Control Number: 38578

Item Number: 29

Addendum StartPage: 0

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 203*
ME	=	*Motor efficiency, based on NEMA Standard Efficiency Motor, see Table 204*
SME	=	*Mechanical efficiency of sucker rod pump, see Table 203*
TimeClock%On	=	*Stipulated baseline timeclock setting, see Table 203*
$Run_{constant}$, $Run_{coefficient}$	=	*8.336, 0.956. Derived from SPE 16363* [365]
VolumetricEfficiency%	=	*Average well gross production divided by theoretical production (provided on rebate application)*

Deemed Energy and Demand Savings Tables

Table 203. Deemed Variables for Energy and Demand Savings Calculations

Variable	Stipulated/deemed values
LF (Load Factor)	25%[366]
ME (motor efficiency)	See Table 2-137
SME (pump mechanical efficiency)	95%[367]
Timeclock%On	65%[368]

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%).

[365] 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).

[366] *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.

[367] Engineering estimate for standard gearbox efficiency.

[368] A TimeClock%On of 80% is typical from observations in other jurisdictions, but that was adjusted to 65% for a conservative estimate. This value will be reevaluated once Texas field data is available.

Table 204. NEMA Premium Efficiency Motor Efficiencies[369]

Motor horsepower	Nominal full load efficiency					
	Open motors (ODP)			Enclosed motors (TEFC)		
	6 poles 1200 rpm	4 poles 1800 rpm	2 poles 3600 rpm	6 poles 1200 rpm	4 poles 1800 rpm	2 poles 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 175.

Measure Life and Lifetime Savings

The EUL for this measure is 15 years.[370]

[369] 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.

[370] 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 following 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[371]

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.

[371] 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 205. 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	10/202	TRM v8.0 update. General reference checks and text edits.

2.6.4 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[372].

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.[373] 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.

[372] 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

[373] 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.[374]

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

Equation 178

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 179

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

Equation 180

[374] 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 (Table 206)*
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] (Table 206)*
EF_{conv}	=	*Conventional single-speed pump energy factor [gal/W·hr] (Table 206)*
gal	=	*The volume of the pool in gallons, (Table 207)*
$turn_{day}$	=	*Turnovers per day, number of times the volume of the pool is run through the pump per day, (Table 207)*
EF_{ES}	=	*ENERGY STAR® weighted energy factor [gal/W·hr] (Table 207)*
60	=	*Constant to convert between minutes and hours*
1,000	=	*Constant to convert from kilowatts to watts*

Table 206. Conventional Pool Pumps Assumptions[375]

New rated pump HP	Hours limited hours[376]	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

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

376 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 207. ENERGY STAR® Pool Pumps Assumptions[377]

New rated pump HP	Turnovers/day limited hours	Turnovers/day 24/7 Operation	Gallons	EF_{ES} (gal/W·h)
≤ 1.25	5.4	5.4	20,000	8.7
1.25 < hp ≤ 1.75	5.6	5.6	20,000	8.9
1.75 < hp ≤ 2.25	5.8	5.8	22,000	9.3
2.25 < hp ≤ 2.75	5.4	5.4	25,000	7.4
2.75 < hp ≤ 3	5.2	5.2	28,000	7.1

Demand Savings Algorithms

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

Equation 181

Where:

hours = *Conventional single-speed pump daily operating hours (Table 206)*

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 208*

Table 208. Demand Factors[378]

Operation	Summer DF	Winter DF
24/7 Operation	1.0	1.0
Seasonal/Limited Hours	1.0	0.5

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

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

Deemed Energy and Demand Savings Tables

Table 209. ENERGY STAR® Variable Speed Pool Pump Energy Savings[379]

	Year-round operation		
	24/7 operation	Limited hours	Seasonal operation (7 months)
New rated pump HP	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 210. 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 211. 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.

---

379 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

According to DEER 2014, the estimated useful life for this measure is 10 years.[380]

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-nurnout, 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

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

Document Revision History

Table 212. 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.

2.6.5 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[381], and assume baseline computer settings never enter sleep mode, and 60% of computers are turned off each night.[382]

---

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

[382] 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.[383]

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 182

$$kW_{savings} = kWh_{savings} \times PWPLS$$

Equation 183

Where:

W_{active} = *total wattage of the equipment, including computer and monitor, in active/idle mode; see Table 213*

$hrs_{active_{pre}}$ = *annual number of hours the computer is in active/idle mode before computer management software is installed; see Table 214*

$hrs_{active_{post}}$ = *annual number of hours the computer is in active/idle mode after computer management software is installed; see Table 214*

W_{sleep} = *total wattage of the equipment, including computer and monitor, in sleep mode; see Table 213*

$hrs_{sleep_{pre}}$ = *annual number of hours the computer is in sleep mode before computer management software is installed; see Table 214*

$hrs_{sleep_{post}}$ = *annual number of hours the computer is in sleep mode after computer management software is installed; see Table 214*

W_{off} = *total wattage of the equipment, including computer and monitor, in off mode; see Table 213*

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

$hrs_{off_{pre}}$ = annual number of hours the computer is in off mode before computer management software is installed; see Table 214

$hrs_{off_{post}}$ = annual number of hours the computer is in off mode after computer management software is installed; see Table 214

1,000 = Conversion factor: 1 kW / 1,000 W

$PWPLS$ = Probability weighted peak load share; see Table 215

Table 213. Computer Power Management—Equipment Wattages[384]

Equipment	W_{active}	W_{sleep}	W_{off}
Conventional Monitor[385]	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 214. Computer Power Management—Operating Hours[386]

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-work days/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

384 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.

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

386 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 215. Computer Power Management—Probability Weighted Peak Load Share, All Activity Types

Climate zone	Summer PWPLS	Winter PWPLS
1	0.108	0.018
2	0.104	0.020
3	0.110	0.020
4	0.103	0.023
5	0.125	0.047

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 213, Table 214, and Table 215. The following tables provide these deemed values.

Table 216. 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 217. 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	0.007	0.001	0.006	0.001	0.007	0.001	0.006	0.001	0.008	0.003
Conventional Computer	0.017	0.003	0.017	0.003	0.018	0.003	0.017	0.004	0.020	0.008
Conventional Notebook	0.005	0.001	0.005	0.001	0.005	0.001	0.005	0.001	0.006	0.002
ENERGY STAR® Monitor	0.006	0.001	0.005	0.001	0.006	0.001	0.005	0.001	0.006	0.002
ENERGY STAR® Computer	0.010	0.002	0.009	0.002	0.010	0.002	0.009	0.002	0.011	0.004
ENERGY STAR® Notebook	0.003	0.000	0.003	0.001	0.003	0.001	0.003	0.001	0.003	0.001

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 EUL of this measure is based on the useful life of the computer equipment which is being controlled, 3 years.[387]

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.

- Type of equipment
  - Conventional or ENERGY STAR®
  - Monitor, computer, or notebook

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Not applicable.

Document Revision History

Table 218. Nonresidential Computer Power Management Revision History

TRM version	Date	Description of dhange
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.

[387] 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.

2.6.6 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 223. 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 EPAct 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)[388].

With these changes, motors ranging from one to 500 hp bearing the "NEMA Premium" trademark will align with national energy efficiency standards and legislation. The Federal Energy

[388] 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.

Management Program (FEMP) adopted NEMA MG 1-2006 Revision 1 2007 in its Designated Product List for federal customers.

