



WATER HEATING
HEAT PUMP WATER HEATER
SWWH014-01

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MEASURE NAME

Heat Pump Water Heater

STATEWIDE MEASURE ID

SWWH014-01

TECHNOLOGY SUMMARY

Conventional electric-resistance water heaters usually consist of a glass-lined steel tank with foam insulation. Energy efficient units have a greater amount of insulation. Located at the base and top end of the tank are two electrical heating elements. Cold water enters the base of the tank and is heated by the lower electrical heating element. The water then rises to the top portion of the tank where the hot water is drawn for consumption. During periods of high demand, the electrical heating element located at the top end of the tank can be turned on to provide additional water heating.

Heat pump water heaters achieve higher efficiency compared to electric-resistance water heaters. Like electric-resistance water heaters, most heat pump water heaters consist of a glass-lined steel tank with foam insulation. Heat pump water heaters are typically equipped with supplemental electric-resistance elements for periods of high demand.

The most significant barrier to a water heater retrofit is the existing nature of water heater replacement. Approximately 37% of consumers replace their water heaters due to the sudden failure of their existing water heater.¹ When a water heater fails, most consumers will purchase a replacement that is the cheapest and most readily available model that is also easy to install. These prevailing attitudes do not encourage consumers to make the extra effort to find more advanced, energy-efficient technologies that are now available on the market.

MEASURE CASE DESCRIPTION

The qualifying measure efficiencies for the heat pump water heater, and the corresponding base case unit, are specified below. Efficiency requirements have been updated from using the energy factor metric to the uniform energy factor (UEF) metric, as required by federal regulations. The minimum qualifying measure efficiencies exceed the California Title 20 and Code of Federal Regulations standards (see Code Requirements).

¹ Ciani, A. (Russell Research). 2018. *Water Heater Market Characterization Report*. Prepared for the Northwest Energy Efficiency Alliance (NEEA). Report # E18-395. April 3.

Base Case and Measure Case Specification

Electric Heat Pump (Measure Case)		Electric Water Heater (Base Case)	
Storage Volume (gal.)	Efficiency (UEF)	Storage Volume (gal.)	Efficiency (UEF)
< 45 Vol. ≤ 55	3.09	≤ 35	0.92
	3.31		0.92
	3.09	< 35 Vol. ≤ 45	0.92
	3.31		0.92
	3.09	< 45 Vol. ≤ 55	0.92
	3.31		0.92
< 55 Vol. ≤ 75	3.33	< 55 Vol. ≤ 75	2.91
> 75 gal	3.42	> 75	3.00

BASE CASE DESCRIPTION

The base case measure is defined as an electric storage water heater with a storage volume of 30, 40, or 50 gallons, as specified in the table above. The minimum base case efficiencies are consistent with the Code of Federal Regulations standards (see Code Requirements).

The California Public Utilities Commission (CPUC) Energy Division webinar on 2019 Database of Energy Efficient Resources (DEER) and the DEER 2017 and 2018 Updates² presented an analysis of the 2012 California Lighting and Appliance Saturation Survey (CLASS) data³ that showed electric storage water heaters are not typically installed at 60 and 75-gallon capacities. Thus, the base case for these sizes is a heat pump water heater with a uniform energy factor (UEF) equal to 2.91 and 3.00 respectively, as the industry standard practice (determined based on the UEF ratings of lower efficiency heat pump models on the market.)

CODE REQUIREMENTS

Applicable state and federal codes and standards for heat pump water heaters are specified in the table below. Note that the Code of Federal Regulations, 10 CFR 430.32(d) stipulates requirements for electric storage water heaters but not heat pump water heaters. Title 20 follows the federal code.

² California Public Utilities Commission (CPUC), Energy Division. 2017. "DEER2019 and Revised DEER2017 + DEER2018 Updates." July 18.

