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WATER HEATING

BOILER, COMMERCIAL

SWWH005-04

CONTENTS

MEASURE NAME

Boiler, Commercial

STATEWIDE MEASURE ID

SWWH005-04

TECHNOLOGY SUMMARY

A commercial hot water boiler is a pressure vessel that transfers heat to water. In most boilers, a heat exchanger separates the combustion products from the water. A boiler can be configured as an integrated packaged boiler, or, in some cases, may be connected to a separate tank that contains an internal heat exchanger. The California Appliance Efficiency Regulations (Title 20) and Building Energy Efficiency Standards (Title 24) define 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] Commercial domestic hot water boilers are included within this definition.

Due to the relatively larger burner size, a commercial domestic hot water boiler is capable of providing hot water on a continuous basis. The commercial boiler has a relatively high energy efficiency levels because standby losses of a storage tank are essentially eliminated. A hot water boiler is most efficient for a point-of-use application with no circulation loop or in combination with a large hot water storage tank when a building utilizes a circulation loop. When the building utilizes a hot water recirculation loop, a commercial boiler is inefficient for applications without a storage tank due to the temperature loss in the circulation system, which causes the instantaneous water heater to run continuously without any water demand. They are problematic in central systems with circulation loops which have long pipe runs from the water heater to the faucet and no recirculation pump.

An energy efficient commercial boiler may have one or more of the following features: high efficiency/low NOx burner, power burner, water tube, relatively large heat exchanger surface, and/or flue exhaust heat recovery system.

Uniform energy factor (UEF) is the standard efficiency unit for instantaneous water heaters with a rated input < 200 kBtu per hour.[2] Thermal efficiency (TE) is the standard efficiency unit for instantaneous water heaters with rated input ≥ 200 kBtu per hour. Commercial domestic hot water boilers are included as instantaneous water heaters.

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[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.

[2] 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.

MEASURE CASE DESCRIPTION

This measure is defined as the replacement of an instantaneous water heater or a commercial hot water boiler with a more efficient instantaneous water heater or a commercial hot water boiler of similar rated input, as specified below. These measure efficiencies were adopted after consideration of the California Title 20 and Title 24 standards, and from analysis of the distribution of high-efficiency instantaneous water heaters certified in the California Energy Commission (CEC) Modernized Appliance Efficiency Database System.[3] The minimum qualifying measure efficiencies exceed both the Title 20 and the Code of Federal Regulations minimum standards (see Code Requirements). The measure efficiency ratings are used for the calculation of energy savings by climate zone for each measure offering.

Measure Case Specification

Boiler Efficiency Tier	Boiler Size	Rated Input (kBtu/hr)	Min. Qualifying Efficiency Rating	Measure Efficiency
Non-condensing – Tier 1	Small/Med	< 200	0.84 UEF	0.85 UEF
	Large	≥ 200	84% TE	85.0% TE
Condensing – Tier 2	Small/Med	< 200	0.87 UEF	0.90 UEF
	Large	≥ 200	90% TE	93.7 % TE
Condensing – Tier 3	Large	≥ 200	96 % TE	97.4 % TE

Additional context regarding the measure case specification follows:

- *Small (< 200 kBtu/hr) Tier 1 hot water boiler.* Approximately 6% of the models in the CEC Appliance Efficiency Database have an UEF equal to 0.84. The minimum qualifying Uniform Energy Factor (UEF) is set to 0.84 while calculating the savings at 0.85 UEF.
- *Small (< 200 kBtu/hr) Tier 2 hot water boiler*. The qualifying UEF is set to the standard Tier 2 value of 0.87 UEF to be consistent across all types of boiler and water heaters. The measure is available at 0.87 UEF, while savings were calculated with 0.90 UEF.
- *Large (≥ 200 kBtu/hr) Tier 1 hot water boiler*. Since the Title 20 and Title 24 standards require 80.0% thermal efficiency (TE), the qualifying TE is set equal to 84% because there is a good selection of boilers with TE between 84% and 90%. The qualifying TE is set equal to 84% and savings were calculated with 85% TE.
- *Large (≥ 200 kBtu/hr) Tier 2 hot water boiler.* The qualifying TE is set equal to the standard Tier 2 value of 90% to be consistent across all types of boiler and water heaters.
- *Large (≥ 200 kBtu/hr) Tier 3 hot water boiler.* The qualifying TE is set equal to the standard Tier 3 value of 96% to be consistent across all types of boiler and water heaters.

