eTRM
best in class

WATER HEATING

TANKLESS WATER HEATER, COMMERCIAL

SWWH006-06

CONTENTS

MEASURE NAME

Tankless Water Heater, Commercial

STATEWIDE MEASURE ID

SWWH006-06

TECHNOLOGY SUMMARY

A tankless water heater, or an "instantaneous" or "continuous flow" water heater, is a high-powered water heater that instantly heats water as it flows through the heat exchanger of the unit. In most cases, these types of water heaters heat water directly without the use of a storage tank. When a hot water tap is turned ON, cold water travels through a pipe and into the unit. A gas burner heats the water and as a result, there is a constant supply of hot water at the point-of-use.

Compared to a storage water heater, a tankless unit has a relatively large burner that rapidly heats water to the desired temperature. Due to the rapid "instantaneous" heating, a tankless water heater does not require a storage tank (although a small tank may be included). Due to the larger burner size, tankless water heaters can provide hot water on a continuous basis. They save energy because the standby losses associated with a storage tank are essentially eliminated.

Typically, a tankless water heater can provide hot water at a rate of two to five gallons per minute (gpm) which could limit its applications.[1] A tankless water heater is most useful in a point-of-use application – at the faucet and with no circulation loop. They are 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. A tankless water heater is also problematic in a central system with circulation loops with long pipe runs from the water heater to the faucet.

MEASURE CASE DESCRIPTION

The measure case is defined as a tankless water heater that replaces a storage water heater. The minimum qualifying efficiency ratings of each measure offering are specified below. As shown, small instantaneous water heaters and large instantaneous water heaters each have two measure offerings distinguished by the minimum efficiency rating. These measure case efficiencies were adopted after consideration of the California Appliance Efficiency Regulations (Title 20, see Code Requirements) and as a result of analysis of the distribution of high-efficiency instantaneous water heaters certified in the California Energy Commission (CEC) Modernized Appliance Efficiency Database System.[2]

[1] U.S. Department of Energy (DOE). (n.d.). "*Tankless or Demand-Type Water Heaters*."

[2] California Energy Commission (CEC). (n.d.) "Modernized Appliance Efficiency Database System (MAEDBS)." Accessed in March 2012 and May 2014

Measure Case Specification

Measure Description	Input Rating (kBtu/hr)	Tier	Min Efficiency Rating	Efficiency Unit
Small Instantaneous Gas Water Heater (<200kbtuh capacity rated in UEF)	< 200	Tier I	0.81	UEF
	< 200	Tier II	0.87	UEF
Medium Instantaneous Water Heater	(76 – 200)	Tier II	0.90	TE
Large Gas Instantaneous Water Heater	≥ 200	Tier I	0.80	TE
	≥ 200	Tier II	0.90	TE
	≥ 200	Tier III	0.96	TE

BASE CASE DESCRIPTION

The base case technology for this measure is defined as a storage water heater that meets the efficiency ratings specified below. The measures offerings established for this measure are offered as normal replacement and new construction installations. Therefore, the baseline for each measure is defined by either Code or standard practice. In this case, all measure offerings were evaluated against the code defined by the California Appliance Efficiency Regulations (Title 20, see Code Requirements). The table below provides the base case description for each measure offering. These baselines are utilized for both efficiency tiers of small and large instantaneous gas water heater measures.

Base Case Specification

Measure Case Description	Base Case Description (Code/Standard Baseline)
Small Instantaneous Gas Water Heater	Small Storage Gas Water Heater Tech ID: *Stor_UEF-Gas-040gal-MD-0.58UEF* * Volume – 40 gallon UEF = 0.58 RE = 0.76 Cap = 37.2 kBtu/hr UA = 7.93 Btu/hr-F Aux: 350 Btu/hr
Medium Gas Instantaneous Water Heater	Large Gas Storage Water Heater Tech ID: *Stor_TE-Gas-gt75kBtuh-0.80Et* * Average Volume – 82.8 gallon TE = 0.80 Cap = 165.8kBtu/hr UA = 16.49 Btu/hr-F Stdby Loss = 0.56%/hr
Large Gas Instantaneous Water Heater	Large Gas Storage Water Heater Tech ID: *Stor_TE-Gas-gt75kBtuh-0.80Et* * Average Volume – 82.8 gallon TE = 0.80 Cap = 165.8kBtu/hr UA = 16.49 Btu/hr-F Stdby Loss = 0.56%/hr