Additiontally, 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)[389] (see Table 222) 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)[390], as listed in Table 224.

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 222.

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.

[389] 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. Accessed July 2020.

[390] 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. Accessed July 2020.

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 219 or Table 220 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 184

Demand Savings Algorithms

HVAC Applications:

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

Equation 185

Industrial Applications[391]:

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

Equation 186

Where:

hp	=	*Nameplate horsepower data of the motor*
0.746	=	*hp-to-kWh conversion Factor (kW/hp)*[392]
LF	=	*Estimated load factor (if unknown, see Table 219 or Table 220)*

[391] Assumes 3-shift operating schedule

[392] 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. Accessed July 2020.

$\eta_{baseline,ROB}$	=	*Assumed original motor efficiency (Table 222)*[393]
η_{post}	=	*Efficiency of the newly installed motor*
Hrs	=	*Estimated annual operating hours (if unknown, see Table 219 or Table 220)*
CF	=	*Coincidence Factor (see Table 219)*
$kWh_{savings,ROB}$	=	*Total energy savings for a new construction or ROB project*
$kW_{savings,ROB}$	=	*Total demand savings for a new construction or ROB project*

Table 219. Premium Efficiency Motors—HVAC Assumptions by Building Type

Building type	Load factor[394]	CF[395]	HVAC fan hours[396]
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

[393] In the case of rewound motors, in-situ efficiency may be reduced by a percentage as found in Table 221

[394] Itron 2004-2005 DEER Update Study, Dec 2005; Table 3-25. Accessed September 2019 http://deeresources.com/files/deer2005/downloads/DEER2005UpdateFinalReport_ItronVersion.pdf

[395] 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

[396] Factors are equivalent to Table 80 Yearly Motor Operation Hours by Building Type for HVAC Frequency Drives

Table 220. Premium Efficiency Motors—Industrial Assumptions by Building Type

Industrial processing	Load factor[397]	Hours[398]					
		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 221. Rewound Motor Efficiency Reduction Factors[399]

Motor horsepower	Efficiency reduction factor
< 40	0.010
≥ 40	0.005

397 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-19. Accessed 07/2020. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

398 United States Industrial Electric Motor Systems Market Opportunities Assessment, Dec 2002; Table 1-15. Accessed 07/2020. https://www1.eere.energy.gov/manufacturing/tech_assistance/pdfs/mtrmkt.pdf

399 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. Accessed July 20220.

Table 222. Premium Efficiency Motors—New Construction and Replace-on-Burnout Baseline Efficiencies by Motor Size[388,392]

hp	Open motors: $\eta_{baseline, ROB}$ 6-pole	Open motors: $\eta_{baseline, ROB}$ 4-pole	Open motors: $\eta_{baseline, ROB}$ 2-pole	Closed motors: $\eta_{baseline, ROB}$ 6-pole	Closed motors: $\eta_{baseline, ROB}$ 4-pole	Closed motors: $\eta_{baseline, ROB}$ 2-pole
1	82.5	85.5	77.0	82.5	85.5	77.0
1.5	86.5	86.5	84.0	87.5	86.5	84.0
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91.0	88.5	91.0	91.7	89.5
10	91.7	91.7	89.5	91.0	91.7	90.2
15	91.7	93.0	90.2	91.7	92.4	91.0
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 223); 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 223. Remaining Useful Life (RUL) of Replaced Motor[400]

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[401]	0.0
9	5.9		

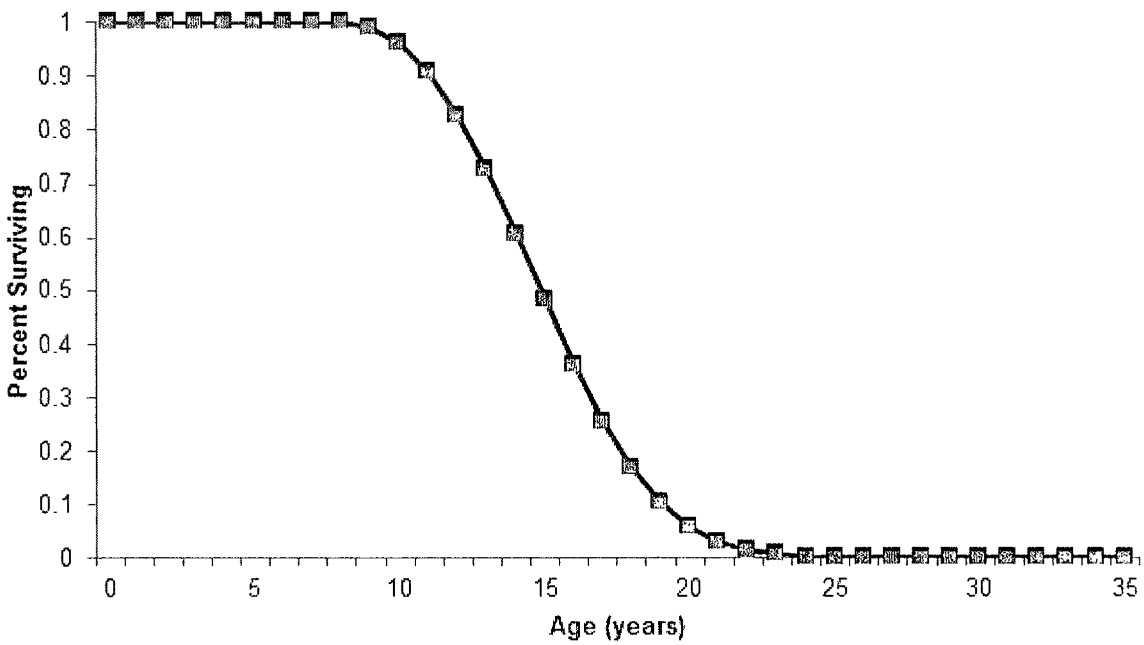
[400] Current federal standard effective date is 12/19/2010. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should use the ROB baseline instead.

[401] RULs are capped at the 75th percentile of equipment age, 17 years, as determined based on DOE survival curves (see Figure 5). 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.

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 5.

Figure 5. Survival Function for Premium Efficiency Motors[402]



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 5. 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.

[402] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. Accessed July 2020. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

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 187

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 188

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 189

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 190

Industrial Applications

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

Equation 191

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 192

Industrial Applications

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

Equation 193

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 194

Where:

$\eta_{baseline,ER}$	=	*Assumed original motor efficiency for remaining EUL time period (Table 224 or)*[403]
$kWh_{savings,RUL}$	=	*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*

[403] Ibid.

Table 224. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size[390]

	Open motors: $\eta_{baseline, ER}$			Closed motors: $\eta_{baseline, ER}$		
hp	6-pole	4-pole	2-pole	6-pole	4-pole	2-pole
1	80.0	82.5	75.5	80.0	82.5	75.5
1.5	84.0	84.0	82.5	85.5	84.0	82.5
2	85.5	84.0	84.0	86.5	84.0	84.0
3	86.5	86.5	84.0	87.5	87.5	85.5
5	87.5	87.5	85.5	87.5	87.5	87.5
7.5	88.5	88.5	87.5	89.5	89.5	88.5
10	90.2	89.5	88.5	89.5	89.5	89.5
15	90.2	91.0	89.5	90.2	91.0	90.2
20	91.0	91.0	90.2	90.2	91.0	90.2
25	91.7	91.7	91.0	91.7	92.4	91.0
30	92.4	92.4	91.0	91.7	92.4	91.0
40	93.0	93.0	91.7	93.0	93.0	91.7
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 225. Premium Efficiency Motors—Early Retirement Baseline Efficiencies by Motor Size for 250-500 hp Motors Manufactured Prior to June 1, 2016[404]

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

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 median estimated useful life (EUL) for premium efficiency motors is 15 years.[405]

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

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

[405] 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

- Newly installed motor efficiency
- Description of motor service
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

References and Efficiency Standards

Petitions and Rulings

Not applicable

Relevant Standards and Reference Sources

- 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 226. 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.

