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WATER HEATING
TANKLESS WATER HEATER, RESIDENTIAL
SWWH013-01

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MEASURE NAME

Instantaneous (Tankless) Water Heater, Residential

STATEWIDE MEASURE ID

SWWH013-01

TECHNOLOGY SUMMARY

A storage water heater is a water heater that heats and stores water at a thermostatically-controlled temperature for delivery on demand an input less than 4,000 Btu per hour per gallon of stored water. Tankless natural gas water heaters differ from storage-type water heaters in that they heat incoming water only when there is a demand for hot water, rather than heating and maintaining a constant stored supply of hot water. As a result, an instantaneous water heater for a given application needs a higher kBtu/hr input rating than a storage-type natural gas water heater for the same application. The California Appliance Efficiency Regulations (Title 20) defines an instantaneous water heater as “a water heater that has an input rating of at least 4,000 Btu per hour per gallon of stored water.”¹ All “tankless” water heaters are “instantaneous” water heaters and tankless water heaters generally have rated inputs less than 200 kBtu/hr.

An instantaneous unit has relatively high energy efficiency level because standby losses from a storage tank is essentially eliminated. Without storage, the instantaneous water heater must have a much higher burner capacity to handle peak demands. Therefore, the input rating of a given base case storage-type water heater is lower than the input rating of the corresponding measure case instantaneous heater.

A condensing instantaneous water heater model has more heat exchange surface between the hot exhaust gasses and the water being heated. This allows the water to absorb more of the exhaust gas heat, which in turn reduces the temperature of the exhaust gasses and condenses the exhaust by products. By using the heat from the exhaust gas, which is wasted by standard tankless models, a condensing natural gas tankless water heater can achieve a higher energy factor (EF) than a comparably-sized traditional storage-type or non-condensing instantaneous water heater.

An instantaneous water heater is most useful in a point-of-use application – at the faucet and with no circulation loop. It will be inefficient in applications with a circulation loop due to the temperature loss in the circulation system which causes the tankless water heater to run without water demand. An instantaneous water heater is also problematic in a central system with a circulation loop with a long pipe run from the water heater to the faucet.

¹ California Energy Commission (CEC). 2017. *2016 Appliance Efficiency Regulations*. CEC-400-2017-002.

California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings*. CEC-400-2015-037-CMF.

MEASURE CASE DESCRIPTION

This measure is defined as the replacement of a storage water heater with a tankless water heater in a residential application. The qualifying measure specification for the residential tankless water heater is specified below.

Since it is considered industry standard practice to purchase a storage water heater for a residential application, Tier 1 includes tankless water heaters listed at the Code of Federal Regulations standards of uniform energy factor (UEF) equal to 0.81 for low to high draw patterns.² The minimum qualifying measure efficiency for Tier 2 exceeds the California Titles 2 and 24 and the Code of Federal Regulations standards.

Measure Case Specification

Building Type	Measure Case Equipment	Input Rating (kBtu/hr)	Draw	Measure Case Min. Efficiency (UEF)
Single Family / Multifamily	Tankless Water Heater, Non-condensing – Tier 1	≤ 175	Low	0.81
		≤ 175	Medium	0.81
		≤ 175	High	0.81
	Tankless Water Heater, Condensing – Tier 2	≤ 175	Low	0.87
		≤ 175	Medium	0.87
		≤ 175	High	0.87

BASE CASE DESCRIPTION

The base case equipment is defined as a 40-gallon storage water heater for single family installations and a large storage natural gas water heater for multifamily installations. The base case efficiency specification is provided below and are consistent with the Code of Federal Regulations minimum efficiency standards, and emission limits set forth in California Appliance Efficiency Regulations (Title 20), Building Energy Efficiency Standards (Title 24) and emissions regulations (See Code Requirements).

Gas Base Case Specification

Buiding Type	Base Case Equipment	Draw	Base Case Min. Efficiency (UEF)
Single Family / Multifamily	40 gal ≤ 75 kBtuh	Low	0.52
		Medium	0.58
		High	0.64

² California Energy Commission. 2015. 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. CEC-400-2015-037-CMF.