* Source *DEER-WaterHeater-Calculator-v4.2.xlsm*

CODE REQUIREMENTS

Applicable state and federal codes and standards for instantaneous heater/boilers are specified in the tables below.[3]

Applicable State and Federal Codes and Standards for Direct Contact Water Heaters

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2019)	1605.1 (f), Large water heaters 1605.3(f), Small water heaters	January 1, 2019
CA Building Energy Efficiency Standards – Title 24 (2019)	110.3	January 1, 2020
Federal Standards – Code of Federal Regulations	10 CFR 430.32(d)	December 29, 2016
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 Appliance Efficiency Regulations (2016 Title 20)

Equipment Type	Rated Input (kBtu/hr)	Rated Volume (gal)	Efficiency Units	Min. Efficiency	Max. Standby Loss (Btu/hr)
Instantaneous Water Heaters *V is the rated volume in gallons; Q is the rated input is Btu/hr*					
Large	≥ 200	< 10	TE	80%	---
Large	≥ 200	≥ 10	TE	80%	$Q/800 + 110\sqrt{V}$

[3] California Energy Commission (CEC). 2019. *2019 Appliance Efficiency Regulations*. CEC-400-2019-002. Section 1605.1(f) & 1605.3(f).

California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings.* CEC-400-2015-037-CMF. Section 110.3.

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

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) UEF
Instantaneous – not federally regulated	< 200,000	≥ 2.0	unspecified	0.62 – (.0019 * V) UEF

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.

[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?"

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

Product Class	*Rated Storage Volume and Input Rating (if applicable)*	*Draw Pattern*	*Minimum Uniform Energy Factor**
Gas-fired Storage Water Heater	≥ 20 gallons and ≤ 55 gallons	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 gallons and ≤ 100 gallons	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 gallons	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 gallons and ≤ 55 gallons	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 gallons and ≤ 120 gallons	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 gallons and ≤ 120 gallons	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 gallons and >50,000 Btu/h	Very small	0.80
		Low	0.81
		Medium	0.81
		High	0.81
Instantaneous Electric Water Heater	< 2 gallons	Very small	0.91
		Low	0.91
		Medium	0.91
		High	0.92
Grid-Enabled Water Heater	> 75 gallons	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 = Rated Storage Volume in gallons.			

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 filed 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:	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

(2) For instantaneous gas-fired water heaters, instantaneous electric water heaters, and residential-duty commercial electric instantaneous water heaters: Use New Max GPM … to select the applicable draw pattern from the table in this paragraph:

Instantaneous Water Heater Draw Patterns

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

In addition to the aforementioned federal standards, commercial storage and tankless water heaters are covered by ENERGY STAR.[6]

ENERGY STAR Commercial Gas Fired Instantaneous Water Heaters – Product Type Requirements

Product Type	ENERGY STAR Requirement
Gas Instant	≥ 200,000 Btu/hr input
	≥ 4,000 BTU/hr per gallon of stored water

ENERGY STAR Commercial Gas Fired Instantaneous Heaters – Minimum Efficiency Requirements

Product Type	Criteria	ENERGY STAR Requirement
Instantaneous (All Draw Patterns)	Thermal Efficiency (TE)	TE ≥ 0.94

ENERGY STAR Residential Gas Fired Instantaneous Water Heaters – Product Type Requirements

Product Type	ENERGY STAR Requirement
Gas Instant	< 200,000 Btu/hr input
	≥ 4,000 BTU/hr per gallon of stored water
	Max GPM ≥ 2.9 over a 67°F rise

ENERGY STAR Residential Gas Fired Instantaneous Heaters – Minimum Efficiency Requirements

Product Type	Criteria	ENERGY STAR Requirement
Instantaneous (All Draw Patterns)	Uniform Energy Factor (UEF)	UEF ≥ 0.87

NORMALIZING UNIT

kBtu per hour of rated input capacity (Cap-kBtuh).

[6] ENERGY STAR. 2018. "ENERGY STAR Program Requirements for Commercial Water Heaters. Eligibility Criteria Version 2.0." Effective on October 1, 2018.

