

## Document Revision History

Table 214. High-Speed Doors—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.6 NONRESIDENTIAL: WATER HEATING

### **2.6.1 Heat Pump Water Heaters Measure Overview**

**TRM Measure ID:** C-WH-HW

**Market Sector:** Commercial

**Measure Category:** Water Heating

**Applicable Building Types:** Office, retail, warehouse, schools, lodging, master-metered multifamily

**Fuels Affected:** Electricity and gas

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

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

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

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

This measure involves the replacement of a electric storage water heater with an ENERGY STAR compliant heat pump water heater (HPWH) in a commercial application.

### **Eligibility Criteria**

This measure applies to commercial consumer electric storage heat pump water heaters. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

First hour rating (FHR) is a proxy for draw pattern. There are no certified ENERGY STAR water heaters in the very small usage category, and that draw pattern is not covered in the current ENERGY STAR specification. 98 percent of certified units are in the medium and high usage categories. However, HPWHs with low usage draw patterns are eligible as long as they comply with minimum ENERGY STAR FHR requirements.

### **Baseline Condition**

The baseline condition is an electric storage water heater (EWH) with baseline efficiency Uniform Energy Factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.<sup>460</sup>

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<sup>460</sup> 10 CFR Part 430.32 Energy and water conservation standards and their effective dates.

[www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebee184bb0ae03e7f0&mc=true&node=se10.3.430\\_132&rgn=div8](http://www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8)

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.<sup>461</sup> The TRM will add an early retirement baseline after the effective date for the new standard.

**Table 215. HPWHs—Federal Standard for Consumer Electric Storage Water Heaters**

Rated storage volume	Draw pattern	FHR <sup>463,465</sup>	UEF <sup>464</sup>
$\geq 20$ gal and $\leq 55$ gal	Very Small Usage	$0 \leq \text{FHR} < 18$	$0.8808 - (0.0008 \times V_r)$
	Low Usage	$18 \leq \text{FHR} < 51$	$0.9254 - (0.0003 \times V_r)$
	Medium Usage	$51 \leq \text{FHR} < 75$	$0.9307 - (0.0002 \times V_r)$
	High Usage	$75 \leq \text{FHR}$	$0.9349 - (0.0001 \times V_r)$
$> 55$ gal and $\leq 120$ gal	Very Small Usage	$0 \leq \text{FHR} < 18$	$1.9236 - (0.0011 \times V_r)$
	Low Usage	$18 \leq \text{FHR} < 51$	$2.0440 - (0.0011 \times V_r)$
	Medium Usage	$51 \leq \text{FHR} < 75$	$2.1171 - (0.0011 \times V_r)$
	High Usage	$75 \leq \text{FHR}$	$2.2418 - (0.0011 \times V_r)$

The DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank sizes greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater.

### High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 216.<sup>465</sup>

<sup>461</sup> Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. <https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063>.

<sup>462</sup> “The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs” presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. <https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf>.

<sup>463</sup> Assume FHR equal to that of installed water heater.

<sup>464</sup>  $V_r$  is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

<sup>465</sup> ENERGY STAR HPWH Key Product Criteria. [https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments\\_0.pdf](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf).

**Table 216. HPWHs—ENERGY STAR Specification**

<u>Criteria</u>		<u>ENERGY STAR Requirement</u>
<u>UEF</u>	<u>Integrated HPWH</u>	<u>UEF ≥ 3.30</u>
	<u>Integrated HPWH, 120 volt/15 amp circuit</u>	<u>UEF ≥ 2.20</u>
	<u>Split-system HPWHT</u>	<u>UEF ≥ 2.20</u>
<u>First-hour rating</u>		<u>FHR ≥ 45 gallons per hour</u>
<u>Warranty</u>		<u>Warranty ≥ 6 years on sealed system</u>
<u>Safety</u>		<u>UL 174 and UL 1995 or UL 60335-2-40</u>
<u>Lower compressor cut-off temperature (reporting requirement only)</u>		<u>Report ambient temperature below which the compressor cuts off and electric-resistance-only operation begins</u>

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.<sup>466</sup>

HPWHs depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces where temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.<sup>467</sup>

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

HPWH savings are calculated on a per-unit basis. Deemed savings are calculated utilizing the standard algorithms outlined below for water heating. Consumption in gallons per year is estimated using data from Building America Performance Analysis Procedures for Existing Homes.<sup>468</sup> Temperature data are based on TMY3 dataset.<sup>469</sup> The area served by the HPWH may only be a portion of a commercial building, the area served by the water heater must be

<sup>466</sup> ENERGY STAR-certified water heaters qualified product listing.  
[https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search\\_text=&type\\_filter=Hybrid%2FElectric+Heat+Pump&fuel\\_filter=Electric&brand\\_name\\_isopen=0&input\\_rate\\_thousand\\_btu\\_per\\_hour\\_isopen=0&markets\\_filter=United+States&zip\\_code\\_filter=&product\\_types=Select+a+Product+Category&sort\\_by=brand\\_name&sort\\_direction=asc&page\\_number=0&lastpage=0](https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0)

<sup>467</sup> Heat Pump Water Heaters. Department of Energy, May 2012.  
<http://energy.gov/energysaver/articles/heat-pump-water-heaters>

<sup>468</sup> Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. <https://www.nrel.gov/docs/fy06osti/38238.pdf>.

<sup>469</sup> TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer.  
<https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here:  
<https://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

documented. Alternately, the daily demand per unit in the table may also be used to estimate consumption and translated to annual consumption.

## Energy Savings Algorithm

$$\text{Energy Savings } [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{\text{setpoint}} - T_{\text{supply,annual}}) \times \left( \frac{1}{UEF_{\text{pre}}} - \frac{1}{UEF_{\text{post}}} \right)}{3,412}$$

**Equation 207**

Where:

$\rho$  = Water density [lbs/gal] = 8.33

$C_p$  = Specific heat of water [Btu/lb·°F] = 1

$GPY$  = Estimated annual hot water use in gallons/year.

Calculation options: [GPY/SF x A] or [DD x Quantity x days/yr]  
(see Table 217).

**Table 217. HPWHs—Water Heater Consumption (Gal/Year)<sup>470</sup>**

Building Type	Unit used for Consumption Measurement	Daily Demand per unit per day (DD)	Units per 1,000 sq ft	Applicable Days per Year (days/yr)	Gallons per 1,000 sq ft per day	GPY/SF
Small Office	person	1	2.3	250	2.3	0.575
Large Office	person	1	2.3	250	2.3	0.575
Retail	employee	2	1.0	365	2	0.73
Warehouse	employee	2	0.5	250	1	0.25
Elementary School	person	0.6	9.5	200	5.7	1.14
Secondary School	Person	1.8	9.5	200	17.1	3.42
Motel (lodging)	unit (room)	20	5.0	365	100	36.5
Hotel (lodging)	unit (room)	14	2.2	365	30.8	11.242
Other	employee	1	0.7	250	0.7	0.175
Master Meter Multifamily	Energy savings identified Volume 2, Residential, Measure 2.4.2					

<sup>470</sup> Osman S, & Koomey, J. G J 1995, National Laboratory 1995. Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting. Table 2. <https://escholarship.org/uc/item/2i42t2c3>.

$A$	=	<u>Building square footage served by the water heater</u>
$DD$	=	<u>Daily demand per day</u>
$Quantity$	=	<u>Quantity of the units identified in Table for building type</u>
$T_{setpoint}$	=	<u>Water heater setpoint temperature [°F]<sup>471</sup> = 120</u>
$T_{supply,annual}$	=	<u>Average annual supply water temperature [°F] (see Table 218)</u>
$UEF_{pre}$	=	<u>Baseline uniform energy factor (calculate per Table 215)</u>
$UEF_{post}$	=	<u>Uniform energy factor of new water heater</u>
$3,412$	=	<u>Constant to convert from Btu to kWh</u>

**Table 218. HPWHs—Water Mains Temperature (°F)<sup>472</sup>**

Climate zone	$T_{supply,annual}$	$T_{supply,seasonal}$	
		Summer	Winter
<u>Zone 1: Amarillo</u>	<u>62.9</u>	<u>73.8</u>	<u>53.7</u>
<u>Zone 2: Dallas</u>	<u>71.8</u>	<u>84.0</u>	<u>60.6</u>
<u>Zone 3: Houston</u>	<u>74.7</u>	<u>84.5</u>	<u>65.5</u>
<u>Zone 4: Corpus Christi</u>	<u>77.2</u>	<u>86.1</u>	<u>68.5</u>
<u>Zone 5: El Paso</u>	<u>70.4</u>	<u>81.5</u>	<u>60.4</u>

## Demand Savings Algorithm

$$\begin{aligned}
 & \text{Peak Demand Savings } [\Delta kW] \\
 & = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left( \frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}} \right)}{3,412} \times CF_{S/W}
 \end{aligned}$$

**Equation 208**

Where:

$T_{supply,seasonal}$	=	<u>Seasonal supply water temperature [°F] (see Table 218)</u>
$CF_{S/W}$	=	<u>Seasonal peak coincidence factor (see Table 219)</u>

<sup>471</sup> 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.” Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

<sup>472</sup> Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, <https://maps.nrel.gov/nsrdb-viewer/>. Data for Texas climate zones can also be accessed directly here: <https://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.

**Table 219. HPWHs—Seasonal Peak CFs<sup>473</sup>**

Building Type	Commercial		Lodging	
	Summer	Winter	Summer	Winter
<u>Zone 1: Amarillo</u>	<u>0.00016</u>	<u>0.00011</u>	<u>0.00012</u>	<u>0.00015</u>
<u>Zone 2: Dallas</u>	<u>0.00017</u>	<u>0.00011</u>	<u>0.00012</u>	<u>0.00012</u>
<u>Zone 3: Houston</u>	<u>0.00016</u>	<u>0.00011</u>	<u>0.00012</u>	<u>0.00015</u>
<u>Zone 4: Corpus Christi</u>	<u>0.00016</u>	<u>0.00011</u>	<u>0.00012</u>	<u>0.00015</u>
<u>Zone 5: El Paso</u>	<u>0.00018</u>	<u>0.00011</u>	<u>0.00012</u>	<u>0.00014</u>

## **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.

Note that this measure does not account for the interactive air conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.

## **Deemed Summer Demand Savings Tables**

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

## **Deemed Winter Demand Savings Tables**

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

## **Claimed Peak Demand Savings**

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

## **Upstream/Midstream Delivery**

For upstream/midstream program designs where the building type is known, use the GPY identified in Table 286 associated with the proper building type and the area of the building must be reported.

For program designs where the building type is unknown, you use the savings coefficients from the Other building type and assume the area served by the water heater is equal to 5,000 square feet.

<sup>473</sup> Probability weighted seasonal peak CFs are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations.  
<http://loadshape.epri.com/enduse>

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 13 years.<sup>474</sup>

## 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
- Building type
- Building area served or Daily demand and quantity of units identified.
- Manufacturer and model number of new HPWH
- Baseline volume (gallons), FHR, and UEF
- New HPWH volume (gallons), FHR, and UEF
- Proof of purchase – with date of purchase and quantity
  - Alternative: photo of unit installed or another pre-approved method of installation verification.

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

**Table 220. Commercial Heat Pump Water Heaters—Revision History**

<u>TRM version</u>	<u>Date</u>	<u>Description of change</u>
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 origin.</u>

<sup>474</sup> 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, “Heat Pump Water Heaters and American Homes: A Good Fit?” p 9-74.  
<https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf>.



## **2.6.12.6.2 Central Domestic Hot Water Controls Measure Overview**

**TRM Measure ID:** NR-WH-DC

**Market Sector:** Commercial

**Measure Category:** Water heating

**Applicable Building Types:** Multifamily, lodging, nursing homes, dormitories, prisons, offices, and education

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

Central domestic hot water (DHW) systems with recirculation pumps distribute hot water continuously throughout the building to the end-users. DHW pump controls save energy by reducing the operating hours of the circulation pumps and reducing thermal losses throughout the distribution system.

### **Eligibility Criteria**

This measure applies to commercial and lodging applications with a central DHW system that includes a pump to circulate hot water through the distribution loop. To be eligible for these deemed savings, the control strategy must include operating the pump only when the hot water circulation loop temperature drops below a specific value, and there is hot water demand called by an end-user.

### **Baseline Condition**

The baseline condition is a new or existing central DHW system with a circulation pump that operates continuously.

### **High-Efficiency Condition**

The measure requires the installation of a pump controller with a combination temperature and demand control method.

## Energy and Demand Savings Methodology

Savings for central DHW controls come from circulation pump controller runtime reduction and thermal distribution loss reduction. Pump runtime savings apply to all projects, while thermal distribution loss reduction applies only to lodging sites with an electrically fueled water heater.

### Savings Algorithms and Input Variables

#### Circulation Pump Savings Algorithm

$$\text{Pump Energy Savings } [\Delta kWh] = kW_{\text{pump}} \times (\text{Pump}_{\%On\_base} - \text{Pump}_{\%On\_eff}) \times \text{Hours} \quad \text{Equation 209}$$

$$\text{Pump Peak Demand Savings } [\Delta kW] = kWh_{\text{savings,pump}} \times \text{CFPLS} \quad \text{Equation 210}$$

Where:

$kW_{\text{pump}}$	=	The demand used by the circulation pump, obtained from the project site; if unknown, assume 0.075 kW
$\text{Pump}_{\%On\_base}$	=	Baseline pump operation as percentage of time, 100%
$\text{Pump}_{\%On\_eff}$	=	Efficient pump operation as percentage of time, 7% <sup>475</sup>
Hours	=	Hours per year = 8,760
<u>CFPLS</u>	=	<u>Seasonal peak coincidence factor—Probability-weighted peak load share, see Table 221</u>

**Table 221. Central DHW Controls—Seasonal Peak CFsProbability-Weighted Peak Load Share<sup>476</sup>**

Building type	Commercial		Lodging <sup>477</sup>	
	Summer peak	Winter peak	Summer peak	Winter peak
Climate Zone 1: Amarillo	0.00016	0.00011	0.00012	0.00015
Climate Zone 2: Dallas	0.00017	0.00011	0.00012	0.00014
Climate Zone 3: Houston	0.00016	0.00011	0.00012	0.00015

<sup>475</sup> A 93 percent pump runtime reduction is assumed based on the average runtime reduction of field studies conducted at multiple sites: “Evaluation of New DHW System Controls in Hospitality and Commercial Buildings,” Minnesota Department of Commerce, average reduction of 87 percent; and “Energy-Efficiency Controls for Multifamily Domestic Hot Water Systems,” New York State Energy Research and Development Authority, average reduction of 99 percent.

<sup>476</sup> Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. <http://loadshape.epri.com/enduse>.

<sup>477</sup> For the purposes of this measure, the lodging building type applies to all buildings where lodging takes place, including multifamily, hotels, nursing homes, dormitories, prisons, and similar.

Building type	Commercial		Lodging <sup>477</sup>	
	Summer peak	Winter peak	Summer peak	Winter peak
Climate Zone 4: Corpus Christi	0.00016	0.00011	0.00012	0.00015
Climate Zone 5: El Paso	0.00018	0.00011	0.00012	0.00014

### Thermal Distribution Savings Algorithm

$$\text{Thermal Energy Savings } [\Delta kWh] = \# \text{ Units} \times kWh_{reference} \times \text{HDD Adjustment}$$

Equation 211

$$\text{Thermal Peak Demand Savings } [\Delta kW] = kWh_{savings,thermal} \times CFPLS$$

Equation 212

Where:

- # Units = The number of dwelling units at the project site
- $kWh_{reference}$  = Annual kWh energy savings from reference study (see Table 222)
- HDD Adjustment = Climate adjustment for Texas heating degree days (see Table 223)

**Table 222. Central DHW Controls—Reference kWh by Water Heater and Building Type<sup>478</sup>**

Water heater type	Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise
kWh reference	539	332	211	130

**Table 223. Central DHW Controls—HDD Adjustment Factors<sup>479</sup>**

Climate zone	HDD adjustment
Climate Zone 1: Amarillo	1.9
Climate Zone 2: Dallas	1.1
Climate Zone 3: Houston	0.7
Climate Zone 4: Corpus Christi	0.5
Climate Zone 5: El Paso	1.1

<sup>478</sup> Reference kWh are the annual energy savings per dwelling unit from the Southern California Edison Company Work Paper SCE13WP002, Demand Control for Centralized Water Heater Recirculation Pump for California Climate Zone 13.

<sup>479</sup> HDD Adjustment factors for DHW controls are derived by dividing the HDD for each Texas climate zone by the HDD from the reference climate zone (California Climate Zone 13).

## Deemed Energy Savings Tables

Table 224 presents the energy savings (kWh) for a range of pump sizes for all climate zones. The deemed savings are provided for convenience, but the algorithm may be used for pump sizes that differ from the assumed wattage listed in the tables.

