**Work Paper PGECOPRO101**

**Process Boiler**

**Revision # 3**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Process Boiler**

**Measure Codes H11, H15**

# At-A-Glance Summary

|  |  |  |
| --- | --- | --- |
| **Applicable Measure Codes:** | **H11 – Water Process Boiler** | **H15 – Steam Process Boiler** |
| **Measure Description:** | Replacement of process water boiler with new boiler. Must have combustion test to verify combustion efficiency of 85% or better and input rating < 20,000 kBTUh | Replacement of process steam boiler with new boiler. Must have combustion test to verify combustion efficiency of 83% or better and input rating < 20,000 kBTUh |
| **Energy Impact Common Units:** | Per kBTUh of boiler rated input | Per kBTUh of boiler rated input |
| **Base Case Description:** | Process water boiler with **combustion efficiency of 82%.**  Source: 2013 Title 24 | Process steam boiler with **combustion efficiency of 80%.**  Source: 2013 Title 24 and DOE Steam Tip Sheet |
| **Base Case Energy Consumption:** | **36.7 Therms / kBTUh**  Source: Engineering Calculations | **36.7 Therms / kBTUh**  Source: Engineering Calculations |
| **Measure Energy Consumption:** | **33.8 Therms / kBTUh**  Source: Engineering Calculations | **35.3 Therms / kBTUh**  Source: Engineering Calculations |
| **Energy Savings (Base Case – Measure)** | **2.9Therms / kBTUh**  Source: Engineering Calculations | **1.4 Therms / kBTUh**  Source: Engineering Calculations |
| **Costs Common Units:** | Per kBTUh of boiler rated input | Per kBTUh of boiler rated input |
| **Base Case Equipment Cost ($/unit):** | **$8.43kBTUh**  Source: DEER 2008 | **$10.12/kBTUh**  Source: DEER 2008 |
| **Measure Equipment Cost ($/unit):** | **$9.93/kBTUh**  Source: DEER 2008 | **$11.82/kBTUh**  Source: DEER 2008 |
| **Gross Measure Cost ($/unit)** | **$1.50/kBTUh**  Source: DEER 2008 | **$1.70/kBTUh**  Source: DEER 2008 |
| **Measure Incremental Cost ($/unit):** | **$1.50/kBTUh**  Source: DEER 2008 | **$1.70/kBTUh**  Source: DEER 2008 |
| **Effective Useful Life (years):** | EUL: 20yrs  RUL: 6.67yrs  Source: DEER 2014 EUL/RUL Values and Summary Documentation | EUL: 20yrs  RUL: 6.67yrs  Source: DEER 2014 EUL/RUL Values and Summary Documentation |
| **Program Type:** | ROB and NC | ROB and NC |
| **Net-to-Gross Ratios:** | 0.60  Source: DEER 2011 NTG Values – Industrial; All other EEMs with no evaluated NTGR; existing EEM programs with same delivery mechanism for more than 2 years | 0.60  Source: DEER 2011 NTG Values – Industrial; All other EEMs with no evaluated NTGR; existing EEM programs with same delivery mechanism for more than 2 years |
| **Important Comments:** | Gross measure cost is assumed to be the same as the incremental measure cost. | Gross measure cost is assumed to be the same as the incremental measure cost. |

# Work Paper Approvals

The following Manager(s) approved this work paper through the PG&E Electronic Data Routing System under Routing Requisition # 2014-36028

|  |
| --- |
|  |
| **Grant Brohard**  Manager, Technical Product Support |
| **Carolyn Weiner**  Manager, Products |