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	Com
Normal replacement	DnDeemed	Com
Normal replacement	UpDeemed	Com
New construction	DnDeemDI	Com
New construction	DnDeemed	Com
New construction	UpDeemed	Com
Accelerated replacement	DnDeemDI	Com

For accelerated replacement application types, this measure adopts the program-level "Preponderance of Evidence Assessment" described in Version 2.0 of the Accelerated Replacement Using Preponderance of Evidence report developed by the utilities and stakeholders to provide guidance for the California programs ("POEV 2.0", see Section 7).[7] "Continued viability" and "program influence" must be demonstrated as the evidence of accelerated replacement.

To demonstrate the viability of the pre-existing system or to show that the program is replacing equipment that is "installed and operating," the customer must be approached by a direct install implementer. Additionally, the program must obtain and provide additional documentation, including (but not limited to) the following:

- Targeted segment of the market or customers
- Customer/site information
- Make/model of pre-existing equipment and/or
- Performance/flowrate measurements of pre-existing equipment, and/or
- Photograph of pre-existing equipment in place and operating

Program influence evidence can be demonstrated through one of the three alternatives listed in Section 7.3 of POEV 2.0. This measure establishes the program-level evidence of program influence by adopting the net-to-gross (NTG) ratio from prior program evaluation results.

[7] Track 1 Working Group. 2016. Accelerated Replacement Using Preponderance of Evidence. Version 2.0. December 7.

Specific documentation requirements will be determined by the program administrator and will be specified in the program implementation plan.

Eligible Products

Eligible commercial tankless water heaters must meet the following requirements:

- Meet or exceed the minimum qualifying efficiency ratings in the Measure Case Description and must comply with emission limits per air district, if applicable. Note that Tier 2 & 3 hot water heaters are condensing and often require flue modifications to handle the condensate.
- For *normal replacement installations*, only gas-for-gas replacements are eligible.
- Meet the definition of a tankless water heater, as defined by the California Energy Commission:
  - Be used primarily for domestic hot water
  - Provide hot water only when there is a hot water draw from the end use.
  - Have an input rating of at least 4,000 Btu/hr per gallon of stored water.

Eligible Building Types

This measure is applicable for any existing commercial domestic (or "service") hot water application in a nonresidential facility of any building type or vintage.

Eligible Climate Zones

The measure is applicable in all California climate zones.

PROGRAM EXCLUSIONS

This measure does not include water heaters or hot water boilers used for space conditioning, industrial (process) end-use applications, pools, or spas.

This measure cannot be used to supply hot water to a circulation loop without an intermediary hot water storage tank.

DATA COLLECTION REQUIREMENTS

The data utilized for the impact and cost analysis of this measure are considered to be sufficient. The energy and demand impact values are approved values through the Database for Energy Efficient Resources (DEER)

USE CATEGORY

Service & domestic hot water (SHW)

ELECTRIC SAVINGS (kWh)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

GAS SAVINGS (Therms)

The gas unit energy savings (UES) of small instantaneous water heaters rated by a uniform energy factor (UEF) were modeled using the Database for Energy Efficient Resources (DEER) methodologies in the DEER-WaterHeater-Calculator-v4.2.xlsm.[8] Due to sizing issues of large water heaters with the newest water heater calculator, savings for the large instantaneous units were adopted from DEER2014 and DEER 2021 measures.

DEER Measure Codes

Statewide Measure Offering ID	Energy Impact ID	Measure Description	DEER Version
SWWH006A	NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p81UEF-40g	Small Instantaneous Gas Water Heater ≤ 200 kBtuh, UEF ≥ 0.81	DEER-WaterHeater-Calculator-v4.2
SWWH006B	NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p87UEF-40g	Small Instantaneous Gas Water Heater ≤ 200 kBtuh, UEF ≥ 0.87	DEER-WaterHeater-Calculator-v4.2
SWWH006C	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p80Et	Large Gas Instantaneous Water Heater ≥ 200 kBtuh, Et = 0.80	DEER2014
SWWH006D	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p90Et	Large Gas Instantaneous Water Heater ≥ 200 kBtuh, Et = 0.90	DEER2014
SWWH006E	NG-WtrHt-MedInst-Gas-76to200kBtuh-lt2G-0p90Et	Small Gas Instantaneous Water Heater ≤ 200 kBtuh, Et = 0.90	DEER-WaterHeater-Calculator-v4.2
SWWH006F	NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p96Et	Large Gas Instantaneous Water Heater ≥ 200 kBtuh, Et = 0.96	DEER-WaterHeater-Calculator-v4.2a

Annual Unit Energy Consumption

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.

