



## WATER HEATING

### STORAGE WATER HEATER, RESIDENTIAL

SWWH012-01

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## MEASURE NAME

Storage Water Heater, Residential

## TECHNOLOGY SUMMARY

Conventional electric-resistance and natural gas water heaters consist of a glass-lined steel tank with foam insulation. An electric or natural gas burner is located at the base end of the tank where cold water enters and is heated by the burner. The heated water rises to the top portion of the tank where the hot water is drawn for consumption.

Relative to a standard model, a high-efficiency storage water heater is characterized by having superior insulating material and more effective heat transfer surfaces. These features reduce the water heater envelope losses and the energy required to maintain the water at the desired setpoint temperature. These attributes improve the energy performance of the water heater and provide an opportunity for energy savings.

## MEASURE CASE DESCRIPTION

This measure is defined as the installation of an electric or gas storage water heater with 30, 40, or 50-gallon storage capacity. The measure case specifications by storage capacity are specified below. The minimum qualifying measure efficiencies exceed the California Appliance Efficiency Regulations (Title 20) and the Code of Federal Regulations. Energy savings are calculated by climate zone for each of the measure offering.

### Measure Case Specification

Storage Capacity (gal.)	Draw	Min. Qualifying Efficiency (UEF)
30	Medium	0.64
40	Medium	0.64
	High	0.68
50	Medium	0.64
	High	0.68

## BASE CASE DESCRIPTION

The base case is defined a gas standard efficiency storage water heater with 30, 40, or 50-gallon storage capacity. The minimum base case efficiencies are consistent with the federal U.S. Department of Energy (DOE) standards (see Code Requirements).

### Base Case Specification

Storage Capacity (gal.)	Draw Pattern	Min. Efficiency (UEF)
30	Med	0.64
40	Med	0.64
40	High	0.68
50	Med	0.64

Storage Capacity (gal.)	Draw Pattern	Min. Efficiency (UEF)
50	High	0.68

## CODE REQUIREMENTS

Applicable state and federal codes and standards for residential storage water heaters are noted below.

### Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2018)	Sections 1605.1(f)(2)	January 1, 2018
CA Building Energy Efficiency Standards – Title 24 (2016)	Section 110.3	January 21, 2016
Federal Standards – Code of Federal Regulations	10 CFR 430.32(d)	December 29, 2016

**California Appliance Efficiency Regulations (Title 20).**<sup>1</sup> Section 1605.1(f) of Title 20<sup>2</sup> stipulates the minimum efficiency standards for small storage water heaters (units with an input rating  $\leq 75,000$  Btu/hr).

### Title 20 Standards for Small Water Heaters

Product class	Rated storage volume***	Energy factor**
Gas-fired Storage .....	$\geq 20$ gal and $\leq 55$ gal .....	$0.675 - (0.0015 \times V_R)$
	$> 55$ gal and $\leq 100$ gal .....	$0.8012 - (0.00078 \times V_R)$
Oil-fired Storage .....	$\leq 50$ gal .....	$0.68 - (0.0019 \times V_R)$
Electric Storage .....	$\geq 20$ gal and $\leq 55$ gal .....	$0.960 - (0.0003 \times V_R)$
	$> 55$ gal and $\leq 120$ gal .....	$2.057 - (0.00113 \times V_R)$
Tabletop* .....	$\geq 20$ gal and $\leq 120$ gal .....	$0.93 - (0.00132 \times V_R)$
Gas-fired Instantaneous† .....	$< 2$ gal .....	$0.82 - (0.0019 \times V_R)$
Electric Instantaneous* .....	$< 2$ gal .....	$0.93 - (0.00132 \times V_R)$

\* Tabletop and electric instantaneous water heater standards were not updated by the April 2010 final rule.

\*\*  $V_R$  is the "Rated Storage Volume" (in gallons), as determined by 10 CFR 429.17.