2.6.7 Central Domestic Hot Water (DHW) Controls Measure Overview

TRM Measure ID: NR-MS-DC

Market Sector: Commercial

Measure Category: Miscellaneous

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

Fuels Affected: Electricity

Decision/Action Type: Retrofit, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

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

Eligibility Criteria

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

Baseline Condition

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

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

Savings Algorithms and Input Variables

Circulation Pump Savings Algorithm

$$Annual\ Pump\ Energy\ Savings\ [kWh] = kW_{pump} \times (Pump\%On\_base - Pump\%On\_eff) \times Hours$$

Equation 195

$$Pump\ Demand\ Savings\ [kW] = Annual\ Pump\ Energy\ Savings\ \times PLS$$

Equation 196

Where:

kW_{pump}	=	*The demand used by the circulation pump, obtained from the project site. If unknown, assume 0.075 kW.*
Pump%On_base	=	*Baseline pump operation as percentage of time, 100%.*
Pump%On_eff	=	*Efficient pump operation as percentage of time, 7%*[406]*.*
Hours	=	*Hours per year = 8,760.*
PLS	=	*Probability weighted peak load share, Table 227.*

[406] A 93% pump runtime reduction is assumed based on the average runtime reduction of field studies conducted at multiple sites: "Evaluation of New DHW System Controls in Hospitality and Commercial Buildings," Minnesota Department of Commerce, average reduction of 87%; and "Energy-Efficiency Controls for Multifamily Domestic Hot Water Systems," New York State Energy Research and Development Authority, average reduction of 99%.

Table 227. Central DHW Controls—Probability Weighted Peak Load Share[407]

Building type	Commercial		Lodging[408]	
Climate zone	Summer peak	Winter peak	Summer peak	Winter peak
Zone 1	0.00016	0.00011	0.00012	0.00015
Zone 2	0.00017	0.00011	0.00012	0.00014
Zone 3	0.00016	0.00011	0.00012	0.00015
Zone 4	0.00016	0.00011	0.00012	0.00015
Zone 5	0.00018	0.00011	0.00012	0.00014

Thermal Distribution Savings Algorithm

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

Equation 197

$$Thermal\ Demand\ Savings\ [kW] = Annual\ Thermal\ Energy\ Savings\ \times PLS$$

Equation 198

Where:

 # Units = *The number of dwelling units at the project site.*

$kWh_{reference}$ = *Annual kWh energy savings from reference study, Table 228.*

HDD Adjustment = *Climate adjustment for Texas heating degree days, Table 229.*

PLS = *Probability weighted peak load share, Table 227.*

Table 228. Central DHW Controls—Reference kWh by Water Heater and Building Type[409]

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

[407] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the EPRI Load Shape Library 6.0. ERCOT regional End Use Load Shapes for Water and Process Heating. Peak Season, Peak Weekday values used for summer calculations. Off Peak Season, Peak Weekday values used for winter calculations. http://loadshape.epri.com/enduse. Accessed July 2020.

[408] For the purposes of this measure, the lodging building type applies to all buildings where lodging takes place, including multifamily, hotels, nursing homes, dormitories, prisons, and similar.

[409] Reference kWh are the annual energy savings per dwelling unit from the Southern California Edison Company Work Paper SCE13WP002, Demand Control for Centralized Water Heater Recirculation Pump for California Climate Zone 13.

Table 229. Central DHW Controls—HDD Adjustment Factors[410]

Climate zone	HDD adjustment
Zone 1	1.9
Zone 2	1.1
Zone 3	0.7
Zone 4	0.5
Zone 5	1.1

Deemed Energy Savings Tables

Table 230 presents the energy savings (kWh) for a range of pump sizes for all climate zones. The deemed savings are provided for convenience, but the algorithm may be used for pump sizes that differ from the assumed wattage listed in the tables.

Table 230. Central DHW Controls—Annual kWh Circulation Pump Savings

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

Table 231 presents the thermal energy savings (kWh) per dwelling unit for all climate zones. Thermal energy savings only apply to lodging building types where lodging takes place (multifamily, hotels, nursing homes, dormitories, prisons, and similar). For commercial applications, please follow a custom approach.

Table 231. Central DHW Controls—Annual kWh Thermal Distribution Savings per Dwelling Unit

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

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

Deemed Summer and Winter Demand Savings Tables

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

Table 232. Central DHW Controls—Peak Demand kW Circulation Pump Savings

Pump size	Climate zone	Commercial		Lodging	
		Summer peak kW	Winter peak kW	Summer peak kW	Winter peak kW
≤ 50	Zone 1	0.065	0.045	0.049	0.061
	Zone 2	0.069	0.045	0.049	0.057
	Zone 3	0.065	0.045	0.049	0.061
	Zone 4	0.065	0.045	0.049	0.061
	Zone 5	0.073	0.045	0.049	0.057
50 < watts < 100	Zone 1	0.098	0.067	0.073	0.092
	Zone 2	0.104	0.067	0.073	0.086
	Zone 3	0.098	0.067	0.073	0.092
	Zone 4	0.098	0.067	0.073	0.092
	Zone 5	0.110	0.067	0.073	0.086
100 ≤ watts < 150	Zone 1	0.163	0.112	0.122	0.153
	Zone 2	0.173	0.112	0.122	0.143
	Zone 3	0.163	0.112	0.122	0.153
	Zone 4	0.163	0.112	0.122	0.153
	Zone 5	0.183	0.112	0.122	0.143
≥ 150	Zone 1	0.196	0.134	0.147	0.183
	Zone 2	0.208	0.134	0.147	0.171
	Zone 3	0.196	0.134	0.147	0.183
	Zone 4	0.196	0.134	0.147	0.183
	Zone 5	0.220	0.134	0.147	0.171

Table 233. Central DHW Controls—Peak Demand kW Thermal Savings per Dwelling Unit

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Zone 1	0.12	0.07	0.05	0.03	0.15	0.09	0.06	0.04
Zone 2	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02
Zone 3	0.04	0.03	0.02	0.01	0.06	0.03	0.02	0.01

Climate zone	Summer peak				Winter peak			
	Electric resistance		Heat pump		Electric resistance		Heat pump	
	Low rise	High rise	Low rise	High rise	Low rise	High rise	Low rise	High rise
Zone 4	0.03	0.02	0.01	0.01	0.04	0.02	0.01	0.01
Zone 5	0.07	0.04	0.03	0.02	0.08	0.05	0.03	0.02

Claimed Peak Demand Savings

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

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for central DHW controls is 15 years.[411]

Program Tracking Data and Evaluation Requirements

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

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

References and Efficiency Standards

Petitions and Rulings

Not applicable.

[411] DEER 2014.

Relevant Standards and Reference Sources

- DEER 2014 EUL update.

Document Revision History

Table 234. Nonresidential Central DHW Controls 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.

