369]**

| 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 (22—RUL)

[369] See Volume 1, Appendix B.

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

*Where*:

*RUL* = *Remaining useful life (see* Table 350*); 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 352: Remaining Useful Life (RUL) of Replaced Freezer**

| 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[370,371] | 0.0 |

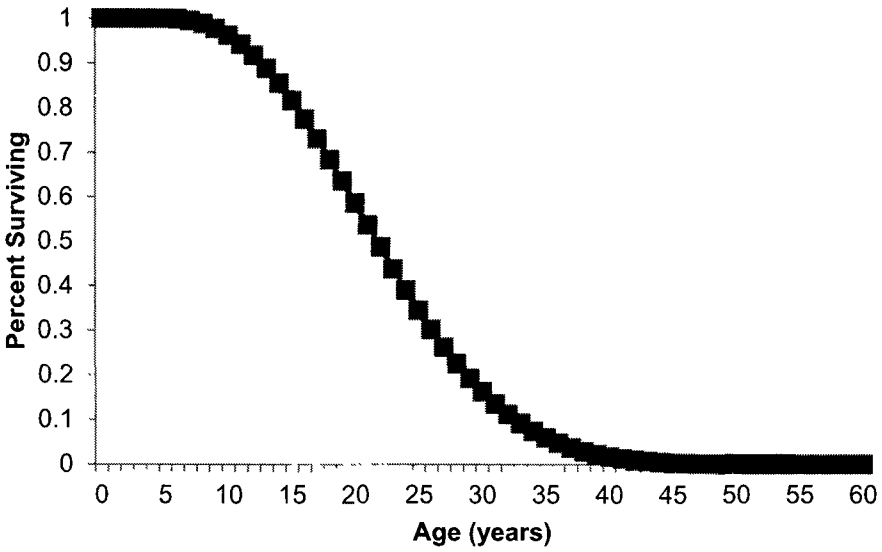
## Derivation of RULs

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 12.

[370] RULs are capped at the 75th percentile of equipment age, 27 years, as determined based on DOE survival curves (see 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.

[371] 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 13: Survival Function for ENERGY STAR® Freezers[372]**




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 12. 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.

## *Energy Savings Algorithms*

For the RUL time period:

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

**Equation 147**

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

[372] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

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

**Equation 148**

*Where*:

$kWh_{manf}$ = *841 kWh/Year*[373]

$kWh_{baseline}$ = *Federal standard baseline energy usage (see* Table 350*)*

$kWh_{ES}$ = *ENERGY STAR® average energy usage (see* Table 350*)*

## *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 149**

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 150**

*Where*:

*LSAF* = *Load shape adjustment factor (*Table 351

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.

[373] 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.

*Where*:

*RUL* = *Remaining Useful Life (see Table 342)*

*EUL* = *Estimated Useful Life = 22 years*[374]

## Deemed Energy Savings Tables

**Table 353: 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 |

[374] 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 354: 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 355: 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 |

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

## Deemed Winter Demand Savings Tables

**Table 356: 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 357: 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 |

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

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 22 years based on the current DOE Final Rule standards for residential freezers.[375]

# 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
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Installed freezer type (upright or chest)
- Installed 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

This section is not applicable.

[375] 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 358: Residential ENERGY STAR® Clothes Dryers Revision History**

| TRM Version | Date | Description of Change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |

## 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, duplex, and triplex; multifamily; manufactured

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** 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[376].

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.[377] 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.

[376] These product types are excluded by the ENERGY STAR® specifications.

[377] 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/. http://www.nrel.gov/docs/fy12osti/54242.pdf.

## Baseline Condition

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

## 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. ENERGY STAR® has not published updates to the calculator for version 2.0, and therefore, the deemed input assumptions that follow are based on certification version 1.0. This measure will be updated when the ENERGY STAR® Pool Pump Savings Calculator is updated to version 2.0.

