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HVAC

CENTRAL BOILER DUAL SETPOINT TEMP. CONTROLLER, MULTIFAMILY

SWWH024-01

CONTENTS

MEASURE NAME

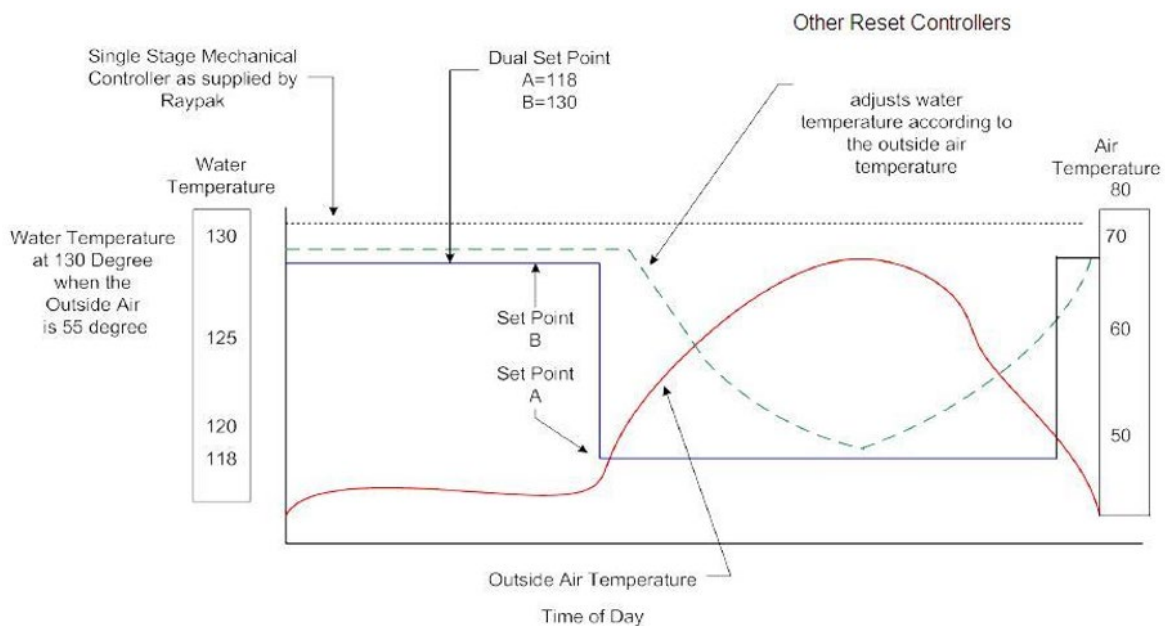Central Boiler Dual Setpoint Temperature Controller, Multifamily

STATEWIDE MEASURE ID

SWWH024-01

TECHNOLOGY SUMMARY

This energy efficiency measure is based on the addition of an advanced electronic controller to a central hot water boiler in a multifamily residential building. Better insulation and tighter envelopes reduce space the heating load for both new and existing multifamily homes. As a result, the decreased space heating load 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.

A combined space heating and domestic hot water system during warmer weather allows the temperature of hot water delivered to the dwelling units to be turned down from 135 °F to 140 °F to about 120 °F. (See figure below) This reduction in the 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.

Dual Setpoint Controller for Shared Combination Service Systems

According to the Gas Technology Institute, "[c]ombined 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." [1] 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.

Two studies pertaining to this measure are summarized below.