**Table 224. Central DHW Controls—Circulation Pump Energy Savings**

Pump size (watts)	Assumed wattage	Annual pump kWh savings
≤ 50	50	407
50 > watts < 100	75	611
100 ≤ watts < 150	125	1,018
≥ 150	150	1,222

Table 225 presents the thermal energy savings (kWh) per dwelling unit for all climate zones. Thermal energy savings only apply to lodging building types where lodging takes place (multifamily, hotels, nursing homes, dormitories, prisons, and similar). For commercial applications, please follow a custom approach.

**Table 225. Central DHW Controls—Thermal Distribution Energy Savings per Dwelling Unit**

Climate zone	Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise
Climate Zone 1: Amarillo	1,007	620	395	243
Climate Zone 2: Dallas	566	349	222	137
Climate Zone 3: Houston	372	229	146	90
Climate Zone 4: Corpus Christi	249	153	98	60
Climate Zone 5: El Paso	590	364	231	143

## Deemed Summer and Winter Demand Savings Tables

The following tables present the peak demand impacts for all climate zones.

**Table 226. Central DHW Controls—Circulation Pump Peak Demand Savings**

Pump size	Climate zone	Commercial		Lodging	
		Summer kW	Winter kW	Summer kW	Winter kW
≤ 50	Climate Zone 1: Amarillo	0.065	0.045	0.049	0.061
	Climate Zone 2: Dallas	0.069	0.045	0.049	0.057
	Climate Zone 3: Houston	0.065	0.045	0.049	0.061
	Climate Zone 4: Corpus Christi	0.065	0.045	0.049	0.061
	Climate Zone 5: El Paso	0.073	0.045	0.049	0.057

Pump size	Climate zone	Commercial		Lodging	
		Summer kW	Winter kW	Summer kW	Winter kW
50 > watts < 100	Climate Zone 1: Amarillo	0.098	0.067	0.073	0.092
	Climate Zone 2: Dallas	0.104	0.067	0.073	0.086
	Climate Zone 3: Houston	0.098	0.067	0.073	0.092
	Climate Zone 4: Corpus Christi	0.098	0.067	0.073	0.092
	Climate Zone 5: El Paso	0.110	0.067	0.073	0.086
100 ≤ watts < 150	Climate Zone 1: Amarillo	0.163	0.112	0.122	0.153
	Climate Zone 2: Dallas	0.173	0.112	0.122	0.143
	Climate Zone 3: Houston	0.163	0.112	0.122	0.153
	Climate Zone 4: Corpus Christi	0.163	0.112	0.122	0.153
	Climate Zone 5: El Paso	0.183	0.112	0.122	0.143
≥ 150	Climate Zone 1: Amarillo	0.196	0.134	0.147	0.183
	Climate Zone 2: Dallas	0.208	0.134	0.147	0.171
	Climate Zone 3: Houston	0.196	0.134	0.147	0.183
	Climate Zone 4: Corpus Christi	0.196	0.134	0.147	0.183
	Climate Zone 5: El Paso	0.220	0.134	0.147	0.171

**Table 227. Central DHW Controls—Thermal Distribution Peak Demand Savings per Dwelling Unit**

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Climate Zone 1: Amarillo	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Climate Zone 2: Dallas	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Climate Zone 3: Houston	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01
Climate Zone 4: Corpus Christi	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Climate Zone 5: El Paso	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years, as specified in the California Database of Energy

## **Program Tracking Data and Evaluation Requirements**

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

- Climate zone
- Circulation pump wattage
- Building type: commercial or lodging
- Building size: Low rise or high rise
- Water heater type: electric resistance or heat pump
- If lodging, number of lodging units at project site

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 228. Central DHW Controls—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>480</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

### **2.6.22.6.3 Showerhead Temperature Sensitive Restrictor Valves**

#### **Measure Overview**

**TRM Measure ID:** NR-WH-SV

**Market Sector:** Commercial

**Measure Category:** Water heating

**Applicable Building Types:** Lodging

**Fuels Affected:** Electricity

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

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

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

#### **Measure Description**

This measure consists of installing a temperature sensitive restrictor valve (TSRV)<sup>481</sup> between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95°F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

#### **Eligibility Criteria**

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in commercial lodging applications. Buildings must have electrically-fueled hot water to be eligible for this measure.

#### **Baseline Condition**

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

#### **High-Efficiency Condition**

The high-efficiency condition is a temperature sensitive restrictor valve installed on a commercial lodging shower arm and showerhead with either a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead.

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<sup>481</sup> A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

#### *Estimated Hot Water Usage Reduction*

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

$$\text{Annual Showerhead Behavioral Waste} = SHFR \times BW \times n_s \times 365 \frac{\text{days}}{\text{year}} \times \frac{OCC}{n_{SH}}$$

**Equation 213**

Where:

<i>SHFR</i>	=	<i>Showerhead flow rate, gallons per minute [gpm] (see Table 229)</i>
<i>BW</i>	=	<i>Behavioral waste, minutes per shower (see Table 229)</i>
<i>n<sub>s</sub></i>	=	<i>Number of showers per occupied room per day (see Table 229)</i>
<i>365</i>	=	<i>Constant to convert days to years (see Table 229)</i>
<i>OCC</i>	=	<i>Occupancy rate (see Table 229)</i>
<i>n<sub>SH</sub></i>	=	<i>Number of showerheads per room (see Table 229)</i>

Applying the formula to the values used for Texas from Table 229 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$\text{Showerhead (2.5 GPM): } 2.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1,838 \text{ gal}$$

$$\text{Showerhead (2.0 GPM): } 2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1,471 \text{ gal}$$

$$\text{Showerhead (1.75 GPM): } 1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1,287 \text{ gal}$$

$$\text{Showerhead (1.5 GPM): } 1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 1,103 \text{ gal}$$

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 229.

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

**Equation 214**



Where:

$HW\%$  = Hot water percentage (see Table 229)

Gallons of hot water saved per year (2.5 GPM):  $1,838 \times 0.825 = 1,516 \text{ gal}$

Gallons of hot water saved per year (2.0 GPM):  $1,471 \times 0.825 = 1,213 \text{ gal}$

Gallons of hot water saved per year (1.75 GPM):  $1,287 \times 0.825 = 1,062 \text{ gal}$

Gallons of hot water saved per year (1.5 GPM):  $1,103 \times 0.825 = 910 \text{ gal}$

**Table 229. Showerhead TSRVs—Hot Water Usage Reduction**

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower) <sup>482</sup>	1.742			
Showers/occupied room/day <sup>483</sup>	1.756			
Occupancy rate <sup>484</sup>	65.9%			
Showerheads/room <sup>485</sup>	1.0			
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water <sup>486</sup>	80-85%, or 82.5% on average			
Hot water saved/year (gal)	1,516	1,213	1,062	910

## Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$\text{Energy Savings per TSRV } [\Delta kWh] = \frac{\rho \times C_p \times V \times (T_{\text{Setpoint}} - T_{\text{Supply,Avg}})}{RE \times 3,412}$$

**Equation 215**

<sup>482</sup> Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

<sup>483</sup> Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

<sup>484</sup> 2001-2021 U.S. hotel occupancy rates from Statista. <https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/>. Used average of last 5 pre-COVID years (2015-2019).

<sup>485</sup> Assuming industry standard for standard one-bathroom rooms.

<sup>486</sup> 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.

Where:

$\rho$	=	Water density [lb/gal] = 8.33
$C_p$	=	Specific heat of water [Btu/lb°F] = 1
$V$	=	Hot water saved per year per showerhead [gal] (see Table 229)
$T_{Setpoint}$	=	Water heater setpoint [°F] <sup>487</sup> = 120
$T_{Supply,Avg}$	=	Average supply water temperature [°F] (see Table 230)
$RE$	=	Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric-resistance water heaters, or 2.2 for heat-pump water heaters. <sup>488</sup>
3,412	=	Constant to convert from Btu to kWh

## Demand Savings Algorithms

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

$$\text{Demand Savings per TSRV } [\Delta kW] = \frac{\rho \times C_p \times V \times (T_{Setpoint} - T_{Supply,Seasonal})}{RE \times 3,412 \times 365} \times CF_{S/W}$$

Equation 216

Where:

$T_{Supply,Seasonal}$	=	Seasonal supply water temperature (see Table 230)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 231)

<sup>487</sup> 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.

<sup>488</sup> Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. <https://www.ahridirectory.org/>.

**Table 230. Showerhead TSRVs—Water Mains Temperatures**

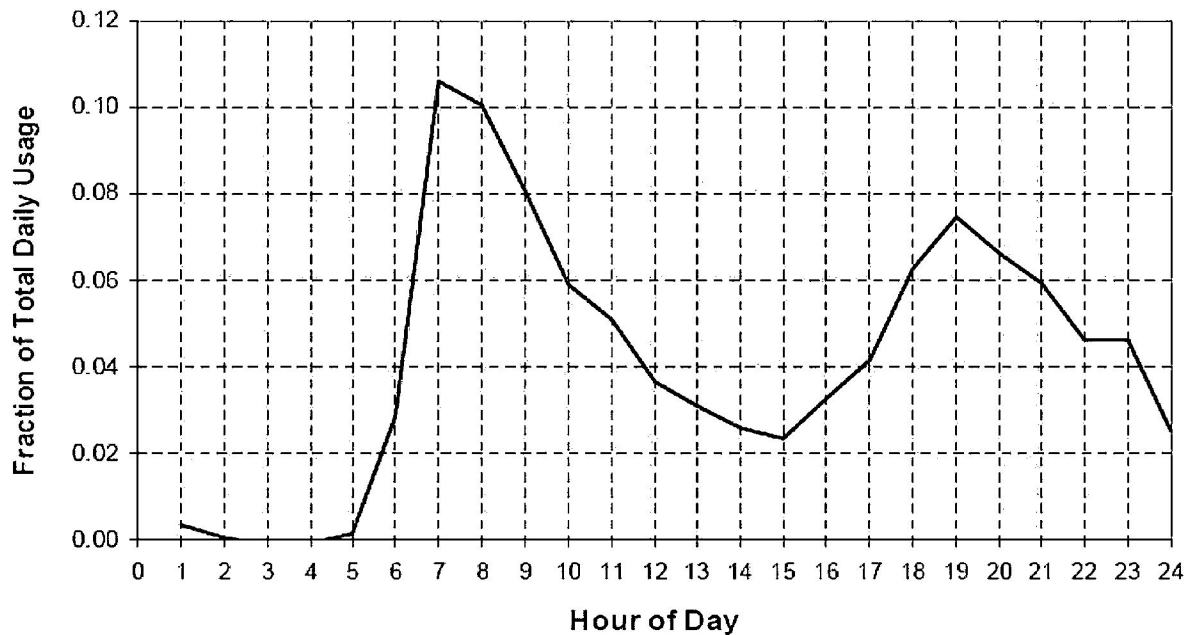
Climate zone	Water mains temperature (°F) <sup>489</sup>		
	T <sub>SupplyAverage</sub>	T <sub>SupplySeasonal</sub>	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

**Table 231. Showerhead TSRVs—Peak Coincidence Factors**

Climate zones	Summer	Winter
Climate Zone 1: Amarillo	0.039	0.073
Climate Zone 2: Dallas	0.035	0.075
Climate Zone 3: Houston	0.038	0.080
Climate Zone 4: Corpus Christi	0.038	0.068
Climate Zone 5: El Paso	0.028	0.069

<sup>489</sup> Based on typical meteorological year (TMY) dataset for TMY3: <https://sam.nrel.gov/weather-data.html>.

Figure 5. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile<sup>490</sup>



## Deemed Energy Savings Tables

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

## Deemed Summer Demand Savings Tables

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

## Deemed Winter Demand Savings Tables

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

## Claimed Peak Demand Savings

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

<sup>490</sup> Building America Performance Analysis Procedures for Existing Homes.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.<sup>491</sup> This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).<sup>492</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

Table 232. Showerhead TSRVs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>491</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

<sup>492</sup> 2014 California Database for Energy Efficiency Resources. <http://www.deeresources.com/>.

## **2.6.32.6.4 Tub Spout and Showerhead Temperature-Sensitive Restrictor Valves Measure Overview**

**TRM Measure ID:** NR-WH-TV

**Market Sector:** Commercial

**Measure Category:** Water heating

**Applicable Building Types:** Lodging

**Fuels Affected:** Electricity

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

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

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

This 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)<sup>493</sup> between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95°F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

### **Eligibility Criteria**

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in commercial lodging applications. Buildings must have electrically-fueled hot water to be eligible for this measure.

### **Baseline Condition**

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

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<sup>493</sup> A temperature-sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

## High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a commercial lodging shower arm and showerhead with a standard (2.5 gpm) or low-flow (2.0, 1.75, or 1.5 gpm) showerhead.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

#### *Estimated Hot Water Usage Reduction*

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

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

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

**Equation 217**

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

**Equation 218**

Where:

$\%WUE_{SH}$	=	Showerhead percentage of warm-up events (see Table 233)
$\%WUE_{TS}$	=	Tub spout percentage of warm-up events (see Table 233)
$SHFR$	=	Showerhead flow rate, gallons per minute (gpm) (see Table 233)
$TSFR$	=	Tub spout flow rate, gallons per minute (gpm) (see Table 233)
$BW$	=	Behavioral waste, minutes per shower (see Table 233)
$n_s$	=	Number of showers per occupied room per day (see Table 233)
$365$	=	Constant to convert days to years (see Table 233)
$OCC$	=	Occupancy rate (see Table 233)
$n_{SH}$	=	Number of showerheads per room (see Table 233)

Applying the formula to the values from Table 233 returns the following values:

$$\text{Showerhead (1.5 GPM): } 0.6 \times \left( 1.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} \right) = 662$$

$$\text{Showerhead (1.75 GPM): } 0.6 \times \left( 1.75 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} \right) = 772$$

$$\text{Showerhead (2.0 GPM): } 0.6 \times \left( 2.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} \right) = 882$$

$$\text{Showerhead (2.5 GPM): } 0.6 \times \left( 2.5 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} \right) = 1,103$$

$$\text{Tub Spout (5.0 GPM): } 0.4 \times \left( 5.0 \times 1.742 \times 1.756 \times 365 \times \frac{0.659}{1.0} \right) = 1,471$$

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

$$\text{Annual Diverter Waste} = \text{DLR} \times t_s \times n_s \times 365 \frac{\text{days}}{\text{year}} \times \frac{\text{OCC}}{n_{SH}}$$

**Equation 219**

Where:

DLR = Diverter leakage rate (gpm) (see Table 233)

$t_s$  = Shower time (min/shower) (see Table 233)

Applying the formula to the values used for Texas from Table 233 returns the following values:

$$\text{Diverter (0.8 GPM): } 0.8 \times 7.8 \times 1.756 \times 365 \times \frac{0.659}{1.0} = 2,634$$

**Part 3:** To determine gallons of water saved per year can be found by multiplying the total waste by the percentage of hot water from Table 233.

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

**Equation 220**

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 233)

$HW\%_D$  = Diverter hot-water percentage (see Table 233)

Applying the formula to the values from Table 233 returns the following values:

Total Annual Waste (1.5 gpm):  $(662 + 1,471) \times 0.825 + 2,634 \times 0.737 = 3,700$

Total Annual Waste (1.75 gpm):  $(772 + 1,471) \times 0.825 + 2,634 \times 0.737 = 3,791$

Total Annual Waste (2.0 gpm):  $(882 + 1,471) \times 0.825 + 2,634 \times 0.737 = 3,882$

Total Annual Waste (2.5 gpm):  $(1,103 + 1,471) \times 0.825 + 2,634 \times 0.737 = 4,064$

**Table 233. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction**

Description	Part 1—Behavioral waste		Part 2—Diverter leakage	Part 3—Total
	Showerhead warm-up	Tub spout warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			–
Tub-spout flow rate (gpm) <sup>494</sup>	–	5.0		–
Percentage of warm-up events <sup>495</sup>	60%	40%		–
Average behavioral waste (minutes per shower) <sup>496</sup>		1.742		–
Average diverter leakage-rate (gpm) <sup>497</sup>		–	0.80	–
Average shower time (minutes) <sup>498</sup>		–	7.8	–
Showers/occupied room/day <sup>499</sup>				1.756
Occupancy rate <sup>500</sup>				65.9%

<sup>494</sup> Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

<sup>495</sup> Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

<sup>496</sup> Shower Stream 2019 pilot study based on 747 metered shower events with an average duration of 104.51 seconds. This represents a subset of the total data set, as this value was not recorded for the entire data set. This assumption will be updated in future years to reflect additional pilot study data.

<sup>497</sup> Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverter.

<sup>498</sup> Cadmus and Opinion Dynamics Evaluation Team, “Memorandum: Showerhead and Faucet Aerator Meter Study”. Prepared for Michigan Evaluation Working Group.