³ DNV GL. 2014. *WO21: Residential On-site Study: California Lighting and Appliance Saturation Study (CLASS 2012)*. Prepared for the California Public Utilities Commission, Energy Division. CALMAC Study ID: CPU0095.01.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2018)	Section 1605.1(f)(2)	January 1, 2018
CA Building Energy Efficiency Standards – Title 24 (2019)	Section 110.1	January 1, 2020
Federal Standards – Code of Federal Regulations	10 CFR 430.32(d)	December 29, 2016

Code of Federal Regulations. In December 2016 the U.S. Department of Energy (DOE) issued a Final Ruling in Docket No. EERE-2015-BT-TP-0007 that established a new efficiency rating for all residential and some commercial water heating technologies are rated.⁴ All water heaters within the scope of the ruling will no longer be rated with the energy Factor (EF), thermal efficiency (TE), or standby loss ratings; the Uniform Energy Factor (UEF) is the new metric for the energy efficiency of water heaters. A UEF rating is determined by assigning a water heater into one of four different categories of hot water usage and then evaluating its performance based on that usage.⁵ The four categories are based on *draw pattern* – *very small, low, medium, and high*. This allows water heaters to be compared more easily between different types (i.e., storage and tankless), as long as units are compared within the same bin.

With this final ruling, the DOE established a mathematical conversion between the values determined using the ER, TE, and SL test procedures and the values determined using the uniform efficiency descriptor test procedure. The DOE used the conversion factors to derive minimum energy performance standards based on UEF. The standards denominated in UEF are neither more nor less stringent than the EF-denominated standards for consumer water heaters and for commercial water-heating equipment based on the TE and SL metrics.

The following table from the Final Ruling provides the conversion equations from EF to UEF.

⁴ U.S. Department of Energy (DOE). 2016. “Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Consumer and Commercial Water Heaters.” *Federal Register: The Daily Journal of the United States*. 81 Fed. Reg. 250. December 29, 2016.

⁵ A.O. Smith. (n.d.) “What Does UEF Mean To You?”

Uniform Energy Factor Requirements of the Code of Federal Regulations

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor
Gas-fired Storage Water Heater	≥20 gal and ≤55 gal	Very Small	0.3456 – (0.0020 × V _r)
		Low	0.5982 – (0.0019 × V _r)
		Medium	0.6483 – (0.0017 × V _r)
		High	0.6920 – (0.0013 × V _r)
	>55 gal and ≤100 gal	Very Small	0.6470 – (0.0006 × V _r)
		Low	0.7689 – (0.0005 × V _r)
		Medium	0.7897 – (0.0004 × V _r)
		High	0.8072 – (0.0003 × V _r)
Oil-fired Storage Water Heater	≤50 gal	Very Small	0.2509 – (0.0012 × V _r)
		Low	0.5330 – (0.0016 × V _r)
		Medium	0.6078 – (0.0016 × V _r)
		High	0.6815 – (0.0014 × V _r)
Electric Storage Water Heaters	≥20 gal and ≤55 gal	Very Small	0.8808 – (0.0008 × V _r)
		Low	0.9254 – (0.0003 × V _r)
		Medium	0.9307 – (0.0002 × V _r)
		High	0.9349 – (0.0001 × V _r)
	>55 gal and ≤120 gal	Very Small	1.9236 – (0.0011 × V _r)
		Low	2.0440 – (0.0011 × V _r)
		Medium	2.1171 – (0.0011 × V _r)
		High	2.2418 – (0.0011 × V _r)
Tabletop Water Heater	≥20 gal and ≤120 gal	Very Small	0.6323 – (0.0058 × V _r)
		Low	0.9188 – (0.0031 × V _r)
		Medium	0.9577 – (0.0023 × V _r)
		High	0.9884 – (0.0016 × V _r)
Instantaneous Gas-fired Water Heater	<2 gal and >50,000 Btu/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater ...	<2 gal	Very Small	0.91
		Low	0.91
		Medium	0.91
		High	0.92
Grid-Enabled Water Heater	>75 gal	Very Small	1.0136 – (0.0028 × V _r)
		Low	0.9984 – (0.0014 × V _r)
		Medium	0.9853 – (0.0010 × V _r)
		High	0.9720 – (0.0007 × V _r)

*V_r is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Source: Code of Federal Regulations at 10 CFR 430.32(d).