2.6.8 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: NR-MS-SV

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Lodging

Fuels Affected: Electricity, gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)[412] between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95°F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

Eligibility Criteria

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in commercial lodging applications. To use deemed savings, the fuel type of the water heater must be electricity or gas.

Baseline Condition

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

High-Efficiency Condition

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

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

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

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

Equation 199

Where:

SHFR = *Showerhead flow rate, gallons per minute (gpm) (see Table 235)*

BW = *Behavioral waste, minutes per shower (see Table 235)*

n_S = *Number of showers per occupied room per day (see Table 235)*

365 = *Constant to convert days to years (see Table 235)*

$OccC_P$ = *Occupancy rate (see Table 235)*

n_{SH} = *Number of showerheads per room (see Table 235)*

Applying the formula to the values used for Texas from Table 235 returns the following values for baseline behavioral waste in gallons per showerhead per year:

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

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

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

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

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 235.

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

Equation 200

Where:

HW% = *Hot water percentage (see Table 235)*

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

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

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

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

Table 235. Showerhead TSRVs—Hot Water Usage Reduction

Description	2.5 gpm	2.0 gpm	1.75 gpm	1.5 gpm
Average behavioral waste (minutes per shower)[413]				1.742
Showers/occupied room/day[414]				1.756
Occupancy rate[415]				65.9%
Showerheads/room[416]				1.0
Behavioral waste/showerhead/year (gal)	1,838	1,471	1,287	1,103
Percent hot water[417]				80-85%, or 82.5% on average
Hot water saved/year (gal)	1,516	1,213	1,062	910

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

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

[415] 2001-2019 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 5 years (2015-2019).

[416] Assuming industry standard for standard one-bathroom rooms.

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

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

Equation 201

Where:

ρ	=	*Water density, 8.33 lbs/gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
V	=	*Gallons of hot water saved per year per showerhead (see Table 235)*
$T_{SetPoint}$	=	*Water heater setpoint: 120°F* [418]
T_{Supply}	=	*Average supply water temperature (see Table 236)*
RE	=	*Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.* [419]
$ConversionFactor$	=	*3,412 Btu/kWh for electric or 100,000 Btu/therm for gas*

Demand Savings Algorithms

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

---

418 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

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

$$Demand\ Savings\ per\ TSRV = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times Conversion\ Factor \times 365} \times CF$$

Equation 202

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 236)*

CF = *Peak coincidence factor (see Table 237)*

Table 236. Showerhead TSRVs—Water Mains Temperatures

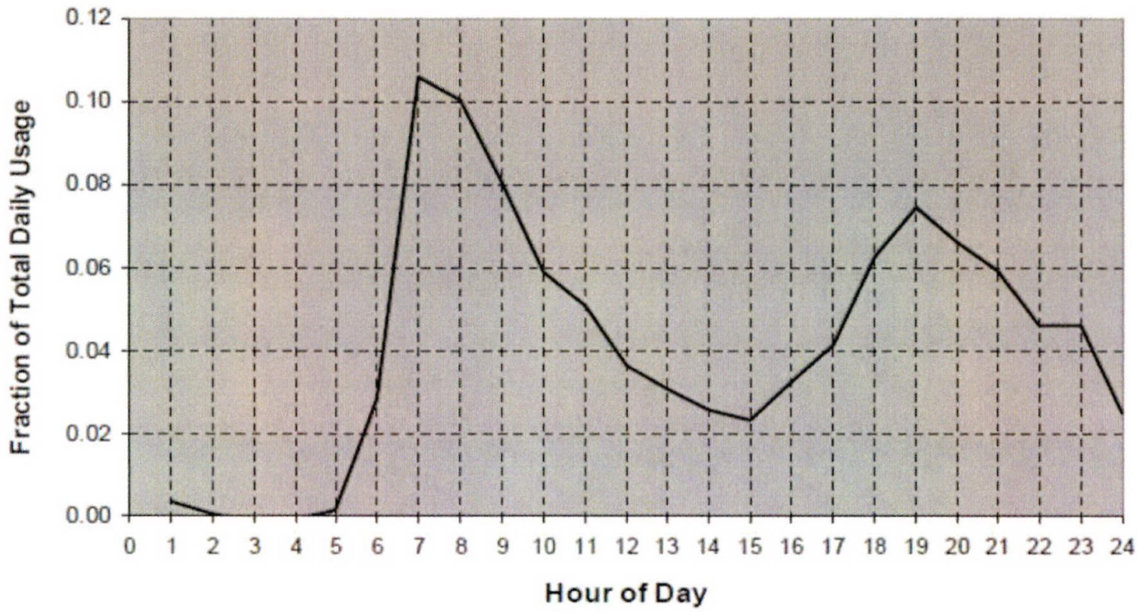
Climate zone	Water mains temperature (°F)[420]		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$ Summer	$T_{SupplySeasonal}$ Winter
Climate Zone 1: Amarillo	62.9	73.8	53.7
Climate Zone 2: Dallas	71.8	84.0	60.6
Climate Zone 3: Houston	74.7	84.5	65.5
Climate Zone 4: Corpus Christi	77.2	86.1	68.5
Climate Zone 5: El Paso	70.4	81.5	60.4

Table 237. Showerhead TSRVs—Peak Coincidence Factors

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

420 Based on typical meteorological year (TMY) dataset for TMY3: https://nsrdb.nrel.gov/about/tmy.html.

Figure 6. Showerhead TSRVs – Shower, Bath, and Sink Hot Water Use Profile[421]



Deemed Energy Savings Tables

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

Deemed Summer Demand Savings Tables

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

Deemed Winter Demand Savings Tables

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

Claimed Peak Demand Savings

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

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is established at 10 years.

[421] Building America Performance Analysis Procedures for Existing Homes.

This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[422]

Program Tracking Data and Evaluation Requirements

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

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

Document Revision History

Table 238. Nonresidential Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.

[422] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.

2.6.9 Tub Spout and Showerhead Temperature Sensitive Restrictor Valves Measure Overview

TRM Measure ID: NR-MS-TV

Market Sector: Commercial

Measure Category: Miscellaneous

Applicable Building Types: Lodging

Fuels Affected: Electricity, gas

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

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure consists of replacing existing tub spouts and showerheads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV)[423] between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95˚F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

Eligibility Criteria

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in commercial lodging applications. To use these deemed savings, the fuel type of the water heater must be electricity or gas.

Baseline Condition

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

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

High-Efficiency Condition

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

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

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

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

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

Equation 203

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

Equation 204

Where:

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 239)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 239)*

SHFR = *Showerhead flow rate, gallons per minute (gpm) (see Table 239)*

TSFR = *Tub spout flow rate, gallons per minute (gpm) (see Table 239)*

BW = *Behavioral waste, minutes per shower (see Table 239)*

n_S = *Number of showers per occupied room per day (see Table 239)*

365 = *Constant to convert days to years (see Table 239)*

OCC = *Occupancy rate (see Table 239)*

n_{SH} = *Number of showerheads per room (see Table 239)*

Applying the formula to the values from Table 239 returns the following values:

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

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

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

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

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

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

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

Equation 205

Where:

DLR = *Diverter leakage rate (gpm) (see Table 239)*

t_S = *Shower time (min/shower) (see Table 239)*

Applying the formula to the values used for Texas from Table 239 returns the following values:

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

Part 3: To determine gallons of water saved per year can be found by multiplying the total waste by the percent of hot water from Table 239.

