

Step 3 - Calculate kW_{full} 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:

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

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
- η = Motor efficiency of a standard efficiency motor (see Table 238)

Table 238. Water Pumping VFDs—Motor Efficiencies⁵⁰⁰

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		

⁵⁰⁰ 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.

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.

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_{new} from Annual kWh_{baseline} 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	Winter peak demand kW savings per motor HP
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.⁵⁰¹

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.

- Climate zone or county
- Unit quantity
- 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.
v11.0	10/2023	TRM v11.0 update. No revision.

⁵⁰¹ 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).⁵⁰²

⁵⁰² 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)⁵⁰³ (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)⁵⁰⁴, 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.

⁵⁰³ 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>.

⁵⁰⁴ Federal Standards for Electric Motors, Tables 3 (≤ 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 Applications⁵⁰⁵:

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

Equation 233

Where:

- | | | |
|-------|---|--|
| HP | = | Nameplate horsepower data of the motor |
| 0.746 | = | Constant to convert from hp to kWh ⁵⁰⁶ |
| LF | = | Estimated load factor (if unknown, see Table 241 or Table 242) |

⁵⁰⁵ Assumes three-shift operating schedule

⁵⁰⁶ 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)⁵⁰⁷
- η_{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)
- $kWh_{savings,ROB}$ = 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 Motors—HVAC Input Assumptions

Building type	Load factor ⁵⁰⁸	CF ⁵⁰⁹	HVAC fan hours ⁵¹⁰
Healthcare: Inpatient	0.75	1.00	8,760
Office: Large (>30k sq. ft.)			4,424
Office: Small (≤30k sq. ft.)			4,006
Education: K-12 school			4,173
Education: College/university			4,590
Mercantile: All retail			5,548
Food service: Quick-service restaurant			6,716
Food service: Full-service restaurant			5,256

⁵⁰⁷ In the case of rewind motors, in-situ efficiency may be reduced by a percentage as found in Table 243.

⁵⁰⁸ Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25.

http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

⁵⁰⁹ 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

⁵¹⁰ Factors are equivalent to Table 90 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 242. Premium Motors—Industrial Input Assumptions

Industrial processing	Load factor ⁵¹¹	Hours ⁵¹²					
		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. Premium Motors—Rewound Motor Efficiency Reduction Factors⁵¹³

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

Table 244. Premium Motors—NC/ROB Baseline Efficiencies by Motor Size (%)^{502,506,518}

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

⁵¹¹ 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

⁵¹² 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

⁵¹³ US 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 Motors—Remaining Useful Life (RUL) of Replaced Motor⁵¹⁴

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	17 ⁵¹⁵	0.0
9	5.9		

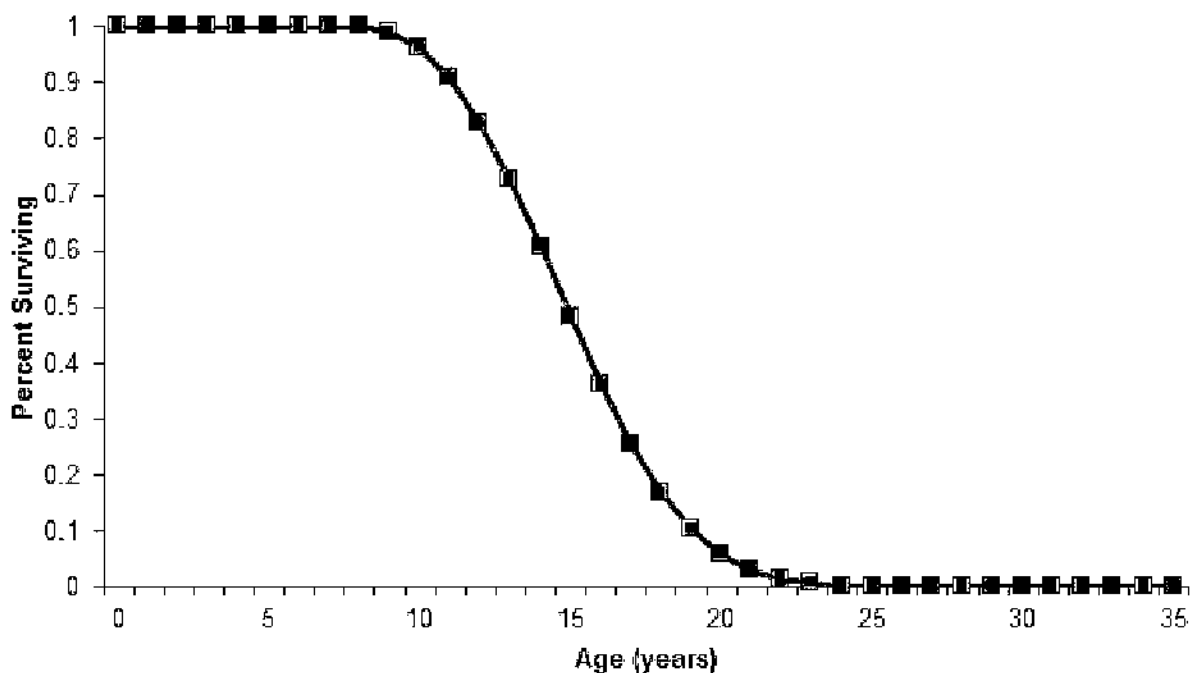
Derivation of RULs

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.

⁵¹⁴ 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.

⁵¹⁵ RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see Figure 7). 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 Motors—Survival Function for Premium Efficiency Motors⁵¹⁶



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

⁵¹⁶ 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.

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)⁵¹⁷
- $kWh_{savings,RUL}$ = 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 Motors—ER Baseline Efficiencies by Motor Size (%)^{504,518}

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

⁵¹⁷ Ibid.

⁵¹⁸ 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 Motors—ER Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)^{519,520}

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.

⁵¹⁹ Federal Standards for Electric Motors, Table 4,

⁵²⁰ 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.⁵²¹

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:

- Unit quantity
- 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.

⁵²¹ US 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 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.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.

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”⁵²² 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 number⁵²³ 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.

⁵²² 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.

⁵²³ 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*⁵²⁴ (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*,⁵²⁵ 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.⁵²⁶

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 243⁵²⁷

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

⁵²⁴ 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).

⁵²⁵ *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.

⁵²⁶ The EM&V Team will work with SPS/Xcel Energy in developing the sample plan for the field data collection effort.

⁵²⁷ 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 245⁵²⁸

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 ⁵²⁹
VolumetricEfficiency%	=	Average well gross production divided by theoretical production (provided on rebate application)
8,760	=	Total hours per year

⁵²⁸ 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).

⁵²⁹ 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% ⁵³⁰
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95% ⁵³¹
Time clock%On	65% ⁵³²

Table 250. Pump-Off Controllers—NEMA Premium Efficiency Motor Efficiencies⁵³³

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%

⁵³⁰ 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.

⁵³¹ Engineering estimate for standard gearbox efficiency.

⁵³² 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.

⁵³³ 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.

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.⁵³⁴

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 times⁵³⁵

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.

⁵³⁴ 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.

⁵³⁵ 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.
v11.0	10/2023	TRM v11.0 update. No revision.

