**Workpaper WPSCGNRPH120206A**

**Revision 5**

**Southern California Gas Company**

**Customer Programs Department**

Process Boilers (Including Direct Contact Water Heaters)

Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision No. | Date | **Description** | **Author** |
| B | Mar. 20, 2006 | Original release | Rick Tidball (EEA) |
| C | Nov. 21, 2008 | Added NAICS codes | Chan Paek (SoCalGas) |
| 4 | May 18, 2012 | Simplified categories and updated cost and efficiency data | Stu Knoke (ICF) |
| 5 | May 28, 2014 | Estimated gas savings to include California's 16 Climate Zones. | Raad Bashar (SCG) |
|  |  |  |  |

# 

Measure Summary Tables

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Measure ID | Measure Name | Program Application Type (RE, NC, ROB, ER, etc) | EUL/RUL (yr) | CZ | Building Type | Building Vintage | Unit  Definition | NTG IMC | NTG Savings | Program Delivery Method (CustIncent, PreReb, Dirinstall, etc) | Gross Realization Rate (GRR) | % Eligible for TOU AC Adjustment |
| 1 | Process Hot Water Boilers, Tier 1 (85% CE or 83% TE) | ROB | 20/0 | IOU | Ind,COM | Ex | MBtu/hr | 0.6 | 0.6 | PreReb | 1 | 0 |
| 2 | Process Hot Water Boilers, Tier 1 (85% CE or 83% TE) | ROB | 20/0 | 1 | Ind,COM | Ex | MBtu/hr | 0.6 | 0.6 | PreReb | 1 | 0 |
| 18 | Process Hot Water Boilers, Tier 2 (90% CE or 88% TE) | ROB | 20/0 | IOU | Ind,COM | Ex | MBtu/hr | 0.7 | 0.7 | PreReb | 1 | 0 |
| 19 | Process Hot Water Boilers, Tier 2 (90% CE or 88% TE) | ROB | 20/0 | 1 | Ind,COM | Ex | MBtu/hr | 0.7 | 0.7 | PreReb | 1 | 0 |
| 35 | Process Steam Boilers, 93% TE | ROB | 20/0 | IOU | Ind,COM | Ex | MBtu/hr | 0.6 | 0.6 | PreReb | 1 | 0 |
| 36 | Process Steam Boilers, 93% TE | ROB | 20/0 | 1 | Ind,COM | Ex | MBtu/hr | 0.6 | 0.6 | PreReb | 1 | 0 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | 1st Baseline | | | | 2nd Baseline | | | |
| Measure ID | Measure Name | Gas Savings (therms/unit) | Base Total Cost ($/unit) | Measure Total Cost ($/unit) | Incremental Measure Cost ($/unit) | Gas Savings (therms) | Base Total Cost ($/unit) | Measure Total Cost ($/unit) | Incremental Measure Cost ($/unit) |
| 1 | Process Hot Water Boilers, Tier 1 (85% CE or 83% TE) | 0.85 | $10.78 | $12.94 | $2.17 |  |  |  |  |
| 2 | Process Hot Water Boilers, Tier 1 (85% CE or 83% TE) | 0.96 | $10.78 | $12.94 | $2.17 |  |  |  |  |
| 18 | Process Hot Water Boilers, Tier 2 (90% CE or 88% TE) | 1.95 | $10.78 | $22.95 | $12.17 |  |  |  |  |
| 19 | Process Hot Water Boilers, Tier 2 (90% CE or 88% TE) | 2.55 | $10.78 | $22.95 | $12.17 |  |  |  |  |
| 35 | Process Steam Boilers, 93% TE | 0.47 | $14.89 | $19.24 | $4.35 |  |  |  |  |
| 36 | Process Steam Boilers, 93% TE | 0.50 | $14.89 | $19.24 | $4.35 |  |  |  |  |

\*\*See Attachment B for the complete list of measures.