<sup>499</sup> Shower Stream 2019 pilot study based on 2,406 metered shower events. Weighted average calculated by dividing total shower events by total number of devices. This assumption will be updated in future years to reflect additional pilot study data.

<sup>500</sup> 2001–2021 U.S. hotel occupancy rates from Statista. <https://www.statista.com/statistics/200161/us-annual-accommodation-and-lodging-occupancy-rate/>. Used average of last five pre-COVID years (2015–2019).

Description	Part 1—Behavioral waste		Part 2— Diverter leakage	Part 3— Total
	Showerhead warm-up	Tub spout warm-up		
Showerheads/room <sup>501</sup>				1.0
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	662	1,471	2,634	4,766
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	772			4,877
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	882			4,987
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	1,103			5,207
Percentage hot water <sup>502</sup>	80-85%, or 82.5% average		73.7%	–
Gallons of hot water saved per year (1.5 gpm)			–	3,700
Gallons of hot water saved per year (1.75 gpm)			–	3,791
Gallons of hot water saved per year (2.0 gpm)			–	3,882
Gallons of hot water saved per year (2.5 gpm)			–	4,064

## Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$\text{Energy Savings per TS System } [\Delta kWh] = \frac{\rho \times C_p \times V \times (T_{\text{Setpoint}} - T_{\text{Supply,Avg}})}{RE \times 3,412}$$

**Equation 221**

Where:

- $\rho$  = Water density [lb/gal] = 8.33
- $C_p$  = Specific heat of water [Btu/lb°F] = 1
- $V$  = Hot water saved per year per showerhead [gal] (see Table 233)

<sup>501</sup> Assuming industry standard for standard one-bathroom rooms.

<sup>502</sup> Average percentage of 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.

$T_{Setpoint}$	=	Water heater setpoint [°F] <sup>503</sup> = 120
$T_{Supply,Avg}$	=	Average supply water temperature [°F] (see Table 234)
$RE$	=	Recovery efficiency (or in the case of heat-pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters, or 2.2 for heat-pump water heaters <sup>504</sup>
3,412	=	Constant to convert from Btu to kWh

## Demand Savings Algorithms

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

$$\text{Demand Savings per TS System } [\Delta kW] = \frac{\rho \times C_p \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times 3,412 \times 365} \times CF_{S/W}$$

**Equation 222**

Where:

$T_{Supply,Seasonal}$	=	Seasonal-supply water temperature (see Table 234)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 235)

**Table 234. Tub Spout/Showerhead TSRVs—Water Mains Temperatures**

Climate zone	Water mains temperature (°F) <sup>505</sup>		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5

<sup>503</sup> 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.

<sup>504</sup> Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. <https://www.ahridirectory.org/>.

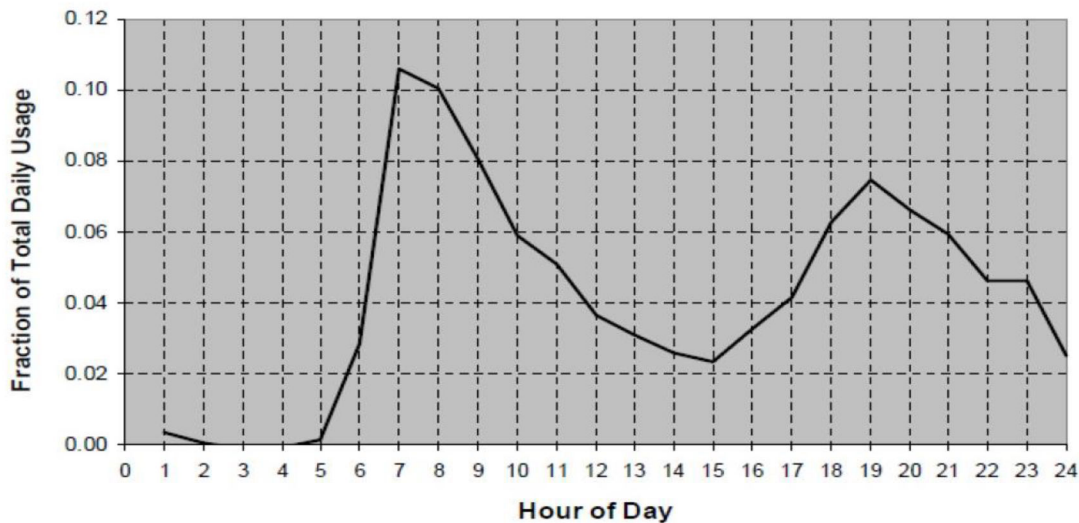
<sup>505</sup> Based on typical meteorological year (TMY) dataset for TMY3: <https://sam.nrel.gov/weather-data.html><https://nsrdb.nrel.gov/about/tmy.html>.

Climate zone	Water mains temperature (°F) <sup>505</sup>		
	T <sub>SupplyAverage</sub>	T <sub>SupplySeasonal</sub>	
		Summer	Winter
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

**Table 235. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors**

Climate zones	Summer	Winter
Climate Zone 1: Amarillo	0.039	0.073
Climate Zone 2: Dallas	0.035	0.075
Climate Zone 3: Houston	0.038	0.080
Climate Zone 4: Corpus Christi	0.038	0.068
Climate Zone 5: El Paso	0.028	0.069

**Figure 6. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile<sup>506</sup>**



## Deemed Energy and Demand Savings Tables

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

## Claimed Peak Demand Savings

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

<sup>506</sup> Building America Performance Analysis Procedures for Existing Homes.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.<sup>507</sup>

## Program Tracking Data and Evaluation Requirements

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

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

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

Table 236. Tub Spout/Showerhead TSRVs—Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. Restricted measure to electricity savings and removed gas savings coefficients. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. No revision.

<sup>507</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **2.7 NONRESIDENTIAL: MISCELLANEOUS**

### **2.7.1 Variable Frequency Drives for Water Pumping Measure Overview**

**TRM Measure ID:** NR-MS-WP

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

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

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

This measure involves the installation of a variable frequency drive (VFD) in a water pumping application such as for domestic water supply, wastewater treatment, and conveyance.

### **Eligibility Criteria**

Water pumps must be less than or equal to 100 hp. New construction systems are ineligible. Equipment used for irrigation or process loads are ineligible.

### **Baseline Condition**

The baseline condition is a water pump with no variable speed-control ability.

### **High-Efficiency Condition**

The high-efficiency condition is the installation of a VFD on a water pump.

### **Energy and Demand Savings Methodology**

### **Savings Algorithms and Input Variables**

Demand savings are calculated for each hour over the course of the year:

**Step 1:** Determine the percentage flow rate for each of the year (*i*)

**Baseline Technology**<sup>508</sup>:

$$\%power_{base} = 2.5294 \times \%GPM_i^3 - 4.7443 \times \%GPM_i^2 + 3.2485 \times \%GPM_i + 0$$

**Equation 223**

Where:

*%GPM* = Percentage flow rate (see Table 237)  
*i* = Each hour of the year

**Table 237. Water Pumping VFDs—Water Demand Profile**<sup>509</sup>

Hour ending	% flow rate	Hour ending	% flow rate
1	0.078	13	0.529
2	0.039	14	0.471
3	0.010	15	0.412
4	0.010	16	0.471
5	0.039	17	0.549
6	0.275	18	0.725
7	0.941	19	0.863
8	1.000	20	0.824
9	0.961	21	0.745
10	0.843	22	0.608
11	0.765	23	0.529
12	0.608	24	0.294

**VFD Technology**<sup>510</sup>:

$$\%power_{VFD} = 0.7347 \times \%GPM_i^3 - 0.301 \times \%GPM_i^2 + 0.5726 \times \%GPM_i + 0$$

**Equation 224**

**Step 3** - Calculate kW<sub>full</sub> using the hp from the motor nameplate, load factor and the applicable motor efficiency. Use that result and the %power results to determine power consumption at each hour:

<sup>508</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Constant Speed, no VSD.

<sup>509</sup> NREL, Development of Standardized Domestic Hot Water Event Schedules for Residential Buildings, Fig. 2 Combined domestic hot water use profile for the Benchmark, representing average use. <https://www.nrel.gov/docs/fy08osti/40874.pdf>.

<sup>510</sup> PNNL, ANSI/ASHRAE/IES Standard 90.1-2016 Performance Rating Method Reference Manual, Table 87 Default Part-load CIRC-PUMP-FPLR Coefficients – Default (VSD, No Reset).

$$kW_{full} = 0.746 \times HP \times \frac{LF}{\eta}$$

Equation 225

$$kW_i = kW_{full} \times \%power_i$$

Equation 226

Where:

- $\%power_i$  = Percentage of full load pump power needed at the  $i^{th}$  hour calculated by an equation based on the control type
- $kW_{full}$  = Fan motor demand operating at typical design conditions
- $kW_i$  = Pump real-time power at the  $i^{th}$  hour of the year
- HP = Rated horsepower of the motor
- LF = Load factor—ratio of the operating load to the nameplate rating of the motor; default assumption is 75%
- 0.746 = Constant to convert from hp to kW
- $\eta$  = Motor efficiency of a standard efficiency motor (see Table 238)

Table 238. Water Pumping VFDs—Motor Efficiencies<sup>511</sup>

Motor hp	Full load efficiency	Motor hp	Full load efficiency
1	0.855	25	0.936
2	0.865	30	0.941
3	0.895	40	0.941
5	0.895	50	0.945
7.5	0.910	60	0.950
10	0.917	75	0.950
15	0.930	100	0.954
20	0.930		

**Step 4** - Calculate the kW savings for each of the top 20 hours within the applicable peak probability analysis for the building’s climate zone from Volume 1.

<sup>511</sup> Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors.  
[https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431\\_125](https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125).



## Hourly and Peak Demand Savings Calculations

$$kW_{i,Saved} = kW_{i,Baseline} - kW_{i,VFD}$$

Equation 227

$$kW_{PDPF,Saved} = \frac{\sum_{i=1}^{20}(kW_{i,Saved} * PDPF_i)}{\sum_{i=1}^{20}(PDPF_i)}$$

Equation 228

Where:

$PDPF$  = Winter peak demand probability factor from the applicable climate zone table in Volume 1; there are no summer demand savings for this measure

Energy Savings are calculated in the following manner:

**Step 1** – For both the baseline and new technology, calculate the sum of individual kWh consumption in each hour of the year:

$$Energy\ Savings\ [\Delta kWh] = \sum_{i=1}^{8,760} (kW_i)$$

Equation 229

Where:

8,760 = Total number of hours in a year

**Step 2** – Subtract Annual kWh<sub>new</sub> from Annual kWh<sub>baseline</sub> to get the energy savings:

$$Energy\ Savings\ [kWh] = kWh_{baseline} - kWh_{new}$$

Equation 230

## Deemed Energy and Demand Savings Tables

Table 275 presents the deemed summer and winter peak kilowatt savings per motor horsepower.

**Table 239. Water Pumping VFDs—Energy and Peak Demand Savings per Motor HP**

Climate zone	kWh savings per motor HP <sup>a</sup>	Winter peak demand kW savings per motor HP <sup>a</sup>
Climate Zone 1: Amarillo	1,389	0.097
Climate Zone 2: Dallas		0.069
Climate Zone 3: Houston		0.067

Climate zone	kWh savings per motor HP	Winter peak demand kW savings per motor HP
Climate Zone 4: Corpus Christi		0.138
Climate Zone 5: El Paso		0.106

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 12.5 years, which is the average EUL for pump VSD applications as specified in the California Database of Energy Efficiency Resources (DEER) READI tool.<sup>512</sup>

## Program Tracking Data and Evaluation Requirements

The list below of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Quantity
- Climate zone
- Motor horsepower

## References and Efficiency Standards

### Petitions and Rulings

- This section not applicable.

## Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

Table 240. Water Pumping VFDs—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. General text edits.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>512</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## 2.7.2 Premium Efficiency Motors Measure Overview

**TRM Measure ID:** NR-MS-PM

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** Commercial

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, early retirement, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

Currently a wide variety of NEMA premium efficiency motors from 1 to 500 horsepower (hp) are available. Deemed saving values for demand and energy savings associated with this measure must be for electric motors with an equivalent operating period (hours x load factor) over 1,000 hours.

### Eligibility Criteria

To qualify for early retirement, the premium efficiency unit must replace an existing, full-size unit with a maximum age of 16 years. To determine the remaining useful life of an existing unit, see Table 245. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

### Baseline and High-Efficiency Conditions

#### *New Construction or Replace-on-Burnout*

EISA 2007 Sec 313 adopted new federal standards for motors manufactured in the United States from December 19, 2010, to before June 1, 2016, with increased efficiency requirements for 250-500 hp motors as of June 1, 2016. These standards replace legislation commonly referred to as EP Act 1992 (the Federal Energy Policy Act of 1992). The standards can also be found in section 431.25 of the Code of Federal Regulations (10 CFR Part 431).<sup>513</sup>

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<sup>513</sup> Federal Standards for Electric Motors, Table 1: Nominal Full-load Efficiencies of General Purpose Electric Motors (Subtype I), Except Fire Pump Electric Motors, <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>. Accessed July 2020.

With these changes, motors ranging from one to 500 hp bearing the “NEMA Premium” trademark will align with national energy efficiency standards and legislation. The Federal Energy Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

Additionally, NEMA premium standards include general purpose electric motors, subtype II (i.e., motors ranging from 1-200 hp and 200-500 hp) including:

- U-frame motors
- Design C motors
- Close-coupled pump motors
- Footless motors
- Vertical solid shaft normal thrust (tested in a horizontal configuration)
- 8-pole motors
- All poly-phase motors up to 600 volts (minus 230/460 volts, covered EAct-92)

Under these legislative changes, 200-500 hp and subtype II motor baselines will be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EAct)<sup>514</sup> (see Table 244) and are thus no longer equivalent to pre-1992/pre-EAct defaults.

### **Early Retirement**

The baseline for early retirement projects is the nameplate efficiency of the existing motor to be replaced, if known. If the nameplate is illegible and the in-situ efficiency cannot be determined, then the baseline should be based on the minimum efficiency allowed under the Federal Energy Policy Act of 1992 (EAct)<sup>515</sup>, as listed in Table 246.

NEMA premium efficiency motor levels continue to be industry standard for minimum-efficiency levels. The savings calculations assume that the minimum motor efficiency for replacement motors for both replace-on-burnout and early retirement projects exceeds that listed in Table 244.

For early retirement, the maximum age of eligible equipment is capped at the expected 75 percent of the equipment failure (17 years). ROB savings should be applied when age of the unit exceeds 75 percent failure age. This cap prevents early retirement savings from being applied to projects where the age of the equipment greatly exceeds the estimated useful life of the measure. 1-200 hp motors manufactured as of December 19, 2010 and 250-500 hp motors manufactured as of June 1, 2016 are not eligible for early retirement.

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<sup>514</sup> Federal Standards for Electric Motors, Table 4: Nominal Full-load Efficiencies of NEMA Design B General Purpose Electric Motors (Subtype I and II), Except Fire Pump Electric Motors, <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>.

<sup>515</sup> Federal Standards for Electric Motors, Tables 3 ( $\leq 200$  hp), and 4 ( $> 200$ hp), <https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#sp10.3.431.b>.

## **Energy and Demand Savings Methodology**

### **Savings Algorithms and Input Variables**

Actual motor operating hours are expected to be used to calculate savings. Short and/or long-term metering can be used to verify estimates. If metering is not possible, interviews with facility operators and review of operations logs should be conducted to obtain an estimate of actual operating hours. If there is not sufficient information to accurately estimate operating hours, then the annual operating hours in Table 241 or Table 242 can be used.