[3] California Energy Commission (CEC). (n.d.) "Modernized Appliance Efficiency Database System (MAEDBS)." https://cacertappliances.energy.ca.gov/Login.aspx. Accessed in March 2012 and May 2014

BASE CASE DESCRIPTION

The base case of this measure is defined by boiler size only (small/medium, < 200 kBtu/hr and large, ≥ 200 kBtu/hr). The minimum base case efficiencies are consistent with the Code of Federal Regulations minimum standards (see Code Requirements).

Base Case Specification

Boiler Size	Rated Input (kBtu/hr)	Min. Efficiency Rating
Small/Med	< 200	0.81 UEF
Large	≥ 200	80% TE

CODE REQUIREMENTS

Applicable state and federal codes and standards and energy use standards for instantaneous heater/boilers are specified in the tables below.[4] In addition, water heating equipment must comply with nitrogen oxide (Nox) emissions limits set forth by air quality management districts (AQMDs) or air pollution control districts (APCDs) throughout the California.[5]

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)	Section 1605.3(f)	January 1, 2019
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)	December 29, 2016
	10 CFR 431.110(a)	October 9, 2015

[4] California Energy Commission (CEC). 2019. *2019 Appliance Efficiency Regulations*. CEC-400-2019-002. Section 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).

[5] South Coast Air Quality Management District (AQMD). 2004. Rule 1121 - Control of Nitrogen Oxides from Residential-Type, Natural Gas-Fired Water Heaters. Amended September 3, 2004.

South Coast Air Quality Management District (AQMD). 2006. Rule 1146.2 - Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters. Amended May 5, 2006.

Bay Area Air Quality Management District (BAAQMD). 2007. *Regulation 9 – Inorganic Gaseous Pollutants: Rule 6 – Nitrogen Oxides Emissions from Natural Gas-Fired Boilers and Water Heaters.* November 7.

San Joaquin Valley Air Pollution Control District. 2009. *Rule 4902 - Residential Water Heaters.* Amended March 19, 2009.

Sacramento Metropolitan Air Quality Management District. 2010. *Rule 414, Water Heaters, Boilers and Process Heaters Rated Less Than 1,000,000 BTU Per Hour.* Amended March 25, 2010.

Yolo-Solano Air Quality Management District. 2009. *Rule 2.38 - Natural Gas-Fired Water Heaters and Small Boilers.* Revised April 8, 2009.

Ventura County Air Pollution Control District. 2010. *Rule 74.11 - Natural Gas-Fired Water Heaters.* Revised January 12, 2010.

Code	Applicable Code Reference	Effective Date
California Air Quality Management and Air Pollution Control Districts		
South Coast AQMD	Rule 1121 Rule 1146.2	September 3, 2004 May 5, 2006
Bay Area AQMD	Regulation 9, Rule 6	November 7, 2007
San Joaquin Valley APCD	Rule 4902	March 19, 2009
Sacramento Metropolitan AQMD	Rule 414	March 25, 2010.
Yolo-Solano AQMD	Regulation II, Rule 2.37	April 8, 2009.
Ventura County Air Pollution Control District	Rule 74.11	January 12, 2010

California Appliance Efficiency Regulations (Title 20) and Code of Federal Regulations

Equipment Type	Rated Input (kBtu/hr)	Rated Volume (gal)	Efficiency Units	Minimum Efficiency	Maximum Standby Loss (Btu/hr)
Instantaneous Water Heaters *V is the rated volume in gallons; Q is the rated input is Btu/hr.*					
Small federally-regulated (Medium & High Draw Pattern)	> 50 & < 200	< 2	UEF	0.81	---
Small non-federal regulated	≤ 50	Unspecified	UEF	0.62-(0.0019xV)	---
Small non-federal regulated	< 200	≥ 2	UEF	0.62-(0.0019xV)	---
Large	≥ 200	< 10	TE	0.80	---
Large	≥ 200	≥ 10	TE	0.80	Q/800 + 110√V

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 some commercial water heating technologies.[6] 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.[7] 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

[6] 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.

[7] A.O. Smith. (n.d.) "What Does UEF Mean To You?"

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.

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

NORMALIZING UNIT

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

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).[8] "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.

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

Eligible Products

Boilers must meet the following eligibility requirements:

- Meet 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.
- Only gas-for-gas installations are eligible.
- Meet the definition of an instantaneous 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 per hour per gallon of stored water.