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 spa⁵³⁶.

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.⁵³⁷ 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.

⁵³⁶ 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>

⁵³⁷ 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, 2021.⁵³⁸

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.⁵³⁹

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

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

⁵³⁸ Federal standard for dedicated-purpose pool pumps.

https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67.

⁵³⁹ 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 Assumptions⁵⁴⁰

New pump HP	Hours, limited ⁵⁴¹	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

⁵⁴⁰ 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.

⁵⁴¹ 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^{542,543}

New pump HP	TO, limited	TO, 24/7	V [gal]	EF _{ES} (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 Factors⁵⁴⁴

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 Savings⁵⁴⁵

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

⁵⁴² ENERGY STAR® turnover and EF values are taken from pump curves found in the ENERGY STAR® Pool Pump Savings Calculator.

⁵⁴³ Turnovers calculated as TO = hours x 60 x PFR_{conv} ÷ V.

⁵⁴⁴ Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

⁵⁴⁵ 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.⁵⁴⁶

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 or county

⁵⁴⁶ 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

TRM version	Date	Description of change
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.
v11.0	10/2023	TRM v11.0 update. No revision.

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.⁵⁴⁷

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.

⁵⁴⁷ 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 studies⁵⁴⁸ 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.⁵⁴⁹

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.

⁵⁴⁸ 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.

⁵⁴⁹ 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 ⁵⁵⁰	Heat pump				Electric resistance heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
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
10-degree setup/setback offset								
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 ⁵⁵⁰	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
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

⁵⁵⁰ 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 ⁵⁵⁰	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
10-degree setup/setback offset								
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 ⁵⁵⁰	Heat pump				Electric heat			
	HVAC only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
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
10-degree setup/setback offset								
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 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 Study⁵⁵¹. 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 or county
- 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

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.

⁵⁵¹ 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.

Document Revision History

Table 262. Lodging Occupancy Sensors—Revision History

TRM version	Date	Description of change
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.
v11.0	10/2023	TRM v11.0 update. No revision.

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, 2019.⁵⁵²

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 Savings⁵⁵³

Climate zone	kWh savings	Summer kW savings ⁵⁵⁴	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

⁵⁵² Appliance Standards for Refrigerated Beverage Vending Machines.

https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

⁵⁵³ Pacific Gas and Electric, Work Paper VMCold, Revision 3, August 2009, Measure Code R97.

⁵⁵⁴ 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.

Table 264. Vending Controls—Refrigerated Reach-In Energy and Peak Demand Savings⁵⁵⁵

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 Savings⁵⁵⁶

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.⁵⁵⁷

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

⁵⁵⁵ Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.

⁵⁵⁶ Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.

⁵⁵⁷ 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.
- 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

TRM version	Date	Description of change
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.
v11.0	10/2023	TRM v11.0 update. No revision.

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 Calculator⁵⁵⁸, and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.⁵⁵⁹

⁵⁵⁸ ENERGY STAR Low Carbon IT Calculator available for download at:
https://www.energystar.gov/products/low_carbon_it_campaign/put_your_computers_sleep.

⁵⁵⁹ 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.⁵⁶⁰

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings [ΔkWh]

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

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)

⁵⁶⁰ 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 Wattages⁵⁶¹

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional monitor ⁵⁶²	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

⁵⁶¹ 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.

⁵⁶² Average of 17.0-24.9 inches monitor sizes taken from the ENERGY STAR® Office Equipment Calculator.

Table 268. Computer Power Management—Operating Hours⁵⁶³

Building activity type	Hrs _{Active,pre}	Hrs _{Active,post}	Hrs _{Sleep,pre}	Hrs _{Sleep,post}	Hrs _{Off,pre}	Hrs _{Off,post}
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 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 monitor	51.3
ENERGY STAR computer	89.5
ENERGY STAR notebook	27.5

⁵⁶³ Hours taken from assumptions in the ENERGY STAR calculator. Hours_{pre} assume baseline computer settings never enter sleep mode, and 36% of computers are turned off each night. Hours_{post} 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.⁵⁶⁴

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)

⁵⁶⁴ 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.

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

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. 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.
v11.0	10/2023	TRM v11.0 update. No revision.

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, 2021.⁵⁶⁵

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

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

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

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

Equation 256

Where:

- Hrs_{plug} = Time per day the vehicle is plugged into the EVSE and not charging [hours]⁵⁶⁶ = 2.8
- W_{plug} = Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging [W]⁵⁶⁷ = 6.9 W

⁵⁶⁵ 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.

⁵⁶⁶ 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.

⁵⁶⁷ 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]⁵⁶⁸ = 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]⁵⁶⁹ = 3.3
- $days_C$ = Number of charging days per year [days]⁵⁷⁰ = 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 factor⁵⁷¹
- PDPF = Peak demand probability factor (see Table 273)

Table 273. EVSE—Peak Demand Probability Factors⁵⁷²

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

⁵⁶⁸ 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.

⁵⁶⁹ Average No Vehicle Mode Input Power from ENERGY STAR certified EVSE product list.

⁵⁷⁰ 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. $365 \times 0.56 = 204$.

⁵⁷¹ ENERGY STAR Electric Vehicle Chargers Buying Guidance: "ENERGY STAR 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>.

⁵⁷² 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 Climate zone	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.⁵⁷³

⁵⁷³ 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.

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 or county
- Location Type (public, workplace, or fleet) ⁵⁷⁴
- 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

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. Added reference for ENERGY STAR version.
v11.0	10/2023	TRM v11.0 update. No revision.

⁵⁷⁴ 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 Requirements⁵⁷⁵

Performance factor		Requirement
Charge return factor	100 percent, 80 percent 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 area 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:

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

⁵⁷⁵ 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 W to kW

Table 278. Battery Chargers—Charging and Idle Hours Assumptions⁵⁷⁶

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 Assumptions⁵⁷⁷

Equipment	W _{C,pre}	W _{M,pre}	W _{NB,pre}	W _{C,post}	W _{M,post}	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 Factors⁵⁷⁸

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.

⁵⁷⁶ "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.

⁵⁷⁷ "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.

⁵⁷⁸ "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

Equipment	kWh savings	Summer kW savings	Winter kW savings
Single phase	1,111	0.02	–
Three phase	5,562	0.63	–

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.⁵⁷⁹

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

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

⁵⁷⁹ "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.

2.7.10 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

$$\text{Energy Savings } [\Delta kWh] = \Delta \text{Water (gallons)} / 1,000,000 \times E_{\text{water supply}} \quad \text{Equation 261}$$

$$\Delta \text{Water} = \frac{S_L \text{ (lb/hr)}}{8.33 \text{ (lbs/gal)}} \times \text{Hours} \times L \quad \text{Equation 262}$$

$$S_L = 24.24 \times P_{ia} \times D^2 \times A \times FF \quad \text{Equation 263}$$

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{\text{Hours}} \times DF \quad \text{Equation 264}$$

Where:

$E_{\text{water supply}}$	=	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 ²)
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
- CF* = Peak 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 *CF* for stand-alone retail

Table 283. Steam Traps—Savings Calculation Input Assumptions⁵⁸⁰

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, <i>S_L</i> (lb/hr/trap)	Hours	<i>L</i>
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

⁵⁸⁰ 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

Table 284. Steam Traps—Commercial Heating Hours

Climate zone	Hours (HDD) ⁵⁸¹
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

⁵⁸¹ 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 store	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 restaurant	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 restaurant	2.47E-04	3.09E-04	2.57E-04	1.75E-04	1.34E-04
	Healthcare	Inpatient	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient	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 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
	Service	Service: Excluding food	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
	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
	Food sales	Convenience store	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
		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 restaurant	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 restaurant	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	Inpatient	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient	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
	Public assembly	Public assembly	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
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Service	Service: Excluding food	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.⁵⁸²

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 or county 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.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures.