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

Equation 206

Where:

SHBW = *Showerhead behavioral waste (gal)*

TSBW = *Tub spout behavioral waste (gal)*

DW = *Diverter waste (gal)*

$HW\%_{SH,TS}$ = *Showerheads and tub spout hot water percentage (see Table 239)*

$HW\%_{D}$ = *Diverter hot water percentage (see Table 239)*

Applying the formula to the values from Table 239 returns the following values:

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

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

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

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

Table 239. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction

Description	Part 1- behavioral waste		Part 2—diverter leakage	Part 3—total
	Showerhead warm-up	Tub spout warm-up		
Baseline showerhead flow rate (gpm)	1.5, 1.75, 2.0, or 2.5			N/A
Tub spout flow rate (gpm)[424]	N/A	5.0		N/A
Percent of warm-up events[425]	60%	40%		N/A
Average behavioral waste (minutes per shower)[426]		1.742		N/A
Average diverter leakage rate (gpm)[427]		N/A	0.80	N/A
Average shower time (minutes)[428]		N/A	7.8	N/A
Showers/occupied room/day[429]				1.756
Occupancy rate[430]				65.9%
Showerheads/room[431]				1.0

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

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

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

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

428 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.

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

430 2001-2019 U.S. hotel occupancy rates from Statista. https://www.statista.com/statistics/200161/us-annual-accomodation-and-lodging-occupancy-rate/. Used average of last 5 years (2015-2019).

431 Assuming industry standard for standard one-bathroom rooms.

Description	Part 1- behavioral waste		Part 2—diverter leakage	Part 3—total
	Showerhead warm-up	Tub spout warm-up		
Gallons behavioral waste per tub spout/showerhead per year (1.5 gpm)	662	1,471	2,634	4,766
Gallons behavioral waste per tub spout/showerhead per year (1.75 gpm)	772			4,877
Gallons behavioral waste per tub spout/showerhead per year (2.0 gpm)	882			4,987
Gallons behavioral waste per tub spout/showerhead per year (2.5 gpm)	1,103			5,207
Percent hot water[432]	80-85%, or 82.5% average		73.7%	N/A
Gallons hot water saved per year (1.5 gpm)			N/A	3,700
Gallons hot water saved per year (1.75 gpm)			N/A	3,791
Gallons hot water saved per year (2.0 gpm)			N/A	3,882
Gallons hot water saved per year (2.5 gpm)			N/A	4,064

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

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

Equation 207

Where:

ρ = *Water density, 8.33 lbs/gallon*

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

V = *Gallons of hot water saved per year per showerhead (see Table 239)*

$T_{SetPoint}$ = *Water heater setpoint: 120°F* [433]

---

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

[433] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

T_{Supply} = *Average supply water temperature (see Table 240)*

RE = *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters, 2.2 for heat pump water heaters, or 0.8 for gas hot water heaters.*[434]

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

Demand Savings Algorithms

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

$$Demand\ Savings\ per\ TS\ System = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal})}{RE \times Conversion\ Factor \times 365} \times CF$$

Equation 208

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see Table 240)*

CF = *Peak coincidence factor (see Table 241)*

Table 240. Tub Spout/Showerhead TSRVs—Water Mains Temperatures

Climate zone	Water mains temperature (°F)[435]		
		$T_{SupplySeasonal}$	
	$T_{SupplyAverage}$	Summer	Winter
Zone 1: Amarillo	62.9	73.8	53.7
Zone 2: Dallas	71.8	84.0	60.6
Zone 3: Houston	74.7	84.5	65.5
Zone 4: Corpus Christi	77.2	86.1	68.5
Zone 5: El Paso	70.4	81.5	60.4

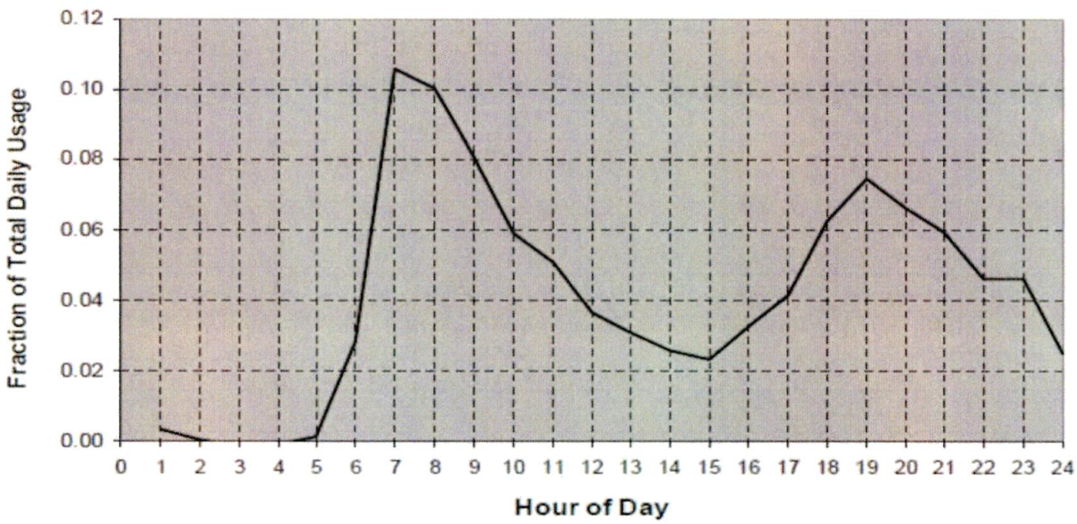
434 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database. https://www.ahridirectory.org/.

435 Based on typical meteorological year (TMY) dataset for TMY3: https://nsrdb.nrel.gov/about/tmy.html.

Table 241. Tub Spout/Showerhead TSRVs—Peak Coincidence Factors

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

Figure 7. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile[436]



Deemed Energy and Demand Savings Tables

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

Claimed Peak Demand Savings

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

[436] Building America Performance Analysis Procedures for Existing Homes.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for this measure is established at 10 years.

This value is consistent with the EUL reported for a low-flow showerhead in the 2014 California Database for Energy Efficiency Resources (DEER).[437]

Program Tracking Data and Evaluation Requirements

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

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

Document Revision History

Table 242. Nonresidential Tub Sprout and Showerhead Temperature Sensitive Restrictor Valves Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 origin.

[437] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/.

2.6.10 ENERGY STAR® Electric Vehicle Supply Equipment (EVSE) Measure Overview

TRM Measure ID: NR-MS-EV

Market Sector: Commercial

Measure Category: Appliance

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 209

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

Equation 210

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

Equation 211

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

Equation 212

Where:

hrs_{plug} = *Hours per day the vehicle is plugged into the EVSE and not charging, 2.8 hrs.*[438]

W_{plug} = *Wattage of the EVSE when the vehicle is plugged into the EVSE but not charging, 6.9 W.*[439]

hrs_{unplug_C} = *Hours per day the vehicle is not plugged into the EVSE on a charging day, 19.0 hrs.*[440]

438 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.

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

440 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.*[441]
$days_C$	=	*Number of charging days per year, 204 days.*[442]
$days_{NC}$	=	*Number of non-charging days per year, 161 days.*
1000	=	*conversion from Wh to kWh*
0.6	=	*Efficiency adjustment factor*[443]
PDPF	=	*Peak demand probability factor, Table 243*

Table 243. EVSE Peak Demand Probability Factors[444]

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 244 presents the deemed annual energy savings per EVSE.