Eligible Building Types

This measure is applicable to any domestic hot water application in any existing commercial building of any vintage.

Eligible Climate Zones

The measure is applicable in all California climate zones.

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

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

Data collection requirements are to be determined.

USE CATEGORY

Service & domestic hot water (SHW)

ELECTRIC SAVINGS (kWh)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

GAS SAVINGS (THERMS)

The unit energy savings (UES) of small high efficiency commercial boilers rated in Uniform Energy Factor (UEF) were modeled using the Database for Energy Efficient Resources (DEER) methodologies. Specifically, the UES were derived using the DEER water heater calculator tool,[9] 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. Version 4.2 of the calculator utilizes hourly output from the DEER2015 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. While Small Tier 2 technologies were in the calculator, new technology needed to be added in for the Small Tier 1 units.[10] None of the measures needed were built into *DEER-WaterHeater-Calculator-v4.2.xlsm* and had to be added in custom to fit the requirements of the workpaper.

[9] California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021"DEER-WaterHeater-Calculator-v4.2.xlsm." Updated September 17, 2020.

[10] *DEER-WaterHeater-Calculator-v4.2 SoCalGas Custom measures.xlsm*

Due to sizing issues of large water heaters with the newest water heater calculator, savings for the large instantaneous units were adopted from READI which are DEER2014 and DEER2021 measures.

Measure Offerings and Impact IDs

Statewide Measure Offering ID	Energy Impact ID	Measure Description	Savings Source
SWWH005A	NG-WtrHt-SmlBoiler-Gas-lt200kBtuh-lt2G-MD-0p81UEF-40g *(modified)*	Small Gas Boiler < 200 kBtuh, UEF ≥ 0.84	DEER-WaterHeater-Calculator-v4.2 (SWWH005-04)
SWWH005B	NG-WtrHt-SmlBoiler-Gas-lt200kBtuh-lt2G-MD-0p87UEF-40g *(modified)*	Small Gas Boiler < 200 kBtuh, UEF ≥ 0.87	DEER-WaterHeater-Calculator-v4.2 (SWWH005-04)
SWWH005C	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p85Et *(Re-baseline)*	Large Gas Boiler ≥ 200 kBtuh, Et = 0.84	DEER2014 (Re-baseline)
SWWH005D	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p90Et *(Re-baseline)*	Large Gas Boiler ≥ 200 kBtuh, Et = 0.90	DEER2014 (Re-baseline)
SWWH005E	NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p96Et *(Re-baseline)*	Large Gas Boiler ≥ 200 kBtuh, Et = 0.96	DEER-WaterHeater-Calculator-v4.2a (Re-baseline)

**All statewide measure offerings are modified from existing DEER Energy Impact IDs or are customized using the DEER Water Heater Calculator. The IDs shown in the table below are those that most closely resemble the statewide offering or were used as starting points for the Energy Impact IDs above.*

DEER Measure Codes

Statewide Measure Offering ID	DEER Energy Impact ID	Relationship to Energy Impact ID	DEER Version
SWWH005A	NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p81UEF-40g	Modified the baseline technology from storage to instantaneous and modified measure efficiency	DEER-WaterHeater-Calculator-v4.2
SWWH005B	NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p87UEF-40g	Modified the baseline technology from storage to instantaneous	DEER-WaterHeater-Calculator-v4.2
SWWH005C	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p85Et	Modified the baseline technology from storage to instantaneous	DEER2014
SWWH005D	NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p90Et	Modified the baseline technology from storage to instantaneous	DEER2014
SWWH005E	NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p96Et	Modified the baseline technology from storage to instantaneous	DEER 2014 (baseline) DEER-WaterHeater-Calculator-v4.2a (measure)

The table below provides the base case and measure case efficiencies for commercial boilers water heaters. Note that DEER does not include high-efficiency commercial hot water boilers that replace less efficient commercial domestic hot water boilers. Therefore, the instantaneous water heater cases in DEER were adapted for this purpose. Additional points regarding the efficiency ratings in DEER:

- The small instantaneous water heater (≤200 kBtu/hr) qualifying uniform energy factors (UEFs) from DEER2021 are used for Tier 2. Tier 1 technology was created using the binning file for average burn capacity and UEF.
- The large (> 200 kBtu/hr) instantaneous water heater qualifying thermal efficiencies from DEER 2014 are used for large commercial boilers for Tier 1 and Tier 2. Tier 3 unit was modeled by CPUC in the DEER Water Heater Calculator v4.2a.

