Work Paper WPSCGREWH180305A

**Revision 0**

**Southern California Gas Company**

**Customer Programs Department**

**Multi-Family Central Boiler Dual Setpoint Temp. Controller**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | MF-Dual-setpoint-temp-control |
| **Measure Description** | Adding a dual outdoor temperature reset and burners staging controller to a central hot water boiler. |
| **Base Case Description** | Central hot water boiler with a basic aquastat controls serving an existing hydronic system in multi-family building. |
| **Units** | per dwelling |
| **Energy Savings** | 8 to 15 therms per year per dwelling unit depending on Climate Zone |
| **Full Measure Cost ($/unit)** | $167 per dwelling unit |
| **Incremental Measure Cost ($/unit)** | REA = $167 and ER = $131 per dwelling unit |
| **Effective Useful Life** | 20 years (High Efficiency Boiler, DEER EUL ID: WtrHt-Instant-Res)  RUL = 6.67 years |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | ET-Default: Emerging Technologies approved by ED through work paper review |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 3/5/18 | Raad Bashar, SCG. | * New workpaper |
| 0 | 3/22/18 | Bo White & Marc Esser, NegaWatt Consulting | * Performed energy analysis (section-2) and cost estimates (section-4) |

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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This energy efficiency measure is based on the addition of an advanced electronic controller to a central HW boiler in MF residential buildings. Better insulation and tighter envelopes are reducing space heating loads for new and existing MF homes. As a result, decreased space heating loads make it possible

for both space and domestic water heating loads to be provided with a single heating plant, thus saving significant amounts of energy.

The base case is a centralized gas-fired hot water boiler serving dwelling-units with combined space heating and domestic hot water. The system operates with no controls or basic aquastat tank temp setpoint using manufacturer’s built-in controller with tank temp feedback from an analog thermostat. The basic aquastat control lacks accuracy, requires extensive calibration, and inefficiently allow all stages to fire at once (on/off). The aquastat high limit and a low limit tank temperature setpoint are widely used in older boilers. Emerging Technologies field evaluation report supports this baseline that the typical on-site operation is the constant, single aquastat setpoint of roughly 130°F with both boiler states jumpered together. (Attachment B, page 16.)

The measure case utilizes an electronic controller that responds to hot water demand and weather conditions by controlling the supply water temperature setpoint reset based on outside air temperature. With that, it fires the fewest stages needed to meet the heating load.

The application of combi systems (combined space heating and domestic hot water) during warmer weather allow the temperature of hot water delivered to the dwelling units to be turned down from 135°–140°F to about 120°F. This reduction in temperature setpoint allows the system to operate at lower heating capacity and reduces pipe heat loss in the distribution system, thereby saving energy. Furthermore, the advanced controller monitors return water temperature to further reduce supply water setpoint during periods of warmer weather and/or low building heating demand. Another feature is burner staging optimization to prevent temperature setpoint overshooting or short cycling.

Table 1: Base, Standard, and Measure Cases

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Dual setpoint temp controller |
| Existing Condition | No controls or basic aquastat tank temp control |
| Code/Standard | DEER 2016 required Outdoor temp reset control for HW boilers |
| Industry Standard Practice | N/A |

Table 2: Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| 540758 | TBD | TBD | TBD | MF Dual setpoint temperature controller |

**General Eligibility Requirements:**

* The energy efficiency measure is applicable to existing multifamily residential buildings that have a centralized, gas-fired hot water boiler serving a combi system. Combined hydronic systems utilize one heat source that provides both space heating and domestic hot water, figure 1.
* **Boilers were installed before the year 2005** (i.e. Not in DEER Outdoor temperature reset requirement).
* Boilers with integrated reset controls are not eligible.

**Implementation and Installation Requirements:**

* Controller installation and configuration shall be per the controller vendor’s installation manual.
* Refer to Appendix-A, for the General Sequential Installation and Configuration Steps and Troubleshooting.

**Mandatory Requirements for Program Restrictions and Guidelines:**

* The controller must have the capability to provide hot water temperature modulation with outdoor temperature changes.
* The controller is wired and programmed for burner sequencing (stage and rotate) up to 2 on/off boilers, or a single 2 stage boiler.
* Run fewer stages for longer periods to avoid purging losses.

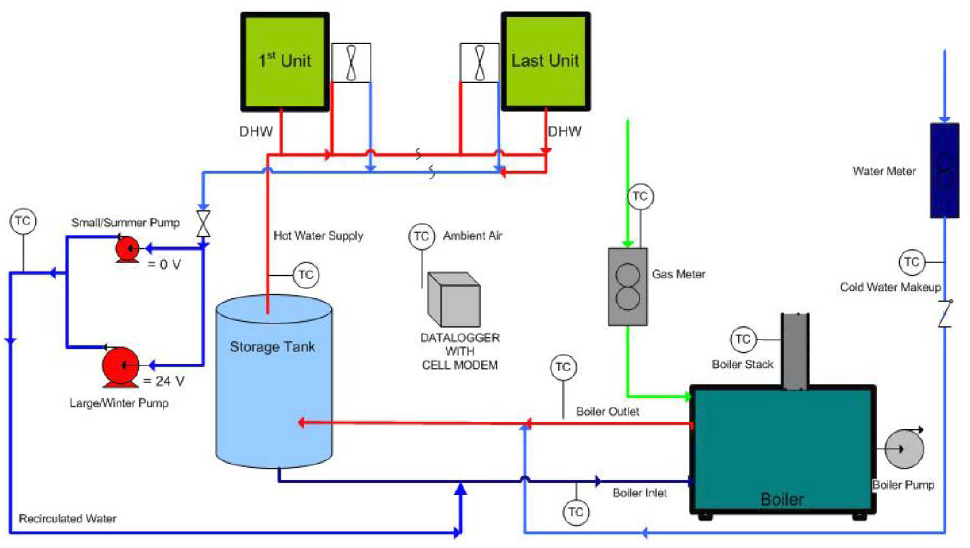


Figure 1: Typical Apartment Complex: Combined Duty HW Diagram

## 1.2 Technical Description

According to the Residential Water Heating Program (Gas Technology Institute, 2012), “Combined hydronic systems present an attractive option for high efficiency homes because these systems utilize one heat source that provides both space heating and domestic hot water.” In other words, implementing energy savings measures in such combined systems provides good value since the two largest gas end uses are addressed at one location.