California Title 20: Minimum Uniform Energy Factor Requirements for Residential Duty Commercial Water Heaters

(B) Residential-Duty Commercial Water Heaters. Each residential-duty commercial water heater must have a minimum uniform energy factor not less than the values shown in Table F-5.

Table F-5
Standards for Residential-Duty Commercial Water Heaters

Product Class	Specifications *	Draw Pattern	Minimum Uniform Energy Factor ^b
Gas-fired Storage	> 75 kBtu/hr and ≤ 105 kBtu/hr and ≤ 120 gallons	Very Small	0.2674 – (0.0009 × V _r)
		Low	0.5362 – (0.0012 × V _r)
		Medium	0.6002 – (0.0011 × V _r)
		High	0.6597 – (0.0009 × V _r)
Oil-fired Storage	> 105 kBtu/hr and ≤ 140 kBtu/hr and ≤ 120 gal	Very Small	0.2932 – (0.0015 × V _r)
		Low	0.5596 – (0.0018 × V _r)
		Medium	0.6194 – (0.0016 × V _r)
		High	0.6740 – (0.0013 × V _r)
Electric Instantaneous	> 12 kW and ≤ 58.6 kW and ≤ 2 gal	Very Small	0.80
		Low	0.80
		Medium	0.80
		High	0.80

* Additionally, to be classified as a residential-duty commercial water heater, a commercial water heater must meet the following conditions:
 (1) if the water heater requires electricity, it must use a single-phase external power supply; and
 (2) the water heater must not be designed to heat water to temperatures greater than 180°F.

^b V_r is the rated storage volume (in gallons), as determined pursuant to 10 CFR section 429.44.

Source: California Energy Commission (CEC). 2018 Appliance Efficiency Regulations. CEC-400-2017-002. Section 1605.1(f) Table F-5

NORMALIZING UNIT

Each.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Specifically, for New Construction, the baseline can be a gas-fired water heater. But, energy savings and measure cost in this workpaper are estimated and reported as the difference between the corresponding Heat Pump Water Heater and the baseline electric resistance water heater.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility for Investor-Owned Utilities

Measure Application Type	Delivery Type	Sector
Normal replacement	DnDeemed	Res
Normal replacement	DnDeemDI	Res
Normal replacement	UpDeemed	Res
New construction	DnDeemed	Res
New construction	DnDeemDI	Res
New construction	UpDeemed	Res

Eligible Products

The heat pump water heater must meet the storage capacity and minimum efficiency requirements set forth in the Measure Case Description. Only residential-style electric storage water heaters are eligible and the installed water heater storage capacity must be 45 gallons or greater.

Eligible Building Types

This measure is applicable to single-family, multifamily, and double-wide mobile home residential buildings types.

Eligible Climate Zones

The measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

Replacement of an “instantaneous” or “tankless” water heaters does not qualify.

A new heat pump water heater with storage capacity less than 45 gallons does not qualify.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Service & domestic hot water

ELECTRIC SAVINGS (kWh)

The energy savings of heat pump water heaters and electric storage water heaters are rated in uniform energy factor (UEF). Unit energy savings (UES) were modeled using the Database for Energy Efficient Resources (DEER) methodologies. Specifically, energy use and savings were derived using the DEER water heater calculator tool,⁶ a macro-enabled Excel workbook developed by consultants of the California Public Utilities Commission (CPUC) Energy Division to standardize the inputs and savings calculations for water heating measures. The calculator "utilizes hourly output from the DEER2014 DOE2 building prototypes for hot water loads and ambient conditions along with new technology definitions to estimate the hourly energy use of gas, electric, and heat pump water heaters. This tool was developed as a replacement of an earlier version (v1.1) to accommodate the modeling requirements of heat pump water heaters and to provide a relatively easy method to add new measures and technologies based on PA program requirements."⁷ Further, the "simulation tool ... uses the technology definitions to determine the hot water energy use for each climate zone, building type and building vintage that are part of the standard DEER applicability parameters. Measure savings are determined by comparing the energy use associated with the technologies defined in the measure definition."⁸

The following table indicates the measures taken directly from or created with the DEER Remote Ex-Ante Database Interface (READI) tool.

