**Work Paper PGECOPRO106**

**Direct Contact Water Heater**

**Revision 5**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Direct Contact Water Heater**

**Measure Codes H16**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Applicable Measure Codes:** | **H16** |
| **Measure Description:** | Replacement of process water boiler with new, direct contact water boiler. Must have Thermal Efficiency (TE) of 90% or better (AFUE > 88% if rated input capacity < 300MBtuh). |
| **Energy Impact Common Units:** | Per MBtuh (1,000 Btuh) of rated input capacity |
| **Base Case Description:** | Source: Describe the existing base case technology that will be replaced with the energy efficient technology (state: existing customer equipment or code/standard). Existing standard efficiency process boiler with assumed efficiency and operating hours.  Source: CEC boiler efficiency listings6, operating hours from Boiler Population Survey[[1]](#endnote-1). |
| **Base Case Energy Consumption:** | 36.7 therms / MBtuh / yr  Source: PG&E Calculations. Base case process boiler with typical efficiency of 80.2% per CEC boiler efficiency listings. |
| **Measure Energy Consumption:** | 30.0 therms / MBtuh / yr  Source: PG&E Calculations. Average boiler meeting program requirements of 90% efficiency or better. |
| **Energy Savings**  **(Base Case – Measure):** | 6.7 therms / MBtuh / yr  Source: PG&E Calculations. |
| **Costs Common Units:** | Per MBtuh (DEER2014 used KBtuh in database, but refers to the same MBtuh value, MBtuh is the industry reference) |
| **Base Case Equipment Cost ($/unit):** | $12.22 / MBtuh  Source: Southern California Gas (SCG) WP[[2]](#endnote-2) |
| **Measure Equipment Cost ($/unit):** | $22.95 / MBtuh  Source: SCG WP |
| **Measure Incremental Cost ($/unit):** | $10.73 / MBtuh  Source: SCG WP2 |
| **Effective Useful Life (years):** | Source: DEER 2016, WtrHt-Instant-Com, 20 years |
| **Measure Application Type:** | Replace on Burnout (ROB) |
| **Net-to-Gross Ratios:** | Source: DEER 2016, Com-Default >2yrs, 0.60 |
| **Important Comments:** |  |

# Document Revision History

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Revision #** | **Revision Date** | | | **Section-by-Section Description of Revisions** | | **Author (Company)** |
| **Revision 0** | 04/11/2008 | | | Original work paper: Direct Contact Water Heater PGECOPRO106 R0.doc | | Jim Kelsey and Nicolas Fauchier-Magnan (kW Engineering) |
| **Revision 1** | | 05/12/2009 | **Revision 1**  **Changes in Calculation Methodology:** Savings in R0 differ from MDSS due to the use of savings from the process boiler workpaper. R0 and R1 use calculated savings for a direct contact boiler, therefore increased therm savings exist.  Net –to-Gross (NTG) Ratio changed per DEER2008 from 0.96 to 0.46 | | Charlene Spoor (PG&E) | |
| **Revision 2** | | 6/10/2012  8/22/2012 | Net-To Gross changed in 2011 DEER to Com-Default>2yrs 0.60  Updated BLD, CZ and VIN to ANY per READI nomenclature | | Charlene Spoor (PG&E) | |
| **Revision 3** | 05/21/2014 | | | Updated to new template | | Charlene Spoor (PG&E Clci) |
| **Revision 4** | 3/29/2016 | | | Updated to latest ex ante format 2016; added midstream channel; updated cost to match with SoCal Gas | | Linda Wan (PG&E) |
| **Revision 5** | 4/1/2017 | | | Removed downstream channel from measure code. Effective 4/1/2017. | | Linda Wan (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

***Description –*** For this measureonly direct contact water heaters for process end-uses qualify. In direct contact water heater systems design, heat from a flame comes into direct contact with small droplets of cold water which run through a stainless steel heat exchange media. Droplets composed from the process come into direct contact with rising heat from the flame and the water is heated directly. Boilers must meet efficiency requirements based on size as shown in

Table **1** below; please note that based on boiler size, the requirements apply to either AFUE (Annual Fuel Utilization Efficiency) or to thermal efficiency.