## 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.[378]

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

**Equation 151**

*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:

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

**Equation 152**

$$kWh_{ES} = kWh_{HS} + kWh_{LS}$$

**Equation 153**

$$kWh_{HS} = \frac{PFR_{HS} \times 60 \times hours_{HS} \times days}{EF_{HS} \times 1000}$$

[378] 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.

**Equation 154**

$$kWh_{LS} = \frac{PFR_{LS} \times 60 \times hours_{LS} \times days}{EF_{LS} \times 1000}$$

**Equation 155**

*Where:*

| | | |
|---|---|---|
| $kWh_{HS}$ | = | *ENERGY STAR® variable speed pool pump energy at high speed [kWh]* |
| $kWh_{LS}$ | = | *ENERGY STAR® variable speed pool pump energy at low speed [kWh]* |
| $hours_{conv}$ | = | *Conventional single-speed pump daily operating hours (Table 359)* |
| $hours_{HS}$ | = | *ENERGY STAR® variable speed pump high speed daily operating hours (Table 360)* |
| $hours_{LS}$ | = | *ENERGY STAR® variable speed pump low speed daily operating hours (Table 360)* |
| *days* | = | *Operating days per year = 365 days (default)* |
| *PFRconv* | = | *Conventional single-speed pump flow rate [gal/min] (Table 359)* |
| $PFR_{HS}$ | = | *ENERGY STAR® variable speed pump high speed flow rate [gal/min] (Table 360)* |
| $PFR_{LS}$ | = | *ENERGY STAR® variable speed pump low speed flow rate [gal/min] (Table 360)* |
| *EFconv* | = | *Conventional single-speed pump energy factor [gal/W·hr] (Table 359)* |
| $EF_{HS}$ | = | *ENERGY STAR® variable speed pump high speed energy factor [gal/W·hr] (Table 360)* |
| $EF_{LS}$ | = | *ENERGY STAR® variable speed pump low speed energy factor [gal/W·hr] (Table 360)* |
| 60 | = | *Constant to convert between minutes and hours* |
| 1,000 | = | *Constant to convert from kilowatts to watts* |

**Table 359: Conventional Pool Pumps Assumptions[379]**

| Rated Pump HP (New) | Hours[380] $_{conv}$ | $PFR_{conv}$(gal/min) | $EF_{conv}$ (gal/W·h) |
|---|---|---|---|
| ≤ 1.25 | 9.1062 | 60.0631 | 2.3964 |
| 1.25 < hp ≤ 1.75 | | 64.3846 | 2.0885 |
| 1.75 < hp ≤ 2.25 | | 65.4375 | 1.9451 |
| 2.25 < hp ≤ 2.75 | | 68.4000 | 1.8805 |
| 2.75 < hp ≤ 3 | | 73.1111 | 1.6453 |

**Table 360: ENERGY STAR® Pool Pumps Assumptions[381,382]**

| Rated Pump HP (New) | $Hours_{LS}$ | $Hours_{HS}$ | $PFR_{HS}$ (gal/min) | $EF_{HS}$ (gal/W·h) | $PFR_{LS}$ (gal/min) | $EF_{LS}$ (gal/W·h) |
|---|---|---|---|---|---|---|
| ≤ 1.25 | 9.7 | 4.3 | 56.0 | 2.398 | 31.0 | 5.407 |
| 1.25 < hp ≤ 1.75 | | | 61.0 | 2.267 | 31.9 | 5.433 |
| 1.75 < hp ≤ 2.25 | | | 66.4 | 1.954 | 33.0 | 5.221 |
| 2.25 < hp ≤ 2.75 | | | 66.0 | 2.024 | 34.0 | 4.796 |
| 2.75 < hp ≤ 3 | | | 74.0 | 1.617 | 37.0 | 4.764 |

## *Demand Savings Algorithms*

$$kW_{Savings} = \left[\frac{kWh_{conv}}{hours_{conv}} - \left(\frac{kWh_{HS} + kWh_{LS}}{hours_{HS} + hours_{LS}}\right)\right] \times \frac{DF}{days}$$