⁵⁸² 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>

2.7.11 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

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

Equation 265

Where:

HP_{motor}	=	Horsepower of the motor, actual nameplate
0.746	=	Constant to convert from hp to kW
LF	=	Motor load factor ⁵⁸³ = 75%
η	=	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 ⁵⁸⁴

Table 289. Hydraulic Gear Lubricants—Motor Efficiencies⁵⁸⁵

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		

⁵⁸³ 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.

⁵⁸⁴ 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. Accessed September 2022.

⁵⁸⁵ 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.

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.⁵⁸⁶

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.
v11.0	10/2023	TRM v11.0 update. No revision.

⁵⁸⁶ 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>.

2.7.12 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% ⁵⁸⁷
η	=	Motor efficiency (use default from Table 291 if actual is not available)
hours	=	Operating hours per year, actual
EI	=	Efficiency increase ⁵⁸⁸ = 3.2%

Table 291. Hydraulic Oils—Motor Efficiencies⁵⁸⁹

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		

⁵⁸⁷ 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.

⁵⁸⁸ Focus on Energy Lubricant Study, <https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study>.

⁵⁸⁹ 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.

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.⁵⁹⁰

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.
v11.0	10/2023	TRM v11.0 update. No revision.

⁵⁹⁰ 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>

2.7.13 Hand Dryers Measure Overview

TRM Measure ID: NR-MS-HD

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Retail, commercial, and industrial settings

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This document presents the methodology for calculating the savings realized from installing efficient hand dryers, which save energy by drying with air movement using motion sensors, thus reducing hand-drying time.

Eligibility Criteria

To qualify for this measure, existing hand dryer equipment must currently utilize more than 5 watt-hour (Wh) or more per use and replacement hand dryers must consume no more than 5 Wh per use. This measure is applicable in retail, commercial and industrial settings.

Baseline Condition

The baseline efficiency case is a hand dryer which utilizes more than 5 Wh or more per use. These hand dryers are often push-button activated.

High-Efficiency Condition

Eligible high-efficiency equipment is a hand dryer equipped with motion sensors that uses 5 Wh or less per use.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The energy savings from the installation of efficient hand dryers are a result of savings due to decrease in power and or runtime of the efficient hand dryers over the pre-retrofit equipment. The energy and demand savings are calculated using the following equations:

$$\text{Energy Savings } [\Delta kWh] = \frac{UPD \times DPY \times \Delta Wh}{1,000} \times IEF_E$$

Equation 267

$$\Delta Wh = Wh_{Baseline} - Wh_{Efficient}$$

Equation 268

Where:

- UPD* = Number of uses per day (see Table 274)
- DPY* = Number of days the facility operates per year (if unknown, see Table 274)
- IEF_E* = Interactive effects factor for energy (see Table 293)

Table 293. Hand Dryers—Deemed Energy and Demand Interactive Factors⁵⁹¹

Space conditioning type	IEF _E	IEF _D
Refrigerated air	1.05	1.10
Evaporative cooling	1.02	1.04
None (unconditioned/uncooled)	1.00	1.00

Wh_{Baseline} = Baseline energy consumption in watt-hours, 20.65⁵⁹²

Wh_{Efficient} = Efficient energy consumption in watt-hours, 3.94⁵⁹³

$$\text{Peak Demand Savings } [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF \times IEF_D$$

Equation 269

⁵⁹¹ Texas Technical Reference Manual, Volume 2, Section 2.1, Table 11, Nonresidential Lighting.

⁵⁹² Baseline and efficient Wh per use are averages of the energy consumption of 48 surveyed individual hand dryer units by CLEAResult in Arkansas which consume either greater than 5 Wh or less than 5 Wh per use, respectively. The difference between these equals the assumed Wh savings per use.

⁵⁹³ Ibid.

Where:

- AOH = Annual operating hours (see Table 294)
- CF = Peak coincidence factor (see Table 294)
- IEF_D = Interactive effects factor for demand (see Table 293)

Table 294. Hand Dryers—Savings Calculation Input Assumptions

Usage level	Building type	Coincidence factor ⁵⁹⁴					AOH ⁵⁹⁵	UPD ⁵⁹⁶	DPY ⁵⁹⁷
		CZ 1	CZ 2	CZ 3	CZ 4	CZ 5			
Low	Office	0.87	0.88	0.86	0.90	0.90	36	50	250
	Warehouse	0.79	0.81	0.79	0.80	0.85			
Medium/moderate	Grocery (small)	0.90	0.90	0.90	0.90	0.90	235	225	365
	Restaurant	0.90	0.90	0.90	0.90	0.90			
	Retail	0.90	0.90	0.90	0.90	0.90			
High	Conference center	0.65	0.65	0.65	0.65	0.65	339	500	237
	School ⁵⁹⁸	0.39	0.39	0.90	0.87	0.40			
	Stadium	0.65	0.65	0.65	0.65	0.65			
	Theater	0.65	0.65	0.65	0.65	0.65			
	University	0.90	0.90	0.90	0.90	0.90			
High (grocery)	Grocery/retail (large)	0.90	0.90	0.90	0.90	0.90		500	365
Heavy duty/extreme	Airport	0.90	0.90	0.90	0.90	0.90	2,614	2,500	365
	Transportation center	0.90	0.90	0.90	0.90	0.90			

⁵⁹⁴ Coincidence factors from the Texas TRM Volume 3, Section 2.1, Table 8, Nonresidential Lighting. It is assumed that building occupancy with respect to lighting is an appropriate proxy for occupants' utilization of hand dryers.

⁵⁹⁵ The assumed annual operating hours per building type are calculated as a simple average of 16 surveyed efficient hand dryers' cycle times multiplied by the assumed uses per day and days per year per usage level (as indicated in Table 294), then converted to hours by dividing this product by 3,600.

⁵⁹⁶ Industry Standard. Medium/Moderate Uses per day is supported by both Excel Dryer Data (Cost Savings with Hand Dryers vs Average Cost of Paper Towels <https://www.exceldryer.com/calculator-dial/>) and World Dryer Data (<http://staging.worlddryer.com/savings-calculator>)

⁵⁹⁷ Technology Data Characterizing Water Heating in Commercial Buildings: Application to End-Use Forecasting, Osman Sezgen and Jonathan G. Koomey, Lawrence Berkeley National Laboratory, December 1995. Table 2. <https://eta-publications.lbl.gov/sites/default/files/lbnl-37398e.pdf>.