Like other Space Heating systems including boilers and furnaces, combi system efficiencies may be negatively impacted by low Space Heating load in warmer weather climate applications and during shoulder months of the heating season. Cycling losses associated with turndown and standby losses become a higher factor into overall efficiencies. Therefore, Combi system performance would benefit from control strategies that account for low Space Heating loads relative to burner capacities.

The application of combi systems during warmer weather allow the temperature of hot water delivered to the dwellings units to be turned down from 135°–140°F to about 120°F, figure-2.

Temperature Trends

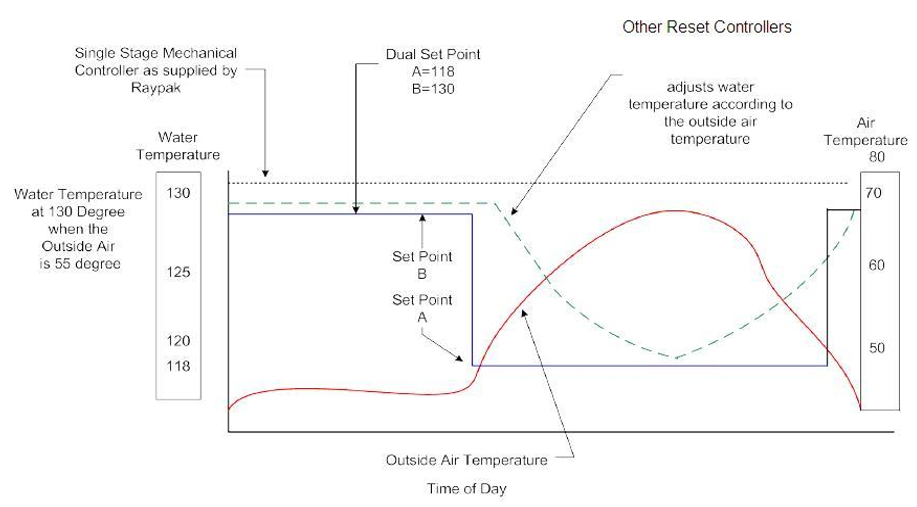


Figure 2*:* Dual Setpoint Controller for Shared Combination Service Systems

## 1.3 Installation Types and Delivery Mechanisms

The installation type for this energy efficiency measure, indicated in Table 3, is a Retrofit Add-on (REA). The measure involves the installation of more advanced control with additional sensors to replace the basic aquastat tank temp control in the system or upgrades the existing uncontrolled hot water boiler with a more advanced controller.

Table 3: Installation Type Descriptions

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | | **Life** | |
| 1st Baseline (BL) | 2nd BL | | 1st BL | 2nd BL |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | | EUL | N/A |
|  |  | |  |  |  |

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

Table 4: Delivery Method Descriptions

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Prescriptive Rebate  (PreReb) | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. |
| Direct Install (DirInstall) | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

The DEER2016 established a new baseline for Hot water boilers, conventional and condensing types, of all sizes. In that, a hot water loop temperature reset control was added to all simulations for vintages starting with 2006 based on Title 24 requirements that have been in place since October 2005. The baseline reset control for DEER is assumed to be an outdoor temperature-based control that resets hot water temperature between 165 and 140 F for the conventional type boiler. For condensing boilers, the outdoor temperature reset control had a reduced temperature range of 140 to 115 F, (Attachment-A).

Even though these reset temperature ranges are applicable to “Commercial boilers” that serve space heating or process heating loads greater than 140 deg. F, the Central HW boiler in this workpaper is mainly dedicated to domestic water heating loads with a HW loop setpoint temperature of < 140°F. However, the workpaper will not violate that rule and will exclude newer boilers from this measure.

Therefore, this measure applies only to HW boilers that were installed before the year 2005 (i.e. No reset required in DEER and T-24 code). In addition, the dual setpoint temp control will provide OA reset temp and burner staging controls.

Table 5: DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | N/A |

**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. Field evaluations had been conducted by So Cal Gas Emerging Technologies Programs. See Attachment B and C.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| ET-Default | Emerging Technologies approved by ED through work paper review | Any | Any | Any | 0.85 |

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

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

**Effective and Remaining Useful Life**

The effective useful life (EUL) for the HW boiler controls of 20 years is taken from the DEER 2014 for commercial SHW EULs. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

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

### 1.4.2 Codes and Standards Analysis

The 2005 Title-24code states the following:

*Section 144 (j) 4: Chilled and Hot Water Temperature Reset Controls. Chilled and hot water systems with a design capacity exceeding 500,000 Btu/h supplying chilled or heated water (or both) shall include controls that automatically reset supply water temperatures as a function of representative building loads or outside air temperature.*

Table 6: Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 20 (2016) | N/A |  |
| Title 24 (2016) | Section 144 (j) 4: Chilled and Hot Water Temperature Reset Controls | October 1, 2005 |

See Attachment A, Baseline Summary worksheet for the baseline assumption.

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

The following studies provided a reasonable savings estimate from the addition of boiler controller in MF residential space and water heating system.

### Study Title:

### Combination Boiler Reset Controller Field Evaluation, So Cal Gas Emerging Technologies Program

NegaWatt Consulting, Inc., July 2015, (*Attachment B)*

The objective of this study was to evaluate the energy and cost savings of five retrofit boiler controllers that save energy by providing more sophisticated control than constant storage tank water setpoint with an aquastat. The tested controllers either provide outside air reset, dynamically modify setpoint dead-band by delaying burner firing, or measure proxy demand data to determine periods of low demand when a lower setpoint is acceptable.

The controllers were tested on integrated combination boilers i.e. “Raydronics” systems that provide both domestic hot water and heating hot water for fan coils in a single loop to multiple residencies in a multi-family residence (MFR) complex. The baseline for each controller will be its respective boiler with the controller disabled and with the tank supply water temperature set to a constant setpoint.

