Multifamily Boiler Controls – Process Evaluation

SoCal Gas' and SDG&E's 2006-2008 Multifamily Energy Efficiency Rebate Program

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CALMAC Study ID: SDG0227.01
March 19, 2008

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1. Background

The 2004-2005 Statewide Multifamily Rebate Program evaluation[1] concluded that the realization rate for energy savings for the boiler controller measure was low (12 percent) and that there was a large variation in savings that can be expected from site to site. Multifamily programs are facing a great deal of uncertainty with this measure and are considering options on how to address this measure, including dropping it from the program portfolio of measures. The results of the evaluation led to a number of research issues with boiler control measure energy savings analysis, including:

- The true and reliable savings of boiler controllers and the adequacy of data for the estimation of energy savings
    - Analysis didn't include the collection of participant site data
    - Inaccurate tracking of system data
    - Deficient tracking and billing data
    - Unknown end-uses of hot water, e.g., space heat
    - Boiler controllers installed in facilities that already had controls, resulting in incorrect baseline usage
- What Multifamily Programs can do to utilize this measure

To this end, KEMA Services Inc. (KEMA) was contracted by Southern California Gas Company (SoCal Gas) and San Diego Gas & Electric Company (SDG&E) to conduct this study of multifamily boiler controllers installed in conjunction with their PY2006-08 Multifamily Energy Efficiency Rebate Programs (SDG&E 3017 and SCG 3510). The purpose was to better understand the energy savings of the measure and the factors that affect savings. In this study KEMA:

- Analyzed the energy savings of the boiler control measure in multi-family buildings using
    - Extensive and timely data collection
    - Site-specific billing estimates of savings
- Made program design recommendations based on the findings of the study
    - Identified scenarios where potential for energy savings exists
    - Characterized these scenarios

This study was conducted at the request of the California Public Utilities Commission. The study was managed by Rob Rubin of SDG&E, and funded through the public goods charge (PGC) for energy efficiency. The report number is SDG0227.01 for SDG&E, and SCG0208.01 for SoCal Gas, and is available for download at www.calmac.org.

[1] Itron, "Impact Evaluation of the 2004-2005 Statewide Multifamily Boiler Control Measure," December 20, 2006.

2. Executive Summary

2.1 Introduction

There are four basic control strategies for central domestic hot water (CDHW) recirulation systems for multifamily buildings. SoCal Gas' and SDG&E's multifamily programs provide incentives to contractors who install CDHW controls. KEMA conducted research on SoCal Gas' and SDG&E's behalf to understand what strategies are employed, how much energy they save, whether there are system or installation issues that affect overall performance, and what changes to their programs SoCal Gas and SDG&E should consider in order to achieve more reliable savings.

The table below summarizes the four strategies. In its review of SoCal Gas and SDG&E participant projects, KEMA did not find any examples of the first and fourth strategies. All installations were either Strategy 2 or 3. The researchers have seen example of all four strategies in the past. Each strategy has its advantages, and each is more appropriate than the others for specific situations. For example, a relatively small multifamily building with a fairly homogonous tenant population would be the ideal candidate for Strategy 1. As soon as the building size reaches approximately 40 tenants, or includes a wide diversity of tenants (with diverse hot water use schedules), the Demand Control will provide less savings than other strategies. Likewise, a very large campus with very diverse end uses all served by one central plant can best be controlled by a locally monitored system designed to keep the hot water return coming back into the boiler room at a constant temperature.

Table 1
Multifamily Boiler Control Strategies

#	Strategy	Description	What is Controlled?	Continuous Monitoring?	Examples
1	**Demand Control**	One sensor monitors flow (demand) and another sensor monitors water temperature near the last apartment. If temp in supply line is high enough when demand occurs, pumps stays off. If temp is too low, pump comes on until temp near last apartment rises *X* degrees, then shuts off.	Pump on/off	possible, but not seen	Metlund System, Taco
	Temperature Modulation Control				
2	Set Schedule	Pumps stays on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set after 2-4 weeks of usage data is collected. Schedule is modified by contractor if changes in occupancy or use warrant it.	Hot water supply temp.	yes, remote	EDC Technologies
3	Learned Schedule	Pumps stay on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set **automatically** by controller based on previous ~ two weeks of temperature data (as a surrogate for water use demand data).	Hot water supply temp.	no	Energex, Protemp
4	Constant Return Temperature	Pumps stay on 24/7. Hot water supply temp is dynamically adjusted by controllers to maintain 103°F **return** temperature 24/7.	Hot water supply temp.	Local, with alarms	Davis Retirement Community

2.2 Overview of Energy Savings Analysis

Gas savings from boiler controllers was estimated using a pre-post customer specific change model that compared participants' gas consumption before and after the installation of the controller. The overall realization rate for boiler controllers was 24.70 percent, almost twice what was estimated in a prior study by Itron. However, the biggest issue may be the great variability in sites and installations, resulting in a wide range of project specific realization rates. This which reinforces what the Itron study found and suggests that this measure is risky in terms of actually acquiring the level of savings that had originally been assumed, i.e., the *ex ante* savings. The expectation of savings may need to be revised downward.

Average realization rates varied across specific contractors and across brands of controllers. This suggests that average savings from controllers may be improved through a systematic implementation approach. This approach may include better screening of candidate sites, more uniform selection and installation protocols, contractor training, system repairs before installing controls, and commissioning of the installations. Improvement in these areas should increase the reliability of savings. These issues are discussed in Section 7.

2.3 Overview of Site Surveys

The site surveys were structured to allow for the collection data in the field that would encompass the requirements stipulated to each contractor participating in the program, in addition to capturing current site conditions. Much of the information collected was necessary in order to properly identify system components, basic arrangements and the type of control/strategies deployed to achieve gas savings. While it is not possible to completely capture all conditions at all of the sites participation in the program the data collection efforts were driven toward identifying variables that effect energy use relating to hot water consumption. These effects were taken to account when performing the surveys to ensure proper identification of malfunctions and/or Inefficiencies which adversely affect savings.

2.4 Overview of Contractor Surveys

Surveys (both electronic and oral) of the installing contractors and controls manufacturers allowed us to assess what the contractors' approaches are to many of the issues that we found in the field. To a large extent, their answers reinforced some of our in-the-field findings, but on several issues their responses raise more questions. For example, there is a wide disparity between setpoint temperatures we found in the field and what the contractors indicate as their experience. One of the key learnings to come of the contractor interviews is that understanding of system design, operational parameters, fault conditions varies significantly.

2.5 Findings

Several factors were taken under consideration which in turn produced the findings. KEMA's goals were to identify why the realization rate was low, ensure the research being performed produce an explanation of the results and provide recommendations to improve the programs success. The findings were based on a logical progression of discovery utilizing a data driven collection method with a comprehensive approach. KEMA requested and inspected 58 Sites participating in the Multifamily Energy Efficiency Rebate Program. Of the original 46 Sites inspected KEMA excluded 8 sites from the analysis due to having one centralized gas meter serving many end uses. KEMA requested 12 additional sites to replenish the 8 excluded and make allowances for the possibility of the additional sites having the same meter configuration. A total of 50 sites were included in the analysis. After running a preliminary analysis on the 50 sites KEMA decided it was necessary to obtain additional temperature readings on 32 Boiler Systems (15 of the 50 sites). The additional temperature readings were taken/recorded from the following locations of each Hot Water System: Hot Water Supply to Users (HWS to Users), Storage Tank, City Water Supply, Boiler Outlet, Hot Water Supply to Storage Tank (HWS to Tank), Hot Water Return from Storage Tank to Boiler (HWR from Tank), Hot Water Return from Users (HWR form Users), Tank Thermostat Setting (Tank Thermostat), Controller Set Point. The additional temperature measurements provided direction in ascertaining the average temperature set point in comparison to some of the assumptions in calculating savings. To cross check our findings KEMA requested a total of 6 additional Pre-1970' non-participant sites to establish an average set point temperature. Based upon the collection of these readings it had become apparent that the majority of Pre/Post-1970's sites had a set point of 131 degrees or greater. Of the 50 Sites 14 were Pre-1970's. With readings indicating the assumptions were within reason we focused our attention on identification of malfunctions and/or Inefficiencies which adversely affect savings.

The following findings were noted while performing inspections of the hot water systems: Calcium carbonate build-up in tank type heaters, Dirty burner tips, short cycling of burners, Hot water system sizing, out of calibration boiler controllers and tank stats, broken refractory in fire box, un-insulated system piping, low hot water return temperatures causing condensate depression on heat exchanger, failed return water recirculation pumps, system piping not engineering according to manufacturers specifications, heat exchanger fouling (covered with soot deposits) Boiler under sizing (requiring higher set point to keep up with demand) crossover at system piping due to failed or missing cold water check valve. Water leaks present at pump shafts, flanges, valves and instrumentation.

2.6 Recommendations

The Recommendations section (Section 7) is quite extensive. KEMA approached this research with the idea that the most valuable result would be recommendations to help SoCal Gas and SDG&E make the programs more effective, and the savings more reliable in the PY2009-11 cycle.

Although the idea of a pay-for-performance program design is a particularly attractive option for increasing savings reliability, the attendant cost and risk to contractors would probably cause a precipitous drop in participation. KEMA does not recommend that approach for this program. KEMA recommends a set of steps that SoCal Gas and SDG&E should take to increase the expertise of the installers, increase the likelihood that controls will operate as intended, and increase the rigor of SoCal Gas' and SDG&E's review of installers' practices. These improvements include standardizing certain steps in the installers' site assessment process, the selection of controls, and inspection procedures. It also includes training for the contractors and SoCal Gas' and SDG&E's inspectors. As a backstop, KEMA also provides recommendations on how pre- and post-installation monitoring should be conducted if SoCal Gas and SDG&E should decide to pursue the pay-for-performance program model. Finally, we have included recommendations for additional research that SoCal Gas and SDG&E should undertake to answer some of the more salient questions about central DHW systems that continue to lead to uncertainty in energy savings.

3. Energy Savings Analysis

3.1 Overview

This section discusses the billing analysis employed to assess the impacts of the boiler controllers installed at sites in this study. The reliable estimation of gas saving has been problematic in the gas utility industry. Ken Keating said: "Another lesson that comes out of these 2004-05 evaluations is to remind us how hard it is to find reliable gas savings -- whether it's clock thermostats or boiler controls or pre-rinse spray wash valves, gas savings are tough to achieve."[2] This analysis sought to try to determine the savings that can be attributed to boiler control measures under the Multi-Family Program. This study took into consideration the lessons learned from the 2006 Itron study, "Impact Evaluation of the 2004-2005 Statewide Multifamily Boiler Control Measure," December 20, 2006. (see Appendices)

The prior analysis employed billing analysis and was not supported with any site-specific survey data. The results indicated large variability in potential savings from boiler controllers. Typically, billing analysis approach does not work very well when there is high variability in savings, as there is the case with this measure. The current study attempted to control for at least some of the variability by collecting on-site data prior to and just as soon as possible after the installation of the boiler controller. This approach might also help us understand how one might predict potential savings at a site, if indeed energy savings from this measure can be related to site and/or equipment specific verifiable parameters that are determined to be predictors of energy savings.

A number of issues were brought up during the project kick-off meeting including:

- **Adequacy of program-related data for the evaluation.** The prior study's analysis didn't include collection of participant site data. The prior study also struggled with inadequate billing data, especially for those facilities with multiple gas meters. Some of the tracking system data provided was incomplete or inaccurate, particularly with respect to identifying all gas account numbers at a given site.

- **Presence of existing boiler controllers.** Itron indicated that in discussions with contractors, that as much as 30 percent of the installations were at facilities that had existing boiler controllers. The savings at these facilities would be greatly diminished since the boiler was already controlled, unless, of course, the controller had not been functioning for a lengthy period of time.

- **Space heating and water heating on the same gas meter.** Since the controllers in question are intended primarily to control DHW systems, the presence of space heating on the same gas meter as the boiler would add complexity to the analysis.

[2] Ken Keating. In a e-mail transmittal to Rassmussen, T; Hall, N; and Lai, P,; January 6, 2007.

This analysis sought to address these issues through rigorous pre- and post-installation on-site data collection. Through on-site data collection, the following tasks were performed:

- The gas account/meter serving the boiler(s) was/were identified;
- Projects with an existing boiler controller were eliminated from the study (assuming that these sites would have low savings and would be eliminated from future programs);
- Sites with space heating also being served by the boiler were eliminated (assuming that gas savings from boiler controls at these sites would confound the intent of the study); and
- Number of dwelling units served by the boiler quantified.

There are several approaches available to compare pre and post period usage. The conditional demand analysis (CDA) approach utilizes regression analysis and detailed information regarding the usage characteristics of each site to estimate energy savings. This approach is typically utilized with a large number of participants and long periods of usage history (minimum of 12 months pre installation and 9 months post installation history). The statistically adjusted engineering (SAE) approach utilizes regression analysis to estimate an adjustment coefficient to an engineering estimate of savings. Like the conditional demand analysis, long periods of usage history are required. The approach used in this study is a customer change model approach. This approach compares use by customer account of the post-installation period with the pre-installation period of the prior year. Average change per account is computed and then summed across all accounts to derive an overall savings. This is then compared to the expected savings to develop a realization rate. This approach works quite well for programs where little post installation gas usage data exists, and where there are smaller participant numbers.

3.2 Data Sources

This analysis used three primary sources of data:

- **Billing data.** KEMA obtained billing data for participants from the utility. Several downloads of data were used, and we incorporated as much data into the analysis as time would allow. The most current analysis was based on data that were pulled February 11, 2008.
- **Program application forms.** Application forms provided data on the customer facility, the installing contractor, and the type of control proposed to be installed. The contact data from the applications were used to initiate contacts with the participants (to conduct the on-site surveys).
- **On-site inspections.** A wide variety of data on the facilities were was collected through pre- and post-installation surveys. Among the key parameters verified through these inspections were:

- ID number of the gas meter to which the boiler was connected
- Description of the central DHW system (including number/type of controllers)
- Whether or not there was an existing controller before program participation
- Number of apartment units per controller

KEMA performed pre-installation inspections at a total of 58 participating sites. Eight (8) sites were rejected due to issues regarding the metering. These facilities had one meter that served the boiler, space heating in individual dwelling units, and gas uses in common facilities. Several more sites were removed from the sample because they already had existing boiler controllers. The analysis file contained information for 46 sites. After a detailed review of these sites, eight (8) more sites were removed from the analysis data set because the proposed date of controller installation was not noted and controllers were not installed at the time of the analysis. Three (3) more sites were removed when our on-site inspection revealed that the gas meters served individual dwelling units. One (1) site was rejected because the measure installed was a new water heater instead of a controller. Lastly, gas account information for one (1) site could not be located, even with the gas meter number. The data set with enough pre and post usage data adequate for analysis consisted of 33 sites.