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1. General Measure & Baseline Data
   1. Measure & Delivery Description
      1. Measure description
         1. Process boilers are pressure vessels that transfer heat to water for manufacturing. Manufacturing involves the mechanical or chemical transformation of materials or substances into a new product that is neither a structure nor any other fixed improvement.
         2. In most boilers, a heat exchanger separates the combustion products from the water. Boilers can be configured as an integrated packaged boiler, or, in some cases, the boiler (which may resemble an instantaneous water heater) may be connected to a separate tank that contains an internal heat exchanger. Energy efficient units may have one or more of the following features: high-efficiency/low NOx burners, power burners, water tubes, relatively large heat exchange surfaces, and flue exhaust heat recovery systems.
         3. Another type of process heating arrangement is the direct contact water heater. In direct contact water heaters, the combustion products directly contact the water and heat from the flame comes into direct contact with small droplets of cold water that run through a stainless steel heat exchange media. Droplets composed from this process come into direct contact with rising heat from the flame and as a result the water is heated directly.
         4. The 2008 Process Boilers Workpaper includes a more detailed technology description in its Appendix A[[1]](#endnote-1).
      2. Market Applicability
         1. These measures are applicable to any small or medium process boiler application.
         2. Process boilers with the input rate equal to 20MMBtuh (≤ 20,000 kBtu/hr) or less can qualify for this measure.
         3. The primary application for this measure is the industrial sector (NAICS 31-33), but process boilers are not limited to the industrial sector. For example, process boilers are used in the following sectors: agricultural sector (NAICS 11), oil & gas extraction (NAICS 21), and dry-cleaning/laundry services (NAICS 8123).
         4. Boilers used primarily for domestic hot water or space heating end uses do not qualify.
      3. Terms & Conditions
         1. Only process boilers (i.e., units not primarily used for domestic hot water or space heating use) qualify.
         2. This rebate is available to end-use customers in NAICS codes 11, 21, 31-33, and 8123.
         3. The rebate applies to gas-for-gas equipment replacements on burnout or for new installations in existing buildings.
         4. The rebate does not apply to New Construction.
         5. The manufacturer’s name and equipment model number must be provided.
         6. A flue gas analysis (FGA) measured under full load conditions is required to document combustion efficiency under full load conditions after the installation is complete. If necessary, customers must provide proof of unit efficiency (e.g., manufacturer’s equipment specification sheet).
      4. Delivery Method
         1. The preferred delivery method is a downstream prescriptive rebate offered to the gas customer.
      5. Qualifying Efficiency
         1. Test methods for measuring boiler efficiencies are referenced in the California Titles 20 and 24 standards2,3.
         2. Minimum qualifying combustion efficiency (CE) for process boilers:
            1. 85% for Tier 1 hot water boilers (non-condensing)
            2. 90% for Tier 2 hot water boilers (condensing)
            3. 83% for steam boilers
         3. Direct contact water heaters are included under the Tier 2 condensing hot water boiler category.
         4. Tier 2 condensing hot water boilers require the return water temperature to be significantly lower than 100 °F to achieve these high efficiencies. In addition, Tier 2 condensing hot water boilers often require flue modifications to handle the condensate. These modifications increase installation costs and may be eligible for a higher rebate amount.
   2. DEER Differences Analysis
      1. Measure Efficiency
         1. The “2011 Database for Energy-Efficient Resources (DEER) for Use in the California IOU 2013-14 Energy Efficiency Planning”[[2]](#endnote-2) does not include process boilers.
         2. The “Revised DEER Measure Cost Summary (05\_30\_2008) Revised (06\_02\_2008)”[[3]](#endnote-3) has incomplete efficiency data for process boilers that mimics the data for space heating boilers, including the inappropriate use of annual fuel utilization efficiency for boilers with rated input less than 300 MBtu/hr.
         3. Tier 1 hot water boiler – the qualifying CE is set to 85% to match medium and large space heating hot water boilers.
         4. Tier 2 hot water boiler – the qualifying CE is set to 90% to be consistent across all types of boilers and water heaters (90% efficiency can only be achieved with condensing boilers).
         5. Steam boiler – the qualifying CE is set to 83% to match medium and large space heating steam boilers. Also, 83% CE is used due to the limited availability of medium and large steam boilers with CE above 83% in the CEC Energy Efficiency Appliance Database[[4]](#endnote-4). .
      2. Baseline Efficiency
         1. The “2011 Database for Energy-Efficient Resources (DEER) for Use in the California IOU 2013-14 Energy Efficiency Planning”[[5]](#endnote-5) does not include process boilers.
         2. Hot water boiler – the Titles 20 and 24 standard value of 80% CE for gas packaged boilers is used in this workpaper.
         3. Steam boiler – the Titles 20 and 24 standard value of 80% CE for gas packaged boilers is used in this workpaper.
      3. Incremental Measure Cost
         1. The “Revised DEER Measure Cost Summary (05\_30\_2008) Revised (06\_02\_2008)”3 has incomplete cost data for process boilers that mimics the data for space heating boilers.
         2. Data were collected through a survey of vendors that sell process boilers and direct contact water heaters in California. The incremental measure costs used in this workpaper are the arithmetic average of the survey cost data for each of the categories of boiler type and efficiency used in this workpaper.
   3. Code Analysis
      1. There is no code or other jurisdictional requirements related to these measures.
   4. Measure Effective Useful Life
      1. The effective useful life (EUL) for space heating boilers of 20 years is taken from DEER 2011 update[[6]](#endnote-6).
   5. Net-to-Gross Ratios for Different Program Strategies
      1. DEER 2014 recommends a default Net-to-Gross ratio of 0.60 (NTG\_ID: Ind-Default>2yrs) as all equipment covered under this program is for process heating purpose[[7]](#endnote-7).
      2. The 2014 DEER documents recommend a net-to-gross ratio (NTG\_ID: All-Default<=2yrs) of 0.70 for new commercial technologies, which would include Tier 2 condensing process hot water boilers.
   6. Gross Realization Rate
      1. Gross realization rate of 1.00 is applied to the measures in this document.
   7. Time-of-Use Adjustment Factor
      1. N/A
2. Energy Savings & Demand Reduction Calculations
   1. Load Shapes
      1. N/A
   2. Energy Savings
      1. The annual gas energy savings are calculated from the annual operating time, load factor, rated input, and the efficiency ratio of the baseline unit and the new high-efficiency unit. The energy savings is calculated for process hot water boilers (including direct contact water heaters) and process steam boilers. The data and calculations for annual operating time, load factor, and rated input are included in an Excel file embedded as Attachment A.
      2. Annual Operating Time
         1. The annual operating time represents the number of hours that gas equipment is expected to be in operation or available for operation at any input rating (zero load, part load, or full load). Hours when the equipment is shut down are not included.
         2. For determining the annual operating time, the following steps were followed:
            1. In 2006, a SoCalGas MAS query was conducted to identify gas customers with North American Industry Classification System (NAICS) categories 31, 32, or 33. The query identified gas customers that had only process hot water boilers or only process hot water boilers in combination with gas space heating. A similar query was run for steam boilers.
            2. The results were divided into four categories:

≤2 MMBtu/hr input with process hot water output

2-10 MMBtu/hr input with process hot water output

≤2 MMBtu/hr input with process steam output

2-10 MMBtu/hr input with process steam output

* + - * 1. The monthly scheduled operating time for each process boiler was calculated using data entered in the MAS database. This data was typically entered in multiple fields in the form of hrs/day, days/week, and weeks/yr.
        2. The annual operating time is 12 times the average monthly scheduled operating time.
        3. The resulting annual operating times are listed in Table 1 below.
    1. Load Factor
       1. The load factor for hot water and steam boilers are based on an analysis of the SoCalGas MAS database records and energy use data. The load factor is the average load percentage during the scheduled operating hours (i.e., the actual gas consumption divided by maximum possible gas consumption by the process boiler).
       2. For determining load factors, the following steps were followed:
          1. The SoCalGas MAS database was searched for customers meeting the following criteria:

North American Industry Classification System (NAICS) categories 31, 32, or 33.

Customers with process hot water boilers only, or process hot water boilers in combination with gas space heating boilers with rated input ≤10 MMBtu/hr.

Customers with process steam boilers only, or process steam boilers only in combination with gas space heating boilers with rated input ≤10 MMBtu/hr.

* + - * 1. The results were divided into four categories:

≤2 MMBtu/hr rated input, process hot water output

2-10 MMBtu/hr rated input, process hot water output.