### ***New Construction or Replace-on-Burnout***

#### **Energy Savings Algorithms**

$$kWh_{savings,ROB} = HP \times 0.746 \times LF \times \left( \frac{1}{\eta_{baseline,ROB}} - \frac{1}{\eta_{post}} \right) \times Hrs$$

**Equation 231**

#### **Demand Savings Algorithms**

**HVAC Applications:**

$$kW_{savings,ROB} = \left( \frac{kWh_{savings,ROB}}{Hrs} \right) \times CF$$

**Equation 232**

**Industrial Applications<sup>516</sup>:**

$$kW_{savings,ROB} = \left( \frac{kWh_{savings,ROB}}{8,760 \text{ hours}} \right)$$

**Equation 233**

*Where:*

HP	=	Nameplate horsepower data of the motor
0.746	=	Constant to convert from hp to kWh <sup>517</sup>
LF	=	Estimated load factor (if unknown, see Table 241 or Table 242)

<sup>516</sup> Assumes three-shift operating schedule

<sup>517</sup> U.S. DOE, Technical Support Document, "Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 10.2.2.1 Motor Capacity". Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

- $\eta_{baseline,ROB}$  = Assumed original motor efficiency [%] (see Table 244)<sup>518</sup>
- $\eta_{post}$  = Efficiency of the newly installed motor [%]
- Hrs = Estimated annual operating hours (if unknown, see Table 241 or Table 242)
- CF = Peak coincidence factor (see Table 241 **Error! Reference source not found.**)
- $kWh_{savings,ROB}$  = Total energy savings for a new construction or ROB project
- $kW_{savings,ROB}$  = Total demand savings for a new construction or ROB project

**Table 241. Premium Efficiency Motors—HVAC Input Assumptions**

Building type	Load factor <sup>519</sup>	CF <sup>520</sup>	HVAC fan hours <sup>521</sup>
<del>Hospital</del> <u>Healthcare: Inpatient</u>	0.75	1.00	8,760
<del>Office: Large office</del> (>30k SqFt)			4,424
<del>Office: Small office</del> (≤30k SqFt)			4,006
<del>Education: K-12 school</del>			4,173
<del>Education: College/university</del>			4,590
<del>Mercantile: All retail</del>			5,548
<del>Food service: Quick-service restaurant</del> <del>Restaurant (fast-food)</del>			6,716
<del>Food service: Full-service restaurant</del> <del>(sit-down)</del>			5,256

<sup>518</sup> In the case of rewind motors, in-situ efficiency may be reduced by a percentage as found in **Error! Reference source not found.**

<sup>519</sup> Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25.

[http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport\\_ItronVersion.pdf](http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf)

<sup>520</sup> Commercial Prototype Building Models HVAC operating schedules for hours ending 15-18. U.S. Department of Energy. [https://www.energycodes.gov/development/commercial/prototype\\_models](https://www.energycodes.gov/development/commercial/prototype_models)

<sup>521</sup> Factors are equivalent to Table 90 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

**Table 242. Premium Efficiency Motors—Industrial Input Assumptions**

Industrial processing	Load factor <sup>522</sup>	Hours <sup>523</sup>					
		Chem	Paper	Metals	Petroleum refinery	Food production	Other
1-5 hp	0.54	4,082	3,997	4,377	1,582	3,829	2,283
6-20 hp	0.51	4,910	4,634	4,140	1,944	3,949	3,043
21-50 hp	0.60	4,873	5,481	4,854	3,025	4,927	3,530
51-100 hp	0.54	5,853	6,741	6,698	3,763	5,524	4,732
101-200 hp	0.75	5,868	6,669	7,362	4,170	5,055	4,174
201-500 hp	0.58	5,474	6,975	7,114	5,311	3,711	5,396
501-1,000 hp		7,495	7,255	7,750	5,934	5,260	8,157
> 1,000 hp		7,693	8,294	7,198	6,859	6,240	2,601

**Table 243. Rewound Motor Efficiency Reduction Factors<sup>524</sup>**

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

**Table 244. Premium Efficiency Motors—NC/ROB Baseline Efficiencies by Motor Size (%)<sup>513,517,529</sup>**

hp	Open motors: $\eta_{\text{baseline, ROB}}$			Closed motors: $\eta_{\text{baseline, ROB}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0

<sup>522</sup> United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. [https://www1.eere.energy.gov/manufacturing/tech\\_assistance/pdfs/mtrmkt.pdf](https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf)

<sup>523</sup> United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. [https://www1.eere.energy.gov/manufacturing/tech\\_assistance/pdfs/mtrmkt.pdf](https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf)

<sup>524</sup> U.S. DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors, 8.2.2.1 Annual Energy Consumption”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

hp	Open motors: $\eta_{\text{baseline, ROB}}$			Closed motors: $\eta_{\text{baseline, ROB}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
20	92.4	93.0	91.0	91.7	93.0	91.0
25	93.0	93.6	91.7	93.0	93.6	91.7
30	93.6	94.1	91.7	93.0	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93.0	94.1	94.5	93.0
60	94.5	95.0	93.6	94.5	95.0	93.6
75	94.5	95.0	93.6	94.5	95.4	93.6
100	95.0	95.4	93.6	95.0	95.4	94.1
125	95.0	95.4	94.1	95.0	95.4	95.0
150	95.4	95.8	94.1	95.8	95.8	95.0
200	95.4	95.8	95.0	95.8	96.2	95.4
250	95.8	95.8	94.0	95.8	96.2	95.8
300	95.8	95.8	95.4	95.8	96.2	95.8
350	95.8	95.8	95.4	95.8	96.2	95.8
400	–	95.8	95.8	–	96.2	95.8
450	–	96.2	96.2	–	96.2	95.8
500	–	96.2	96.22	–	96.22	95.8

### **Early Retirement**

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

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

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 245); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.0 years

*EUL* = Estimated useful life = 15 years

**Table 245. Premium Efficiency Motors—Remaining Useful Life (RUL) of Replaced Motor<sup>525</sup>**

Age of replaced motor (years)	RUL (years)	Age of replaced motor (years)	RUL (years)
1	13.9	10	5.0
2	12.9	11	4.2
3	11.9	12	3.6
4	10.9	13	3.0
5	9.9	14	2.5
6	8.9	15	2.0
7	7.9	16	1.0
8	6.9	17 <sup>526</sup>	0.0
9	5.9		

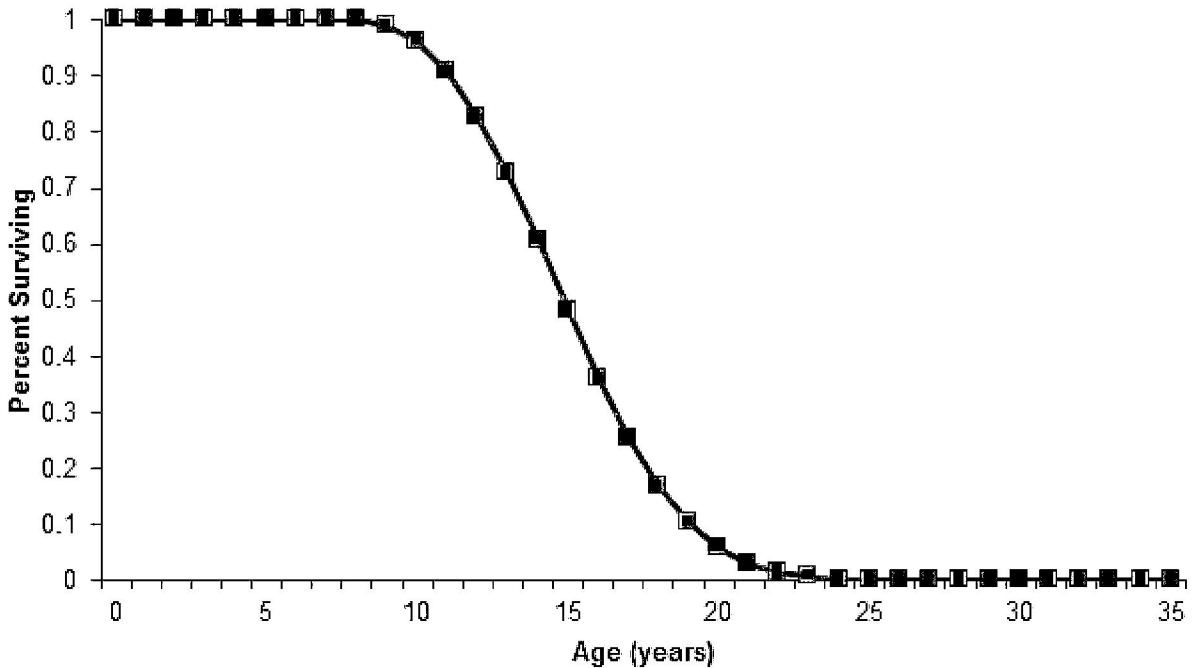
### **Derivation of RULs**

Premium Efficiency Motors have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the motors installed in a given year will no longer be in service, as described by the survival function for a general fan or air compressor application in Figure 7.

<sup>525</sup> Current federal standard effective date is 12/19/2010. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead.

<sup>526</sup> RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see **Error! Reference source not found.**). Systems older than 17 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

Figure 7. Premium Efficiency Motors—Survival Function for Premium Efficiency Motors<sup>527</sup>



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 7. The age of the motor being replaced is found on the horizontal axis, and the corresponding percentage of surviving motors 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 motor being replaced is 15 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 17 years. Therefore, the RUL of the motor being replaced is  $(17 - 15) = 2$  years.

### Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,RUL} = hp \times 0.746 \times LF \times \left( \frac{1}{\eta_{baseline,ER}} - \frac{1}{\eta_{post}} \right) \times Hrs$$

Equation 234

<sup>527</sup> 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](http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf).

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

$$kWh_{savings,EUL} = hp \times 0.746 \times LF \times \left( \frac{1}{\eta_{baseline,ROB}} - \frac{1}{\eta_{post}} \right) \times Hrs$$

**Equation 235**

It follows that total lifetime energy savings for early retirement projects are then determined by adding the savings calculated under the two preceding equations:

$$kWh_{savings,ER} = kWh_{savings,RUL} \times RUL + kWh_{savings,EUL} \times (EUL - RUL)$$

**Equation 236**

### ***Demand Savings Algorithms***

To calculate demand savings for the early retirement of a motor, 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:

#### **HVAC Applications**

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{Hrs} \times CF$$

**Equation 237**

#### **Industrial Applications**

$$kW_{savings,RUL} = \frac{kWh_{savings,RUL}}{8,760 \text{ hours}}$$

**Equation 238**

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

#### **HVAC Applications**

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{Hrs} \times CF$$

**Equation 239**

#### **Industrial Applications**

$$kW_{savings,EUL} = \frac{kWh_{savings,EUL}}{8,760 \text{ hours}}$$

**Equation 240**

Annual deemed 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.

$$kW_{savings,ER} = kW_{savings,RUL} \times RUL + kW_{savings,EUL} \times (EUL - RUL)$$

**Equation 241**

Where:

- $\eta_{baseline,ER}$  = Assumed original motor efficiency for remaining EUL time period (Table 246 or Table 247)<sup>528</sup>
- $kWh_{savings,RUL}$  = Energy savings for RUL time period in an ER project
- $kWh_{savings,EUL}$  = Energy savings for remaining EUL time period in an ER project
- $kW_{savings,RUL}$  = Demand savings for RUL time period in an ER project
- $kW_{savings,EUL}$  = Demand savings for remaining EUL time period in an ER project
- $kWh_{savings,ER}$  = Total energy savings for an ER project
- $kW_{savings,ER}$  = Total demand savings for an ER project

**Table 246. Premium Efficiency Motors—ER Baseline Efficiencies by Motor Size (%)<sup>515,529</sup>**

hp	Open motors: $\eta_{baseline,ER}$			Closed motors: $\eta_{baseline,ER}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7

<sup>528</sup> Ibid.

<sup>529</sup> For unlisted motor horsepower values, round down to the next lowest horsepower value.

hp	Open motors: $\eta_{\text{baseline, ER}}$			Closed motors: $\eta_{\text{baseline, ER}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
50	93.0	93.0	92.4	93.0	93.0	92.4
60	93.6	93.6	93.0	93.6	93.6	93.0
75	93.6	94.1	93.0	93.6	94.1	93.0
100	94.1	94.1	93.0	94.1	94.5	93.6
125	94.1	94.5	93.6	94.1	94.5	94.5
150	94.5	95.0	93.6	95.0	95.0	94.5
200	94.5	95.0	94.5	95.0	95.0	95.0
250	95.4	95.4	94.5	95.0	95.0	95.4
300	95.4	95.4	95.0	95.0	95.4	95.4
350	95.4	95.4	95.0	95.0	95.4	95.4
400	–	95.4	95.4	–	95.4	95.4
450	–	95.8	95.8	–	95.4	95.4
500	–	95.8	95.8	–	95.8	95.4

**Table 247. Premium Efficiency Motors—ER Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)<sup>530,531</sup>**

hp	Open motors: $\eta_{\text{baseline, ER}}$			Closed motors: $\eta_{\text{baseline, ER}}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
250	95.4	95.4	94.5	95.0	95.0	95.4
300	95.4	95.4	95.0	95.0	95.4	95.4
350	95.4	95.4	95.0	95.0	95.4	95.4
400	–	95.4	95.4	–	95.4	95.4
450	–	95.8	95.8	–	95.4	95.4
500	–	95.8	95.8	–	95.8	95.4

## Deemed Energy and Demand Savings Tables

Not applicable

<sup>530</sup> Federal Standards for Electric Motors, Table 4,

<sup>531</sup> For unlisted motor horsepower values, round down to the next lowest horsepower value.

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years.<sup>532</sup>

## 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:

- Number of units installed
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Horsepower
- Estimated annual operating hours and estimated load factor
- Number of poles in and horsepower of original motor
- Newly-installed motor efficiency (%)
- Description of motor service application
- 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)

## References and Efficiency Standards

### Petitions and Rulings

Not applicable

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

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<sup>532</sup> U.S. DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>

## Document Revision History

**Table 248. Premium Efficiency Motors—Revision History**

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Replacement-burnout and Early Retirement clarifications.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. Added guidance for rounding down motor size in the baseline efficiency lookup table. Incremented RUL table for code compliance.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.</u>

## 2.7.3 Pump-Off Controllers Measure Overview

**TRM Measure ID:** NR-MS-PC

**Market Sector:** Commercial

**Measure Category:** Controls

**Applicable Building Types:** Industrial

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Field study, engineering algorithms, and estimates

### Measure Description

Pump-off controllers (POC) are micro-processor-based devices that continuously monitor pump down conditions (i.e., when the fluid in the well bore is insufficient to warrant continued pumping). These controllers are used to shut down the pump when the fluid falls below a certain level and “fluid pounding”<sup>533</sup> occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

### Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number<sup>534</sup> prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a *conventional* well (above ground or vertical, with a standard induction motor of 480V or less).

### Baseline Condition

The baseline condition is an existing conventional well (with an API number prior to September 11, 2014) with rod pumps operating on time clock controls or less efficient control devices.

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<sup>533</sup> Fluid pounding occurs when the downhole pump rate exceeds the production rate of the formation. The pump strikes the top of the fluid column on the down stroke causing extreme shock loading of the components which can result in premature equipment failure.

<sup>534</sup> The API number is a unique, permanent identifier assigned by the American Petroleum Institute. The API number should correspond to a well that was in existence prior to the date of PUCT Docket 42551.



## High-Efficiency Condition

The efficient condition is the same well, retrofitted with a pump-off controller.

## Energy and Demand Savings Methodology

Two main sources were referenced to develop the savings methods for the POC measure: *Electrical Savings in Oil Production*<sup>535</sup> (SPE 16363), which identified a relationship between volumetric efficiency and pump run times and the *2006-2008 Evaluation Report for PG&E Fabrication, Process, and Manufacturing Contract Group*,<sup>536</sup> which showed a reduction in savings from the SPE 16363 paper. These two methods were the basis of the current savings calculations and deemed inputs listed below. To develop Texas-specific stipulated values, field and metering data will be collected when there is sufficient uptake in the measure and used to calibrate and update the savings calculation methods and input variables for a future version of the TRM.<sup>537</sup>

## Savings Algorithms and Inputs

The energy and demand algorithms and associated input variables are listed below:

$$\text{Energy Savings } [\Delta kWh] = kW_{avg} \times (\text{TimeClock}\%On - \text{POC}\%On) \times 8,760$$

**Equation 242**

$$\text{Demand Savings } [\Delta kW] = \frac{kWh_{savings}}{8,760}$$

**Equation 243**<sup>538</sup>

The inputs for the energy and peak coincident demand savings are listed below:

$$kW_{avg} = HP \times 0.746 \times \frac{LF}{SME}$$

**Equation 244**

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<sup>535</sup> Bullock, J.E. "SPE 16363 *Electrical Savings in Oil Production*", (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

<sup>536</sup> *2006-2008 Evaluation Report for PG&E Fabrication, Process and Manufacturing Contract Group*. CALMAC Study ID: CPU0017.01. Itron, Inc. Submitted to California Public Utilities Commission. February 3, 2010.

<sup>537</sup> The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

<sup>538</sup> The equations in the petition for peak demand simplify to the equation shown.

$$POC\%On = \frac{Run_{constant} + Run_{coefficient} \times VolumetricEfficiency\% \times TimeClock\%On \times 100}{100}$$

Equation 245<sup>539</sup>

Where:

$kW_{avg}$	=	The demand used by each rod pump
HP	=	Rated pump-motor horsepower
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor—ratio of average demand to maximum demand (see Table 249)
ME	=	Motor efficiency, based on NEMA Standard Efficiency Motor (see Table 250)
SME	=	Mechanical efficiency of sucker-rod pump (see Table 249)
Time Clock%On	=	Stipulated-baseline time clock setting (see Table 249)
$Run_{constant}, Run_{coefficient}$	=	8.336, 0.956, derived from SPE 16363 <sup>540</sup>
VolumetricEfficiency%	=	Average well gross production divided by theoretical production (provided on rebate application)
8,760	=	Total hours per year

<sup>539</sup> This equation from the petition deviates from that in SPE 16363 but will provide conservative savings estimates. The equation will be updated and made consistent when this measure is updated with field data. The correct equation term is  $(Run_{constant} + Run_{coefficient} \times VolumetricEfficiency\%)$  with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25 percent).