**Table 1 - Required Efficiency by Size**

|  |  |
| --- | --- |
| **Input Rating** | **Required Efficiency** |
| ≤300 MBtuh | AFUE ≥ 88% |
| > 300 MBtuh | Thermal Efficiency > 90% |

***Program Restrictions and Guidelines***

The measure applies to industrial process boilers and is not intended for domestic hot water or space heating.

***Terms and Conditions***

Boilers must meet a minimum thermal efficiency of 90% as installed (or AFUE > 88% for boilers with rated input ≤ 300MBtuh). The rebate is offered through the midstream channel only.

***Market Applicability***

This measure is applicable to any industrial process boiler. The rebate is offered as Replace on Burnout (ROB), replacing a standard efficiency boiler.

Measure code H16 rebate is offered through the midstream channel only.

## 1.2 Product Technical Description

This measure encourages the replacement of standard-efficiency boilers with high-efficiency direct contact boilers. Direct contact boilers are designed to extract all possible energy from natural gas combustion; they use a submerged-flame burner where water is directly in contact with the burning gas. Figure 1 below[[3]](#endnote-3) shows an example of a design of a direct contact water heater.

**Figure 1 – Layout of a Direct-Contact Water Heater**



This measure specifically targets process boilers used by industrial end-use customers who manufacture a sellable product. Because process boilers run a significant fraction of the time, a gain in thermal efficiency of a process boiler can result in significant savings.

## 1.3 Measure Application Type

The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2014 for code update, spreadsheet *SPTdata\_format-V0.97.xls*, defines the terms as follows:

Table 2 Measure Application Type[[4]](#endnote-4)

*Identifies the measure application type in the Measure Implemenation table in DEER2011.*

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| ROB | Replace on Burnout | *measure applied when existing equipment fails or maintenance requires replacement* |

## 

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

Table 3 DEER User and Technology Table



**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

Table 4 Net-to-Gross Ratio

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR value was obtained using the DEER READI tool. The relevant IR value for the measure in this work paper is in the table below:

Table 5 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective Useful Life / Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The closest relevant EUL and RUL values for the measure in this work paper are in the table below:

Table 6 Effective and Remaining Useful Life

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| WtrHt-Instant-Com | Commercial Instantaneous Water Heater | Com | SHW | 20 | 6.67 |

**Hours of Operation**

The hours of operation for direct contact water heaters are 24 hours per day, 356 days per year, or 8760 hours per year.

## 1.4.2 Codes & Standards Requirements Base Case and Measure Information

***Title 20:*** This measure falls under Title 20 [2015][[5]](#endnote-5) of the California Energy Regulations. Under this regulation, all water heaters for retail sale in California shall meet the efficiency requirements shown in the table below:

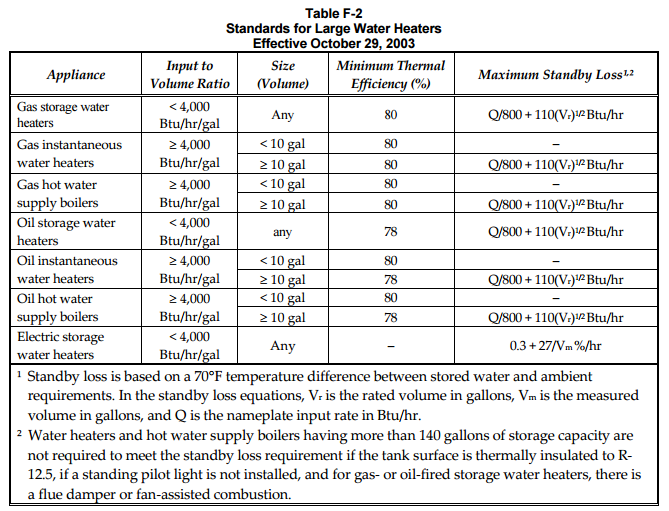


Figure 2 Table Excerpt from Title 20 [2015]

***Title 24:*** This measure does not fall under Title 24 [2013].

***Federal Standards:*** This measure does not fall under Federal DOE or EPA Energy Regulations.

## 1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

There are no M&V or other studies which apply to Direct Contact Water Heaters. Information on the base and measure case is found in the other sub-sections of 1.4. Market Potential for California was estimated using the following studies and databases for this measure:

* A study of US industrial and commercial boiler population1
* CEC boiler inventory[[6]](#endnote-6)
* Economic data relating GDP per industry in California and in the US[[7]](#endnote-7)

## 1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

Title 20 requires a minimum combustion efficiency of 80% for all large gas water heaters. This covers all the boilers considered in this measure. Please note that the requirements of this measure apply to thermal efficiency, not combustion efficiency.