**Equation 156**

*Where*:

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

$hours_{conv}$ = *Conventional single-speed pump daily operating hours (Table 360)*

$kWh_{HS}$ = *ENERGY STAR® variable speed pool pump energy at high speed [kWh]*

$kWh_{LS}$ = *ENERGY STAR® variable speed pool pump energy at low speed [kWh]*

[379] Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[380] The daily average operating hours for conventional single-speed pumps, based on 2014 residential pool pump program survey results from CenterPoint Energy.

[381] ENERGY STAR® PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

[382] The daily average operating hours for low and high VSP settings, based on 2016 residential pool pump program data from CenterPoint Energy.

| | | |
|---|---|---|
| $hours_{HS}$ | = | *ENERGY STAR® variable speed pump high speed daily operating hours (Table 360)* |
| $hours_{LS}$ | = | *ENERGY STAR® variable speed pump low speed daily operating hours (Table 360)* |
| *DF* | = | *Demand Factor (Table 361)* |
| *days* | = | *Operating days per year = 365 days (default)* |

**Table 361: Demand Factors**

| Climate Zone | Summer DF | Winter DF |
|---|---|---|
| 1 | 0.258 | -0.002 |
| 2 | 0.329 | 0.025 |
| 3 | 0.276 | 0.108 |
| 4 | 0.266 | 0.036 |
| 5 | 0.497 | -0.143 |

## Deemed Energy Savings Tables

**Table 362: ENERGY STAR® Variable Speed Pool Pump Energy Savings[383]**

| Rated Pump hp (New) | kWh Savings |
|---|---|
| ≤ 1.25 | 1,581 |
| 1.25 < hp ≤ 1.75 | 2,367 |
| 1.75 < hp ≤ 2.25 | 2,166 |
| 2.25 < hp ≤ 2.75 | 2,677 |
| 2.75 < hp ≤ 3 | 2,902 |

## Deemed Summer Demand Savings Tables[384]

**Table 363: ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings**

| Rated Pump HP (New) | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|---|
| ≤ 1.25 | 0.216 | 0.275 | 0.231 | 0.222 | 0.415 |
| 1.25 < hp ≤ 1.75 | 0.287 | 0.365 | 0.307 | 0.295 | 0.552 |
| 1.75 < hp ≤ 2.25 | 0.292 | 0.371 | 0.312 | 0.300 | 0.562 |
| 2.25 < hp ≤ 2.75 | 0.333 | 0.423 | 0.356 | 0.342 | 0.640 |

[383] The results in this table may vary slightly from results produced by the ENERGY STAR® calculator because of rounding of default savings coefficients throughout the measure and pool volume.
[384] Ibid.

| Rated Pump HP (New) | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|---|
| 2.75 < hp ≤ 3 | 0.388 | 0.493 | 0.414 | 0.399 | 0.746 |

## Deemed Winter Demand Savings Tables

**Table 364: ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings**

| Rated Pump HP (New) | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|---|
| ≤ 1.25 | -0.001 | 0.021 | 0.091 | 0.030 | (0.119) |
| 1.25 < hp ≤ 1.75 | -0.002 | 0.028 | 0.120 | 0.040 | (0.159) |
| 1.75 < hp ≤ 2.25 | -0.002 | 0.028 | 0.122 | 0.040 | (0.161) |
| 2.25 < hp ≤ 2.75 | -0.002 | 0.032 | 0.140 | 0.046 | (0.184) |
| 2.75 < hp ≤ 3 | -0.002 | 0.037 | 0.163 | 0.054 | (0.214) |