Combination Boiler Reset Controller Field Evaluation (NegaWatt Consulting, Inc., July 2015).[2] 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 multifamily 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 (Information and energy Services, Inc. IES, 2011).[3] 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 southern California multifamily residential facilities.
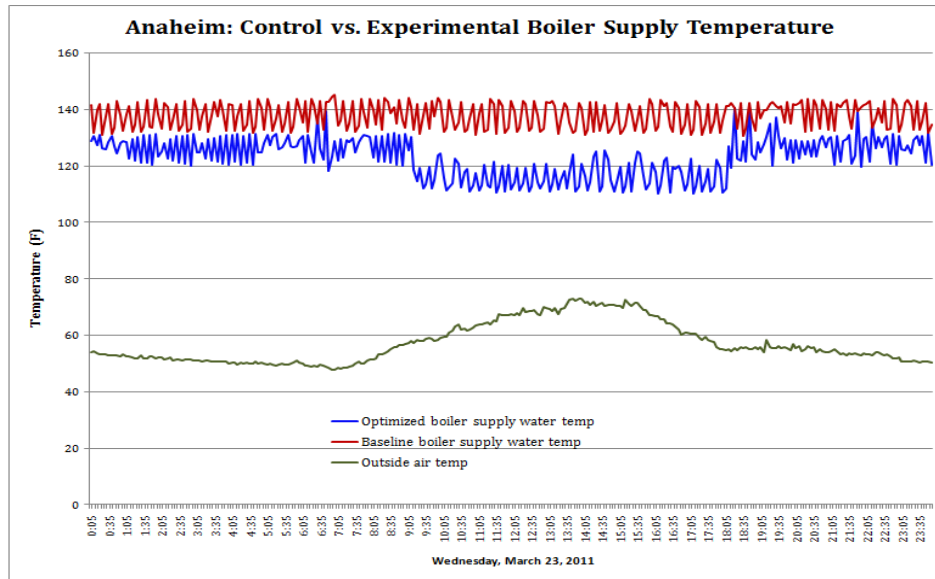
The controller reduces the water temperature set-point when space heating is not required. The savings are achieved in two ways; first by controlling the set point temperature of the water in the storage tank, then by controlling the firing rate of the boiler. An average savings of 21.6% or 5.7 therms 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 below.

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[1] Gas Technology Institute. 2012. *Residential Water Heating Program. Facilitating the Market Transformation to Higher Efficiency Gas-Fired Water Heating.* Prepared for the California Energy Commission (CEC). CEC-500-2013-060. December.

[2] White, B. and M. Esser (NegaWatt Consulting). 2015. *Combination Boiler Reset Controller Field Evaluation. Final Report.* Conducted for the Southern California Gas Company (SCG). Emerging Technologies Program Project ID ET12SCG0004. July 6.

[3] Information & Energy Services, Inc. 2011. *Engineering Measurement & Verification Study: A dual Setpoint controller for Combination Service Boilers.* Prepared for Sempra Energy.

Performance Temperature Trends

Retrofit Controller Performance

MEASURE CASE DESCRIPTION

The measure case is defined as a retrofit add-on measure that 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. However, hot water systems that are greater than 500,000 Btu/hr capacity and installed after 2005 do not qualify for this measure. Please see the Code Requirement section for details.

Measure Offerings

Statewide Measure Offering ID	Measure Offering Description
SWWH024A	Dual Set Point Boiler Control for Space Heating, MFm

BASE CASE DESCRIPTION

The base case is defined as a centralized gas-fired hot water boiler that serves dwelling-units with combined space heating and domestic hot water. The system operates with no controls or basic aquastat tank temp setpoint using manufacturer 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.

CODE REQUIREMENTS

This measure is governed by the California Building Energy Efficiency Standards (Title 24),[4] Section 144 (j) 4: Chilled and Hot Water Temperature Reset Controls. Since 2005, Title 24 has required chilled and hot water systems with a design capacity exceeding 500,000 Btu/h supplying chilled or heated water (or both) to include controls that automatically reset supply water temperatures as a function of representative building loads or outside air temperature.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20 (2016)	None.	
CA Building Energy Efficiency Standards – Title 24 (2016)	Section 144 (j) 4: Chilled and Hot Water Temperature Reset Controls	October 1, 2005
Federal Standards	None.	

NORMALIZING UNIT

None

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances

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[4] California Energy Commission (CEC). 2015. *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings (Title 24)*. CEC-400-2015-037-CMF.

and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility

Measure Application Type	Delivery Type	Sector
Add-on equipment	DnDeemDI	Res
Add-on equipment	DnDeemed	Res

Eligible Products

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.

The existing boilers must have been installed before the year 2005 (requirement for hot water temperature reset control has been required by code since 2005, see Code Requirements).

The controller must have the capability to provide hot water temperature modulation with outdoor temperature changes.

The controller must be wired and programmed for burner sequencing (stage and rotate) up to two ON/OFF boilers, or a single two-stage boiler.

Run fewer stages for longer periods to avoid purging losses.

Eligible Building Types and Vintages

This measure is applicable for any existing or new multifamily building.

Eligible Climate Zones

This measure is applicable in any California climate zone.

PROGRAM EXCLUSIONS

A boiler with integrated reset controls is not eligible.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

HVAC

ELECTRIC SAVINGS (kWh)

Not applicable.

PEAK ELECTRIC DEMAND REDUCTION (kW)

Not applicable.