3.3 Energy Savings Model

Gas savings were estimated using a pre-post customer specific change model that compared participants' gas consumption before and after the installation of the controller. The basic model used is shown in Equation 1. Due to the extensive data collection and relatively small number of study participants, we were able to control for the major confounding data, such as, number of dwelling units, incomplete billing data, and uncertainty about other end-uses. The customer specific change model approach is preferred to a statistical model approach for two reasons. First, the post period for most customers in this study is fewer than five (5) months, where statistical models require longer streams of usage history. Second, statistical models estimate average savings for all customers with the influence of the model error-term taken into account, while individual customer analysis does not have error-terms.

(Equation 1)

$$\text{Savings} = T_{\text{Pre-installation}} - T_{\text{Post-instakkatuib}},$$
$$\text{where:}$$
$$T_{\text{Pre-installation}} = \text{Average Daily Therm Consumption before controller installation,}$$
$$T_{\text{Post-instakkatuib}} = \text{Average Daily Therm Consumption after controller installation.}$$

These savings were calculated on a site-by-site basis and compared with the *ex ante* savings to calculate the realization rate. If the billing start date was later than the controller installation date, the month in which the installation occurred was assigned to the post installation period. The pre installation billing period was the months of the previous year that were equivalent to the post-installation period to which we had access. The billing period (month) of the installation was "blocked out" from the analysis. We computed average daily use by period (pre installation or post installation) for each customer, and the calculated difference between pre period average use and post period average use.

3.3.1 Ex Ante Savings

Ex ante savings for the program were taken from "*Demand-Controlled Set-back DHW Thermostat Controller Replacement of an Existing DHW Constant-Temperature Controller (Multifamily Residential),*" Southern California Gas Company's work papers for the program. (see Appendix) Table 2 shows the ex ante savings per apartment unit for small (<30 units) and large (>30 units) complexes.

Table 2
Ex Ante Therm Savings Estimates

Vintage	No. Apt Units	Annual Therm Savings per Apt per Controller	Assumed # of Apts Per Complex	Annual Therm Savings per Controller
Pre 1970	Small: Less than 30	45	25	1,125
	Large: Equal to or Greater than 30	45	50	2,250
Post 1970	Small: Less than 30	34	25	850
	Large: Equal to or Greater than 30	34	50	1,699

Source: Workpapers: Demand-Controlled Set-back DHW Thermostat Controller Replacement of an Existing DHW Constant-Temperature Con-troller (Multifamily Residential)
Southern California Gas Company, December 19, 2005.

Ex ante savings were incorporated using two approaches. The first was to use the *Annual Therm Savings Per Controller* which assumes 25 apartments and 50 apartments for small and large complexes, respectively. The second approach used the number of actual apartments multiplied by the Annual Therm Savings Per Apartment per Controller. In general, we found the realization rate for the *ex ante* savings based on the number of actual apartment units to be slightly higher than the savings based on the number of controllers. This is primarily because the assumed number of apartment units per complex used to estimate the savings per controller initially, is less than the actual number of apartments in almost all cases.

4. Site Surveys

KEMA reviewed the information provided by Itron identifying their approach and depth of detail collected from the sites, contractors and control manufacturers. KEMA then concluded it would be necessary to collect more information to more accurately associate the account to building(s), the gas meter serving the boiler, and any other end uses. We then verified the gas meter serving the boiler receiving the controller. Once all of the nomenclature was collected from the boiler and hot water system, KEMA worked with the on site staff to establish the number of apartments units served by the central domestic hot water (CDHW) system receiving the energy management controller. Once we established the number units served by the CDHW system, we interviewed the onsite contact questions regarding occupant characteristics and vacancy rates over the period of the study. We collected as much field information as possible to account for variables that may affect any of these factors.

4.1 Methodology

Upon request, SoCal Gas provided KEMA with the following information: 2006 Multifamily Energy Efficiency Rebate Reservation Form and 2006 Multifamily Energy Efficiency Rebate Program Application Form which includes:

- Terms and Conditions
- Apartment and Common Area Products Form
- Apartment, Common Area, and Mechanical Product Location Form
- Customer provided Billing Invoice from So Cal Gas
- Invoice from Installing Contractor identifying date of purchase and installation of product

Once KEMA had this information, we entered it into our CDCAR. The additional data collected was driven by noting conditions that could affect energy use. These conditions include but are not limited to:

- Pre and post controller installations
- Equipment operation and configurations
- Temperature readings and sensor placement
- Temperature settings and control strategies
- Equipment nomenclature and capacity
- Site layout and end uses served
- Dates of control purchases and proved dates of control installations
- Occupant characteristics and percentage of occupancy

KEMA began with studying the requirements set forth for each participating contractor as stipulated in the 2006 Multifamily Energy Efficiency Rebate Program Application Form. Each field of information required on the Application Form was incorporated into a Central Data Collection and Analysis Repository (CDCAR) for the purpose of creating uniformity, comparisons, and early identification of missing data. The terms and conditions included within the application form were thoroughly reviewed and the parameters stated were included in the CDCAR. Lastly, the program specifications outlined in the specification sheets were included in the CDCAR to ensure compliance while conducting each field audit.

Before beginning the site survey process, KEMA initiated dual inspections with SoCal Gas' field inspectors. This phase of the collection efforts was necessary to understand what requirements and processes were currently in place for a Pre-Site Inspection (required prior to approving the installation of controls). The inspections performed by SoCal Gas' inspectors were limited to identification of any existing energy management controls. While some inspectors demonstrated an understanding of the requirements of the pre-site inspections, there were others who demonstrated uncertainty when asked to identify the difference between an energy management control and a typical boiler control. The Pre-Site Inspection process did not incorporate verification of parameters stated in the terms and conditions, nor did it include identification of water leaks, piping insulation, piping configurations or visual inspection of boiler equipment operation. The inspection mostly focused upon whether or not an existing management control was already present.

The inspection mostly focused upon whether or not an existing management control was already present. One particular inspection performed at Site 6854 had an existing controller that was in place for an abandoned DHW/Space Heating system. On the surface, one would see a controller prominently labeled "System Manager" (see Figure 1), with the word "Energy" in plain view. The inspector for SoCal Gas was unable to discern the purpose or current function of the control, so he naturally assumed there was a pre-existing energy management control. Because the DHW/space heating system had been retrofitted, and DHW and space heating were made independent of each other, the existing controls were irrelevant.

Figure 1
Existing Controller

In another instance when KEMA and the program inspector were conducting dual inspections, the inspector had determined an "existing control" was in place (Site 6925) when there was none. So Cal Gas was informed of the situation and KEMA educated the inspectors on what they were observing. An example of currently installed controls is shown in Figure 2 below.

Figure 2
Typical Controller

After completing the dual inspection process on a few sites, KEMA proceeded with performing site surveys on the remaining sites. As stated in the data section, once all the necessary information was received and entered into our CDCAR, KEMA set up an appointment with the onsite contact at each location. We explained that our purpose was to perform a site inspection and collect information on behalf of SoCal Gas' and SDG&E's Multifamily Energy Efficiency Rebate Programs. We would start by requesting access to the water heater or boiler, and asking if they knew the location of the gas meters that serve each building. We informed them that it would take us some time to acquire the boiler/hot water system information, and that we would like to ask them some addition questions when we completed obtaining system data and prior to leaving the site. We then collected data on the boiler/hot water system, gas meter verification, other end uses, (pool, spa, BBQ, laundry, etc.) building and number of units served. After that we would conduct an interview with the on-site contact and verify the information we collected. We asked about occupant characteristics and occupancy percentage. We asked questions pertaining to equipment maintenance, known malfunctions and other changes that would be pertinent to estimating boiler control impacts. We then debriefed the with site staff with our findings if there appeared to be any known issues they should be aware of (safety, water leaks, unusual operations, etc.).

4.2 Site Data

Of the original 46 sites, inspected KEMA excluded eight (8) sites from the analysis due to having one centralized gas meter serving many end uses. KEMA requested 12 additional sites to replenish the eight (8) excluded and make allowances for the possibility of the additional sites having the same meter configuration. A total of 50 sites were included in the study. After running a preliminary analysis on the 50 sites KEMA determined that it would be advantageous to obtain temperature readings on sample of the systems inspected. In all, temperature readings were taken for 32 boiler systems (15 of the 50 sites since some sites have multiple boilers). The temperature readings were recorded from the following locations of each hot water system:

- Hot water supply to users (HWS to users)
- Storage tank
- City water supply
- Boiler outlet
- Hot water supply to storage tank (HWS to tank)
- Hot water return from storage tank to boiler (HWR from tank)
- Hot water return from users (HWR form users)
- Tank thermostat setting (tank thermostat)
- Controller set point.

The temperature measurements provided direction in ascertaining the average temperature set point in comparison to some of the assumptions in calculating savings. For the purpose of this study temperature set point is defined as: *the temperature that is used by the main control that determines the final temperature of the hot water supply to the end user*. To cross check our findings, KEMA also took temperature readings from 15 additional pre-1970 non-participant sites. Table 3 shows the temperature data for each site. *Site #* is a unique identification number used to identify program participants. The non-participant sites were given a Site # of "NP," non-participant.

Table 3
Temperatures for Selected Sites

												HWS to Users			Storage Tank			City Water			Boiler Outlet			HWS to Tank			HWR from Tank			HWR from Users			Tank Thermostat			Controller Set Point		
Site #	Year Built	HWS to Users	Storage Tank	City Water	Boiler Outlet	HWS to Tank	HWR from Tank	HWR from Users	Tank Thermostat	Controller Set point	Boiler QTY	120 or less	121-127	127-143	120 or less	121-127	127-140	55 or Less	56-66	67-77	120 or less	121-131	131-150	120 or less	121-131	131-150	120 or less	121-127	127-140	120 or less	121-127	127-140	120 or less	121-131	131-150	120 or less	121-131	131-150
7269	1977	142	132	75	145	135	120	120	140	N/A	1			1			1			1			1			1	1			1					1			
7278	1988	121	121	70	122	122	119	118	150	N/A	1		1			1				1		1			1		1			1					1			
7278	1988	121	121	70	122	122	119	118	150	N/A	1		1			1				1		1			1		1			1					1			
7281	1989	N/A	N/A	N/A	123	123	115	115	N/A	N/A	1											1			1		1			1								
7281	1989	N/A	N/A	N/A	123	123	115	115	N/A	N/A	1											1			1		1			1								
7276	2001	136	134	62	150	143	131	121	145	145	1			1			1		1				1			1			1		1				1			1
7276	2001	136	134	62	143	143	131	121	145	143	1			1			1		1				1			1			1		1				1			1
7276	2001	136	134	62	140	143	131	121	145	140	1			1			1		1				1			1			1		1				1			1
7276	2001	125	124	62	130	130	125	118	N/A	130	1		1			1			1				1		1			1		1							1	
7276	2001	125	124	62	127	130	125	118	N/A	128	1		1			1			1			1			1			1		1							1	
7276	2001	125	124	62	125	130	125	118	N/A	126	1		1			1			1			1			1			1		1							1	
7276	2001	125	124	62	124	130	125	118	N/A	124	1		1			1			1			1			1			1		1							1	
7276	2001	134	130	62	147	142	128	120	145	143	1			1			1		1				1			1			1	1					1			1
7276	2001	134	130	62	142	142	128	120	145	141	1			1			1		1				1			1			1	1					1			1
7276	2001	134	130	62	90	142	128	120	145	139	1			1			1		1			1				1			1	1					1			1
7276	2001	134	130	62	90	142	128	120	145	137	1			1			1		1			1				1			1	1					1			1
7279	1989	140	142	64	144	143	136	130	N/A	142	1			1			1		1				1			1			1			1						1
7279	1989	140	142	64	144	143	136	130	N/A	142	1			1			1		1				1			1			1			1						1
7275	1991	134	N/A	55	134	N/A	N/A	133	N/A	135	1			1					1				1									1						1
7280	1991	152	N/A	57	160	N/A	N/A	143	N/A	160	1			1					1				1									1						1
7283	1985	155	155	64	164	160	148	90	170	N/A	1			1			1		1				1			1			1	1					1			
7277	1985	132	119	56	140	135	135	128	N/A	140	1			1	1				1				1			1			1			1						
NP	1973	148	N/A	95	N/A	N/A	N/A	137	145	N/A	1			1						1												1			1			
NP	1973	137	N/A	84	N/A	N/A	N/A	107	135	N/A	1			1						1										1					1			
NP	1973	130	N/A	80	N/A	N/A	N/A	115	130	N/A	1			1						1										1				1				
NP	1970	120	N/A	53	N/A	N/A	N/A	118	120	N/A	1	1						1												1			1					
NP	1970	122	N/A	67	N/A	N/A	N/A	115	132	N/A	1		1							1										1					1			
NP	1970	120	N/A	75	N/A	N/A	N/A	115	120	N/A	1	1								1										1			1					
NP	1970	123	N/A	74	N/A	N/A	N/A	107	132	N/A	1		1							1										1					1			
NP	1970	122	N/A	74	N/A	N/A	N/A	119	142	N/A	1		1							1										1					1			
NP	1970	123	N/A	74	N/A	N/A	N/A	107	145	N/A	1		1							1										1					1			
NP	1970	121	N/A	74	N/A	N/A	N/A	107	160	N/A	1		1							1										1					1			
NP	1970	144	N/A	75	N/A	N/A	N/A	125	135	N/A	1			1						1											1				1			
NP	1970	135	N/A	80	N/A	N/A	N/A	122	135	N/A	1			1						1											1				1			
NP	1970	134	N/A	71	N/A	N/A	N/A	N/A	132	N/A	1			1						1															1			
NP	1970	107	N/A	64	N/A	N/A	N/A	N/A	110	N/A	1	1							1	1													1					
NP	1970	121	N/A	63	N/A	N/A	N/A	N/A	120	N/A	1		1						1														1					
										Total	37	3	12	20		6	11		19	16		9	13		8	12	5	4	11	23	5	6			21		4	11

As observed in the temperature readings shown in Table 3, there are two (2) participant sites (7275 and 7280) that do not have a storage tank, so they are designed to run continuously. One of these sites, Site 7280, had an especially high mechanical modulating control set point of 160 degrees. For those sites with no storage tank, the benefit of an energy management control would only apply to running at a lower set point since the boiler is sized to make hot water on demand.