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

442 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.

443 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. Accessed July 2020.

444 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 244. EVSE Annual Energy Savings

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

Table 245 presents the deemed summer and winter peak kW savings per EVSE.

Table 245. 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.[445]

Program Tracking Data and Evaluation Requirements

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

- Climate zone
- Location Type: public, workplace, or fleet
- EVSE make and model number
- Vehicle year, make, and model

[445] 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, Accessed July 2020.

- Estimated number of miles driven per day

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 246. Nonresidential Electic Vehicle Supply Equipment Revision History

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 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 213

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

Equation 214

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 215

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

Equation 216

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

Equation 217

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

Equation 218

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*[446]
kW_baseline	=	*Demand of the second-tier baseline system, usually the baseline ROB system*[447]
kW_installed	=	*Demand of the replacement system*[448]
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*[446]
kWh_baseline	=	*Energy usage of the second-tier baseline system, usually the baseline ROB system*[447]
kWh_installed	=	*Energy usage of the replacement system*[448]

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 219

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

Equation 220

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

Equation 221

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

Equation 222

---

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

447 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).

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

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* [449]
d	=	*Discount rate weighted average cost of capital (per utility)* [449]
AC_{kW}	=	*Avoided cost per kW ($/kW)* [449]
AC_{kWh}	=	*Avoided cost per kWh ($/kWh)* [449]
ML_{FT}	=	*First-tier Measure Life (calculated in Equation 213)*
ML_{ST}	=	*Second-tier measure life (calculated in Equation 214)*

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

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

Equation 223

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

Equation 224

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*

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 225

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

Equation 226

[449] 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.

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:

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

Equation 227

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

Equation 228

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 223*
$NPV_{Total,\ kWh}$	=	*Total energy contributions to NPV of both ER and ROB component, calculated in Equation 224*
$NPV_{EUL,\ kW}$	=	*Capacity contributions to NPV without weighting, using original EUL, calculated in Equation 225*
$NPV_{EUL,\ kWh}$	=	*Energy contributions to NPV without weighting, using original EUL, calculated in Equation 226*

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:

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

Equation 229

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

Equation 230

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 8.0

Volume 4: Measurement and Verification Protocols

Program Year 2021

Last Revision Date:

November 2020

Public Utility Commission of Texas

Texas Technical Reference Manual

Version 8.0

Volume 4: Measurement and Verification Protocols

Program Year 2021

Last Revision Date:

November 2020

Table of Contents

List of Figures

List of Tables

Acknowledgments

The Technical Reference Manual is maintained by the Public Utility Commission of Texas' independent Evaluation, Monitoring, and Verification (EM&V) team led by Tetra Tech.

This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Energy (TXu 1-904-705), ICF, CLEAResult, and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2016 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2018 by Frontier Energy. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as consistent structure and level of information.

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	8.0 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	Added DOE CCMS certification to eligibility list.
Residential	Whole house	Residential new construction	For reference home specification, added IECC 2015 for mechanical ventilation and federal standard efficiency for appliances.
Residential and Nonresidential	Renewables	Residential and nonresidential solar photovoltaics	Updated instructions for new version of PVWatts® and references to NREL National Solar Radiation Database (NSRD) (previously TMY3).
Residential and Nonresidential	Renewables	Solar shingles	No revisions.
Nonresidential	Miscellaneous	Behavioral	Added hourly interval data as a requirement, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period.
Nonresidential	Miscellaneous	Air compressors less than 75hp	No revisions.
Nonresidential	Miscellaneous	Commercial retro-commissioning	Updated model fitness requirements, added CalTRACK2.0 technical appendix as a guide to normalize consumption models, and clarified guidance on normalized energy model fitness, baseline development, and reporting period.
Nonresidential	Miscellaneous	Thermal energy storage	Added 30-minute interval data as a requirement when using IPMVP option C.
Residential	Load management	Residential load curtailment	Added guidance on rounding, ensuring meters are functioning prior to an event, and changing the error threshold from one to two percent of total participants.
Nonresidential	Load management	Nonresidential load curtailment	Added guidance on rounding.

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 indictors 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 require 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

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

Equation 29

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

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 2-37and Table 2-38); Nonresidential Volume 3 Table 2-16 through Table 2-20)*
CF	=	*Summer peak coincidence factor for appropriate climate zone, building type, and equipment type (Residential Volume 2 Equations 49 and 50); Nonresidential Volume 3 Tables 2-16 through Table 2-20)*
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 3-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 3-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 (2.7182818284590452353602874713527)*
Z	=	*Elevation-Altitude [feet]*
T	=	*Absolute temperature, Rankine scale* $[°R = °\mathrm{F} + 459.67]$
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 degrees Fahrenheit is the outdoor dry bulb temperature at AHRI test conditions*
10°F	=	*10 degrees Fahrenheit 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 the 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)*]; or, 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 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]	
$C_8 = -1.0440397\text{ E}+04$	$C_{11} = 1.2890360\text{ E}-05$
$C_9 = -1.1294650\text{ E}+01$	$C_{12} = -2.4780681\text{ E}-09$
$C_{10} = -2.7022355\text{ E}-02$	$C_{13} = 6.5459673\text{ E}+00$

[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.

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.

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
Test 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 Schedule2.5.2APPENDIX A:. 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

[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.

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.

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.

[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.

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.
- 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.

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 a 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
- Budget (as applicable)

- Report format
- Quality assurance

The following equations will be used to calculate energy saving estimates:

$$\text{Peak } Demand\ Savings\ (kW)^{12} = kW_{Baseline} - kW_{New}$$

Equation 31

Where:

$kW_{Baseline}$ = *The peak demand established for the measure load before the retrofit.*

kW_{New} = *The peak demand established for the measure load after the retrofit.*

$$Energy\ Savings\ (kWh) = kWh_{Baseline} - kWh_{New}$$

Equation 32

Where:

$kWh_{Baseline}$ = *Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year.*

kWh_{New} = *Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year.*

Savings Algorithms and Input Variables (Used to Estimate Initial Savings Potential Only)

The follow savings algorithms are provided and are only to be used as an initial means to estimate energy savings prior to measure implementation.

The algorithms use current deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values. The building type and climate zone must match those of the deemed lookup tables referenced herein. Otherwise, custom values for these inputs must be developed.

$$Summer\ Peak\ Demand\ Savings\ [kW_{Savings,C}] = \left(\frac{CAP_{pre,C}}{\eta_{pre,C}} - \frac{CAP_{post,C}}{\eta_{post,C}}\right) \times CF_C \times \frac{1kW}{1{,}000W}$$

Equation 33

[12] TRM volume 1, section 4.2 provides a basis for estimating peak coincident demand reductions attributable to the implementation of energy efficiency measures in Texas. This is based on measure-specific load during the identified peak hours according to section 4.2.2.

$$Winter\ Peak\ Demand\ Savings\ [kW_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times CF_H \times \frac{1kW}{3{,}412\ Btuh}$$

Equation 34

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{CAP_{pre,C}}{\eta_{pre,C}} - \frac{CAP_{post,C}}{\eta_{post,C}}\right) \times EFLH_C \times \frac{1kW}{1{,}000W}$$

Equation 35

$$Energy\ (Heating)[kWh_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times EFLH_H \times \frac{1kW}{3{,}412\ Btuh}$$

