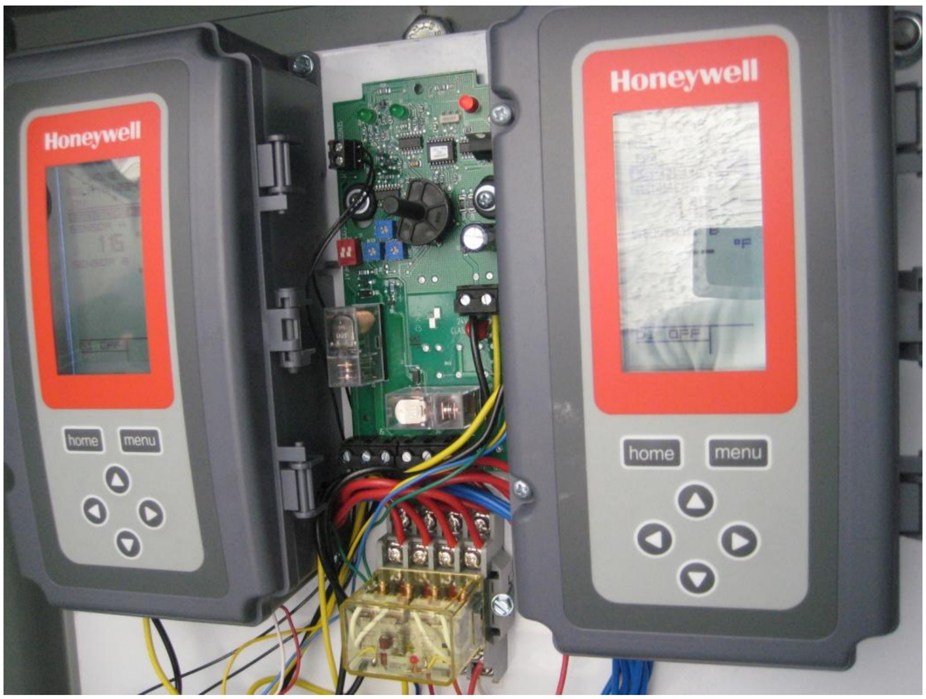
Engineering Measurement & Verification Study:

A Dual Setpoint Controller for Combination Service Boilers

Southern California Multi-Family Residential

2010-2011



Prepared by:
Information & Energy Services, Inc.
IES, Inc.
Information & Energy Services Inc

Prepared for:
Sempra Energy
Sempra Energy®
Emerging Technology Program

Table of Contents

Executive Summary

The “X” boiler controller is an energy savings controller for combined heating and domestic hot water systems that changes the water temperature set-point to a lower temperature 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.

Information & Energy Services, Inc. (IES) under contract with Sempra Energy – Emerging Technologies Program, studied the effects of the “X” Boiler Controller in a *"real-world"* application at eight (8) southern California multi-family residential facilities. This study has found the following primary results:

- The “X” Boiler Controller is estimated to **consume 19.3% LESS** than the baseline natural gas consumption per apartment unit (21.6% not including Redlands).
- The “X” Boiler Controller is estimated to **save 4.9 therms per apartment unit in an average month**. (5.7 therms not including Redlands)
- The “X” Boiler Controller is estimated to **save 59.1 therms per apartment unit in an average year**. (69.5 therms not including Redlands)

Typical savings are between 15% and 32%. The savings measured at the Redlands site are considerably less at 4.5% due to the water short circuiting inside the storage tank. Preliminary results by site are shown in Table 1.1 below.

Table 1.1: “X” Boiler Controller Savings Results

Site	City	TYPE	Avg. Therms Cons per Living Unit per day	% Saved
"P"	Anaheim	BASELINE	1.23	
"P"	Anaheim	OPTIMIZED	0.84	32%
"W"	Costa Mesa	BASELINE	0.90	
"W"	Costa Mesa	OPTIMIZED	0.77	15%
"HC"	Huntington Beach	BASELINE	1.17	
"HC"	Huntington Beach	OPTIMIZED	1.00	15%
"HM"	Moreno Valley	BASELINE	0.81	
"HM"	Moreno Valley	OPTIMIZED	0.65	19%
"C"	Pomona	BASELINE	0.63	
"C"	Pomona	OPTIMIZED	0.48	23%
"S"	Rancho Cucamonga	BASELINE	0.97	
"S"	Rancho Cucamonga	OPTIMIZED	0.71	26%
"R"	Redlands	BASELINE	0.67	
"R"	Redlands	OPTIMIZED	0.64	4%
"M"	San Dimas	BASELINE	1.12	
"M"	San Dimas	OPTIMIZED	0.79	29%

Savings calculations on the following pages are based upon measured natural gas consumption.

Background & Technology Description

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

"R" system is the term used by Company "R" to describe their design of a combination domestic hot water and space heating system that provides space heating from domestic hot water. Per it's system design, the water temperature set-point is 140 degree Fahrenheit in order to provide optimum heat to the building.

The "X" controller is an energy savings controller that 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. These boilers typically have 3-4 burners staged in series to meet various load changes.

Depending on the application and number of boiler stages, one to four O.E.M. "Z" programmable logic controllers are used to process the temperature(s) in the storage tank and cycle the stages of the boiler on/off. An additional temperature controller and relays are integrated into the control to measure the ambient air temperature and change the water temperature set-point back to a higher temperature as space heating is required. The outside air temperature will determine if the high (winter) or low (summer) set-point is used. Even as the temperature is increased the controller will still optimize the firing rate/stages of the boiler. The "X" boiler controller uses a proprietary temperature sensor that collects the temperature of the water in the storage tank. This becomes an important factor when controlling/staging the boiler firing rates.

Please note that at no time is the system locked out (demand limiting) – hot water is always available to occupants and the "X" boiler Control System will cause the boiler to maintain the tank water temperature set-point. No fuzzy logic is used to automate the temperature set point adjustments. It is expected that operator only needs to set it once with little if any adjustments throughout the change of seasons.

Figure 1.1: "X" Boiler Controller

The controller being studied is a dual set-point controller, and has two tank water temperature set-points, referred to here as high temperature and low temperature. When the ambient temperature rises, the "X" boiler controller will place the boiler water set-point at the low temperature setting to conserve energy. Conversely, if the ambient air temperature is detected to be below the threshold (such as at night or a cold day) the boiler will be placed on the high water temperature set-point in order to be able to provide more heat to the apartment fan coils. The high temperature set-point is typically approximately 140F while the low temperature set-point is approximately 120F. Even with 120F water being supplied to the fan coils, heat is still available from the apartment fan coil units if a resident were to adjust their thermostat to call for heating. Domestic water at 120F is considered sufficient for bathing, washing, etc.[1]

The energy savings are achieved by allowing the system to operate at the low temperature water set-point during the mild to hot weather conditions found much of the year throughout the Southern California area. According to "X" company, there are hundreds of "Y" systems within the Southern California Gas Company (SCG) service territory, each consuming approximately 350 therms per apartment unit per year. The potential market is of significant size.

[1] Municipal health codes typically require approximately 120°F domestic hot water systems to eliminate threat of Legionaries dieses.

Test Methodology

This section details the steps IES technicians took in order to identify the potential benefits and detriments of the "X" Boiler Optimization Device. It details how the test was performed, the data logging equipment used and how the data were analyzed.

Monitoring Procedure

Data were collected electronically and recorded at 5 minute intervals over one year period. Total study length was scheduled to be 9 elapsed monthly readings. Building hot water system conditions were recorded, including building supply and return water temperatures, circulation pump amperage, and boiler natural gas consumption. Ambient air temperature was also recorded in 5 minute intervals at each site.

IES was responsible for data collection on a monthly basis at each of the eight test sites. Gas meters were read manually, HOBO data loggers were harvested, and each boiler and "X" boiler controller was inspected for consistency and proper operation. Any abnormal conditions were noted.

Where possible each optimized boiler was selected as a pair with another un-optimized boiler as a baseline. Both optimized and baseline boilers in each pair are the same size and have roughly the same load (number of apartment units). In the case of Anaheim, Costa Mesa, Huntington Beach, Pomona, Redlands and San Dimas some boilers have been changed from optimized to baseline by changing the control sequence used by the "X" boiler controller to a simulated baseline mode. This was done because the load on the boilers was either known to be different between the two buildings due to laundry facilities in one building and not in the other or to make sure that the possibility of different loads was controlled for. For data analysis purposes, both site by site and average per unit-day savings figures were prepared as well as direct boiler to boiler comparisons.

Site Selection

Sites were selected by "X" and approved by IES. Sites were chosen to represent the various conditions found throughout the San Bernardino County and Orange County areas with the most "Y" systems installed. Site selection also took into consideration whether or not gas meters were already installed to measure gas consumed at each boiler. Please see Figure 2.1 for a map of "Y" systems installed in the SCG service territory. Figure 2.2 shows the location of the eight (8) sites chosen for this study.

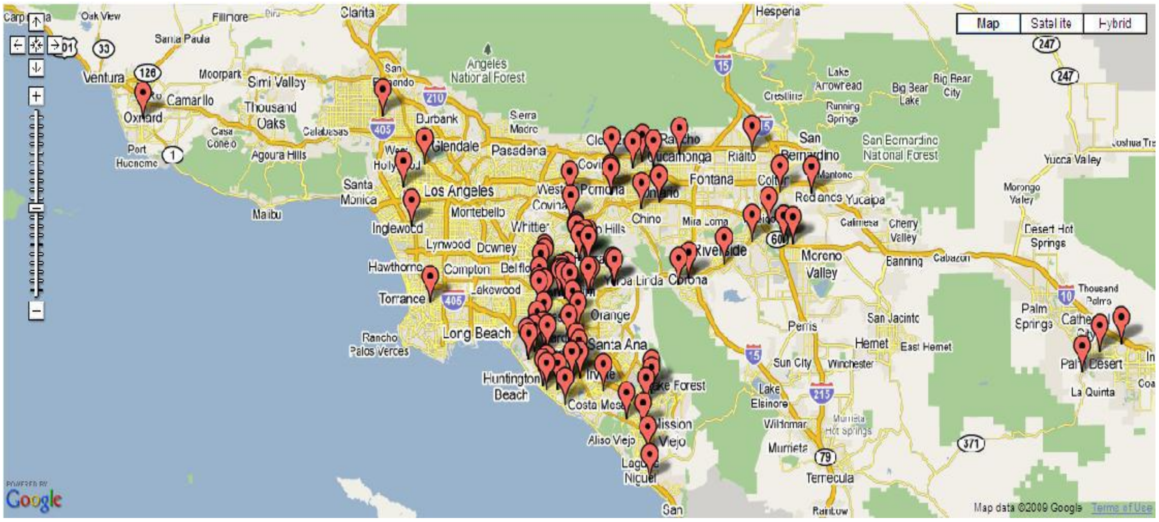


Figure 2.1: Map of Known "Y" Systems in SCG Territory

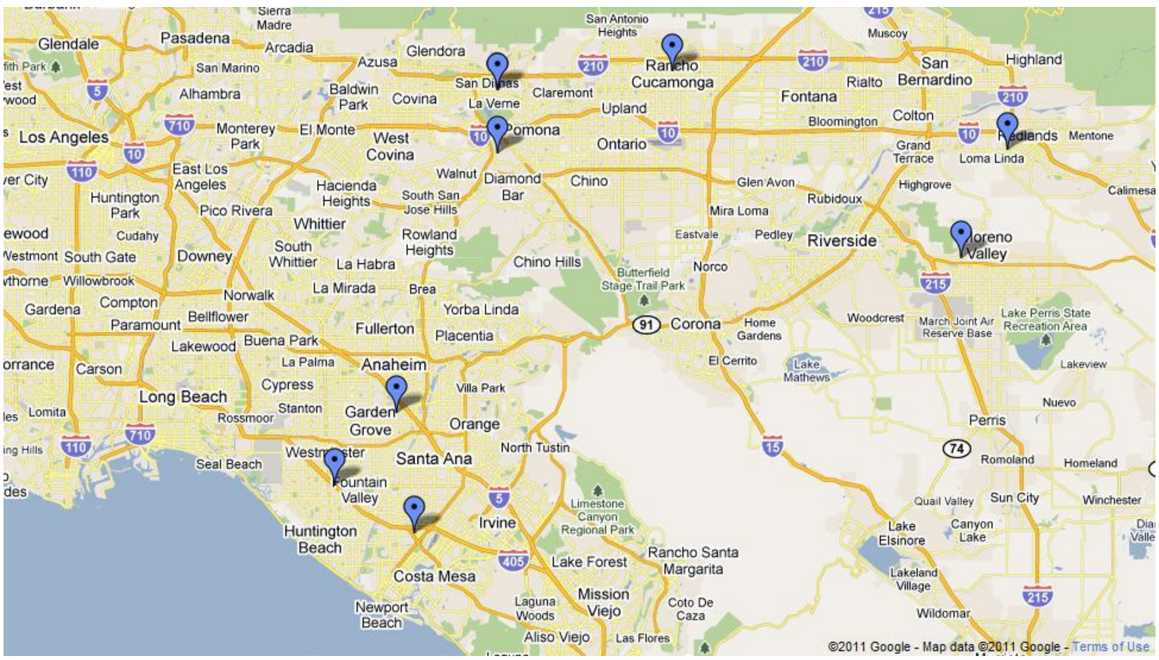


Figure 2.2: Map of "Y" Locations in this Study

Figure 2.2 shows that both Orange County and San Bernardino County are represented in this study, with both northern and southern locations covered.