GAS SAVINGS (Therms)

The gas unit energy savings (UES) for this measure were derived from energy use simulations of the base case and measure case scenarios.

OpenStudio[5], which is based on EnergyPlus[6], was used to simulate the building energy use. The Database for Energy Efficient Resources (DEER) batch processor, MASControl2, which is based on eQuest, was not 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 to create the OpenStudio baseline model for that climate zone.

In addition, the DEER Water Heater Calculator v2.1[7] was used as a guideline for annual water heating gas usage and the DEER Thermostat spreadsheet[8] was used as 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

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[5] OpenStudio energy modeling software, developed in collaboration by NREL, ANL, LBNL, ORNL, and PNNL, OpenStudio 2.4.0 has been released January 5, 2018 at https://www.openstudio.net/

[6] EnergyPlus™ is a whole building energy simulation program, DOE developed in collaboration with NREL, updated version 8.9.0 was released on March 31, 2018 at https://energyplus.net/

[7] DEER-Water Heater-Calculator-v2.1. http://www.deeresources.com/files/DEER2015/download/2015DEER-SmallStorageWaterHeaterUpdate-24Nov2014.xlsx

More current versions of the Water Heater Calculator did not change annual hot water use in multifamily buildings.

[8] California Public Utilities Commission (CPUC), Energy Division. 2016. "DEER2017-MultiFamily_Tstat-Weights-2016-07-20.xlsm." Updated July 20.

California Public Utilities Commission (CPUC), Energy Division. 2016. "DEER2017-SingleFamily_Tstat-Weights-2016-07-20.xlsm." Updated July 20.

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 below. Domestic hot water and space heating energy usage is not shown because the DEER Water Heating Calculator v2.1 and the DEER Thermostat spreadsheet[9] are more appropriate.

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 v2.1 assumptions and results are shown 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.

DEER Water Heater Calculator v2.1 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)

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[9] California Public Utilities Commission (CPUC), Energy Division. 2016. "DEER2017-MultiFamily_Tstat-Weights-2016-07-20.xlsm." Updated July 20.

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 resulted in an approximate heating setpoint of 73 °F.

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 the OpenStudio 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.[10]
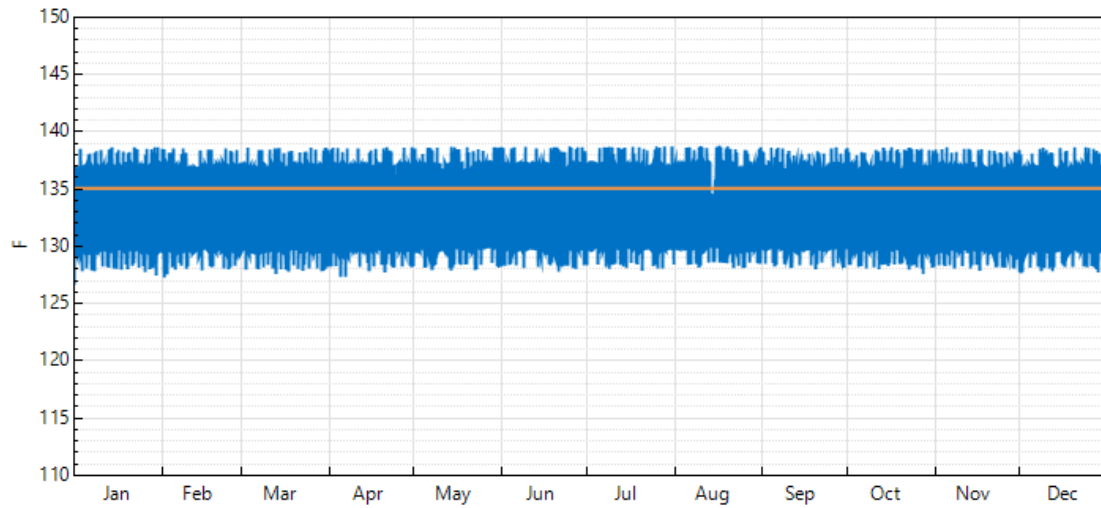
OpenStudio Model Assumptions