CODE REQUIREMENTS

Applicable state and federal code and standards are detailed below. Additionally, water heating equipment must comply with emissions limits set forth by air quality management districts (AQMDs) or air pollution control districts (APCDs) throughout the State.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2018)	Section 1605.3(f)	May 1, 2018
CA Building Energy Efficiency Standards – Title 24 (2016)	Section 110.3	January 1, 2017
Federal Standards – Code of Federal Regulations	10 CFR 430.32(d)	May 1, 2018
California Air Quality Management District (AQMD)/Air Pollution Control District Regulations		
South Coast AQMD (SCAQMD)	Rule 1121 Rule 1146.2	September 3, 2004 May 5, 2006
Bay Area AQMD (BAAQMD)	Regulation 9, Rule 6	November 7, 2007
San Joaquin Valley APCD (SJVAPCD)	Rule 4902	March 19, 2009
Sacramento Metropolitan AQMD (SMAQMD)	Rule 414	March 25, 2010
Yolo-Solano AQMD (YSAQMD)	Regulation II, Rule 2.37	April 8, 2009
Ventura County Air Pollution Control District (VCAPCD)	Rule 74.11	January 12, 2010

California Title 20 Gas Appliance Standards and Code of Federal Regulations

Gas Water Heater	Input Rating (Btu/hr)	Rated Storage Volume - V (gal)	Draw Pattern	Minimum Efficiency Rating
Instantaneous – federally regulated	> 50,000	< 2.0	Very Small	0.80 UEF
			Low	0.81 UEF
			Medium	0.81 UEF
			High	0.81 UEF
Instantaneous – not federally regulated	≤ 50,000	any	unspecified	0.62 – (.0019 * V) EF
Instantaneous – not federally regulated	≤ 200,000	≥ 2.0	unspecified	0.62 – (.0019 * V) EF

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	UpDeemed	Res
Normal replacement	DnDeemed	Res

Eligible Products

Equipment must meet the minimum qualifying uniform energy factor (UEF) for a small or medium (< 200 kBtu/hr) tankless water heater as specified in the Measure Case Description.

Equipment must meet the minimum emission requirements per air quality management district, if applicable.

The measure pertains to the installation of a small tankless water heater as a normal replacement of a natural gas storage water heater or for a new installation in an existing building.

Only tankless water heaters, as defined by the California Energy Commission (CEC), qualify; they must:

- Be used primarily for domestic hot water
- Be installed at the point of use
- Provide hot water only when there is a hot water draw from the end use
- Not be connected to an external storage tank
- Have an input rating of at least 4,000 Btu per hour per gallon of stored water
- Never be used to supply hot water to a circulation loop

The manufacturer and equipment model number must be provided.

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

Eligible Building Types

This measure is applicable only to single family and multifamily residential domestic hot water applications with a water heater in (single family only), or attached to, each dwelling unit or in adjacent units (multifamily only).

Any building vintage that meets these criteria is eligible.

Eligible Climate Zones

The measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

Water heaters or hot water boilers used for commercial domestic hot water, space conditioning, industrial (process) end-use, pool, or spa applications are not eligible.

This measure does not apply to new construction installations but allows new installations in existing buildings.

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) of small instantaneous water heaters (≤ 175 MBtu/hr) were drawn from the Database for Energy Efficient Resources (DEER) using the DEER water heater calculator tool, an involved 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 accommodates 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."³ 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."⁴

The following table indicates measures taken directly from or created with the DEER READI tool.

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

⁴ California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2015 Service and Domestic Water Heater Measures Update." October 1. Page 10.

DEER Measure Codes

Measure Code	READI Version
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-LW-Op81UEF-40g	2.5.1
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-MD-Op81UEF-40g	2.5.1
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-HI-Op81UEF-40g	2.5.1
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-LW-Op87UEF-40g	2.5.1
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-MD-Op87UEF-40g	2.5.1
RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-HI-Op87UEF-40g	2.5.1

The energy savings were estimated using the DEER water heater calculator version 3.3.⁵ This calculator was used to estimate the unit energy consumption (UEC) for both the baseline and measure case, as explained below. The conversion of UEC based upon an energy factor (EF) rating to the uniform energy factor (UEF) rating is also provided below. The UES was then calculated as the difference between the baseline and measure case UEC.