\*\*\* Rated Storage Volume limitations result from either a lack of test procedure coverage or from divisions created by DOE when adopting standards. The division at 55 gallons for gas-fired and electric storage water heaters was established in the April 16, 2010 final rule amending energy conservation standards. 75 FR 20112. The other storage volume limitations shown in this table are a result of test procedure applicability and are discussed in the July 2014 final rule. 79 FR 40542 (July 11, 2014).

† The standard for gas-fired instantaneous water heaters applies only to gas-fired instantaneous water heaters with a rated input of greater than 50,000 Btu/h.

**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.<sup>3</sup> 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

<sup>1</sup> California Energy Commission (CEC). 2014. *2014 Appliance Efficiency Regulations*. CEC-400-2014-009-CMF.

<sup>2</sup> California Energy Commission (CEC). 2017. *2016 Appliance Efficiency Regulations*. CEC-400-2017-002.

<sup>3</sup> 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.

evaluating its performance based on that usage.<sup>4</sup> 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.

**Table II.1 – Consumer Water Heater Energy Conservation Standards Denominated in UEF**

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 .....	$0.9884 - (0.0016 \times V_r)$

  

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor
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 by 10 CFR 429.17.

\*\*For instantaneous water heaters the standard is represented as a single value rather than as a function of storage volume. Because the UEF standard only applies to models with less than 2 gallons of storage volume, the coefficient becomes zero, and the standard does not vary for models between 0 and 2 gallons.

<sup>4</sup> A.O. Smith. (n.d.) "What Does UEF Mean To You?"

The final ruling also includes tables that define each of the draw patterns categories, as follows:

*Section 429.17 (B) Determine the applicable draw pattern as follows:*

*(1) For consumer gas-fired water heaters, consumer oil-fired water heaters, consumer electric water heaters, tabletop water heaters, grid enabled water heaters, residential-duty commercial gas water heaters, residential-duty commercial oil fired water heaters: Use the New FHR [First Hour Rating] ... to select the applicable draw pattern from the table in this paragraph:*

#### Storage Water Heater Draw Patterns

New FHR greater than or equal to:	and new FHR less than:	Draw pattern
0 gallons .....	18 gallons .....	Very Small.
18 gallons .....	51 gallons .....	Low.
51 gallons .....	75 gallons .....	Medium.
75 gallons .....	No upper limit .....	High.

## 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.

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

### Implementation Eligibility

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

### Eligible Products

Eligible water heaters must comply with the measure case specification (see Measure Case Description).

Only storage water heaters as defined by the California Energy Commission qualify, and they must:

- Be used primarily for domestic hot water
- “Storage water heater” means a water heater that heats and stores water within the appliance at a thermostatically-controlled temperature for delivery on demand, and that has an input less than 4,000 Btu per hour per gallon of stored water.

Equipment must comply with the test methods referenced in the California Building Energy Efficiency Standards (Title 24) and the California Appliance Efficiency Regulations (Title 20). Additionally, the equipment must meet minimum emissions requirements as defined by local air quality management districts. See Code Requirements.

Only gas-for-gas normal replacements or for new construction installations are eligible.

Normal replacements must replace a storage water heater with another storage water heater.

The manufacturer and equipment model number must be provided.

If necessary, customer must provide proof of unit efficiency (e.g., manufacturer’s equipment specification sheet).

#### *Eligible Building Types*

This measure is applicable to any single-family, multi-family, and double-wide mobile home residential building of any vintage.

#### *Eligible Climate Zones*

The measure is applicable in all California climate zones.

### PROGRAM EXCLUSIONS

Fuel switching is not allowed.

Water heaters used for space conditioning, process end use applications, pools or spas are not eligible.

Water heaters for nonresidential applications are not eligible.

### DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

### USE CATEGORY

Service & domestic hot water

### ELECTRIC SAVINGS (kWh)

Not applicable.

## PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

## GAS SAVINGS (Therms)

The unit energy savings (UES) for this measure were estimated using the Database of Energy Efficient Resources (DEER) water heater calculator tool, 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 DEER water heater calculator utilizes hourly output from the DOE2 building prototypes for hot water loads and ambient conditions to estimate hourly gas consumption. Version 3.3 of the DEER water heater calculator was used for the gas energy savings analysis for this measure.<sup>5</sup>

The baseline energy factor (EF) values in DEER have been converted to uniform energy factor (UEF) to conform to the 2018 federal standards (see Code Requirements).<sup>6</sup>

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

### DEER Measure Codes

Measure Code
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-MD-Op64UEF
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-MD-Op64UEF
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HD-Op68UEF
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-MD-Op64UEF
RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HD-Op68UEF

The water heater calculator was used to estimate the baseline and measure case unit energy consumption (UEC); the UES was calculated as the difference.

The annual UEC is estimated with the expression below.

$$WH_{\text{annual Therm}} = \left[ \sum_{\text{hour}=1}^{8760} \left( \frac{(HW_{\text{load}} + UA_{\text{load}} - Aux_{\text{load}} + Btu_{\text{Aux}})}{RE * 100,000} \right)_{\text{hour}} \right]$$

For each hour:

$$HW_{\text{load}} = \text{Volume} * (T_{\text{tank}} - T_{\text{main}}) * \frac{Btu}{Gal * F}$$

<sup>5</sup> California Public Utilities Commission (CPUC), Energy Division. 2018. "DEER-WaterHeater-Calculator-v3.3.xlsm." Updated August 2018.

<sup>6</sup> California Public Utilities Commission (CPUC), Energy Division. 2018. "2018 Residential Water Heaters." March 1.

$$UA_{load} = Tank_{UA} * (T_{tank} - T_{ambient})$$

$$Tank_{UA} = \left( \frac{\frac{RE}{UEF} - 1}{\left( \frac{24 \frac{hr}{day}}{41092 \frac{Btu}{day}} - \frac{1}{UEF * P * 1000} \right)} \right) \div (67.5)$$

$$Aux_{load} = -(Btuh_{Aux} * Eff_{Aux})$$

$$Btu_{Aux} = (pilot\ light \left( \frac{btu}{hr} \right) * 1hr * \frac{1\ Therm}{100,000\ Btu})$$

$WH_{load\ annual}$  = annual water heater energy consumption

$HW_{load}$  = hourly water heater load due to water use

$UA_{load}$  = hourly load due to tank shell loss(Btu)

$Aux_{load}$  = pilot light heat rate(Btu/hr) contribution to water heater

$RE$  = recovery efficiency

$UEF$  = uniform energy factor

$P$  = water heater input capacity rate (Btu/hr)

### Sample Calculation

The calculation of the consumption for one hour of the year per the water heating schedule was adopted from the “DEER-WaterHeater-Calculator-v3.3”. Considering hour 8, which heats 0.6 gallons of water in climate zone 9 for a single-family dwelling.

$$HW_{load} = 0.6\ gal \times (135\ F - 44\ F) \times 8.2 \frac{Btu}{gal \times F} = 386\ Btu$$

$$Tank_{UA} = \left( \frac{\frac{0.804}{0.60067} - 1}{\left( \frac{24 \frac{hr}{day}}{41092 \frac{Btu}{day}} - \frac{1}{0.60067 * 30,000 \frac{Btu}{hr}} \right)} \right) \div (67.5) = \frac{9.53\ Btu}{hr \times F}$$

$$UA_{load} = \frac{9.53\ Btu}{hr \times F} \times (135\ F - 44\ F) \times 1hr = 867\ Btu$$

$$Aux_{load} = - \left( 350 \frac{Btu}{hr} \times .67 \right) \times 1\ hr = -235\ Btu$$

$$Btu_{Aux-for\ 1\ hour} = (350) \left( \frac{Btu}{hr} \right) \times 1hr = 350\ Btu$$



$$WH_{1 \text{ hour load}} = \left[ \sum_{\text{hour}=1}^{8760} \left( \frac{(366 \text{ Btu} + 867 \text{ Btu} - 235 \text{ Btu} + 350 \text{ Btu})}{.804 \times 100,000} \right)_{\text{hour } 8} \right] = 0.01617 \text{ Therm}$$

The above result is for one hour of the year; the process was repeated for all annual hours and summed to yield the annual water heater load. The savings were then computed as the difference between the measure annual UEC and the baseline annual UEC.