⁵⁹⁸ Assuming K-12 without summer session

Deemed Energy and Demand Savings Tables

The deemed energy and demand savings for hand dryers with unknown number of operating days per year, base/efficient cycles times, and base/efficient unit wattages are as follows:

Table 295. Hand Dryers—Energy Savings

Usage level	Building type	Deemed energy savings
Low	Office	223
	Warehouse	223
Medium/moderate	Grocery (small)	1,468
	Restaurant	1,468
	Retail	1,468
High	Conference center	2,118
	School ⁵⁹⁹	2,118
	Stadium	2,118
	Theater	2,118
	University	2,118
High (grocery)	Grocery/retail (large)	3,262
Heavy duty/extreme	Airport	16,312
	Transportation center	16,312

⁵⁹⁹ Assuming K–12 without summer session.

Table 296. Hand Dryers—Peak Demand Savings

Usage level	Building type	Deemed demand savings				
		CZ 1	CZ 2	CZ 3	CZ 4	CZ 5
Low	Office	5.43	5.49	5.37	5.62	5.62
	Warehouse	4.93	5.05	4.93	4.99	5.30
Medium/moderate	Grocery (small)	5.62	5.62	5.62	5.62	5.62
	Restaurant	5.62	5.62	5.62	5.62	5.62
	Retail	5.62	5.62	5.62	5.62	5.62
High	Conference center	4.06	4.06	4.06	4.06	4.06
	School ⁶⁰⁰	2.43	2.43	5.62	5.43	2.50
	Stadium	4.06	4.06	4.06	4.06	4.06
	Theater	4.06	4.06	4.06	4.06	4.06
	University	5.62	5.62	5.62	5.62	5.62
High (grocery)	Grocery/retail (large)	8.65	8.65	8.65	8.65	8.65
Heavy duty/extreme	Airport	5.62	5.62	5.62	5.62	5.62
	Transportation center	5.62	5.62	5.62	5.62	5.62

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 years⁶⁰¹ for efficient hand dryers.

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 or county
- Building type
- Cooling type

⁶⁰⁰ Assuming K–12 without summer session.

⁶⁰¹ Based on studies conducted by two separate parties; Comparative Environmental Life Cycle Assessment of Hand Drying Systems by Quantis (pg. 2) and Guidelines to Reduce/Eliminate Paper Towel Use by Installing Electric Hand Dryers by Partners in Pollution Prevention P3 (pg. 17).

- Hand dryer quantity
- Hand dryer make and model

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 297. Hand Dryers—Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin
v11.0	10/2023	TRM v11.0 update. No revision.

2.7.14 Laser Projectors Measure Overview

TRM Measure ID: NR-LT-LP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Motion picture theaters

Fuels Affected: Electricity

Decision/Action Types: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the replacement of a lamp-based projector with a laser projector. The conversion from a traditional lamp-based projector system to a laser projector benefits from reduced energy consumption via electricity savings and HVAC savings. With advancements in solid-state technology, laser projectors typically require half the electricity to obtain the equivalent light and resolution output as lamp-based projectors. Due to this reduced electricity consumption, laser projectors also benefit from HVAC savings, with significantly less energy wasted as heat. Another benefit of laser projectors is that they do not require the use of lamps, which can be costly from an equipment and operations standpoint.

Despite the various ways laser projectors result in energy savings, this measure solely focuses on the electricity savings for operating the projector. Due to interactive effects unique to each site, this measure will not consider the corresponding HVAC savings, so annual savings estimates are conservative.

Eligibility Criteria

This measure applies to the replacement of any motion picture theater lamp-based projector. At this time, this measure is limited to retrofit applications where the baseline lamp wattage is specified to match site conditions. Eligibility may be extended to new construction applications once sufficient program implementation data can be collected to establish an appropriate baseline.

Baseline Condition

There is no federal standard applicable to lamp-based projectors. The baseline condition is any commercial cinema lamp-based projector that is replaced by a laser projector. The measure does not consider home, office, venue or any projector replacements that are outside of a professional cinema setting.

High-Efficiency Condition

The high-efficiency condition is a professional commercial cinema laser projector with an equivalent (or no greater than 110%) lumen output of the baseline projector being replaced.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for laser projectors.

Energy Savings Algorithms

Energy savings for this measure are determined to be the difference in maximum operating input rate for the baseline and efficient projector multiplied by the total yearly operating hours for the facility.

$$\text{Energy Savings [kWh]} = (kW_{pre} - kW_{installed}) \times \text{Hours}$$

Equation 270

$$\text{Summer Peak Demand Savings [kW}_S] = (kW_{pre} - kW_{installed}) \times CF_S$$

Equation 271

$$\text{Winter Peak Demand Savings [kW}_W] = (kW_{pre} - kW_{installed}) \times CF_W$$

Equation 272

Where:

kW_{pre} = Total kW of existing lamp-based projector

$kW_{installed}$ = Total kW of efficient laser projector

Hours = Annual operating hours = 3,653 hours⁶⁰² (use actual hours if known)

CF_S = Summer peak coincidence factor = 0.65 (all climate zones)⁶⁰³

CF_W = Winter peak coincidence factor = 0 (all climate zones)⁶⁰⁴

⁶⁰² "HVAC considerations for lamp and laser projectors in cinema," Barco. July 26, 2021. The reference uses 11.5 hours per day (or 4,200 hours) as an example. This measure assumes 10 hr/day as a conservative assumption, but allows for the use of custom hours based on site conditions. Default hours are calculated as 10 hr/day x 365.25 day/year = 3,653 hours.

⁶⁰³ Refer to Lamps and Fixtures measure for the public assembly building type, which is applicable to motion picture theaters.

⁶⁰⁴ Ibid.

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 for cinema laser projectors.^{605,606,607}

Program Tracking Data and Evaluation Requirements

The program database should specify and track the list of primary inputs and contextual data provided below. This will inform the evaluation process and ensure proper application of the savings.

- Building type
- Baseline lamp-based projector manufacturer and model number
- Baseline projector lamp wattage
- Baseline lamp-based projector nameplate photo
- New laser projector manufacturer and model number
- New laser projector wattage
- New projector nameplate photo
- Proof of purchase: invoice showing model number and quantity purchased

Document Revision History

Table 298. Laser Projectors—Revision History

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

⁶⁰⁵ Average rated life of 18 Barco and Christie cinema laser projectors = 41,667 hours. Dividing by annual operating hours yields EUL.

⁶⁰⁶ Barco cinema projector product listing. <https://www.barco.com/en/products/projection/overview?facets=barco-dxp%3Aproduct%2Fproduct-category%2Fprojection%2Fcinema-projectors>.

⁶⁰⁷ Christie cinema projector product listing. <https://www.christiedigital.com/products/cinema/projection/>.

APPENDIX A: MEASURE LIFE CALCULATIONS FOR DUAL BASELINE MEASURES

The following appendix describes the method to calculate savings for any dual baseline measure, including all early retirement measures. This supersedes the previous Measure Life Savings found in PUCT Dockets 40083 and 40885 and is revised to clarify the understanding of the measure life calculations and reduce any misrepresentation of net present value (NPV) of early retirement projects.