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

For each hour:

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

[8] California Public Utilities Commission (CPUC), Energy Division. 2020. "DEER-WaterHeater-Calculator-v4.2.xlsm." Updated September 16, 2020.

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

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

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

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

$WH_{load\ annual} = annual\ water\ heater\ energy\ consumption$
$HW_{load} = hourly\ water\ heater\ load\ due\ to\ water\ use$
$UA_{load} = hourly\ load\ due\ to\ tank\ shell\ loss(Btu)$
$Aux_{load} = pilot\ light\ heat\ rate(Btu/hr)\ contribution\ to\ water\ heater$
$RE = recovery\ efficiency$
$UEF = uniform\ energy\ factor$
$P = water\ heater\ input\ capacity\ rate\ (Btu/hr)$

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.

Tankless Water Heater EF to UEF Conversion

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

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

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

$$\eta_r = recovey\ efficiency\ of\ EF\ rated\ water\ heater$$

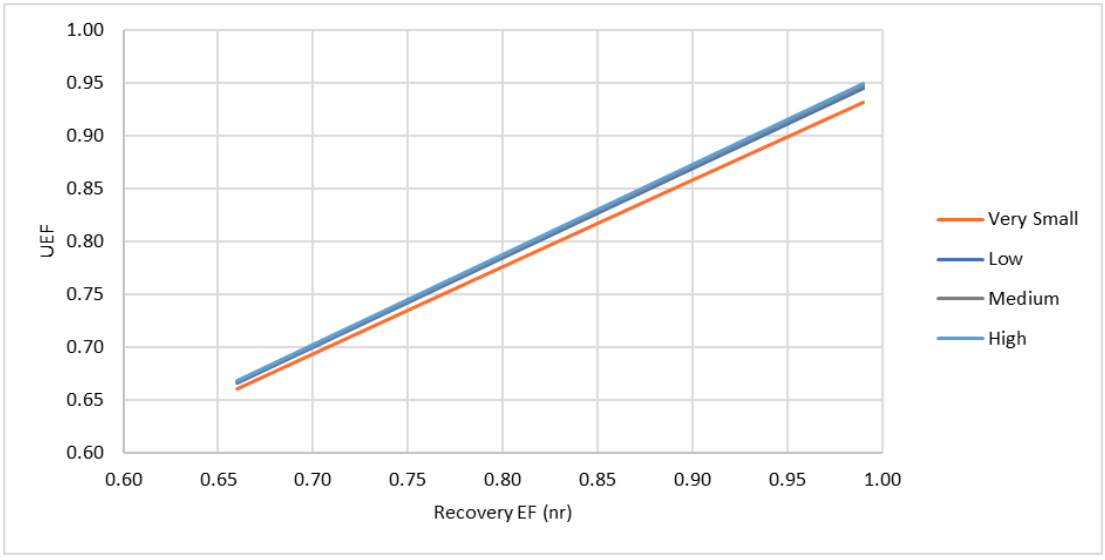
$$A = coefficient\ dependant\ on\ draw\ pattern\ as\ shown\ in\ table\ above$$

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

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

A plot of the UEF calculation for small instantaneous water heaters for all four draw patterns is provided in the figure below.[9] As shown, the difference in UEF ratings are miniscule between the low, medium, and high draw patterns. Due to this small difference, *the analysis for this measure utilizes one UEF value and one savings value for both medium and high draw patterns for nonresidential tankless water heaters.*

Plot of UEF and Recovery Efficiency Ratings, by Draw Pattern



[9] Southern California Gas Company (SCG). 2018. "WPSCGNRWH120206B-Rev7_Att A_Savings Calculations and Measure Summary.xlsx." See "UEF Calcs" tab.

Storage Water Heater EF to UEF Conversion

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}.