Equation 36

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

Equation 37

Note: Use EER as efficiency value for kW savings calculations and SEER/IEER and COP as efficiency value for kWh savings calculations. The COP expressed for units > 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$\eta_{pre,H/post,H} = COP = \frac{HSPF}{3.412}$$

Equation 38

Where:

$Cap_{pre,C/H}$ = *Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [Btuh];*

$Cap_{post,C/H}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh];*

$\eta_{pre,C}$ = *Cooling efficiency of existing equipment [Btu/W] (i.e., EER_{pre})*

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in* Table 10*) [Btu/W]*

$\eta_{pre,H}$ = *Heating efficiency of existing equipment [COP]*

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(Must exceed baseline efficiency standards in* Table 10*) [COP]*

$EFLH_{C/H}$ = *Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$CF_{C/H}$	=	*Summer/winter peak coincidence factor for appropriate climate zone, building type, and equipment type (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*
$HSPF_{pre,H}$	=	*Heating Season Performance Factor (HSPF) of existing equipment [BTU/W]*
$HSPF_{post,H}$	=	*Heating Season Performance Factor (HSPF) of newly installed equipment [BTU/W]*
3.412	=	*The amount of British Thermal Units (Btu) per hour in one watt (1 W = 3.412 Btuh)*

Deemed Energy and Demand Savings Tables

Not applicable.

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.

Additional Calculators and Tools

The regression software used for estimating annual energy use and demand should be clearly specified within the M&V plan and M&V report.

Measure Life and Lifetime Savings

The EUL for commercial split and packaged air conditioners and heat pumps is 15 years.[13]

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: ER system type conversion
- Building type
- Climate zone
- Baseline equipment type
- Baseline equipment rated cooling and heating capacities
- Baseline equipment cooling and heating efficiency ratings
- Baseline number of units

[13] A 15-year EUL is cited in several places: PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed equipment make and model
- Installed number of units
- Installed cooling and heating efficiency ratings

References and Efficiency Standards

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.
- 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

- 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 11. M&V Ground Source Heat Pumps Revision History

TRM version	Date	Description of change
v3.1	11/05/2015	TRM v3.1 origin.
v4.0	10/10/2016	No revisions.
v5.0	10/10/2017	No revisions.
v6.0	10/2018	Combined minimum efficiency levels into a single table. Added formulas for winter peak heating savings.
v7.0	10/2019	No revisions.
v8.0	10/2020	No revisions.

2.1.3 Variable Refrigerant Flow Systems Measure Overview

TRM Measure ID: NR-HV-VR

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: Commercial

Fuels Affected: Electricity

Decision/Action Types: Early retirement (ER), replace-on-burnout (ROB), and new construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: Not applicable

Savings Methodology: EM&V and whole facility measurement, calculator

This protocol is used to estimate savings for variable refrigerant flow systems (VRF) measures through an M&V approach. The development of the VRF 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 developed. The protocol allows for flexible 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 variable refrigerant flow (VRF) 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 VRF system.

Applicable VRF efficient measure types include:

- Air-cooled systems where multiple compressors are connected to a single refrigerant loop
- Water-cooled where multiple compressors are connected to a single water-source loop, which allows heat recovery between compressor units

Eligibility Criteria

- This measure applies to replacing an existing HVAC system with a new VRF system or a new construction VRF system.
- Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[14,15]

Baseline Condition

Early Retirement: The baseline for retrofit projects is specific to the existing HVAC system being replaced by a new VRF; that is, the baseline case is defined by existing system manufacturer, model number, AHRI nominal efficiencies, and operating parameters. Alternatively, the use of a prescriptive savings calculation procedure for savings is allowed for existing system replacements, but the baseline must follow the new construction/replace-on-burnout procedure.

Replace-on-Burnout (ROB) and New Construction (NC): The baseline for ROB or NC projects is a code-minimum VRF system as specified by ASHRAE 90.1-2013. VRF system minimum efficiencies are not currently covered by IECC 2015. Minimum efficiency conditions are shown in Table 12 below. See the Deemed Energy and Demand Savings section below for more details.

High-Efficiency Condition

High-efficiency conditions for VRF equipment must meet applicable standards. AHRI energy ratings for EER and COP, by manufacturer model numbers, follow required test protocols and parameters and must meet or exceed current DOE EERE and ASHRAE 90.1 minimum efficiency requirements from Table 12. Both air-cooled and water-cooled systems are rated per AHRI Standard 1230.

Table 12. Baseline Efficiency Levels for Electrically Operated VRF ACs and HPs

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Conditioners, Air Cooled	< 65,000	All	VRF multi-split system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-9
	≥ 65,000 and < 135,000	None or Electric Resistance		11.2 EER 13.1 IEER	
	≥ 135,000 and < 240,000			11.0 EER 12.9 IEER	
	≥ 240,000			10.0 EER 11.6 IEER	

[14] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[15] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Cooled (cooling mode)	< 65,000	All	VRF multi-split system	13.0 SEER	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000	None or Electric Resistance	VRF multi-split system	11.0 EER 12.3 IEER	
			VRF multi-split system with heat recovery	10.8 EER 12.1 IEER	
	≥ 135,000 and < 240,000		VRF multi-split system	10.6 EER 11.8 IEER	
			VRF multi-split system with heat recovery	10.4 EER 11.6 IEER	
	≥ 240,000		VRF multi-split system	9.5 EER 10.6 IEER	
			VRF multi-split system with heat recovery	9.3 EER 10.4 IEER	
VRF Water Source (cooling mode)	< 65,000	All	VRF multi-split system 86^{0}F entering water	12.0 EER	ASHRAE 90.1-2013 Table 6.8.1-10
			VRF multi-split system with heat recovery 86^{0}F entering water	11.8 EER	
	≥ 65,000 and < 135,000		VRF multi-split system 86^{0}F entering water	12.0 EER	
			VRF multi-split system with heat recovery 86^{0}F entering water	11.8 EER	
	≥ 135,000		VRF multi-split system 86^{0}F entering water	10.0 EER	
			VRF multi-split system with heat recovery 86^{0}F entering water	9.8 EER	

System type	Capacity (Btu/h)	Heating section type	Subcategory or rating condition	Baseline efficiencies	Source
VRF Air Cooled (heating mode)	< 65,000 (cooling capacity)	-	VRF multi-split system	7.7 HSPF	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 65,000 and < 135,000 (cooling capacity)		VRF multi-split system 47°F db/43°F wb outdoor air	3.3 COP_H	
			VRF multi-split system 17°F db/15°F wb outdoor air	2.25 COP_H	
	≥ 135,000 (cooling capacity)		VRF multi-split system 47°F db/43°F wb outdoor air	3.2 COP_H	
			VRF multi-split system 17°F db/15°F wb outdoor air	2.05 COP_H	
VRF Water Source (heating mode)	< 135,000 (cooling capacity)	-	VRF multi-split system 68°F entering water	4.2 COP_H	ASHRAE 90.1-2013 Table 6.8.1-10
	≥ 135,000 (cooling capacity)		VRF multi-split system 68°F entering water	3.9 COP_H	

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 VRF 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 is driven by the desire to create and implement 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 to determine savings 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 report. 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
- Budget (as applicable)
- Report format
- Quality assurance

The following equations will be used to calculate energy saving estimates:

$$Peak\ Demand\ Savings\ (kW)^{16} = kW_{Baseline} - kW_{New}$$

Equation 39

Where:

$kW_{Baseline}$ = *The peak demand established for the measure load before the retrofit.*

kW_{New} = *The peak demand established for the measure load after the retrofit.*

[16] TRM volume 1, section 4.2 provides a basis for estimating peak coincident demand reductions attributable to the implementation of energy efficiency measures in Texas. This is based on measure-specific load during the identified peak hours according to section 4.2.2.

$$Energy\ Savings\ (kWh) = kWh_{Baseline} - kWh_{New}$$

Equation 40

Where:

$kWh_{Baseline}$ = *Annual energy consumption as determined by the regression equation, using the pre-retrofit degree-day and occupancy factors with post-retrofit temperature data from the measurement year.*

kWh_{New} = *Total annual energy consumption as reported in utility meter data for the post-retrofit measurement year.*

Savings Algorithms and Input Variables (Used to Estimate Initial Savings Potential Only)

The follow savings algorithms are provided and are only to be used as an initial means to estimate energy savings prior to measure implementation.