<sup>540</sup> Bullock, J.E. "SPE 16363 Electrical Savings in Oil Production, (paper presented at the Society of Petroleum Engineers California Regional Meeting held in Ventura, California, April 8-10, 1987).

## Deemed Energy and Demand Savings Tables

**Table 249. Pump-Off Controllers—Savings Calculation Input Assumptions**

Variable	Stipulated/deemed values
LF (Load factor)	25% <sup>541</sup>
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95% <sup>542</sup>
Time clock%On	65% <sup>543</sup>

**Table 250. Pump-Off Controllers—NEMA Premium Efficiency Motor Efficiencies<sup>544</sup>**

Motor horsepower	Nominal full-load efficiency					
	Open motors (ODP)			Enclosed motors (TEFC)		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
	1200 rpm	1800 rpm	3600 rpm	1200 rpm	1800 rpm	3600 rpm
15	91.7%	93.0%	90.2%	91.7%	92.4%	91.0%
20	92.4%	93.0%	91.0%	91.7%	93.0%	91.0%
25	93.0%	93.6%	91.7%	93.0%	93.6%	91.7%
30	93.6%	94.1%	91.7%	93.0%	93.6%	91.7%
40	94.1%	94.1%	92.4%	94.1%	94.1%	92.4%
50	94.1%	94.5%	93.0%	94.1%	94.5%	93.0%
60	94.5%	95.0%	93.6%	94.5%	95.0%	93.6%
75	94.5%	95.0%	93.6%	94.5%	95.4%	93.6%
100	95.0%	95.4%	93.6%	95.0%	95.4%	94.1%
125	95.0%	95.4%	94.1%	95.0%	95.4%	95.0%
150	95.4%	95.8%	94.1%	95.8%	95.8%	95.0%
200	95.4%	95.8%	95.0%	95.8%	96.2%	95.4%

<sup>541</sup> Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011. Adjusted based on Field Measurements provided by ADM Associates, based on 2010 custom projects.

<sup>542</sup> Engineering estimate for standard gearbox efficiency.

<sup>543</sup> A Time Clock%On of 80 percent is typical from observations in other jurisdictions, but that was adjusted to 65 percent for a conservative estimate. This value will be reevaluated once Texas field data is available.

<sup>544</sup> DOE Final Rule regarding energy conservation standards for electric motors. 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I] [https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=6&action=viewlive](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=6&action=viewlive).

## Claimed Peak Demand Savings

Because the operation of the POC coincident with the peak demand period is uncertain, a simple average of the total savings over the full year (8,760 hours) is used, as shown in Equation 243.

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 15 years.<sup>545</sup>

## Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Motor manufacturer
- Motor model number
- Rated motor horsepower
- Motor type (TEFC or ODP)
- Rated motor RPM
- Baseline control type and time clock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times<sup>546</sup>

## References and Efficiency Standards

### Petitions and Rulings

- PUCT Docket 42551—Provides energy and demand savings calculations and EUL

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

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<sup>545</sup> CPUC 2006-2008 Industrial Impact Evaluation "SCIA\_06-08\_Final\_Report\_Appendix\_D-5": An EUL of 15 years was used for the ex-post savings, consistent with the SPC—Custom Measures and System Controls categories in the CPUC Energy Efficiency Policy Manual (Version 2) and with DEER values for an energy management control system.

<sup>546</sup> Per PUCT Docket 42551, Southwestern Public Service Company (SPS)/Xcel Energy has agreed to collect field data in 2015 on post-run times for a sample of wells to improve the accuracy of POC saving estimates.

## Document Revision History

Table 251. Pump-Off Controllers—Revision History

TRM version	Date	Description of change
v2.1	01/30/2015	TRM v2.1 origin.
v3.0	04/10/2015	TRM v3.0 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	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.7.4 ENERGY STAR® Pool Pumps Measure Overview

TRM Measure ID: NR-MS-PP

Market Sector: Commercial

Measure Category: Appliances

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

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 pool pump.

### Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa<sup>547</sup>.

Multi-speed pool pumps are not permitted. 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.<sup>548</sup> The default pump curves provided in the ENERGY STAR® Pool Pump Savings Calculator indicate that the motor operating at half-speed will be unable to meet the minimum turnover requirements for commercial pool operation as mandated by Texas Administrative Code.

<sup>547</sup> These pump products are ineligible for ENERGY STAR® v3.0 certification:  
<https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification.pdf>

<sup>548</sup> Hunt, A. and Easley, S., "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), U.S. DOE. May 2012.  
<http://www.nrel.gov/docs/fy12osti/54242.pdf>.

## Baseline Condition

The baseline condition is a 1 to 5 horsepower (hp) standard efficiency single-speed pool pump. This measure is only applicable to retrofit applications. New construction applications are not eligible as of July 19, 2021.<sup>549</sup>

## High-Efficiency Condition

The high-efficiency condition is a 1 to 5 hp variable speed pool pump that is compliant with the current ENERGY STAR® Version 3.1 Specification, effective July 19, 2021.

## Energy and Demand Savings Methodology

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

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR® Pool Pump Savings Calculator with Texas selected as the applicable location, so Texas-specific assumptions were used.<sup>550</sup>

$$\text{Energy Savings } [\Delta kWh] = kWh_{conv} - kWh_{ES}$$

Equation 246

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:

$$kWh_{conv} = \frac{PFR_{conv} \times 60 \times \text{hours} \times \text{days}}{EF_{conv} \times 1,000}$$

Equation 247

$$kWh_{ES} = \frac{V \times TO \times \text{days}}{EF_{ES} \times 1,000}$$

Equation 248

<sup>549</sup> Federal standard for dedicated-purpose pool pumps.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=67](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67).

<sup>550</sup> The ENERGY STAR® Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR® website at: <https://www.energystar.gov/productfinder/product/certified-pool-pumps/results>.

Where:

$PFR_{conv}$	=	Conventional single-speed pump flow rate [gal/min] (see Table 252)
$EF_{conv}$	=	Conventional single-speed pump energy factor [gal/W·hr] (see Table 252)
$EF_{ES}$	=	ENERGY STAR®-weighted energy factor [gal/W·hr] (see Table 253)
hours	=	Conventional single-speed pump daily operating hours (see Table 252)
days	=	Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)
$V$	=	Pool volume [gal] (see Table 253)
$TO$	=	Turnovers per day, number of times the volume of the pool is run through the pump per day (see Table 253)
60	=	Constant to convert between minutes and hours
1,000	=	Constant to convert from kilowatts to watts

**Table 252. Pool Pumps—Conventional Pump Input Assumptions<sup>551</sup>**

New pump (HP)	Hours, limited <sup>552</sup>	Hours, 24/7	$PFR_{conv}$ (gal/min)	$EF_{conv}$ (gal/W·h)
≤ 1.25	12	24	75.5000	2.5131
1.25 < hp ≤ 1.75			78.1429	2.2677
1.75 < hp ≤ 2.25			88.6667	2.2990
2.25 < hp ≤ 2.75			93.0910	2.1812
2.75 < hp ≤ 5			101.6667	1.9987

<sup>551</sup> Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

<sup>552</sup> Limited hours assumes that pump operating hours are 12 hours per day, based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.



**Table 253. Pool Pumps—ENERGY STAR® Pump Input Assumptions<sup>553,554</sup>**

New pump HP	TO, limited	TO, 24/7	V [gal]	EF <sub>ES</sub> (gal/W·h)
≤ 1.25	2.7	5.4	20,000	8.7
1.25 < hp ≤ 1.75	2.8	5.6	20,000	8.9
1.75 < hp ≤ 2.25	2.9	5.8	22,000	9.3
2.25 < hp ≤ 2.75	2.7	5.4	25,000	7.4
2.75 < hp ≤ 5	2.6	5.2	28,000	7.1

### Demand Savings Algorithms

$$\text{Peak Demand Savings } [\Delta kW] = \frac{kWh_{conv} - kWh_{ES}}{\text{hours}} \times \frac{CF_{S/W}}{\text{days}}$$

**Equation 249**

Where:

$CF_{S/W}$  = Summer/winter seasonal peak coincidence factor (see Table 254)

**Table 254. Pool Pumps—Coincidence Factors<sup>555</sup>**

Operation	Summer CF	Winter CF
24/7 operation	1.0	1.0
Seasonal/limited hours	1.0	0.5

### Deemed Energy and Demand Savings Tables

**Table 255. Pool Pumps—Energy Savings<sup>556</sup>**

New pump HP	Year-round operation		Seasonal operation (7 months)
	24/7 operation	Limited hours	
	kWh savings	kWh savings	kWh savings
≤ 1.25	11,259	5,630	3,282
1.25 < hp ≤ 1.75	13,518	6,759	3,941
1.75 < hp ≤ 2.25	15,263	7,632	4,449
2.25 < hp ≤ 2.75	15,773	7,887	4,598
2.75 < hp ≤ 5	19,250	9,625	5,612

<sup>553</sup> ENERGY STAR® turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

<sup>554</sup> Turnovers calculated as TO = hours x 60 x PFR<sub>conv</sub> ÷ V.

<sup>555</sup> Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

<sup>556</sup> 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.

**Table 256. Pool Pumps—Summer Peak Demand Savings**

New pump (HP)	24/7 operation or year-round limited hours demand savings (kW)	Seasonal operation demand savings (kW)
≤ 1.25	1.285	0.749
1.25 < hp ≤ 1.75	1.543	0.900
1.75 < hp ≤ 2.25	1.742	1.016
2.25 < hp ≤ 2.75	1.801	1.050
2.75 < hp ≤ 5	2.198	1.281

**Table 257. Pool Pumps—Winter Peak Demand Savings**

New pump HP	24/7 operation demand savings (kW)	Year-round limited hours demand savings (kW)	Season operation demand savings (kW)
≤ 1.25	1.285	0.643	0.375
1.25 < hp ≤ 1.75	1.543	0.772	0.450
1.75 < hp ≤ 2.25	1.742	0.871	0.508
2.25 < hp ≤ 2.75	1.801	0.900	0.525
2.75 < hp ≤ 5	2.198	1.099	0.641

## Claimed Peak Demand Savings

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

## Additional Calculators and Tools

ENERGY STAR® Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR® website at <https://www.energystar.gov/productfinder/product/certified-pool-pumps/results>.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.<sup>557</sup>

## 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:

- For all projects
  - Climate zone

<sup>557</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

- Pool pump rated horsepower
- Proof of purchase including quantity, make, and model information
- Copy of ENERGY STAR® certification
- Facility operation type: 24/7, year-round limited hours, seasonal
- For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs)
  - Items listed above for all projects
  - Decision/action type: early retirement, replace-on-burnout, or new construction
  - Rated horsepower of existing pool pump
  - Existing and new pump operating hours

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 47612—Provides deemed savings for ENERGY STAR® pool pumps

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 258. Pool Pumps—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v5.0	10/2017	TRM v5.0 origin.
v6.0	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. Added ineligible products list. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. General text edits. Corrected turnovers/day values in the assumptions table.
v10.0	10/2022	TRM v10.0 update. Updated for ENERGY STAR Version 3.0 Specification. Increased upper limit for pump horsepower to 5 to better reflect product availability.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.7.5 Lodging Guest Room Occupancy-Sensor Controls Measure Overview

**TRM Measure ID:** NR-MS-LC

**Market Sector:** Commercial

**Measure Category:** HVAC, indoor lighting

**Applicable Building Types:** Hotel/motel guestrooms, schools/colleges (dormitory)

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

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

**Savings Methodology:** Energy modeling

### Measure Description

This measure, commonly referred to as a guest room energy management (GREM) system, captures the potential energy and demand savings resulting from occupancy sensor control of HVAC and lighting in unoccupied hotel/motel guest rooms. Hotel and motel guest room occupancy schedules are highly variable, and guests often leave HVAC equipment and lighting on when they leave the room. Installation of occupancy controls can reduce the unnecessary energy consumption in unoccupied guest rooms. Savings have also been developed for the use of this measure in college dormitories.<sup>558</sup>

### Eligibility Criteria

To be eligible for HVAC savings, controls must be capable of either a 5°F or 10°F temperature offset. To be eligible for lighting savings, at least 50 percent of all the lighting fixtures in a guest room—both hardwired and plug-load lighting—must be actively controlled.

### Baseline Condition

The baseline condition is a guest room or dorm room without occupancy controls.

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<sup>558</sup> The original petition also includes savings for HVAC-only control in master-metered multifamily individual dwelling units. These values are not reported here because the permanent occupation of a residential unit is significantly different from the transitory occupation of hotel/motels and even dormitories. This measure is not currently being implemented and is not likely to be used in the future, but it can be added to a future TRM if warranted.

## High-Efficiency Condition

The high-efficiency condition is a guest room or dorm room with occupancy controls. The occupancy sensors can control either the HVAC equipment only or the HVAC equipment and the interior lighting (including plug-in lighting).

The occupancy-based control system must include, but not be limited to, infrared sensors, ultrasonic sensors, door magnetic strip sensors, and/or card-key sensors. The controls must be able to either completely shut-off the HVAC equipment serving the space and/or place it into an unoccupied temperature setback/setup mode.

## Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies<sup>559</sup> and prototypical ASHRAE 90.1-1999 occupancy schedules were used in the energy simulation runs to create realistic vacancy schedules. The prototype models were then adjusted to simulate an occupancy control system, which was compared to the baseline models.<sup>560</sup>

## Savings Algorithms and Inputs

A building simulation approach was used to produce savings estimates.

## Deemed Energy and Demand Savings Tables

Energy and demand savings are provided by region, for HVAC-only, HVAC + lighting control configurations, and for three facility types: motel guest rooms, hotel guest rooms, and dormitory rooms.

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<sup>559</sup> HVAC occupancy rates appear to be based on a single HVAC study of three hotels, but not dorms or multifamily buildings. For the lighting study, a typical guest room layout was used as the basis for the savings analysis. Hotel guest rooms are quite different from either dorms or multifamily units.

<sup>560</sup> A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

**Table 259. Lodging Occupancy Sensors—Motel per Room Energy and Peak Demand Savings**

Climate zone <sup>561</sup>	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.059	267	0.075	380	0.059	341	0.075	441
Climate Zone 2: Dallas	0.076	315	0.091	443	0.076	365	0.091	485
Climate Zone 3: Houston	0.082	324	0.097	461	0.082	351	0.097	484
Climate Zone 4: Corpus Christi	0.086	354	0.103	500	0.086	369	0.103	513
Climate Zone 5: El Paso	0.063	251	0.078	379	0.063	283	0.078	406
<b>10-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.111	486	0.126	598	0.111	627	0.126	726
Climate Zone 2: Dallas	0.146	559	0.161	686	0.146	640	0.161	761
Climate Zone 3: Houston	0.151	559	0.166	695	0.151	602	0.166	735
Climate Zone 4: Corpus Christi	0.163	617	0.179	761	0.163	650	0.179	792
Climate Zone 5: El Paso	0.118	432	0.133	561	0.118	482	0.133	607

**Table 260. Lodging Occupancy Sensors—Hotel per Room Energy and Peak Demand Savings**

Climate zone <sup>561</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.053	232	0.072	439	0.053	303	0.072	530
Climate Zone 2: Dallas	0.073	258	0.093	452	0.073	303	0.093	505
Climate Zone 3: Houston	0.074	242	0.094	430	0.074	260	0.094	450

<sup>561</sup> Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo was “Panhandle”, Dallas-Ft Worth was “North”, Houston was “South Central”, El Paso was “Big Bend”, and Corpus Christi was “Rio Grande Valley” using McAllen as a reference city.