Metering Equipment

In most cases sites were selected with individually metered gas consumption at each boiler[2]. At the Huntington Beach, San Dimas, and Anaheim sites new Roots 15C175 or 2M175 gas meters were installed to sub meter each boiler being studied (two per facility). In all other cases the existing utility gas meter was read manually by IES staff on a monthly basis. All other data is collected on 5 minute intervals and stored on HOBO U12-006 data loggers placed on each boiler. Temperature is measured at boiler entrance water pipe (Return Water) and boiler exit water pipe (Supply Water), as well as ambient air temperature at each site. All temperature data being recorded is measured using HOBO air/water/soil temperature probes. Amps to the boiler water circulation pump is also being metered, using a HOBO transformer, model CTV-A. Boiler water pump amps are measured to determine runtime of the pump. Table 2.1 on the following page shows the list of metering equipment used on each boiler to collect the data used in this study.

Table 2.1: Metering Equipment Summary (per boiler)

Data Point Name	Equipment Description	Manufacturer	Manufacturer's Model Number
Gas Consumption	Meter on boiler gas header	*various*	*various*
Supply Water Temperature	Surface probe on building water supply line	Onset Corp. (HOBO)	HOBO: TMC20-HD air/water/soil probe
Return Water Temperature	Surface probe on building water return line	Onset Corp. (HOBO)	HOBO: TMC20-HD air/water/soil probe
Ambient Air Temperature (F DB)	Air temperature sensor, co-located next to "X" sensor	Onset Corp. (HOBO)	HOBO: TMC20-HD air/water/soil probe
Boiler water pump Amps	CT on power supply to boiler water pump	Onset Corp. (HOBO)	HOBO: CTV-A current transformer
HOBO Data Logger	Records data to internal memory for manual monthly downloading	Onset Corp. (HOBO)	HOBO: U12-006 4 channel data logger

To increase the number of boilers in the study, HOBO loggers were only placed on most of the boilers in the study; a few additional boilers were added to the original measurement plan by IES. In most cases a Dresser Roots positive displacement gas meter was the existing equipment that was used to take the gas consumption measurements. Please see Figures 2.3 and 2.4 on the following page for a view of a typical Dresser Roots gas meter of each face type.

[2] In the case of the Pomona site, each building is individually metered; however cooking is electric at this facility.

Figure 2.3: Typical Gas Meter—dial face (left)
Figure 2.4: Typical Gas Meter—odometer (right)

The HOBO data logger was placed inside the boiler cabinet in most cases, with temperature probes and current transformer wiring hidden inside the cabinet for an unobtrusive installation. Please see Figure 2.5 below for a typical logger installation. Temperature probes were surface mounted on the supply and return water pipes. Good temperature transfer between the pipe wall and sensor probe was ensured using KELE thermo conductive gel and foil backed foam insulation tape. Water temperature probe installation is shown in Figure 2.6 on the following page.

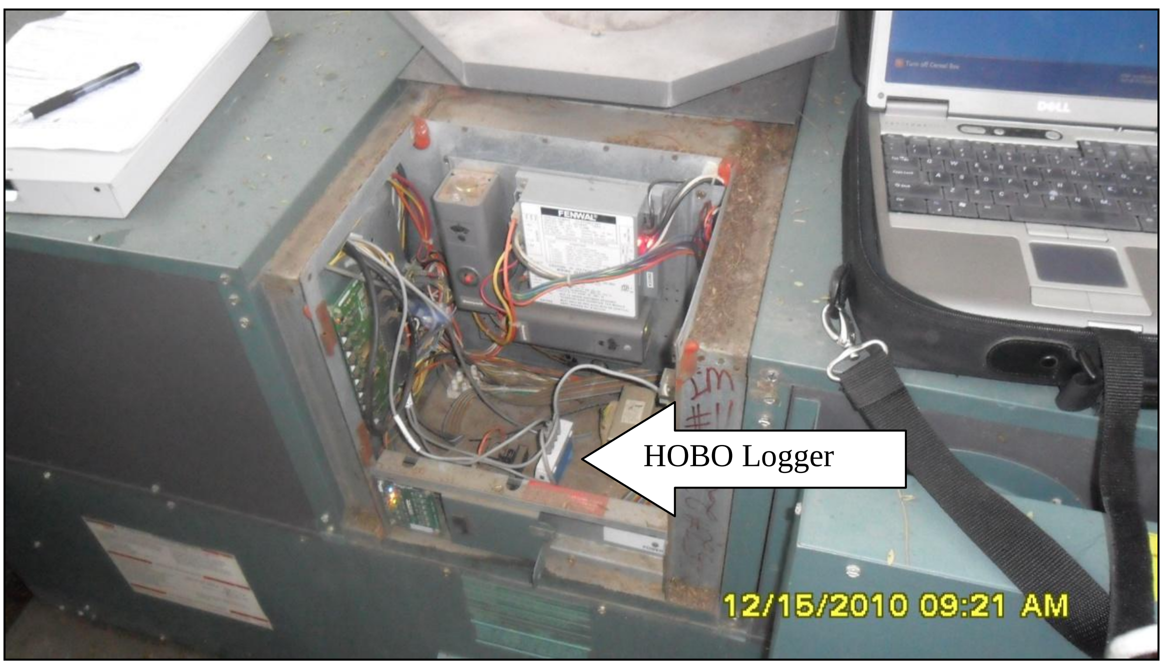


Figure 2.5: Typical HOBO Logger Installation

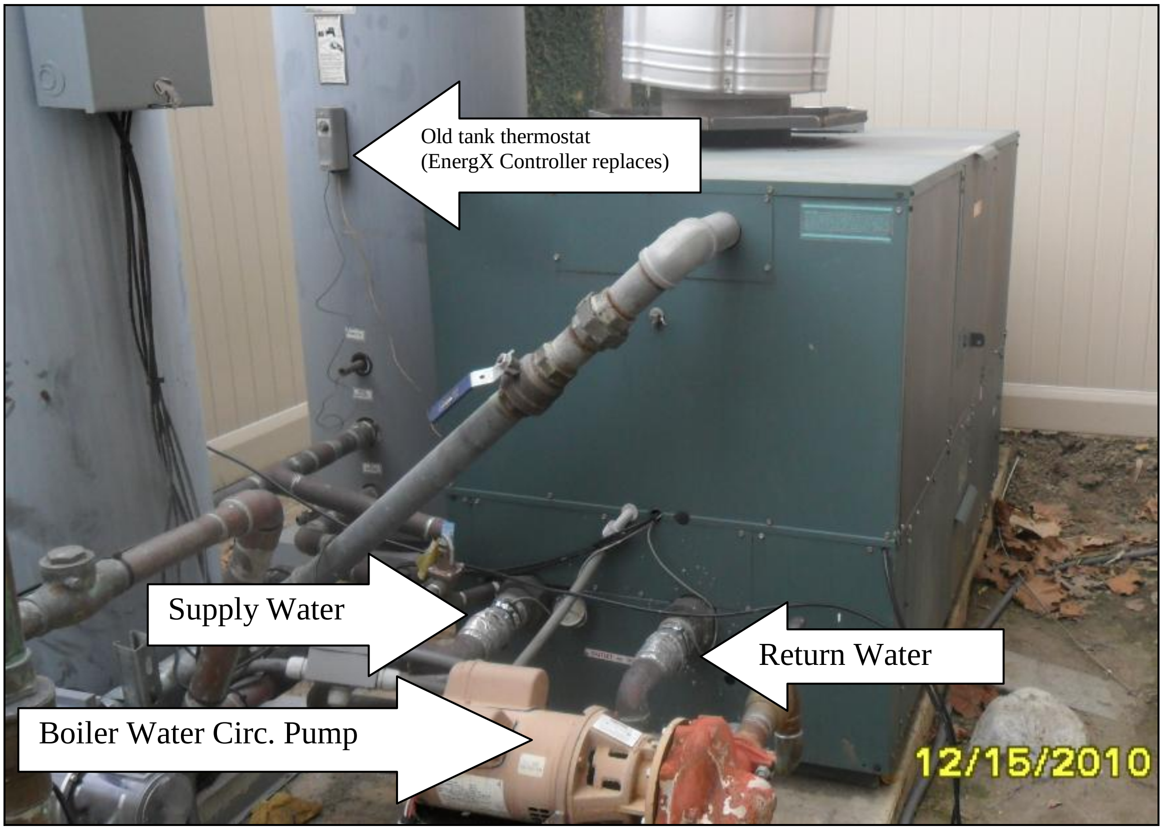


Figure 2.6: Typical Water Temperature Probe Installation

Please see Figure 2.7 on the following page for a generalized schematic of the plumbing and sensor locations on a typical "Y" system. The "SS" site was used for this diagram.

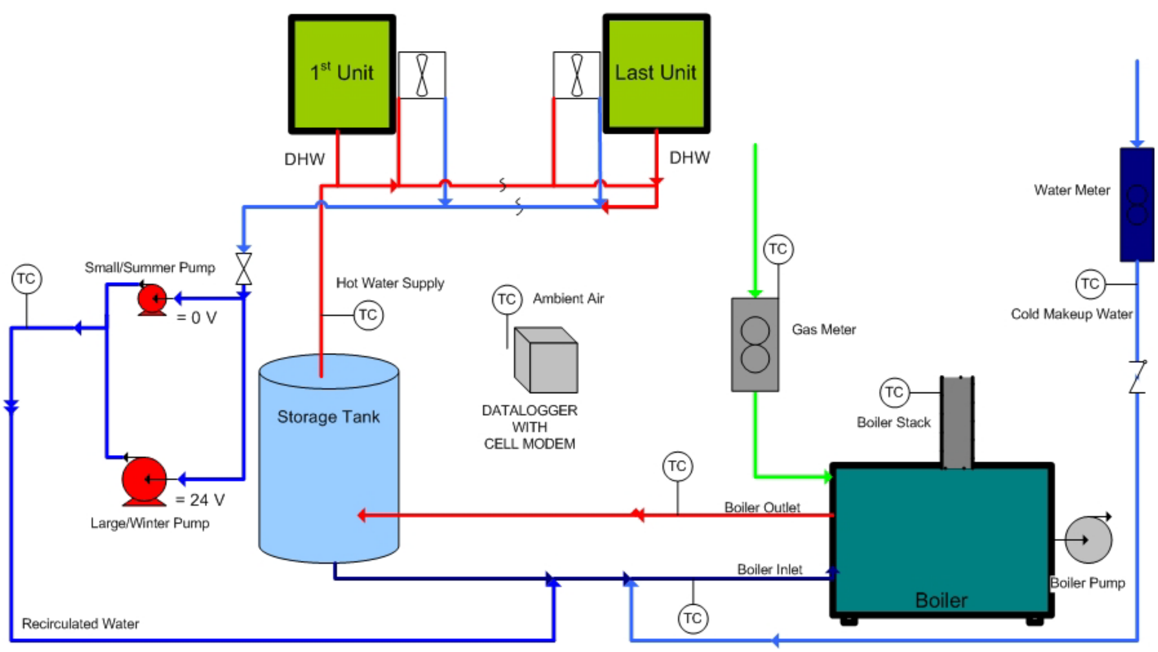


Figure 2.7: Generalized "Y" Plumbing Layout Diagram

Data Analysis

The data collected was analyzed by IES to determine the overall performance of the "X" controller. Specifically, the analysis involved calculating the natural gas consumption per day and per unit for each boiler and comparing baseline consumption to optimized consumption. When two boilers at the same property are the same size and have roughly the same load (same number of apartments served) we can compare the two boilers directly by making the assumption that the optimized boiler would behave in the same way as the baseline boiler if the "X" controller had not been installed. Please see Figure 2.8 on the following page for this type of analysis performed at the Anaheim site comparing the monthly Therms consumed per unit-day by the baseline and optimized boilers.