### A Dual Setpoint Controller for Combination Service Boilers (Emerging Technologies Program)

Information and energy Services, Inc. (IES), 2011, (*Attachment C)*

Information & Energy Services, Inc. under contract with Sempra Energy – Emerging Technologies Program, studied the effects of a boiler controller in a real-world application at eight (8) southern California multi-family residential facilities.

The controller reduces the water temperature set-point when space heating is not required. The savings are achieved in two ways; first by controlling the set point temperature of the water in the storage tank, then by controlling the firing rate of the boiler. An average savings of 21.6% or 5.7 therms saved per month per apartment was calculated in this study.

As an example of the analysis performed, the Anaheim site uses two boilers of the same size and have roughly the same load (same number of apartments served) were directly compared by assuming that the optimized boiler would behave in the same way as the baseline boiler if the controller had not been installed. The performance of the controller with respect to Outdoor air temperature and the monthly Therms consumed per unit-day by the baseline and optimized boilers are shown in Figures 3 and 4, below.

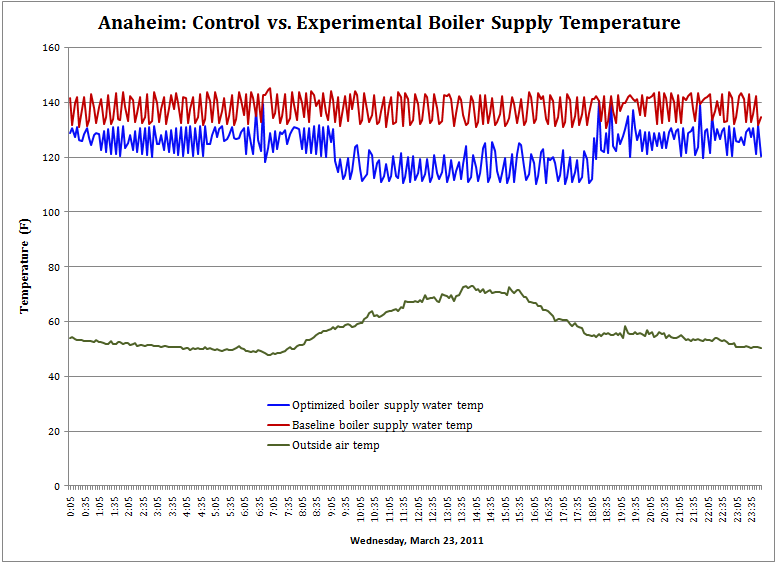


Figure 3: Performance Temperature Trends

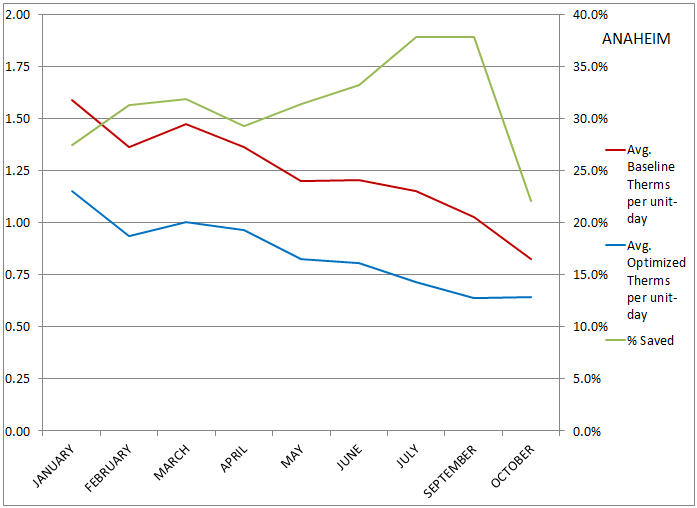


Figure 4: Retrofit Controller Performance

## 1.6 Data Quality and Future Data Needs

Based on the previous two studies, NegaWatt Consulting was hired to model a Combi system in a MF building that operates with a basic control (aquastat) in the baseline with an advanced electronic controller for the proposed measure case. EnergyPlus software program was selected to model the Hydronic Combi system and the dual setpoint controls.

# Section 2. Calculation Methodology

OpenStudio[[1]](#endnote-1), which is based on EnergyPlus[[2]](#endnote-2), was used to calculate the energy savings. MASControl2[[3]](#endnote-3), which is based on eQuest[[4]](#endnote-4), could not be used because eQuest does not support combination boilers with supply water outdoor air temperature reset. Instead, one MASControl2 model for one Climate Zone (i.e., Climate Zone 9) was selected, exported, and used as a guideline when creating the OpenStudio baseline model for that Climate Zone. In addition, the DEER Water Heater Calculator spreadsheet[[5]](#endnote-5) was used as a guideline for annual water heating gas usage and the DEER Thermostat spreadsheet[[6]](#endnote-6) was used a guideline for annual space heating gas usage.

Two other Climate Zones (6 and 16) were modeled in OpenStudio. A linear trendline of annual gas savings versus heating degree days at a 50°F basepoint for the three Climate Zones was used to estimate savings for the other Climate Zones.

Note that there are a few significant differences between the energy modeling approach and the field study approach. First, the building characteristics (e.g., building size, gas demand) and heating plant characteristics (e.g., system efficiency, recirculation loop size, pump flow rate and control) are different. Second, only one full load burner stage at constant efficiency was implemented in the energy models, so potential savings from short cycling reduction or otherwise were not captured. OpenStudio supports multiple distinct boiler stages and variable boiler efficiency based on part load ratio and/or return water temperature, but it is not straightforward to properly implement and savings from short cycling prevention are not modeled.

The MASControl2 settings and some building characteristics are shown in the below table. Domestic hot water and space heating energy usage is not shown because the DEER Water Heating Calculator spreadsheet (i.e., “DEER-WaterHeater-Calculator-v2.1.xlsm”) and the DEER Thermostat spreadsheet (i.e., “DEER2017-MultiFamily\_Tstat-Weights-2016-07-20.xlsm”) are more appropriate for that.