# 

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Revision Date** | **Section-by-Section Description of Revisions** | **Author (Company)** |
| **Revision 0** | **02/27/08** | **Original workpaper:**  **Process BoilerPGECOPRO101 R0.doc** | **Jim Kelsey and Nicolas Fauchier-Magnan (kW Engineering)** |
| **Revision 1** | **3/23/2010** | **Process BoilerPGECOPRO101 R1.doc update including available 2008 DEER cost data, and update NTGR value to 0.46.** | **Breesa Kassing (PG&E) and Charlie Middleton (PG&E)** |
| **Revision 2** | **5/24/2012** | **Process BoilerPGECOPRO101 R2.doc update including available 2011 DEER data and update NTGR value to 0.60.** | **Justin Westmoreland (PG&E)** |
|  | **8/28/2012** | **Nomenclature Update** | **Justin Westmoreland (PG&E)** |
| **Revision 3** | **04/25/2014** | **Formatted to new template. Updated for Title 24 code impact.** | **Curtis Lee**  **(kW Engineering)**  **Charlie Middleton (PG&E)** |

# Table of Contents

[At-A-Glance Summary i](#_Toc386966966)

[Work Paper Approvals iii](#_Toc386966967)

[Document Revision History iv](#_Toc386966968)

[Table of Contents v](#_Toc386966969)

[List of Tables vi](#_Toc386966970)

[*Section 1. General Measure & Baseline Data* 1](#_Toc386966971)

[1.1 Product Measure Description & Background 1](#_Toc386966972)

[1.2 Product Technical Description 1](#_Toc386966973)

[1.3 Measure Application Type 2](#_Toc386966974)

[1.4 Product Base Case and Measure Case Data 2](#_Toc386966975)

[1.4.1 DEER Base Case and Measure Case Information 2](#_Toc386966976)

[1.4.2 Codes & Standards Requirements Base Case and Measure Information 4](#_Toc386966977)

[1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information 5](#_Toc386966978)

[1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases 5](#_Toc386966979)

[1.4.5 Time-of-Use Adjustment Factor 6](#_Toc386966980)

[1.5 Summary of Inputs for Savings Calculations 7](#_Toc386966981)

[*Section 2. Calculation Methods* 8](#_Toc386966982)

[2.1 Electric Energy Savings Estimation Methodologies 8](#_Toc386966983)

[2.2. Demand Reduction Estimation Methodologies 8](#_Toc386966984)

[2.3. Gas Energy Savings Estimation Methodologies 8](#_Toc386966985)

[*Section 3. Load Shapes* 11](#_Toc386966986)

[3.1 Base Case Load Shapes 11](#_Toc386966987)

[3.2 Measure Load Shapes 11](#_Toc386966988)

[*Section 4. Base Case & Measure Costs* 12](#_Toc386966989)

[4.1 Base Case(s) Costs 12](#_Toc386966990)

[4.2 Measure Case Costs 13](#_Toc386966991)

[4.3 Incremental & Full Measure Costs 14](#_Toc386966992)

[4.3.1 Gross Measure Costs 14](#_Toc386966993)

[4.3.2 Incremental Measure Costs 14](#_Toc386966994)

[Index 16](#_Toc386966995)

[References 17](#_Toc386966996)

# 

# 

# List of Tables

[Table 1 - Measure Application Type 2](#_Toc384033519)

[Table 2 - Net-to-Gross Ratios 3](#_Toc384033520)

[Table 3 - Baseline by Measure Application Type 8](#_Toc384033521)

[Table 4 - Average Capacity Factor 9](#_Toc384033522)

[Table 5 - Average Combustion Efficiencies 10](#_Toc384033523)

# 

# *Section 1. General Measure & Baseline Data*

## 1.1 Product Measure Description & Background

**Catalog Description**

* H11 Water Process Boiler
* H15 Steam Process Boiler

**Program Restrictions and Guidelines**

This work paper documents the rationale for the savings methodologies and assumptions for Process Boilers, as listed in the Boilers and Water Heating Rebate Catalog. The Boilers and Water Heating Rebate Catalog is part of Pacific Gas and Electric Company’s Customer Energy Efficiency Program. PG&E offers incentives to industrial customers for installing qualifying, high-efficiency equipment.