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

$$\eta_r = recovey\ efficiency$$

$$EF = energy\ factor$$

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

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

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

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

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-v4.2" for measure "RG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-LW-

0p81UEF-40g". Considering hour 8, which heats 0.6 gallons of water in climate zone 9 for a single-family dwelling.

$$HW_{load} = 0.6\ gal \times\ (135\ F - 60.23\ F) \times 8.2 \frac{Btu}{gal \times F} = 386\ Btu$$

$$Tank_{UA} = \frac{0\ Btu}{hr \times F}$$

$$UA_{load} = \frac{0.00\ Btu}{hr \times F} \times (135\ \text{F} - 44\ \text{F}) \times 1hr = 0\ Btu$$

$$Aux_{load} = -\left(0 \frac{Btu}{hr} \times .67\right) \times 1\ hr = 0\ Btu$$

$$Btu_{Aux-for\ 1\ hour} = (0)\left(\frac{Btu}{hr}\right) \times 1hr = 0\ Btu$$

$$WH_{1\ hour\ load} = \left[\sum_{hour=1}^{1} \left(\frac{(386\ \text{Btu} +\ 0\ \text{Btu} - 0\ \text{Btu} + 0\ \text{Btu})}{0.840 \times 100{,}000}\right)_{hour\ 8}\right] = 0.0046\ Therm$$

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.

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 and RUL specified for this measure are provided below. Note that RUL is only applicable for add-on equipment and accelerated replacement measures. While EUL is based on Instantaneous water heaters, the preexisting technology is storage so the RUL is based on storage water heaters.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	20.0	California Public Utilities Commission (CPUC), Energy Division. 2003. *Energy Efficiency Policy Manual v 2.0.* Page 18 Table 4.1. California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
RUL (yrs)	5.0	California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."

BASE CASE MATERIAL COST ($/UNIT)

For a *normal replacement* installation, the customer must purchase a new water heater to continue operating, therefore the base case material cost is that of a base case (standard) boiler/tankless water heater.

The base case material costs were derived from two U.S. Department of Energy (DOE) Technical Support Documents (TSDs): Pool Heaters, Direct Heating Equipment and Water Heaters (EERE-2006-STD-0129)[10] and Commercial Water Heating Equipment (EERE-2014-BT-STD-0042).[11]

- TSD "Pool Heaters, Direct Heating Equipment and Water Heaters (EERE-2006-STD-0129)" reports total installed cost (IP) for small tankless water heaters as the sum of consumer product price (CPP) and cost to the consumer to install products (INST) (IP = CPP + INST).
- TSD "Commercial Water Heating Equipment (EERE-2014-BT-STD-0042)" reports the total installed cost for large tankless water heaters as the sum of equipment retail price and the installation cost but does not present the exact equipment retail and installation cost values used in the summation. The large tankless water heaters are reported as one single cost value.

An online vendor cost survey and the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc. were considered to develop the cost data. The vendor cost survey provided a reference point for product costs but did not provide sufficient data for installation cost due to the various installation set-ups. The 2010-2012 Measure Cost Study did not appear to take ultra-low Nox production cost into consideration for gas tankless water heaters. Air quality regulations were only mentioned in the study in reference to boiler projects.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material costs were derived from two U.S. Department of Energy (DOE) Technical Support Documents (TSDs): Pool Heaters, Direct Heating Equipment and Water Heaters (EERE-2006-STD-0129)[12] and Commercial Water Heating Equipment (EERE-2014-BT-STD-0042).[13]

- TSD "Pool Heaters, Direct Heating Equipment and Water Heaters (EERE-2006-STD-0129)" reports total installed cost (IP) for small tankless water heaters as the sum of consumer product price (CPP) and cost to the consumer to install products (INST) (IP = CPP + INST).
- TSD "Commercial Water Heating Equipment (EERE-2014-BT-STD-0042)" reports the total installed cost for large tankless water heaters as the sum of equipment retail price and the installation cost

[10] 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.

[11] U.S. Department of Energy (DOE). 2016. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Water Heating Equipment.* Prepared by Navigant Consulting, Inc. and Pacific Northwest National Laboratory. Docket ID: EERE-2014-BT-STD-0042.

[12] 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.

[13] U.S. Department of Energy (DOE). 2016. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Water Heating Equipment.* Prepared by Navigant Consulting, Inc. and Pacific Northwest National Laboratory. Docket ID: EERE-2014-BT-STD-0042.

but does not present the exact equipment retail and installation cost values used in the summation. The large tankless water heaters are reported as one single cost value.