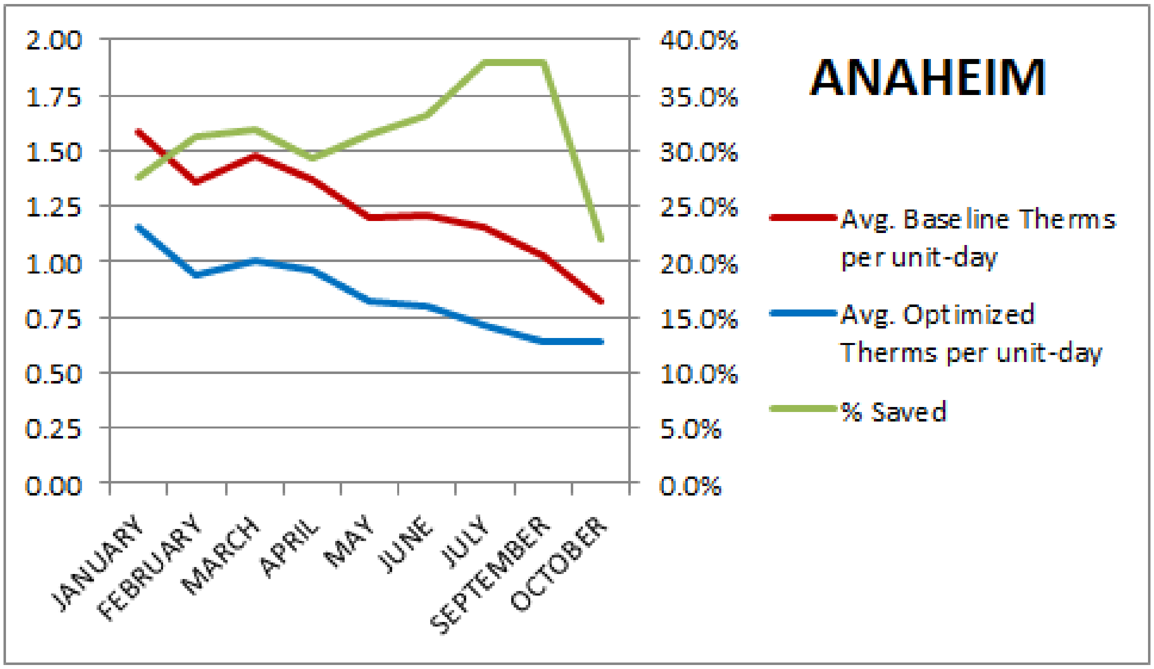


Figure 2.8: Monthly gas consumption per unit-day (Anaheim, CA)

In Figure 2.8 above, the two boilers are directly compared with the assumption that the load was the same on both boilers. Since data were collected simultaneously we know that the weather was the same for both buildings.

At the Costa Mesa facility the load on the two boilers was not the same due to a laundry room in one building and no laundry room in the other. Therefore for this site we must compare the overall performance of all optimized boiler-months to the performance to all baseline boiler-months. Each month, one of the boilers is set as simulated baseline, and the other is set as optimized. This type of analysis is performed at sites where it is possible to swap boilers between baseline and optimized mode. Table 2.2 below shows the gas consumption per unit day over the months of January to September. Note that each boiler was set first in baseline and then optimized mode in two-month intervals. Savings are derived by comparing the optimized boiler to the baseline boiler over the same time period. The savings from month to month are very different mainly because the boiler being designated baseline or optimized has changed and various other attributes about the boiler are coming into play. In January and February boiler #2 was baseline and #3 was optimized. In March and April boiler #3 was baseline and #2 was optimized, then they were switched back again.

Table 2.2: Month-by-Month Summary (Costa Mesa)

COSTA MESA								
#	Month (2011)	Baseline Boiler	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	Optimized Boiler	% Saved	Avg. Monthly Therms Saved per Unit*
1	JANUARY	#2	0.99	1.11	#3	-12.8%	(3.8)
2	FEBRUARY	#2	0.97	0.94	#3	3.0%	0.9
3	MARCH	#3	1.21	0.83	#2	31.5%	11.4
4	APRIL	#3	1.13	0.76	#2	32.6%	11.0
5	JULY	#2	0.77	0.66	#3	14.3%	3.3
6	SEPTEMBER	#2	0.71	0.60	#3	14.7%	3.1
7	OCTOBER	#2	0.73	0.57	#3	21.4%	4.7
AVERAGE			0.93	0.78		15.7%	4.4

* 30 days per month (for consistency)

savings derived as difference between baseline boiler and optimized boiler over the same time period

Please see Figure 2.8 below for monthly gas consumption per unit-day at each boiler in each mode at Costa Mesa.

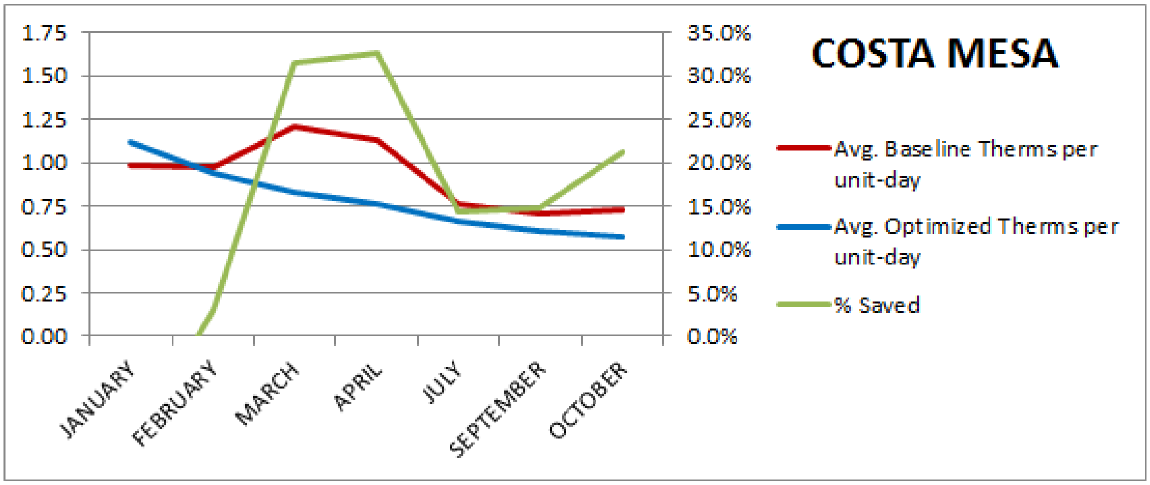


Figure 2.8: Monthly gas consumption per unit-day (Costa Mesa)

If boiler #2 is compared to itself, i.e. baseline mode compared to optimized mode then we note a savings of only 3.4%. This is the comparison of the (baseline) consumption per unit day in January, February, July, September, and October to the (optimized) consumption in March and April. The boiler #2 savings is low because when #2 was set as optimized the performance was moderate over the shoulder months of March and April. Combined with typical (not above average) baseline performance the difference between baseline and optimized performance of boiler #2 was only 3.4%.

When boiler #3 is compared to itself the savings is estimated at a difference of 35.1%. This is derived as the comparison of the (baseline) consumption per unit day in March and April to the (optimized) consumption in January, February, July, September, and October. The Boiler #3 savings is large because when #3 was set as baseline mode in the shoulder months of March and April the consumption was above average setting a high baseline, while it's optimized consumption in the winter months was average (some time was spent at the high temperature set-point) and it's optimized performance in the warm to shoulder months of July, September, and October was good with very low consumption. See Table 2.3 below showing the boiler to boiler comparison results.

Table 2.2: Month-by-Month Summary (Costa Mesa)

COSTA MESA					
#	BOILER #	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	BOILER #2	0.82	0.79	3.4%	0.8
2	BOILER #3	1.17	0.76	35.1%	12.3
AVERAGE		**0.99**	**0.77**	**22.0%**	**6.5**

* 30 days per month (for consistency)

savings derived as difference between baseline mode and optimized mode over the same boiler

To find a meaningful measure of overall performance, all optimized and all baseline data was averaged in order to compare. Boiler #3 has laundry, while #2 does not. Please note that May and June data were removed due to the gas meter not being read at the same time boiler mode was switched over.

Hot water temperature data was collected; please see Figure 2.9 for a typical day of data demonstrating the dual set-points of the "X" controller.

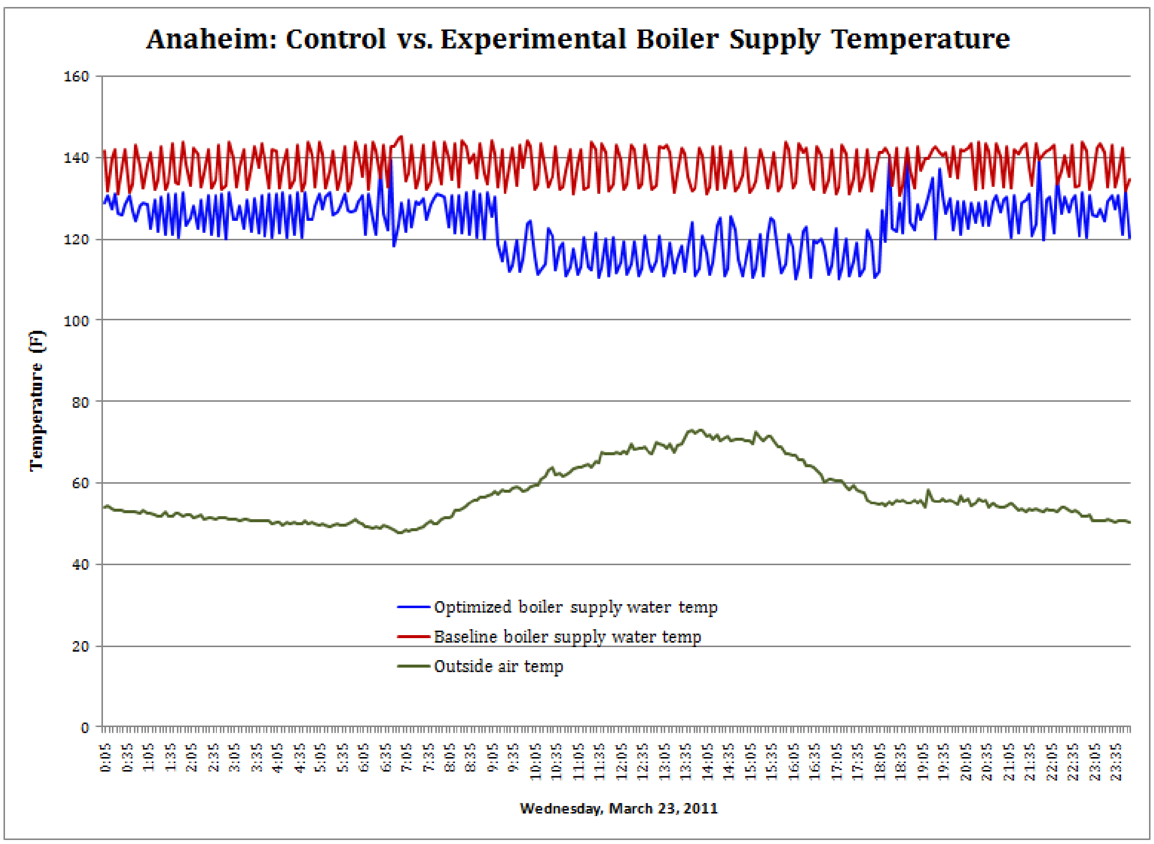


Figure 2.9: Supply Water Temperature (Typical Day)

Please note that as the ambient air temperature (dark green line) gets warmer, the supply water temperature (blue line) is reset to a lower temperature of 120°F. The baseline boiler's supply water temperature (red line) does not respond to changes in the ambient air temperature and remains at 140°F throughout the day. Figure 2.9 was made with data from the Anaheim facility, collected on March 23, 2011; other days and other sites are similar.

Calculations are performed by treating each gas meter reading as a unique data point. Both the number of days between meter readings (approximately one month) and the number of apartment units served by each boiler are considered when calculating the energy consumption per unit-day for each meter reading. To have a way to compare between different boilers and different properties, the energy consumption per unit-day must be used. Please see Equation #1 below for the equation used to calculate energy consumption per-unit day for an example boiler.

Equation #1

Where Therms consumed is calculated using Equation #2, shown below.

Equation #2

Where HCF consumed is calculated using Equation #3, shown below.

Equation #3

In order to have a way to compare between different boilers and between different properties, the energy consumption per unit-day must be used. Detailed natural gas savings results will be presented in the following section and in Appendix I.

Results

In general, energy savings were estimated as the difference between the baseline boiler and the optimized boiler. Each monthly gas meter reading for each boiler was considered as a unique data point (consumption was calculated per unit-day). In order to calculate average savings the number of unit-days served by baseline boilers and optimized boilers was calculated for each site. The total gas consumption by both baseline and optimized boilers was summed for each site. Gas consumption was tracked in HCF and converted to therms using the simplified conversion of 1026 Btu per cubic foot (all sites). Average gas consumption per unit-day was calculated for baseline and optimized boilers at each site using the total unit days served and total gas consumed. Equations #1 - #3 presented in the previous section were used. Please see Table 3.1 below for study results.