Process boiler baseline efficiency values were calculated based on efficiency listings published by the California Energy Commission (CEC)6 (referred to as the CEC inventory). Thermal efficiencies (not combustion efficiencies) were used to be consistent with the measure’s requirements. The CEC inventory includes over 3,000 gas boilers for steam and hot water production. The hot water boilers were sorted in order of increasing efficiency.

The base case efficiency was calculated as a simple average of the thermal efficiencies of boilers listed in the CEC inventory. For the base case, only standard-efficiency boilers (boilers with thermal efficiency between 80% and 82%) were considered. Figure 2 below shows the number of boilers by efficiency level from the CEC database.

No direct contact water heaters are listed in the inventory and we performed out own efficiency benchmarking based on data from five different direct contact boiler manufacturers. Based on this benchmarking, we found that the average available direct contact boiler has an efficiency of 98.1%. The table below shows the results of this benchmarking:

Table 7 Direct Contact Water Heater Benchmarking[[8]](#endnote-8)



The table below represents the associated CEC efficiency data:

Table 8 CEC Efficiency Data



# Section 2. Calculation Methods

## 2.1 Electric Energy Savings Estimation Methodologies

There is no electric energy savings associated with this measure.

## 2.2. Demand Reduction Estimation Methodologies

There is no anticipated demand reduction associated with this measure

## 2.3. Gas Energy Savings Estimation Methodologies

The key parameters for this energy savings calculation are the average input rating for each measure (see below), the baseline and measure boiler efficiencies (discussed above), and the equivalent full-load hours (see below). The following paragraphs describe how these parameters were determined and present the calculation steps and results.

**Average input rating**

Average input rating was calculated using an analysis of industrial and commercial boilers done for Oak Ridge National Labs in 2005.1 This analysis gives average input ratings of boilers in different industries across the US. To tailor these data to the California industry, we used economic data7 listing the GDP of different industry sectors, both nationwide and in California. The table below lists the summary data and results:

Table 9 Average Boiler Input Rating by Industries



**Capacity Factor and Equivalent full-load hours (EFLH)**

Boilers, like many gas systems, have modulating controls that allow them to operate at a fraction of their nominal capacity. As a result, the number of operating hours of a boiler is not an accurate representation of its energy consumption, and the average capacity factor needs to be taken into account. This capacity factor is the ratio of actual energy consumption during a certain time period and the consumption that would have occurred if the boiler were at full capacity during the same period (see formula below):



The capacity factor was calculated using the same method as for the average boiler efficiency: data from the analysis of industrial and commercial boilers1 was combined with industry-specific GDP data7 to get an accurate estimation of the average process boiler capacity factor in California. Equivalent full-load hours are calculated by multiplying the total operating hours of the boiler by its capacity factor. Data for calculating weighted average capacity factor is shown below in the table below:

Table 10 Average Boiler Capacity Factor by Industries



**Calculation method and fundamental assumptions**

For calculating energy savings, the following assumptions were used:

* New direct contact unit has the same input rating (measured in MBtuh) as the unit being replaced.
* Both units (old and new) deliver the same amount of hot water on an annual basis (i.e., customer demand for hot water does not change). The direct contact unit will thus have less full-load equivalent full-load hours than the base case unit.

With these assumptions, the energy saved by a new direct contact unit was calculated as follows:



Where:

∆Q = Energy saved (therms/yr), as a result of installing the direct contact water heater

EFLH = Equivalent Full-Load Hours (hrs/yr). See above for details on how the equivalent full load hours were estimated.