Option 1 provides reduced savings claimed over the full EUL. Option 2 provides higher savings claimed over a reduced EUL. The lifetime savings are the same for both options 1 and 2. Option 1 calculations were originally provided in Docket [43681].

Option 1—Weighting Savings and Holding Measure Life Constant

Step 1: Determine the measure life for first-tier (FT) and second-tier (ST) components of the calculated savings:

$$\text{First Tier (FT) Period} = ML_{FT} = RUL \quad \text{Equation 273}$$

$$\text{Second Tier (ST) Period} = ML_{ST} = EUL - RUL \quad \text{Equation 274}$$

Where:

RUL = The useful life corresponding with the first tier-savings; for early retirement projects, *RUL* is the remaining useful life determined from lookup tables based on the age of the replaced unit (or default age when actual age is unknown)

EUL = The useful life corresponding with the second-tier savings; for early retirement projects, *EUL* is the estimated useful life as specified in applicable measure from Texas TRM (or approved petition)

Step 2: Calculate the FT demand and energy savings and the ST demand and energy savings:

$$\Delta kW_{FT} = kW_{retired} - kW_{installed} \quad \text{Equation 275}$$

$$\Delta kW_{ST} = kW_{baseline} - kW_{installed} \quad \text{Equation 276}$$

$$\Delta kWh_{FT} = kWh_{retired} - kWh_{installed} \quad \text{Equation 277}$$

$$\Delta kWh_{ST} = kWh_{baseline} - kWh_{installed}$$

Equation 278

Where:

ΔkW_{FT}	=	First-tier demand savings
ΔkW_{ST}	=	Second-tier demand savings
$kW_{retired}$	=	Demand of the first-tier baseline system, usually the retired system ⁶⁰⁸
$kW_{baseline}$	=	Demand of the second-tier baseline system, usually the baseline ROB system ⁶⁰⁹
$kW_{installed}$	=	Demand of the replacement system ⁶¹⁰
ΔkWh_{FT}	=	First-tier energy savings
ΔkWh_{ST}	=	Second-tier energy savings
$kWh_{retired}$	=	Energy usage of the first-tier baseline system, usually the retired system ⁶⁰⁸
$kWh_{baseline}$	=	Energy usage of the second-tier baseline system, usually the baseline ROB system ⁶⁰⁹
$kWh_{installed}$	=	Energy usage of the replacement system ⁶¹⁰

Step 3: Calculate the avoided capacity and energy cost contributions of the total NPV for both the ER and ROB components:

$$NPV_{FT,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{FT}} \right\} \times \Delta kW_{FT}$$

Equation 279

$$NPV_{ST,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kW_{ST}$$

Equation 280

$$NPV_{FT,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{FT}} \right\} \times \Delta kWh_{FT}$$

Equation 281

⁶⁰⁸ Retired system refers to the existing equipment that was in use before the retrofit has occurred.

⁶⁰⁹ Baseline used for a replace-on-burnout project of the same type and capacity as the system being installed in the Early Retirement project (as specified in the applicable measure).

⁶¹⁰ Replacement system refers to the installed equipment that is in place after the retrofit has occurred.

$$NPV_{ST,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{ML_{ST}} \right\} \times \frac{(1+e)^{ML_{FT}}}{(1+d)^{ML_{FT}}} \times \Delta kWh_{ST}$$

Equation 282

Where:

$NPV_{FT,kW}$	=	Net Present Value (kW) of first-tier projects
$NPV_{ST,kW}$	=	Net Present Value (kW) of second-tier projects
$NPV_{FT,kWh}$	=	Net Present Value (kWh) of first-tier projects
$NPV_{ST,kWh}$	=	Net present value (kWh) of second-tier projects
e	=	Escalation rate ⁶¹¹
d	=	Discount rate weighted average cost of capital (per utility) ⁶¹¹
AC_{kW}	=	Avoided cost per kW (\$/kW) ⁶¹¹
AC_{kWh}	=	Avoided cost per kWh (\$/kWh) ⁶¹¹
ML_{FT}	=	First-tier measure life (calculated in Equation 273)
ML_{ST}	=	Second-tier measure life (calculated in Equation 274)

Step 4: Calculate the total capacity and energy cost contributions to the total NPV:

$$NPV_{Total,kW} = NPV_{FT,kW} + NPV_{ST,kW}$$

Equation 283

$$NPV_{Total,kWh} = NPV_{FT,kWh} + NPV_{ST,kWh}$$

Equation 284

Where:

$NPV_{Total,kW}$	=	Total capacity contributions to NPV of both first-tier and second-tier component
$NPV_{Total,kWh}$	=	Total energy contributions to NPV of both first-tier and second-tier component

⁶¹¹ The exact values to be used each year for the escalation rate, discount rate, and avoided costs are established by the PUC in Substantive Rule §25.181 and updated annually, as applicable. Please note that the discount rates are based on a utility's weighted average cost of capital and, as such, will vary by utility and may change each year.

Step 5: Calculate the capacity and energy cost contributions to the NPV without weighting by demand and energy savings for a scenario using the original EUL:

$$NPV_{EUL,kW} = AC_{kW} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{EUL} \right\}$$

Equation 285

$$NPV_{EUL,kWh} = AC_{kWh} \times \frac{1+e}{d-e} \times \left\{ 1 - \left[\frac{1+e}{1+d} \right]^{EUL} \right\}$$

Equation 286

Where:

$NPV_{EUL,kW}$ = Capacity contributions to NPV without weighting, using original EUL

$NPV_{EUL,kWh}$ = Energy contributions to NPV without weighting, using original EUL

Step 6: Calculate the weighted demand and energy savings by dividing the combined capacity and energy cost contributions from the ER and ROB scenarios by the non-savings weighted capacity and energy cost contributions from the single EUL scenario. These weighted savings are claimed over the original measure EUL:

$$\begin{aligned} \text{Weighted } kW &= \frac{NPV_{Total\ kW}}{NPV_{EUL,kW}} \\ &= \frac{\left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RII} \right) \times (kW_{retired} - kW_{installed}) \right] + \left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RII-RII} \right) \times \frac{(1+e)^{RII}}{(1+d)^{RII}} \times (kW_{baseline} - kW_{installed}) \right]}{\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL} \right)} \end{aligned}$$

Equation 287

$$\begin{aligned} \text{Weighted } kWh &= \frac{NPV_{Total\ kWh}}{NPV_{EUL,kWh}} \\ &= \frac{\left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RII} \right) \times (kWh_{retired} - kWh_{installed}) \right] + \left[\left(1 - \left(\frac{1+e}{1+d} \right)^{RII-RII} \right) \times \frac{(1+e)^{RII}}{(1+d)^{RII}} \times (kWh_{baseline} - kWh_{installed}) \right]}{\left(1 - \left(\frac{1+e}{1+d} \right)^{EUL} \right)} \end{aligned}$$

Equation 288

Where:

Weighted kW = Weighted lifetime demand savings

Weighted kWh = Weighted lifetime energy savings

$NPV_{Total, kW}$ = Total capacity contributions to NPV of both ER and ROB component, calculated in Equation 283

- $NPV_{Total, kWh}$ = Total energy contributions to NPV of both ER and ROB component, calculated in Equation 284
- $NPV_{EUL, kW}$ = Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 285
- $NPV_{EUL, kWh}$ = Energy contributions to NPV without weighting, using original EUL, calculated in Equation 286

Option 2—Weighting Measure Life and Holding First Year Savings Constant

Repeat Step 1 through Step 4 from Option 1.

