



WATER HEATING
HEAT PUMP WATER HEATER, RESIDENTIAL
SWWH014-02

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MEASURE NAME

Heat Pump Water Heater, Residential

STATEWIDE MEASURE ID

SWWH014-02

EFFECTIVE DATE*January 1, 2021***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 use 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 in alignment 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 65 and 80-gallon capacities. Baselines reflect code UEFs and those on the market based on AHRI/CEC database analysis and are taken directly from the DEER Water Heater Calculator v4.1.

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 tables provide the UEF equations for various water heater product classes, sizes, and draw patterns.

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	$0.3456 - (0.0020 \times V_r)$
		Low	$0.5982 - (0.0019 \times V_r)$
		Medium	$0.6483 - (0.0017 \times V_r)$
		High	$0.6920 - (0.0013 \times V_r)$
	>55 gal and ≤100 gal	Very Small	$0.6470 - (0.0006 \times V_r)$
		Low	$0.7689 - (0.0005 \times V_r)$
		Medium	$0.7897 - (0.0004 \times V_r)$
		High	$0.8072 - (0.0003 \times V_r)$
Oil-fired Storage Water Heater	≤50 gal	Very Small	$0.2509 - (0.0012 \times V_r)$
		Low	$0.5330 - (0.0016 \times V_r)$
		Medium	$0.6078 - (0.0016 \times V_r)$
		High	$0.6815 - (0.0014 \times V_r)$
Electric Storage Water Heaters	≥20 gal and ≤55 gal	Very Small	$0.8808 - (0.0008 \times V_r)$
		Low	$0.9254 - (0.0003 \times V_r)$
		Medium	$0.9307 - (0.0002 \times V_r)$
		High	$0.9349 - (0.0001 \times V_r)$
	>55 gal and ≤120 gal	Very Small	$1.9236 - (0.0011 \times V_r)$
		Low	$2.0440 - (0.0011 \times V_r)$
		Medium	$2.1171 - (0.0011 \times V_r)$
		High	$2.2418 - (0.0011 \times V_r)$
Tabletop Water Heater	≥20 gal and ≤120 gal	Very Small	$0.6323 - (0.0058 \times V_r)$
		Low	$0.9188 - (0.0031 \times V_r)$
		Medium	$0.9577 - (0.0023 \times V_r)$
		High	$0.9884 - (0.0016 \times V_r)$
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	$1.0136 - (0.0028 \times V_r)$
		Low	$0.9984 - (0.0014 \times V_r)$
		Medium	$0.9853 - (0.0010 \times V_r)$
		High	$0.9720 - (0.0007 \times V_r)$

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

^a 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 to estimate hourly energy use for a variety of water heaters."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 latest version, DEER Water Heater Calculator v4.1, contains updated UEFs and technology definitions which affect the energy impact of each measure. The following are measures selected from the DEER Water Heater Calculator v4.1:

⁶ California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021 DEER Water Heater Calculator Documentation. "DEER-WaterHeater-Calculator-v4.1.xlsm." Updated June 1, 2020.

⁷ California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021 DEER Water Heater Calculator Documentation. "DEER Water Heater Calculator Documentation v4.0 for DEER2021" Updated April 30, 2020.

⁸ California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021 DEER Water Heater Calculator Documentation. "DEER Water Heater Calculator Documentation v4.0 for DEER2021" Updated April 30, 2020.

DEER Energy Impact IDs

DEER IDs
RE-WtrHt-SmlStrg-HP-lte6kW-rep30G-MD-3p09UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-rep30G-MD-3p31UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-rep40G-MD-3p09UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-rep40G-MD-3p31UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-rep50G-MD-3p09UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-rep50G-MD-3p31UEF-50g
RE-WtrHt-SmlStrg-HP-lte6kW-65G-3p33UEF
RE-WtrHt-SmlStrg-HP-lte6kW-80G-3p42UEF

PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction is calculated in the DEER Water Heater Calculator v4.1.⁹ The calculator implements a detailed NREL event schedule to capture the peak loads for residential buildings.¹⁰ This schedule is different than that used for energy (kWh) calculations. An 8760 hourly peak demand profile is generated from the NREL schedule for each climate zone. Annual demand impact is then calculated as the average kWh reduction over the defined DEER peak period. Demand reduction is calculated from the difference between the baseline and measure demand impacts.

