2.7 NONRESIDENTIAL: MISCELLANEOUS

2.7.1 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.[428]

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 221. Vending Machine Controls—Refrigerated Cold Drink Unit Deemed Savings[429]

Climate zone	kWh savings	Summer kW savings[430]	Winter kW savings
Zone 1: Amarillo	1,612	0.023	0.060
Zone 2: Dallas		0.021	0.063
Zone 3: Houston		0.022	0.060
Zone 4: Corpus Christi		0.022	0.064
Zone 5: El Paso		0.015	0.068

[428] Appliance Standards for Refrigerated Beverage Vending Machines. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=29#current_standards.

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

[430] 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 222. Vending Machine Controls—Refrigerated Reach-In Unit Deemed Savings[431]

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

Table 223. Vending Machine Controls—Non-Refrigerated Snack Unit Deemed Savings[432]

Climate zone	kWh savings	Summer kW savings	Winter kW savings
Zone 1: Amarillo	387	0.005	0.013
Zone 2: Dallas		0.004	0.013
Zone 3: Houston		0.005	0.013
Zone 4: Corpus Christi		0.005	0.014
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.[433]

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

[431] Pacific Gas and Electric, Work Paper VMReach, Revision 3, August 2009, Measure Code R143.
[432] Pacific Gas and Electric, Work Paper VMSnack, Revision 3, August 2009, Measure Code R98.
[433] 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

- 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://aceee.org/files/proceedings/2002/data/papers/SS02_Panel10_Paper05.pdf.
- DEER 2014 EUL update.

Document Revision History

Table 224. Nonresidential Vending Machine 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 revisions.
v3.0	04/10/2015	TRM v3.0 update. No revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

2.7.2 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.[434]

Eligibility Criteria

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

Baseline Condition

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

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

High-Efficiency Condition

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

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

Energy and Demand Savings Methodology

Energy and demand savings are deemed values based on energy simulation runs performed using EnergyPro Version 5. Building prototype models were developed for a hotel, motel, and dormitory building types. The base case for each prototype model assumed a uniform temperature setting and was calibrated to a baseline energy use. Occupancy patterns based on both documented field studies[435] 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.[436]

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.

[435] 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.

[436] A more detailed description of the modeling assumptions can be found in Docket 40668 Attachment A, pages A-46 through A-58.

Table 225. Deemed Energy and Demand Savings for Motel per Guest Room, by Region

Climate zone[437]	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								
Amarillo (Panhandle)	0.059	267	0.075	380	0.059	341	0.075	441
Dallas (North)	0.076	315	0.091	443	0.076	365	0.091	485
Houston (South)	0.082	324	0.097	461	0.082	351	0.097	484
McAllen (Valley)	0.086	354	0.103	500	0.086	369	0.103	513
El Paso (West)	0.063	251	0.078	379	0.063	283	0.078	406
10-degree setup/setback offset								
Amarillo (Panhandle)	0.111	486	0.126	598	0.111	627	0.126	726
Dallas (North)	0.146	559	0.161	686	0.146	640	0.161	761
Houston (South)	0.151	559	0.166	695	0.151	602	0.166	735
McAllen (Valley)	0.163	617	0.179	761	0.163	650	0.179	792
El Paso (West)	0.118	432	0.133	561	0.118	482	0.133	607

Table 226. Deemed Energy and Demand Savings for Hotel per Guest Room, by Region

Climate zone	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								
Amarillo (Panhandle)	0.053	232	0.072	439	0.053	303	0.072	530
Dallas (North)	0.073	258	0.093	452	0.073	303	0.093	505
Houston (South)	0.074	242	0.094	430	0.074	260	0.094	450
McAllen (Valley)	0.081	260	0.102	451	0.081	267	0.102	459
El Paso (West)	0.056	178	0.075	360	0.056	196	0.075	380
10-degree setup/setback offset								
Amarillo (Panhandle)	0.102	426	0.121	568	0.102	557	0.121	684
Dallas (North)	0.134	452	0.154	617	0.134	517	0.154	676
Houston (South)	0.136	423	0.156	599	0.136	446	0.156	621
McAllen (Valley)	0.149	467	0.169	652	0.149	483	0.169	667
El Paso (West)	0.106	312	0.126	479	0.106	338	0.126	501

[437] Regions used in the original petition were mapped to current TRM representative weather stations and regions as follows: Amarillo (Panhandle) was "Panhandle", Dallas-Ft Worth (North) was "North", Houston (South) was "South Central", El Paso (West) was "Big Bend", and McAllen (Valley) was "Rio Grande Valley".

Table 227. Deemed Energy and Demand Savings for Dormitories per Room, by Region

Climate zone	Heat pump				Electric heat			
	HVA only		HVAC and lighting		HVAC only		HVAC and lighting	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh
5-degree setup/setback offset								
Amarillo (Panhandle)	0.034	136	0.061	319	0.034	152	0.061	316
Dallas (North)	0.048	214	0.076	425	0.048	223	0.076	428
Houston (South)	0.051	242	0.078	461	0.051	244	0.078	462
McAllen (Valley)	0.053	265	0.081	492	0.053	266	0.081	492
El Paso (West)	0.031	110	0.059	327	0.031	110	0.059	326
10-degree setup/setback offset								
Amarillo (Panhandle)	0.073	261	0.084	404	0.073	289	0.084	417
Dallas (North)	0.078	293	0.105	505	0.078	304	0.105	511
Houston (South)	0.081	326	0.108	543	0.081	328	0.108	545
McAllen (Valley)	0.088	368	0.114	591	0.088	370	0.114	593
El Paso (West)	0.045	151	0.060	448	0.045	153	0.060	450

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years based on the value for retrofit energy management system (EMS) HVAC control from the Massachusetts Joint Utility Measure Life Study[438]. This value is also consistent with the EUL for lighting control and HVAC control measures in PUCT Docket Nos. 36779 and 40668.

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- HVAC system and equipment type
- Heating type (heat pump, electric resistance)
- Temperature offset category (5 or 10° F)

[438] 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.

- 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

- ASHRAE Standard 90.1-1999
- Measure Life Study. Prepared for The Massachusetts Joint Utilities by ERS. November 17, 2005.
- Codes and Standards Enhancement Initiative (CASE): Guest Room Occupancy Controls, 2013 California Building Energy Efficiency Standards. October 2011.

Document Revision History

Table 228. Nonresidential Lodging Guest Room Occupancy Sensor Controls 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revisions.

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"[439] occurs. POCs save energy by optimizing the pump run-times to match the flow conditions of the well.

Eligibility Criteria

The POC measure is only available as a retrofit measure for existing wells (wells with an existing API number[440] prior to September 11th, 2014) with rod pumps using 15 hp or larger motors operating on time clock controls or less efficient devices. These cannot be integrated with a variable frequency drive and only apply to POCs using load cells, which measure the weight on the rod string for greater precision. Additionally, the POC must control a *conventional* well (above ground or vertical, with a standard induction motor of 480V or less).

Baseline Condition

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

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439 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.

440 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*[441] (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,*[442] 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.[443]

Savings Algorithms and Inputs

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

$$Energy\ Savings\ [kWh] = kW_{avg} * (TimeClock\%On - POC\%On) * 8760$$

Equation 206

$$Demand\ Savings\ [kW] = \frac{EnergySavings}{8760}$$

Equation 207[444]

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

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

Equation 208

[441] 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).

[442] *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.