≤2 MMBtu/hr rated input, process steam output

2-10 MMBtu/hr rated input, process steam output

* + - * 1. The monthly scheduled operating time for each process boiler was calculated using data entered in the MAS database. This data was typically entered in multiple fields in the form of hrs/day, days/week, and weeks/yr.
        2. The maximum possible gas usage for the five-month period of May through September at a customer site was calculated by multiplying the nameplate boiler rated input by the scheduled operating hours. It was assumed that during this time period, all of the gas consumption occurred due to process boiler use. If the customer had more than one process boiler, all boilers were included in the calculation of maximum gas use. If the customer had space heating boilers, they were not included in the calculation, since space heating boilers were assumed to not operate during the relatively warm five-month time period.
        3. Actual gas usage for each customer was determined by examining the customer monthly billing records for 2004 (May-September).
        4. Load factors were calculated by dividing the actual gas use by the maximum possible gas use.
        5. To eliminate suspect records, customer sites with load factors greater than 100% or less than 10% were eliminated from the analysis.
        6. After screening suspect records, 490 customer sites remained. These 490 customer sites were used to compute weighted average load factors for each of the four categories (steam and hot water, ≤ 2 MMBtu/hr and 2-10 MMBtu/hr). The resulting load factors are listed in Table 1 below.
      1. The baseline load factors for direct contact water heaters were set equal to the load factors for process hot water boilers (direct contact water heaters are assumed to be a replacement option for process hot water boilers).

1. Average Load Factors and Operating Hours by Equipment Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment Type** | **Process Hot Water Boiler** | | **Process Steam Boiler** | |
| **Rated Input (MMBtu/hr) 🡪** | **≤ 2** | **2 – 10** | **≤ 2** | **2 – 10** |
| Number of Customers Analyzed | 86 | 30 | 218 | 156 |
| Scheduled Annual Operating Time | 4,305 | 5,545 | 3,479 | 4,711 |
| Average Load Factor | 29.7% | 24.4% | 30.1% | 32.0% |

* + 1. Rated Input
       1. To determine average equipment rated input, the SoCalGas MAS database was searched for customers meeting the following criteria:
          1. North American Industry Classification System (NAICS) categories 31, 32, 33
          2. Customers with process hot water boilers only, or process hot water boilers only in combination with gas space heating boilers with rated input ≤10 MMBtu/hr.
          3. Customers with process steam boilers only, or process steam boilers only in combination with gas space heating boilers with rated input ≤10 MMBtu/hr.
       2. The results were divided into four categories:
          1. ≤2 MMBtu/hr input, process hot water output
          2. 2-10 MMBtu/hr input, process hot water output
          3. ≤2 MMBtu/hr input, process steam output
          4. 2-10 MMBtu/hr input, process steam output
       3. The monthly scheduled operating time for each process boiler was calculated using data entered in the MAS database. This data was typically entered in multiple fields in the form of hrs/day, days/week, and weeks/yr.
       4. The maximum possible gas usage for the five-month period of May through September at a customer site was calculated by multiplying the nameplate boiler rated input by the scheduled operating hours. It was assumed that during this time period, all of the gas consumption occurred due to process boiler use. If the customer had more than one process boiler, all boilers were included in the calculation of maximum gas use. If the customer had space heating boilers, they were not included in the calculation, since space heating boilers were assumed to not operate during the relatively warm five-month time period.
       5. Actual gas usage for each customer was determined by examining the customer monthly billing records for 2004 (May-September).
       6. Load factors were calculated by dividing the actual gas use by the maximum possible gas use.
       7. To eliminate suspect records, customer sites with load factors greater than 100% or less than 10% were eliminated from the analysis.
       8. After screening suspect records, 490 customers remained. A weighted average of the equipment rated input for each of the four categories was computed, yielding the values shown in Table 2 below.
       9. The baseline rated inputs for direct contact water heaters were set equal to the baseline rated inputs for process hot water boilers (direct contact water heaters are assumed to be a replacement option for process hot water boilers).