Table 7: MASControl2 Assumptions & Results

|  |  |
| --- | --- |
| **Item** | **Value** |
|
| Building Type | Residential multi-family |
| Climate Zone | 9 |
| Vintage | 2002-2005 (i.e., 2003) |
| HVAC System(s) | “rDXGF” (i.e., packaged units with compressor and gas furnace) |
| Case(s) | Pre-existing |
| Thermostat Index | 3 |
| Residential Unit Quantity and Floor Area | 12 residential units; 1,000 square feet each |
| Total floor area | 13,518 square feet (12,000 conditioned, 1,518 unconditioned) |
| Water heater type | Individual gas-fired storage water heaters |

The DEER Water Heater Calculator assumptions and results are shown in the table below. Note that the calculator reports hot water usage at 135°F, even though residential fixtures can be satisfied with a mixed water temperature of 115°F. OpenStudio supports specification of draw schedules at mixed water temperatures and flow rates, so an appropriate calculation was performed. Note also that the recovery efficiency here is lower than the efficiency of the boiler in the OpenStudio models, and the boiler is assumed to not have a standing pilot light.

Table 8: DEER Water Heater Calculator Assumptions & Results

|  |  |
| --- | --- |
| **Item** | **Value** |
|
| Building Type | Residential multi-family |
| Climate Zone | 9 |
| Water heater type | Gas-fired storage, 30 gallons, 0.59 EF |
| Water heater capacity | 30,000 Btu/hr |
| Water heater recovery efficiency | 0.758 |
| Water heater tank UA | 7.996 Btu/hr-°F |
| Water heater auxiliary (i.e., standing pilot light) Btu/hr | 350 Btu/hr |
| Water heater auxiliary efficiency | 0.67 |
| Water heater location | Garage |
| **Domestic hot water usage [water]** | **37.6 gallons/residential unit/day of 135°F hot water** |
| **Domestic hot water usage [gas]** | **164.8 therms/residential unit/yr (105.8 excluding tank heat loss and standing pilot light)** |

The DEER Thermostat spreadsheet assumptions and results are shown in the table below. The five thermostat schedules in the spreadsheet were weighted using the weights in the spreadsheet, which approximately gave a heating setpoint of 73°F.

Table 9: DEER Thermostat spreadsheet

|  |  |
| --- | --- |
| **Item** | **Value** |
|
| Building Type | Residential multi-family |
| Climate Zone | 9 |
| Vintage | 2003 |
| HVAC System(s) | “rDXGF” (i.e., packaged units with compressor and gas furnace) |
| Average Thermostat Heating Setpoint | ~73°F (after weighting the five thermostat schedules) |
| **Space heating gas usage** | **56.4 therms/residential unit/yr** |

Since there is no automated tool to convert eQuest model files to OpenStudio or EnergyPlus files, the “Create DOE Prototype Building” measure within OpenStudio’s Building Component Library was used to create the first OpenStudio model. “MidriseApartment” was selected as the building type, ASHRAE 90.1-2007 was selected as the energy code, and “ASHRAE 169-2006-3B” was selected as the climate zone. The building geometry, materials, water heating systems, and HVAC systems were then manually modified to match the properties of the MASControl2 eQuest model and the energy usage in the DEER spreadsheets. The Climate Zone file was upgraded to the latest California version. See below for screenshots of the building geometry and heating system, and a table showing the major assumptions. Details are in *Attachment-D*.