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

[444] 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 209[445]

Where:

kW_{avg}	=	*The demand used by each rod pump*
HP	=	*Rated pump-motor horsepower*
0.746	=	*Conversion factor from hp to kW*
LF	=	*Motor load factor—ratio of average demand to maximum demand, see Table 229*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 230*
SME	=	*Mechanical efficiency of sucker-rod pump, see Table 229*
TimeClock%On	=	*Stipulated-baseline timeclock setting, see Table 229*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956, derived from SPE 16363* [446]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

Deemed Energy and Demand Savings Tables

Table 229. Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/deemed values
LF (Load factor)	25%[447]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[448]
Timeclock%On	65%[449]

[445] 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 ($Run_{contstant}$ + $Run_{coefficient}$ * VolumetricEfficiency%) with the volumetric efficiency expressed as percent value not a fraction (i.e., 25 not 0.25 for 25 percent).

[446] 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).

[447] *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.

[448] Engineering estimate for standard gearbox efficiency.

[449] A TimeClock%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.

Table 230. NEMA Premium Efficiency Motor Efficiencies[450]

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%

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 207.

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.[451]

[450] 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.

[451] 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.

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 timeclock percent on time (or actual on-time schedule)
- Volumetric efficiency
- Field data on actual energy use and post-run times[452]

References and Efficiency Standards

Petitions and Rulings

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

Relevant Standards and Reference Sources

- 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).
- 79 FR 30933. Full-load Efficiencies for General Purpose Electric Motors [Subtype I]
- 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.
- Comprehensive Process and Impact Evaluation of the (Xcel Energy) Colorado Motor and Drive Efficiency Program, FINAL. Tetra Tech. March 28, 2011.

[452] 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 231. Nonresidential 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 revisions.
v4.0	10/10/2016	TRM v4.0 update. No revisions.
v5.0	10/2017	TRM v5.0 update. No revisions.
v6.0	10/2018	TRM v6.0 update. No revisions.
v7.0	10/2019	TRM v7.0 update. No revisions.
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.

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, new construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

This measure applies to all commercial applications, indoor or outdoor, with a pump size up to 3 hp; larger sizes should be implemented through a custom program. Motor-only retrofits are not eligible. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa[453].

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.[454] 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.

Baseline Condition

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

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[453] These pump products are ineligible for ENERGY STAR® v3.0 certification: https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%203.0%20Pool%20Pumps%20Specification.pdf

[454] 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. U.S. DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf.

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

Energy Savings Algorithms

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

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

Equation 210

Where:

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

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

Algorithms to calculate the above parameters are defined as:

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

Equation 211

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

Equation 212

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

Where:

hours	=	*Conventional single-speed pump daily operating hours (see Table 232)*
days	=	*Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*
PFR_{conv}	=	*Conventional single-speed pump flow rate [gal/min] (see Table 232)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (see Table 232)*
gal	=	*The volume of the pool in gallons (see Table 233)*
$turn_{day}$	=	*Turnovers per day, number of times the volume of the pool is run through the pump per day (see Table 207)*
EF_{ES}	=	*ENERGY STAR®-weighted energy factor [gal/W·hr] (see Table 207)*
60	=	*Constant to convert between minutes and hours*
$1{,}000$	=	*Constant to convert from kilowatts to watts*

Table 232. Conventional Pool Pumps Assumptions[456]

New rated pump HP	Hours limited hours[457]	Hours, 24/7 Operation	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 ≤ 3			101.6667	1.9987

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

[457] 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.

Table 233. ENERGY STAR® Pool Pumps Assumptions[458]

New rated pump HP	Turnovers/day limited hours	Turnovers/day 24/7 Operation	Gallons	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 ≤ 3	2.6	5.2	28,000	7.1

Demand Savings Algorithms

$$kW_{Savings} = \frac{kWh_{conv} - kWh_{ES}}{hours} \times \frac{DF}{days}$$

Equation 213

Where:

hours = *Conventional single-speed pump daily operating hours (see Table 232)*

days = *Operating days per year = year-round operation: 365 days; seasonal operation: 7 months x 30.4 days/month = 212.8 days (default)*

DF = *Demand factor from Table 234*

Table 234. Demand Factors[459]

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

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

[459] Based on 2016 Commercial pool pump program data reviewed by the Texas Evaluation Contractor.

Deemed Energy and Demand Savings Tables

Table 235. ENERGY STAR® Variable Speed Pool Pump Energy Savings[460]

New rated 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 ≤ 3	19,250	9,625	5,612

Table 236. ENERGY STAR® Variable Speed Pool Pump Summer Demand Savings

New rated 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 ≤ 3	2.198	1.281

Table 237. ENERGY STAR® Variable Speed Pool Pump Winter Demand Savings

New rated 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 ≤ 3	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.

[460] 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.

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/downloads/Pool_Pump_Calculator_2020.05.05_FINAL.xlsx.

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.[461]

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
  - 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

- The applicable version of the ENERGY STAR® specifications and requirements for pool pumps

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

Document Revision History

Table 238. Nonresidential ENERGY STAR® 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 revisions.
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.

2.7.5 Computer Power Management Measure Overview

TRM Measure ID: NR-MS-CP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: All building types applicable

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed value (per machine)

Savings Methodology: Algorithms

Measure Description

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

Eligibility Criteria

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

Baseline Condition

The baseline conditions are the estimated number of hours that the computer spends in active, sleep, and off modes before the power settings are actively managed. Operating hours may be estimated from metering, or the default hours provided in the calculation of deemed savings may be used. The default baseline hours are taken from the ENERGY STAR® modeling study assumptions contained in the Low Carbon IT Savings Calculator[462], and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.[463]

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

[463] 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.[464]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$kWh_{savings} = \frac{W_{active}\left(hrs_{active_{pre}} - hrs_{active_{post}}\right) + W_{sleep}\left(hrs_{sleep_{pre}} - hrs_{sleep_{post}}\right) + W_{off}\left(hrs_{off_{pre}} - hrs_{off_{post}}\right)}{1{,}000}$$

Equation 214

$$Summer\ kW_{savings} = \left(W_{active} - W_{sleep}\right) \times CF_{inactive}$$

Equation 215

$$Winter\ kW_{savings} = 0$$

Equation 216

Where:

W_{active}	=	*Total wattage of the equipment, including computer and monitor, in active/idle mode (see Table 239)*
$hrs_{active_{pre}}$	=	*Annual number of hours the computer is in active/idle mode before computer management software is installed (see Table 240)*
$hrs_{active_{post}}$	=	*Annual number of hours the computer is in active/idle mode after computer management software is installed (see Table 240)*
W_{sleep}	=	*Total wattage of the equipment, including computer and monitor, in sleep mode (see Table 239)*
$hrs_{sleep_{pre}}$	=	*Annual number of hours the computer is in sleep mode before computer management software is installed (see Table 240)*

[464] Based on 2015 custom project metering from El Paso Electric.

$hrs_{sleep_{post}}$	=	*Annual number of hours the computer is in sleep mode after computer management software is installed (see Table 240)*
W_{off}	=	*Total wattage of the equipment, including computer and monitor, in off mode (see Table 239)*
$hrs_{off_{pre}}$	=	*Annual number of hours the computer is in off mode before computer management software is installed (see Table 240)*
$hrs_{off_{post}}$	=	*Annual number of hours the computer is in off mode after computer management software is installed (see Table 240)*
1,000	=	*Conversion factor: 1 kW / 1,000 W*
CF	=	*Coincidence factor (see Table 241)*

Table 239. Computer Power Management—Equipment Wattages[465]

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional monitor[466]	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

Table 240. Computer Power Management—Operating Hours[467]

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

465 Equipment wattages taken from the ENERGY STAR® Office Equipment Calculator, updated October 2016. Available for download at https://www.energystar.gov/buildings/facility-owners-and-managers/existing-buildings/save-energy/purchase-energy-saving-products.

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

467 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 241. Computer Power Management—Coincidence Factors, All Activity Types

Climate zone	Summer CF		Winter CF	
	Active	Inactive	Active	Inactive
1	0.65	0.35	0.11	0.89
2	0.62	0.38	0.12	0.88
3	0.66	0.34	0.12	0.88
4	0.62	0.38	0.14	0.86
5	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 239, Table 240, and Table 241. The following tables provide these deemed values.