Climate zone <sup>561</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Climate Zone 4: Corpus Christi	0.081	260	0.102	451	0.081	267	0.102	459
Climate Zone 5: El Paso	0.056	178	0.075	360	0.056	196	0.075	380
<b>10-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.102	426	0.121	568	0.102	557	0.121	684
Climate Zone 2: Dallas	0.134	452	0.154	617	0.134	517	0.154	676
Climate Zone 3: Houston	0.136	423	0.156	599	0.136	446	0.156	621
Climate Zone 4: Corpus Christi	0.149	467	0.169	652	0.149	483	0.169	667
Climate Zone 5: El Paso	0.106	312	0.126	479	0.106	338	0.126	501

**Table 261. Lodging Occupancy Sensors—Dormitory per Room Energy and Peak Demand Savings**

Climate zone <sup>561</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
<b>5-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.034	136	0.061	319	0.034	152	0.061	316
Climate Zone 2: Dallas	0.048	214	0.076	425	0.048	223	0.076	428
Climate Zone 3: Houston	0.051	242	0.078	461	0.051	244	0.078	462
Climate Zone 4: Corpus Christi	0.053	265	0.081	492	0.053	266	0.081	492
Climate Zone 5: El Paso	0.031	110	0.059	327	0.031	110	0.059	326
<b>10-degree setup/setback offset</b>								
Climate Zone 1: Amarillo	0.073	261	0.084	404	0.073	289	0.084	417
Climate Zone 2: Dallas	0.078	293	0.105	505	0.078	304	0.105	511
Climate Zone 3: Houston	0.081	326	0.108	543	0.081	328	0.108	545

Climate zone <sup>561</sup>	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Climate Zone 4: Corpus Christi	0.088	368	0.114	591	0.088	370	0.114	593
Climate Zone 5: El Paso	0.045	151	0.060	448	0.045	153	0.060	450

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study<sup>562</sup>. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

## Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Climate zone
- HVAC system and equipment type
- Heating type (heat pump, electric resistance)
- Temperature offset category (5 or 10° F)
- Control type (HVAC only, HVAC and lighting)
- Building type (hotel, motel, dormitory)
- Number of rooms

<sup>562</sup> Energy and Resource Solutions (2005). *Measure Life Study*. Prepared for the Massachusetts Joint Utilities; Table 1-1, Prescriptive Common Measure Life Recommendations, Large C&I retrofit, HVAC Controls, EMS.



## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40668—Provides deemed energy and demand savings values under “Guestroom, Dormitory and Multi-family Occupancy Controls for HVAC and Lighting Systems,” page 25 and Attachment pages A-46 through A-58.
- PUCT Docket 36779—Provides EULs for commercial measures.

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 262. Lodging Occupancy Sensors—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v2.0	04/18/2014	TRM v2.0 origin.
v3.0	04/10/2015	TRM v3.0 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	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. Changed Climate Zone 4 reference city from McAllen to Corpus Christi.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.7.6 Vending Machine Controls Measure Overview

**TRM Measure ID:** NR-MS-VC

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** All building types applicable

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

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

**Savings Methodology:** M&V

### Measure Description

This measure is for the installation of vending machine controls to reduce energy usage during periods of inactivity. These controls reduce energy usage by powering down the refrigeration and lighting systems when the control device signals that there is no human activity near the machine. If no activity or sale is detected over the manufacturer's programmed time duration, the device safely de-energizes the compressor, condenser fan, evaporator fan, and any lighting. For refrigerated machines, it will power up occasionally to maintain cooling to meet the machine's thermostat set point. When activity is detected, the system returns to full power. The energy and demand savings are determined on a per-vending machine basis.

### Eligibility Criteria

This measure applies to refrigerated beverage vending machines manufactured and purchased prior to August 31, 2012. Refrigerated beverage vending machines manufactured after this date must already comply with current federal-standard maximum daily-energy consumption requirements.

All non-refrigerated snack machines are eligible if controls are installed on equipment consistent with the baseline condition below. Display lighting must not have been permanently installed.

### Baseline Condition

The baseline condition is a 120-volt single phase refrigerated beverage or non-refrigerated snack vending machine without any controls.

## High-Efficiency Condition

The high-efficiency condition is a 120-volt single-phase refrigerated beverage or non-refrigerated-snack vending machine with occupancy controls and compliant with the current federal standard, effective January 8, 2019.<sup>563</sup>

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Energy savings are deemed based on a metering study completed by Pacific Gas & Electric (PG&E). Delta load shapes for this measure are taken from a Sacramento Municipal Utility District (SMUD) metering study. Demand savings for refrigerated cold drink units are calculated based on a probability-weighted analysis of hourly consumption impacts, and demand savings for other unit types are adjusted proportionally based on differences in rated product wattage.

### Deemed Energy and Demand Savings Tables

Energy and demand savings are specified by unit type and climate zone in the following tables:

**Table 263. Vending Controls—Refrigerated Cold Drink Energy and Peak Savings<sup>564</sup>**

Climate zone	kWh savings	Summer kW savings <sup>565</sup>	Winter kW savings
Climate Zone 1: Amarillo	1,612	0.023	0.060
Climate Zone 2: Dallas		0.021	0.063
Climate Zone 3: Houston		0.022	0.060
Climate Zone 4: Corpus Christi		0.022	0.064
Climate Zone 5: El Paso		0.015	0.068

<sup>563</sup> Appliance Standards for Refrigerated Beverage Vending Machines.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/standards.aspx?productid=29#current\\_standards](https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards).

<sup>564</sup> Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

<sup>565</sup> Chappell, C., Hanzawi, E., Bos, W., Brost, M., and Peet, R. (2002). "Does It Keep the Drinks Cold and Reduce Peak Demand? An Evaluation of a Vending Machine Control Program," 2002 ACEEE Summer Study on Energy Efficiency in Buildings Proceedings, pp. 10.47-10.56.

[https://www.eceee.org/static/media/uploads/site-2/library/conference\\_proceedings/ACEEE\\_buildings/2002/Panel\\_10/p10\\_5/paper.pdf](https://www.eceee.org/static/media/uploads/site-2/library/conference_proceedings/ACEEE_buildings/2002/Panel_10/p10_5/paper.pdf).

**Table 264. Vending Controls—Refrigerated Reach-In Energy and Peak Demand Savings<sup>566</sup>**

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Climate Zone 1: Amarillo	1,086	0.026	0.069
Climate Zone 2: Dallas		0.024	0.073
Climate Zone 3: Houston		0.026	0.068
Climate Zone 4: Corpus Christi		0.026	0.074
Climate Zone 5: El Paso		0.017	0.078

**Table 265. Vending Controls—Non-Refrigerated Snack Energy and Peak Demand Savings<sup>567</sup>**

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Climate Zone 1: Amarillo	387	0.005	0.013
Climate Zone 2: Dallas		0.004	0.013
Climate Zone 3: Houston		0.005	0.013
Climate Zone 4: Corpus Christi		0.005	0.014
Climate Zone 5: El Paso		0.003	0.014

## Claimed Peak Demand Savings

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

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 5 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID Plug-VendCtrler.<sup>568</sup>

## Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly:

- Vending machine type (refrigerated cold drink unit, refrigerated reach-in unit, or non-refrigerated snack unit with lighting)
- Vending machine manufacture date

<sup>566</sup> Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

<sup>567</sup> Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

<sup>568</sup> DEER READI (Remote Ex-Ante Database Interface). <http://www.deeresources.com/index.php/readi>.

## **References and Efficiency Standards**

### **Petitions and Rulings**

- PUCT Docket 40669—Provides energy and demand savings and measure specifications. Appendix A:  
[https://interchange.puc.texas.gov/Documents/40669\\_3\\_735684.PDF](https://interchange.puc.texas.gov/Documents/40669_3_735684.PDF).
- PUCT Docket 36779—Provides EUL for Vending Machine Controls.

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 266. Vending Controls—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v3.0	04/10/2015	TRM v3.0 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	10/2018	TRM v6.0 update. No revision.
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. Clarified baseline condition and updated demand savings for compliance with current peak definition.
v9.0	10/2021	TRM v9.0 update. General text edits.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.7.7 Computer Power Management Measure Overview

**TRM Measure ID:** NR-MS-CP

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Building Types:** All building types applicable

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed value (per machine)

**Savings Methodology:** Algorithms

### Measure Description

This measure presents deemed savings for implementation of computer power management strategies. Computer power management includes the use of operational settings that automate the power management features of computer equipment, including automatically placing equipment into a low power mode during periods of inactivity. This may be done either with built-in features integral to the computer operating system or through an add-on software program. Typically, this measure is implemented across an entire network of computers.

### Eligibility Criteria

To be eligible for this measure, computers must not have any automatic sleep or other low power setting in place. Both conventional and ENERGY STAR® computer equipment are eligible for this measure. Applicable building types include offices and schools.

### Baseline Condition

The baseline conditions are the estimated number of hours that the computer spends in active, sleep, and off modes before the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default baseline hours are taken from the ENERGY-STAR® modeling study assumptions contained in the Low Carbon IT Savings Calculator<sup>569</sup>, and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.<sup>570</sup>

<sup>569</sup> ENERGY STAR® Low Carbon IT Calculator available for download at:

[https://www.energystar.gov/products/low\\_carbon\\_it\\_campaign/put\\_your\\_computers\\_sleep](https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep).

<sup>570</sup> Based on 2015 custom project metering from El Paso Electric.

## High-Efficiency Condition

The efficient conditions are the estimated number of hours that the computer spends in active, sleep, and off modes after the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default efficient hours are taken from the ENERGY STAR® modeling study assumptions contained in the Low Carbon IT Savings Calculator and assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.<sup>571</sup>

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

*Energy Savings* [ $\Delta kWh$ ]

$$= \frac{W_{active}(Hrs_{active,pre} - Hrs_{active,post}) + W_{sleep}(Hrs_{sleep,pre} - Hrs_{sleep,post}) + W_{off}(Hrs_{off,pre} - Hrs_{off,post})}{1,000}$$

**Equation 250**

$$\text{Summer Peak Demand Savings } [\Delta kW] = (W_{active} - W_{sleep}) \times CF_{inactive,S}$$

**Equation 251**

$$\text{Winter Peak Demand Savings } [\Delta kW] = 0$$

**Equation 252**

Where:

$W_{active}$	=	Total wattage of the equipment, including computer and monitor, in active/idle mode (see Table 267)
$Hrs_{active,pre}$	=	Annual number of hours the computer is in active/idle mode before computer management software is installed (see Table 268)
$Hrs_{active,post}$	=	Annual number of hours the computer is in active/idle mode after computer management software is installed (see Table 268)
$W_{sleep}$	=	Total wattage of the equipment, including computer and monitor, in sleep mode (see Table 267)
$Hrs_{sleep,pre}$	=	Annual number of hours the computer is in sleep mode before computer management software is installed (see Table 268)
$Hrs_{sleep,post}$	=	Annual number of hours the computer is in sleep mode after computer management software is installed (see Table 268)

<sup>571</sup> Based on 2015 custom project metering from El Paso Electric.

- $W_{off}$  = Total wattage of the equipment, including computer and monitor, in off mode (see Table 267)
- $Hrs_{off,pre}$  = Annual number of hours the computer is in off mode before computer management software is installed (see Table 268)
- $Hrs_{off,post}$  = Annual number of hours the computer is in off mode after computer management software is installed (see Table 268)
- 1,000 = Constant to convert from W to kW
- $CF_{inactive,S}$  = Inactive summer peak coincidence factor (see Table 269)

**Table 267. Computer Power Management—Equipment Wattages<sup>572</sup>**

Equipment	$W_{active}$	$W_{sleep}$	$W_{off}$
Conventional monitor <sup>573</sup>	18.3	0.30	0.30
Conventional computer	48.11	2.31	0.96
Conventional notebook (including display)	14.82	1.21	0.61
ENERGY STAR® monitor	15.0	0.26	0.26
ENERGY STAR® computer	27.11	1.80	0.81
ENERGY STAR® notebook (including display)	8.61	0.89	0.46

<sup>572</sup> Equipment wattages taken from the ENERGY STAR® Office Equipment Calculator, updated October 2016. Available for download at [https://www.energystar.gov/buildings/save\\_energy\\_commercial\\_buildings/ways\\_save/energy\\_efficient\\_products](https://www.energystar.gov/buildings/save_energy_commercial_buildings/ways_save/energy_efficient_products).

<sup>573</sup> Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR® Office Equipment Calculator.



**Table 268. Computer Power Management—Operating Hours<sup>574</sup>**

Building activity type	Hrs <sub>active,pre</sub>	Hrs <sub>active,post</sub>	Hrs <sub>sleep,pre</sub>	Hrs <sub>sleep,post</sub>	Hrs <sub>off,pre</sub>	Hrs <sub>off,post</sub>
Typical office (8 hours/day, 5 days/week, 22 non-workdays/year)	4,650	1,175	0	2,105	4,110	5,480
Typical school (8 hours/day, 5 days/week, 113 non-school days/year)	4,213	727	0	1,970	4,547	6,063

**Table 269. Computer Power Management—Coincidence Factors**

Climate zone	Summer CF		Winter CF	
	Active	Inactive	Active	Inactive
Climate Zone 1: Amarillo	0.65	0.35	0.11	0.89
Climate Zone 2: Dallas	0.62	0.38	0.12	0.88
Climate Zone 3: Houston	0.66	0.34	0.12	0.88
Climate Zone 4: Corpus Christi	0.62	0.38	0.14	0.86
Climate Zone 5: El Paso	0.75	0.25	0.28	0.72

## Deemed Energy and Demand Savings Tables

Energy and demand savings are deemed values for conventional and ENERGY STAR<sup>®</sup> equipment, based on the input assumptions listed in Table 267, Table 268, and Table 269. The following tables provide these deemed values.

**Table 270. Computer Power Management—Energy Savings for Offices & Schools**

Equipment	kWh Savings
Conventional LCD monitor	62.6
Conventional computer	161.4
Conventional notebook	48.2
ENERGY STAR <sup>®</sup> monitor	51.3
ENERGY STAR <sup>®</sup> computer	89.5
ENERGY STAR <sup>®</sup> notebook	27.5

<sup>574</sup> Hours taken from assumptions in the ENERGY STAR<sup>®</sup> calculator. Hours<sub>pre</sub> assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night. Hours<sub>post</sub> assume managed computer settings enter sleep mode after 15 minutes of inactivity, and 80% of computers are turned off each night.

**Table 271. Computer Power Management—Peak Demand Savings for Offices & Schools**

Equipment	Climate Zone 1: Amarillo		Climate Zone 2: Dallas		Climate Zone 3: Houston		Climate Zone 4: Corpus Christi		Climate Zone 5: El Paso	
	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)
Conventional LCD monitor	0.006	–	0.007	–	0.006	–	0.007	–	0.004	–
Conventional computer	0.016	–	0.017	–	0.015	–	0.017	–	0.011	–
Conventional notebook	0.005	–	0.005	–	0.005	–	0.005	–	0.003	–
ENERGY STAR® monitor	0.005	–	0.006	–	0.005	–	0.006	–	0.004	–
ENERGY STAR® computer	0.009	–	0.010	–	0.009	–	0.010	–	0.006	–
ENERGY STAR® notebook	0.003	–	0.003	–	0.003	–	0.003	–	0.002	–

## Claimed Peak Demand Savings

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

Winter demand savings are not specified for this measure based on an assumption that the reduced operating hours are not achieved during the winter peak period.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) of this measure is 3 years, based on the useful life of the computer equipment being controlled.<sup>575</sup>

## Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked within the program database to inform the evaluation and apply the savings properly.

- Equipment type
  - Conventional or ENERGY STAR®
  - Monitor, computer, or notebook
- Application type (office, school)

<sup>575</sup> Internal Revenue Service, 1.35.6.10, Property and Equipment Capitalization, Useful life for Laptop and Desktop Equipment. July 2016. [https://www.irs.gov/irm/part1/irm\\_01-035-006](https://www.irs.gov/irm/part1/irm_01-035-006).

## **References and Efficiency Standards**

### **Petitions and Rulings**

Not applicable.

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 272. Computer Power Management—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Incorporated version 2 baseline adjustments and revised savings.
v9.0	10/2021	TRM v9.0 update. Updated peak demand savings coefficients and deemed savings. Added application type to documentation requirements. Eliminated winter demand savings.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

## 2.7.8 ENERGY STAR® Electric Vehicle Supply Equipment Measure Overview

**TRM Measure ID:** NR-MS-EV

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

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

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure applies to the installation of electric vehicle supply equipment (EVSE) meeting the specifications of ENERGY STAR® Level 2 at a commercial site. EVSE is the infrastructure that enables plug-in electric vehicles (PEV) to charge onboard batteries. Level 2 EVSE require 240-volt electrical service. This measure provides deemed savings for the energy efficiency improvement of an ENERGY STAR® EVSE over a standard or non-ENERGY STAR® EVSE.

### Eligibility Criteria

Eligible equipment includes ENERGY STAR® compliant Level 2 EVSE installed in a commercial application, which includes public, multifamily, workplace, and fleet locations. Public locations are sites where an EVSE is intended to be used by the public or visitors to the site. This includes locations such as retail, education, municipal, hospitality, and other similar locations. For the purposes of this measure, multifamily sites are public locations. Workplace locations include sites where an EVSE is intended to be used by employees to charge their personal vehicles when reporting to the workplace site. Fleet locations include sites where an EVSE is intended to be used to charge a fleet of company vehicles. The EVSE may be installed for use on either an all-battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV). Savings estimates for this measure are based on studies of light duty vehicles; EVSE for charging heavy duty vehicles should pursue custom M&V.