Step 5: Reverse calculate the EUL for the capacity and energy contributions to the NPV for a scenario using the first-tier savings:

$$EUL_{kW} = \frac{\ln \left[\frac{NPV_{Total, kW} \times (d - e)}{\Delta kW_{FT} \times AC_{kW} \times (1 + e)} \right]}{\ln \left[\frac{(1 + e)}{(1 + d)} \right]}$$

Equation 289

$$EUL_{kWh} = \frac{\ln \left[\frac{NPV_{Total, kWh} \times (d - e)}{\Delta kWh_{FT} \times AC_{kWh} \times (1 + e)} \right]}{\ln \left[\frac{(1 + e)}{(1 + d)} \right]}$$

Equation 290

Where:

- EUL_{kW} = EUL for capacity contribution to NPV using first-tier savings
- EUL_{kWh} = EUL for energy contribution to NPV using first-tier savings

Step 6: Confirm that capacity EUL and energy EUL are equivalent. First-tier savings are claimed over this weighted EUL.

Public Utility Commission of Texas

Texas Technical Reference Manual

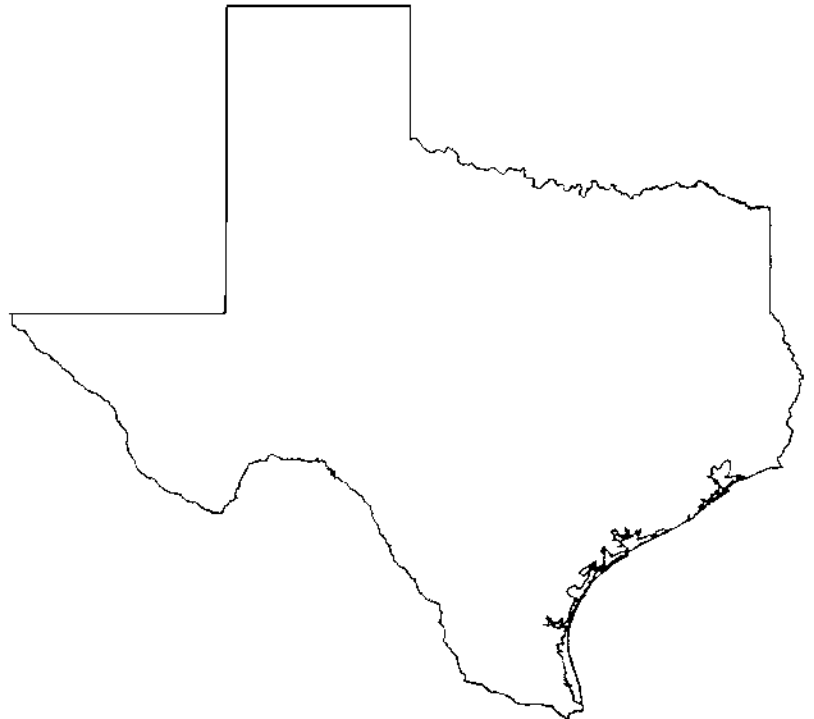
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Acknowledgments

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TRM Technical Support

Technical support and questions can be emailed to the EM&V team's project manager (lark.lee@tetrattech.com) and PUCT staff (therese.harris@puct.texas.gov).

1. INTRODUCTION

This volume of the TRM contains Measurement and Verification (M&V) protocols for determining and/or verifying utility claimed energy and demand savings for particular measures or programs ((§ 25.181(q)(6)(A)). Table 1 provides an overview of the M&V measures contained within Volume 4 and the types of savings estimates available for each one.

M&V protocols are included for the following measures:

- HVAC: Air Conditioning Tune-up
- HVAC: Ground Source Heat Pump
- HVAC: Variable Refrigerant Flow Systems
- Whole House: Residential New Construction
- Whole House: Smart Home Energy Management System (SHEMS)
- Building Energy Codes: Residential Energy Code Compliance Enhancement
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Renewables: Solar Attic Fans
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors Less than 75 hp
- Miscellaneous: Nonresidential Measurement and Verification
- Miscellaneous: Thermal Energy Storage
- Load Management: Residential Load Curtailment
- Load Management: Nonresidential Load Curtailment

Additional M&V protocols will be included in future versions of TRM Volume 4 as they are submitted, reviewed, and approved by the EM&V team and Commission staff. TRM Volume 1: Overview and User Guide, Section 4: Structure and Content details the organization of the measure templates presented in this volume.

Table 1. Residential and Nonresidential M&V Savings by Measure Category

Sector	Measure category	Measure description	11.0 update
Residential and nonresidential	HVAC	Air conditioning tune-ups	Added age requirement to eligibility. Removed pressure correlation equation and replaced with deemed pressure by climate zone. Added language describing efficiency loss factor determination in more detail and implementer/evaluator responsibilities. Added an additional airflow rate determination method. Added additional tracking system and documentation requirements. Added reference to ASHRAE Fundamentals Chapter 1.
Nonresidential	HVAC	Ground source heat pumps	Updated program tracking and documentation.
Nonresidential	HVAC	Variable refrigerant flow systems	Updated baseline conditions to match the federal regulations.
Residential	Whole house	Residential new construction	Added clarification on baseline study usage and clarified that RESNET accreditation is not required and utilities can request EM&V review and approval of new software.
Residential	Whole house	Smart home energy management system (SHEMS)	No revision.
Residential	Building energy codes	Residential energy code compliance enhancement	Adjusted calculation process to estimate building population.
Residential and nonresidential	Renewables	Residential and nonresidential solar photovoltaics	Eliminated alternate savings method and adjusted premium module type requirements to match PVWatts. Clarified assumptions to use in PVWatts analysis.
Residential and nonresidential	Renewables	Solar shingles	No revision.
Residential	Renewables	Solar attic fans	No revision.
Nonresidential	Miscellaneous	Behavioral	No revision.
Nonresidential	Miscellaneous	Air compressors less than 75 hp	No revision.
Nonresidential	Miscellaneous	Nonresidential custom	TRM v11.0 origin.
Nonresidential	Miscellaneous	Nonresidential measurement and verification	Minor clarifications.
Nonresidential	Miscellaneous	Energy storage	Revised measure to be for energy storage, not just thermal energy storage.
Nonresidential	Miscellaneous	Uninterruptible power supply	TRM v11.0 origin.

Sector	Measure category	Measure description	11.0 update
Residential	Load management	Residential load curtailment	No revision.
Nonresidential	Load management	Nonresidential load curtailment	Updated utility program details (added three winter load management programs). Added guidance on selecting baseline days when there is a tie between the days used to calculate the baseline.