Table 242. Computer Power Management—Deemed Energy Savings Values, All Climate Zones

Equipment	Office or school kWh
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

Table 243. Computer Power Management—Deemed Demand Savings Values, Office, or School

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	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	0.007	0	0.006	0	0.007	0	0.004	0
Conventional computer	0.016	0	0.017	0	0.015	0	0.017	0	0.011	0
Conventional notebook	0.005	0	0.005	0	0.005	0	0.005	0	0.003	0
ENERGY STAR® monitor	0.005	0	0.006	0	0.005	0	0.006	0	0.004	0

Equipment	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)	Summer (kW)	Winter (kW)
ENERGY STAR® computer	0.009	0	0.010	0	0.009	0	0.010	0	0.006	0
ENERGY STAR® notebook	0.003	0	0.003	0	0.003	0	0.003	0	0.002	0

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.[468]

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)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

[468] 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.

Document Revision History

Table 244. Nonresidential 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.

2.7.6 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 249. 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).[469]

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

[469] 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.

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 EPAct-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 (EPAct)[470] (see Table 248) and are thus no longer equivalent to pre-1992/pre-EPAct 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 (EPAct)[471], as listed in Table 250.

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 248.

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.

[470] 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.

[471] Federal Standards for Electric Motors, Tables 3 (≤ 200 hp), and 4 (> 200hp), 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 245 or Table 246 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 217

Demand Savings Algorithms

HVAC Applications:

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

Equation 218

Industrial Applications[472]:

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

Equation 219

Where:

hp	=	*Nameplate horsepower data of the motor*
0.746	=	*hp-to-kWh conversion Factor (kW/hp)[473]*
LF	=	*Estimated load factor (if unknown, see Table 245 or Table 246)*

[472] Assumes three-shift operating schedule

[473] 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 248)*[474]
η_{post}	=	*Efficiency of the newly installed motor [%]*
Hrs	=	*Estimated annual operating hours (if unknown, see Table 245 or Table 246)*
CF	=	*Coincidence factor (see Table 245)*
$kWh_{savings,ROB}$	=	*Total energy savings for a new construction or ROB project*
$kW_{savings,ROB}$	=	*Total demand savings for a new construction or ROB project*

Table 245. Premium Efficiency Motors—HVAC Assumptions by Building Type

Building type	Load factor[475]	CF[476]	HVAC fan hours[477]
Hospital	0.75	1.00	8,760
Large office (>30k SqFt)			4,424
Small office (≤30k SqFt)			4,006
K-12 school			4,173
College			4,590
Retail			5,548
Restaurant (fast-food)			6,716
Restaurant (sit-down)			5,256

[474] In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 247.

[475] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

[476] 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

[477] Factors are equivalent to Table 85 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 246. Premium Efficiency Motors—Industrial Assumptions by Building Type

Industrial processing	Load factor[478]	Hours[479]					
		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 247. Rewound Motor Efficiency Reduction Factors[480]

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

Table 248. Premium Efficiency Motors—New Construction and Replace-on-Burnout Baseline Efficiencies by Motor Size (%)[469,473]

hp	Open motors: $\eta_{baseline, ROB}$			Closed motors: $\eta_{baseline, ROB}$		
	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

478 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

479 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

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

hp	Open motors: $\eta_{baseline, ROB}$			Closed motors: $\eta_{baseline, ROB}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
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
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	N/A	95.8	95.8	N/A	96.2	95.8
450	N/A	96.2	96.2	N/A	96.2	95.8
500	N/A	96.2	96.22	N/A	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 249); 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 249. Remaining Useful Life (RUL) of Replaced Motor[481]

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[482]	0.0
9	5.9		

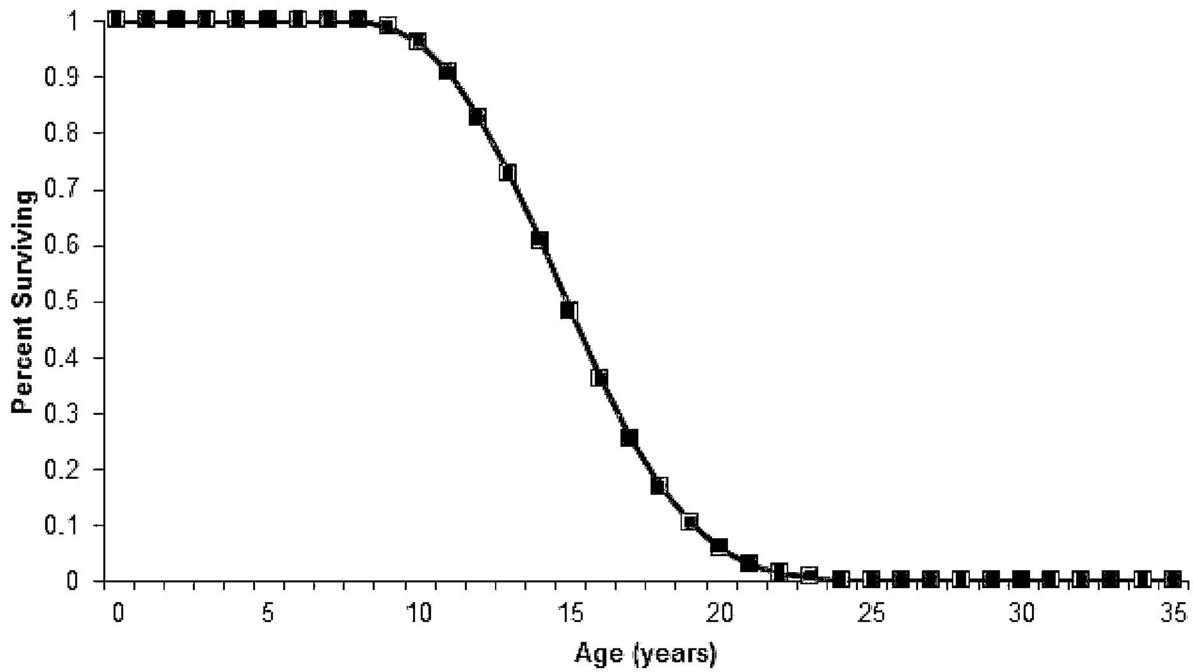
Derivation of RULs

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.

[481] 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.

[482] 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. Survival Function for Premium Efficiency Motors[483]



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 220

[483] 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 221

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 222

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 223

Industrial Applications

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

Equation 224

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 225

Industrial Applications

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

Equation 226

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 227

Where:

$\eta_{baseline,ER}$ = *Assumed original motor efficiency for remaining EUL time period (Table 250 or Table 251)*[484]

$kWh_{savings,RUL}$ = *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 250. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size (%)[471]

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

[484] Ibid.

hp	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
40	93.0	93.0	91.7	93.0	93.0	91.7
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	N/A	95.4	95.4	N/A	95.4	95.4
450	N/A	95.8	95.8	N/A	95.4	95.4
500	N/A	95.8	95.8	N/A	95.8	95.4

Table 251. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016 (%)[485]

hp	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
	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	N/A	95.4	95.4	N/A	95.4	95.4
450	N/A	95.8	95.8	N/A	95.4	95.4
500	N/A	95.8	95.8	N/A	95.8	95.4

[485] Federal Standards for Electric Motors, Table 4,

Deemed Energy and Demand Savings Tables

Not applicable

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.[486]

Program Tracking Data and Evaluation Requirements

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

- Number of units installed
- The project type of the installation (new construction, replace-on-burnout, or early retirement)
- Horsepower
- Estimated annual operating hours and estimated load factor
- Number of poles in and horsepower of original motor
- Newly-installed motor efficiency (%)
- Description of motor service application
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

References and Efficiency Standards

Petitions and Rulings

Not applicable

[486] 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

Relevant Standards and Reference Sources

- Federal Energy Policy Act of 1992 (EPAct)
    - Defaults prior to EPAct 1992 from the DOE's *MotorMaster+* database (circa 1992)
- 2007 Energy Independence and Security Act (EISA)
- The applicable version of the Technical Support Document for electric motors

Document Revision History

Table 252. Nonresidential Premium Efficiency Motors Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Replace-on-burnout and Early Retirement clarifications.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits.