The ranges of temperature we recorded enabled us to see that eight (8) systems had set point temperatures above 140 °F and four (4) systems with set point temperatures 130 °F and below. Based upon the collection of these readings it became apparent that the majority of the systems had a set point of 131 °F or greater.

4.3 Results

The additional temperature readings taken on both the participating and non-participating sites provided enough information to conclude the average 137 °F temperature set point assumptions (in the SoCal Gas workpapers upon which the ex ante estimate is based) are somewhat higher than our findings, yet are within reason. In an effort to find a more plausible reason for the low realization rates, we focused our attention on identification of malfunctions and/or inefficiencies that adversely affect savings.

The following findings were noted while performing inspections of the hot water systems: Calcium carbonate build-up in tank type heaters, dirty burner tips, short cycling of burners, hot water system sizing, out of calibration boiler controllers and tank stats, broken refractory in fire box, un-insulated system piping, low hot water return temperatures causing condensate depression on heat exchanger, failed return water recirculation pumps, system piping not engineering according to manufacturers specifications, heat exchanger fouling (covered with soot deposits) boiler under sizing (requiring higher set point to keep up with demand) crossover at system piping due to failed or missing cold water check valve. Water leaks present at pump shafts, flanges, valves and instrumentation.

The table below shows that missing pipe insulation, build-up in tanks, and fouled burner tips were very common, while burner short cycling, broken refractories in the firebox, failed pumps and crossover at equipment were less common.

Figure 3: Frequency of CDHW System Faults

Faults	Okay	Fault Found	Unknown
build-up in tank type heaters	20%	70%	10%
dirty burner tips	40%	50%	10%
short cycling of burners	70%	10%	20%
hot water system sizing	60%	20%	20%
out of calibration boiler controllers or tank stats	65%	15%	20%
broken refractory in fire box	80%	10%	10%
un-insulated system piping,	20%	80%	0%
low hot water return temperatures	60%	20%	20%
failed return water recirculation pumps	70%	10%	20%
piping not engineering	65%	15%	20%
heat exchanger fouling	40%	30%	30%
boiler under sizing	50%	20%	30%
crossover at equipment piping	75%	5%	20%
leaks present at pump shafts, flanges or gages	95%	5%	0%

5. Contractor Surveys

5.1 Overview

For the purpose of analyzing the performance and effectiveness of the program while providing recommendations for improvements, KEMA developed and used a contractor survey. The questions related to conditions we had seen and practices we questioned as the result of inspecting 58 sites, inspecting 143 boilers/control systems, performing on site contact interviews at all sites, reviewing program documents (e.g., applications), and conducting additional research within the industry. Creation of the survey instrument was further informed by the researchers' field experience, knowledge of hot water systems (both boilers and water heaters), installation of controls, commissioning, functional testing, programming, system servicing, and review of the previous Itron study.

5.2 Survey and Oral Interview

The questionnaire was sent to each participating contractor/control manufacturer with a request that they answer the questions and email the survey back to KEMA. The questions covered compliance, system repairs, how issues and improvements are handled, use of check lists, determination of hot water set point, control response, operations, control failures, sequence of operations, common practices, control strategies, competitor differentiation, presence of low flow fixtures, water usage data, expectations for savings, recording of previous set points and anti scalding device verification.

Upon receipt of a participant's completed questionnaire, KEMA requested a one-on–one interview to clarify the answers to each question, delve deeper into some issues, and answer any questions the participants may have had. This process allowed an opportunity to discuss and clarify the questions in a manner that draws upon the experience of the contractors, and provides direct answers to the approaches taken when participating in the program. Some insights that were gleaned during this process included how each contractor handled crossover. Some had a set of known parameters, which they compared against an established/expected Delta T. This comparison provided a quick answer while others left it to the customers to inform them. Most all the contractors ensure through some form of check list the system is functioning properly prior to leaving the site. Each system has fail safe mode when a control system is taken off line or power failure conditions exist, when the systems go offline they revert back to the original operation prior to control installation. Most of the contractors also agreed that the system set point is best between 110 and 120 °F. Although some pointed out that the minimum set point may vary as long as a delta T (supply – return) of 10-15 °F.

When asked if savings expectations change between boilers and water heaters the answers were mixed. One contractor stated "thermal savings depends upon the outgoing temperatures and the Delta-T difference in the recirculation return line." Another stated "savings are typically 3.5% less for water heaters due to 'low recovery' characteristics." These may include piping size and equipment size; water heaters are seldom used for larger multifamily facilities. Of the other six contractors from whom we have received responses so far, 3 said savings expectations for adding controls to water heaters were no different from expectations related to boilers, and 3 said there was a different (with some cursory explanations). These explanations are just a few examples of the differing experiences, beliefs, and practices encountered when applying different control types and strategies to various types of equipment and system configurations. This is an area about which contractors should be encouraged to provide KEMA with more discussion and clarification. All of the contractors stated that their staff checks out systems for pre-existing controls. They maintain that each system is investigated for significant leakage and documented for other potentially significant problems.

During the oral interviews, KEMA went over each of the questions sent to the contractors to ensure each question was understood. We also had the opportunity to share with the contractors some of our motivations for asking the questions. During one oral interview, the contractor shared a thorough explanation of cross over, providing insight on how he diagnoses it. He also shared and some of the end-users' experiences in attempting to address it. He explained that crossover could be very easily revealed when he is able to collect and analyze the system temperatures. Temperatures are examined from a delta T perspective, and are compared to demand usage periods, equipment run time, and boiler cycling (on/off) times over a 24 hour period. Through this type of information analysis, he believes that crossover can be readily detected, and recommendations for solutions provided to the customer.

Another learning gleaned from the survey/interview process was that some of the contractors prefer that the primary circulation pumps remain running continuously. One offered the following explanation: if the primary pump runs continuously, mixing the hot and cold water **in the tank** tempers the water that is in the primary loop. Without this tempering, there are higher swings in the temperature seen by the Aquastat on the primary loop return line during the process of reaching a stable set point, and there will be more periods when tenants do not receive satisfactorily hot enough water. This generally leads to maintenance staff simply turning up the supply temperature. Boiler manufacturers, such as RayPak, have some extensive views on the causes of standby losses that appear to contradict this view. They state there are significant energy losses caused by constantly running the primary pump.

5.3 Summary Results

Table 4 and Table 5 provide a summary of the responses to the contractor e-mail survey. Eight of the 10 surveys sent out were returned. A complete tabulation of the responses is shown in the Appendix.

- E-Mail survey respondents
    - 5 contractors
    - 2 contractor/manufacturers

- o 1 manufacturer-only

The tables show all respondents as contractors to maintain respondent confidentiality.

Table 4 shows the responses to questions pertaining to characteristics of the site prior to installation of the controller.

Table 4
Pre-Installation Site Characteristics
Contractor Survey

Contractor	Average RR	Existing Controller	Have or use water usage data?	Do exp(savings) change w/ system type? Boiler vs HW? Condensing vs std boiler.	Do yo ask about low flow or fixture mixing valves?	Do you verify whether mixing valves are installed? If yes how does it affect your control?
Contractor B	41.3%	Check Document existing	no. do monitor for HW leaks.	yes.	yes	yes. But doesn't impact the choice of control....it may alter controller programming.
Contractor E	37.5%	Did Not Respond	Did Not Respond	Did Not Respond	Did Not Respond	Did Not Respond
Contractor G	31.2%	Did Not Respond	Did Not Respond	Did Not Respond	Did Not Respond	Did Not Respond
Contractor D	19.8%	Check Document existing	no. do have w/h thm usage.	yes. w/h have 3.5% less savings than boilers. Condensing units don't necessarily save much.	yes	no. Anti-scald is handled in 3 ways: setpoint 115-125 degF max; boiler must have a safe op control scheme per code, set 5 degF above our max; all heaters have a built-in max per code.
Contractor C	15.4%	Procedures to review tracking database	no.	no.	no. low flow mandated...assume they're installed.	I haven't observed may anti-scald valves in SoCal.
Contractor F	9.0%	Remove controls if no longer mfred or serviced by mfr.	Occasionally.	no.	Sometimes.	yes, may not be a good application, may need replumbing.
Contractor A	-20.1%	Check	Only if customer has reqt to do so.	very little	Just mixing valves.	yes. Make appropriate recommendations based on the application.
Contractor H	No Projects			no.	yes	yes. Requires sensor placement mod, maybe re-programming.
Contractor I	No Projects	Check	Occasionally.	yes.	yes	yes. No effect on solution.
Contractor J	No Projects	Check Does not document	no	no.		none yet.

When contractors were asked if they:

- Check for an existing energy saving boiler controller:
  - They all maintain that they check for an existing controller
  - One company stated they will replace a controller only if it is no longer made, serviced by the manufacturer, or out of warranty
  - Most appear inclined to install even when there is an existing controller

- Check to see if there are any repairs, improvements, or replacement of equipment that need to be made:
  - All respondents do check
  - 2 indicated the system must be operating properly before they will install a controller
  - 1 provides the customer with a report documenting any needed repairs or other recommendations to ensure full energy savings potential
- Test for potentially significant cross-over problems:
  - All answered yes
  - 1 asks on-site personnel or the site's boiler service company if there are any cross-over problems
  - None mentioned checking for a check valve on the CWS line
- Verify whether anti-scald mixing valves are installed:
  - 7 indicated they do or sometimes do check
  - 1 does not
  - 2 indicated they have never seen them in SoCal
  - 2 indicated that programming of the controller may be affected; 2 indicated it wouldn't
  - 1 indicated plumbing modification may be necessary

Table 5 shows the responses to questions pertaining to controller installation practices of the respondents.

Table 5
Installation Practices
Contractor Survey

Contractor	Average RR	Comprehensive Site Survey	Use Pre-Install Checklist	Check for Repairs or Improvements	Test & ID Crossover Problems	Use Pre-Startup Checklist	Ensure components are operating properly before leaving	Method Used to determine setpoint	Record DHW set point prior to installation?
Contractor B	41.3%		yes	yes	yes	yes	yes	Between 110-120 degF. Use recorded data and continuous commissioning.	yes, and it's validated with client.
Contractor E	37.5%	Did Not Respond	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Contractor G	31.2%	Did Not Respond	DNR	DNR	DNR	DNR	DNR	DNR	DNR
Contractor D	19.8%	yes	yes	yes, system must be operating properly.	Yes. Delta-T target 10-18. If more then notify customer to repair.	no	yes, it's documented	Avg return T is used to set min setpoint. Telemetry used to remotely monitor and adjust.	yes. Site survey.
Contractor C	15.4%		Visual inspection	System must be operating properly.	yes. Check with boiler service and maint. staff	Monitor system 3-4 days before switching to controller.	yes	Computer programs itself within max/min. Try to deliver 114 degF to last apt in loop.	yes and try to monitor temps several days before install.
Contractor F	9.0%	yes. Full site inspection report.	yes	yes, inspection report with recommended repairs.	ID suspected x-over problem, recommend service.	yes	yes. Listen and watch boiler or heater fire, sensors are properly placed.	Start with max from existing t-stat. Controller learns usage and adjusts schedule.	yes. Becomes initial supply setting.
Contractor A	-20.1%		yes	yes	yes	yes	yes	Measure water temp at fixture. Suggest the lowest setpoint (usually 120 deg-f at the fixture).	yes.
Contractor H	No Projects		yes				yes	Maximum supply is typically pre-existing set point; established by historical usage. Minimum set point is 105 plus the loop loss. This is often adjusted (down) as history is available.	
Contractor I	No Projects		yes	yes	yes	yes	yes	Codes, savings	yes
Contractor J	No Projects		yes	yes	yes	no	yes	Experience and preset temps.	yes

When contractors were asked if they:

- Use a pre-installation checklist
  - All responded yes, but for one it is not a formal checklist
- Use a pre-startup checklist
  - 5 use a pre-startup checklist; 2 do not
  - 1 monitors the system 3-4 days prior to startup
- Ensure system components are operating properly before leaving the site
  - All answered yes

- Record DHW setpoint prior to installation
  - All answered yes
- Set the controller's initial setpoint using a systematic approach
  - 3 used the setpoint prior to installation
  - 2 use remote monitoring to determine setpoint
  - 1 delivers 114°F at last apartment in the loop
  - 1 uses codes

6. Findings

6.1 Energy Savings

The energy savings analysis is shown in this subsection. The analysis shows a comparison to the earlier study by Itron, a comparison between different installers, between different controls, and comparisons between some differences in CDHW system configuration (e.g., boiler vs. water heater).

6.1.1 Energy Savings - SoCalGas

The overall realization rate for boiler controllers was about 25 percent, as shown in Table 6. This is somewhat higher than the realization rate of 12 percent in the prior Itron study, but it still indicates there are significant issues that should be resolved to improve the program's verified savings. Perhaps the biggest issue is the wide range in realization rates, as shown in Table 7, which reinforces what the Itron study found, that this measure is risky in terms of counting on savings. Later in this study, we identify approaches that may mitigate some of this risk. In some instances, though not all, we are able to identify a relationship between observable parameters and high or low energy savings.

Table 6
Energy Savings From Boiler Controller Measures in Multifamily SoCalGas

Avg Change Per Day for Total Site (Therms)	Ex Post Annual Savings Total Site (Therms)	Ex Ante Annual Savings	Realization Rate
132.278	48,281	195,451	24.70%

Table 7 shows the *ex ante* and *ex post* savings estimates and realization rates by site.