Base Case and Measure Case Instantaneous Water Heater Efficiencies in DEER 2021

Boiler Size	Rated Input (kBtu/hr)	Efficiency Units	Baseline Efficiency	DEER Eligible Technologies
Small	< 200	UEF	81%	≥ 81%, ≥ 87%, ≥ 95%
Medium	150 (76-200)	TE	0.80	0.80, 0.90, 0.96

Base Case and Measure Case Instantaneous Water Heater Efficiencies in DEER 2014

Boiler Size	Rated Input (kBtu/hr)	Efficiency Units	Baseline Efficiency	DEER Eligible Technologies
Large	≥ 200	TE	0.80	0.80, 0.85, 0.90

Boiler Efficiencies. DEER-WaterHeater-Calculator-v4.2 included a binning file used to determine the average properties of certain water heater measures and criteria. This file was used to calculate the average UEF, and burn capacity of the water heater technologies for each measure. The table provided shows the range of water heater efficiencies in the Binning file database of water heating products with a rated input to storage volume ratio greater than 4,000 Btu/hr/gallon.[11] Non-condensing and condensing water heaters were included, although a water heater with an UEF > than 0.87 or a thermal efficiency (TE) > 88%, respectively, is most likely a condensing water heater.

Instantaneous Water Heater Efficiency Ranges

Boiler Size	Rated Input (kBtu/hr)	Minimum Efficiency	Maximum Efficiency
Small	50 – 199	0.81 UEF	0.97 UEF
Large	200 – 2,400	80.0% TE	98.0% TE

Standard Efficiencies. The efficiency ratings for base case and measure case commercial hot water boilers are specified below.

[11] California Public Utilities Commission (CPUC), Energy Division. 2020. DEER2021"DEER-WaterHeater-Calculator-v4.2.xlsm." Updated September 17, 2020.

Baseline and Measure Case Efficiencies for High Efficiency Commercial Hot Water Boilers

Boiler Efficiency Tier	Boiler Size	Rated Input (kBtu/hr)	Min. Baseline Efficiency	Measure Case Efficiency
Non-condensing – Tier 1	Small/Med	< 200	0.81 UEF	0.84 UEF
	Large	≥ 200	80% TE	84% TE
Condensing – Tier 2	Small/Med	< 200	0.81 UEF	0.87 UEF
	Large	≥ 200	80% TE	90% TE
Condensing – Tier 3	Large	≥ 200	80% TE	96% TE

Annual Unit Energy Consumption

Gas Unit Energy Savings Calculation

The DEER-WaterHeater-Calculator-v4.2 baselines and technologies were used as the basis for savings for the small boilers in this measure. The water heater calculator produces a savings for each commercial building type to create one average "Com" building type savings for each of the 16 climate zones. For calculating UES, the following assumptions were adopted:

- The average efficiency rating for the base case commercial hot water boiler is 0.81 UEF for small hot water boilers and 80% TE for a large hot water boiler. This aligns with the California Title 20 efficiency standards for instantaneous water heaters.
- The average efficiency rating for commercial hot water boiler measure case units are determined by the average TE or UEF of all measure qualifying units in the binning file included with DEER-WaterHeater-Calculator-v4.2.xlsm

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:

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

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

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

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

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

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

For large water heaters, the water heater calculator was not used. DEER2014 tankless water heater measures use a storage water heater as the baseline. In order to scale the DEER measures for a boiler baseline, the savings from the DEER measure *NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p80Et* were subtracted from the respective DEER measure savings in order to scale the measure savings down for a boiler baseline.

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.

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.

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

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 specified for this measure is specified below. Note that RUL is only applicable for add-on equipment and accelerated replacement measures.

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). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."
RUL (yrs)	6.67	California Public Utilities Commission (CPUC). 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx."

BASE CASE MATERIAL COST ($/UNIT)

When the customer replaces equipment on burnout (normal replacement) or buys new equipment, the customer must buy a new water heater to continue operating, therefore the base case material cost is equal to the cost of a base case (standard) boiler/tankless water heater.

The base case material cost was 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). The small tankless water heaters are reported in those cost details.
- 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 as resources to develop the cost data. The vendor cost survey provided a reference point for product cost but did not provide sufficient data to represent installation costs due to the various installation set-ups. The Itron 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.