Table 3.1: Gas Consumption Data Summary

#	Site Name (City)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Apartment*	Avg. Annual Therms Saved per Apartment	Climate Zone
1	Anaheim	1.23	0.84	32.0%	11.9	144.4	8
2	Costa Mesa	0.90	0.77	15.2%	4.1	50.0	6
3	Huntington Beach	1.17	1.00	14.6%	5.1	62.1	6
4	Moreno Valley	0.81	0.65	19.4%	4.7	57.0	10
5	Pomona	0.63	0.48	23.3%	4.4	53.8	9
6	Alta Loma	0.97	0.71	26.5%	7.7	93.7	10
7	Redlands	0.67	0.64	4.5%	0.9	10.9	10
8	San Dimas	1.12	0.79	29.0%	9.7	118.1	9
AVERAGE		**0.84**	**0.68**	**19.3%**	**4.9**	**59.1**	

* 30 days per month (for consistency)

Please note that there are encouraging savings figures at all sites, with somewhat less success at Redlands. If the data were to be considered without Redlands we would see an average savings of 21.6% or 5.7 therms saved per month using a 30 day month for consistency. Further investigation into the cause of this discrepancy found that the plumbing on the tank was done incorrectly resulting in a short-circuit path of the water through the tank where the intake and exit are located next to each other. Additionally the baseline LAARS boilers were installed with a dual stage control that helps match the boiler output to the load and generally improves the efficiency over a single stage control. At all other sites the baseline "R" controller with "A" was installed as single stage control. The "X" controller in all cases is a two, three, or four stage controller depending on boiler capabilities. When the "X" controller is used as a "simulated baseline" controller it is re-set to a new water temperature set-point that does not vary with outside air temperature, but the multi-stage control sequence is left in place.

There are two reasons that the Redlands site has a lower gas savings result compared to the other sites: the first reason is that the tanks are plumbed incorrectly leading to the water short-cycling with the intake and return ports right next to each other; the second reason is that the baseline boilers are already controlled in a dual-stage configuration to match load. All other test sites with "baseline" boilers have single stage control. "Simulated baseline" boilers have multi-stage controls. For example the baseline boiler at the Huntington Beach site is simulated using an "X" controller set to keep the water in the tank at 135F regardless of the outside air temperature, so the "simulated baseline" boiler fires in multiple stages to match the building load and is more efficient than a single stage boiler with true baseline controls ("A") like we see at the Moreno Valley site.

Based on information provided by "X", apartment units are 1000 SqFt for two-bedroom units and 900 SqFt for single bedroom units. No information on the number of single and two-bedroom units was provided. Since all units are highly similar in size, a good comparison can be made by directly comparing number of units rather than square footage. Occupancy was not considered in the savings calculations due to inconsistent and very little occupancy information being available from the host apartment management companies. No data was available on the number of residents living in any unit that was occupied. From anecdotal evidence we have learned that occupancy rates are very high at all host sites, in the 80-95% range, making occupancy a small factor affecting savings.

Due to the nature of the “Y” heating system we expect that overall heating demand will diminish as the weather warms up in the spring and then summer months. The “X” controller will allow greater energy savings during warmer weather because the cooler water temperature set-point will be engaged for a greater percentage of the time. The baseline boilers will always be set at the hotter water temperature set-point for 100% of the time regardless of weather conditions. Water temperature data was collected both via data logger and spot checking at each monthly inspection. To verify that controller set-points were not being modified without approval Table 3.2 has been prepared to compare the monthly spot checks. Table 3.2 shows controller set-point where available; when not available the tank temperature is shown (assumption being that the controller is satisfied when set-point = tank temperature). When available, temperature used was supply water temperature as measured with a handheld IR thermometer. While there are some inconsistencies between the observations, they are small and can be checked against the logged supply water temperature.

In Anaheim the supply water set-point was 116F from December through May, and after May was measured to be 118F. In Costa Mesa, the optimized boiler temperature ranges between 114F and 116F until the June reading when it was set at 118. From January to October the Costa Mesa optimized boiler ranged between 119F and 122F with the exception of 125F in July. In Huntington Beach the optimized supply water set-point was 118-119F up through March with 115F in April-May, and 126F from June on. Boiler 1-1 in Moreno Valley ranged between 120F and 123F, while boiler 2-1 ranged between 115F to 116F January to March and 119 to 121 from March to October. At Pomona optimized boilers ranged between 115F and 125F. In Rancho Cucamonga optimized boiler #1 had a set-point of 120F to 122F except in the month of January where tank temperature was measured at 128F (cold weather); boiler #2 had a set-point of 119F, except December, January, and October were measured at 126F, 130F, 130F respectively (cold weather). For the most part Redlands optimized boilers were measured between 117F and 120F set-point with boiler #9 in October as the exception, which was measured at 126F. At San Dimas when boiler #1 was optimized it was set at 119F, when boiler #3 was optimized it was set at 122F. Please see Table 3.2 on the following page. The cells highlighted in a salmon color represent baseline mode while the cells highlighted in light blue represent optimized mode.

Table 3.2: Water Temperature Data over Time

Inspected Water Temperature												
City	**Boiler Name**	**Nov-10**	**Dec-10**	**Jan-11**	**Feb-11**	**Mar-11**	**Apr-11**	**May-11**	**Jun-11**	**Jul-11**	**Sep-11**	**Oct-11**
Anaheim	BLDG F (#5)	X	110	sup 139	133	132	137	136	136	118	135	120
Anaheim	BLDG B (#6)	X	116	115	116	115	115	116	118	134	118	118
Costa Mesa	#2 (middle)	X	128	138	130	119	119	121	135	135	135	135
Costa Mesa	#3 (back)	X	113	119	118	137	134	136	125	122	122	119
Huntington Beach	BLDG F	sup 105	135	132	131	132	133	135	126	126	126	124
Huntington Beach	BLDG C	sup 115	119	118	119	119	sup 114	115	135	137	137	135
Moreno Valley	Phase 1-2	sup 133	sup 142	sup 143	sup 147	sup 150	X	sup 137	sup 141	sup 140	sup 138	sup 125
Moreno Valley	Phase 2-2	sup 133	sup 126	sup 132	sup 136	137	sup 128	sup 140	sup 130	sup 136	sup 138	sup 130
Moreno Valley	Phase 1-1	sup 127	121	120	120	121	123	122	122	120	120	120
Moreno Valley	Phase 2-1	sup 125	115	116	116	119	119	121	121	121	121	121
Pomona	400 Ferrara	X	sup 136	sup 131	X	sup 140	sup 144	sup 136	sup 130	sup 147	sup 141	sup 134
Pomona	400 Portofino	X	sup 122	sup 120	sup 120	sup 138	sup 170	sup 143	sup 157	sup 153	sup 141	sup 138
Pomona	460 Ferrara	X	sup 121	sup 119	X	X	sup 126	118	sup 132	sup 128	sup 163	sup 130
Pomona	420 Lucera	X	132	119	119	117	116	116	130	119	119	118
Pomona	420 Portofino	X	115	117	119	115	115	116	137	137	137	137
Pomona	470 Lucera	X	130	121	115	X	116	118	119	119	119	125
Pomona	480 Portofino	X	116	121	120	110	117	123	120	120	131	133
Rancho Cucamonga	#5	sup 117	sup 144	sup 128	X	sup 161	sup 161	sup 132	sup 131	sup 134	sup 135	sup 164
Rancho Cucamonga	#8	X	sup 109	sup 127	X	X	sup 121	sup 122	sup 126	sup 130	sup 143	sup >121
Rancho Cucamonga	#1	sup 96	sup 90	128	121	117	119	121	121	120	120	122
Rancho Cucamonga	#2	sup 113	126	130	118	120	118	119	119	119	119	130
Redlands	#2	sup 128	sup >117	sup 124	sup 136	X	X	sup 135	sup 135	sup 131	sup 134	134
Redlands	#3	sup 137	sup 122	sup 150	sup 141	sup 137	sup 137	178	sup 133	136	135	sup 131
Redlands	#5	sup 115	112	114	116	117	117	180	125	120	120	120
Redlands	#8	X	sup 113	117	118	123	124	130	sup 135	139	141	165
Redlands	#9	X	116	118	121	129	117	119	119	120	119	126
Redlands	#11	sup 118	sup 120	125	121	130	126	119	119	120	120	120
San Dimas	#1	X	X	117	116	134	138	136	sup 132	119	119	118
San Dimas	#3	X	X	130	130	122	sup 110	122	137	137	122	122

Legend
Baseline Boiler Mode
Optimized Boiler Mode

NOTES:

Setpoint used when available, othewise tank temperature was used. If neither was available supply water temperature was used

Supply water temperature will be less than setpoiont, and in some cases is very low due to no flow

Please see Table 3.3 below for a timeline of each boiler's energy consumption per unit-day. The cells highlighted in a salmon color represent baseline mode while the cells highlighted in light blue represent optimized mode.

Table 3.3: Performance Data over Time

Therms Consumed per Unit-Day											
City	***Boiler Name***	***Dec-10***	***Jan-11***	***Feb-11***	***Mar-11***	***Apr-11***	***May-11***	***Jun-11***	***Jul-11***	***Sep-11***	***Oct-11***
Anaheim	BLDG F (#5)	n/a	1.59	1.36	1.47	1.36	1.20	1.20	1.15	1.03	0.83
Anaheim	BLDG B (#6)	n/a	1.15	0.94	1.00	0.97	0.82	0.80	0.72	0.64	0.64
Costa Mesa	#2 (middle)	n/a	0.99	0.97	0.83	0.76	n/a	n/a	0.77	0.71	0.73
Costa Mesa	#3 (back)	n/a	1.11	0.94	1.21	1.13	n/a	n/a	0.66	0.60	0.57
Huntington Beach	BLDG F	1.13	1.53	1.28	1.32	1.25	1.14	1.02	0.96	0.95	0.95
Huntington Beach	BLDG C	1.02	1.36	1.06	1.14	1.02	0.84	1.21	1.10	1.06	1.07
Moreno Valley	Phase 1-2	n/a	1.15	n/a	1.05	0.94	0.75	0.76	0.59	0.55	0.56
Moreno Valley	Phase 2-2	0.93	1.22	n/a	1.11	0.98	0.75	0.71	0.54	0.48	0.49
Moreno Valley	Phase 1-1	0.71	0.94	n/a	0.82	0.71	n/a	0.59	0.43	0.42	0.41
Moreno Valley	Phase 2-1	0.82	1.08	n/a	0.99	0.82	0.60	0.53	0.40	0.36	0.36
Pomona	400 Ferrara	0.75	0.88	0.83	n/a	0.86	0.66	0.70	0.58	0.50	0.59
Pomona	400 Portofino	0.72	0.96	0.86	0.89	1.01	0.79	0.67	0.53	0.47	0.50
Pomona	460 Ferrara	0.54	0.70	0.63	0.63	0.61	0.56	0.55	0.45	0.31	0.36
Pomona	420 Lucera	n/a	0.71	0.66	0.79	0.71	0.58	0.66	0.36	0.29	0.31
Pomona	420 Portofino	0.63	0.71	0.55	0.55	0.54	0.45	0.54	n/a	0.45	0.48
Pomona	470 Lucera	0.51	0.62	0.57	0.64	0.57	0.49	0.44	0.38	0.33	0.36
Pomona	480 Portofino	0.48	0.55	0.52	0.52	0.45	0.35	0.31	0.27	n/a	0.39
Rancho Cucamonga	#5	0.80	n/a	0.82	1.09	1.00	0.87	0.61	0.59	0.50	0.44
Rancho Cucamonga	#8	1.34	1.89	1.71	1.43	1.27	0.99	0.96	0.78	0.73	0.49
Rancho Cucamonga	#1	0.99	1.18	1.00	0.96	0.96	0.68	0.62	0.50	0.36	0.45
Rancho Cucamonga	#2	0.67	1.13	0.79	0.71	0.65	0.49	0.44	0.38	0.47	0.38
Redlands	#2	0.81	1.13	n/a	0.85	0.74	0.70	0.56	0.34	0.40	0.37
Redlands	#3	0.73	1.03	n/a	0.86	0.83	0.71	0.59	0.57	0.45	0.43
Redlands	#5	0.67	1.01	n/a	0.85	n/a	0.89	0.52	n/a	0.36	0.33
Redlands	#8	0.62	1.03	n/a	0.77	0.72	0.58	n/a	0.62	0.53	0.40
Redlands	#9	0.66	1.19	n/a	0.89	0.83	0.70	0.62	0.57	0.46	0.36
Redlands	#11	0.82	0.98	n/a	n/a	1.00	0.47	0.40	0.50	0.33	0.38
San Dimas	#1	n/a	n/a	1.45	2.06	1.36	n/a	0.96	0.82	0.82	0.79
San Dimas	#3	n/a	n/a	0.91	0.83	n/a	0.74	0.95	0.69	0.46	0.49

Baseline Boiler Mode
Optimized Boiler Mode

Overall the "X" controller was shown to have a positive effect on natural gas conservation in each combined HHW / DHW system into which it was installed and tested, when compared to "Y" systems without the "X" controller. Averaging data from all eight sites yields a **19.3% savings** over the baseline. This yields an estimated **annual natural gas savings of 59.1 therms per apartment**. If the data from the Redlands site is not included (statistical outlier) then the savings is estimated at 21.6% over baseline or 69.5 therms per year per apartment unit. Based on the results of this study the savings can justify the usefulness of the product for the building operator. Additional calculations, detailed savings, and raw data are included in Appendix III as an Excel workbook.