Table 7
Ex Ante and Ex Post Savings by Site Number
SoCalGas

Post 1970 Flag	Over 30 Units flag	Site_Nbr	Vintage	Dwelling Units	Avg Change Per Day for Total Site (Therms)	Annual Savings Total Site (Therms)	# Controllers At Site	Ex Ante Savings per Controller	Ex-Ante Annual Savings Total Site Based on Complex Size Category (Therms)	Realization Rate	Annual Therm Savings per Apt per Controller	Ex-Ante Annual Savings Savings per Controller	Realization Rate
0	0	7064	1963	24	0.729	266	1	1,125	1,125	23.64%	45	1,080	24.62%
0	1	6853	1960	55	-5.234	(1,910)	1	2,250	2,250	-84.91%	45	2,475	-77.19%
0	1	6854	1960	115	-0.821	(300)	6	2,250	13,500	-2.22%	45	5,175	-5.79%
0	1	6945	1969	32	-1.95	(712)	1	2,250	2,250	-31.64%	45	1,440	-49.43%
0	1	7065	1969	193	9.095	3,320	5	2,250	11,250	29.51%	45	8,685	38.22%
0	1	7066	1965	132	-0.709	(259)	4	2,250	9,000	-2.88%	45	5,940	-4.36%
0	1	7067	1964	119	8.01	2,923	3	2,250	6,750	43.31%	45	5,355	54.59%
0	1	7105	1968	768	41.596	15,182	13	2,250	29,250	51.91%	45	34,560	43.93%
0	1	7106	.	249	5.262	1,921	6	2,250	13,500	14.23%	45	11,205	17.14%
1	0	6949	1984	24	-0.563	(205)	2	850	1,700	-12.08%	45	1,080	-19.02%
1	1	6924	1982	200	-5.154	(1,881)	1	1,699	1,699	-110.73%	34	6,800	-27.67%
1	1	6925	1988	84	7.091	2,588	1	1,699	1,699	152.34%	34	2,856	90.63%
1	1	6926	1988	60	0.28	102	1	1,699	1,699	6.02%	34	2,040	5.01%
1	1	6928	1979	49	1.793	654	1	1,699	1,699	38.51%	34	1,666	39.27%
1	1	6929	1986	44	-0.339	(124)	1	1,699	1,699	-7.28%	34	1,496	-8.26%
1	1	6931	1973	530	15.409	5,624	14	1,699	23,786	23.65%	34	18,020	31.21%
1	1	6950	2006	303	-1.985	(725)	5	1,699	8,495	-8.53%	34	10,302	-7.03%
1	1	6953	1972	63	-1.295	(473)	1	1,699	1,699	-27.81%	34	2,142	-22.06%
1	1	6954	1974	100	12.253	4,472	1	1,699	1,699	263.24%	34	3,400	131.54%
1	1	6956	1980	150	2.564	936	2	1,699	3,398	27.54%	34	5,100	18.35%
1	1	6968	1979	374	4.311	1,574	7	1,699	11,893	13.23%	34	12,716	12.37%
1	1	6990	2004	140	-6.378	(2,328)	1	1,699	1,699	-137.02%	34	4,760	-48.91%
1	1	6996	1980	112	13.676	4,992	2	1,699	3,398	146.91%	34	3,808	131.09%
1	1	6997	1980	152	-0.388	(142)	2	1,699	3,398	-4.17%	34	5,168	-2.74%
1	1	6999	1972	54	1.601	584	1	1,699	1,699	34.40%	34	1,836	31.83%
1	1	7000	1972	54	2.392	873	1	1,699	1,699	51.38%	34	1,836	47.55%
1	1	7001	1980	120	4.208	1,536	8	1,699	13,592	11.30%	34	4,080	37.65%
1	1	7003	1980	188	23.857	8,708	6	1,699	10,194	85.42%	34	6,392	136.23%
1	1	7004	1980	88	3.043	1,111	2	1,699	3,398	32.69%	34	2,992	37.12%
1	1	7006	1972	54	6.496	2,371	1	1,699	1,699	139.55%	34	1,836	129.13%
1	1	7008	1980	208	-6.111	(2,230)	6	1,699	10,194	-21.88%	34	7,072	-31.54%
1	1	7009	1980	209	-1.086	(396)	4	1,699	6,796	-5.83%	34	7,106	-5.58%
1	1	7068	1973	148	0.625	228	5	1,699	8,495	2.69%	34	5,032	4.54%
Grand Total					**132.278**	**48,281**	**116**		**216,301**	**22.32%**		**195,451**	**24.70%**

6.1.1.1 Savings By Installation Contractor

Table 8 shows the savings by contractor. It can be seen that there are two modes: those with realization rates in excess of 30 percent and those with realization rates less than 20 percent. It was not immediately clear what the reasons may be for this modality. In Section 5.3 we examined the reported installation practices by contractors. Most contractors indicated they incorporated many good standard practices as part of their normal installation processes. It's not completely clear whether these practices are being systematically conducted and implemented properly.

Table 8
Therm Savings by Contractor

				Annual Therm Savings		Realization Rate	
Contrac-tor	**Control** Manufacturer	**No. Sites**	**Apts**	**Ex Ante**	**Ex Post**	**Aver-age**	**Range**
B	**1**	10	1,239	42,126	17,406	41.3%	-31.5% to 136.2%
E	**2**	3	1,210	54,450	20,423	37.5%	17.1% to 43.9%
H	**2**	1	530	18,020	5,624	31.2%	n/a
D	**3**	4	420	16,150	3,198	19.8%	-77.2% to 131.5%
C	**2**	4	773	29,043	4,466	15.4%	-4.4% to 54.6%
G	**3**	5	437	14,858	1,340	9.0%	-27.7% to 90.6%
A	**3**	6	586	20,804	-4,176	-20.1%	-49.4% to 24.6%
	Grand Total	**33**	**5,203**	**195,451**	**48,281**	**24.7%**	

6.1.1.2 Savings by Control Manufacturer and Control Strategy

Table 9 shows therm savings by controller manufacturer and control strategy. Three brands of CDHW controllers were installed in participating sites. The data in Table 8 indicates that at least part of the issue of low realization rates is installer-related. However, the data in Table 9 show there is also a significant difference in the realization rates related to the manufacturers. It is not clear how much of this difference is a function of the controller, the control technology/strategy, or the installation and commissioning. There was no variation between sites in the control strategies employed by specific contractors, using specific controllers. Another way of stating this is that once an installer developed a pattern for controlling a system, s/he applied it to all subsequent systems, even though that strategy may not have been the most appropriate for all subsequent installations. As shown in Table 9, all three controllers used a temperature modulation control strategy.

Table 9
Therm Savings by Control Manufacturer

Control Mfr	Control Strategy	Ex Post Annual Savings Total (Therms)	Ex-Ante Annual Savings Expectation	Realization Rate
Mfr 1	Temperature Modulation w/ continuous monitoring and periodic manual re-set	17,406	42,126	41.32%
Mfr 2	Temperature Modulation w/ automated learning and adjustment	30,514	101,513	30.06%
Mfr 3	Temperature Modulation w/ automated learning and adjustment	362	51,812	0.70%
	Total	**48,281**	**195,451**	**24.70%**

The basic boiler control strategies in current use are shown in Table 10. The program provides incentives for demand control and temperature modulation based controllers. The controllers in the current sample only used the temperature modulation strategy: Strategies II and III. Manufacturer 1 employs Strategy II, and Manufacturers 2 and 3 employ Strategy III. No installations in this study employed either Strategy I or Strategy IV. Please note that on average, the savings from installations using Manufacturer 3's equipment were essential zero. Savings from installations with Manufacturer 1's equipment were about 35% higher than with Manufacturer 2's equipment, but were still only 41% of program expectations. While we were limited in analyzing the effectiveness of different control strategies on savings and realization rates, we do explore the concept of matching a control strategy to given site characteristics in Section 7.1.1.

Table 10
Types of Boiler Controllers and Control Strategies

#	Strategy	Description	What is Controlled?	Continuous Monitoring?
I	**Demand Control**	One sensor monitors flow (demand) and another sensor monitors water temperature near the last apartment. If temp in supply line is high enough when demand occurs, pumps stays off. If temp is too low, pump comes on until temp near last apartment rises *X* degrees, then shuts off.	Pump on/off	possible, but not general practice
	Temperature Modulation Control			
II	Set Schedule	Pumps stays on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set after 2-4 weeks of usage data is collected. Schedule is modified by contractor if changes in occupancy or use warrant it.	Hot water supply temperature	yes, remote monitoring by control manufacturer
III	Learned Schedule	Pumps stay on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set **automatically** by controller based on previous ~ two weeks of temperature data (as a surrogate for water use demand data).	Hot water supply temperature	no
IV	Constant Return Temperature	Pumps stay on 24/7. Hot water supply temp is dynamically adjusted by controllers to maintain 103°F **return** temperature 24/7.	Hot water supply temperature	Local (building maintenance), with alarms

6.1.1.3 Savings By Type of Water Heater

Two types of water heating systems were installed at participant facilities, boilers and water heaters. (See the appendix for a brief description of the differences.) Average realization rates for each type are shown in Table 11. The majority of systems utilized boilers. On average, CDHW systems with boilers had a realization rate of 31.9 percent, while systems with water heaters were much lower, actually showing a negative average realization rate. Of the six sites with water heaters, four had negative realization rates, as compared with seven of the 24 boiler sites.

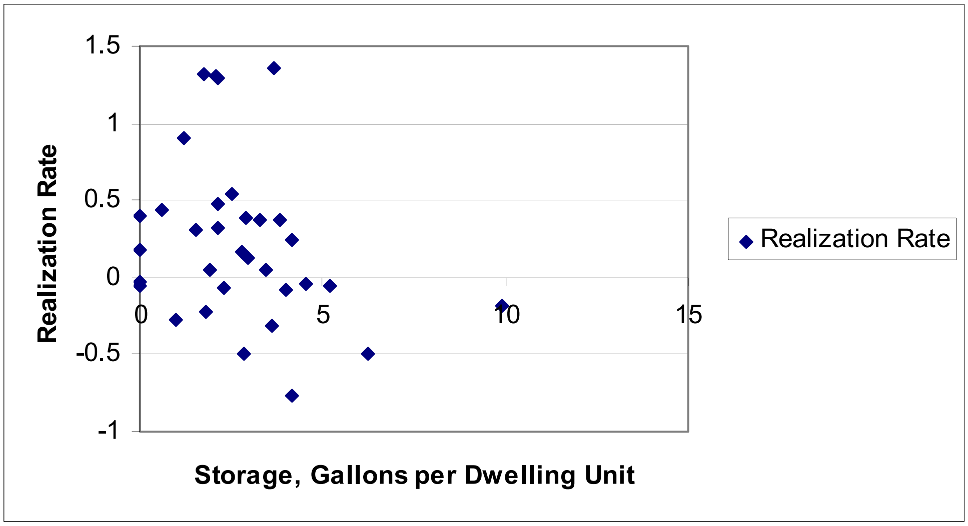
Table 11
Realization Rates By Heater Type

		Realization Rate	
Heater Type	Qty	Average	Range
Boiler	24	31.9%	-77.2% to 136.2%
Water Heater	6	-8.2%	-49.4% to 24.6%
Hybrid[3]	3	11.9%	-5.6% to 43.9%

6.1.1.4 Savings By Gallons of Storage Per Dwelling Unit

During our interviews, we heard one control manufacturer postulate that the most efficient system would be one with a really large storage capacity. To test out that potential, we compared realization rates to storage capacity per dwelling unit. Although too many other factors could not be controlled for in this cursory evaluation, from the graph in Figure 4, it appears that there is no relationship at all.

Figure 4
Realization Rate By Gallons of Storage Per Dwelling Unit



6.1.1.5 Variability

As mentioned earlier, perhaps the biggest issue is the wide range of realization rates for this measure and the inherent risk of obtaining the energy savings with this measure as it has been implemented. KEMA collected data on a number of potentially relevant parameters through this study. Great variability of savings is the bane of energy efficiency programs. However, with measures such as boiler controllers, the

[3] Some CDHW systems had both a boiler and a water heater. This is distinguished from the systems that have a boiler and an unfired hot water storage tank.

number of factors potentially affecting energy use and savings is very large. There are behavioral and mechanical issues that may affect the ability of a boiler controller to do its job effectively. For example, if a DHW system is not plumbed correctly, a controller may actually lead to increased usage. Our analysis sought to identify mitigation strategies for some of the risk elements, thereby decreasing the variability of savings. Many of the suggested program improvements can be summarized as applying a more systematic approach to customer recruitment. This will mean screening out potential participants that do not pass the adopted screening criteria. These program design issues are discussed more fully in Section 7.

6.1.2 Energy Savings – SDG&E

A separate energy savings analysis was performed on the sites from SDG&E's service area. SDG&E had a limited number of sites with controllers installed, to be included in the study. The depth of the analysis was limited due to the small number of participant sites. Table 12 shows the ex ante and ex post savings estimates for participants. These data show realization rates somewhat larger than those for SoCal Gas; in fact in this sample, all realizations rates were at least positive (compared to ¼ of the SoCal Gas sites having negative realization rates). However, it is difficult to draw meaningful conclusions based on a sample with only six sites. Additionally, the contractors active in the SoCal Gas service territory are not the same as those in the SDG&E territory, so they were not included in the surveys or oral interviews.

Table 12
Ex Ante and Ex Post Savings by Site Number
SDG&E

				Ex Ante Unit Savings		Ex Post		Ex Ante Savings Based On # Controllers		Ex Ante Savings Based On Savings per Apt Unit	
Site_Nbr	Year Built	Qty Boiler Controllers	Qty Dwelling Units	Ex Ante Savings Per Controller	Ex Ante Savings Per Apt Unit	Avg Change Per Day for Total Site	Ex Post Annual Savings Total Site	Ex Ante Annual Savings Total Site	Realization Rate	Ex Ante Annual Savings Savings per Unit	Realization Rate
10337	1918	1	8	1,125	45	1.5705	573	1,125	50.96%	360	159.23%
10158	1987	1	7	850	34	0.3734	136	850	16.04%	238	57.27%
10190	1979	1	8	850	34	0.9372	342	850	40.25%	272	125.76%
10342	1971	1	50	1,699	34	0.6987	255	1,699	15.01%	1700	15.00%
10367	1973	2	80	1,699	34	1.3688	500	3,398	14.70%	2720	18.37%
10394	1996	2	104	1,699	34	5.6405	2,059	3,398	60.59%	3536	58.22%
						10.5891	**3,865**	**11,320**	**34.14%**	**8,826**	**43.79%**

6.2 Installation Practices

Installation practices observed during this study were inconsistent from contractor to contractor, from one installation to the next by the same installing contractor, and at times, even between what contractors said and what wee observed. Each installation varied in type, complexity and quality. Some installations closely followed code requirements, while other installations did not conform to prevailing codes. In each case, it is necessary to install a controller in an enclosure, using sensor wiring and power supplies rated to meet the site environmental conditions. This is true whether the controllers are located inside an equipment room or exposed to the environment.