2.7.7 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 an ENERGY STAR® compliant Level 2 EVSE.

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

$$ENERGY\ STAR\ Idle\ Consumption\ [kWh] = \frac{(hrs_{plug} \times W_{plug} + hrs_{unplug\_C} \times W_{unplug}) \times days_C + hrs_{unplug\_NC} \times W_{unplug} \times days_{NC}}{1000}$$

Equation 228

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

Equation 229

$$Annual\ Energy\ Savings\ [kWh] = Baseline\ Idle\ Consumption - ENERGY\ STAR\ Idle\ Consumption$$

Equation 230

$$Demand\ Savings\ [kW] = \frac{Annual\ Energy\ Savings\ (kWh)}{hrs_{unplug\_C} \times days_C + hrs_{unplug\_NC} \times days_{NC}} \times PDPF$$

Equation 231

Where:

hrs_{plug} = *Hours per day the vehicle is plugged into the EVSE and not charging, 2.8 hrs*[487]

W_{plug} = *Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging, 6.9 W*[488]

hrs_{unplug_C} = *Hours per day the vehicle is not plugged into the EVSE on a charging day, 19.0 hrs*[489]

[487] 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.

[488] Average Idle Mode Input Power from ENERGY STAR® certified EVSE product list as of July 13, 2020.

[489] 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.

hrs_{unplug_NC} = *Hours per day the vehicle is not plugged into the EVSE on a non-charge day, 24 hrs*

W_{unplug} = *Wattage of the EVSE when the vehicle is not plugged into the EVSE, 3.3 W*[490]

$days_C$ = *Number of charging days per year, 204 days*[491]

$days_{NC}$ = *Number of non-charging days per year, 161 days*

1000 = *Constant to convert from W to kW*

0.6 = *Efficiency adjustment factor*[492]

PDPF = *Peak demand probability factor (see Table 253)*

Table 253. EVSE Peak Demand Probability Factors[493]

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

Deemed Energy and Demand Savings Tables

Table 254 presents the deemed annual energy savings per EVSE.

Table 254. EVSE Annual Energy Savings

Annual energy savings (kWh) (all location types)
19.7

[490] Average No Vehicle Mode Input Power from ENERGY STAR® certified EVSE product list.
[491] NREL "Charging Electric Vehicles in Smart Cities: An EVI-Pro Analysis of Columbus Ohio," page 25; 0.56 charging sessions per day per plug in Austin, Texas. 365 x 0.56 = 204.
[492] 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.
[493] 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.

Table 255 presents the deemed summer and winter peak kW savings per EVSE.

Table 255. EVSE Peak Demand Savings

Location type	Public		Workplace		Fleet	
Climate zone	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
Zone 1: Amarillo	0.0012	0.0012	0.0022	0.0019	0.0008	0.0012
Zone 2: Dallas	0.0012	0.0012	0.0022	0.0019	0.0006	0.0012
Zone 3: Houston	0.0012	0.0011	0.0022	0.0017	0.0007	0.0010
Zone 4: Corpus Christi	0.0012	0.0013	0.0022	0.0020	0.0007	0.0014
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.[494]

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:

- Quantity
- Climate zone
- Location Type (public, workplace, or fleet) [495]
- EVSE manufacturer and model number

[494] 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.

[495] Refer to Eligibility Criteria section for location type definitions.

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for electric vehicle supply equipment.

Document Revision History

Table 256. Nonresidential Electric Vehicle Supply Equipment 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.

2.7.8 Variable Frequency Drives for Water Pumping Measure Overview

TRM Measure ID: NR-MS-WP

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Business Types: All

Fuels Affected: Electricity

Decision/Action Type: Retrofit

Program Delivery Type: Prescriptive

Deemed Savings Type: Look-up tables

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

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

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

Baseline Technology[496]:

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

Equation 232

Where:

%GPM	=	*Percentage flow rate (see Table 257)*
i	=	*Each hour of the year*

Table 257. VFD for Water Pumping—Water Demand Profile[497]

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

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

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

Hour ending	Percentage flow rate
21	0.745
22	0.608
23	0.529
24	0.294

VFD Technology[498]:

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

Equation 233

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 234

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

Equation 235

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 the pump typical design point*
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	=	*HP to kW conversion factor*
η	=	*Motor efficiency of a standard efficiency motor (see Table 258)*

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

Table 258. Motor Efficiencies[499]

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

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 236

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

Equation 237

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*

499 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.

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:

$$Annual\ kWh = \sum_{i=1}^{8760} (kW_i)$$

Equation 238

Where:

8760 = *Total number of hours in a year*

Step 2 – Subtract Annual kWh_{new} from Annual $kWh_{baseline}$ to get the Annual Energy Savings:

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

Equation 239

Deemed Energy and Demand Savings Tables

Table 255 presents the deemed summer and winter peak kW savings per EVSE.

Table 259. Water Pump VFD Savings per Motor HP

Climate zone	Annual kWh savings per motor HP	Winter peak demand kW savings per motor HP
Zone 1: Amarillo		0.097
Zone 2: Dallas		0.069
Zone 3: Houston	1,389	0.067
Zone 4: Corpus Christi		0.138
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.[500]

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

Program Tracking Data and Evaluation Requirements

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

- Quantity
- Climate zone
- Motor horsepower

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

Document Revision History

Table 260. Nonresidential Water Pumping VFD Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

2.7.9 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

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

Equation 240

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

Equation 241

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

Equation 242

$$Peak\ Demand\ Savings\ (kW) = \frac{Annual\ Energy\ Savings\ (kWh)}{Hours} \times DF$$

Equation 243

Where:

$E_{water\ supply}$	=	*Water supply energy factor: 2,300 kWh/million gallons*
S_L	=	*Average steam loss per trap (lb/hr) (see Table 261)*
Hours	=	*Annual hours when steam system is operational, equal to heating degree days by climate zone (see Table 262)*
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 261*
24.24	=	*Constant lb/(hr-psia-in2)*
P_{ia}	=	*Average steam trap inlet pressure, absolute (psia),* $P_{ig} + P_{atm}$
P_{ig}	=	*Average steam trap inlet pressure, gauge (psig) (see Table 261)*
P_{atm}	=	*Atmospheric pressure, 14.7 psia*

D	=	*Diameter of orifice (inches), use actual if possible, or defaults in Table 261*
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*
DF	=	*Demand factor, assume value of 1 for industrial and process steam applications; for commercial heating applications, see Table 32 through Table 36 in Section 2.2.2; for commercial dry cleaners, use DF for stand-alone retail*

Table 261. Steam Traps—Default Inputs[501]

Steam system	Psig	Diameter of orifice (inches)	Flow factor	Average steam loss, S_L (lb/hr/trap)	Hours	L
Commercial dry cleaners	82.8	0.125	100%	18.5	2,425	0.27
Industrial or process low pressure < 15 psig	-	-		6.9	8,282	0.16
Industrial or process medium pressure > 15 and < 30 psig	16	0.1875	50%	6.5	8,282	0.16
Industrial or process medium pressure > 30 and < 75 psig	47	0.2500		23.4	8,282	0.16
Industrial or process high pressure > 75 and < 125 psig	101			43.8	8,282	0.16
Industrial or process high pressure > 125 and < 175 psig	146			60.9	8,282	0.16
Industrial or process high pressure > 175 and < 250 psig	202			82.1	8,282	0.16
Industrial or process high pressure > 250 and < 300 psig	263			105.2	8,282	0.16
Commercial heating LPS	-	-	100%	6.9	Table 262	0.27