### Baseline Condition

The baseline condition is a non-ENERGY STAR® compliant Level 2 EVSE.

## High-Efficiency Condition

The high-efficiency condition is a Level 2 EVSE compliant with ENERGY STAR® Version 1.1 Specification, effective March 31, 2021.<sup>576</sup>

## Energy and Demand Savings Methodology

Savings for EVSE come from efficiency gains of the ENERGY STAR® equipment during operating modes when the vehicle is plugged in but not charging and when not plugged in. Deemed savings are calculated according to the following algorithms.

### Savings Algorithms and Input Variables

$$= \frac{\text{ENERGY STAR Idle Consumption [kWh]} \times \text{days}_C + \text{ENERGY STAR Idle Consumption [kWh]} \times \text{days}_{NC}}{1,000}$$

**Equation 253**

$$\text{Baseline Idle Consumption [kWh]} = \frac{\text{ENERGY STAR Idle Consumption}}{0.6}$$

**Equation 254**

$$\text{Energy Savings } [\Delta\text{kWh}] = \text{Baseline Idle Consumption} - \text{ENERGY STAR Idle Consumption}$$

**Equation 255**

$$\text{Peak Demand Savings } [\Delta\text{kW}] = \frac{\Delta\text{kWh}}{\text{Hrs}_{unplug,C} \times \text{days}_C + \text{Hrs}_{unplug,NC} \times \text{days}_{NC}} \times \text{PDPF}$$

**Equation 256**

Where:

$$\text{Hrs}_{plug} = \text{Time per day the vehicle is plugged into the EVSE and not charging [hours]}^{577} = 2.8$$

$$\text{W}_{plug} = \text{Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging [W]}^{578} = 6.9 \text{ W}$$

<sup>576</sup> ENERGY STAR® Program Requirements for Electric Vehicle Supply Equipment Eligibility Criteria v1.1. [https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20DC%20EVSE%20Final%20Specification\\_0.pdf](https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20DC%20EVSE%20Final%20Specification_0.pdf).

<sup>577</sup> National Renewable Energy Laboratory (NREL), February 2018, "Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio," page 26, Table 8: Charging Statistics by Location Type and Level, ChargePoint Data. Average across all location types, dwell time minus charging duration.

<sup>578</sup> Average Idle Mode Input Power from ENERGY STAR® certified EVSE product list as of July 13, 2020.

- $Hrs_{unplug,C}$  = Time per day the vehicle is not plugged into the EVSE on a charging day [hours]<sup>579</sup> = 19
- $Hrs_{unplug,NC}$  = Time per day the vehicle is not plugged into the EVSE on a non-charge day [hours] = 24
- $W_{unplug}$  = Wattage of the EVSE when the vehicle is not plugged into the EVSE [W]<sup>580</sup> = 3.3
- $days_C$  = Number of charging days per year [days]<sup>581</sup> = 204
- $days_{NC}$  = Number of non-charging days per year [days] = 161
- 1,000 = Constant to convert from W to kW
- 0.6 = Efficiency adjustment factor<sup>582</sup>
- PDPF = Peak demand probability factor (see Table 273)

**Table 273. EVSE—Peak Demand Probability Factors<sup>583</sup>**

Location type	Public		Workplace		Fleet	
	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF	Summer PDPF	Winter PDPF
Climate Zone 1: Amarillo	0.46526	0.46032	0.87484	0.75271	0.27206	0.44421
Climate Zone 2: Dallas	0.45808	0.47380	0.86213	0.75558	0.22867	0.42040
Climate Zone 3: Houston	0.46134	0.42544	0.87173	0.68222	0.26507	0.34306
Climate Zone 4: Corpus Christi	0.46892	0.49816	0.87553	0.77324	0.25862	0.50077
Climate Zone 5: El Paso	0.42680	0.51324	0.80969	0.92091	0.15042	0.57715

<sup>579</sup> NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 26, Table 8; 24 hours per day minus average dwell time.

<sup>580</sup> Average No Vehicle Mode Input Power from ENERGY STAR<sup>®</sup> certified EVSE product list.

<sup>581</sup> NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 25; 0.56 charging sessions per day per plug in Austin, Texas. 365 x 0.56 = 204.

<sup>582</sup> ENERGY STAR<sup>®</sup> Electric Vehicle Chargers Buying Guidance: “ENERGY STAR<sup>®</sup> certified EV charger... on average use 40% less energy than a standard EV charger when the charger is in standby mode (i.e., not actively charging a vehicle).” <https://www.energystar.gov/products/other/evse>.

<sup>583</sup> Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from NREL “Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio,” page 27, Figure 21: Daily distribution of ChargePoint charging events by EVSE type and day of the week.

## Deemed Energy and Demand Savings Tables

Table 274 presents the deemed annual energy savings per EVSE.

**Table 274. EVSE—Energy Savings**

kWh Savings (all location types)
19.7

Table 275 presents the deemed summer and winter peak kW savings per EVSE.

**Table 275. EVSE—Peak Demand Savings**

Location type	Public		Workplace		Fleet	
	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
Climate Zone 1: Amarillo	0.0012	0.0012	0.0022	0.0019	0.0008	0.0012
Climate Zone 2: Dallas	0.0012	0.0012	0.0022	0.0019	0.0006	0.0012
Climate Zone 3: Houston	0.0012	0.0011	0.0022	0.0017	0.0007	0.0010
Climate Zone 4: Corpus Christi	0.0012	0.0013	0.0022	0.0020	0.0007	0.0014
Climate Zone 5: El Paso	0.0011	0.0013	0.0021	0.0023	0.0004	0.0016

### Claimed Peak Demand Savings

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

### Additional Calculators and Tools

Not applicable.

### Measure Life and Lifetime Savings

The estimated useful life (EUL) for an EVSE is assumed to be 10 years.<sup>584</sup>

<sup>584</sup> U.S. Department of Energy Vehicle Technologies Office, November 2015, “Costs Associated with Non-Residential Electric Vehicle Supply Equipment” p. 21.

[https://afdc.energy.gov/files/u/publication/evse\\_cost\\_report\\_2015.pdf](https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf).

## **Program Tracking Data and Evaluation Requirements**

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

- Climate zone
- Location Type (public, workplace, or fleet)<sup>585</sup>
- EVSE quantity
- EVSE manufacturer and model number

## **References and Efficiency Standards**

### **Petitions and Rulings**

- This section not applicable.

### **Relevant Standards and Reference Sources**

Please refer to measure citations for relevant standards and reference sources.

### **Document Revision History**

**Table 276. EVSE—Revision History**

<b>TRM version</b>	<b>Date</b>	<b>Description of change</b>
v8.0	10/2020	TRM v8.0 origin.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.
v10.0	10/2022	TRM v10.0 update. Added reference for ENERGY STAR version.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>585</sup> Refer to Eligibility Criteria section for location type definitions.



## **2.7.9 Industrial High-Frequency Battery Chargers Overview**

**TRM Measure ID: NR-MS-BC**

**Market Sector: Commercial**

**Measure Category: Other/Miscellaneous**

**Applicable Building Types: Any commercial**

**Fuels Affected: Electricity**

**Decision/Action Type: Retrofit, new construction**

**Program Delivery Type: Prescriptive**

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

**Savings Methodology: Engineering algorithms and estimates**

### **Measure Description**

Industrial electric vehicle fleets used for material handling, or forklifts, use battery charging systems to convert AC source power into DC power required to charge the vehicle batteries. Traditional charging systems include Ferro resonant (FR) and silicon-controlled rectifier (SCR) charging equipment. This measure is for a single high-frequency battery charger that converts AC to DC power more efficiently than traditional systems due to switch mode operation that reduces heat and power loss throughout the system.

### **Baseline Condition**

The baseline condition is a typical FR or SCR charging system operating in an industrial warehouse setting to power forklifts.

### **High-Efficiency Condition**

There is no federal standard for large industrial battery chargers. Therefore, the efficient condition is the energy efficiency standard for large battery systems in California Appliance Efficiency Regulations, Title 20, which is detailed in the following table.

**Table 277. Battery Chargers – Efficiency Requirements<sup>586</sup>**

Performance Factor		Requirement
Charge return factor	100%, 80% depth of discharge	≤ 1.10
	40% depth of discharge	≤ 1.15
Power conversion efficiency		≥ 89%
Power factor		≥ 90%
No battery mode power		≤ 10 W

## Energy and Demand Savings Methodology

Battery charger systems operate in three modes: charge, maintenance, and no battery. In charge mode, the battery is accumulating charge. Maintenance mode occurs when the battery is fully charged and the charger is simply supplying energy to counteract natural discharge. No battery mode indicates that the battery has been fully disconnected from the charger.

## Savings Algorithms and Input Variables

The deemed savings values are calculated using the following algorithms:

$$hours = DC \times 8,760$$

**Equation 257**

$$\begin{aligned}
 \text{Energy Savings [kWh}_{\text{savings}}] &= hours_C \times \frac{W_{C,pre} - W_{C,post}}{1,000} + hours_M \times \frac{W_{M,pre} - W_{M,post}}{1,000} \\
 &+ hours_{NC} \times \frac{W_{NC,pre} - W_{NC,post}}{1,000}
 \end{aligned}$$

**Equation 258**

$$\text{Summer Peak Demand Savings [kW}_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_S$$

**Equation 259**

$$\text{Winter Peak Demand Savings [kW}_{\text{savings}}] = \frac{kWh_{\text{savings}}}{hours_C + hours_M + hours_{NB}} \times CF_W$$

**Equation 260**

Where:

$$\underline{8,760} = \underline{\text{Annual hours per year}}$$

<sup>586</sup> California Appliance Efficiency Regulations, Title 20, Section 1605.3 State Standards for Non-Federally-Regulated Appliances, (w) Battery Chargers and Battery Charger Systems. <https://energycodeace.com/content/reference-ace-t20-tool>.

$DC_{C/M/NB}$  = Duty cycle in charging, maintenance, and no battery mode (see Table 278)

$hours_{C/M/NB}$  = Annual number of hours in charging, maintenance, and no battery mode (see Table 278)

$W_{C/M/NB}$  = Wattage draw in charging, maintenance, and no battery mode (see Table 279)

$CF_{S/W}$  = Seasonal peak coincidence factor (see Table 280)

1,000 = Conversion Constant for watts to kilowatts

**Table 278. Battery Chargers – Charging and Idle Hours Assumptions<sup>587</sup>**

Equipment	$DC_c$	$DC_M$	$DC_{NB}$	$hours_c$	$hours_M$	$hours_{NB}$
Single phase	45%	31%	24%	3,942	2,716	2,102
Three phase	94%	=	6%	8,234	=	526

**Table 279. Battery Chargers – Pre/Post Charging and Idle Wattage Assumptions<sup>588</sup>**

Equipment	$W_{C,pre}$	$W_{C,post}$	$W_{M,pre}$	$W_{M,post}$	$W_{NB,pre}$	$W_{NB,post}$
Single phase	2,000	50	50	1,767	10	10
Three phase	5,785	89	34	5,111	10	10

**Table 280. Battery Charging System – Coincidence Factors<sup>589</sup>**

Equipment	Summer	Winter
Single phase	0.19	=
Three phase	1	=

## Deemed Energy and Peak Demand Savings Tables

The deemed energy and seasonal peak savings values are presented in the following table.

<sup>587</sup> “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 6. <https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11-Battery-Charger-Title-20-CASE-Report-v2-2-2.pdf>.

<sup>588</sup> “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010.  $W_{pre}$ : Table 7,  $W_{post}$ : Table 10. <https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11-Battery-Charger-Title-20-CASE-Report-v2-2-2.pdf>.

<sup>589</sup> “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 7 and Table 10. <https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11-Battery-Charger-Title-20-CASE-Report-v2-2-2.pdf>.

**Table 281. Battery Chargers — Deemed Energy and Demand Savings per Charger**

<u>Equipment</u>	<u>kWh savings</u>	<u>Summer kW savings</u>	<u>Winter kW savings</u>
<u>Single phase</u>	<u>1,111</u>	<u>0.02</u>	<u>=</u>
<u>Three phase</u>	<u>5,562</u>	<u>0.63</u>	<u>=</u>

## **Claimed Peak Demand Savings**

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

## **Measure Life and Lifetime Savings**

The estimated useful life (EUL) for high efficiency battery chargers is 15 years.<sup>590</sup>

## **Program Tracking Data and Evaluation Requirements**

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

- Battery charger quantity
- Battery charger manufacturer and model number
- Charger type (single phase, three phase)
- Depth of discharge
- Charge return factor
- Power conversion efficiency
- Power factor
- No battery mode power (W)

## **Document Revision History**

**Table 282. Industrial High-Frequency Battery Chargers—Revision History**

<u>TRM version</u>	<u>Date</u>	<u>Description of change</u>
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 origin</u>

<sup>590</sup> “Analysis of Standard Options for Battery Charger Systems,” Ecos Consulting for Title 20 CASE Initiative. Version 2.2.2. October 1, 2010. Table 18. [https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11\\_Battery\\_Charger\\_Title\\_20\\_CASE\\_Report\\_v2-2-2.pdf](https://www.kannahconsulting.com/wp-content/uploads/2016/08/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf).

## **2.7.92.7.10 Steam Trap Repair and Replacement Measure Overview**

**TRM Measure ID:** NR-MS-ST

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

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

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

Faulty steam traps that allow steam to leak require makeup water to re-generate the lost steam. This measure applies to the replacement or repair of faulty mechanical (thermostatic, thermodynamic, bucket, or fixed orifice) steam traps in industrial and commercial facilities. The measure also covers annual maintenance of venturi steam traps after their deemed 20-year measure life.

### **Eligibility Criteria**

The measure is applicable to failed steam traps in commercial and industrial applications less than 300 pounds per square in gauge (psig). Residential, multifamily, and heating radiator applications are not eligible to claim savings under the methods in this measure.

### **Baseline Condition**

The baseline condition is a faulty (blocked, leaking, or blow-through) mechanical steam trap in need of replacement or repair.

### **High-Efficiency Condition**

The high-efficiency condition is the repair of a faulty steam trap, replacement with a venturi steam trap installed in compliance with ASME PTC 39-2005, or annual maintenance of a venturi steam trap.

A venturi steam trap removes condensate from steam systems by utilizing the thermodynamic pressure properties of water passing through a fixed venturi orifice rather than by the moving parts found in traditional steam traps. There are numerous steam system parameters that influence operating pressure, system load, and system operations. Venturi steam traps are an engineering solution that must be designed and sized by a qualified professional based on specific site conditions.

Annual maintenance of a venturi steam trap after exhausting its deemed 20-year measure life with savings awarded on a year-to-year basis includes the removal, cleaning, and replacement of the trap strainer. Some traps may contain an integrated strainer blowdown valve for improved maintenance.

## **Energy and Demand Savings Methodology**

Electrical energy savings for this measure are calculated based on the energy associated with makeup required to replace water lost due to steam leaks. Savings are presented per trap.