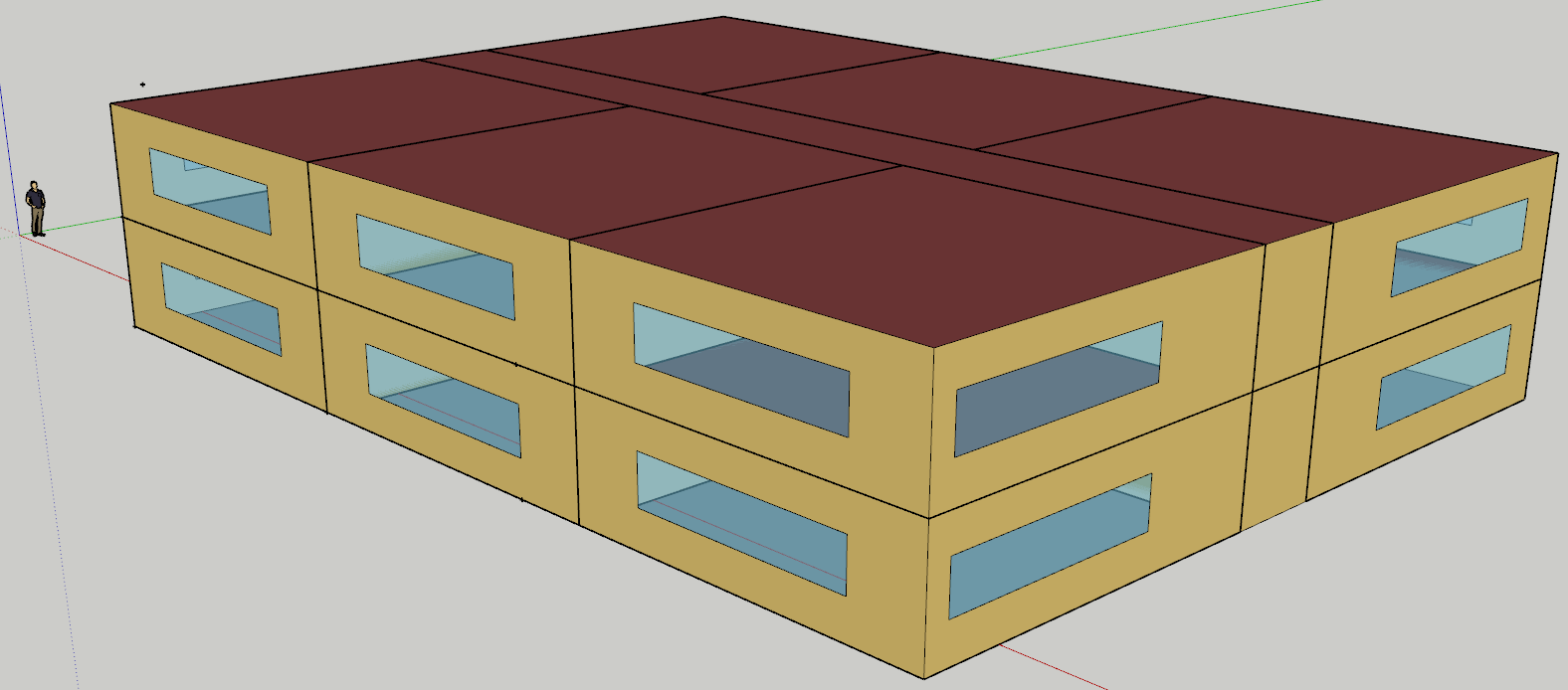


Figure 5: Building Geometry

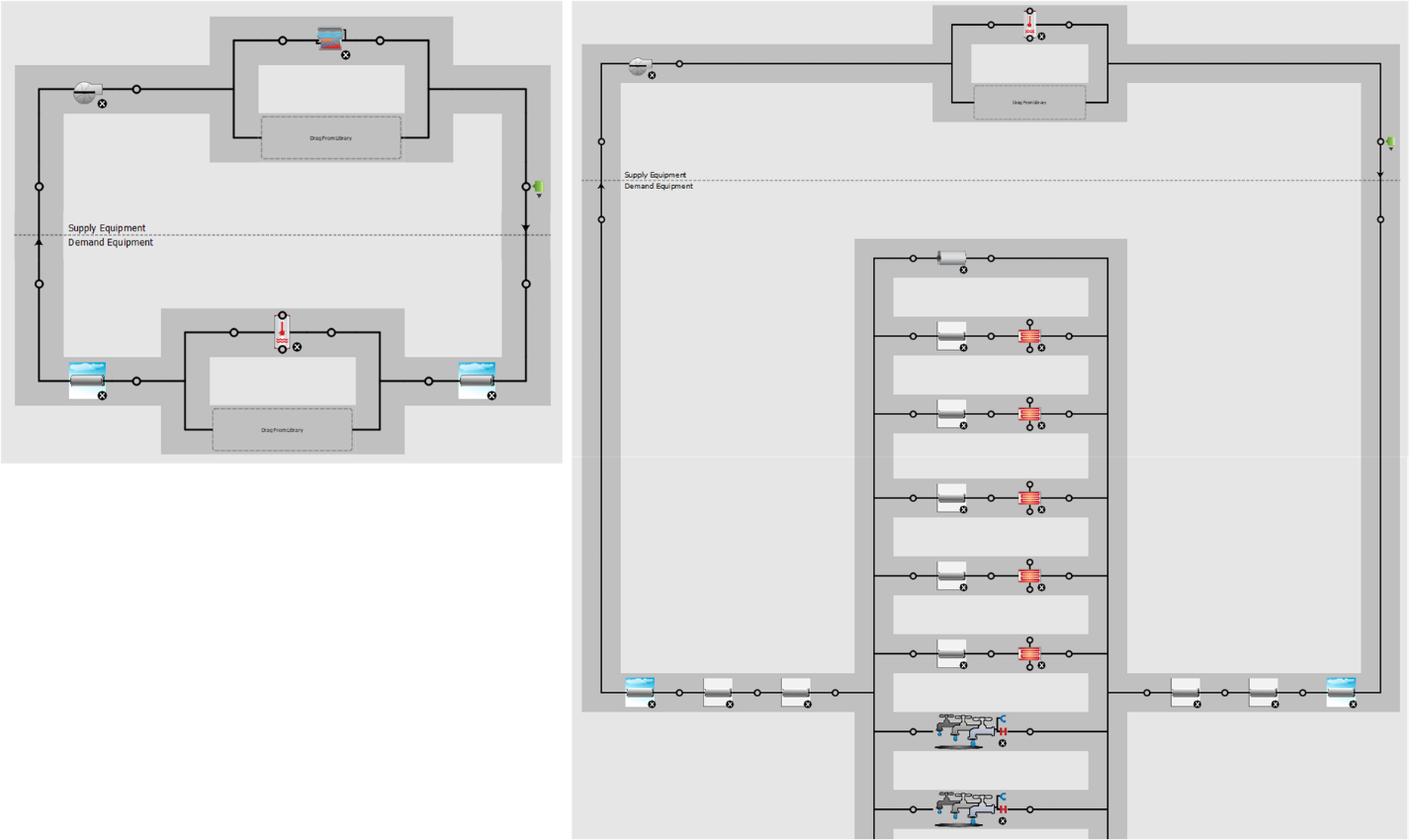


Figure 6: Primary & Secondary Loop (later partially shown for brevity)

Table 10: OpenStudio Model Assumptions

|  |  |
| --- | --- |
| **Item** | **Value** |
|
| Building Type | Residential multi-family |
| Climate Zone | 6, 9, and 16 |
| Vintage | Envelope matches the MASControl2 model |
| HVAC System(s) | Packaged units with compressor and HHW coil |
| Thermostat Setpoints | Cooling Setpoint of 75°F, heating setpoint of 73°F |
| Residential Unit Qty. and Floor Area | 12 residential units; 1,000 square feet each |
| Total floor area | 13,518 square feet (12,000 conditioned, 1,518 unconditioned) |
| Water heating system type | Central combination heating system: boiler; storage tank; primary-secondary constant volume pumping; heating hot water coils and domestic water fixtures on the same loop. |
| Boiler output capacity | Climate zones 6 & 9: 272,495.7 Btu/hr (auto-sized with 1.5 sizing factor)  Climate zone 16: 375,972.6 Btu/hr (auto-sized with 2.0 sizing factor) |
| Boiler recovery efficiency | 0.80 |
| Boiler temperature delta | 20°F |
| Tank setpoint and differential temperature | Baseline: 135°F, 5°F temperature differential  **Proposed: 135°F/120°F (at 55°F/75°F ambient hourly), 5°F differential** |
| Primary pump flow rate | Climate zones 6 & 9: 27.2 gpm (auto-sized per sizing factor)  Climate zone 16: 37.5 gpm (auto-sized per sizing factor) |
| Primary pump head | 15 feet |
| Secondary pump flow rate | Climate zones 6 & 9: 40.0 gpm (selected), constant speed  Climate zone 16: 50.3 gpm (auto-sized), constant speed |
| Secondary pump head | 40 feet |
| Tank UA | 7.996 Btu/hr-°F |
| Tank capacity | Climate zones 6 & 9: 150 gallons (selected)  Climate zone 16: 200 gallons (selected) |
| Central plant location | Outdoors |
| Hot water usage | 52.3 gallons/day/residential unit of 115°F mixed water at the fixtures |
| Piping material | Copper with no insulation |
| Piping length and diameter | 20' of 2" pipe outdoors; 110' of 2" indoor pipe; 380’ of 1.5" indoor pipe; 120' of 3/4" indoor pipe at fan coils |
| Temperature around indoor pipe | 70°F |
| Heating hot water coil design conditions | 130°F entering water; modulating control valves.  Climate zones 6 & 9: 30°F temperature delta  Climate zone 16: 20°F temperature delta |