Annual Unit Energy Consumption

The DEER water heater calculator version 3.3 utilizes hourly output from the DOE₃ building prototypes for hot water loads and ambient conditions to estimate hourly gas consumption. The baseline EF values in DEER have been converted to UEF for consistency with the new DOE efficiency requirements. The calculation to determine the UEC based upon UEF is provided below, followed by the conversion from EF to UEF.

The annual UEC for a tankless water heater is estimated with the expression below.

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

For each hour:

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

$$UA_{\text{load}} = \text{Tank}_{UA} \times (T_{\text{tank}} - T_{\text{ambient}})$$

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

⁵ California Public Utilities Commission (CPUC), Energy Division. 2018. "DEER2020 Small Storage and Small Instantaneous Water Heater Energy Use Calculator." "DEER-WaterHeater-Calculator-v3.3.xlsm." August 30.

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

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

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)

Conversion from Energy Factor to Uniform Energy Factor

It is important to note that while EF values were based on a single draw pattern, the UEF value is based on four different draw patterns. This workpaper requires there to be two conversion methods covered: for instantaneous (measure) and storage (baseline) water heaters.

First, the draw pattern for a given instantaneous water heater must be determined. The UEF has four potential draw patterns. One out of those four will provide the correct conversion from EF to UEF. The EUF draw pattern is determined by the new maximum gallons per minute (New Max GPM) per the DOE test procedure. The following defines the conversion to the new GPM.

$$New Max GPM = 1.1461 \times Max GPM_p$$

Max GMP_p = prior maximum gallons per minute of the EF rated water heater

Using the *New Max GPM*, the appropriate draw pattern can be selected in the table below.

New Max GPM greater than or equal to:	New Max GPM rating less than:	Draw Pattern
0 gallons/minute	1.7 gallons/minute	Very Small
1.7 gallons/minute	2.8 gallons/minute	Low
2.8 gallons/minute	4 gallons/minute	Medium
4 gallons/minute	No upper limit	High

The draw pattern can then be used to select the coefficient (A) necessary for the conversion to UEF.

Draw Pattern	Coefficient A
Very Small	0.026915
Low	0.010917
Medium	0.008362
High	0.005534

$$UEF_{model} = \frac{\eta_r}{1 + A\eta_r}$$

η_r = recovery efficiency of EF rated water heater

A = coefficient dependant on draw pattern as shown in table above

The UEF for an instantaneous water heater can then be found using the following formula.

$$UEF = 0.1006 + 0.8622 \times UEF_{model}$$

The DOE process to convert a gas-fired storage water heater from EF value to UEF is as follows:

First, the draw pattern for a given storage water heater must be determined. The UEF has four potential draw patterns. One out of those four, will provide the correct conversion from EF to UEF. The EUF draw pattern is determined by the new first hour rating (FHR) per the DOE test procedure. The following defines the conversion to the new FHR.

$$FHR = 25.0680 + 0.6535 * FHR_p$$

FHR_p = prior first hour rating of the EF rated water heater

Using the FHR, the appropriate draw pattern can be selected in the table below.

New FHR greater than or equal to:	New FHR rating 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

The draw pattern can then be used to select the constant coefficients in the below table.

Draw Pattern	a	b	c	d
Very small	0.250266	57.5	0.039864	67.5
Low	0.065860	57.5	0.039864	67.5
Medium	0.045503	57.5	0.039864	67.5
High	0.029794	57.5	0.039864	67.5

Along with the water heater specifications listed below, the constant coefficients are used to determine the UEF_{WHAM} .

$$UEF_{WHAM} = \left[\frac{1}{\eta_r} + \left(\frac{1}{EF} - \frac{1}{\eta_r} \right) \left(\frac{aP\eta_r - b}{cP\eta_r - d} \right) \right]^{-1}$$

η_r = recovery efficiency

EF = energy factor

a, b, c, d = constant coefficients dependant on draw pattern

P = water heater input rate (Btu/hr)



Finally, the UEF for a storage water heater can then be determined with the following formula.

$$UEF = 0.0746 + 0.8653 \times UEF_{WHAM}$$

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 specified 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)	20.0	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)

For a *normal replacement installation*, the customer must buy a new water heater to continue operating, so the base case material cost is that of a base case storage water heater.

The WO017 Ex Ante Measure Cost Study conducted by Itron, Inc.⁶ was used to create a regression for the baseline costs.⁷ The energy factor (EF)-based values from the study were converted to uniform energy

⁶ Itron, Inc. 2014. 2010-2012 WO017 Ex Ante Measure Cost Study Final Report. Prepared for the California Public Utilities Commission.