### **Savings Algorithms and Input Variables**

$$Energy\ Savings\ [\Delta kWh] = \Delta Water\ (gallons) / 1,000,000 \times E_{water\ supply}$$

**Equation 261**

$$\Delta Water = \frac{S_L\ (lb/hr)}{8.33\ (lbs/gal)} \times Hours \times L$$

**Equation 262**

$$S_L = 24.24 \times P_{ia} \times D^2 \times A \times FF$$

**Equation 263**

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{Hours} \times DF$$

**Equation 264**

Where:

$E_{water\ supply}$	=	Water supply energy factor: 2,300 kWh/million gallons
$S_L$	=	Average steam loss per trap (lb/hr) (see Table 283)
Hours	=	Annual hours when steam system is operational, equal to heating degree days by climate zone (see Table 284)
$L$	=	Percentage leakage, 1 per each leaking trap with a system audit to document leaks; for full system replacement without a system audit, use default values from Table 283
24.24	=	Constant lb/(hr-psia-in <sup>2</sup> )
$P_{ia}$	=	Average steam trap inlet pressure, absolute (psia), $P_{ig} + P_{atm}$
$P_{ig}$	=	Average steam trap inlet pressure, gauge (psig) (see Table 283)
$P_{atm}$	=	Atmospheric pressure, 14.7 psia

- D* = Diameter of orifice (inches), use actual if possible, or defaults in Table 283
- A* = Adjustment factor: 50% for all steam systems; this factor is to account for reducing the maximum theoretical steam flow to the average steam flow (the Enbridge factor)
- FF* = Flow factor for medium- and high-pressure steam systems to address industrial float and thermodynamic style traps where additional blockage is possible
- DFCF* = Peak **demand factor coincidence factor**, assume value of 1 for industrial and process steam applications; for commercial heating applications, see Table 36 through Table 40 in Section 2.2.2; for commercial dry cleaners, use *DFCF* for stand-alone retail

**Table 283. Steam Traps—Savings Calculation Input Assumptions<sup>591</sup>**

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, S <sub>L</sub> (lb/hr/trap)	Hours	L
Commercial dry cleaners	82.8	0.125	100%	18.5	2,425	0.27
Industrial or process low pressure < 15 psig	-	-		6.9	8,282	0.16
Industrial or process medium pressure > 15 and < 30 psig	16	0.1875	50%	6.5	8,282	0.16
Industrial or process medium pressure > 30 and < 75 psig	47	0.2500		23.4	8,282	0.16
Industrial or process high pressure > 75 and < 125 psig	101			43.8	8,282	0.16
Industrial or process high pressure > 125 and < 175 psig	146			60.9	8,282	0.16
Industrial or process high pressure > 175 and < 250 psig	202			82.1	8,282	0.16
Industrial or process high pressure > 250 and < 300 psig	263			105.2	8,282	0.16
Commercial space heating low pressure steam (LPS)	-	-	100%	6.9	Table 284	0.27

<sup>591</sup> Default inputs for the steam trap measure are sourced from the Illinois TRM version 9.0, Volume 2, measure 4.4.16 Steam Trap Replacement or Repair. [https://www.ilsag.info/wp-content/uploads/IL-TRM\\_Effective\\_010121\\_v9.0\\_Vol\\_2\\_C\\_and\\_I\\_09252020\\_Final.pdf](https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf)

**Table 284. Steam Traps—Commercial Heating Hours**

Climate zone	Hours (HDD) <sup>592</sup>
Climate Zone 1: Amarillo	4,565
Climate Zone 2: Dallas	2,567
Climate Zone 3: Houston	1,686
Climate Zone 4: Corpus Christi	1,129
Climate Zone 5: El Paso	2,677

## Deemed Energy and Demand Savings Tables

**Table 285. Steam Traps—Energy Savings**

Steam system	Climate zone	Annual kWh savings (per trap, without audit)	Annual kWh savings (per trap with audit)
Commercial dry cleaners	All	3.3	12.4
Industrial or process low pressure < 15 psig	All	2.5	15.8
Industrial or process medium pressure > 15 and < 30 psig	All	2.4	15.0
Industrial or process medium pressure > 30 and < 75 psig	All	8.6	53.4
Industrial or process high pressure > 75 and < 125 psig	All	16.0	100.2
Industrial or process high pressure > 125 and < 175 psig	All	22.3	139.2
Industrial or process high pressure > 175 and < 250 psig	All	30.0	187.7
Industrial or process high pressure > 250 and < 300 psig	All	38.5	240.5
Commercial space heating LPS	1 Amarillo	2.3	8.7
	2 DFW	1.3	4.9
	3 Houston	0.9	3.2
	4 Corpus	0.6	2.2
	5 El Paso	1.4	5.1

<sup>592</sup> Heating degree days are calculated from TMY3 Hourly Weather Data by Climate Zone, available at <http://texasefficiency.com/index.php/regulatory-filings/deemed-savings>.



## Claimed Peak Demand Savings

**Table 286. Steam Traps—Peak Demand Savings, Without Audit**

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Commercial dry cleaners	Mercantile	Stand-alone retail	1.36E-03	7.57E-04	5.92E-04	3.03E-04	3.58E-04
Low pressure ≤ 15 psig	All	Industrial or process	3.05E-04	3.05E-04	3.05E-04	3.05E-04	3.05E-04
Medium pressure > 15 and < 30 psig	All	Industrial or process	2.89E-04	2.89E-04	2.89E-04	2.89E-04	2.89E-04
Medium pressure ≥ 30 and < 75 psig	All	Industrial or process	1.03E-03	1.03E-03	1.03E-03	1.03E-03	1.03E-03
High pressure ≥ 75 and < 125 psig	All	Industrial or process	1.94E-03	1.94E-03	1.94E-03	1.94E-03	1.94E-03
High pressure ≥ 125 and < 175 psig	All	Industrial or process	2.69E-03	2.69E-03	2.69E-03	2.69E-03	2.69E-03
High pressure ≥ 175 and < 250 psig	All	Industrial or process	3.63E-03	3.63E-03	3.63E-03	3.63E-03	3.63E-03
High pressure ≥ 250 and < 300 psig	All	Industrial or process	4.65E-03	4.65E-03	4.65E-03	4.65E-03	4.65E-03
Commercial space heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/ university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	2.21E-04	3.39E-04	2.57E-04	1.54E-04	1.90E-04
		Secondary school	2.21E-04	3.03E-04	2.78E-04	1.80E-04	2.21E-04
	Food sales	Convenience <u>store</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	2.21E-04	2.57E-04	2.26E-04	1.80E-04	1.44E-04

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
		24-hour full-service <u>restaurant</u>	2.21E-04	2.52E-04	2.26E-04	1.85E-04	1.39E-04
		Quick-service restaurant	2.47E-04	3.14E-04	2.62E-04	1.75E-04	1.34E-04
		24-hour quick-service <u>restaurant</u>	2.47E-04	3.09E-04	2.57E-04	1.75E-04	1.34E-04
	Healthcare	<del>Hospital</del> <u>Inpatient</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient <u>healthcare</u>	1.39E-04	1.44E-04	1.49E-04	4.12E-05	2.06E-05
	Large multifamily	Midrise apartment	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lodging	Large hotel	4.42E-04	4.22E-04	1.70E-04	1.08E-04	1.08E-04
		Nursing home	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Small hotel/motel	1.85E-04	2.16E-04	9.77E-05	5.14E-05	3.09E-05
	Retail	Stand-alone retail	5.09E-04	2.83E-04	2.21E-04	1.13E-04	1.34E-04
		24-hour <del>stand-alone</del> retail	2.21E-04	2.93E-04	2.11E-04	1.29E-04	1.44E-04
		Strip mall	2.01E-04	2.83E-04	2.16E-04	1.08E-04	1.39E-04
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	3.70E-04	3.39E-04	2.16E-04	1.23E-04	1.39E-04
		Small office	1.49E-04	2.06E-04	1.44E-04	7.20E-05	7.72E-05
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
	Service	Service: <u>Excluding food</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	1.39E-04	1.44E-04	9.77E-05	4.12E-05	2.06E-05

**Table 287. Steam Traps—Peak Demand Savings, With Audit**

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Commercial dry cleaners	Mercantile	Stand-alone retail	5.05E-03	2.80E-03	2.19E-03	1.12E-03	1.33E-03
Low pressure ≤ 15 psig	All	Industrial or process	1.91E-03	1.91E-03	1.91E-03	1.91E-03	1.91E-03
Medium pressure > 15 and < 30 psig	All	Industrial or process	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03
Medium pressure ≥ 30 and < 75 psig	All	Industrial or process	6.45E-03	6.45E-03	6.45E-03	6.45E-03	6.45E-03
High pressure ≥ 75 and < 125 psig	All	Industrial or process	1.21E-02	1.21E-02	1.21E-02	1.21E-02	1.21E-02
High pressure ≥ 125 and < 175 psig	All	Industrial or process	1.68E-02	1.68E-02	1.68E-02	1.68E-02	1.68E-02
High pressure ≥ 175 and < 250 psig	All	Industrial or process	2.27E-02	2.27E-02	2.27E-02	2.27E-02	2.27E-02
High pressure ≥ 250 and < 300 psig	All	Industrial or process	2.90E-02	2.90E-02	2.90E-02	2.90E-02	2.90E-02
Commercial space heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/ university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	8.19E-04	1.26E-03	9.53E-04	5.72E-04	7.05E-04
		Secondary school	8.19E-04	1.12E-03	1.03E-03	6.67E-04	8.19E-04

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
	Food sales	Convenience <u>store</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	8.19E-04	9.53E-04	8.38E-04	6.67E-04	5.33E-04
		24-hour full-service <u>restaurant</u>	8.19E-04	9.34E-04	8.38E-04	6.86E-04	5.14E-04
		Quick-service restaurant	9.14E-04	1.16E-03	9.72E-04	6.48E-04	4.95E-04
		24-hour quick-service <u>restaurant</u>	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	<u>Hospital</u> <u>Inpatient</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient <u>healthcare</u>	5.14E-04	5.33E-04	5.52E-04	1.52E-04	7.62E-05
	Large multifamily	Midrise apartment	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Lodging	Large hotel	1.64E-03	1.56E-03	6.29E-04	4.00E-04	4.00E-04
		Nursing home	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Small hotel/motel	6.86E-04	8.00E-04	3.62E-04	1.91E-04	1.14E-04
	Retail	Stand-alone retail	1.89E-03	1.05E-03	8.19E-04	4.19E-04	4.95E-04
		24-hour stand-alone retail	8.19E-04	1.09E-03	7.81E-04	4.76E-04	5.33E-04
		Strip mall	7.43E-04	1.05E-03	8.00E-04	4.00E-04	5.14E-04
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	1.37E-03	1.26E-03	8.00E-04	4.57E-04	5.14E-04
		Small office	5.52E-04	7.62E-04	5.33E-04	2.67E-04	2.86E-04

Steam type	Building type	Principal building activity	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Service	Service: <u>Excluding food</u>	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	5.14E-04	5.33E-04	3.62E-04	1.52E-04	7.62E-05

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 6 years for standard steam traps and 20 years for venturi steam traps.<sup>593</sup>

## Program Tracking Data and Evaluation Requirements

The list below of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Application type of steam system
- Climate zone if application is commercial heating
- Steam trap quantity
- Type of measure undertaken for each trap: repaired, replaced, or maintained
- Audit documentation, if conducted, including count of leaking or faulty steam traps
- Maintenance documentation, if conducted, indicating strainer maintenance activities undertaken

## References and Efficiency Standards

### Petitions and Rulings

- This section not applicable.

### Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

### Document Revision History

**Table 288. Steam Traps—Revision History**

TRM version	Date	Description of change
v9.0	10/2021	TRM 9.0 origin.
v10.0	10/2022	TRM 10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. Aligned building type names across all commercial measures.</u>

<sup>593</sup> EULs for the steam trap measure are sourced from the Illinois TRM 9.0, volume 2, measure 4.4.16 Steam Trap Replacement or Repair. [https://www.ilsag.info/wp-content/uploads/IL-TRM\\_Effective\\_010121\\_v9.0\\_Vol\\_2\\_C\\_and\\_I\\_09252020\\_Final.pdf](https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf)

## **2.7.102.7.11 Hydraulic Gear Lubricants Measure Overview**

**TRM Measure ID:** NR-MS-HL

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Algorithm

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

Hydraulic gear lubricants are used in manufacturing. Energy efficient hydraulic gear lubricants offer reduced energy consumption over standard lubricants because they have a lower coefficient of friction which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which in turn reduces the energy requirements. Additionally, efficient lubricants have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures which optimizes volumetric and mechanical efficiency.

### **Eligibility Criteria**

The measure is applicable to manufacturing and industrial sites using hydraulic gear lubricants for gearboxes.

### **Baseline Condition**

The baseline condition is a gearbox using standard hydraulic lubricants.

### **High-Efficiency Condition**

The high-efficiency condition is a gearbox using energy-efficiency hydraulic lubricants which have a higher viscosity index than standard lubricants.

### **Energy and Demand Savings Methodology**

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

## Savings Algorithms and Input Variables

$$\text{Energy Savings } [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times \text{hours} \times EI$$

Equation 265

Where:

$HP_{motor}$	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor <sup>594</sup> = 75%
$\eta$	=	Motor efficiency (use default from Table 289 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase = 1.0% per gear mesh <sup>595</sup>

Table 289. Hydraulic Gear Lubricants—Motor Efficiencies<sup>596</sup>

Motor hp	Full load efficiency	Motor hp	Full load efficiency
1	0.855	25	0.936
2	0.865	30	0.941
3	0.895	40	0.941
5	0.895	50	0.945
7.5	0.910	60	0.950
10	0.917	75	0.950
15	0.930	100	0.954
20	0.930		

<sup>594</sup> Assume motor is designed to operate at maximum efficiency, near 75% of rated load. See DOE Motor Challenge Fact Sheet available at <https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf>. Accessed August 2021.

<sup>595</sup> Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. [https://www.ilsag.info/wp-content/uploads/IL-TRM\\_Effective\\_010121\\_v9.0\\_Vol\\_2\\_C\\_and\\_I\\_09252020\\_Final.pdf](https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf). Accessed September 2022.

<sup>596</sup> Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. [https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431\\_125](https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125).



## Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

## Claimed Peak Demand Savings

There are no demand savings for this measure.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the equipment that the lubricant is used with.<sup>597</sup>

## Program Tracking Data and Evaluation Requirements

The list below of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Quantity
- Motor horsepower
- Motor operating hours

## References and Efficiency Standards

### Petitions and Rulings

- This section not applicable.

## Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

Table 290. Hydraulic Gear Lubricants—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>597</sup> U.S. DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>.

## **~~2.7.11~~2.7.12 Hydraulic Oils Measure Overview**

**TRM Measure ID:** NR-MS-HO

**Market Sector:** Commercial

**Measure Category:** Miscellaneous

**Applicable Business Types:** All

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Algorithm

**Savings Methodology:** Engineering algorithms and estimates

### **Measure Description**

Hydraulic oils are lubricants used in manufacturing. Energy-efficient hydraulic oil lubricants offer reduced energy consumption over standard oils because they have a lower coefficient of friction, which reduces the friction between two moving parts (rotating pump equipment and hydraulic oil). This lower coefficient of friction reduces friction between moving components which, in turn, reduces the energy requirements. Additionally, efficient oils have a high viscosity index which reduces the effect of temperature and allows constant viscosity over a range of operating temperatures, optimizing volumetric and mechanical efficiency at the pumps rated output. Additionally, energy efficient hydraulic oils reduce the operating temperature of the hydraulic system.

### **Eligibility Criteria**

The measure is applicable to manufacturing and industrial sites using hydraulic oil lubricants for hydraulic equipment performance.

### **Baseline Condition**

The baseline condition is hydraulic equipment using standard hydraulic oils.

### **High-Efficiency Condition**

The high-efficiency condition is hydraulic equipment using energy-efficient hydraulic oils which have a higher viscosity index than standard oils.

## Energy and Demand Savings Methodology

Electrical energy savings for this measure are calculated based on the energy reduction associated with a reduced coefficient of friction between moving hydraulic machine parts. There are no demand savings for this measure.

### Savings Algorithms and Input Variables

$$\text{Energy Savings } [\Delta kWh] = HP_{motor} \times 0.746 \times \frac{LF}{\eta} \times \text{hours} \times EI$$

Equation 266

Where:

$HP_{motor}$	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor, 75% <sup>598</sup>
$\eta$	=	Motor efficiency (use default from Table 291 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase <sup>599</sup> = 3.2%

Table 291. Hydraulic Oils—Motor Efficiencies<sup>600</sup>

Motor hp	Full load efficiency	Motor hp	Full load efficiency
1	0.855	25	0.936
2	0.865	30	0.941
3	0.895	40	0.941
5	0.895	50	0.945
7.5	0.910	60	0.950
10	0.917	75	0.950
15	0.930	100	0.954
20	0.930		

<sup>598</sup> Assume motor is designed to operate at maximum efficiency, near 75% of rated load. See DOE Motor Challenge Fact Sheet available at <https://www.energy.gov/sites/prod/files/2014/04/f15/10097517.pdf>. Accessed August 2021.

<sup>599</sup> Focus on Energy Lubricant Study, <https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study>.

<sup>600</sup> Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nominal Full-Load efficiencies of General Purpose Electric Motors (Subtype 1), 4 pole motors. [https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431\\_125](https://www.ecfr.gov/cgi-bin/retrieveECFR?n=pt10.3.431#se10.3.431_125).

## Deemed Energy and Demand Savings Tables

There are no savings tables for this measure. Reference the savings equation listed above.

## Claimed Peak Demand Savings

There are no demand savings for this measure.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is 10 years based on the expect life of the motor that the oil is used with.<sup>601</sup>

## Program Tracking Data and Evaluation Requirements

The list below of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Quantity
- Motor horsepower
- Motor operating hours

## References and Efficiency Standards

### Petitions and Rulings

- This section not applicable.

## Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

## Document Revision History

Table 292. Hydraulic Oils—Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.
v10.0	10/2022	TRM v10.0 update. No revision.
<u>v11.0</u>	<u>10/2023</u>	<u>TRM v11.0 update. No revision.</u>

<sup>601</sup> U.S. DOE, Technical Support Document, “Energy Efficiency Program for Commercial Equipment: Energy Conservation Standards for Electric Motors”, Median of “Table 8.2.23 Average Application Lifetime”. Download TSD at: <https://www.mercatus.org/system/files/1904-AC28-TSD-Electric-Motors.pdf>