**Terms and Conditions:**

Requirements from Boilers and Water Heating Catalog:

* This rebate is available to industrial end-use customers who manufacture a saleable product typically in NAICS codes 31-33, but other NAICS codes may apply.
* Application must include the manufacturer’s name and model name/number for the equipment.
* Installation address must have a commercial natural gas account with PG&E
* Boilers used primarily for domestic hot water, space conditioning; pools or spas do not qualify for this rebate.
* Must meet efficiency requirements based on input ratings and types shown in the *Space Heating Boiler Table* as listed in the PG&E rebate catalog.

**Market Applicability:**

This measure is applicable to any industrial process boiler and not applicable to boilers used for space heating, domestic hot water, pools, or spas. This measure is applicable to any commercial application through upstream and downstream channels.

## 1.2 Product Technical Description

Process boilers are pressure vessels that transfer heat to water for use primarily in process applications. Energy efficient units often feature high-efficiency and/or low NOx burners, and typically have features such as forced air burners, relatively large heat exchange surfaces, and/or utilize heat recovery from stack gases.

## 1.3 Measure Application Type

The DEER measure application types are defined in the table below:

Table 1 - Measure Application Type[[1]](#endnote-1)

*Identifies the measure application type in the Measure Implementation table in DEER2014.*

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| ER | Early retirement | *measure applied while existing equipment still viable, or retrofit of existing equipment* |
| ROB | Replace on Burnout | *measure applied when existing equipment fails or maintenance requires replacement* |
| NC | New Construction | *measure applied during construction design phase as an alternative to a code-compliant standard design* |

Measures H11, and H15 are applicable to industrial installations. The savings for all measures are calculated assuming that the installation is either new construction (NC) or replace-on-burnout (ROB).

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

The DEER 2014 database does not contain measures equivalent to either of the PG&E catalog measures H11 or H15. Therefore, custom temperature bin calculations have been developed to estimate energy savings resulting from H11 and H15. See Section 2 for further detail.

The DEER 2014 documentation does contain applicable information for measure cost, equipment-useful life, net-to-gross, and initial-service rate for measures H11, and H15.

DEER does not contain measure costs for process boilers, and only contains data for non-process boilers. However, process boilers are assumed to be the same equipment type as non-process boilers for costing purposes. Therefore, we took cost values from the DEER 2008 cost data[[2]](#endnote-2) directly. The following is a sample of the measure costs. See Appendix C[[3]](#endnote-3) for a complete list of DEER costs.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | **Costs ($)** | | |  |
| **Measure Code** | **Building type** | **Bldg Vintage** | **Climate Zone** | **Base Case** | **Measure Case** | **IMC** | **DEER Version** |
| H11 | ANY | EX | CZ01 | $8.54 | $10.07 | $1.52 | DEER 2008 |
| H11 | ANY | EX | CZ02 | $8.11 | $9.56 | $1.45 | DEER 2008 |
| H11 | ANY | EX | CZ03 | $8.87 | $10.45 | $1.58 | DEER 2008 |
| H11 | ANY | EX | CZ04 | $8.85 | $10.42 | $1.58 | DEER 2008 |

*All costs are noted as $ per rated kBTUh*

**Net-to-Gross Assumption:**

Table 2 below summarizes all applicable DEER based net-to-gross ratios[[4]](#endnote-4) for programs that may be used by these measures.

Table 2 – DEER Net-to-Gross Ratios

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **DEER Spreadsheet** | |
| Program Approach | NTG | File name | Cell # |
| Ind-Default>2yrs | 0.6 | Appendix D - DEER2014 NTGR | 48 |

The NTG Ratios in Table 2 are appropriate for the measures because:

* Measures are for industrial applications
* No evaluated NTGR available for this measure
* Equipment has the same delivery mechanism for more than two years

**Effective Useful Life:**

The effective-useful life estimates were taken directly from DEER support tables. See Appendix E.[[5]](#endnote-5)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Building Type** | **Building Vintage** | **Climate Zone** | **EUL (yrs)** | **RUL (yrs)** | **DEER Version** | **EUL IDs** | **Description** | **Index Number** |
| ALL | EX | PG&E | 20 | 6.7 | DEER2014 | PrcHt-Blr | High Efficiency Boiler | 457 |
| ALL | EX | PG&E | 20 | 6.7 | DEER2014 | PrcHt-StmBlr | High Efficiency Boiler | 553 |

The EUL and RUL values in the table above are appropriate for the measures because:

* Measure description matches Use Category, Use Sub Category, and Tech Group

**In-service rate/first year installation rate:**

In-service rate was not found in DEER or any supporting documentation. We have therefore assumed that the ISR is 1.0 for all measures based on engineering judgment.