⁷ Southern California Gas Company. 2018. "WPSCGREWH120919A-Rev4 Cost Regression.xlsx"

factor (UEF) values using the U.S. DOE conversion methodology (See Gas Savings). The resultant UEF values paired with cost data, were then plotted and expanded using a constrained linear regression. The California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDS) was referenced to verify the average specifications of the storage water heaters relative to the efficiency rating. Along this regression line, the costs values for the desired UEF values for storage water heaters were found.

Note that these costs included both purchase and installation (material and labor) costs.

MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case material cost was derived from the U.S. Department of Energy (DOE) Technical Support Document (TSD): Pool Heaters, Direct Heating Equipment and Water Heaters (EERE-2006-STD-0129).⁸ The extracted data includes both labor and material cost.⁹ While the DOE data is older than the cost data presented in the 2010-2012 Ante Measure Cost Study conducted by Itron, Inc.,¹⁰ a comparison with project invoices showing cost information¹¹ for tankless water heaters confirms the DOE data is representative of measure case material costs.

Condensing water heaters typically use PVC for venting flue exhaust which is cheaper and easier to install than sheet metal used for non-condensing water heaters. Venting material used with non-condensing water heaters are not suitable for condensing due to material properties. Plastics used for condensing water heaters have lower vent temperatures limits and are not suitable for non-condensing water heaters. The cost difference in venting material and installation is captured in data extracted from the TSD.

The TSD reports total installed cost (IP) for small storage and tankless water heaters as the sum of consumer product price (CPP) and cost to the consumer to install products (INST) ($IP = CPP + INST$). The small tankless water heaters are reported in those cost details.

Note that these costs included both purchase and installation (labor and material) costs.

BASE CASE LABOR COST (\$/UNIT)

See Base Case Material Cost.

⁸ U.S. Department of Energy (DOE). 2009. *Technical Support Document: Energy Conservation Program for Consumer Products: Energy Conservation standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters*. Prepared by Navigant Consulting, Inc. and Lawrence Berkeley National Laboratory. Docket ID: EERE-2006-STD-129.

See: Southern California Gas Company. 2014. "WPSCGREWH120919A-Rev4 Rev2 Cost Data.xlsx"

⁹ Southern California Gas Company. 2014. "WPSCGREWH120919A-Rev4 Rev2 Cost Data.xlsx"

¹⁰ Itron, Inc. 2014. *2010-2012 WO017 Ex Ante Measure Cost Study Final Report*. Prepared for the California Public Utilities Commission.

¹¹ Southern California Gas Company. 2018. "WPSCGREWH120919A-Rev4 Invoice Summary.xlsx."

MEASURE CASE LABOR COST (\$/UNIT)

See Measure Case Material Cost.

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. This NTG value is 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. This sector average NTG (“default NTG”) is 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 – residential	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.

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 the inputs and methods based upon the California Database of Energy Efficient Resources (DEER), 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-WaterHeater-Calculator-v3.3
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-LW-Op81UEF-40g RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-MD-Op81UEF-40g RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-HI-Op81UEF-40g RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-LW-Op87UEF-40g RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-MD-Op87UEF-40g RG-WtrHt-SmlInst-Gas-Ite175kBtuh-It2G-HI-Op87UEF-40g
NTG	Source: DEER. NTG of 0.55 is associate with NTG ID: <i>Res-Default>2yrs.</i>
GSIA	GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER. The EUL of 20 years is associated with EUL ID: <i>WtrHt-Instant-Res</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision
01	03/13/2018	Jennifer Holmes, Cal TF Staff	The draft of the text fields for this statewide measure is based upon: WPSCGREWH120919A Revision 3 (August 8, 2016) – savings and cost methodology for single-family applications PGECODHW101 Revision 7 (February 15, 2017) – savings and cost methodology for multifamily applications Consensus reached among Cal TF members
	02/08/2019	Jennifer Holmes, Cal TF Staff	Update to include: WPSCGREWH120919A, Revision 4 (October 12, 2018)
	02/28/2019	Jennifer Holmes, Cal TF Staff	Revisions for submission of version 01.