501 Default inputs for the steam trap measure are sourced from the Illinois TRM version 9.0, measure 4.4.16 Steam Trap Replacement or Repair. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf

Table 262. Steam Trap—Hours

Climate zone	Hours (HDD)[502]
1	4,565
2	2,567
3	1,686
4	1,129
5	2,677

Deemed Energy and Demand Savings Tables

Table 263. Steam Trap—Annual 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 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

[502] 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 264. Steam Trap—Peak Demand Savings, Without Audit

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	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 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	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

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Food service	Full-service restaurant	2.21E-04	2.57E-04	2.26E-04	1.80E-04	1.44E-04
		24-hour full-service	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	2.47E-04	3.09E-04	2.57E-04	1.75E-04	1.34E-04
	Healthcare	Hospital	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient healthcare	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 stand-alone retail	2.21E-04	2.93E-04	2.11E-04	1.29E-04	1.44E-04
		Strip mall	2.01E-04	2.83E-04	2.16E-04	1.08E-04	1.39E-04
	Office	Large office	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Medium office	3.70E-04	3.39E-04	2.16E-04	1.23E-04	1.39E-04
		Small office	1.49E-04	2.06E-04	1.44E-04	7.20E-05	7.72E-05
	Public assembly	Public assembly	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Service	Service	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Warehouse	Warehouse	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Other	Other	1.39E-04	1.44E-04	9.77E-05	4.12E-05	2.06E-05

Table 265. Steam Trap—Peak Demand Savings, With Audit

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	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 heating LPS	Data center	Data center	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Education	College/ university	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Primary school	8.19E-04	1.26E-03	9.53E-04	5.72E-04	7.05E-04
		Secondary school	8.19E-04	1.12E-03	1.03E-03	6.67E-04	8.19E-04

Steam type	Building type	Principal building activity	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Food sales	Convenience	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Supermarket	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Food service	Full-service restaurant	8.19E-04	9.53E-04	8.38E-04	6.67E-04	5.33E-04
		24-hour full-service	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	9.14E-04	1.14E-03	9.53E-04	6.48E-04	4.95E-04
	Healthcare	Hospital	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
		Outpatient healthcare	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	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	Religious worship	Religious worship	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
	Service	Service	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.[503]

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

- This section not applicable.

Relevant Standards and Reference Sources

None

Document Revision History

Table 266. Nonresidential Steam Trap Repair and Replacement Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

[503] EULs for the steam trap measure are sourced from the Illinois TRM version 9.0, measure 4.4.16 Steam Trap Replacement or Repair. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf.

2.7.10 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

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 244

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[504]
n	=	*Motor efficiency, actual or default to value in Table 267*
hours	=	*Operating hours per year, actual*
EI	=	*Efficiency increase, 1.0% per gear mesh*[505]

Table 267. Motor Efficiencies[506]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936
30	0.941
40	0.941
50	0.945

504 Assume motor is designed to operate at maximum efficiency, neat 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.

505 Illinois TRM v9.0 Volume 2, Measure 4.8.21 Energy Efficient Gear Lubricants, reference 1,354 identifying Exxon Mobil studies. https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_2_C_and_I_09252020_Final.pdf. Accessed August 2021.

506 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.

Motor horsepower	Full load efficiency
60	0.950
75	0.950
100	0.954

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.[507]

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

None

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

Document Revision History

Table 268. Nonresidential Hydraulic Gear Lubricants Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

2.7.11 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

$$Annual\ Energy\ Savings\ (kWh) = HP_{motor} \times 0.746 \times \frac{LF}{n} \times hours \times EI$$

Equation 245

Where:

HP_{motor}	=	*Horsepower of the motor, actual nameplate*
0.746	=	*Conversion factor, kW/hp*
LF	=	*Motor load factor, 75%*[508]
n	=	*Motor efficiency, actual or default to value in Table 269*
hours	=	*Operating hours per year, actual*
EI	=	*Efficiency increase, 3.2%*[509]

Table 269. Motor Efficiencies[510]

Motor horsepower	Full load efficiency
1	0.855
2	0.865
3	0.895
5	0.895
7.5	0.910
10	0.917
15	0.930
20	0.930
25	0.936

[508] Assume motor is designed to operate at maximum efficiency, neat 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.

[509] Focus on Energy Lubricant Study, https://focusonenergy.com/newsroom/lubricant-improves-efficiency-new-study.

[510] Code of Federal Regulations, Title 10, Chapter II, Subchapter D, Part 431.25 Table 1, Nomincal 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.

Motor horsepower	Full load efficiency
30	0.941
40	0.941
50	0.945
60	0.950
75	0.950
100	0.954

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.[511]

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.

[511] 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

Relevant Standards and Reference Sources

None

Document Revision History

Table 270. Nonresidential Hydraulic Oils Revision History

TRM version	Date	Description of change
v9.0	10/2021	TRM v9.0 origin.

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:

$$First\ Tier\ (FT)\ Period = ML_{FT} = RUL$$

Equation 246

$$Second\ Tier\ (ST)\ Period = ML_{ST} = EUL - RUL$$

Equation 247

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:

$$\Delta kW_{FT} = kW_{retired} - kW_{installed}$$

Equation 248

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

Equation 249

$$\Delta kWh_{FT} = kWh_{retired} - kWh_{installed}$$

Equation 250

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

Equation 251

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*[512]
$kW_{baseline}$	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[513]
$kW_{installed}$	=	*Demand of the replacement system*[514]
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*[512]
$kWh_{baseline}$	=	*Energy usage of the second-tier baseline system, usually the baseline ROB system*[513]
$kWh_{installed}$	=	*Energy usage of the replacement system*[514]

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 252

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

Equation 253

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

Equation 254

512 Retired system refers to the existing equipment that was in use before the retrofit has occurred.
513 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).
514 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 255

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* [515]

d = *Discount rate weighted average cost of capital (per utility)* [515]

AC_{kW} = *Avoided cost per kW ($/kW)* [515]

AC_{kWh} = *Avoided cost per kWh ($/kWh)* [515]

ML_{FT} = *First-tier measure life (calculated in Equation 246)*

ML_{ST} = *Second-tier measure life (calculated in Equation 247)*

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

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

Equation 256

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

Equation 257

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*

[515] 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 258

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

Equation 259

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:

$$Weighted\ kW = \frac{NPV_{Total\ kW}}{NPV_{EUL,kW}}$$

$$= \frac{\left[\left(1 - \left(\frac{1+e}{1+d}\right)^{RUL}\right) \times \left(kW_{retired} - kW_{installed}\right)\right] + \left[\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times \left(kW_{baseline} - kW_{installed}\right)\right]}{\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL}\right)}$$

Equation 260

$$Weighted\ kWh = \frac{NPV_{Total.kWh}}{NPV_{EUL,kWh}}$$

$$= \frac{\left[\left(1 - \left(\frac{1+e}{1+d}\right)^{RUL}\right) \times \left(kWh_{retired} - kWh_{installed}\right)\right] + \left[\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL-RUL}\right) \times \frac{(1+e)^{RUL}}{(1+d)^{RUL}} \times \left(kWh_{baseline} - kWh_{installed}\right)\right]}{\left(1 - \left(\frac{1+e}{1+d}\right)^{EUL}\right)}$$

Equation 261

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 256*

$NPV_{Total,\ kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 257*
$NPV_{EUL,\ kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 258*
$NPV_{EUL,\ kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 259*

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:

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

Equation 262

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

Equation 263

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.