⁶ California Public Utilities Commission (CPUC), Energy Division. 2017. DEER2015 Small Storage and Small Instantaneous Water Heater Energy Use Calculator. "DEER-WaterHeater-Calculator-v2.1.xlsm." Updated July 10, 2017.

⁷ California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2015 Service and Domestic Water Heater Measures Update." October 1. Page 3.

⁸ California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2015 Service and Domestic Water Heater Measures Update." October 1. Page 10.

DEER Measure Codes

DEER IDs
RE-WtrHt-SmlStrg-HP-lte12kW-rep30G-3p24EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep30G-3p50EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep40G-3p24EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep40G-3p50EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep50G-3p24EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep50G-3p50EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep60G-3p50EF
RE-WtrHt-SmlStrg-HP-lte12kW-rep75G-3p50EF

The results reported in READI have not been modified and include all 16 California climate zones. This tool compares the energy use of the measure and base case technologies to determine energy savings.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction was derived using the Database of Energy Efficient Resources (DEER) water heater calculator tool (v3.2).⁹ The simulation tool reports hourly savings and reports results for each climate zone, enabling accurate capture of peak demand savings. Results are reported in the Remote Ex-Ante Database Interface (READI) tool. See Electric Savings for a list of DEER measure codes.

The demand reduction values in DEER are based upon the previous peak period of 2 p.m. to 5 p.m. and therefore required modification to derive peak demand reduction for the 4 p.m. to 9 p.m. peak period.¹⁰ Specifically, the normalized hourly load profile for a low-flow shower head was used to determine the scaling factor that was applied to the DEER peak savings. The scaling factor was calculated as the average load for 4 p.m. to 9 p.m. divided by the average load for 2 p.m. to 5 p.m. The resultant scaling factor (below) was calculated to be 2.564 and was applied to the peak demand impacts for all 16 climate zones.¹¹

$$DEERkW_{4to9} = DEERkW_{2to5} \times SF$$

$DEERkW_{4to9}$ = Peak demand reduction in the 4 p.m. to 9 p.m. peak period

$DEERkW_{2to5}$ = Demand reduction values in DEER that are based upon the 2 p.m. to 5 p.m. peak period

SF = Scaling factor

⁹ California Public Utilities Commission (CPUC), Energy Division. 2018. "DEER2019 Small Storage and Small Instantaneous Water Heater Energy Use Calculator." "DEER-WaterHeater-Calculator-v3.2_rev25Sep2018.xlsm." September 25.

¹⁰ California Public Utilities Commission (CPUC). 2018. *Resolution E-4952*. October 11. Op 1.

¹¹ Southern California Edison (SCE). 2019. "SWWH014-01 Peak Demand Calc 2019.02.28.xlsm."

Peak Demand Scaling Factor

Parameter	Value
Peak demand scaling factor	2.564

GAS SAVINGS (Therms)

Not applicable.

LIFE CYCLE

Effective Useful Life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. EUL is often, but not always, derived from measure persistence or retention studies. Remaining Useful Life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The EUL specified for the heat pump water heater is specified below.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	10.0	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
RUL (yrs)	n/a	n/a

BASE CASE MATERIAL COST (\$/UNIT)

Base case material costs are based upon the costs developed for the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc.¹² The costs represent electric storage water heaters of 30, 40, and 50 gallons, and online retailer prices for base cases involving water heaters with storage capacity greater than 55 gallons (specifically, 60 and 75-gallon capacities).

The costs from the Ex Ante Measure Cost Study were then converted to 2018 values using RSMeans historical cost index ratios.¹³

¹² Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

Southern California Edison (SCE). 2017. "SCE17WH001.0 A3 – Costs Calculations.xlsx."

¹³ Gordian. (n.d.) "RSMeans Cost Index.pdf."

MEASURE CASE MATERIAL COST (\$/UNIT)

Measure case equipment costs¹⁴ were calculated as the average of costs of qualifying units sold by online retailers.¹⁵ The market is limited for heat pump water heaters ≥ 2.91 UEF; costs were based upon seven models (represented by five manufacturers). These costs were determined to be representative of unit costs based on online retailer checks in the first quarter of 2019.