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

It should be noted that the more stringent code be applied in all applicable situations. In this case, 2013 Title 24 code supersedes the 2012 Title 20 code as the regulatory baseline for all measures.

***Title 20:*** These measures do fall under Title 20 of the California Energy Regulations. Section 1605 of Title 20 states[[6]](#endnote-6):

*The efficiency of boilers, central furnaces, duct furnaces, and unit heaters shall be no less than, and the standby loss shall be not greater than, the applicable values shown in Tables E-5, E-6, E-7, and E-8. The standards for unit heaters shown in Table E-8 only apply to models manufactured on or before August 8, 2008.*

The table below shows the 2012 California Title 20 Appliance Efficiency Regulations, Section 1605.1, Table E-5, Standards for Gas- and Oil-Fired Central Boilers and Electric Residential Boilers.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 20 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Large Gas Boilers (>=300 kBTUh) | Base | 80% | Combustion Efficiency | Table E-3 |

***Title 24:*** These measures do fall under Title 24 of the California Energy Regulations. Title 24 states[[7]](#endnote-7):

*Any space-conditioning equipment listed in this section may be installed only if the manufacturer has certified to the Commission that the equipment complies with all the applicable requirements of this section.*

1. ***Efficiency.*** *Equipment shall meet the applicable efficiency requirements in TABLE 110.2-A through TABLE 110.2- K subject to the following:*
   1. *If more than one efficiency standard is listed for any equipment in TABLE 110.2-A through TABLE 110.2-K, the equipment shall meet all the applicable standards that are listed; and*
   2. *If more than one test method is listed in TABLE 110.2-A through TABLE 110.2-K, the equipment shall comply with the applicable efficiency standards when tested with each listed test method; and*
   3. *Where equipment can serve more than one function, such as both heating and cooling, or both space heating and water heating, it shall comply with all the efficiency standards applicable to each function; and*
   4. *Where a requirement is for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the capacity shall be as provided for and allowed by the controls, during steady-state operation.*

The table below lists the 2013 California Title 24 Build Energy Efficiency Standards, Section 110.2, Table 110.2-K, Gas- and Oil-Fired Boilers, Minimum Efficiency requirements.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Title 24 Std. Description** | **Base or Measure Case** | **Value** | **Units** | **Code Source or Reference** |
| Boiler, hot water, Gas Fired (> 2,500 kBTUh) | Base | 82% | Combustion Efficiency | Table 110.2-K |
| Boiler, steam, Gas-Fired all, except natural draft(>2,500 kBTUh) | Base | 79% | Thermal Efficiency | Table 110.2-K |

***Federal Standards:*** These measures do not fall under Federal DOE or EPA Energy Regulations.

The applicable codes and standards for these measures to not dictate associated hours of operation, measure or baseline costs, EUL, NTG, or in-service rate for the equipment involved.

## 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 these measures. Information on the base and measure case is found in the sub-sections of 1.4.

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

The following assumptions from other sources were used to estimate savings.

**Energy Savings Assumption (ΔTherms):**

* New high-efficiency unit has the same input rating (measured in kBTUh) as the unit being replaced.
* Both units (old and new) deliver the same amount of hot water or steam on an annual basis (i.e., customer demand for hot water or steam does not change).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Building type** | **Bldg Vintage** | **Climate Zone** | **Interactive Only?**  **Yes / No** | **Gas Savings Therms** | **Units** | **Reference** |
| H11 | ANY | EX | ANY | No | 2.9 | Per kBTUh | Appendix A |
| H15 | ANY | EX | ANY | No | 1.4 | Per kBTUh | Appendix A |

RUL savings are not applicable to this measure because this measure only covers ROB and NC measure types.