One signature installation practice observed was the consistent use of the same type of enclosure regardless of whether the controller was installed inside or outside. In all observations, each contractor utilized cabling enclosed with plastic, polycarbonate or similar plenum rated shielding secured with tie wraps. All installations provided protective insulation over the sensor bulb strapped to the outside of the system piping. However, the insulation wasn't always properly installed and secured, nor always appropriate for exterior use. No outdoor PVC, EMT, Flex or Rigid Conduit was utilized to protect sensor wires.

The majority of the installations were acceptable and permanent. During the survey process, the majority of contractors indicated they utilized:

- An installation check list;
- Pre-installation verification procedures to ensure the existing equipment is in good working order; and
- A pre-start up check list.

However, the on-site inspections revealed some issues regarding the quality of many controller installations. Following are some examples observed during on-site inspections.

Power Supplies. Each control installation requires a power supply. At some of the sites, a power source is readily available. Some of the installations that did not have a readily available power source utilized unconventional methods which are not supported by NEC or local codes. This point is important because an interruption to power can take a controller offline after battery back up (if present) is depleted. One site had power quality issues which required the property management company to dispatch an electrician when the boiler went offline.

Sensor Installation. When the energy management controls are installed, various sensors are strapped to the outside of the system piping. Site 6926 serves as an example (see photo in Figure 5). Sometimes the sensor wiring is well protected. However for several installations, the wiring and connections will likely endure damage over time by the elements and personnel. The installation, including placement, insulation and attachment of these sensors, is inconsistent from contractor to contractor – even for the same controller.

Commissioning. Several contractors indicated that they monitor sites for a period of time to ensure proper operation. One indicated a systematic approach of monitoring sites, establishing control strategies based on observed patterns, and adjusting as conditions dictate. All contractors indicated that they ensure that controls and systems operate properly prior to leaving the site. One contractor responded that they do some form of commissioning or continuous commissioning. Commissioning is the systematic process of ensuring that a system is designed, installed, and tested to perform according to the design intent. Commissioning requires systems to be fully operational. The proper operation of the system is verified and documented. In addition, it includes training site staff to ensure proper use and maintenance of the system. The contractor that routinely performed the most complete system commissioning had the highest average realization rate among all the contractors.

Figure 5
Unprotected Control Connections

6.3 Controls Matching

Based upon field observations, control matching is determined by the contractor. The participant agreement does not specify what control strategy should be applied to equipment types or system configurations. That choice is always left to the contractor and each of the contractors interviewed in the study only installs one brand of control. This is an area of concern because the system configuration discovered in the filed can seriously hinder therm savings expectations for a specific control,. Three control manufacturers were represented, but each contractor was linked to just one control manufacturer. For example, none of the contractors in the study install controls that cycle the pump off when it is not needed, and prior research has shown that that is a very effective strategy for smaller multifamily CDHW systems.

Similarly, sensors are more readily installed on a system with a boiler and storage tank due to the piping in the primary loop providing a point of reference between each component (e.g., the directly heated water and the stored water). A traditional water heater will only produce hot water out, cold water in and return water from the users. Hot and cold water mixing is all internal to the tank. With boiler/storage tank configurations, external piping enables the contractor to take field readings, and make better control strategy decisions. Sensor placement in water heater based systems will have to be reconsidered in order to achieve the optimal therm savings. As quoted by one contractor, "a difference of savings can be expected between the two equipment types."

Another type of system that we observed in two cases was a boiler with no storage tank. Although installation on either of these systems had not taken place by the end of the study, a contractor was proposing installing controls on each of them. It is not clear that any control (other than perhaps a demand/pump control) would create significant savings with this particular system configuration.4 Taking these examples into consideration, it becomes clear that controls matching can help assure savings.

[4] Note that in the "Recommendations" section, KEMA recommends that systems without any storage capacity be excluded from the program. The best step to take to make these systems more efficient is to add a storage tank – before trying to control the distribution loop.

Figure 6
Control Matching

#	Strategy	Description	Site Matching
I	**Demand Control**	One sensor monitors flow (demand) and another sensor monitors water temperature near the last apartment. If temp in supply line is high enough when demand occurs, pumps stays off. If temp is too low, pump comes on until temp near last apartment rises *X* degrees, then shuts off.	This type of control is best used where there are relatively few dwelling units (3-40) and a relatively uniform use schedule.
	Temperature Modulation Control		
II	Set Schedule	Pumps stays on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set after 2-4 weeks of usage data is collected. Schedule is modified by contractor if changes in occupancy or use warrant it.	This strategy is the best one for large systems, and for owners of a significant portfolio of properties since there is an ongoing relationship with the controls manufacturer.
III	Learned Schedule	Pumps stay on 24/7. Hot water supply temp is kicked up or down to ensure water is just hot enough to meet the varying demand. Schedule is set **automatically** by controller based on previous ~ two weeks of temperature data (as a surrogate for water use demand data).	This strategy is most appropriate for large sites with maintenance staff who perform regular maintenance inspections on CDHW equipment.
IV	Constant Return Temperature	Pumps stay on 24/7. Hot water supply temp is dynamically adjusted by controllers to maintain 103°F **return** temperature 24/7.	This is best for extremely large campuses with a significant diversity of use schedules, and with sophisticated site managers who can monitor and operate a comples system.

6.3.1 Controls that Cause Short-Cycling of Power Burners

During the field inspection process Site 6955 had one water heater that was short cycling due to the controls. Based upon our observations, it appeared that the facility personnel were aware of the issue but did not know how to address the problem, nor who to call. When this was brought to the attention of the on-site property management team, it became evident that the property mangers (who chose to have energy management controls installed) did not communicate with the onsite staff. In this case, we provided them with the information needed to remedy the issue. Monitoring of the energy management system would catch these types of conditions, but not all control strategies include monitoring. It is important to note when the on board boiler controls detect system malfunctions, that the energy management solutions have a means of notifying the end users.

6.3.2 Impact of Temperature Modulating Controls on High Efficiency Boilers

High Efficiency Boilers, some of which in this sample are other wise known as Hi Deltas, run 25% of the time to heat the DHW. Although these boilers prove to be efficient during their run cycle, they do require that the return water temperatures are above 125 °F, preferably 135 °F. This requirement has a tendency to affect the Energy Management controls which are running 100% of the time. The temperature requirement of the manufacturer actually limits how low the supply temperature limit can be set and the range the controls can operate within. The same is true if the end-user has the requirement that supply water temperatures not exceed 128 °F. The boiler will have to be set up to have the water leaving the boiler go thorough a mixing valve to cool down the water prior to being supplied to the occupants. This configuration can cause excessive consumption. An additional study should address the manufacturers' temperature requirements compared to the end-users desired set point, and the ideal state learned by an energy management system. We did not have sufficient data to determine the impact in this sample.

6.3.3 Demand Controls on Large Diverse Occupancy Buildings

There were no sites with demand controls in the sample. Therefore, nothing new was learned about this potential control/system mismatch.

6.4 Data Accuracy

6.4.1 Confounding Conditions

Several variables could significantly affect energy use for hot water at participant sites. DOE produced a table of approximate impacts from a number of these variables[5], which is reproduced in Figure 7. According to DOE, some of these variables can have a very significant impact on site energy use for hot water. During our site inspections, interviews of site management personnel, surveys and subsequent interviews with contractors and manufacturers, we gathered information on many of these issues. Summaries are presented in this section.

[5] Although the table is originally from U.S. DOE, this version is reprinted from Raypak's web site, as it is apparently no longer available from DOE's site.

Figure 7
Energy Impact of System Variable (from DOE via Raypak web site)

Changes in occupancy	Each individual person adds approximately 25 - 35 gallons of hot water consumption per day (approximately 1,000 gallons of hot water per month) or about 6 therms of gas consumption per month
Changes in Weather	In cooler weather people take hotter showers (approx 10° f) equating to 1 therm increase per person per month or a 15% increase for cold days vs. hot days
The temperature of water supply to replenish the system	A 13 deg change (45° vs. 58°) inlet water temperature = over 1 therm per month increase per person or 15% summer to winter increase
Desired temperature setting	120° vs. 130° increase in delivery temperature equals a 12% change in energy consumption per person
Hot water system sizing and efficiency	An undersized system will require hotter temperatures to supply demand. For every 10° temperature increase add approx. 12% increase in energy consumption to heat the water.
Changes in heating system operation or system degradation (i.e. crossover or pump problems)	Problems with system plumbing or equipment (*especially crossover problems*) create hot water consumption that is important in that it represents all wasted energy, for every gallon of water wasted while waiting for hot water, a new gallon of cold water is introduced into the system to be heated. The same effect happens when a re-circulating pump malfunctions or is disabled. A typical problem with a pump or crossover will account for 10 - 30 minutes of wasted water flow per day per person. At a minimum 2 gallons per minute that potentially represents an additional therm consumption of 6 or more therms per month per person
Other hot water consumption (GPM)	• Water leaks from various sources - Leaking faucets or appliances • Crossover – Hot leaks into the cold water system, i.e., hot water is found in toilets and sprinkler system • Underground leaks in the system plumbing • Impact on energy consumption can be major and difficult to quantify

Although assessing the absolute magnitude or each was beyond the scope of this study, KEMA did gather information during site visits on several factors.

6.4.1.1 Other Hot Water Uses

The majority of our survey revealed that domestic hot water is regularly used for laundry, dishwashers, shower/bathtub, kitchen sink and, on rare occasions, water softeners within a home owners association. One site mentioned elsewhere in this report (6854) had been utilizing hot water for space heating but had been retrofitted over the years.

6.4.1.2 Other Gas Uses

This study sought to evaluate savings from sites that would provide the optimal circumstances for observable energy savings from boiler controllers. In assessing sites for inclusion in the study we excluded sites that had space heat, and the potential for largely unidentifiable gas loads that may exist on some large, single metered campus-like facilities. Thus, sites with one gas meter and gas end uses other than laundry room dryers, pool heaters, jacuzzi heaters, and BBQ's were excluded from the analysis. Since our analysis used a customer-specific change model, the uses noted would have caused very little noise in the comparison of pre- and post-installation usage, and exclusion of those sites would have made the sample population unacceptably small.

6.4.1.3 Gas Leaks

During our inspections, we noted that some of the sites showed evidence of gas piping replacement, and visibly older (sometimes rusted) adjacent piping, as seen in Figure 8. It is difficult to know how these conditions affect each site and how many sites have gas leakage. Nevertheless, when we conducted inspection, any significant signs of gas leakage were noted.

Figure 8
Replaced Gas Piping

6.4.1.4 Apartments Served

During the inspection process, we verified the number of apartments served by the boiler serving each building. A short interview with the on-site management staff verified the accuracy of the count.

6.4.1.5 Occupancy Rates

During the short interview process with the on-site management staff, KEMA asked about occupant characteristics and occupancy/vacancy pattern. We asked if there had been any changes in the vacancy rate in the past year or two. The majority of the sites checked maintained at least a 95% occupancy rate, and none of them indicated any noticeable change in the rate. This was helpful in determining if there were months that could significantly impact therms usage.

6.4.2 Weather Related Differences

KEMA did not run a comparison analysis of the weather data for the post-installation period and the equivalent months in the pre-installation period.

6.4.3 Unaccounted for Changes in Related Equipment

During KEMA's inspection of each site, the boiler model number and serial number were recorded. The equipment was all at least 2 years old. There was only one known instance of a customer who replaced major equipment on the same gas meter. They replaced a pool heater that had been out of commission for the prior two years. This would have created confusing results in the analysis; however that particular site had already been removed from our analysis.

6.4.4 Temperature Settings

Readings of temperature settings were taken on over 32 pieces of equipment. This included non participant sites as well. This information proved to be helpful in discerning the average temperature set point of each site. As the chart in Table 3 indicates, most systems had a setpoint of 131°F or greater. A model used to predict energy savings from installation of a controller needs to use the actual site set points or a reasonable average of what can be expected across all installations. As indicated in the table from the U.S. DOE (see Figure 6), a 10°F higher temperature set point can account for a 12% increase in energy use.

6.5 Equipment Conditions

6.5.1 Cross-over Loops

Cross over was inspected on each of the systems at the equipment only. The inspection entailed visual inspection of piping arrangements and checking for check valves on the cold water supply lines. We also took temperature readings at cold water lines as illustrated in our inspection. Through this inspection and our temperature readings, we were able to identify that at least 5% of the systems had crossover. Some were more obvious due to leaking check valves, while others were caused by malfunctions downstream of the equipment room. The conditions we discovered are only the most obvious ones. Further investigation of crossover (particularly related to in-unit lavatory and shower fixtures) is warranted with possible recommendations to incorporate inspections before and after installations of controls. Starting immediately though, contractors can check for the presence/absence of a CWS check valve, and basic functionality of it.

6.5.2 Leaks

We inspected systems for leaks at the boiler room and at accessible equipment and pipes only. Roughly 5% of the systems inspected had leaks from the primary circulation pump mechanical shaft seal, flange connections, and instrumentation (e.g., pressure and temperature gauge fittings). We identified other leaks from union fittings that were corroded due to the lack of dielectric unions. Of the few leaks that were found, none constituted a major problem.

6.5.3 Pump Functionality

Both primary and secondary circulation pumps were checked during the inspection for operation, water leakage and cycling. The majority of the primary pumps inspected were found to be in continuous operation and were integral to the boiler (i.e., provided by the manufacturer). Integral pumps on the high efficiency boilers (most of which are known as “High Delta”) have a tendency to have controls ensuring the option to have intermittent pump operation. We were not able to verify whether this feature was utilized. Verification of intermittent or constant primary pump operation would require continuous monitoring for at least a full day. When there are nearly continuous draws (as during the day at a large MF complex), it is not possible to verify whether the primary pump would shut off when there is no demand. Since the controls installed on all the sites in this study were temperature modulation controls, the secondary pumps were in continuous operation with no control interlock for cycling with boiler or utilization of a timer.