R = input rating (MBtuh, ie kBtu/h)

Eb = Efficiency (%) of the baseline unit being replaced

Em = Efficiency (%) of the new high-efficiency unit (also called the measure efficiency)

100 = Conversion factor from MBtuh to therms

The interim values and final results of the gas savings calculations are presented in the table below:

Table 11 Gas Savings Calculations



# Section 3. Load Shapes

Load shapes for base case and measure case are based on E3 calculator load shapes and follow an Annual gas impact profile.

## 3.1 Base Case Load Shapes

Base case load shapes follow the Annual gas impact profile.

## 3.2 Measure Load Shapes

Measure case load shapes follow an Annual gas impact profile.

# Section 4. Base Case & Measure Costs

All costs estimates in this document are based on a cost survey performed by Southern California Gas (SCG).2 This data was used to determine an average cost per MMBtuh both for the base case and for the measure. The costs for this workpaper correspond with SCG’s Tier 2 hot water boilers.

## 4.1 Base Case Costs

Please note that the costs taken into account here are only the materials costs. It was assumed that installation costs were the same for the base case and the measure.

Table 12 Base Case Cost

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Application Type** | **Average Base Case Cost/MBtuh** |
| H16 | ROB | $12.22 |

## 4.2 Measure Costs

The table below presents the measure equipment costs:

Table 13 Average Measure Case Boiler Cost Results

|  |  |  |
| --- | --- | --- |
| **Measure Code** | **Measure Application Type** | **Average Measure Case Cost/MBtuh** |
| H16 | ROB | $22.95 |

## 4.3 Full & Incremental Measure Cost

Table 14 Full and Incremental Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |
| RET/ER | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REF | (MEC + MLC) – (BEC + BLC) | MEC + MLC | N/A |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Table 15 Full and Incremental Costs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure ID** | **Measure Application Types** | **Average Base Case Cost/MBtuh** | **Average Measure Case Cost/MBtuh** | **Average Incremental Measue Cost per MBtuh** |
| H16 | ROB | $12.22 | $22.95 | $10.73 |

# 

# References

1. “Characterization of the US Industrial / Commercial Boiler Population,” Oak Ridge National Laboratory by Energy and Environmental Analysis, Inc. , May 2005. [↑](#endnote-ref-1)
2. “Process Boilers (Including Direct Contact Water Heaters); WPSCGNRPH120206A\_Rev5, Energy and Environmental Analysis, Inc. for Southern California Gas Company, May 2014. [↑](#endnote-ref-2)
3. “High-Efficiency Direct-Contact Water Heater” by the Office of Industrial technologies – Energy Efficiency and Renewable Energy – U.S. Department of Energy. August 2001 [↑](#endnote-ref-3)
4. The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata\_format-V0.97.xls.* [↑](#endnote-ref-4)
5. Singh, Harinder, Ken Rider, and Jared Babula. 2015. 2015 Appliance Efficiency Regulations. California Energy Commission. Publication Number: CEC‐400‐2015‐021. [↑](#endnote-ref-5)
6. CEC efficiency data available online at <http://www.energy.ca.gov/appliances/appliance/excel_based_files/boilers/> [↑](#endnote-ref-6)
7. Bureau of Economic Analysis – Regional Economic Accounts – Gross Domestic Products by State –<http://www.bea.gov/regional/gsp/> - see also appendices [↑](#endnote-ref-7)
8. References used for benchmarking (snapshots of the webpages available in the appendix) :

   Ellis corporation: <http://www.elliscorp.com/>

   Armstrong international, Flo-Direct water heater: <http://armstrong-intl.com/files/common/allproductscatalog/flodirect.pdf>

   Kemco Systems, Direct Contact Water Heater: <http://www.kemcosystems.com/Water-System-Components/TE100-Water-Heater.html>

   Canada Office of Energy Efficiency, Ultra-High efficiency direct contact water heater: <http://oee.nrcan.gc.ca/publications/infosource/pub/ici/caddet/english/r438.cfm?attr=20>

   Sofame Technologies, Inc: <http://www.sofame.com/Benefits_eng.htm>

   QuikWater, High Efficiency Direct Contact Water Heater: <http://www.quikwater.com/qw_products_twintower.htm> [↑](#endnote-ref-8)