2. M&V MEASURES

2.1 M&V: HVAC

2.1.1 Air Conditioning Tune-Ups Measure Overview

TRM Measure ID: R-HV-TU and NR-HV-TU

Market Sector: Residential and commercial

Measure Category: HVAC

Applicable Building Types: Residential; commercial

Fuels Affected: Electricity

Decision/Action Type(s): Operation and maintenance (O&M)

Program Delivery Type(s): Custom

Deemed Savings Type: Deemed efficiency loss factors are applied to measured operating performance indicators to estimate energy saving impacts; the deemed efficiency loss factors estimate equipment improvements based on each unit's specific operating conditions

Savings Methodology: Algorithms, EM&V, and deemed efficiency loss corresponding to whether refrigerant charge was adjusted

AC tune-ups promote a holistic approach to improve the operational efficiency of existing air conditioners by completing six tune-up service measures. This protocol is used to estimate savings for tune-up measures through an M&V approach that relies on test-out measurements of key AC performance indicators following completion of all tune-up service measures.

The M&V protocols are for air conditioner tune-ups (AC tune-up) for equipment where the six tune-up service measures are completed by professional air conditioning technicians. Tuned air conditioners are then performance tested under protocol conditions to ensure the AC system is under significant load and at steady-state conditions prior to recording measurements. Compliance with these M&V protocols ensures reliable performance measurements to estimate the energy savings impacts from the combined effects of all six tune-up service measures.

Measure Description

AC tune-ups must be professionally completed by qualified air conditioning service technicians using measurement tools and equipment. This protocol covers assumptions made for baseline equipment efficiencies based on previous M&V tune-ups in Texas from a three-year rolling average. The energy savings estimations process is designed to efficiently estimate electric energy and demand savings attributable to each participating AC tune-up unit. Following the completion of the service measures, the M&V methodology for tune-ups requires in-field measurement and recording of AC performance parameters under protocol conditions to record *in situ*, post-tune-up performance to calculate estimated energy impacts.

The AC tune-up requires completion of six tune-up service measure tasks listed below:

- Clean condenser surfaces
- Clean evaporator surfaces
- Clean blower assembly (fan blades, plenum interior)
- Verify filter is clean: change or clean as needed
- Verify airflow within 15 percent of 400 cubic feet per minute per ton; adjust as needed
- Check refrigerant charge; adjust as needed

Applicable equipment types include:

- Packaged and split air conditioners (DX or air-cooled)
- Packaged and split heat pumps (air-cooled)

Eligibility Criteria

This measure only applies to existing air conditioning equipment (split and packaged air conditioner and heat pump systems) that receive the tune-up and have not been serviced through a utility program in the last five years. For an AC tune-up to be eligible to use the deemed efficiency loss factors and savings approach, the AC tune-up must include completion of the tune-up service measures, and the following conditions must be met:

- Use of program-specified measurement equipment and accuracies
- Tune-up completed by a qualified technician
- Document all service procedures completed during tune-up (e.g., clean AC components, verify airflow, and check/adjust refrigerant charge)
- Outdoor air temperature must be:
 - Greater than 75°F dry bulb or
 - Greater than 70°F wet bulb and greater than 56°F dry bulb

Baseline Condition

The baseline efficiency conditions are calculated (see Equation 6 and Equation 8) based on the efficiency loss values determined by this protocol (see Table 2).

High-Efficiency Condition

The high-efficiency conditions are calculated based on measurements taken in the field with calibrated equipment after the tune-up has been performed. These test-out (TO) measurements are then adjusted to Air-Conditioning Refrigeration and Heating Institute (AHRI)-standard operating conditions to develop an in-situ post-tune-up high-efficiency condition. The equipment efficiency effects are used to estimate cooling and heating (heat pumps only) energy impacts as applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

Equation 1

$$\text{Peak Demand Savings } [kW_{\text{savings,C}}] = Cap_{\text{Rated}} \times \left(\frac{1}{\eta_{\text{pre,C}}} - \frac{1}{\eta_{\text{post,C}}} \right) \times CF \times \frac{kW}{1000 W}$$

Equation 2

$$\text{Energy (Cooling) } [kWh_{\text{savings,C}}] = Cap_{\text{Rated}} \times \left(\frac{1}{\eta_{\text{pre,C}}} - \frac{1}{\eta_{\text{post,C}}} \right) \times EFLH_C \times \frac{kW}{1000 W}$$

Equation 3

$$\text{Energy (Heating) } [kWh_{\text{savings,H}}] = Cap_{\text{Rated}} \times \left(\frac{1}{\eta_{\text{pre,H}}} - \frac{1}{\eta_{\text{post,H}}} \right) \times EFLH_H \times \frac{kW}{1000 W}$$

Equation 4

$$\eta_{\text{post,C}} = \eta_{\text{TO,C}} \times \text{EER Adjustment Factor}$$

Equation 5

$$\eta_{\text{pre,C}} = (1 - \text{efficiency loss}) \times \eta_{\text{post,C}}$$

Equation 6

$$\eta_{\text{post,H}}^{(1)} = 0.3342 \times \eta_{\text{post,C}}^{(2)} + 3.9871$$

Equation 7

$$\eta_{\text{pre,H}} = (1 - \text{efficiency loss}) \times \eta_{\text{post,H}}$$

Equation 8

$$\text{Test Out Efficiency } [\eta_{\text{TO,C}}] = \frac{Cap_{\text{post,C}}}{Power_{\text{TO,C}}}$$

Equation 9

¹ Developed by Cadmus: 2013 Portfolio Evaluation, Entergy Arkansas, Appendix A

² For this protocol, the cooling efficiency of the existing equipment measured after tune-up and adjusted to AHRI-standard conditions (i.e., $\eta_{\text{post,C}}$) is used as a proxy for the post-tune-up heating efficiency.

$$Cap_{post,C} = Cap_{TO,C} \times Capacity\ Adjustment\ Factor$$

Equation 10

$$Cap_{TO,C} = (h_{Return\ Air} - h_{Supply\ Air}) \times (Mass\ Flow\ Rate)$$

Equation 11

$$Enthalpy\ of\ Moist\ Air\ (Return\ Air/Supply\ Air), [h] = C_p \times t_{db} + W \times (1061 + 0.444 \times t_{db})$$

Equation 12

Specific Heat of Moist Air, $[C_p]$

$$= -2.0921943 \times 10^{-14} \times t_{db}^4 + 2.5588383 \times 10^{-11} \times t_{db}^3 + 1.2900877 \times 10^{-8} \times t_{db}^2 + 5.8045267 \times 10^{-6} \times t_{db} + 0.23955919$$

Equation 13

$$Humidity\ Ratio, [W] = \frac{(1093 - 0.556t_{wb})W_s - C_p(t_{db} - t_{wb})}{1093 + 0.444t - t_{wb}}$$

Equation 14

$$Saturation\ Humidity\ Ratio, [W_s] = (0.62198) \times \frac{p_{ws}}{p - p_{ws}}$$

Equation 15

The Saturation Over Liquid Water equation is:

$$\ln(P_{ws}) = \frac{C_8}{T_{wb}} + C_9 + C_{10} \times T_{wb} + C_{11} \times T_{wb}^2 + C_{12} \times T_{wb}^3 + C_{13} \times \ln(T_{wb})$$