1. Average Rated Inputs by Equipment Type

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment Type** | **Process Hot Water Boiler** | | **Process Steam Boiler** | |
| **Rated Input (MMBtu/hr) 🡪** | **≤ 2** | **2 – 10** | **≤ 2** | **2 – 10** |
| Number of Customers Analyzed | 86 | 30 | 218 | 156 |
| Average Rated Input (MBtu/hr) | 1,273 | 3,920 | 1,257 | 5,310 |

* + 1. Equipment Efficiency
       1. Boiler Combustion Efficiencies. Table 3 shows the range of process boiler combustion efficiencies found in the CEC Appliance Database4. Only 25 medium steam boilers were listed with combustion efficiency at 83%, and none were higher. Only 14 large steam boilers were listed with combustion efficiency at 83%, and none were higher.
       2. Figure 1 shows the distribution of combustion efficiency for non-condensing hot water boilers with rated input ≤2 MMBtu/hr.
       3. Figure 2 shows the distribution of combustion efficiency for non-condensing hot water boilers with rated input 2-10 MMBtu/hr.
       4. Figure 3 shows the distribution of combustion efficiency for condensing hot water boilers with rated input ≤2 MMBtu/hr.
       5. Figure 4 shows the distribution of combustion efficiency for condensing hot water boilers with rated input 2-10 MMBtu/hr.
       6. Figure 5 shows the distribution of combustion efficiency for steam boilers with rated input ≤2 MMBtu/hr.
       7. Figure 6 shows the distribution of combustion efficiency for steam boilers with rated input 2-10 MMBtu/hr.

1. Boiler Efficiency Ranges from California Energy Commission Appliance Efficiency Database4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment Type** | **Rated Input (MBtu/hr)** | **Efficiency Units** | **Minimum Efficiency** | **Maximum Efficiency** |
| Heating Products, Hot Water Boilers, Non-condensing | 300 – 2,000 | CE | 80.0% | 87.0% |
| 2,031 – 9,500 | CE | 80.0% | 87.0% |
| Heating Products, Hot Water Boilers, Condensing | 300 – 2,000 | CE | 85.3% | 98.3% |
| 2,160 – 5,443 | CE | 85.8% | 96.9% |
| Heating Products, Steam Boilers | 300 – 2,000 | CE | 80.0% | 86.0% |
| 2,049 – 10,000 | CE | 80.0% | 83.0% |



1. CEC Efficiency Data (Hot Water Boilers ≤2 MMBtu/hr, Non-condensing)



1. CEC Efficiency Data (Hot Water Boilers 2-10 MMBtu/hr, Non-condensing)



1. CEC Efficiency Data (Hot Water Boilers ≤2 MMBtu/hr, Condensing)



1. CEC Efficiency Data (Hot Water Boilers 2-10 MMBtu/hr, Condensing)



1. CEC Efficiency Data (Steam Boilers ≤2 MMBtu/hr)



1. CEC Efficiency Data (Steam Boilers 2-10 MMBtu/hr)
   * + 1. Baseline and Measure Efficiencies. Table 4 lists the efficiency units and efficiency values recommended for space heating boilers.
          1. The minimum baseline efficiencies match the California Titles 20 and 24 standards for packaged and non-packaged space heater boilers in the same size range.
          2. The qualifying measure efficiency for Tier 1 hot water is similar to the Tier 1 value for large space heating hot water boilers.
          3. The qualifying measure efficiency for Tier 2 hot water matches the Tier 2 value for large space heating hot water boilers.
          4. The qualifying measure efficiency for steam matches the value for large space heating steam boilers, and it is the highest practical qualifying efficiency given the lack of availability of any higher efficiency boilers in the CEC Appliance Database6.
2. Baseline and Qualifying Measure Efficiencies for Process Boilers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Equipment Type** | **Rated Input (MBtu/hr)** | **Efficiency Units** | **Baseline Efficiency** | **Qualifying Efficiency** |
| Hot Water, Tier 1 (non-condensing) | 300-10,000 | CE | 80% | 85% |
| Hot Water, Tier 2 (condensing) | 300-10,000 | CE | 80% | 90% |
| Steam | 300-10,000 | CE | 80% | 83% |

* + 1. Annual Energy Savings
       1. For calculating energy savings, the following assumptions are used:
          1. The high-efficiency boiler has the same rated input (measured in MBtu/hr) as the boiler being replaced.
          2. Both boilers 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).
          3. The average combustion efficiency of hot water and steam boilers for calculating energy savings is assumed to be equal to the average combustion efficiency of the high efficiency boilers in the CEC Appliance Database6 that qualify:

Tier 1 hot water boilers with rated input ≤2 MMBtu/hr range from 85% to 87%, with an average of 85.6%.