Conclusions

After reviewing all of the variables in this study, it is clear that the "X" controller can achieve significant natural gas savings in its intended application. Gas consumption was normalized only by the reported number of units served by each boiler. Occupancy, number of individuals per unit, tenant schedules, and other factors could not be effectively accounted for. Despite these minor drawbacks the savings figures reported are high enough to ensure that the "X" controller is able to generate savings by lowering the water temperature set-point and managing the boiler staging based on load and ambient temperature. In general, savings were on the order of 20% with some sites showing more and some sites less. Based on a review of the data collected thus far IES finds that the "X" Controller can be used successfully on hydronic combined DHW and HHW systems in temperate climates such as Southern California to save natural gas energy.

APPENDIX

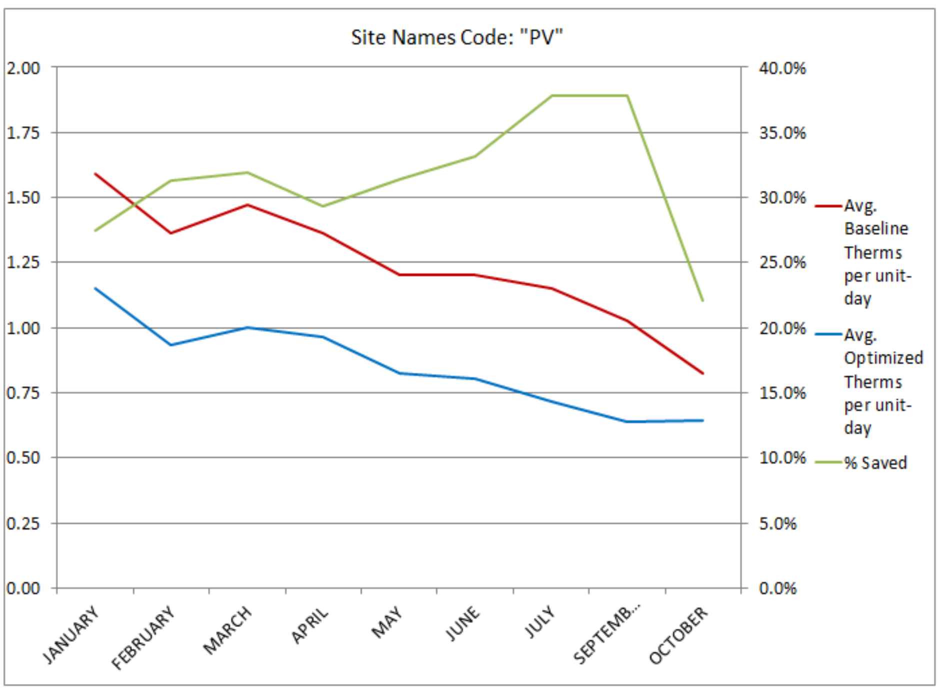
Appendix I: Monthly Performance by Site

Site Names Code: "PV"					
#	Month (2011)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	JANUARY	1.59	1.15	27.5%	13.1
2	FEBRUARY	1.36	0.94	31.3%	12.8
3	MARCH	1.47	1.00	31.9%	14.1
4	APRIL	1.36	0.97	29.3%	12.0
5	MAY	1.20	0.82	31.4%	11.3
6	JUNE	1.20	0.80	33.2%	12.0
7	JULY	1.15	0.72	37.8%	13.1
8	SEPTEMBER	1.03	0.64	37.8%	11.7
9	OCTOBER	0.83	0.64	22.1%	5.5
		BOILER F	BOILER B		
AVERAGE		**1.24**	**0.85**	**31.4%**	**11.7**

* 30 days per month (for consistency)

savings derived as difference between boiler F (baseline) and boiler B (optimized) over the same time period

- Savings derived as difference between boiler F (baseline) and boiler B (optimized) over the same time period
- At "PV" the supply water set-point was 116F from December through May, and after May was measured to be 118F.
- Baseline and Optimized boilers were not swapped at this site. Savings were highest in July to September
- Baseline consumption was consistent except October baseline below normal.



Site Name Code "WV"							
#	Month (2011)	Baseline Boiler	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	Optimized Boiler	% Saved	Avg. Monthly Therms Saved per Unit*
1	JANUARY	#2	0.99	1.11	#3	-12.8%	(3.8)
2	FEBRUARY	#2	0.97	0.94	#3	3.0%	0.9
3	MARCH	#3	1.21	0.83	#2	31.5%	11.4
4	APRIL	#3	1.13	0.76	#2	32.6%	11.0
5	JULY	#2	0.77	0.66	#3	14.3%	3.3
6	SEPTEMBER	#2	0.71	0.60	#3	14.7%	3.1
7	OCTOBER	#2	0.73	0.57	#3	21.4%	4.7
AVERAGE			0.93	0.78		15.7%	4.4

* 30 days per month (for consistency)

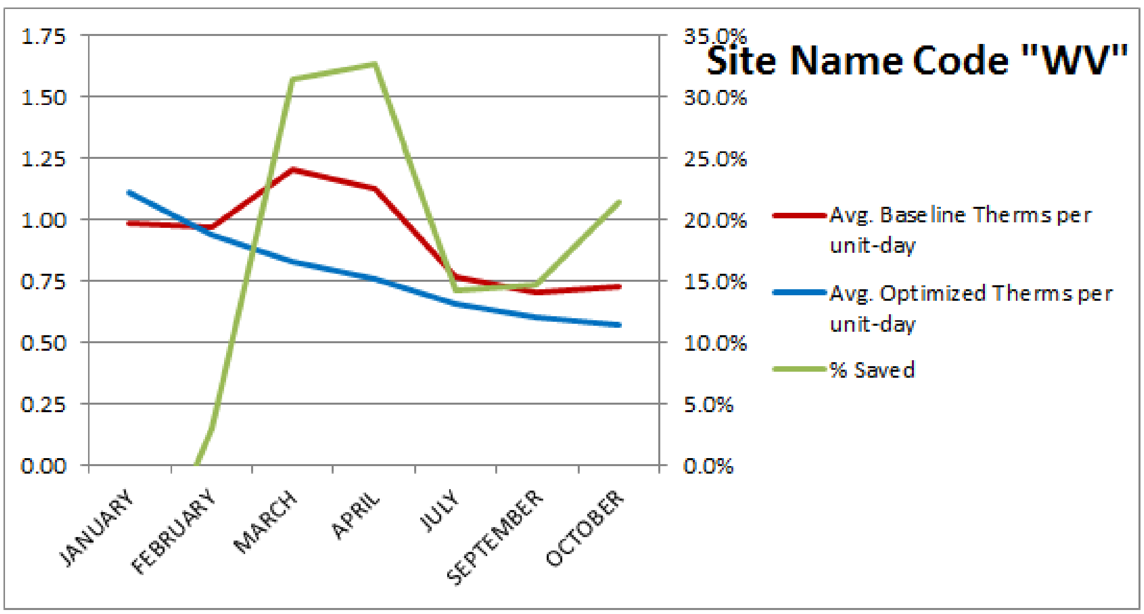
savings derived as difference between baseline boiler and optimized boiler over the same time period

Site Name Code "WV"					
#	BOILER #	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	BOILER #2	0.82	0.79	3.4%	0.8
2	BOILER #3	1.17	0.76	35.1%	12.3
AVERAGE		0.99	0.77	22.0%	6.5

* 30 days per month (for consistency)

savings derived as difference between baseline mode and optimized mode over the same boiler

- In "WV", the optimized boiler temperature ranges between 114F and 116F until the June reading when it was set at 118. From January to October the Costa Mesa optimized boiler ranged between 119F and 122F with the exception of 125F in July.
- Boiler #2 was baseline and #3 optimized before March
- Boiler #3 was baseline and #2 optimized March-April
- Boiler #2 was baseline and #3 optimized after April
- Boiler #3 serves laundry room, #2 does not
- Please note negative savings in January, this is due to the optimized boilers increased load (laundry) compared to the baseline boiler and therefore shows higher consumption.
- The two boilers at this site have different hot water loads, therefore all data is averaged, and the boilers were swapped twice to run each boiler in each mode.



Site Name Code "HC"							
#	Month (2010/11)	Baseline Boiler	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	Optimized Boiler	% Saved	Avg. Monthly Therms Saved per Unit*
1	DECEMBER	*F*	*1.13*	*1.02*	*C*	9.4%	3.2
2	JANUARY	*F*	*1.53*	*1.36*	*C*	11.0%	5.0
3	FEBRUARY	*F*	*1.28*	*1.06*	*C*	17.1%	6.6
4	MARCH	*F*	*1.32*	*1.14*	*C*	13.4%	5.3
5	APRIL	*F*	*1.25*	*1.02*	*C*	18.4%	6.9
6	MAY	*F*	*1.14*	*0.84*	*C*	26.5%	9.0
7	JUNE	C	1.21	1.02	F	15.5%	5.6
8	JULY	C	1.10	0.96	F	12.6%	4.2
9	SEPTEMBER	C	1.06	0.95	F	10.7%	3.4
10	OCTOBER	C	1.07	0.95	F	11.3%	3.6
AVERAGE			**1.21**	**1.03**		**14.6%**	**5.3**

* 30 days per month (for consistency)

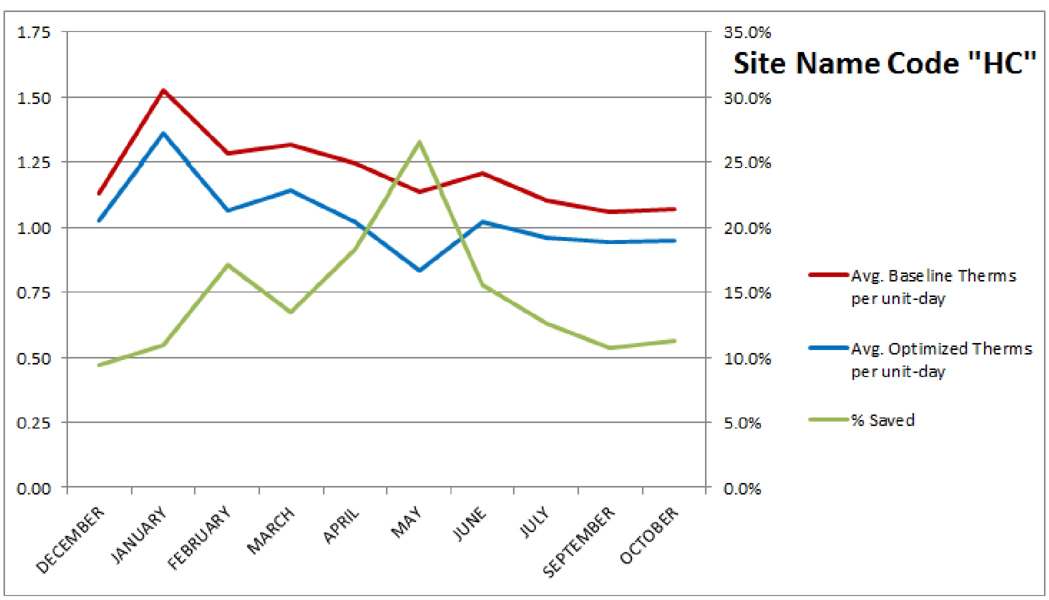
savings derived as difference between baseline boiler and optimized boiler over the same time period

Site Name Code "HC"					
#	BOILER #	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	BOILER F	1.26	0.97	23.5%	8.9
2	BOILER C	1.10	1.07	3.3%	1.1
AVERAGE		**1.18**	**1.02**	**14.1%**	**5.0**

* 30 days per month (for consistency)

savings derived as difference between baseline mode and optimized mode over the same boiler

- In "HC" the optimized supply water set-point was 118-119F up through March with 115F in April-May, and 126F from June on.
- Boiler F was baseline and C optimized through May
- Boiler C was baseline and F optimized after May
- Savings were highest in May, which accompanies the lowest water temperatures
- When comparing Boiler C to itself please note that we are making a comparison of an optimized boiler's consumption in cold weather t a baseline boiler's consumption in hot weather.