Excluding standing pilot light energy usage and tank heat loss, the Climate Zone 9 OpenStudio baseline model showed approximately 102 therms per residential unit per year for water heating, which is similar to the 106 therms in DEER Water Heater Calculator. The model shows 51 therms for space heating, which is close to the 56.4 therms in the DEER Thermostat spreadsheet.

For each pair of baseline and proposed model, the only difference is the supply water setpoint temperature. For the baseline models, the setpoint is fixed at 135°F. The proposed models have linear outdoor air reset. The setpoint is fixed at 135°F at outdoor temperatures less than or equal to 55°F, it’s fixed at 120°F for outdoor temperatures greater than or equal to 75°F, and it’s linear in between. The below screenshots show the baseline and proposed supply water temperature and setpoint for Climate Zone 9.

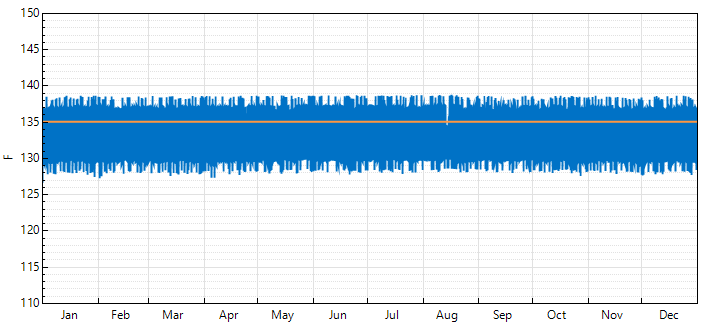


Figure 7: Climate Zone 9 Baseline Heating Supply Water Temperature and Setpoint

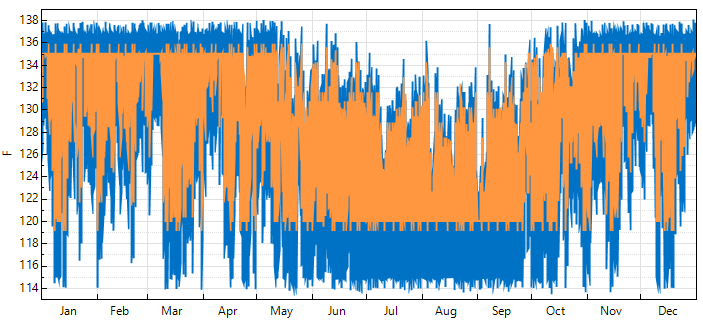


Figure 8: Climate Zone 9 Proposed Heating Supply Water Temperature and Setpoint

The OpenStudio gas savings results per residential unit are shown in the below table. The energy savings at the primary pump is not shown because it was less than 1 kWh per residential unit. Pump savings would be higher for higher primary pump head and/or flow rate.

Table 11: OpenStudio Gas Savings Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate Zone** | **Boiler Gas Usage [therms/unit/yr]** | | | |
| **Baseline** | **Proposed** | **Savings** | **Savings [%]** |
| 6 | 303.6 | 290.9 | **12.68** | **4.2%** |
| 9 | 292.4 | 278.2 | **14.16** | **4.8%** |
| 16 | 521.0 | 513.1 | **7.98** | **1.5%** |

The below table includes a breakdown of gas savings by end use. The end use categories are domestic hot water, heating hot water, tank heat loss, pipe heat loss, and a small uncategorized amount that might be due to a minor software issue. Heat transfer from the pump to the fluid offset a small portion of heating demand. OpenStudio reports demand in Btu/hr, but those values were converted here to therms using the boiler efficiency of 80%. The only way to vary boiler efficiency in OpenStudio is to input an efficiency curve that can vary with boiler firing rate and/or return water temperature. OpenStudio does not account for short cycling, nor is it easy to implement two boiler firing stages. For these reasons and since constant speed boiler pumping (i.e., primary pumping) is standard at these boiler capacities, the boiler was simply modeled as having only one stage, no firing rate modulation, and constant speed primary pumping.

As shown in the first column under Gas Savings, essentially all the savings come from the pipe heat loss reduction, as expected. The Baseline Gas Usage Percent of Demand column shows that when pipe heat loss is a greater portion of the total building gas demand, then outside air reset yields more savings. Pipe heat loss is higher for larger piping systems, higher flow rates, and higher set point temperatures.