Tier 1 hot water boilers with rated input >2 MMBtu/hr range from 85% to 87%, with an average of 85.5%.

Tier 2 hot water boilers with rated input ≤2 MMBtu/hr range from 90% to 98.3%, with an average of 94.4%.

Tier 2 hot water boilers with rated input >2 MMBtu/hr range from 90% to 96.9%, with an average of 93.4%.

Steam boilers with rated input ≤2 MMBtu/hr range from 83% to 86%, with an average of 83.2%.

Steam boilers with rated input >2 MMBtu/hr range were all 83%, with an average of 83%.

* + - 1. With these assumptions, the energy saved by a new high-efficiency boiler is calculated as follows:

*∆Q = t X LF X (R/100) X (1- Eb/Em)* ***Eqn-1***

* + - 1. Where
         1. *∆Q* – Energy Saved (therms/yr). Savings which results from installing the high-efficiency equipment.
         2. *t* – Scheduled Annual Operating Time (hrs/yr). The scheduled operating time represents the time that gas equipment is expected to be in operation or available for operation at any rated input (zero load, part load, or full load). Hours when the equipment is shut down are not included.
         3. *LF* – Load Factor. The load factor is the average load during the scheduled operating time, and is calculated by dividing the actual gas consumption by the maximum possible gas consumption during the scheduled operating time. For non-modulating equipment (e.g., most storage water heaters), the load factor represents the fraction of time that the boiler is operating at its nameplate rated input. For modulating equipment (e.g., most boilers), the load factor can be interpreted in one of two ways: 1) the equivalent fraction of the operating time that the gas equipment operates at its nameplate rated input, or 2) the average input (as a fraction of its nameplate rated input) during the operating time. For a given time interval, a modulating gas system may operate at both part load and full load.
         4. *R* – Rated Input (MBtuh). The rated input is the maximum firing rate, which is generally equivalent to the nameplate rating. The baseline and high-efficiency boilers are assumed to have the same rated input.
         5. *Eb* – Baseline Efficiency (%). Efficiency of the baseline boiler being replaced (also called the reference efficiency).
         6. *Em* – Measure Efficiency (%). Efficiency of the new high-efficiency boiler.
      2. The estimated energy savings for all three categories are shown in Table 5. The data and calculations are included in an Excel file embedded as Attachment B.

1. Annual Energy Savings by Equipment Type

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Equipment Type** | **Tier 1 Hot Water Boiler** | | **Tier 2 Hot Water Boiler** | | **Steam Boiler** | |
| **Rated Input (MMBtu/hr) 🡪** | **≤ 2** | **2 – 10** | **≤ 2** | **2 – 10** | **≤ 2** | **2 – 10** |
| Scheduled Annual Operating Time | 4,305 | 5,545 | 4,305 | 5,545 | 3,479 | 4,711 |
| Average Load Factor | 28.0% | 23.0% | 25.3% | 21.0% | 29.0% | 30.8% |
| Average Rated Input | 1,273 | 3,920 | 1,273 | 3,920 | 1,257 | 5,310 |
| Average Base Efficiency | 80% | 80% | 80% | 80% | 80% | 80% |
| Qualifying Measure Efficiency | 85% | 85% | 90% | 90% | 83% | 83% |
| Average Measure Efficiency | 85.6% | 85.5% | 94.4% | 93.4% | 83.2% | 83.0% |
| Annual Energy Savings (therms/yr/unit) | 1,065 | 3,412 | 2,483 | 7,609 | 506 | 2,893 |
| Annual Energy Savings (therms/yr/MBtuh) | 0.836 | 0.870 | 1.950 | 1.941 | 0.403 | 0.545 |
| Annual Energy Savings (therms/yr/MBtuh) | **0.85** | | **1.95** | | **0.47** | |