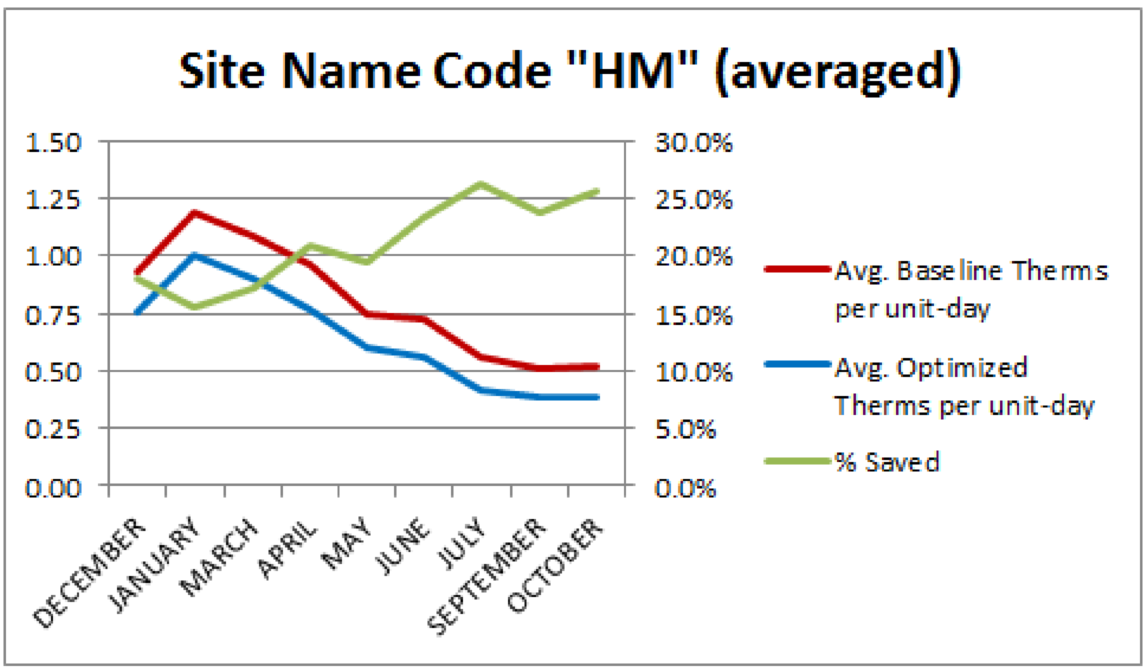


#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
Site Name Code "HM" (averaged)					
1	DECEMBER	0.93	0.76	18.0%	5.0
2	JANUARY	1.19	1.01	15.4%	5.5
3	MARCH	1.09	0.90	17.1%	5.6
4	APRIL	0.96	0.76	20.8%	6.0
5	MAY	0.75	0.60	19.3%	4.3
6	JUNE	0.73	0.56	23.4%	5.1
7	JULY	0.56	0.42	26.1%	4.4
8	SEPTEMBER	0.51	0.39	23.7%	3.6
9	OCTOBER	0.52	0.39	25.5%	4.0
AVERAGE		**0.80**	**0.64**	**20.1%**	**4.8**

* 30 days per month (for consistency)

savings derived as difference between average of baseline boilers and average of optimized boilers over same period

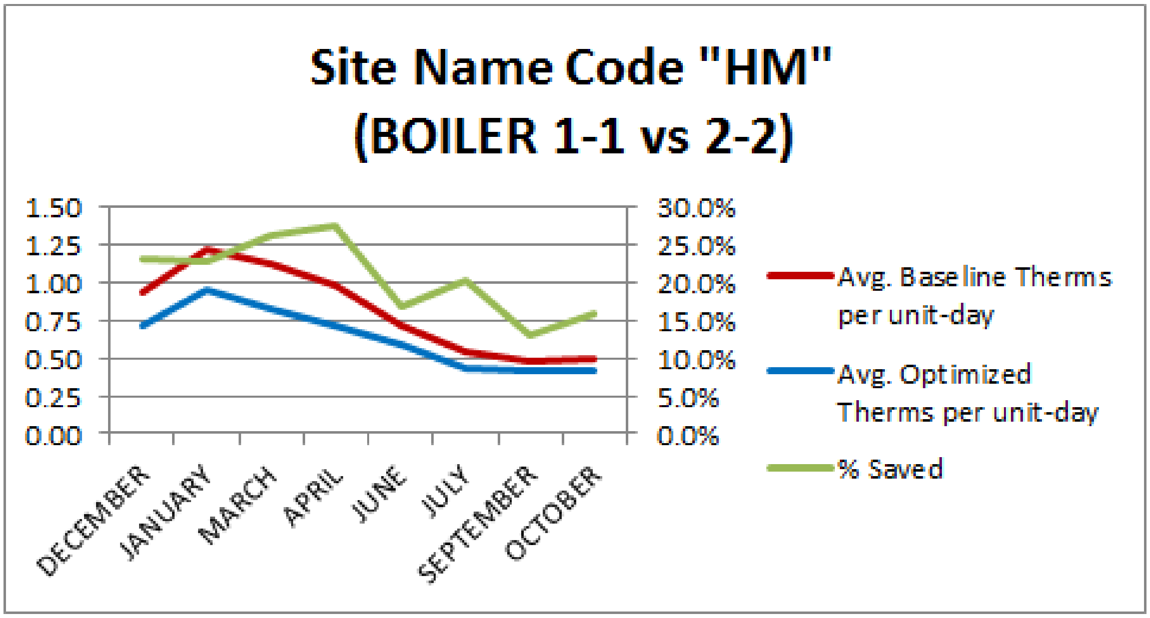
- Boiler 1-1 supply water temperature set-point ranged between 120F and 123F, while boiler 2-1 ranged between 115F to 116F January to March and 119 to 121 from March to October
- Baseline and optimized boilers were not swapped at this site
- Due to low gas consumption at optimized boiler 2-1 the average savings increase as time passes
- Overall gas consumption at all boilers followed a downward trend over time.



Site Name Code "HM" (BOILER 1-1 vs 2-2)					
#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	DECEMBER	0.93	0.71	23.2%	6.4
2	JANUARY	1.22	0.94	22.9%	8.4
3	MARCH	1.11	0.82	26.3%	8.8
4	APRIL	0.98	0.71	27.5%	8.1
5	JUNE	0.71	0.59	16.7%	3.5
6	JULY	0.54	0.43	20.2%	3.3
7	SEPTEMBER	0.48	0.42	13.1%	1.9
8	OCTOBER	0.49	0.41	15.8%	2.3
		BOILER 2-2	BOILER 1-1		
AVERAGE		**0.81**	**0.63**	**22.1%**	**5.3**

* 30 days per month (for consistency)

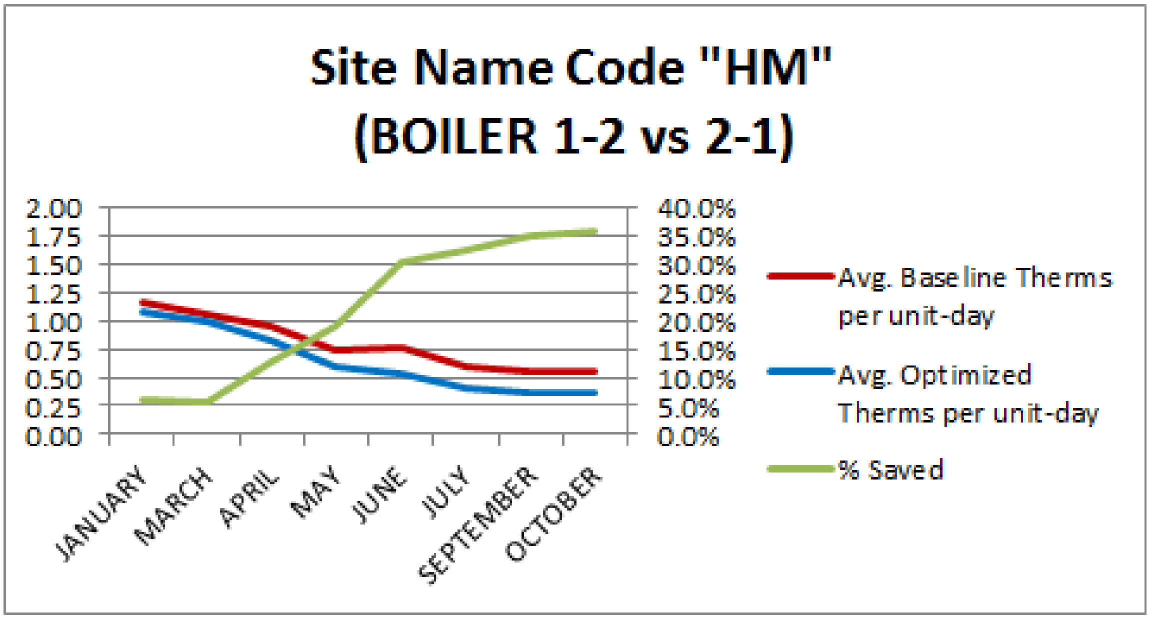
savings derived as difference between baseline boiler 2-2 and optimized boiler 1-1 over the same time period



Site Name Code "HM" (BOILER 1-2 vs 2-1)					
#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	JANUARY	1.15	1.08	6.1%	2.1
2	MARCH	1.05	0.99	5.5%	1.7
3	APRIL	0.94	0.82	12.7%	3.6
4	MAY	0.75	0.60	19.2%	4.3
5	JUNE	0.76	0.53	30.2%	6.8
6	JULY	0.59	0.40	32.6%	5.8
7	SEPTEMBER	0.55	0.36	34.7%	5.7
8	OCTOBER	0.56	0.36	35.7%	6.0
		BOILER 1-2	BOILER 2-1		
AVERAGE		**0.79**	**0.64**	**18.9%**	**4.5**

* 30 days per month (for consistency)

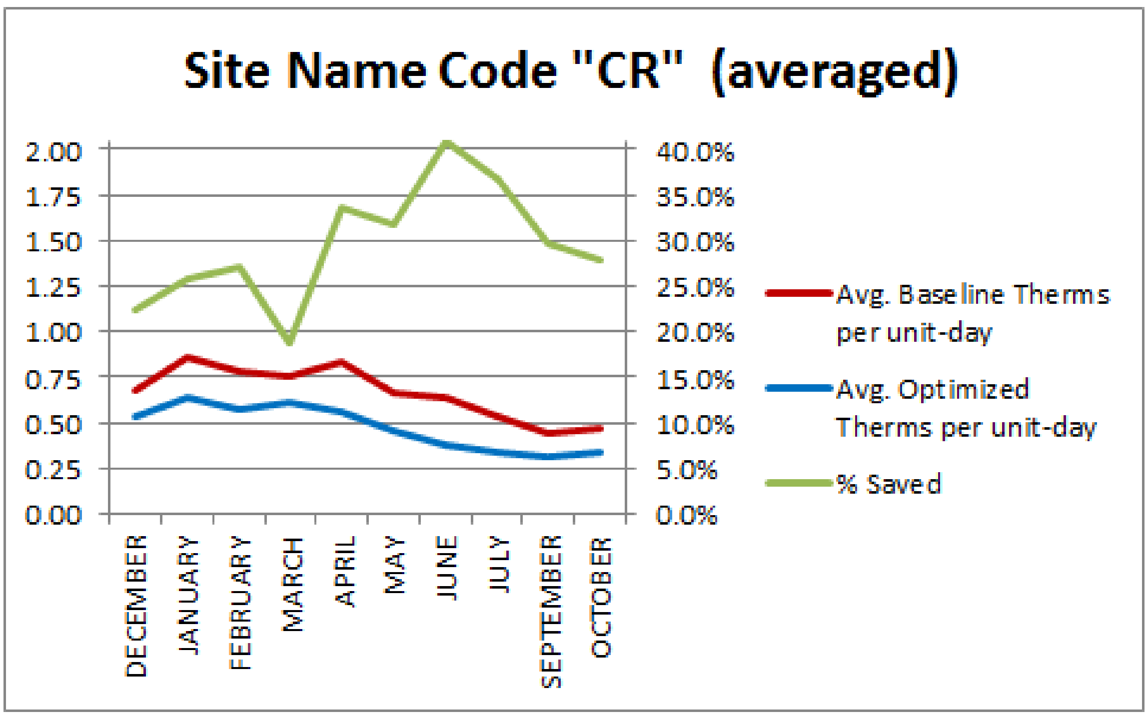
savings derived as difference between baseline boiler 2-1 and optimized boiler 1-2 over the same time period



#	Month (2010-11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
	Site Name Code "CR" (averaged)				
1	DECEMBER	0.68	0.53	22.5%	4.6
2	JANUARY	0.85	0.63	25.7%	6.6
3	FEBRUARY	0.78	0.57	27.1%	6.3
4	MARCH	0.76	0.62	18.7%	4.2
5	APRIL	0.84	0.56	33.5%	8.4
6	MAY	0.67	0.46	31.7%	6.4
7	JUNE	0.63	0.37	40.9%	7.7
8	JULY	0.53	0.34	36.6%	5.8
9	SEPTEMBER	0.44	0.31	29.6%	3.9
10	OCTOBER	0.47	0.34	27.8%	3.9
AVERAGE		**0.67**	**0.47**	**29.0%**	**5.8**

* 30 days per month (for consistency)

- Savings derived as difference between average of baseline boilers and average of optimized boilers over same period
- Optimized boiler set-points ranged between 115F and 125F.
- 400 Ferr., 400 Porto., & 460 Ferr. were dedicated baseline boilers for the entire test
- 420 Luce. was baseline for June only.
- 420 Porto. was baseline after May.
- 480 Porto. was baseline after July.
- Performance was high overall at this site.
- Performance was lowest in March due to a combination of slightly low baseline and slightly elevated consumption from optimized boilers.