6.5.4 Fouled Burners

During our inspection process at sites, we removed the access cover to the burner assembly and checked the flame pattern for proper air fuel mix. Our inspections revealed that regular maintenance activities are not common practice at most of the sites. Over 50% of the systems inspected had fouled burners with various forms of debris inhibiting proper combustion. Due to timing and liability issues, we did not check the manifold gas pressure to burners, or check proper operation of the gas valves. In cases where the burner assemblies are fouled our inspection process allowed us to see if the boiler set point was higher than normal. This is often done to compensate for the fouled burner conditions and get more heat to the water. When KEMA performed burner inspection and noted the temperature setpoint, we also noted that 10% of the systems inspected were experiencing short cycling. Several had flame rollout conditions active or had evidence that it existed at some time. It appears that most contractors inspect for fouled burners, but a specific requirement to ensure inspection and correction of these conditions is not included in the current multifamily programs. As noted in Section 7, KEMA highly recommends including inspection requirements to identify if this conditions exist.

6.5.5 Encrusted Heat Exchangers

An encrusted heat exchanger is normally also caused by lack of burner maintenance. Alternatively, it can result from unusually high dirt and debris in the area, poor gas pressure, improper fuel/air ratio, and lower than manufacturer recommended temperature in the water entering the heat exchanger. KEMA checked each system whenever access was possible, though a high degree of difficulty prohibited photo documentation. Roughly 30% of the systems inspected were found to have encrusted heat exchangers. As with the fouled burners, the boiler control set point is usually set higher than normal by the site maintenance staff, in order to compensate for the insulating barrier created by these conditions. When fouled burners and encrusted heat exchangers occur together, the problem is compounded. After maintenance staff raises the set point, the amount of soot deposited increases. The boiler control will normally begin to short cycle the burner and eventually it leads to flame roll out. At each step in this cascade, the runtime is extended and gas consumption increases for the same (or lesser) satisfactory delivery of hot water. Although it is difficult to combine these two conditions (fouled burners and encrusted heat exchangers) into a single percentage of occurrences, it is safe to assume this compounding problem will significantly reduce the therm savings that SoCal Gas and SDG&E can expect from installing controllers.

7. Recommendations

7.1 Programmatic Recommendations

One of the more important outcomes of this study should be a set of recommendations for SoCal Gas' and SDG&E's program managers on how to structure requirements and incentives for controls on central how water systems in order to achieve consistent, significant, and reliable energy savings. This section provides those recommendations. A key strategy KEMA recommends is balancing rigor so that SoCal Gas and SDG&E cause real energy savings, and simplicity so that participation in the program is attractive as a business proposition. If contractors have to incur an additional $2000 in cost to sell a $5000 job, there will be virtually no participation. In each of the recommendations below, we discuss this balance, and where appropriate, we discuss alternatives that either increase the certainty of savings or reduce participation costs – usually with a negative impact on the other criterion.

7.1.1 Controls/System Matching

As noted in the Findings section, one of the causes for unexpected increases in energy use, and more commonly for less than expected energy savings, is that a control strategy was applied that was either inappropriate for the system, or was at least sub-optimal. There are several strategies that SoCal Gas' and SDG&E's program managers could adopt to help prevent Controls/System Mismatch.

Some manufacturers install their own equipment. For them, it is illogical to expect that they will perform anything other than a cursory analysis of whether their controller can save energy on this property. They are unlikely to invest the time in an analysis of which control strategy is optimal. Additionally, some contractors have a relationship with just one controls manufacturer. SoCal Gas and SDG&E may be able to encourage them to expand their toolboxes. SoCal Gas and SDG&E should encourage all contractors to look at the range of controls available and work to avail themselves of all options. That way, there is a greater likelihood that most controls will be correctly matched to the existing CDHW system.

7.1.1.1 Contractors' Inspections

During the process of completing this study, KEMA created and employed a set of protocols for inspecting sites, and a log form to assure that we captured the important details of the system and site. We recommend that SoCal Gas and SDG&E require contractors to complete these for each site. That will help ensure that the contractors look at all the whole CDHW system, determine all the end uses served by it, and other relevant site details. It is too easy to choose the wrong control strategy for a CDHW system if the contractor does not collect all the relevant information. The completed inspection form should be a part of each project application, and be signed the party performing the inspection for the contractor. A copy of the inspection form that KEMA used for this study is included in an appendix.

One of the primary benefits of this type of uniform inspection protocol is that significant existing problems with systems can be identified before controls are applied that might actually exacerbate the problems. SoCal Gas and SDG&E should include some funding within the program to make necessary and reasonable repairs to systems before providing incentives for upgrading the controls. For example, if a system does not have a check valve where the cold water supply tees into the system, then pumping when there is no usage will often induce form of "cross over," where the pump pushes hot water up the cold water line. Correction of this problem can often save as much energy and water as installing new controls would, and installing the controls without fixing this fault will result in substantially less energy savings than expected.

7.1.1.2 Uniform Selection Protocols

SoCal Gas and SDG&E need contractors to identify the best control strategy for the subject property. Some contractors have an exclusive or semi-exclusive relationship with a controls manufacturer. Indeed, some controls manufacturers often act as their own installers. As the old adage says, "When all you have is a hammer, the whole world looks like a nail." If SoCal Gas and SDG&E require contractors to use a uniform set of protocols for matching a control strategy to a specific system/property, the result should be a significant reduction in the wrong controls being applied. Depending mostly upon whether a reward-for-referral system can be developed, encouraging Contractor A to pass leads to Contractor B when B has the appropriate control and A does not, there may or may not be a reduction in the total number of controls upgrade jobs performed under SoCal Gas' and SDG&E's programs. This strategy may also have the unintended consequence of increasing participation from contractors who represent several controls manufacturers, and decreasing work from those who only offer one solution.

The Uniform Control Selection Protocols (UCSP) can be as simple as a decision tree, or as complex as an engineering model with user entered variables. KEMA recommends that the simpler the protocols, the more likely it is that contractors will be able to recognize the business opportunity. SoCal Gas and SDG&E should consider requiring use of a simple decision tree, but allowing contractors to make a case for individual projects wherein their proposed control strategy does not exactly fit the simple model. Based on the findings of this study, KEMA could recommend a simple model that would then need to be vetted by program staff and contractors.

7.1.1.3 Pre-Installation Engineering Review

Once a contractor has completed the steps above, SoCal Gas and SDG&E program staff should review the recommendations of the contractor before approving the contractor to install the controls. This review should be both quick turn-around, and simple in most cases. For the majority of projects the review would constitute nothing more than review of the inspection report and the UCSP sheet. In cases where the contractor has not used the UCSP work sheet, because s/he feels that the correct control is not the one the sheet would result in, the project proposal might require an engineering review. The contractor's alternative assumptions and logic would need greater scrutiny and would take additional time.

The outcome of the Pre-Installation review would be two-fold. First, a conditional approval for the project would be given to the contractor. Second, the reviewer would create an inspection checklist for use by SoCal Gas and SDG&E program staff.

7.1.1.4 Pre-Installation Inspections (Sampling)

Although it is not likely to be cost-effective for SoCal Gas and SDG&E to perform pre-inspections on 100% of participating projects, they should conduct pre-installation inspections on a sampling basis. This would assure the utility that contractors are following Sempra's site inspection protocols correctly, and are correctly characterizing the sites and the CDHW systems. Staff performing the pre-installation inspections should be guided by a checklist created by the application reviewer.

Initially, 100% of the first few projects for each contractor should be inspected. The exercise should be seen more as a learning exercise than a regulatory or fault-finding one. Once a contractor has demonstrated through accuracy and agreement between stated and actual conditions, that they understand the intent and can correctly characterize sites and systems, inspections can be limited to sampling, say, one in five projects.

7.1.1.5 Post-Installation Inspections

SoCal Gas' and SDG&E's program staff (or their contractors) should perform post-installation inspections. Beyond the obvious benefit of ensuring the controls are installed before the incentive is paid, a post-installation inspection by a qualified inspector can help ensure that the installers are properly following the checklist and making sure that the controls are functioning. SoCal Gas' and SDG&E's inspectors should follow the same checklist as the installers, and verify that the installers trained the site staff and left an operator's manual. The inspections should include going through a functional testing check list, including taking recommended temperature readings on forms shown in the Appendix.

7.1.2 System Condition Inspection (see 6.a.i.1)

SoCal Gas and SDG&E should consider including some funding within the program to make necessary and reasonable repairs to systems before providing incentives for upgrading the controls, and contractors need to identify any significant system faults before selecting and installing controls. When faults (e.g., major leaks, hot/cold water cross-over, boiler malfunctions) can be corrected but are not, adding controls may not result in any energy savings. Correction of these problems can often save as much energy and water as installing new controls would, and installing the controls without fixing this fault will result in substantially less energy savings than expected. In some cases, implementing certain controls strategies may actually exacerbate existing problems. As one control manufacturer stated it, "We do emphasize [to installers of our products] that no controller will solve a systemic problem, and that any additional controller could exacerbate an existing system issue." KEMA recommends that as part of the contractors' initial inspection, they be required to include inspection protocols to identify the following potential CDHW system faults.

7.1.2.1 Cross-Over

Cross-over of hot water into the cold water line, or cold water into the hot water line occurs because of pressure differentials when the two sets of supply lines have an open connection. The most common location for such an open connection is where the cold water supply (make-up) tees into the system. A check valve on the cold water supply line prevents the hot water at this location from being pushed into the cold water line, but not all systems have a check valve installed.

Other open connections often occur at the shower valve or bath lavatory valves in the individual tenant units. The two least expensive (and therefore most commonly used in older multifamily buildings) brands of bath lav valves do not shut off the cold or hot water lines entering the valve even when the valve is in the off position. They simply stop water from flowing form the hot and cold water lines into the sink. Likewise, shower valves are meant to mix the hot and cold water to achieve an acceptable water temperature for a shower. Unless the valve handle is tuned all the way to cold or hot when the valve is turned off, most shower valves allow both hot and cold lines to remain open to the mixing chamber within the valve.

Where an open connection of hot and cold water lines exists, pressure differentials between the two will cause water from one to move into the other. When open connections occur at both locations in a system, crossover can be an even more significant problem. Retrofitting all shower and bath lav fixtures is a costly project that may be well beyond the scope of most plumbing jobs involving CDHW controls, adding a check valve at the cold water supply to the system is not, and should be a requirement of the program.

7.1.2.2 Leaks

Virtually all CDHW systems have leaks. Often, the leaks are not significant enough to matter in comparison with the water and energy savings potential of adding controls to a system. However, in some cases the leaks may account for nearly as much energy as could be saved by correctly controlling the recirculation pump or water temperature (the two primary strategies of CDHW controls). There is no easy way to determine where all the leaks might be. Leaks in the boiler room are relatively easy to locate and should be repaired, if at all significant. Leaks that are underground or within the framing of the building, are not generally accessible to the inspector nor the contractor. Leaks in fixtures in the tenant space are not generally accessible to program staff or controls contractors. The table in Figure 2 notes that there is an impact from leaks but gives no approximation for its impact.

7.1.2.3 Boiler Functions

Several problems can exist with boilers that would cause wasted energy and that could significantly reduce the savings from adding CDHW controls. At the initial inspection, contractors should check for burner tip fouling and scale build-up on the heat exchanger plates. This inspection is performed by removing the access covers and inspecting the burner while the boiler is in operation. Usually, an inspection mirror and a flash light will allow a visual inspection of any excessive build up. In addition, the boiler Delta T (temperature differential between boiler inlet and outlet water) should be recorded with thermometers. Checking the water inlet/outlet temperatures while ensuring the boiler primary circulation pump is in operation also checks for boiler short cycling. A phone call to the manufacture will normally yield the expected performance parameters.

7.1.2.4 Pump Functions

In most cases, contractors will check to make sure that the pumps in the CDHW system are operating before installing their controls. As one contractor put it, if there is a malfunction, the "'last in, first to get blamed' rule applies." However, it is not always the case. Adding a simple, non-invasive inspection of the pump to the checklist will not make additional work for most contractors and could help forestall problems with installations for those who would not have otherwise checked.

7.1.2.5 Piping

There are several issues with the piping of CDHW systems that can easily be inspected, and which can make a significant difference in system performance. Most can be checked without leaving the boiler room. Some have relatively easy fixes. Although others cannot be fixed easily, quickly or inexpensively, the condition should be noted and accounted for when selecting a control strategy and when estimating potential energy savings.

- **Cold Water Make-up Location**

Manufacturers of boilers and water heater provide installation instructions that generally include a piping layout. In some cases this is nothing more than an indication of how to plumb in the cold water supply, the hot water supply and the hot water return. Contractors need to inspect the system to determine if it is correctly plumbed before selecting and adding controls. KEMA found systems with cold water supply plumbed into inappropriate locations according the boiler manufacturers' instructions. For example, one property with a RayPak boiler, we found the cold water supply teed into the return line to the boiler. RayPak (and good practice) indicates that the cold water should be plumbed into the line from the boiler to the storage tank so that it is mixed in the tank.[6] Otherwise, cold water would go directly into the boiler shocking the heat exchanger.

- **Check Valves Installed**

This issue is covered under the cross-over discussion above. (see Section 7.1.2.1)

- **Location of Return Line to Tank**

Location of the secondary return line (the return from the building) point of connection is usually determined by the boiler manufacturer. Most of the time, a secondary return water line will join the primary return line – the return line from the tank to the boiler. This line generally is plumbed to the storage tank near the bottom of tank. See the plumbing example illustrated in our inspection form (in the Appendix).

- **Pipe Insulation**

Pipe insulation for all piping in recirculating systems is now a requirement of the state code for new construction because it very cost effective. Likewise, it is cost-effective for accessible portions of piping in existing recirculation loops but few systems have insulation on the supply or return piping. Contractors should note during their initial site inspections whether pipes are insulated and whether uninsulated pipes

[6] An alternate location for the cold water supply (when not contrary to manufacturer's instructions) is at a separate inlet to the tank.

are accessible. SoCal Gas and SDG&E should consider making funds available for contractors to insulate pipes when they are going to install controls.