* + - 1. The estimated gas savings for SoCal territory were then used to calculate the savings for all 16 weather climate zones in California. From the basic principle of thermodynamics, the energy used by a boiler to raise the temperature of water is calculated by (Q = MC.∆T). Assuming no changes on the boiler operating condition, the Mass flow rate and Specific heat of water for the 16 weather zones should be the same. However, the water temperature difference will vary for the 16 weather zones, since the ground source water temp for these zones averages from (51 to 75°F). Therefore, the previous energy balance equation can be simplified in the following correlation formula:

*∆Q zones (1-16) = ∆Qzone-9(SoCal) x (TSoCal - TMixed temp. zones (1-16)) / (TSoCal - TMixed temp. zone9) Eqn-2*

Where:

* + - * 1. *∆Q* = Energy Saved (therms/yr). Savings which results from installing the high-efficiency measure equipment for each boiler category and weather zone.
        2. T = Supply & Return Temperatures of the hot water leaving and entering the boiler, respectively.
        3. *Subscript zones (1-16)* = California weather zones 1 thru 16, measure (new high-efficiency) equipment.
        4. *Subscript zone-9(SoCal)* = SoCal savings, used as baseline (reference) equipment
        5. *Subscript Mixed temperature* = The mixed water temp entering the boiler will include the following:
* Return water and makeup water (for HW boiler)
* Return water, makeup water and the condensate from the flue gas water vapor (for condensing boiler)
* Steam condensate return, makeup water and steam preheating the feedwater at the deareator (for steam boiler).
  + - * 1. Mixed Temperature was included in equ.2 for the proposed measure (zones 1-16) and baseline (standard, zone-9).
        2. The Supply temperature for three boiler categories used in the calculations, and shown in Table-6, were based on Commercial & Industrial sets of data used in other SCG documents, such as the Pipe Insulation workpaper.

1. Fluid Temperature Specification and Assumptions

|  |  |  |  |
| --- | --- | --- | --- |
| **Working Fluid** | **Rated Input (MMBtu/hr)** | **Fluid Temperature (°F)** | |
| Specification | Used in Analysis |
| Hot Water Boiler | Any | 120-200 | 150 |
| Condensing Boiler | Any | 160-200 | 180 |
| Small Steam Boiler | ≤ 2 | 200-250 | 241 |
| Large Steam Boiler | 2 – 10 | 250-500 | 328 |

* + - 1. The estimated energy savings of the three boiler categories in the California’s 16 weather zones are shown in the Measure Summary Table. The data and calculations are included in the Excel file of Attachment B.

1. Base Case & Measure Costs
   1. Base Case Cost
      1. When the customer is replacing equipment on burnout (ROB) or buying new equipment (NEW), the customer must buy a new boiler to continue operating, so the base case cost is that of a baseline (standard) boiler.
      2. The base case costs are shown in Table 6 below.
         1. The upper section of the table lists the 2008 DEER cost data taken from the “2011 Database for Energy-Efficient Resources (DEER) for Use in the California IOU 2013-14 Energy Efficiency Planning”6. The average base case costs are the average of the measure cost for boilers with medium rated input (between 300 and 2,500 MBtu/hr) and with large rated input (over 2,500 MBtu/hr). In addition, the equipment efficiency ranges used for the DEER cost data do not match the equipment efficiency ranges used in this workpaper.
            1. The 2008 DEER base thermal efficiency for medium rated input is 75%.
            2. The 2008 DEER base combustion efficiency for large rated input is 75%.
         2. The middle section of the table lists the results of a survey of equipment vendors that sell process hot water and steam boilers in California. The vendor calls produced data for the categories of boiler type, rated input, and efficiency used in this workpaper. The base measure costs shown in Table 6 represent an arithmetic average of the equipment cost per MBtu/hr in each category.
         3. The lower section of the table lists the average of the DEER cost data and the survey data. The data and calculations are included in an Excel file embedded as Attachment C.
   2. Gross Measure Cost
      1. The gross measure costs include the cost of the equipment, excluding installation and start-up costs. For the purposes of determining incremental measure costs, the installation and start-up costs are assumed to be the same for the base case and measure equipment.
      2. The gross measure costs are shown in Table 7 below.
         1. The upper section of the table lists the 2008 DEER cost data taken from the “2011 Database for Energy-Efficient Resources (DEER) for Use in the California IOU 2013-14 Energy Efficiency Planning”6. The average gross measure costs are the average of the measure cost for boilers with medium rated input (between 300 and 2,500 MBtu/hr) and with large rated input (over 2,500 MBtu/hr). In addition, the equipment efficiency ranges used for the DEER cost data do not match the equipment efficiency ranges used in this workpaper.
            1. The 2008 DEER measure thermal efficiency for medium rated input is 85%.
            2. The 2008 DEER measure combustion efficiency for large rated input is 85%.
         2. The middle section of the table lists the results of a survey of equipment vendors that sell hot water and steam space heating boilers in California. The gross measure costs shown in Table 7 represent an arithmetic average of the equipment cost per MBtu/hr in each category.
         3. The lower section of the table lists the average of the DEER cost data and the survey data. The cost data and calculations are included in an Excel file embedded as Attachment C.
   3. Incremental Measure Cost
      1. The incremental measure cost (IMC) is the difference between the average base case cost and the average gross measure cost.
      2. The incremental measure costs are shown in Table 7 below.
2. Gross and Incremental Measure Cost by Equipment Type