BASE CASE LABOR COST (\$/UNIT)

Base case labor costs are based upon the costs developed for the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc.¹⁶ The costs represent electric storage water heaters of 30, 40, and 50 gallons, and online retailer prices for base cases involving water heaters with storage capacity greater than 55 gallons (specifically, 60 and 75-gallon capacities).

The costs from the Ex Ante Measure Cost Study were then converted to 2018 values using RSMMeans historical cost index ratios.¹⁷

MEASURE CASE LABOR COST (\$/UNIT)

Measure case labor costs are assumed to equal the base case labor costs for equivalent capacities, as presented in the electric storage water heater section of the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc.¹⁸ The costs from the Ex Ante Measure Cost Study were then converted to 2018 values using RSMMeans historical cost index ratios.¹⁹

Smaller 30, 40, and 50-gallon heaters are replaced with 45 to 55-gallon heat pump water heaters, thus the labor cost for these measures is equal to the base labor cost of a 50-gallon heater. The labor costs for larger heaters are based on 60 and 75 gallons and are assumed to be equal for the base and measure cases.

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The commercial and residential NTG values are based upon

¹⁴ Southern California Edison (SCE). 2018. "SCE17WH001.2 A3 - Costs Calculations.xlsx."

¹⁵ Heat pump water heaters of 3.24 EF or greater were not included in 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc.

¹⁶ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

Southern California Edison (SCE). 2017. "SCE17WH001.0 A3 – Costs Calculations.xlsx."

¹⁷ Gordian. (n.d.) "RSMMeans Cost Index.pdf."

¹⁸ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

¹⁹ Gordian. (n.d.) "RSMMeans Cost Index.pdf."

the average of all NTG ratios for all evaluated 2006 – 2008 residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. The residential and commercial (nonresidential) sector average NTGs (“default NTGs”) are applicable to all new energy efficiency measures that have been offered through residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG - residential	0.55	Itron, Inc. 2011. <i>DEER Database 2011 Update Documentation</i> . Prepared for the California Public Utilities Commission. Page 15-4 Table 15-3.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based. This work paper uses data from DEER 2017, which lists data for a Heat Pump Water Heater (HPWH) that replaces a base case Electric Storage Water Heater (ESWHs). DEER peak demand savings were modified to reflect the change in DEER peak starting in 2020.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes (Adjusted for 2020 peak demand period)
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	No
DEER eQUEST Prototypes	No
DEER Version	DEER 2017 READI v2.5.1
Reason for Deviation from DEER	Peak demand updates
DEER Measure IDs Used	RE-WtrHt-SmlStrg-HP-lte12kW-rep30G-3p24EF RE-WtrHt-SmlStrg-HP-lte12kW-rep30G-3p50EF RE-WtrHt-SmlStrg-HP-lte12kW-rep40G-3p24EF RE-WtrHt-SmlStrg-HP-lte12kW-rep40G-3p50EF RE-WtrHt-SmlStrg-HP-lte12kW-rep50G-3p24EF RE-WtrHt-SmlStrg-HP-lte12kW-rep50G-3p50EF RE-WtrHt-SmlStrg-HP-lte12kW-rep60G-3p50EF RE-WtrHt-SmlStrg-HP-lte12kW-rep75G-3p50EF
NTG	Source: DEER2017. NTG of 0.55 is associate with NTG ID: <i>ResDefault>2yrs.</i>
GSIA	GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER2017. The EUL of 10 years is associated with EUL ID: <i>WtrHt-HtPump</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	12/31/2017	Jennifer Holmes Cal TF Staff	Draft of consolidated text for this statewide measure is based upon: WPSDGEREWH0022, Revision 1.1 (May 1, 2015) SCE13WH001, Revision 3 (January 28, 2015) PGECODHW106, Revision 6 (April 4, 2014) Consensus reached among Cal TF members.
	2/12/2019	John Baffa, TRC	Updated based upon: SCE17WH001, Revision 2 (December 3, 2018) Updated code references for newer versions, converted EF language to UEF, modified peak demand savings to reflect 4 p.m. to 9 p.m. peak period.
	2/28/2019	Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01.
	4/6/2020	Jay Madden, SCE	Added gas-fired water heater baseline.