The table below maps each California climate zone to an IOU service area to identify the appropriate saving value for each California climate zone.

#### Climate Zone-IOU Service Area Mapping

Program Administrator	Climate Zone
SCE	CZ06, CZ08, CZ09, CZ10, CZ13, CZ14, CZ15, CZ16
PG&E	CZ01, CZ02, CZ03, CZ04, CZ05, CZ11, CZ12
SDG&E	CZ07

#### 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 this measure is presented below. Note that RUL is only applicable for add-on equipment and accelerated replacement measures and is not applicable for this measure.

#### Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	11.0	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)

The base case material and labor costs were derived from data drawn from the 2010-2012 WO017 Ex Ante Measure Cost Study Final Report<sup>7</sup> prepared by Itron, Inc. Because this study presents material and

<sup>7</sup> Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Appendix F.1, page 11.

Southern California Edison (SCE). 2019. "SWCR014-01 High Efficiency Display Case - calcs.xlsx"

labor cost for water heaters units rated with energy factor (EF), the EF values were converted to UEF and a regression analysis was completed to determine the cost for each corresponding UEF rating.<sup>8</sup>

### MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case material and labor costs were derived from data drawn from the 2010-2012 WO017 Ex Ante Measure Cost Study Final Report<sup>9</sup> prepared by Itron, Inc. Because this study presents material and labor cost for water heaters units rated with energy factor (EF), the EF values were converted to UEF and a regression analysis was completed to determine the cost for each corresponding UEF rating.<sup>10</sup>

### BASE CASE LABOR COST (\$/UNIT)

Base case labor costs were derived using the same methodology to develop base case material costs. The labor cost is assumed to be equal for the base and measure case, as the process of installation is the same.

### MEASURE CASE LABOR COST (\$/UNIT)

Measure case labor costs were derived using the same methodology to develop the measure case material costs. The labor cost is assumed to be equal for the base and measure case, as the process of installation is the same.

### 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. These 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. These sector average NTGs ("default NTGs") are applicable to all energy efficiency measures that have been offered through residential programs for more than two years and for which impact evaluation results are not available.

#### Net-to-Gross Ratios

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

<sup>8</sup> Southern California Gas Company. 2018. "WPSCGREWH180207A-Rev00\_Att. A - Cost Regression.xlsx"

<sup>9</sup> Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission. Appendix F.1, page 11.

Southern California Edison (SCE). 2019. "SWCR014-01 High Efficiency Display Case - calcs.xlsx"

<sup>10</sup> Southern California Gas Company. 2018. "WPSCGREWH180207A-Rev00\_Att. A - Cost Regression.xlsx"

## 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.

### DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	Yes
DEER Version	DEER 2018 READI v2.4.8
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	RG-WtrHt-SmlStrg-Gas-lte75kBtuh-30G-MD-Op64UEF RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-MD-Op64UEF RG-WtrHt-SmlStrg-Gas-lte75kBtuh-40G-HD-Op68UEF RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-MD-Op64UEF RG-WtrHt-SmlStrg-Gas-lte75kBtuh-50G-HD-Op68UEF
NTG	Source: DEER2019. NTG of 0.55 is associated with NTG ID: <i>Res-Default</i> >2. (electric/gas)
GSIA	GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER2014. The EUL of 11 years is associated with EUL ID: <i>WtrHt-Res-Gas</i>

## REVISION HISTORY

## Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	03/08/2018	Jennifer Holmes, Cal TF Staff	The draft of the text fields for this statewide measure is based upon: PGECODHW104, Revision 6 (April 1, 2017) PGECODHW104, Revision 5 (April 1, 2016) WPSDGEREWH0023, Revision 0 (March 24, 2014) Consensus reached among Cal TF members
	02/07/2019	Jennifer Holmes, Cal TF Staff	Update with: WPSCGREWH180207A, Revision 00 (August 31, 2018)
	02/27/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.