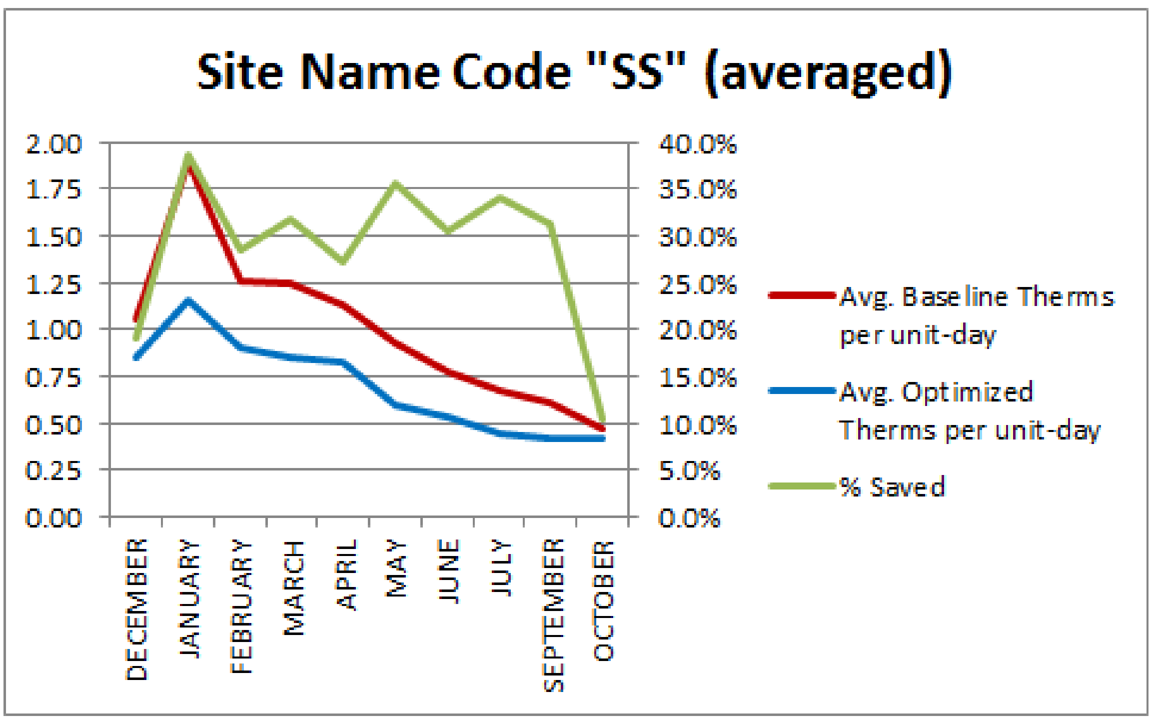


#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
	Site Name Code "SS" (averaged)				
1	DECEMBER	1.05	0.85	19.0%	6.0
2	JANUARY	1.89	1.16	38.7%	22.0
3	FEBRUARY	1.26	0.90	28.5%	10.8
4	MARCH	1.25	0.85	31.7%	11.9
5	APRIL	1.13	0.82	27.3%	9.2
6	MAY	0.93	0.60	35.5%	9.9
7	JUNE	0.78	0.54	30.6%	7.1
8	JULY	0.68	0.45	34.0%	6.9
9	SEPTEMBER	0.61	0.42	31.3%	5.7
10	OCTOBER	0.47	0.42	10.5%	1.5
AVERAGE		**1.00**	**0.70**	**30.2%**	**9.1**

* 30 days per month (for consistency)

savings derived as difference between average of baseline boilers and average of optimized boilers over same period

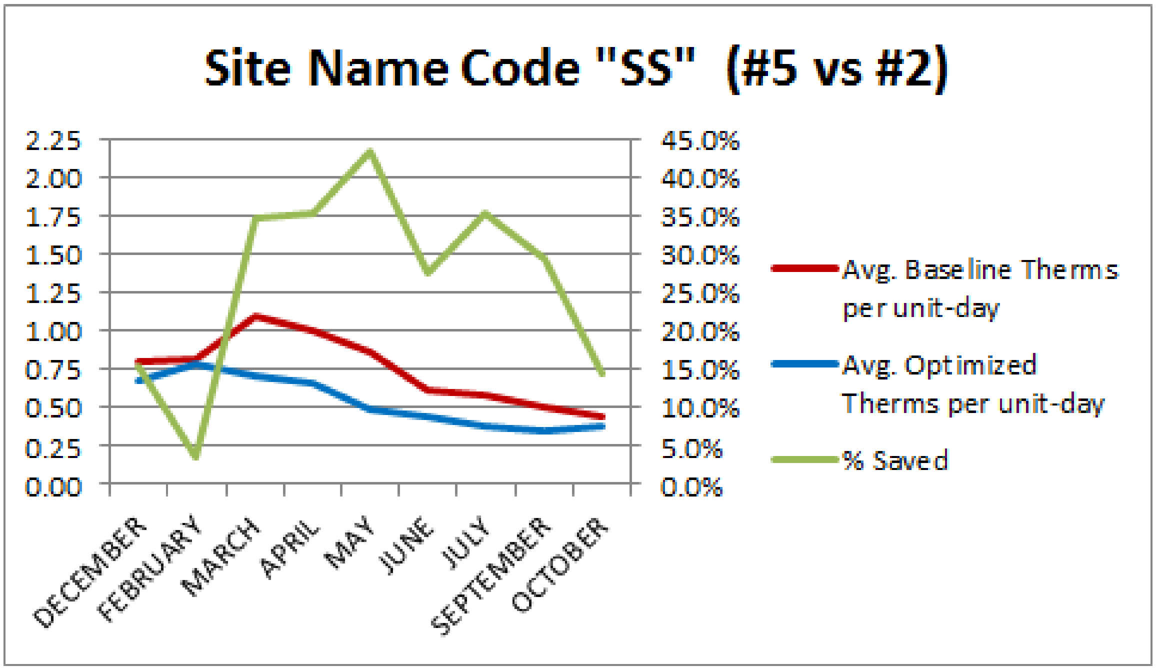
- In "SS" optimized boiler #1 had a set-point of 120F to 122F except in the month of January where tank temperature was measured at 128F (cold weather); boiler #2 had a set-point of 119F, except December, January, and October were measured at 126F, 130F, 130F respectively (cold weather).
- Baseline and optimized boilers were not swapped at this site
- Performance was high overall at this site.
- Performance was highest in January due to unusually high consumption by baseline boiler #8 in that month.
- Performance was also good in May and July.



Site Name Code "SS" (#5 vs #2)					
#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	DECEMBER	0.80	0.67	15.4%	3.7
2	FEBRUARY	0.82	0.79	3.5%	0.9
3	MARCH	1.09	0.71	34.6%	11.3
4	APRIL	1.00	0.65	35.1%	10.6
5	MAY	0.87	0.49	43.2%	11.3
6	JUNE	0.61	0.44	27.6%	5.1
7	JULY	0.59	0.38	35.3%	6.2
8	SEPTEMBER	0.50	0.36	29.2%	4.4
9	OCTOBER	0.44	0.38	14.6%	1.9
		BOILER #5	BOILER #2		
AVERAGE		0.75	0.54	27.4%	6.1

* 30 days per month (for consistency)

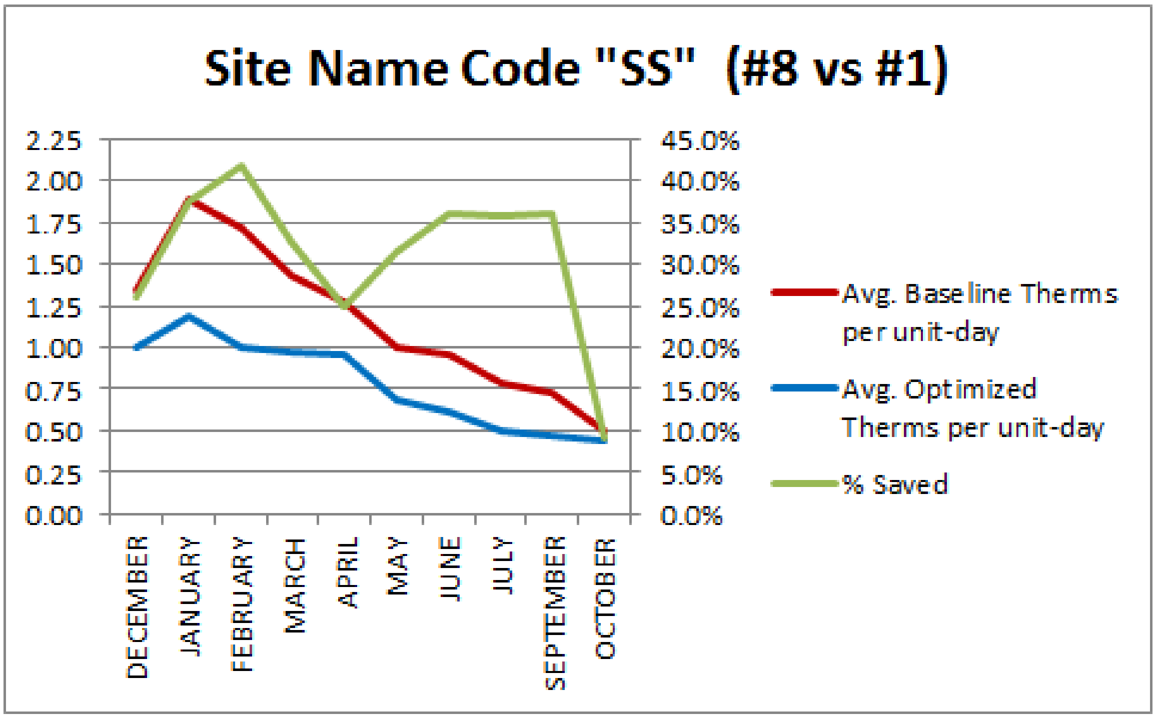
savings derived as difference between baseline boiler #5 and optimized boiler #1 over the same time period



Site Name Code "SS" (#8 vs #1)					
#	Month (2010/11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	DECEMBER	1.34	0.99	26.0%	10.5
2	JANUARY	1.89	1.18	37.4%	21.2
3	FEBRUARY	1.71	1.00	41.7%	21.4
4	MARCH	1.43	0.96	32.6%	14.0
5	APRIL	1.27	0.96	24.8%	9.4
6	MAY	0.99	0.68	31.4%	9.4
7	JUNE	0.96	0.62	36.1%	10.4
8	JULY	0.78	0.50	35.8%	8.4
9	SEPTEMBER	0.73	0.47	35.9%	7.9
10	OCTOBER	0.49	0.45	9.2%	1.4
		BOILER #8	BOILER #1		
AVERAGE		**1.16**	**0.78**	**32.7%**	**11.4**

* 30 days per month (for consistency)

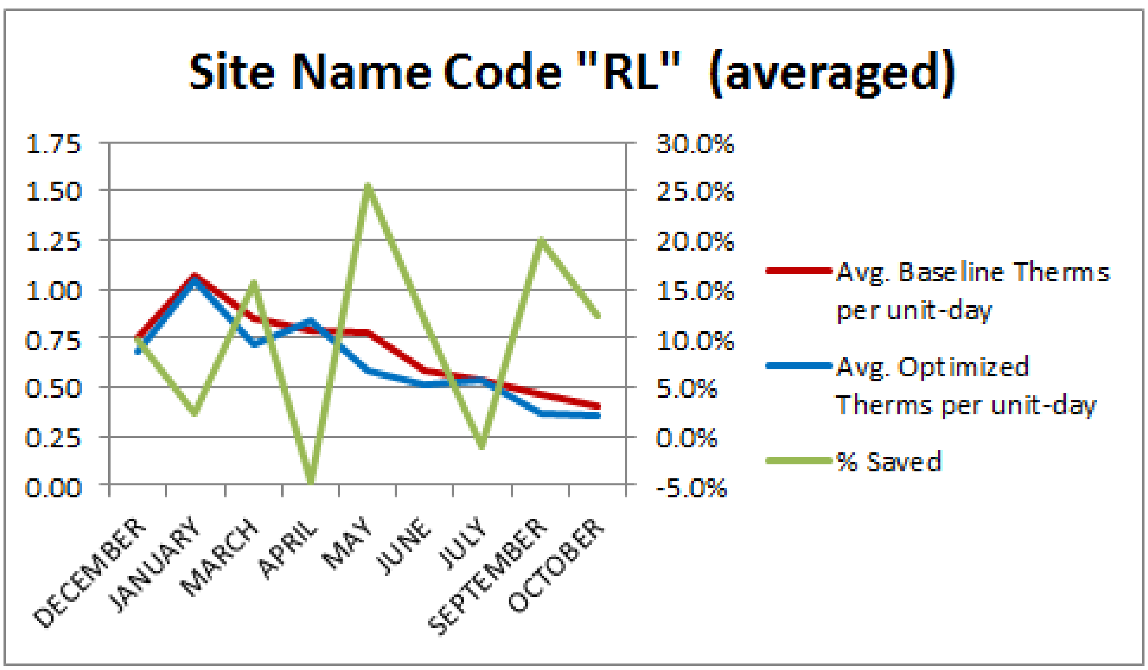
savings derived as difference between baseline boiler #8 and optimized boiler #1 over the same time period