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.

⁹ California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021 DEER Water Heater Calculator Documentation. "DEER-WaterHeater-Calculator-v4.1.xlsm." Updated June 1, 2020.

¹⁰ National Renewable Energy Laboratory (NREL). 2010. Tool for Generating Realistic Residential Hot Water Event Schedules.

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)

Baseline cost data for the 30, 40, and 50 gallon water heaters was collected using online webscraping of applicable electric water heaters during the second quarter of 2020.¹¹ Retailers referenced include Home Depot, Lowes, Grainger, Menards, SupplyHouse, and Supply.com. Costs were averaged based on relevant storage capacity bins. Only electric water heaters with UEFs relevant to the baseline were included. Online retailer prices were also used for base cases involving heat pump water heaters with storage capacity greater than 55 gallons (specifically, 60 and 75-gallon capacities) and were collected during the same period as the measure case costs. Although these capacities greater than 55 gallons are not the same as those used in the savings sections of this workpaper, the difference does not make an appreciable impact on costing. These costs were determined to be representative of unit costs based on online retailer checks in the first quarter of 2020.

MEASURE CASE MATERIAL COST (\$/UNIT)

Measure case equipment costs¹² were calculated as the average of costs of qualifying units sold by online retailers.¹³ The market is limited for heat pump water heaters ≥ 3.00 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 2020.

BASE CASE LABOR COST (\$/UNIT)

The estimated installation hours for each of the baseline water heater technologies and capacities in the workpaper were obtained from RSMeans 2020¹⁴ and multiplied by the RSMeans 2020 hourly plumber rate (\$/hr).¹⁵

¹¹ Southern California Edison (SCE). 2020. "SWWH025-02 MeasureDataSpec.xlsm", Cost Data tab

¹² Southern California Edison (SCE). 2018. "SCE17WH001.2 A3 - Costs Calculations.xlsx."

¹³ 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.

¹⁴ 2020 RSMeans Electrical Cost Data

¹⁵ RSMeans 2020 Residential Labor Rates. <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202020%20Labor%20Rates/Residential%20Labor%20Rates.PDF>

MEASURE CASE LABOR COST (\$/UNIT)

The estimated installation hours for each of the heat pump water heater capacities in the workpaper were obtained from RSMeans 2020¹⁶ and multiplied by the RSMeans 2020 hourly plumber rate (\$/hr).¹⁷ Labor hours for heat pump water heaters were not specifically called out so the hours for electric water heaters were used and are assumed to be applicable.

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 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.

¹⁶ 2020 RSMeans Electrical Cost Data

¹⁷ RSMeans 2020 Residential Labor Rates. <https://www.rsmeansonline.com/References/LABORRATE/2-Year%202020%20Labor%20Rates/Residential%20Labor%20Rates.PDF>

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.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	Yes
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 Water Heater Calculator v4.1
Reason for Deviation from DEER	N/A
DEER Measure IDs Used	RE-WtrHt-SmlStrg-HP-Ite6kW-rep30G-MD-3p09UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-rep30G-MD-3p31UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-rep40G-MD-3p09UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-rep40G-MD-3p31UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-rep50G-MD-3p09UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-rep50G-MD-3p31UEF-50g RE-WtrHt-SmlStrg-HP-Ite6kW-65G-3p33UEF RE-WtrHt-SmlStrg-HP-Ite6kW-80G-3p42UEF
NTG	Source: DEER2011. NTG of 0.55 is associate with NTG ID: <i>ResDefault>2yrs</i> .
GSIA	GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER2014. 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.
02	6/11/2020	Brandon Yamasaki, TRC	Updated savings and measure definitions based on DEER Water Heater Calculator v4.1
	12/23/2020	Jesse Manao, SCE	Updated base material costs and labor costs to 2020 Update to PG&E Implementation IDs