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 temperature limits and are not suitable for non-condensing water heaters. Condensing tankless water heaters are able to use PVC for venting which cost less than traditional venting for non-condensing tankless water heaters. This cost difference can lead to lower overall cost for the Tier 2 small tankless water heater in some cases. Data taken from the TSD "Pool Heaters, Direct Heating Equipment and Water Heaters" (EERE-2006-STD-0129) presents this case. The cost differences in these set-ups are reflected in the cost analysis.

An online vendor cost survey and the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc. were considered to develop the cost data. The vendor cost survey provided a reference point for product cost but did not provide sufficient data for installation cost due to the various installation set-ups. The Measure Cost Study did not appear to take ultra-low Nox production cost into consideration for gas tankless water heaters. Air quality regulations were only mentioned in the study in reference to boiler projects.

BASE CASE LABOR COST ($/UNIT)

Labor costs were derived using the same methodology to develop base case and measure case material costs.

MEASURE CASE LABOR COST ($/UNIT)

Labor costs were derived using the same methodology to develop base case and measure case material costs.

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 commercial 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 commercial sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – Commercial	0.60	Itron, Inc. 2011. *DEER Database 2011 Update Documentation.* 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. *Energy Efficiency Policy Manual Version 5*. 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	n/a
DEER Version	DEER2014 – Large Water Heaters (80% & 90% TE) DEER2021 (*DEER-WaterHeater-Calculator-v4.2a*) – Large Water Heater (96% TE) DEER2021 (*DEER-WaterHeater-Calculator-v4.2*) – Small Water Heaters
Reason for Deviation from DEER	None.
DEER Run and Measure IDs Used	NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p81UEF-40g NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p87UEF-40g NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p80Et NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p90Et NG-WtrHt-MedInst-Gas-76to200kBtuh-lt2G-0p90Et NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p96Et
NTG	Source: DEER2015. NTG of 0.60 is associate with NTG ID: *Com-Default>2yrs*
GSIA	The value of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER 2015. The EUL of 20 years is associated with EUL ID: *WtrHt-Instant-Com*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Complete Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/13/2018	Jennifer Holmes, Cal TF Staff	The draft of the text fields for this statewide measure is based upon: WPSCGNRWH12026B Revision 6 (July 26, 2016) Consensus reached among Cal TF members
	01/04/2019	Jennifer Holmes, Cal TF Staff	Updated draft based upon: WPSCGNRWH12026B, Revision 7 (October 1, 2018)
	02/26/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.
	07/02/2019	Ayad Al-Shaikh, Cal TF Staff	Update DEER IDs
02	04/20/2020	Sergio A Corona, TRC Tai Voong, PG&E	Added measure offering SWWH006E, based upon: *NG-WtrHt-MedInst-Gas-76to200kBtuh-0p90Et* weighted for Commercial building type
03	06/15/2020	Anders Danryd, Engineer, SoCalGas	Update savings using DEER 2021 Water Heater Calculator v4.1, add new “Tier 3” Large Unit
	07/07/2020	Anders Danryd, Engineer, SoCalGas	Per CPUC Comments: Added a new “medium tier” to clarify base case for small unit rated in TE, fixed formatting issues, updated Title 20 references, added RUL to the workpaper,
04	07/21/2020	Anders Danryd, Engineer, SoCalGas	Updated EAD table to include “New” vintage in addition to “Ex”
	08/27/2020	Anders Danryd, Engineer, SoCalGas	Updated workpaper and EAD tables to reflect new version number per CPUC direction
	09/23/2020	Anders Danryd, Engineer SoCalGas	Updated energy savings using DEER 2021 Water Heater Calculator v4.2
	10/09/2020	Anders Danryd, Engineer SoCalGas	Corrected minor typos in the Implementation tab of the EAD table, moved base case cost to correct column
05	11/30/2020	Anders Danryd, Engineer SoCalGas	Update to energy savings per CPUC memo allowing IOU to customize tech ID in the Water Heater Calculatorv4.2. Reduced large water heater input capacity to more accurately normalize savings for all building types, added all Com building types per E5082
06	09/14/2021	Anders Danryd, Engineer SoCalGas	Resubmission with savings for large instant water heaters offerings C, D & F using DEER2014 and updated DEER2021 values Per E-5152
	10/14/2021	Anders Danryd, Engineer SoCalGas	Various text edits due to CPUC comments
	11/17/2021	Anders Danryd, Engineer SoCalGas	Error in EAD where electric and demand savings were switched for all measures