Table 12: OpenStudio Gas Savings by End Use

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Climate Zone** | **End Use** | **Baseline Gas Usage** | | **Proposed Gas Usage** | | **Gas Savings** | |
| **therms/ unit/yr** | **Percent of Demand** | **therms/ unit/yr** | **Percent of Demand** | **therms/ unit/yr** | **Percent** |
| 6 | Domestic Hot Water | 106.06 | 33.2% | 106.06 | 34.6% | 0.00 |  |
| Heating Hot Water | 51.24 | 16.1% | 51.24 | 16.7% | 0.00 |  |
| Tank Heat Loss | 5.15 | 1.6% | 4.75 | 1.6% | 0.40 |  |
| Pipe Heat Loss | 156.09 | 48.9% | 143.86 | 47.0% | 12.24 |  |
| Uncategorized | 0.43 | 0.1% | 0.38 | 0.1% | 0.06 |  |
| Subtotal | 318.99 | 100.0% | 306.29 | 100.0% | 12.70 |  |
| Pump Heat In | -15.42 |  | -15.40 |  | -0.02 |  |
| Total Gas Usage | 303.57 |  | 290.89 |  | 12.68 | 4.2% |
| 9 | Domestic Hot Water | 101.94 | 33.1% | 101.94 | 34.7% | 0.00 |  |
| Heating Hot Water | 51.45 | 16.7% | 51.45 | 17.5% | 0.00 |  |
| Tank Heat Loss | 5.01 | 1.6% | 4.55 | 1.6% | 0.45 |  |
| Pipe Heat Loss | 148.95 | 48.4% | 135.29 | 46.1% | 13.66 |  |
| Uncategorized | 0.42 | 0.1% | 0.37 | 0.1% | 0.06 |  |
| Subtotal | 307.78 | 100.0% | 293.61 | 100.0% | 14.17 |  |
| Pump Heat In | -15.40 |  | -15.38 |  | -0.02 |  |
| Total Gas Usage | 292.38 |  | 278.23 |  | 14.15 | 4.8% |
| 16 | Domestic Hot Water | 126.17 | 23.3% | 126.17 | 23.7% | 0.00 |  |
| Heating Hot Water | 224.64 | 41.5% | 224.64 | 42.2% | 0.00 |  |
| Tank Heat Loss | 5.90 | 1.1% | 5.63 | 1.1% | 0.27 |  |
| Pipe Heat Loss | 182.76 | 33.8% | 175.10 | 32.9% | 7.66 |  |
| Uncategorized | 1.19 | 0.2% | 1.13 | 0.2% | 0.06 |  |
| Subtotal | 540.65 | 100.0% | 532.66 | 100.0% | 7.99 |  |
| Pump Heat In | -19.60 |  | -19.59 |  | -0.01 |  |
| Total Gas Usage | 521.05 |  | 513.07 |  | 7.98 | 1.5% |

To expedite results for all other climate zones, a linear trendline of annual gas savings versus heating degree days was created from the above three climate zones and used to extrapolate the results. This is a gross but sufficient approximation. The results are shown in the below plot and table. The heating degree day data is from the CPUC’s “DEER2013-Weather-Data-Comparison.zip” zip file.

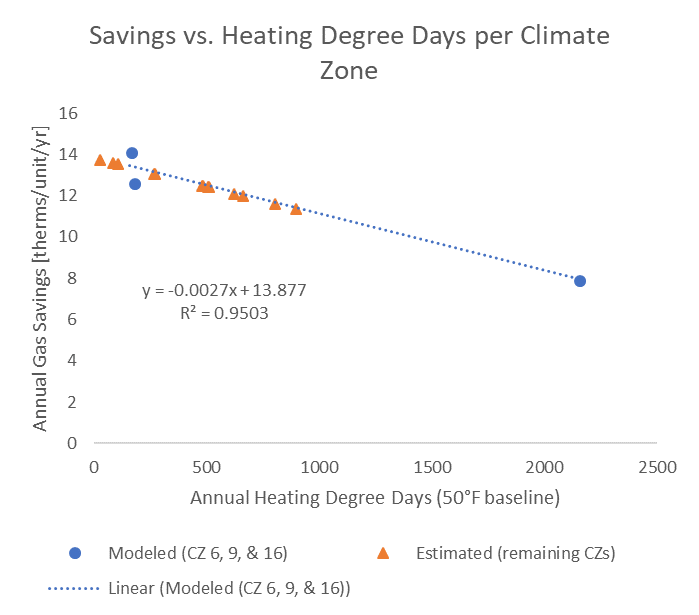


Figure 9: Statewide savings estimate

Table 13: OpenStudio Gas Savings Extrapolated to Other Climate Zones

|  |  |  |  |
| --- | --- | --- | --- |
| **Climate Zone** | **HDD at 50ۜ°F** | **Boiler Gas Usage [therms/unit/yr]** | |
| **Modeled** | **Estimated** |
| 1 | 793.3 |  | 11.7 |
| 2 | 654.8 |  | 12.1 |
| 3 | 262.2 |  | 13.2 |
| 4 | 470 |  | 12.6 |
| 5 | 475.6 |  | 12.6 |
| 6 | 173 | 12.7 |  |
| 7 | 18.9 |  | 13.8 |
| 8 | 96.5 |  | 13.6 |
| 9 | 158.7 | 14.2 |  |
| 10 | 259.8 |  | 13.2 |
| 11 | 615 |  | 12.2 |
| 12 | 503.5 |  | 12.5 |
| 13 | 496.1 |  | 12.5 |
| 14 | 889.1 |  | 11.4 |
| 15 | 77.2 |  | 13.7 |
| 16 | 2148 | 8.0 | 11.7 |

# Section 3. Load Shapes

The multifamily facilities gas load shapes are taken from the 2009 California Residential Appliance Saturation Survey (RASS).

# Section 4. Costs

## 4.1 Base Case Cost

The base case cost of an existing high limit/low limit aquastat tank temperature setpoint controller is $194 and a labor cost of $240, totaling $430. Assuming 12 residential units per central boiler (as in the energy savings section), the base case cost is $36/unit.

**Table 14: Base Case Costs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Description** | **Equipment Cost** | **Labor/Installation Cost** | **Total Cost** |
| High or Low Limit Aquastat, 100-240°F range, 5°F to 30°F Differential | $16/unit\* | $20/unit\*\* | $36/unit |

\* <https://www.supplyhouse.com/Honeywell-L4006A1678-High-or-Low-Limit-Aquastat-100-240-F-range-5-F-to-30-F-Differential?gclid=EAIaIQobChMIqde9t_Pd2wIVCcZkCh3WlwQCEAQYAiABEgIMWPD_BwE>

\*\* RSMeans book 2016 Pluming Cost Data, Space/Hot Water- Thermometer, page 497.

## 4.2 Measure Case Cost

The approximate controller cost is $1,000 and the installation cost is $1,000. Those conservative values are used here. Assuming 12 residential units per central heating system as in the energy savings section above, that gives a full measure cost of $167/unit.