Base case efficiencies are based on 2013 Title 24 minimum efficiencies for boilers. Title 24 requires large water boilers to have a minimum combustion efficiency of 82% and large steam boilers to have a minimum thermal efficiency of 79%.7 While Title 24 is targeted specifically to space conditioning equipment, we have applied the more stringent code regulations to this workpaper.

Since PG&E cannot readily measure thermal efficiency, combustion efficiency will be used to determine the eligibility of the boilers. In addition, because Title 24 evaluates steam boilers in thermal efficiency, we have adjusted the combustion efficiency of a water boiler to estimate the combustion efficiency of a steam boiler. Based on the DOE Steam Tip Sheet #4[[8]](#endnote-8) we have estimated the combustion efficiency for a steam boiler. If we assume a 3% excess oxygen level and assume that steam boilers have flue gas temperatures 100 ⁰F higher than a similarly sized water boiler, we have estimated that steam boilers are 2% less efficient than a comparable water boiler.

Therefore, we have reduced the Title 24 minimum combustion efficiency of a large water boiler by 2% to estimate the Title 24 minimum combustion efficiency for a large steam boiler.

**Hours of Operation**:

* The assumed hours of operation are based on continual plant operation. Variation in plant operating hours is accounted for in the capacity factor. While the boiler may be enabled to operate during the entire year, it may not be operating at its full rated load. To account for this, the capacity factor is multiplied by the enabled hours of operation to obtain the effective full load hours (EFLH). See Section 2 for details.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Building type** | **Building Vintage** | **Climate Zone** | **Hours of Operation hrs/yr** | **Reference** |
| ANY | EX | ANY | 8,760 | N/A |

## 1.4.5 Time-of-Use Adjustment Factor

We are required by CPUC decision 06-06-063 dated June 29, 2006 to apply time-of-use (TOU) adjustment factors on residential A/C and commercial A/C (packaged and split-system direct-expansion cooling) measures only. Since this is not an A/C measure, the TOU adjustment factor is 0.

## 1.5 Summary of Inputs for Savings Calculations

The following sections provide the inputs for calculation.

Summary for Measure H11:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Base Case 1 Average Value** | **Base Case 2 Average Value** | **Measure Case Average Value** | **Reference Section** |
| **Electric Savings\*** | BT | N/A | N/A | N/A | *1.4.1* |
| **Gas Savings\*** | None | 36.7 | N/A | 33.8 | *1.4.1* |
| **Hours of operation** | None | 8,760 | N/A | 8,760 | *1.4.1* |
| **Full Cost** | CZ | $13.33 | N/A | $14.83 | *1.4.1* |
| **Incremental Cost** | CZ | $1.50 | N/A | $1.50 | *1.4.1* |
| **EUL /RUL** | None | 20/6.7 | N/A | 20/6.7 | *1.4.1* |
| **NTG** | None | 0.6 | N/A | 0.6 | *1.4.1* |
| **ISR** | None | 1 | N/A | 1 | *1.4.1* |

Summary for Measure H15:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Input Variable** | **Variations** | **Base Case 1 Average Value** | **Base Case 2 Average Value** | **Measure Case Average Value** | **Reference Section** |
| **Electric Savings\*** | BT | N/A | N/A | N/A | *1.4.1* |
| **Gas Savings\*** | None | 36.7 | N/A | 35.3 | *1.4.1* |
| **Hours of operation** | None | 8,760 | N/A | 8,760 | *1.4.1* |
| **Full Cost** | CZ | $15.81 | N/A | $17.51 | *1.4.1* |
| **Incremental Cost** | CZ | $1.70 | N/A | $1.70 | *1.4.1* |
| **EUL /RUL** | None | 20/6.7 | N/A | 20/6.7 | *1.4.1* |
| **NTG** | None | 0.6 | N/A | 0.6 | *1.4.1* |
| **ISR** | None | 1 | N/A | 1 | *1.4.1* |