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

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[10] Southern California Gas Company (SCG). 2018. "SWWH024-01 Modeling results 2018032
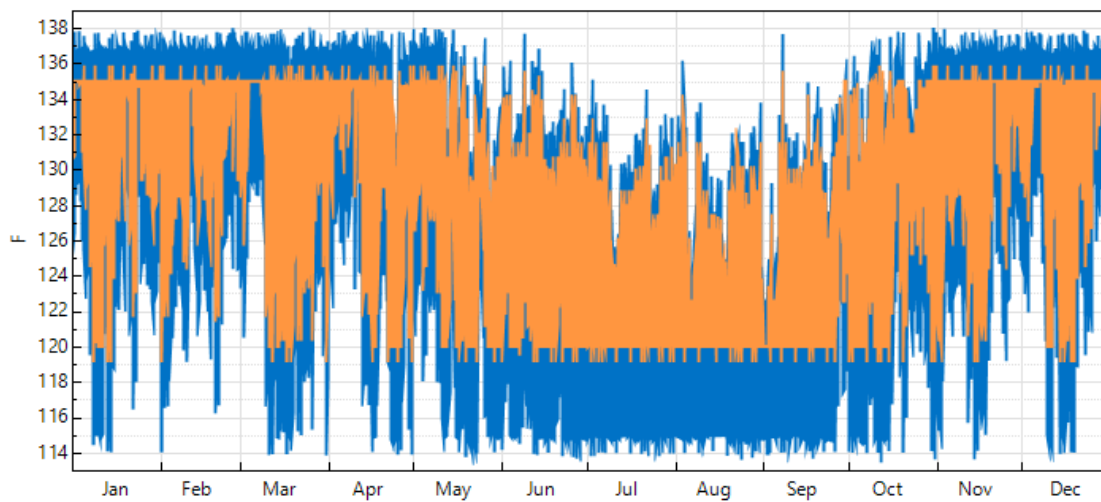
Item	Value
Tank setpoint and differential temperature	Baseline: 135°F, 5°F temperature differential **Proposed: 135°F/120°F (at 55°F/75°F ambient hourly), 5°F differential**
Primary pump flow rate	Climate zones 6 & 9: 27.2 gpm (auto-sized per sizing factor) Climate zone 16: 37.5 gpm (auto-sized per sizing 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, similar to the 106 therms in the DEER Water Heater Calculator v2.1. 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 models, 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 is fixed at 120°F for outdoor temperatures greater than or equal to 75 °F and is linear in between. The screenshots show the baseline and proposed supply water temperature and setpoint for Climate Zone 9.

Climate Zone 9 Baseline Heating Supply Water Temperature and Setpoint

Climate Zone 9 Proposed Heating Supply Water Temperature and Setpoint

The OpenStudio gas savings results per residential unit are shown in the below table.[11] 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.

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[11] The software model was created for three zones and the results were expanded to the remaining zones using HDDs in the regression analysis.

OpenStudio Gas Savings Results

	Boiler Gas Usage [therms/unit/yr]			
Climate Zone	Baseline	Proposed	Savings	Savings [% of baseline]
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 table below includes a breakdown of gas savings by end use.[12] 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.
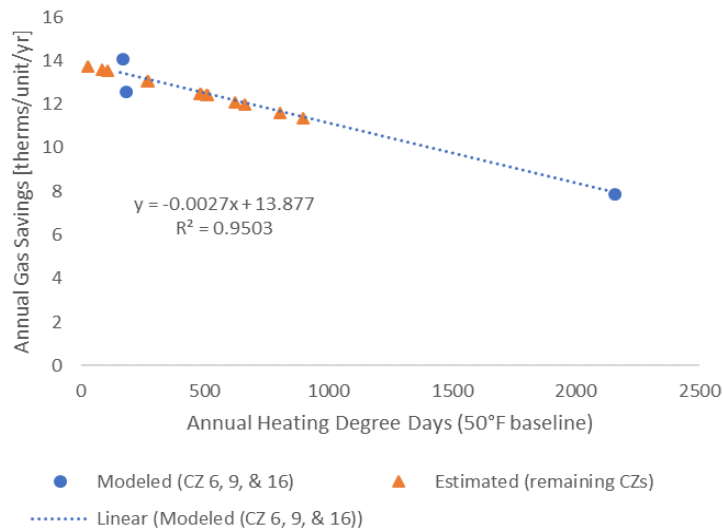
OpenStudio Gas Savings by End Use

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	

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[12] The software model was created for three zones and the results were expanded to the remaining zones using HDDs in the regression analysis.

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
	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%
	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	
16	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[13] 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 figure and table below.

$$y = -0.0027x + 13.877$$
$$R^2 = 0.9503$$

Statewide Savings versus Heating Degree Days

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[13] The heating degree day data is from the CPUC "DEER2013-Weather-Data-Comparison.zip" zip file.