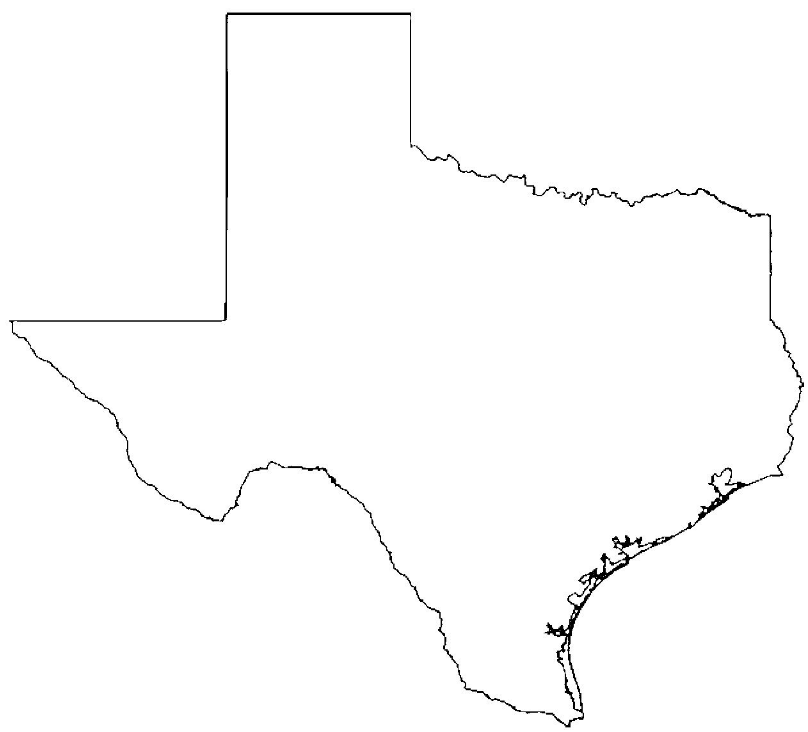
Public Utility Commission of Texas

Texas Technical Reference Manual

Version 9.0

Volume 4: Measurement and Verification Protocols

Program Year 2022



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TRM Technical Support

Technical support and questions can be emailed to the EM&V team's project manager (lark.lee@tetratech.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
- Renewables: Nonresidential Solar Photovoltaics
- Renewables: Residential Solar Photovoltaics
- Renewables: Solar Shingles
- Miscellaneous: Behavioral
- Miscellaneous: Air Compressors less than 75 hp
- Miscellaneous: Commercial Retro-commissioning
- 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	9.0 update
Residential and nonresidential	HVAC	Air conditioning tune-ups	No revisions
Nonresidential	HVAC	Ground source heat pumps	No revisions
Nonresidential	HVAC	Variable refrigerant flow systems	No revisions
Residential	Whole house	Residential new construction	For reference home specification, added HVAC commissioning and dehumidification system
Residential and nonresidential	Renewables	Residential and nonresidential solar photovoltaics	Clarified PVWatts® kWh modeling instructions and documentation requirements; provided guidance for slightly tilted arrays that fall outside lookup table azimuth ranges
Residential and nonresidential	Renewables	Solar shingles	No revisions
Residential	Renewables	Solar attic fans	Reinstate measure requiring M&V data collection
Nonresidential	Miscellaneous	Behavioral	Updated model requirements to account for pandemic and other non-routine events
Nonresidential	Miscellaneous	Air compressors less than 75 hp	No revisions
Nonresidential	Miscellaneous	Commercial retro-commissioning	Updated model requirements to account for pandemic and other non-routine events
Nonresidential	Miscellaneous	Thermal energy storage	No revisions
Residential	Load management	Residential load curtailment	Added peak demand period by utility; added links to program manuals
Nonresidential	Load management	Nonresidential load curtailment	Added eligibility exclusion for critical load customers and removed tables detailing the utility programs; updated links to program manuals

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 six 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. 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 six 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)

Baseline Condition

The baseline efficiency conditions are calculated (see Equation 7) 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 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

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

Equation 1

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

Equation 2

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

Equation 3

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

Equation 4

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

Equation 5

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

Equation 6

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

Equation 7

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

Equation 8

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

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., $\eta_{post,C}$) is used as a proxy for the post-tune-up heating efficiency.

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

Equation 10

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

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

$$Specific\ Heat\ of\ Moist\ Air, [C_p] = -2.0921943x10^{-14} \times t_{db}^4 + 2.5588383x10^{-11} \times t_{db}^3 + 1.2900877x10^{-8} \times t_{db}^2 + 5.8045267x10^{-6} \times t_{db} + 0.23955919$$

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

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

Equation 15

The Saturation Over Liquid Water equation is:

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

Equation 16

$$Saturation\ Pressure\ Over\ Liquid\ Water, [P_{ws}] = e^{\left[\frac{C_8}{T} + C_9 + C_{10} \times T + C_{11} \times T^2 + C_{12} \times T^3 + C_{13} \times ln(T)\right]}$$

Equation 17

$$P_{atm} = \frac{29.92}{2.036} \times (1 - 6.8753x10^{-6} \times Z)^{5.2559}$$

Equation 18

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

Equation 19

$$Specific\ Volume\ (Return\ Air), [v_{Return\ Air}] = \frac{0.7543 \times (t_{db} + 459.67) \times (1 + 1.6078 \times W)}{P}$$

Equation 20

Note that if CFM (airflow) in Equation 19 is determined using method 2 (measured airspeed and duct grill dimensions), then the above CFM value is calculated using Equation 21.

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

Equation 21

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

Equation 22

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

Equation 23

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

Equation 24

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

Equation 25

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

Equation 26

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

Equation 27

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

Equation 28

$$A = 10°\mathrm{F} - \left(Wet\ Bulb_{Return\ Air} - Wet\ Bulb_{Supply\ Air}\right)$$

Equation 29

$$B = (95°\mathrm{F} - Dry\ Bulb_{Oudoor})$$

Equation 30

[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 16); Nonresidential Volume 3 Table 32 through Table 36)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Table 17); Nonresidential Volume 3 Tables 32 through Table 36)*
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 3)*
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*

Efficiency loss	=	*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*)*
P	=	*Measured total pressure of moist air [inches mercury]*
P_{ws}	=	*Saturation pressure over liquid water [psia]*
P_{atm}	=	*Atmospheric pressure [psia]*
v	=	*Specific volume of air [cu.ft./lb]*
Ln.	=	*Natural Logarithm*
e	=	*Natural log constant (2.71828182845904523536028747135 27)*
Z	=	*Elevation altitude [feet]*
T	=	*Absolute temperature, Rankine scale* $[°R = °F + 459.67]$
t_{db}	=	*Measured dry-bulb temperature [°F]*
t_{wb}	=	*Measured wet-bulb temperature [°F]*
$Wet\ Bulb_{Return\ Air}$	=	*Wet-bulb temperature of return air (load) to AC evaporator [°F]*
$Wet\ Bulb_{Supply\ Air}$	=	*Wet-bulb temperature of cooled supply air to indoor space [°F]*
$Dry\ Bulb_{Outdoor}$	=	*Dry-bulb temperature of outdoor air at time of tune-up [°F]*
$h_{Return\ Air}$	=	*Measured enthalpy of return air (load) to AC evaporator [Btu/lb]*
$h_{Suppy\ Air}$	=	*Measured enthalpy of cooled supply air to indoor space [Btu/lb]*
Mass Flow Rate	=	*Measured heat carrying capacity of moist return air [lb/hr]*
CFM	=	*AC supply/return air flow [cu.ft./min.] (Method 1 see Table 4)*
Length	=	*Measured length of duct grill long side [inches] (Method 2)*
Width	=	*Measure width of duct grill short side [inches] (Method 2)*
Air Speed	=	*Measured air velocity at duct grille [feet per second] (Method 2)*

95°F	=	*95°F is the outdoor dry-bulb temperature at AHRI test conditions*
10°F	=	*10°F is the typical wet-bulb temperature change across an evaporator coil at AHRI conditions*

Energy and Demand Savings Tables

Efficiency Loss Factors

The baseline efficiency conditions (η_{pre}) are calculated using the measured post-service test-out (η_{TO}) and AHRI-adjusted (η_{post}) value in combination with the appropriate *efficiency loss* value for that tune-up. The efficiency loss factors, as described in Table 2 below, are dependent on whether a refrigerant charge adjustment was made to the air conditioning unit as part of the tune-up. The efficiency loss factors are also different between unit sizes as well as distinct between the sector types. Therefore, efficiency losses should be developed separately for those with and without a refrigerant charge and residential versus commercial units.