## Claimed Peak Demand Savings

**Table 365: ENERGY STAR® Variable Speed Pool Pump Claimed Demand Savings**

| Rated Pump HP (New) | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
|---|---|---|---|---|---|
| ≤ 1.25 | 0.216 | 0.275 | 0.231 | 0.222 | 0.415 |
| 1.25 < hp ≤ 1.75 | 0.287 | 0.365 | 0.307 | 0.295 | 0.552 |
| 1.75 < hp ≤ 2.25 | 0.292 | 0.371 | 0.312 | 0.300 | 0.562 |
| 2.25 < hp ≤ 2.75 | 0.333 | 0.423 | 0.356 | 0.342 | 0.640 |
| 2.75 < hp ≤ 3 | 0.388 | 0.493 | 0.414 | 0.399 | 0.746 |

## Additional Calculators and Tools

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.

## Measure Life and Lifetime Savings

According to DEER 2014, the estimated useful life for this measure is 10 years.[385]

## 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:

[385] Database for Energy Efficient Resources (2014). http://www.deeresources.com/.

**For all projects**

- Rated horsepower of new pool pump
- Climate zone
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification
- Make and model information

**For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs):**

- Items listed for all projects above
- Decision/action type: early retirement, replace-on-burnout, or new construction
- Rated horsepower of existing pool pump
- Existing and new pool pump operating hours

# References and Efficiency Standards

## Petitions and Rulings

This section is not applicable.

## Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for pool pumps.
- Document Revision History

**Table 366: Residential ENERGY STAR® Pool Pumps 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. Updated eligibility to include above ground pool pumps now eligible for ENERGY STAR® certification. Acknowledged the forthcoming ENERGY STAR® version 2.0. |

## 2.5.8 ENERGY STAR® Air Purifiers Measure Overview

**TRM Measure ID:** R-AP-AP

**Market Sector:** Residential

**Measure Category:** Appliances

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

**Fuels Affected:** Electricity

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

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** 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® air purifier. 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 floor, tabletop, and wall-mounted air purifiers/room air cleaners.

## Baseline Condition

The baseline condition is defined as 1.0 cfm/W for a conventional air purifier unit's efficiency, a value from EPA research conducted in 2011, as cited in the ENERGY STAR® Appliance Savings Calculator[386].

## High-efficiency Condition

The following table displays the ENERGY STAR® Final Version 1.2 requirements for eligible air purifiers effective July 1, 2004.[387] These values are subject to updates in ENERGY STAR®

[386] 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.

[387] Available for download at: https://www.energystar.gov/ia/partners/prod_development/revisions/downloads/room_aircleaners/Room_Air_Cleaners_Final_V1.2_Specification.pdf?6ec0-9f1a.

specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

**Table 367 ENERGY STAR® Specifications for Air Purifiers**

| Product Type | Clean Air Delivery Rate (CADR) | Minimum Performance Requirement | Standby Power Requirement | Ozone Production |
|---|---|---|---|---|
| Air Purifiers or Room Air Cleaners | ≥ 50 cu ft/min | 2.0 cfm/watt | 2.0 W | ≤ 50 ppb |

# 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 and the revised ENERGY STAR® specification in Table 333.[388] 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.

$$kWh_{savings} = (kWh_{baseline,OP} + kWh_{baseline,SB}) - (kWh_{ES,OP} + kWh_{ES,SB})$$

**Equation 157**

$$kWh_{baseline,OP} = \left(\frac{CADR_{baseline}}{Eff_{baseline}}\right)/1000 \times Hours_{OP} \times Days_{OP}$$

**Equation 158**

$$kWh_{baseline,SB} = (8760 - Hours_{OP} \times Days_{OP}) \times W_{baseline,SB}/1000$$

**Equation 159**

$$kWh_{ES,OP} = \left(\frac{CADR_{ES}}{Eff_{ES}}\right)/1000 \times Hours_{OP} \times Days_{OP}$$

**Equation 160**

$$kWhES,SB = 8760 - HoursOP \times DaysOP \times WES,SB/1000$$

**Equation 161**

*Where*:

Quantitative definitions of product criteria: https://www.energystar.gov/products/appliances/air_purifiers_cleaners/key_product_criteria

[388] 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.