[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.

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material cost was 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)[14] and Commercial Water Heating Equipment (EERE-2014-BT-STD-0042).[15]

- 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). The small tankless water heaters are reported in those cost details.
- 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.

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 taken into consideration in the cost analysis.

An online vendor cost survey and the 2010-2012 Ex Ante Measure Cost Study conducted by Itron, Inc. were considered as resources 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 Itron 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 material costs.

MEASURE CASE LABOR COST ($/UNIT)

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

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[14] 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.

[15] 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.

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 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	Yes – Modifications were made by: (1) Small boiler measures were custom added to *DEER-WaterHeater-Calculator-v4.2*; (2) large boiler measures modified DEER2014 and *DEER-WaterHeater-Calculator-v4.2a* Energy Impact IDs by re-baselining from storage water heaters to instantaneous water heaters.
Scaled DEER measure	No. The large boiler measures use DEER2014 and *DEER-WaterHeater-Calculator-v4.2a* Energy Impact ID UES values to effectively re-baseline from storage water heaters to instantaneous water heaters.

DEER Item	Comment / Used for Workpaper
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 Boilers (85% & 90% TE) DEER2021 (*DEER-WaterHeater-Calculator-v4.2a*) – Large Boilers (96% TE) DEER2021 (*DEER-WaterHeater-Calculator-v4.2*) – Small Boilers
Reason for Deviation from DEER	Added in modified version of small boiler to create a "Tier 1" boiler. Added new measures into the calculator to create savings for energy efficient instant water heaters in replacement of code/standard instant water heaters. Changed baseline of large tankless water heaters measures using the DEER 2014 80% TE boiler offering as the baseline for measure case Boilers (DEER measures assume storage baseline).
DEER Run and Measure IDs Used (original EF IDs used as UEF based IDs are not available)	Added: Instantaneous Water Heater, ≤ 200 kBtu/hr, Tier 1 (≥0.84 UEF) – A - NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p81UEF-40g (*modified baseline technology and measure efficiency*) Added: Instantaneous Water Heater, ≤ 200 kBtu/hr, Tier 2 (≥0.87 UEF) – B - NG-WtrHt-SmlInst-Gas-lt200kBtuh-lt2G-MD-0p87UEF-40g (*modified baseline technology*) C - NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p85Et (*modified baseline technology*) D - NG-WtrHt-LrgInst-Gas-gt200kBtuh-0p90Et (*modified baseline technology*) E - NG-WtrHt-LrgInst-Gas-gte200kBtuh-lt2G-0p96Et (*modified baseline technology*)
NTG	Source: DEER. NTG of 0.60 is associate with NTG ID: *Com-Default>2yrs*
GSIA	GSIA ID: *Def-GSIA*
EUL/RUL	The EUL of 20 years is associated with EUL ID: *WtrHt-Instant-Com*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/08/2018	Jennifer Holmes, Cal TF Staff	The draft of the text fields for this statewide measure is based upon: Workpaper WPSSCGNRWH120206C Revision 6 (July 26, 2016) Consensus reached among Cal TF members
	08/20/2018	Rebecca Jenkins, SCG Chan Paek, SCG	Replace the qualifying efficiency of small (<200 kBtuh) instantaneous water heaters from EF to UEF.
	02/27/2019	Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.
02	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 RUL to the workpaper, updated Title 20 references, added New vintage to EAD tables
	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 typo in the Implementation tab of the EAD table
03	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, added all Com building types per E5082
	01/29/2021	Anders Danryd, Engineer SoCalGas	Updated EAD and DataSpec to reflect New TechID for customized water heater measures. Text Edits
04	09/14/2021	Anders Danryd, Engineer SoCalGas	Resubmission with savings for large instant water heaters offerings C, D & E using DEER2014 and updated DEER2021 values Per E-5152
	10/14/2021	Anders Danryd, Engineer SoCalGas	Various text edits due to CPUC comments.
	11/2/2021	Anders Danryd, Engineer SoCalGas	Clarification to text on baseline changes made in modeling due to CPUC comments
	11/17/2021	Anders Danryd, Engineer SoCalGas	Error in EAD where electric and demand savings were switched for all measures
	12/9/2021	Anders Danryd, Engineer SoCalGas	Further clarification to text on baseline changes made in modeling due to CPUC comments, correction in EAD