- **Anti-Scalding (mixing) Valve(s)**

In order to help prevent Legionella, supply water temperatures are often set to 140° F. Anything over 120° at faucets carries a risk of scalding, so it is common to install anti-scalding mixing valves. Manufacturers often pre-plumb the anti-scalding valve to include hot water return and cold water supply. They allow the mixed water to be just a combination of direct hot water supply and return water when that provides an adequately safe temperature, but to include cold water in the mix when necessary. Other systems rely just on the hot water supply and the cold water supply. The configuration of a system will affect the optimum design for controlling the recirculation system, and should be noted by the contractor at the initial inspection.

7.1.2.6 Tank

Hot water storage tanks also need to be inspected. If a tank is leaking or otherwise beyond its useful life, should note that in the initial inspection report and make a determination as to whether it is appropriate to install recirculation controls before the aging tank is replaced. In addition to the overall condition and serviceability of the tank, the contractor should inspect for a number of specific conditions.

- **Pressure Temperature Relief Valve**

Some boilers and some storage tanks are factory equipped with pressure/temperature relief (PTR) valves. In most situations they are added by the equipment installer. Either way, they need to be checked to be sure they work before controls are installed. Checking a PTR valve involves lifting the lever and making sure that water comes out. If the tank does not have a PTR, installing one should be a standard part of a contractor’s control installation procedures.

- **Insulation**

Modern storage tanks are usually manufactured with R-12 to R-16 insulation between the tank and the sheet metal skin. Older tanks can be wrapped with an insulation blanket. Contractors’ initial inspection should note whether the tank has insulation, either internal or external.

- **Aquastat to Boiler (if applicable)**

The Aquastat between the boiler and the storage tank (for applicable systems) should be checked. The contractor should inspect the connections, temperature setting, and whether it controls the boiler/tank pump correctly.

- **Galvanic Corrosion**

"Corrosion" is the term used to describe oxidation of metal. In a water heater or hot water storage tank, the metal of the tank will combine with oxygen in the water creating a metal oxide ("rust" in the case of steel). This process attacks the weakest areas of a tank: seams, welds, and fittings. It not only weakens the tank, but deposits a layer at the bottom of the tank that can interfere with intended flow into or out of the tank. Most tanks employ a sacrificial anode - a rod made of a material that suffers galvanic corrosion more readily than steel – protecting the tank itself. Contractors should inspect the anode to determine whether it requires replacing.

7.1.3 Monitoring Pre and Post Conditions

One option for SoCal Gas and SDG&E that might impose a significantly higher cost of business on some contractors is a requirement that CDHW systems be monitored for performance both before and after installation of controls. The advantage of this approach is that it greatly simplifies the process for SoCal Gas and SDG&E. There would be no need to check pre-installation inspection reports from the contractors, nor even to verify that they made a logical choice in controls for the system. SoCal Gas and SDG&E would have performance data from a set period (say, four months) before the installation, and data from a set period after installation of the controls. If the controls do not cause an energy savings, then the utility would not pay an incentive.

This option has some significant disadvantages too. If a contractor has to install monitoring equipment and ensure the data logging is working before making the sale to the customer, the cost of every controls installation will need to be substantially more. Further, it is unlikely that such a regime could be made cost-effective at all for smaller buildings. Finally, the specter of possibly not being paid until some future date (after savings have been proven), will almost certainly lead to contractors "cherry picking" only those properties where they can be certain before they do anything, that their controls will save energy. Those that are a close call will be ignored.

Nonetheless, SoCal Gas or SDG&E should consider piloting this option for the segment of the existing multifamily market that has high gas usage associated with hot water – to determine whether there is a cost effective way. Some controls installers already include post-installation monitoring (with remote data centers) of water temperatures at two or three strategic points in the CDHW system. On some properties, they also monitor boiler run times. For these installers, there would be less of an additional burden. Still, KEMA does not recommend pre- and post-monitoring and pay-for-performance as a cost-effective program strategy for this market.

7.1.3.1 Gas Usage

The most obvious measurement needed is gas usage. For CDHW systems that are the sole end use on SoCal Gas' or SDG&E's gas meter, this is a simple measurement. For sites where the CDHW system is only one of several end uses on the utility meter, a local gas meter would need to be installed. This is a non-trivial project. It involves a significantly higher level of liability for contractors than simply adding controls would, or even than would installing sensors for the rest of the data listed below. In addition to the liability and extra installation expense, non-utility gas meters traditionally do not have the accuracy of utility gas meters. There may need to be significant additional time calibrating the meters. Consequently, unless the utility is willing to install a utility meter at the boiler room, there is no cost-effective means of directly monitoring the gas usage.

Although domestic hot water related gas usage is what SoCal Gas and SDG&E ultimately want to know, if they use pre- and post-installation monitoring to assess the impact of added controls, KEMA recommends that for systems that do not already have a dedicated gas meter, the utilities should develop protocols for using some combination of the following data as a surrogate for direct gas usage measurements.

7.1.3.2 Water Temperature

From water temperature measurements in conjunction with net water flows and usage, it is possible to estimate gas usage. Readings of water temperatures at the following locations are needed. Please see the description of system configurations in the appendix for an explanation of the locations.

- **Supply (secondary loop)** This is the hot water leaving the storage tank and going into the recirculation loop that supplies the building tenants with hot water.
- **Return (secondary loop)** This is the water in the return line from the building. If the cold water supply tees into it, the sensor should be placed at least a couple feet before the tee.
- **Delivered to End-User** This is the tempered hot water that exits an anti-scalding mixing valve.

- **Storage Tank Temperature** This is the water temperature near the top of the storage tank.

- **Cold Water Supply** This is the make-up water from the municipal or other water source. The sensor should be placed far enough upstream of where the supply tees into the system that conduction through the copper piping will not affect the readings.

7.1.3.3 Boiler On/Off Cycles

This is a reading of when the gas solenoid opens and closes. With the name plate rating of the boiler, it is possible to estimate gas usage by knowing hours of operation times Btu/hour rating. Temperature of the gas as supplied will affect the energy content. And though nameplate ratings are good approximations, they are not completely accurate. Therefore, this method should not be the only estimation used.

7.1.3.4 Pump On/Off Cycles

Although this measurement will have little real value in estimating gas usage, it is a vital measurement for understanding why installed controls did or did not cause energy savings. It includes on/off cycles for the pump on the primary loop as well as the one on the secondary loop. Data from these sensor can help find

7.1.4 Uniform Installation Protocols

KEMA recommends that SoCal Gas and SDG&E develop and distribute a uniform set of installation protocols. For several specifics, the protocols would simply direct the contractor to secure and follow the boiler manufacturers' (tank manufacturer, control manufacturer, missing valve manufacturer, etc.) installation instructions – and supply a copy of the instructions to SoCal Gas or SDG&E (as appropriate) for its post-installation inspection. However, there should be two standard protocols that contractors follow.

7.1.4.1 Decision Tree

KEMA recommends that SoCal Gas and SDG&E develop a decision tree style guideline for installers. Since there are both water heaters and boilers, and indeed several types of boilers, a single set of instructions will have to be structured as a decision tree.

7.1.4.2 Checklist for Installers

SoCal Gas and SDG&E should also have a basic checklist that installers should complete regardless of the type of system. The general purpose of the checklist would be to make sure that CDHW systems with new controls added were functioning appropriately before the contractor walked away. Although this is not full commissioning, it is similar. The checklist, which is intended to augment – not replace – the installer's or control manufacturer's own checklist, would ensure that before leaving the property, the installer:

- Checked the hot water supply temperature. It should be no more than 125°F. If there is an anti-scalding mixing valve, the temperature should be taken down stream from it.
- Checked the PTR valve should be, even if it was checked before installing the controls.
- Checked accessible piping in both the primary and secondary loops to determine if it can cost-effectively be insulated. At the very least, any insulation removed by the contractor in installing the controls should be replaced.
- Verified that there is a check valve on the cold water supply to prevent or reduce cross-over flows.
- Verified that there are no water leaks in the boiler room or other accessible locations.
- Verified that all control sensors are functioning as intended.
- Verified correct operation of the new controls.
- Gave the building maintenance personnel a briefing on the system and controls, and left an operator's manual with them.

7.1.4.3 Training/Qualifying of Contractors and Inspectors

KEMA highly recommends that SoCal Gas and SDG&E also provide training of inspectors and contractors involved in the program.

7.1.4.4 Contractors

In interviews with contractors and manufacturers, KEMA found a wide range of knowledge and interpretations of some basic concepts. KEMA recommends that SoCal Gas and SDG&E put together a course of training on issues relevant to achieving reliable energy savings from installing controls on CDHW systems. The training should be mandatory for contractors participating in the program, and should include both a classroom setting and on site training (perhaps at the Energy Resource Center and the San Diego Energy Resource Center).

Topics to train contractors on should include:

- New SoCal Gas and SDG&E program requirements
- Pre-installation inspections
- Basic categories of control strategies

- System/Control matching and uniform control strategy selection protocols
- Detecting system faults
- Recognizing common CDHW plumbing errors
- System commissioning
- Continuous monitoring

7.1.4.5 Inspectors

SoCal Gas and SDG&E inspect installations before approving paying of incentives, and in some cases, before approving a project for participation. The inspectors may be from the utility's staff, but generally they are from a consulting firm with whom the utility contracts. These inspectors are a critical line of defense in SoCal Gas' and SDG&E's efforts to ensure reliable energy savings from the installation of boiler controls. Consequently, they must be well versed in what to look for, the various CDHW types, systems faults, and all aspects of SoCal Gas' and SDG&E's program requirements. As noted in Section 4, some inspectors were unsure of some of the basic concepts behind boiler controls. Better training will give them the confidence necessary to find and report system faults and poor installations. KEMA recommends that SoCal Gas and SDG&E develop a comprehensive training program for all inspectors who will be involved in the program.

7.2 Further Study

7.2.1.1 Impact of Cross-Over on CDHW Energy/Water Use

Cross-over from hot to cold and vice versa is a well-known but little understood phenomenon in central DHW systems. It is caused by pressure differentials between the hot and cold lines, and open connections between them. The easiest open connection to fix is at the cold water supply to the CDHW system, in the boiler room. The other open connection locations are diffused across the tenants' apartments. These include single lever shower valves, worn or cheap bath lavatory valves, and some clothes washer connections. Cross-over wastes energy by cooling off heated water. It wastes water by causing tenants to dump water down the drain while waiting for the water to get hot.

SoCal Gas and SDG&E should fund a research project to determine the impact of cross-over on individual recirculation systems and the extent of the problem within the multifamily buildings in SoCal Gas' and SDG&E's service territories. The study would involve monitoring of several sites over several months. After energy usage, water usage, and strategic location temperature data was collected on all the study sites for several months, some crossover reduction would be produced by installing checks valves at the cold water supply to the CDHW system. After several months of additional data collection, crossover would be prevented by a combination of bath lavatory valve replacements, shower valve replacements, and check valve installations at the clothes washers.

7.2.2 Develop Cost-Effective CDHW System Monitoring Protocol

The development of data collection protocols is founded on what is known, what is unknown, and what is needed to know. Monitoring of the operation of CDHW systems can help us better understand how these systems operate and how boiler controller savings can be better and more reliably predicted. KEMA recommends that a set of protocols be developed to enable cost-effective and timely monitoring of CDHW in multi-family dwellings. These protocols would need to be effective in gathering the data necessary for assessing system performance, but also economical to ensure the resources are available to install and utilize the monitored data. These time of day data would be used in conjunction with research designs intended to assess the system performance, both uncontrolled and controlled.

7.2.3 Impact of Primary Loop Constant Volume Pumps

The primary loop of a multi-family CDHW system runs between the boiler and the storage water tank. A constant volume pump moves water through this loop. During site surveys two observations were made that warrant further investigation. The pipes in this loop were typically uninsulated and the pump ran continuously, 24-hours a day, 7-days a week. In several instances the uninsulated pipes were exposed to the environment. The effect of such installations on CDHW energy use can be significant and the effectiveness of a boiler controller on such a system can be diminished. KEMA suggests exploring the impact of uninsulated primary loop systems with constant volume pumps on boiler control savings.

8. Appendices

8.1 2006 MF Program Study

Impact Evaluation of the 2004-2005 Statewide Multifamily Boiler Control Measure

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March 12, 2007

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1.

Executive Summary

1.1 Introduction

This report describes the data, methodology, and analysis results of the boiler control measure installed through the 2004-2005 Statewide Multifamily Rebate Program operated by San Diego Gas & Electric Company (SDG&E), Southern California Gas Company (SoCalGas), and Pacific Gas & Electric Company (PG&E), the three California IOUs that provide natural gas services to their customers. The impact analysis uses a Statistically Adjusted Engineering (SAE) regression technique to estimate first year therm savings associated with boiler controller measures. Four sections comprise this report.

- This **Executive Summary** provides a brief overview of the billing analysis method and the high-level IOU-specific results for boiler control measures.
- The **Analysis Methodology** section details the data requirements of an SAE analysis, the data made available to the Itron team for the analysis of the Statewide Multifamily boiler control measure, and the SAE modeling technique used in this analysis.
- The **Impact Evaluation Results** section includes a presentation of estimated gross and net therm savings and realization rates, with a discussion of the lessons learned as the team conducted the analysis.
- The **Recommendations for Future Analysis** section describes the steps that could be taken by the California IOUs and the Itron team to improve any future impact analysis of the multifamily boiler control measure.
- **Appendix A** describes the additional steps that were taken to ensure that the realization rate from the impact evaluation was consistent with alternative methods of evaluation.

1.2 Overview of Billing Analysis

Therm savings from the installation of boiler control measures installed in multifamily complexes was estimated using billing analysis and regression techniques. Statistically Adjusted Engineering (SAE) analysis was used to econometrically estimate a ratio of realized impacts to an a priori engineering estimate of savings. These realized impacts represent the fraction of engineering estimates actually "observed" or "detected" in the statistical analysis of the billing data. Utility-specific SAE coefficients are estimated, and can then be used to calculate therm savings from the installation of boiler controls at multifamily complexes in each utility's service territory.