Table 2. AC Tune-Up Efficiency Loss Factors

Market sector	Refrigerant charge adjusted
Residential	No
	Yes
Commercial	No
	Yes

Power Factors

Capturing power factors from units in the field can be difficult. Stipulating these factors is acceptable, and suggested power factor values are presented by motor type for packaged and split system AC and heat pump units in Table 3.

Table 3. Recommended Power Factors for AC Components

Power factors for AC components	
Motor type	**Power factor**
Blower: Electrically commutated motor (ECM)	0.68
Blower: Permanent-split capacitor motor (PSC)	0.98
Blower: Three phase	0.98
Outdoor condensing unit	0.85
Variable frequency drive (single-phase)	0.87
Variable frequency drive (three-phase)	0.65

Coincidence factor (CF) and equivalent full-load hour (EFLH) values

Residential: The reader is referred to TRM Volume 2 for deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values for residential building types by climate zone for central AC or heat pump units.

Nonresidential: The reader is referred to TRM Volume 3 for deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values by building type and climate zone for packaged and split AC and heat pump units.

Cooling Load Calculation

The cooling capacity ($Cap_{TO,C}$) of the AC unit is calculated automatically from technician measurements at test-out by the data collection and tracking system software using supply and return air enthalpy measurements and the volumetric airflow (CFM) according to Equation 19. There are two methods for estimating the airflow rate. Method 1: Direct air velocity measurements combined with air-grille dimensions times velocity (in feet per second) times 60 minutes per hour [CFM = *(grill area* ft^2*)x (airspeed in feet per minute)*]. Method 2: The technician may select an estimate of airflow using manufacturer's fan charts.

The two methods for determining AC system airflow values following completion of the AC tune-up at test out are summarized in Table 4 below.

Table 4. AC Air Flow Determination Methods for Estimating Cooling Capacity at Test-Out

Method for estimating AC air flow	Data source
Method 1: Handheld anemometer, grill dimension measurements; CFM calculation	L = Air intake grille length (in feet) W = Air intake grille width (in feet) S = Speed of airflow (feet per minute)
Method 2: Generic manufacturer fan charts	Select airflow (CFM) value based on the closest match to: • External static pressure • Nominal tons • Blower speed • Belt horsepower

Table 5. EER Adjustment Factor and Capacity Adjustment Factor Constants

EER adjustment factor and capacity adjustment factor constants[4]	
$C_1 = 1.013421588$	$D_1 = 1.003933337$
$C_2 = 0.017697661$	$D_2 = 0.016648337$
$C_3 = -0.006686796$	$D_3 = -0.006686796$
$C_4 = -0.000931159$	$D_4 = -0.000933205$
$C_5 = 8.04838 \times 10^{-5}$	$D_5 = 0.000222327$
$C_6 = -3.59283 \times 10^{-5}$	$D_6 = -0.000169511$

Table 6. Constants for Saturation Pressure Over Liquid Water Calculation

Saturation pressure over liquid water constants[5]	
$C_8 = -1.0440397\ \mathrm{E}+04$	$C_{11} = 1.2890360\ \mathrm{E}-05$
$C_9 = -1.1294650\ \mathrm{E}+01$	$C_{12} = -2.4780681\ \mathrm{E}-09$
$C_{10} = -2.7022355\ \mathrm{E}-02$	$C_{13} = 6.5459673\ \mathrm{E}+00$

Metering Plan

Equipment Required

The AC tune-up and approved savings protocols herein require the use of equipment in accordance with the toolkit (with specified manufacturer and model numbers) to measure key AC performance parameters in the field. The use of these tools or equivalent ensures consistent data acquisition conformance by all parties. The equipment required in the toolkit is shown in Table 7 for reference.

[4] EER and capacity AHRI adjustment factors and algorithms initially developed by Cadmus for Tune-Up programs in Texas.

[5] Developed by Cadmus: 2013 Portfolio Evaluation, Entergy Arkansas, Appendix A.

Table 7. AC Tune-Up Toolkit Components

Device	Use area	Quantity
Approved digital refrigerant analyzer: • Testo 556 • Testo 560 • Testo 550 • iManifold 913-M and 914-M	Refrigerant charge adjustment Refrigerant pressure Refrigerant temperature Super heat Subcooling	1-2
Testo 318-V Inspection Scope	Visual coil inspection	Optional
Spring clamp probes matched to the Testo A/C Analyzer	Refrigerant line temperatures	2
Testo 417 Large Vane Anemometer	Airflow	1
Testo 605-H2 Humidity Stick Or iManifold 911-M	Supply and return air wet-bulb temperature	2
Refrigeration hoses 5' NRP 45 Deg.	Refrigerant pressure	Set of 3
Charging calculator (R-22)	Refrigerant charge	1
Charging calculator (R-410A)	Refrigerant charge	1
Testo 905-T1 Temperature Stick or Testo 605H Humidity stick Or iManifold 912-M or wired outdoor air temperature probe	Ambient air temperature	1
Testo 510 Compact Digital Manometer (or other digital manometer of comparable accuracy)	Static pressure	1
Magnetic static pressure tips	Static pressure	2
Set of barbed hose tees	Static pressure	1
1/8 mpt x barbed fitting	Static pressure	1
10' silicone tubing	Static pressure	1
Digital volt/amp Meter	Voltage and current	1
Ruler/tape measure	Duct and grill dimensions	1
Tablet computer or smartphone if using iManifold; OR: laptop or desktop to use for data entry if using the Testo kit components	AC tune-up application	1

Metering Schedule

A complete metering schedule identifying the AC tune-up process and measurements performed for AC tune-ups is presented in M&V Metering Schedule. The technician follows the metering schedule during the tune-up process.

Equipment Accuracy

The accuracy for each required piece of metering equipment is shown in Table 8.