Equation 16

$$Saturation\ Pressure\ Over\ Liquid\ Water, [P_{ws}] = e^{\left| \frac{C_8}{T_{wb}} + C_9 + C_{10} \times T_{wb}^2 + C_{12} \times T_{wb}^3 + C_{13} \times \ln(T_{wb}) \right|}$$

Equation 17

$$Mass\ Flow\ Rate = \frac{(CFM)}{(v_{Return\ Air})} \times \left(\frac{60\ minutes}{hour} \right)$$

Equation 18

$$Specific\ Volume\ (Return\ Air), [v_{Return\ Air}] = \frac{0.3704867 \times (t_{db} + 459.67) \times (1 + 1.6078 \times W)}{P}$$

Equation 19

Note that if the CFM (airflow) in Equation 18 is determined using Method 1 (measured airspeed and duct grill dimensions), the above CFM value is calculated using Equation 20.

$$\text{Air Flow, Method 2, [CFM]} = \text{Length} \times \text{Width} \times \text{Air Speed} \times \left(\frac{1 \text{ sq. ft.}}{144 \text{ sq. inch}} \right)$$

Equation 20

$$\text{Total Input Power [Power}_{TO}] = \text{Power}_{Blower}^{(3)} + \text{Power}_{Condenser}$$

Equation 21

$$\text{Blower Single Phase Power [Power}_{Blower}] = \text{Volts} \times \text{Amps} \times \text{PF}$$

Equation 22

$$\text{Condenser Three Phase Power [Power}_{Blower}] = \frac{V_1 + V_2 + V_3}{3} \times \frac{A_1 + A_2 + A_3}{3} \times \sqrt{3} \times \text{PF}$$

Equation 23

$$\text{Condenser Single Phase Power [Power}_{Condenser}] = \text{Volts} \times \text{Amps} \times \text{PF}$$

Equation 24

$$\text{Condenser Three Phase Power [Power}_{Condenser}] = \frac{V_1 + V_2 + V_3}{3} \times \frac{A_1 + A_2 + A_3}{3} \times \sqrt{3} \times \text{PF}$$

Equation 25

$$\text{EER Adjustment Factor} = D_1 + D_2 \times A + D_3 \times B + D_4 \times A^2 + D_5 \times B^2 + D_6 \times A \times B$$

Equation 26

$$\text{Capacity Adjustment Factor} = C_1 + C_2 \times A + C_3 \times B + C_4 \times A^2 + C_5 \times B^2 + C_6 \times A \times B$$

Equation 27

$$A = 10^\circ\text{F} - (\text{Wet Bulb}_{Return Air} - \text{Wet Bulb}_{Supply Air})$$

Equation 28

$$B = (95^\circ\text{F} - \text{Dry Bulb}_{Outdoor})$$

Equation 29

³ Blower power is only added if the AC system is split. If packaged, total input power is measured, condenser power only, as a packaged unit already includes the blower.

Where:

- Cap_{Rated} = Rated nominal equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh
- $Cap_{TO,C}$ = Measured cooling capacity after tune-up [Btuh]; 1 ton = 12,000 Btuh
- $\eta_{pre,C}$ = Cooling efficiency of existing equipment before tune-up [Btuh/W]
- $\eta_{post,C}$ = Cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI-standard conditions [Btuh/W]
- $\eta_{TO,C}$ = Cooling efficiency of existing equipment measured after tune-up [Btuh/W]
- $\eta_{pre,H}$ = Heating efficiency of existing equipment before tune-up [HSPF]
- $\eta_{post,H}$ = Heating efficiency of existing equipment after tune-up and adjusted to AHRI-standard conditions [Btuh/W]; for this protocol $\eta_{post,H}$ is a mathematical estimate based on the proxy for cooling efficiency of existing equipment measured after tune-up and adjusted to AHRI-standard conditions (i.e., $\eta_{post,C}$)

Note: Use EER as efficiency " η_C " for kW and kWh cooling savings calculations. Use Heating Season Performance Factor (HSPF) as efficiency " η_H " for kW and kWh heating savings calculations.

- $EFLH_{C/H}$ = Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (Residential Volume 2, Table 31; Nonresidential Volume 3, Tables 36 through 40)
- CF = Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2, Table 32; Nonresidential Volume 3, Tables 36 through 40)
- Volts = Measured voltage (volts) on single-phase electric power leads to AC components
- Amps = Measured current flow (amps) on single-phase electric power leads to AC components
- PF = Power factor stipulated based on motor type (see Table 4)
- V_1, V_2, V_3 = Measured voltage, line to line on each of the three electric power leads (V_1, V_2, V_3) to AC components for three-phase loads
- A_1, A_2, A_3 = Measured current flow (Amps) on each line (A_1, A_2, A_3) of the three power leads to AC components for three-phase loads

<i>Efficiency loss</i>	=	<i>Efficiency loss factor; derived from a significant sample of field measurement data for units with versus without a refrigerant charge and commercial versus residential unit types (see Table 2)</i>
<i>P</i>	=	<i>Atmospheric air pressure, from Table 3</i>
<i>P_{ws}</i>	=	<i>Saturation pressure over liquid water [psia]</i>
<i>v</i>	=	<i>Specific volume of air [cu.ft./lb]</i>
<i>Ln.</i>	=	<i>Natural Logarithm</i>
<i>e</i>	=	<i>Natural log constant (2.7182818284590452353602874713527)</i>
<i>T</i>	=	<i>Absolute temperature, Rankine scale [$^{\circ}R = ^{\circ}F + 459.67$]</i>
<i>t_{db}</i>	=	<i>Measured dry-bulb temperature [$^{\circ}F$]</i>
<i>t_{wb}</i>	=	<i>Measured wet-bulb temperature [$^{\circ}F$]</i>
<i>Wet Bulb_{Return Air}</i>	=	<i>Wet-bulb temperature of return air (load) to AC evaporator [$^{\circ}F$]</i>
<i>Wet Bulb_{Supply Air}</i>	=	<i>Wet-bulb temperature of cooled supply air to indoor space [$^{\circ}F$]</i>
<i>Dry Bulb_{Outdoor}</i>	=	<i>Dry-bulb temperature of outdoor air at time of tune-up [$^{\circ}F$]</i>
<i>h_{Return Air}</i>	=	<i>Measured enthalpy of return air (load) to AC evaporator [Btu/lb]</i>
<i>h_{Supply Air}</i>	=	<i>Measured enthalpy of cooled supply air to indoor space [Btu/lb]</i>
<i>Mass Flow Rate</i>	=	<i>Calculated mass flow rate of moist return air [lb/hr]</i>
<i>CFM</i>	=	<i>AC supply/return airflow [cu.ft./min.] (see Table 5)</i>
<i>Length</i>	=	<i>Measured length of duct grill long side [inches] (Method 1)</i>
<i>Width</i>	=	<i>Measured width of duct grill short side [inches] (Method 1)</i>
<i>Air Speed</i>	=	<i>Measured air velocity at duct grille [feet per second] (Method 1)</i>
<i>95°F</i>	=	<i>95°F is the outdoor dry-bulb temperature at AHRI test conditions</i>
<i>10°F</i>	=	<i>10°F is the typical wet-bulb temperature change across an evaporator coil at AHRI conditions</i>