$kWh_{baseline,OP}$ = *Baseline/conventional operating energy usage*

$kWh_{baseline,SB}$ = *Baseline/conventional standby energy usage*

$kWh_{ES,OP}$ = *ENERGY STAR® average operating energy usage*

$kWh_{ES,SB}$ = *ENERGY STAR® average standby energy usage*

$CADR_{baseline}$ = *Baseline unit clean air delivery rate (cu ft/min)*

$CADR_{ES}$ = *ENERGY STAR® unit clean air delivery rate (cu ft/min)*

$Eff_{baseline}$ = *Baseline clean air delivery efficiency = 1.0 cfm/watt*

$Eff_{ES}$ = *ENERGY STAR® air delivery efficiency = 3.0 cfm/watt*

$Hours_{OP}$ = *Average hours of operation per day = 16*

$Days_{OP}$ = *Average days of operation per year = 365*

$W_{baseline,SB}$ = *Conventional model standby power = 1.0 watt*

$W_{ES,SB}$ = *ENERGY STAR® model standby power = 0.6 watts*

8760 = *Total hours per year*

## Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{Hours_{OP} \times Days_{OP}} \times CF$$

**Equation 162**

*Where*:

$Hours_{OP}$ = *Average hours of operation per day = 16*

$Days_{OP}$ = *Average days of operation per year = 365*

*CF* = *Coincidence factor =* (Table 368)

Table 368: ENERGY STAR® Air Purifiers Coincidence Factors[389]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.636 | 0.617 | 0.631 | 0.620 | 0.564 |
| Winter | 0.882 | 0.907 | 0.829 | 0.876 | 0.926 |

## Deemed Energy Savings Tables

Table 369: ENERGY STAR® Air Purifiers Energy Savings (kWh)

| ENERGY STAR® Air Purifiers—Energy Savings (kWh) | | |
|---|---|---|
| Dust CADR Range (cu ft/min) | Dust CADR Midpoint | Energy Savings |
| 51-100 | 75 | 293 |
| 101-150 | 125 | 488 |
| 151-200 | 175 | 683 |
| 201-250 | 225 | 877 |
| > 250 | 275 | 1,072 |

[389] See Volume 1, Appendix B.

## Deemed Summer Demand Savings Tables

**Table 370: ENERGY STAR® Air Purifiers Summer Peak Demand Savings (kW)**

| ENERGY STAR® Air Purifiers — Summer Demand Savings (kW) | | | | | |
|---|---|---|---|---|---|
| CADR Range (cu ft/min) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| 51-100 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| 101-150 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| 151-200 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| 201-250 | 0.10 | 0.09 | 0.09 | 0.09 | 0.08 |
| > 250 | 0.12 | 0.11 | 0.12 | 0.11 | 0.10 |

## Deemed Winter Demand Savings Tables

**Table 371: ENERGY STAR® Air Purifiers Winter Peak Demand Savings (kW)**

| ENERGY STAR® Air Purifiers — Winter Demand Savings (kW) | | | | | |
|---|---|---|---|---|---|
| CADR Range (cu ft/min) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| 51-100 | 0.04 | 0.05 | 0.04 | 0.04 | 0.05 |
| 101-150 | 0.07 | 0.08 | 0.07 | 0.07 | 0.08 |
| 151-200 | 0.10 | 0.11 | 0.10 | 0.10 | 0.11 |
| 201-250 | 0.13 | 0.14 | 0.12 | 0.13 | 0.14 |
| > 250 | 0.16 | 0.17 | 0.15 | 0.16 | 0.17 |

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

This section is not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is established at 9 years; a figure cited as obtained from the Appliance Magazine's Portrait of the U.S. Appliance Industry, 1998 on the ENERGY STAR® Appliance Savings Calculator[390].

[390] 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.