The algorithms use current deemed peak demand coincidence factor (CF) and equivalent full-load hour (EFLH) values. The building type and climate zone must match those of the deemed look-up tables referenced herein. Otherwise, custom values for these inputs must be developed.

$$Summer\ Peak\ Demand\ Savings\ [kW_{Savings,C}] = \left(\frac{CAP_{pre,C}}{\eta_{pre,C}} - \frac{CAP_{post,C}}{\eta_{post,C}}\right) \times CF_C \times \frac{1kW}{1{,}000W}$$

Equation 41

$$WinterPeak\ Demand\ Savings\ [kW_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times CF_H \times \frac{1kW}{3{,}412\ Btuh}$$

Equation 42

$$Energy\ (Cooling)\ [kWh_{Savings,C}] = \left(\frac{CAP_{pre,C}}{\eta_{pre,C}} - \frac{CAP_{post,C}}{\eta_{post,C}}\right) \times EFLH_C \times \frac{1kW}{1{,}000W}$$

Equation 43

$$Energy\ (Heating)[kWh_{Savings,H}] = \left(\frac{CAP_{pre,H}}{\eta_{pre,H}} - \frac{CAP_{post,H}}{\eta_{post,H}}\right) \times EFLH_H \times \frac{1kWh}{3{,}412\ Btu}$$

Equation 44

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

Equation 45

Note: Use EER as efficiency value for kW savings calculations and SEER/IEER and COP as efficiency value for kWh savings calculations. The COP expressed for units > 65,000 Btu/h is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$\eta_{pre,H/post,H} = COP = \frac{HSPF}{3.412}$$

Equation 46

Where:

$Cap_{pre,C/H}$ = *Rated equipment cooling/heating capacity of the existing equipment at AHRI standard conditions [Btuh];*

$Cap_{post,C/H}$ = *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh];*

$\eta_{pre,C}$ = *Cooling efficiency of existing equipment [Btu/W] (i.e., EER_{pre})*

$\eta_{post,C}$ = *Rated cooling efficiency of new equipment (i.e., EER_{post} COP_{post})—(Must exceed baseline efficiency standards in* Table 12*) [Btu/W]*

$\eta_{pre,H}$ = *Heating efficiency of existing equipment [COP]*

$\eta_{post,H}$ = *Rated heating efficiency of the newly installed equipment—(must exceed baseline efficiency standards in* Table 12*) [COP]*

$EFLH_{C/H}$ = *Cooling/heating equivalent full load hours for appropriate climate zone, building type, and equipment type [hours] (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$CF_{C/H}$ = *Summer/winter peak coincidence factor for appropriate climate zone, building type, and equipment type (refer to Nonresidential Volume 3 Split System/Single Packaged AC and HP measure)*

$HSPF_{pre,H}$ = *Heating Season Performance Factor (HSPF) of existing equipment [BTU/W]*

$HSPF_{post,H}$ = *Heating Season Performance Factor (HSPF) of newly installed equipment [BTU/W]*

3.412 = *The amount of British Thermal Units (Btu) per hour in one watt (1 W = 3.412 Btuh)*

Deemed Energy and Demand Savings

For new construction, renovation, or existing system replacements (as an alternative compliance path), the use of a deemed savings procedure is available for claiming VRF system efficiency above code minimum efficiencies. The methodology is identical to TRM Volume 3 split system/single packaged air conditioners and heat pumps by substituting the efficiencies from Table 12 as the baseline efficiencies for the new construction and replace on burnout energy and demand savings methodology.

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.

Additional Calculators and Tools

The regression software used to estimate annual energy use and demand should be clearly specified within the M&V plan and M&V report.

Measure Life and Lifetime Savings

The EUL for commercial split and packaged air conditioners and heat pumps is 15 years.[17]

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: ER, ROB, NC, system type conversion
- Building type
- Climate zone
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- For ER only: Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- Installed number of units
- Installed equipment type
- Installed rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For other building types only**: Description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

[17] A 15-year EUL is cited in several places: PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

References and Efficiency Standards

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.
- 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

- ANSI/ASHRAE/IES Standard 90.1-2013. Energy Standard for Buildings Except Low-Rise Residential Buildings. Table 6.8.1-9 through Table 6.8.1-10.
- 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.
- ANSI/AHRI Standard 1230, 2010 Standard for Performance Rating of Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment, http://www.ahrinet.org/App_Content/ahri/files/STANDARDS/ANSI/ANSI_AHRI_Standard_1230_2010_with_Add_2.pdf.

Document Revision History

Table 13. M&V Variable Refrigerant Systems Revision History

TRM version	Date	Description of change
v5.0	10/10/2017	TRM v5.0 origin.
v6.0	10/2018	Minor formula corrections.
v7.0	10/2019	No revisions.
v8.0	10/2020	Added DOE CCMS certification to eligibility list

2.2 M&V: WHOLE HOUSE

2.2.1 Residential New Construction Measure Overview

TRM Measure ID: R-HS-NH

Market Sector: Residential

Measure Category: Whole house

Applicable Building Types: Single-family; manufactured

Fuels Affected: Electricity and gas

Decision/Action Types: New construction (NC)

Program Delivery Type: Custom

Deemed Savings Type: For this measure, savings are not deemed and are estimated based on each house's specific characteristics and parameters.

Savings Methodology: EM&V and whole-house simulation modeling

This M&V protocol details the savings estimate for residential new construction projects. The protocol may be applied to the construction of single-family detached homes, multifamily buildings, or individual units within new multifamily buildings. The residential new construction M&V methodology creates a framework to provide high quality verified savings while not restricting the ability of residential new construction 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 uncertainty in the expected savings. The M&V methodology supports the following M&V goals for the new multifamily buildings programs:

- Improve reliability of savings estimates
- Determine whether energy and peak demand savings goals have been met
- Inform future program planning processes.

Streamlined measurement and verification of residential new construction shall leverage a model-based approach to determine energy savings for each home and adhere to typical IPMVP protocols. Modeling software new to the Texas new multifamily building market must be vetted through the EM&V team. Current software approved by the EM&V team include:

- BeOpt[18]
- RESNET accredited software
- Hourly analysis programs tested in accordance with ASHRAE 140 and meeting the requirements of ASHRAE 90.1 Appendix G (i.e., DOE-2, EnergyPlus, HAP, TRACE, IESVS, etc.)[19]

[18] Applicable for the modeling of individual multifamily dwelling units.
[19] Applicable for the modeling of multifamily buildings or portions thereof.