|  |  |  |  |
| --- | --- | --- | --- |
| **Equipment Type** | **Process Hot Water Boiler, Tier 1** | **Process Hot Water Boiler, Tier 2** | **Process Steam Boiler** |
| **Rated Input (MMBtu/hr) 🡪** | **≥ 300** | **≥ 300** | **≥ 300** |
| **2008 DEER Cost Data** | | | |
| Average Base Cost ($/MBtuh) | $9.33 | N/A | N/A |
| Average Gross Measure Cost ($/MBtuh) | $10.72 | N/A | N/A |
| Average Incremental Measure Cost ($/MBtuh) | **$1.39** | N/A | N/A |
| **2012 Vendor Survey Data** | | | |
| Average Base Cost ($/MBtuh) | $12.22 | $12.22 | $14.89 |
| Average Gross Measure Cost ($/MBtuh) | $15.17 | $22.95 | $19.24 |
| Average Incremental Measure Cost ($/MBtuh) | **$2.95** | **$10.73** | **$4.35** |
| **Average of DEER and 2012 Vendor Survey Data** | | | |
| Base Case ($/MBtuh) | $10.78 | $10.78 | $14.89 |
| Average Gross Measure Cost ($/MBtuh) | $12.94 | $22.95 | $19.24 |
| Average Incremental Measure Cost ($/MBtuh) | **$2.17** | **$12.17** | **$4.35** |

Attachments

Attachment A – Average Input and Load Factor Calculations



Attachment B – Process Boiler Annual Gas Savings Data and Calculations



Attachment C – Process Boiler Cost Data and Calculations



Attachment – Complete Measure List



References

1. *Space Heating Boilers Workpaper*, Revision A, EEA Report No. B-REP-06-599-01A, March 20, 2006.

    [↑](#endnote-ref-1)
2. *DEER Database for Energy-Efficient Resources*, Version 2011 4.00, For Use in the California IOU 2013-14 Energy Efficiency Planning (Accessed Mar. 7, 2012 at <http://www.deeresources.com/>). [↑](#endnote-ref-2)
3. “Revised DEER Measure Cost Summary (05\_30\_2008) Revised (06\_02\_2008)\_Original.xls”, <http://www.deeresources.com/index>

    [↑](#endnote-ref-3)
4. *California Energy Commission Appliance Efficiency Database* (Accessed March 7, 2012 at <http://www.appliances.energy.ca.gov/AdvancedSearch.aspx>). [↑](#endnote-ref-4)
5. *DEER Database for Energy-Efficient Resources*, Version 2011 4.00, For Use in the California IOU 2013-14 Energy Efficiency Planning (Accessed Mar. 7, 2012 at <http://www.deeresources.com/>). [↑](#endnote-ref-5)
6. Technology and Measure Cost Data/Effective and Remaining Useful Life (EUL/RUL) Values, <http://www.deeresources.com/index>. (EUL\_Summary\_10-1-08.xls)

    [↑](#endnote-ref-6)
7. *DEER 2011 Net-To-Gross Ratios*, “DEER2011-NTG\_IncludingCarryoversFromDEER2008\_2011-12-07.xls”,

    [↑](#endnote-ref-7)