Table 15: Proposed Measure Costs

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Cost Measure ID** | **Description** | **Delivery Method** | **Equipment Cost** | **Labor/Installation Cost** | **Total Measure Cost** |
| MF-Dual-setpoint-temp-control | Dual outdoor temperature reset and burners staging controller to a central hot water boiler | Prescriptive Rebate  (PreReb) | $83/unit | $84/unit | $167/unit |

## 4.3 Full and Incremental Measure Cost

The full measure cost of this measure is $167 as shown in Table 15 above.

Table 16: Full and Incremental Measure Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| 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 17: Full and Incremental Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | $167 | $167 | N/A |

# Appendix - A

## Multi-Family Central Boiler Dual Setpoint Temperature Controller: Fieldwork Guidance Document

This generic fieldwork guidance document is meant to aid an experienced third-party plumbing contractor or inspector in controller installation, configuration, and/or inspection. Controller installation and configuration shall be per the controller vendor’s installation manual. This document will help the installer or inspector avoid common installation or configuration issues.

## General Sequential Installation and Configuration Steps

1. Inspect existing combination boiler central plant to understand the system configuration and control.
   1. How many burner stages do the boiler(s) have and how are they sequenced on and off? Are the burner stages jumpered? Trace any control wires connected to the burner stages and inspect any boiler control components. Is an aquastat being used or an electronic controller?
   2. What are the supply water temperature setpoint(s) and differentials? Where is the supply water measured, and how are the control signals connected to the boiler?
   3. How many pumps are there and how are they each controlled? For each pump, determine if it’s constant flow or variable speed, the approximate flow rate, and whether it is a primary or secondary loop pump. Is the pumping system a primary loop only, or a primary-secondary loop?
   4. Are there two separate distribution loops to the building, one for domestic water and one for heating hot water, or is there only one loop? Are there any mixing valves and how are they controlled?
   5. What is the minimum boiler return water temperature and the maximum supply water temperature?
   6. What type of heating coils and valves does the building have (e.g., fan coils or baseboard radiators; two-way, three-way, or modulating valves)?
   7. How many residential units are served and how long is the distribution loop? Is the outdoor and indoor piping insulated?
2. Confirm that the existing system is functional.
   1. Are all components working properly?
   2. Does the property manager or facility staff have any issues with the equipment or have there been any occupant complaints?
3. Install the controller and related sensors and wiring per the manufacturer instructions.
4. Configure the controller settings per the manufacturer instructions.
   1. Confirm settings with property manager and facility staff, especially minimum supply water temperature and related outdoor conditions.
5. Confirm that the system is operating properly.
   1. Confirm that the temperatures shown at the controller are reasonable.
   2. Confirm that the controller enables the boilers as expected.
6. Visit the site the next day or week to confirm that the system is still operating properly.
   1. Confirm that the temperatures are reasonable.
   2. Ask facility staff if there have been any issues or occupant complaints. If so, determine if troubleshooting is required or whether settings should be changed, such as increasing the minimum supply water temperature.

## Troubleshooting

Here below is a non-exhaustive list of potential issues and solutions.

|  |  |
| --- | --- |
| **Potential Issue or Concern** | **Potential Solution or Impact** |
| Existing aquastat was not mounted properly or thermal paste was not used. | An aquastat that is not securely mounted in a tank can be affected by ambient temperature instead of just water temperature, causing more energy usage at low ambient temperature and less at high ambient temperature. Assuming this sensor is replaced by the new control equipment, savings may be less than expected since pseudo outdoor air reset was already in place. |
| Additional occupant complaints of insufficiently hot water after controller installation. | Consider increasing the minimum supply water temperature. If it is already reasonably high enough, check whether there is substantial uninsulated pipe, especially outdoors, and whether the secondary (recirculation) pump has a sufficiently high enough flow rate. Confirm that the pumps have not failed or that their control has not been modified. |
| Boilers appear to be often be short cycling | Check if boiler stages are jumpered of if both are receiving the same control signal. Consider removing the jumper and utilizing multiple stage control if the controller supports that. |
| Supply water setpoints do not match the expected values at given ambient temperature | Confirm controller configuration settings. Confirm sensor positioning and installation. Ensure that the ambient temperature sensor is shaded throughout the day and not conducting heat from the heating plant equipment or piping. Confirm that the supply water temperature sensor is effectively measuring the supply water. Make sure the thermowell is properly installed and that the temperature sensor has sufficient thermal paste. |
| Savings are less than expected, even though the setpoint reductions are aggressive | Assuming there are no occupant complaints, consider reducing the secondary pump flow rate to gain additional energy savings. |

# Attachments

Attachment A – Commercial Space-heating Boilers, DEER2016-ComBoilerUpdate-15May2015.

Attachment B – Combination Boiler Reset Controller Field Evaluation, NegaWatt Consulting, Inc., July 2015.

Attachment C – A Dual Setpoint Controller for Combination Service Boilers, Information and energy Services, Inc. (IES), 2011.

Attachment D – EnergyPlus modeling results

Attachment E – Central Boiler Reset Control (cbrc)\_openstudio\_results\_output\_20180322

# References

1. OpenStudio energy modeling software, developed in collaboration by NREL, ANL, LBNL, ORNL, and PNNL, OpenStudio 2.4.0 has been released 01/05/2018 at <https://www.openstudio.net/> [↑](#endnote-ref-1)
2. EnergyPlus™ is a whole building energy simulation program, DOE developed in collaboration with NREL, updated version 8.9.0 was released on March 31st, 2018 at <https://energyplus.net/> [↑](#endnote-ref-2)
3. The Measure Analysis Software, MASControl2 Building energy modeling, available for download at <http://www.deeresources.com/index.php/deer-versions/deer2019-and-june-2017-updates> [↑](#endnote-ref-3)
4. eQuest Energy Simulation Tool, developed by James J. Hirsch & Associates, <http://www.doe2.com/equest/> [↑](#endnote-ref-4)
5. DEER-Water Heater-Calculator-v2.1. <http://www.deeresources.com/files/DEER2015/download/2015DEER-SmallStorageWaterHeaterUpdate-24Nov2014.xlsx> [↑](#endnote-ref-5)
6. The Single-Family Thermostat Weights, DEER2017-MultiFamily\_Tstat-Weights-2016-07-20. <http://www.deeresources.com/index.php/deer-versions/deer2017#AdditionalResources> [↑](#endnote-ref-6)