# *Section 2. Calculation Methods*

**Table 3 - Baseline by Measure Application Type**

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Measure Life Basis** | **First Baseline Period: Energy Savings Baseline** | **Second Baseline Period: Energy Savings Baseline** |
| ***ER* (early retirement)** | **RUL/EUL-RUL** | Customer Average Baseline | Code Baseline |
| ***ROB* (Replace on Burnout)** | **EUL** | Code Baseline | N/A |
| ***NC* (New Construction)** | **EUL** | Code Baseline | N/A |

Notes:

* For ROB and NC, First Baseline is the baseline for the full EUL. There is no second baseline.

**H11 – Water Process Boiler**

Qualifying water boilers for this measure must have an input rating of less than 20,000 kBTUh. The combustion efficiency must be documented achieving a combustion efficiency of 85% or greater under full load conditions.

**H15 – Steam Process Boiler**

Qualifying steam boilers for this measure must have an input rating of less than 20,000 kBTUh. The combustion efficiency must be documented achieving a combustion efficiency of 83% or greater under full load conditions.

## 2.1 Electric Energy Savings Estimation Methodologies

There are no electric savings (kWh per kBTUh) associated with this measure.

## 2.2. Demand Reduction Estimation Methodologies

There is no Demand Reduction (kW per kBTUh) associated with this measure.

## 2.3. Gas Energy Savings Estimation Methodologies

There are no DEER measures that match catalog measures H11, and H15. Therefore, we calculated energy savings based on average combustion efficiencies from the California Energy Commission (CEC) Appliance Databases[[9]](#endnote-9) and capacity factors taken from the Characterization of the U.S. Industrial/Commercial Boiler Population[[10]](#endnote-10).

**Capacity Factor**

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):

Where,

CF = capacity factor, no units

AGC = actual gas consumption during a given time period, kBTUh

MGC = maximum gas consumption during a given time period, kBTUh

Data from the analysis of industrial and commercial boilers was combined with industry-specific Gross Domestic Product (GDP) data to get an accurate estimation of the average process boiler capacity factor in California. The average capacity factor is estimated by the equation below:

Where,

ACF = average capacity factor, no units

WCF = weighted capacity factor, no units

The weighted capacity factor accounts for the number of boilers in each industry. This factor is weighted based on the total number of boilers surveyed in Characterization of the U.S. Industrial/Commercial Boiler Population9multiplied by the size of each industry based on California GDP information from the Bureau of Economic Analysis.[[11]](#endnote-11) The weighted capacity factor is estimated by the equation below:

Where,

NB = number of boilers in industry, no units

PGDP = percent of California GDP versus nationwide GDP, no units

TBCA = total number of boilers in California, no units

Table 4 - Average Capacity Factor Across Different Industries



To determine the average boiler efficiency in the measure case, the California Energy Commission (CEC) Appliance Databases and records of boilers that PG&E has rebated under this measure were used. The CEC inventory includes over 3,000 gas boilers for steam and hot water production. To determine efficiencies for the measure case boilers in the database were sorted in order of increasing efficiency and divided into steam and hot water boilers.

The measure efficiencies were calculated as a simple average of the efficiencies of boilers listed in the CEC inventory. Finally, an average efficiency was calculated for all models with efficiency of at least 83% and 85% respectively, the minimum efficiency specified for this measure, including very high efficiency condensing models. The calculated average efficiencies are summarized in the following table:

**Table 5 - Average Combustion Efficiencies for High-Efficiency Boilers**



**∆Therms per kBTUh for H11 and H15:**

The gas savings (therms per kBTUh) for measures H11 and H15 is based on the difference between the annual gas usage of the base case boiler and the measure boiler. The gas savings for these measures is defined as:

Where,

GS = gas savings, therms / kBTUh input rating

BCGU = base case gas usage, therms / kBTUh input rating

MCGU = measure case gas usage, therms / kBTUh input rating

Base case annual gas usage is based the average capacity factor, and operating hours. The base case gas usage is calculated as:

Where,

= 0.419, average capacity factor across all industries, no units

H = 8,760, annual operating hours, hr/yr

C = 0.01, conversion factor, therms / kBTU

Measure case annual gas consumption is based on the ratio of efficiencies between the base case efficiency and the measure case efficiency. The measure case gas usage is calculated as:

Where,

= base case efficiency, no units

= measure case efficiency, no units

**Savings for H11 (∆Therms / kBTUh):**

*therms / kBTUh input rating*

*therms / kBTUh input rating*

*therms / kBTUh input rating*

**Savings for H15 (∆Therms / kBTUh):**

*therms / kBTUh input rating*

*therms / kBTUh input rating*

*therms / kBTUh input rating*

# *Section 3. Load Shapes*

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure’s load shape. The measure’s load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure’s Total Resource Cost (TRC) benefit.

## 3.1 Base Case Load Shapes

Load shapes are not applicable to gas measures, however, because the price of gas is not dependent on time-of-use.

## 3.2 Measure Load Shapes

Load shapes are not applicable to gas measures, however, because the price of gas is not dependent on time-of-use.

# *Section 4. Base Case & Measure Costs*

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Measure Life Basis** | **First Baseline Period Gross Measure Cost (RUL)** | **Second Baseline Period Gross Measure Cost (EUL – RUL)** |
| **NC** (New Construction) | EUL | Calculated as Incremental Measure Cost | N/A |
| **ROB** (Replace on Burnout) | EUL | Calculated as Incremental Measure Cost | N/A |
| **ER** (Early Retirement) | RUL/  EUL-RUL | Calculated as Full Gross Measure Cost | Calculated as Negative Full Gross Base Case Cost |

## 4.1 Base Case(s) Costs

The following Measure Application Types are appropriate to these measures. The Base Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Application Type** | **Baseline** | **Average Equipment Cost** | **Average Labor / Installation Cost** | **Maintenance / Other Cost** | **Average Total Base Case Cost** |
| H11 | ROB, NC | Title 24 – compliant natural gas large hot water boiler (>300 kBTUh) | $8.43 | $4.90 | $ N/A | $13.33 |
| H15 | ROB, NC | Title 24 – compliant natural gas large steam boiler (>300 kBTUh) | $10.12 | $5.69 | $ N/A | $15.81 |

*All costs are noted as $ per rated kBTUh*

Base case costs are taken directly from DEER for each measure. Material and labor costs are multiplied by a climate multiplier to account for cost variation in each climate zone. A complete list of costs can be found in Appendix C3. Material costs are calculated as:

Where,

= material base case cost for climate zone, $ per kBTUh

= DEER material cost, $ per kBTUh

= material cost multiplier for climate zone, no units

Labor costs are calculated as:

Where,

= labor cost for climate zone, $ per kBTUh

= DEER labor cost, $ per kBTUh

= labor cost multiplier for climate zone, no units

## 4.2 Measure Case Costs

The following Measure Application Types are appropriate to these measures. The Measure Case Costs are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure Code** | **Measure Application Type** | **Baseline** | **Average Equipment Cost** | **Average Labor / Installation Cost** | **Maintenance / Other Cost** | **Average Total Measure Case Cost** |
| H11 | ROB | Title 20 – compliant natural gas large hot water boiler (>300 kBTUh) | $9.93 | $4.90 | $ N/A | $14.83 |
| H15 | ROB | Title 24 – compliant natural gas large steam boiler (>300 kBTUh) | $11.82 | $5.69 | $ N/A | $17.51 |

*All costs are noted as $ per rated kBTUh*

Measure case costs are taken directly from DEER for each measure. Material and labor costs are multiplied by a climate multiplier to account for cost variation in each climate zone. Costs can be found in Appendix C3. Material costs are calculated as:

Where,

= material measure case cost for climate zone, $ per kBTUh

= DEER material measure cost, $ per kBTUh

= material measure cost multiplier for climate zone, no units

Labor costs are estimated to be the same as the base case labor cost. See Section 4.1 for calculations.