Table 8. Measurement Resolution and Accuracy

Device	Model number	Measurement	Resolution	Accuracy
Inspection scope	Testo 318-V	Visual coil inspection	N/A	N/A
Anemometer	Testo 417[6]	Air flow velocity	0.01m/s	±0.1m/s+1.5% of reading
Manometer	Testo 510[6]	Differential pressure	0.01 inH2O	±0.01 inH2O (0-0.12 inH2O), ±0.02 inH2O (0.13-0.40 inH2O), ±(0.04 inH2O +1.5 % of reading) (rest of range)
Refrigerant system analyzer	Testo 556[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 560[6]	Refrigerant temperature	0.1°F	±0.6°F ±1 digit
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
	Testo 550[6]	Refrigerant temperature	0.1°F	±1.8°F + 1 digit
		Refrigerant pressure	0.1 psi	±0.75% Full Scale + 1 Digit
	iManifold 913-M and 914-M[7]	Refrigerant temperature	0.1°F	±0.4°F
		Refrigerant pressure	0.1 psi	±0.5% Full Scale
DB/WB thermometer	Testo 605-H2[6]	Dry-/wet-bulb temperature	0.1°F	±0.9°F
	iManifold 911-M[7]		0.1°F	±0.4°F
Surface thermometer	Testo 905-T2[6]	Condenser ambient air temperature	0.1°F	±1.8°F (-58 to +212°F)
	iManifold 912-M[7]		0.1°F	±0.4°F
Volt/amp meter	Fluke 27-II[8]	Voltage	0.1 V	±(0.5% +3)
		Current	0.01 A	±(1.5% +2)
Ruler/tape measure	N/A	Air grill dimensions[9]	1/8 in	±1/16 in

Claimed Peak Demand Savings

A summer peak period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

[6] Obtained from Testo product manuals, www.testo.us.
[7] Obtained from Imperial iManifold product website, https://imanifold.com/imanifold/residential-hvac/.
[8] Obtained from Fluke 27-II product manual, http://us.fluke.com. Fluke 27-II not required, but volt/amp meter used must meet or surpass accuracy listed.
[9] Ruler must have 1/8-inch graduations or less.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of residential and commercial AC tune-ups is 5 years.[10]

Program Tracking Data and Evaluation Requirements

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

- Decision/Action Type: O&M
- Building type
- Climate/weather zone
- Equipment type
- Equipment rated cooling and heating capacities
- Equipment cooling and heating efficiency ratings
- Equipment make and model
- Refrigerant type
- Refrigerant adjustment (added/removed, weight)
- Note which five remaining AC tune-up service measures were completed
- Test-out measured cooling capacity
- Test-out measured power inputs
- Test-out measured mass flow rate
- All other operating measurements and parameters listed in M&V protocol

References and Efficiency Standards

Not applicable.

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment
- PUCT Docket 40885—Provides a petition to revise deemed savings values for Commercial HVAC replacement measures. Items covered by this petition and applicable to the tune-up measure include the following:
- Updated demand and energy coefficients for all commercial HVAC systems.

[10] GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group. Page 1-3, Table 1.

- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ANSI/ASHRAE/IES Standard 90.1-2010. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1A through Table 6.8.1D.
- Code of Federal Regulations. Title 10. Part 431—Energy Efficiency Program for Certain Commercial and Industrial Equipment. https://www.govinfo.gov/app/details/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part431.

Document Revision History

Table 9. M&V AC Tune-Up Revision History

TRM version	Date	Description of change
v3.0	4/10/2015	TRM v3.0 origin.
v3.1	11/05/2015	Major methodology updates include revising action/decision type from retrofit to O&M and establishing new efficiency loss factors by including 2014 measurements into the regression analysis. Revised measure details to match the layout of TRM volumes 2 and 3. Added detail regarding Measure Overview, Measure Description, Measure Life, Program Tracking Data and Evaluation Requirements, References and Efficiency Standards, and Document Revision History.
v4.0	10/10/2016	Revised efficiency loss factors based on 2015 results. Added VFD motor types.
v5.0	10/10/2017	Removed reference to deemed efficiency loss factors. Added clarity to separate units by refrigerant charge adjustments and unit size/type. Updated table references.
v6.0	10/2018	No revisions.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.
v9.0	10/2021	No revisions.

2.1.2 Ground Source Heat Pumps Measure Overview

TRM Measure ID: NR-HV-GH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit (RET)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V and whole facility measurement

This protocol is used to estimate savings for ground source heat pump (GSHP) measures through an M&V approach. The development of the GSHP M&V methodology is driven by the desire to create and implement a framework to provide high-quality verified savings while not restricting the ability of program implementers to use the tools and systems they have developed. The protocol allows for flexibility in implementation while developing verified energy savings and balancing the risk associated with the uncertainty in the expected savings.

Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) system replacing an existing heating, ventilating, and air conditioning (HVAC) system. Initial estimated savings are dependent upon the energy efficiency ratings and operational parameters of the existing systems being replaced by the new higher efficiency equipment efficiency ratings and operating parameters. The energy savings estimation process is designed to efficiently estimate electric energy and demand savings attributable to each GSHP system.

Applicable GSHP efficient measure types include:

- Single-stage GSHP
- Multi-stage GSHP
- Closed loop GSHP
- Direct geoexchange (DGX)
- Open loop WSHP
- Water-to-air
- Water-to-water

Eligibility Criteria

This measure only applies when replacing an existing HVAC system with a new GSHP system. New construction GSHP systems are not eligible for applying this methodology.

Baseline Condition

Existing System Replacement: The baseline for retrofit projects is specific to the existing HVAC system being replaced by a new GSHP; that is, existing system manufacturer, model number, an AHRI nominal efficiencies, and operating parameters, define the baseline case.

High-Efficiency Condition

High-efficiency conditions for GSHP equipment must meet applicable standards. AHRI energy ratings for EER and COP by manufacturer model numbers are established following required test protocols and parameters and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements as set forth in Table 10.

Water source heat pumps are verified using manufacturer specifications that clearly show the entering water temperature (EWT), gallons per minute (GPM), and the associated EER rating at ARI/ISO 13256-2 cooling conditions of 77°F EWT and 53.6°F leaving water temperature (LWT) ground loop.

Qualifying DXG GSHPs must be rated in accordance with AHRI 870 rating conditions.

Table 10. Minimum Efficiency Levels for Commercial Single Stage GSHPs[11]

System type	Capacity (Btuh)	Cooling EWT rating condition	Minimum cooling EER	Heating EWT rating condition	Minimum heating COP
Water to air (water loop)	< 17,000	86°F	12.2	68°F	4.3
	≥ 17,000 and < 135,000	86°F	13.0	68°F	4.3
Water to air (groundwater)	< 135,000	59°F	18.0	50°F	3.7
Brine to air (ground loop)	< 135,000	77°F	14.1	32°F	3.2
Water to water (water loop)	< 135,000	86°F	10.6	68°F	3.7
Water to water (groundwater)	< 135,000	59°F	16.3	50°F	3.1
Brine to water (ground loop)	< 135,000	77°F	12.1	32°F	2.5

[11] Values from ASHRAE 90.1-2013.

Energy and Demand Savings Methodology

Whole Facility EM&V Methodology (Used to Estimate Final Savings Potential)

A whole facility EM&V methodology presents a plan to determine energy savings from replacing an existing HVAC system with a new GSHP system to provide heating and cooling for a commercial facility. This methodology measures and verifies initial energy savings estimates. The plan follows procedures guided by whole facility Option C in the International Performance Measurement and Verification Protocol (IPMVP). The development of the whole facility measurement methodology creates and implements a framework to provide high-quality verified savings while keeping within the standards currently used by similar commercial heating, ventilating, and air conditioning (HVAC) measures in TRM Volume 3. The Whole Facility guidance is found in the latest version of the IPMVP Volume 1 EVO 10000-1:2012.

M&V Plan and M&V Report

Preparation of an M&V plan and ultimately an M&V report is required to determine savings. Advanced planning ensures that all data collection and information necessary for savings determination will be available after implementation of the measure(s). The project's M&V plan and M&V report provide a record of the data collected during project development and implementation. These documents may also serve multiple purposes throughout a project, including recording critical assumptions and changing conditions. Documentation should be complete, readily available, clearly organized, and easy to understand.

The methodology described herein involves the use of whole facility electric meter data. An important component of the project is to identify the existing base and new case system information.

In addition to documenting existing and new equipment information, IPMVP describes the following requirements as part of the M&V plan and M&V report contents. These requirements are listed below, and the user is directed to the current version of IPMVP for further detail and guidance.

- Measure intent
- Selected IPMVP option and measurement boundary
- Baseline - period, energy, and conditions
- Reporting period
- Basis for adjustment
- Analysis procedure
- Energy prices (as applicable)
- Meter specifications
- Monitoring responsibilities
- Expected accuracy