#	Month (2010-11)	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
	Site Name Code "RL" (averaged)				
1	DECEMBER	0.76	0.68	9.7%	2.2
2	JANUARY	1.07	1.04	2.3%	0.7
3	MARCH	0.85	0.72	15.7%	4.0
4	APRIL	0.80	0.83	-4.7%	(1.1)
5	MAY	0.78	0.58	25.5%	6.0
6	JUNE	0.58	0.51	11.7%	2.0
7	JULY	0.53	0.54	-1.0%	(0.2)
8	SEPTEMBER	0.47	0.37	20.1%	2.8
9	OCTOBER	0.40	0.35	12.2%	1.5
AVERAGE		**0.69**	**0.63**	**9.6%**	**2.0**

* 30 days per month (for consistency)

- Savings derived as difference between average of baseline boilers and average of optimized boilers over same period
- "RL" optimized boiler supply water set-points were measured between 117F and 120F set-point with exceptions as noted below.
- Savings at this site are low overall, especially in the months of January, April, and July.
- Baseline boilers at this site have LAARS multi-stage control
- Hot water tanks at this site are plumbed incorrectly leading to short-cycling the water in the tank
- In January and April the supply water set-point was 126F and 125F respectively, which is higher than other optimized boilers
- In April and July boiler #5 gas meter data was removed or missed respectively
- Boilers #2 and #3 were baseline for all months.
- Boiler #5 was baseline for May only, optimized other months.
- Boiler #8 was baseline after June, optimized before.
- Boilers #9 and #11 were optimized for all months.



Site Name Code "MV" (combined)					
#	Time Period	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	ALL MONTHS	1.12	0.79	29.0%	9.7
AVERAGE		**1.12**	**0.79**	**29.0%**	**9.7**

* 30 days per month (for consistency)

savings derived as difference between average of all baseline data compared to average of all optimized data over all time periods

Site Name Code "MV"					
#	BOILER #	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Unit*
1	BOILER #1	1.46	0.96	34.2%	15.0
2	BOILER #3	0.83	0.64	22.9%	5.7
AVERAGE		**1.15**	**0.80**	**30.1%**	**10.4**

* 30 days per month (for consistency)

savings derived as difference between baseline mode and optimized mode over the same boiler

- At “MV” when boiler #1 was optimized it was set at 119F, when boiler #3 was optimized it was set at 122F.
- Boiler #1 was set as optimized before March and after June, set as baseline other months
- Boiler #3 was set as optimized boiler from March to May and after June, set as baseline other months.
- Performance was high overall at this site.
- Load was different between the two boilers.
- Savings comparisons are made by averaging all data or by comparing each boiler to itself.

Combined Data Table

#	Site Name Code	Avg. Baseline Therms per unit-day	Avg. Optimized Therms per unit-day	% Saved	Avg. Monthly Therms Saved per Apartment*	Avg. Annual Therms Saved per Apartment	Climate Zone
1	PV	1.23	0.84	32.0%	11.9	144.4	8
2	WV	0.90	0.77	15.2%	4.1	50.0	6
3	HC	1.17	1.00	14.6%	5.1	62.1	6
4	HM	0.81	0.65	19.4%	4.7	57.0	10
5	CR	0.63	0.48	23.3%	4.4	53.8	9
6	SS	0.97	0.71	26.5%	7.7	93.7	10
7	RL	0.67	0.64	4.5%	0.9	10.9	10
8	MV	1.12	0.79	29.0%	9.7	118.1	9
AVERAGE		**0.84**	**0.68**	**19.3%**	**4.9**	**59.1**	

* 30 days per month (for consistency)

Appendix II: M&V Log

M&V Log					
#	Date	Site	Boiler #	Event	Action Taken
1	11/3/2010	RL	#8	Transcription Error	Gas meter reading corrected from 745572 HCF to 74572 HCF
2	11/4/2010	SS	#2	Units Error	Gas meter units changed from KCF to HCF
3	11/4/2010	SS	#1	Small HW Leak at Circulation Pump	Notified site maintenance
4	11/4/2010	SS	#5	Gas Line Not Properly Secured	Notified "X"
5	11/12/2010	CR	420 Luce.	Gas Meter Not Read	None
6	11/12/2010	HC	Bldg. L	Unrelated HW leak	Unrelated to study, notified site maintenance
7	12/15/2010	RL	#11	Transcription Error	Gas meter reading corrected from 5999 HCF to 6999 HCF
8	12/15/2010	SS	#2	Units Error	Gas meter units changed from KCF to HCF
9	12/16/2010	PV	Bldg. H	Exposed wires: pump connection	Notified "X"
10	12/16/2010	PV	Bldg. Q	Unrelated HW leak	Unrelated to study, notified site maintenance
11	12/16/2010	WV	#3	Laundry room is served by this boiler	Operation modes will be swapped from time to time
12	12/16/2010	WV	#2	No laundry room served by this boiler	Operation modes will be swapped from time to time
13	12/16/2010	WV	#2	Exposed wires: pump connection	Notified "X"
14	12/17/2011	CR	470 Luce.	Exposed wires: pump connection	Notified "X"
15	12/31/2010	PV	Bldg. F	Wires to "X" controller were cut by service tech.	All data used as baseline
16	1/11/2011	WV	#2	Small HW Leak at Circulation Pump	Notified site maintenance
17	1/12/2011	CR	480 Porto.	66F waterline, boiler not firing & pump off	None, "X" controller power on, appears OK (tank temp at 121F). Turned pump on
18	1/12/2011	CR	460 Ferr.	Pump was off	Turned pump on
19	1/12/2011	MV	#3	Gas line corroded, leak	Gas line replaced below grade

M&V Log					
#	Date	Site	Boiler #	Event	Action Taken
20	1/13/2011	HM	2-2	1 of 2 Circ. Pumps out of service	Other circ. Pump was working, data should be OK
21	1/13/2011	SS	#2	Units Error	Gas meter units changed from KCF to HCF
22	1/13/2011	RL	#5	IES Temp. probe #2 may have malfunctioned, output at 200F	Replaced supply water temp. probe with new unit
23	2/15/2011	MV	#1	Mode Swapped	Mode changed from optimized to baseline
24	2/15/2011	MV	#3	Mode Swapped	Mode changed from baseline to optimized
25	2/15/2011	WV	#2	Mode Swapped	Mode changed from baseline to optimized
26	2/15/2011	WV	#3	Mode Swapped	Mode changed from optimized to baseline
27	2/24/2011	SS	#2	Units Error	Gas meter units changed from KCF to HCF
28	2/24/2011	CR	400 Porto.	Small HW Leak	Notified site maintenance
29	3/16/2011	CR	400 Ferr.	Gas Meter Not Read	Following meter reading and date used
30	3/16/2011	CR	470 Luce.	Boiler being repaired	Boiler out for short period of time only, therefore data was kept.
31	3/16/2011	CR	420 Luce.	Small HW Leak	None, maintenance staff already working on it.
32	3/16/2011	HC	Bldg L	Unrelated HW leak	Unrelated to study, notified site maintenance
33	3/22/2011	HM	2-2	New Pipe Insulation	None
34	3/22/2011	HM	1-1	New Pipe Insulation	None
35	4/14/2011	CR	400 Porto.	Large HW Leak	Notified site maintenance
36	4/14/2011	CR	400 Ferr.	Hosebib running full open wasting water	Closed valve
37	4/14/2011	CR	420 Luce.	T&P valve leaking	Notified site maintenance
38	4/14/2011	MV	#3	Gas Meter Not Read	Following meter reading and date used

M&V Log					
#	**Date**	**Site**	**Boiler #**	**Event**	**Action Taken**
39	4/14/2011	RL	#3	Counter Rolled Over in Gas Meter	None
40	4/14/2011	RL	#5	Power to "X" controller was off due to service company	Data since last read was removed from study calculations & results.
41	4/15/2011	WV	#2	Small HW Leak	Notified site maintenance
42	5/17/2011	HC	Bldg. F	Mode Swapped	Mode changed from baseline to optimized
43	5/17/2011	HC	Bldg. C	Mode Swapped	Mode changed from optimized to baseline
44	5/17/2011	MV	#1	Mode Swapped	Mode changed from baseline to optimized
45	5/17/2011	MV	#3	Mode Swapped	Mode changed from optimized to baseline
46	5/17/2011	CR	400 Ferr.	Hosebib running full open wasting water	Could not fully close valve, site maintenance notified
47	5/17/2011	CR	420 Luce.	T&P valve leaking	Notified site maintenance
48	5/17/2011	CR	420 Luce.	Mode Swapped	Mode changed from optimized to baseline
49	5/17/2011	CR	420 Porto.	Mode Swapped	Mode changed from optimized to baseline
50	5/18/2011	RL	#2	Counter Rolled Over in Gas Meter	None
51	5/18/2011	RL	#5	Power to "X" controller was still off	Data was used as baseline data
52	5/18/2011	HM	1-1	Gas Meter Not Read	Following meter reading and date used
53	5/17/2011	WV	#2	Gas Meter Not Read	None
54	5/17/2011	WV	#3	Gas Meter Not Read	None
55	5/17/2011	WV	#2	Mode Swapped	Mode changed from optimized to baseline
56	5/17/2011	WV	#3	Mode Swapped	Mode changed from baseline to optimized
57	6/13/2011	WV	#2	Gas Meter Not Read at Changeover (previous mo)	Site data from May & June was removed from study calculations & results.
58	6/13/2011	WV	#3	Gas Meter Not Read at Changeover (previous mo)	Site data from May & June was removed from study calculations & results.
59	6/13/2011	WV	#2	Small HW Leak	Notified site maintenance
60	6/13/2011	HC	Bldg. F	130F water on opt'zd boiler & hot day, tank fires @ 130F tank	None

M&V Log					
#	**Date**	**Site**	**Boiler #**	**Event**	**Action Taken**
61	6/15/2011	MV	#3	New HW Tank	None
62	6/15/2011	MV	#1	New HW Tank	None
63	6/15/2011	MV	#1	Sup. Water temp >130F, OA-T = 87F	Data used as baseline
64	6/15/2011	MV	#1	Mode Swapped	Mode changed from baseline to optimized
65	6/15/2011	RL	#2	Transcription Error	Gas meter reading corrected from 1061 HCF to 1161 HCF
66	6/15/2011	RL	#3	Transcription Error	Gas meter reading corrected from 1856 HCF to 1956 HCF
67	6/15/2011	RL	#11	Counter Rolled Over in Gas Meter	None
68	6/15/2011	RL	#5	"X" controller was back on	Data was used as optimized data
69	6/15/2011	RL	#5	T&P valve leaking	Notified site maintenance
70	6/15/2011	RL	#8	"X" controller cover open. 76F tank temp & 135F sup temp	Data was removed from study calculations & results. See Note #1 below
71	6/15/2011	CR	420 Porto.	Pump was Off	Turned pump on
72	6/15/2011	CR	480 Porto.	Pump was Off	Turned pump on
73	6/15/2011	CR	420 Luce.	"X" Controller power off	Called Mr W. ("X"), used data as baseline mode
74	6/15/2011	CR	420 Luce.	Mode Swapped	Mode changed from baseline to optimized
75	7/27/2011	MV	#3	Mode Swapped	Mode changed from baseline to optimized
76	7/27/2011	RL	#5	"X" controller back online	New data to be used as optimized
77	7/27/2011	RL	#5	Gas Meter Not Read	None
78	7/27/2011	CR	400 Porto.	T&P valve leaking	Notified site maintenance
79	7/27/2011	CR	420 Porto.	Gas Meter Not Read	Following meter reading and date used
80	7/27/2011	CR	480 Porto.	Mode Swapped	Mode changed from optimized to baseline
81	9/8/2011	SS	#2	Boiler was in standby mode	Put boiler in run mode
82	9/9/2011	CR	480 Porto.	Circulation Pump: In Service Failure	Data was removed from study calculations & results.
83	10/3/2011	WV	#2	OA-T probe was in the dirt behind enclosure fence	Air temp data for WV may have errors
84	10/4/2011	CR	480 Porto.	New Pump	None

Note #1: *(from line 70)*

A. "X" controller enclosure cover open to the weather.
B. Boiler did not fire when I was observing it.
C. Return water temp = 118F
D. Supply water temp = 135F
E. Tank temp probe removed, lying on ground next to tank.
F. T1000 controller was being used (set 129)
G. informed Mr. "W" ("X")
H. Use data as baseline going forward

Appendix III: Calculations & Data

Available upon request.