## 4.3 Incremental & Full Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Measure Application Type** | **Gross Measure Cost**  **(RUL Period/First Baseline)** | **Gross Measure Cost**  **(EUL-RUL Period/ Second Baseline)** | **Incremental Measure Cost** |
| ER | Measure Equipment Cost  +Measure Labor Cost | (-1)x(Base Equipment Cost  + Base Labor Cost) | Measure Equipment Cost  – Base Case Equipment Cost |
| ROB | Measure Equipment Cost  – Base Case Equipment Cost | N/A | Measure Equipment Cost  – Base Case Equipment Cost |
| NC | Measure Equipment Cost  – Base Case Equipment Cost | N/A | Measure Equipment Cost  – Base Case Equipment Cost |

## 4.3.1 Gross Measure Costs

Gross Measure Cost is the cost to install an energy efficient measure per the CPUC calculators. This definition implies a different meaning depending on the Measure Application type.

This Measure Application Types is: **ROB,** so the Gross Measure Cost (GMC) is represented by the equation below:

**GMC** = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

**GMC =** Measure Equipment Cost – Base Case Equipment Cost

**Example:**

GMC = $9.93/kBTUh - $8.43/kBTUh = $ 1.50/kBTUh

## 4.3.2 Incremental Measure Costs

Incremental Measure Cost is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. While IMC has a straightforward definition depending on the Measure Application type, the equation does vary.

This Measure Application Types is: **ROB,** so the Incremental Measure Cost (IMC) is represented by the appropriate equation below:

**IMC** = (Measure Equipment Cost + Measure Labor Cost) –

(Base Case Equipment Cost + Base Case Labor Cost)

\*Note: We assume that, unless stated otherwise, the measure case labor and base case labor are assumed to be the same value reducing the equation to the following:

**IMC =** Measure Equipment Cost – Base Case Equipment Cost

**Example:**

IMC = $9.93/kBTUh - $8.43/kBTUh = $ 1.50/kBTUh

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure ID** | **Measure Application Types** | **Average Base Case Total Cost** | **Average Measure Case Total Cost** | **Average Gross Measure Case Cost** | **Average Incremental Measure Cost** |
| H11 | ROB | $13.33 | $14.83 | $1.50 | $1.50 |
| H15 | ROB | $15.81 | $17.51 | $1.70 | $1.70 |

*All costs are noted as $ per rated kBTUh*

# Index

Capacity factor 9

CEC 9, 10, 9

CEC inventory 10

Efficiency 10, 11

Load shapes 12

Measure 10, 11

New Construction 3, 9, 13

NTG Ratios 4

Replace on Burnout 3, 9, 13

Title 20 5

Title 24 5

# 

# References

1. Appendix A - 2014 Database for Energy Efficiency Resources (DEER) Update Study, prepared by Itron Inc., November 2013 ;D13v1.00 [↑](#endnote-ref-1)
2. Appendix B - DEER 2008 Cost Data [↑](#endnote-ref-2)
3. Appendix C - Energy Savings and Cost – execsummconv [↑](#endnote-ref-3)
4. Appendix D - DEER NTG Values [↑](#endnote-ref-4)
5. Appendix E - DEER2014 EUL [↑](#endnote-ref-5)
6. Appendix F - 2012 California Title 20 Appliance Efficiency Regulations, Section 1605.1, Table E-5 [↑](#endnote-ref-6)
7. Appendix G - 2013 Building Energy Efficiency Standards [↑](#endnote-ref-7)
8. Appendix H - DOE Steam Tip Sheet 4 [↑](#endnote-ref-8)
9. California Energy Commission (CEC) Appliance Databases -<http://www.appliances.energy.ca.gov/AdvancedSearch.aspx> [↑](#endnote-ref-9)
10. Appendix I - Characterization Industrial Commercial Boiler Population [↑](#endnote-ref-10)
11. Bureau of Economic Analysis – Regional Economic Accounts – Gross Domestic Products by State – http://www.bea.gov/regional/gsp/ [↑](#endnote-ref-11)