OpenStudio Gas Savings Extrapolated to Other Climate Zones

Climate Zone	HDD at 50°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

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The methodology to calculate the RUL conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends "one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values."[14] This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.[15] Further, as per Resolution E-4807, the California Public Utilities Commission (CPUC) revised add-on measures so that the EUL of the measure is equal to the lower of the RUL of the modified system or equipment or the EUL of the add-on component."[16]

The EUL and RUL for hot water boiler controls is specified below. The RUL value is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

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[14] California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5*. Page 32.

[15] KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

[16] California Public Utilities Commission (CPUC). 2016. Resolution E-4807. December 16. Page 13.

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs)	15.0	California Public Utilities Commission (CPUC), Energy Division. 2003. *Energy Efficiency Policy Manual v 2.0.* Page. 16. California Public Utilities Commission (CPUC), Energy Division. 2014. "DEER2014-EUL-table-update_2014-02-05.xlsx"
RUL (yrs)	5.0	

BASE CASE MATERIAL COST ($/UNIT)

The base case material cost of an existing high limit/low limit aquastat tank temperature setpoint controller was derived from the list price on www.SupplyHouse.com, recorded prior to 2018. The list price was normalized per dwelling unit served by the boiler.

Base Case Cost Inputs

Parameter	Value	Source
High or Low Limit Aquastat, 100-240 °F range, 5 °F to 30 °F Differential	$192.00	Honeywell High or Low Limit Aquastat, 100-240 °F range, 5 °F to 30 °F Differential. Estimate from SupplyHouse.com. SKU L4006A1678.
Residential units served by boiler	12.0	

MEASURE CASE MATERIAL COST ($/UNIT)

The measure case material cost was derived from the list price on SupplyHouse.com, recorded in 2018. The list price was normalized per dwelling unit served by the boiler.

Measure Case Material Cost Inputs

Parameter	Value	Source
Controller cost (dual outdoor temperature reset and burners staging controller to a central hot water boiler)	$1,000.00	Honeywell Modulating Temperature Reset Controller, 70 F to 140 F. Estimate from SupplyHouse.com. SKU T991B1003.
Residential units served by boiler	12.0	

BASE CASE LABOR COST ($/UNIT)

The base case installation labor costs were obtained from the RSMeans 2016 Pluming Cost Data.

Base Case Installation Labor Cost Inputs

Parameter	Value	Source
Installation labor cost ($/dwelling unit)	$20.00	Gordian Group. *RSMeans 2016 Pluming Cost Data.* 39th Annual Edition. Page 497, Space/Hot Water- Thermometer.
Residential units served by boiler	12.0	

MEASURE CASE LABOR COST ($/UNIT)

The total labor cost for installation and programming of the controller was provided by several contractors in 2018. The list price was normalized per dwelling unit served by the boiler.

Measure Installation Labor Cost Inputs

Parameter	Value	Source
Average installation and programming cost (per controller)	$1,000.00	Contractor estimated cost.
Residential units served by boiler	12.0	

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. This NTG value is based upon the average of all NTG ratios for all evaluated 2006 – 2008 residential programs, as documented in the 2011 DEER Update Study conducted by Itron, Inc. This sector average NTG ("default NTG") is applicable to all energy efficiency measures that have been offered through residential sector programs for more than two years and for which impact evaluation results are not available.

Net-to-Gross Ratios

Parameter	Value	Source
NTG – emerging technology	0.85	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5.* Page 21.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current "default" rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. *Energy Efficiency Policy Manual Version 5.* Page 31.

NON-ENERGY IMPACTS

Non-energy benefits for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of inputs and methods used from the Database of Energy Efficient Resources (DEER), and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / 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	No
Reason for Deviation from DEER	N/A
DEER Measure IDs Used	N/A
NTG	Source: DEER2020. The NTG of 0.60 is associated with NTG ID: *Com-Default>2*
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: *Def-GSIA*
EUL/RUL	Source: DEER2020. The value of 15 years is associated with EUL ID: *SHW-EMS*

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	05/20/2019	Raad Bashar, SoCalGas. Bo White & Marc Esser, NegaWatt Consulting	Draft of consolidated text for this statewide measure is based upon: WPSCGREWH180305A, Revision 0 (April 17, 2018)
	06/12/2019	Raad Bashar, SoCalGas. Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01