In the SAE framework, initial estimates of the program participation effects are represented by engineering estimates of savings for each facility. One benefit to using the SAE approach is that the engineering estimate implicitly accounts for the difference in savings associated with different measure types. The coefficient of the engineering estimate of savings is referred to as a realization rate, or the fraction of the engineering estimate realized in the form of actual reductions in natural gas consumption.

1.3 Statewide Level Results

This section presents the estimated 2004-2005 statewide gross and net therm savings achieved by PG&E, SDG&E, and SCG from the installation of boiler controls. The estimate of gross savings is derived by multiplying an a priori engineering estimate of therm savings from boiler controls by an estimated realization rate of savings. The realization rate used to calculate statewide savings from this measure is PG&E's estimated rate. As described in Section 3 of this report, the realization rates estimated for SDG&E and SoCalGas were not statistically significant. We attribute this principally to a lack of contributing data, due in part to: an evaluation plan that did not include the collection of participant phone survey/on-site/metering data, inaccuracies in the tracking data, and a lack of sufficient billing data provided by the utilities. Sufficient data may have been difficult for the utilities to provide had they not anticipated an SAE analysis of multifamily boiler controls would be conducted.

Another possible explanation for the low realization rate estimates could arise from the installation of boiler controllers onto boilers that have been previously controlled. During an interview with one of the boiler control vendors, he estimated that approximately 30% of boiler controllers are installed in facilities already equipped with boiler controllers. It is expected that a controller upgrade, such as that described by this vendor, would result in reduced savings for those particular installations, as the ex-ante estimates are based on a baseline condition without equivalent boiler controls.

Since PG&E's program tracking and billing data are sufficiently complete, we use the estimated realization rate from this analysis to calculate the 2004-2005 statewide multifamily boiler therm savings. Though the PG&E realization rate presented is our best available estimate for the boiler controller measure, we still feel this realization rate should be viewed with caution. Table 8-1 presents estimates of gross and net annual therm savings per boiler controller derived from the billing analysis. Included in this table is the gross engineering estimate of annual savings per boiler controller overall, gross engineering estimates for small and large controllers, the gross estimates of realized savings based on the realization rate estimated for PG&E, and the net estimates of realized savings based on a net-to-gross ratio of 0.83.[7]

The residential multifamily rebate program PY2004/2005 Work Papers state that the estimated gas savings from a water heater and/or boiler controller is approximately 15% of water heating usage, or approximately 231 therms per apartment unit for a typical 40 unit multifamily complex. For boiler controllers installed in multifamily complexes with fewer than 20 units, the engineering estimate is 554.4 therms per boiler controller. The engineering estimate of gross savings for controllers installed in complexes with more than 20 units is 1,388. When these engineering estimates of therm savings per boiler controller are multiplied by the estimated realization rate of 12% for PG&E, the results are relatively small ex-post gross therm savings estimates. Multiplying by the net-to-gross ratio further reduces the estimates of realized savings per boiler controller.

Table 8-1: Statewide 2004-2005 Multifamily Boilers Program Engineering and Realized Therm Savings (Therms/Year/Controller)

Measure	Gross Engineering Estimate of Savings* (A)	Gross Estimate of Realized Savings (12%*A) = G	Net Estimate of Realized Savings (G*83%)
Boiler Controller for Facilities with less than 20 Apartment Units	554.4	66.53	55.22
Boiler Controller for Facilities with more than 20 Apartment Units	1,388	166.56	138.24

* The engineering estimates of savings per boiler controllers were taken from PG&E Multifamily Rebate Program PY2004/PY2005 Work Papers.

1.4 Program Goals and Accomplishments

The gross and net projected goals and recorded accomplishments for each of the utilities operating the multifamily boilers program during 2004-2005 are presented in Table 8-2, which shows that overall, the utilities' recorded accomplishments represent approximately 85% of their goals.

7 This net-to-gross ratio was recently revised downward from 0.89% to 0.83% based on comments received by the California IOUs involved in the multifamily boilers program.

Table 8-2: Gross and Net Program Goals and Recorded Accomplishments for 2004-2005 Statewide Multifamily Boiler Program

Utility	Projected Number of Boilers	Recorded Number of Boilers	Gross		Net Realized	
			Projected Annual Goals (therms)	Recorded Annual Savings (therms)	Projected Annual Goals (therms)	Recorded Annual Savings (therms)
PG&E	1,070	764	951,656	790,346	96,783	80,378
SCG	520	425	426,480	356,204	43,373	36,226
SDG&E	416	361	535,575	473,340	54,468	48,139
TOTAL	**2,006**	**1,550**	**1,913,711**	**1,619,890**	**194,624**	**164,743**

- Results are taken from the following workbooks: 03_ResMultifamilyEERebates_Nov05.xls for SoCalGas, 19 - SDGE SW Residential Multifamily Rebates – Dec 05.xls and 27 – SDGE SW Residential Multifamily Rebates (Proc) – Dec 05.xls for SDG&E, and the AEAP filing, MF rebate tab in a Res data.xls spreadsheet received from PGE. Confirmed as correct source by Frank Lee at PG&E.

2. Analysis Methodology

2.1 Overview

The approach used to estimate realized savings for the boiler control measure is a traditional SAE billing analysis framework. This is a typical specification for studying panel data where a priori engineering estimates of savings are available. Panel data containing many cross-sectional units (i.e., premises) with multiple observations over time for each unit (i.e., monthly data) are used to estimate therm savings over the entire population of participants with usable billing and program tracking data. The resulting estimate is a realization rate that when subsequently applied to the engineering estimate of savings, yields an SAE adjusted ex-post estimate of program savings.

The use of an SAE framework to analyze the installation of boiler controllers in a multifamily setting requires a significant amount of data on multiple units and facilities over time. The needed data include gas consumption for facilities associated with the boiler control installations, engineering estimates of per-unit savings from the installation of boiler controllers, tracking information surrounding the date of installation and quantity of controllers installed at each site, and weather data. Much of this information could have been collected through phone surveys or on-site visits, but budget constraints and difficulties in communicating with managers of multifamily facilities made these data collection activities prohibitive.

2.2 Data Sources

The econometric analysis used three types of data to compute program impacts:

- Monthly billing data for participants covering 2002 – 2006 were requested from the utilities. Below we present the data ultimately received from each utility:
  - PG&E provided billing data covering January 2002 – May 2006
  - SDG&E provided billing data covering June 2003 – May 2006
  - SoCalGas provided billing data covering September 2003 – August 2006[8]

[8] Given the lack of data during the early portion of 2003, it was not possible to estimate a realization rate for controllers installed prior to June 2004 for SDG&E and September 2004 for SoCalGas.

- Monthly weather data matching the period covered by the billing data, and
- Program tracking data for the participants in the 2004 and 2005 multifamily program where boiler controllers were installed.

For the multifamily model, the basic unit of observation is the facility. Aggregating gas use accounts to the facility level allows common area impacts to be captured as part of the modeling process. Aggregating to the facility level requires the participant tracking data to include all relevant account numbers associated with the boiler control installations. The tracking data account numbers are then carefully matched to all relevant facility-level monthly gas bills. The next few sections describe the process by which these data were reviewed, aggregated, and transformed for their use as model inputs.

Program Tracking Data

The following fields from the program tracking data were included in the creation of the analysis database:

- Utility serving the site,
- The type and number of boiler controllers installed,
- The contractor installing the boiler controllers,
- The engineering estimate of savings,
- The account numbers associated with each boiler control installation,[9]
- The number of units in the facility, and
- The project completion date for each boiler control installation.

To ensure the quality of the tracking data, each utility was asked to verify that the tracking information provided to the project team included all account numbers associated with the boiler control installations. A full account number listing is necessary to ensure that all associated consumption data are included in the SAE model.[10]

9 A complete list of all impacted account numbers is necessary to ensure that the model includes all consumption associated with the boiler controllers. For example, if 10 equally sized accounts are associated with a facility receiving 10 boiler controllers and the tracking data only includes one account number, the team will only have access to the change in consumption associated with one boiler. The model will compare the consumption from one account with the savings associated with 10 boilers which were associated with 10 accounts. The model will find an inaccurate and low realization rate in this situation.

10 Analysis of the tracking and billing data suggests that not all of the account numbers associated with SDG&E and SoCalGas installations were provided. Several facilities in the SDG&E and SoCalGas databases had engineering estimates of savings that exceeded the gas usage level of the site. The high ratio of savings-to-usage suggests that the listing of account numbers (Acct_NBR or BAID) in the program tracking database is incomplete. PG&E's 2004 tracking data included multiple account numbers (or SAID numbers) for a given application. Multiple SAID numbers represent multiple meters at a facility. The 2005 tracking data, however, initially included

Consumption Data

A gas billing data request was submitted to PG&E, SDG&E and SoCalGas for each meter at each facility that installed boiler controls. These data consist of all monthly billed consumption data by location and facility ID and the read date associated with the billed consumption.[11] The billing data were aggregated to the facility level. Some facilities were master metered with only one meter serving a large number of dwelling units. Other sites were master metered with several meters serving a large number of dwellings. Furthermore, some sites had separate meters for common area equipment while others did not.

The next step was to review monthly gas consumption on a site-by-site basis. This review identified anomalous billing data at the facility level. This review took several forms. First, data were printed for each location by month and year. This report permitted a detailed examination of the data where problems such as rebilling, missing reads, and estimated reads could be identified. The review of the data led to averaging of reads that covered several months, setting some reads to missing if the data appeared inconsistent with previous and past reads, and elimination of sites with consistent billing data anomalies. After the data were thoroughly reviewed, the database was finalized and merged with other components of the model.

Weather Data

Actual daily heating and cooling degree days were obtained at the start of the analysis for the following stations: Oakland, Red Bluff, Sacramento, San Francisco, San Jose, Santa Rosa, Burbank, Long Beach, Los Angeles, Riverside, San Diego, and SD-Miramar. The weather data were associated with the consumption data based on zip codes and monthly read dates found on the billing data. Once the appropriate degree days were calculated for each billing month of consumption, they were summed and normalized to a monthly value for the use in the model.

2.3 Model Specification

only one SAID number per application. A 2005 tracking data set with a full listing of facility SAID numbers was subsequently provided to the project team.

[11] As stated in footnote 1, it is clear that we did not receive all of SDG&E or SoCalGas account numbers. Eleven SCG sites and 24 SDG&E sites were eliminated from the Sempra data due to a savings to consumption ratio exceeding 0.5. Eight sites from the 2004 program tracking data and 14 sites from the 2005 program tracking data were eliminated from the PG&E database due to the inability to match bills to all SAID numbers at the site.

The SAE model specification to determine the impact of boiler controllers on multifamily gas usage was designed to yield utility-specific results. Each utility's model can be represented by the following equation:

$$\frac{Therm_{it}}{Units_i} = \beta_0 + \beta_1 \frac{Therm_{it-12}}{Units_i} + \beta_2 \frac{BCSAV_{it}}{Units_i} + \beta_3 \Delta CDD_{it} + \beta_4 \Delta HDD_{it} + \beta_5 Winter04$$
$$+ \beta_6 Winter05 + \beta_7 Winter06 + \beta_8 \frac{Therm_{it-12}}{Units_i}\left(\frac{HDD_{it} - HDDNA_i}{HDDN_i}\right) + \varepsilon_{it}$$

where:

$\frac{Therm_{it}}{Units_i} =$	the gas usage per dwelling unit at site *i* in billing period *t*
$\frac{Therm_{it-12}}{Units_i} =$	the gas usage per dwelling unit at site *i* in billing period t-12
$\frac{BCSAV_{it}}{Units_i} =$	the monthly engineering estimates of savings for all installed boiler controllers per dwelling unit at site i
$\Delta CDD_{it} =$	the change in normalized cooling degree days from the previous year's month for site i and month *t* in site *i*'s climate zone (i.e., CDD_{it}-CDD_{it-12})
$\Delta HDD_{it} =$	the change in normalized heating degree days from the previous year's month for site *i* and month *t* in site *i*'s climate zone (i.e., HDD_{it}-HDD_{it-12})
$Winter04 =$	a binary indicator for December 2003, January 2004, and February 2004
$Winter05 =$	a binary indicator for December 2004, January 2005, and February 2005
$Winter06 =$	a binary indicator for December 2005, January 2006, and February 2006
$\varepsilon_{it} =$	a random error term.
$\left(\frac{HDD_{it} - HDDNA_i}{HDDN_i}\right) =$	difference between normalized monthly heating degree days and the average normal monthly heating degree days, divided by annual normal heating degree days

Each coefficient in the model shows the impact on the dependent variable given a one-unit change in the explanatory variable it describes. The following briefly describes each coefficient in the model and how they are interpreted.

$\beta_0 =$	Intercept
$\beta_1 =$	the change in therm/unit given a per-unit change in the 12-month lag of therm/unit
$\beta_2 =$	the change in therm/unit given a per-unit change in the total engineering estimate of savings per unit
$\beta_3 =$	the change in therm/unit given a per-unit change in the 12-month change in cooling degree days
$\beta_4 =$	the change in therm/unit given a per-unit change in the 12-month change in heating degree days
$\beta_5, \beta_6, \beta_7 =$	the adjustment to therm/unit given the winter month and year which the observation's consumption was obtained.
$\beta_8 =$	the change in therm/unit given a per-unit change in the engineering estimate of boiler control savings multiplied by the ratio of the difference of normal monthly heating degree days from average normal monthly heating degree days, divided by annual normal heating degree days

2.3.1 Model Description

Participant per-unit gas usage in billing period *t* was modeled as a function of per-unit usage in the same billing period 12 months prior, as well as weather changes, the engineering estimate of per-unit savings, and other available relevant independent variables.[12] For the first year of the months where the new boiler is in place, the per-unit engineering estimate of savings is non-zero. In all other months, the per-unit engineering estimate of savings is zero. The coefficient on this variable represents the portion of the predicted impacts of the boiler controller actually detected in the bills. Usage from January 2002 through the most recent available month in 2006 was requested from the utilities. Data from all of 2003 are necessary to allow the model to use the facility's per-installation usage to control for facility specific consumption patterns. These data

[12] SDG&E and SoCalGas do not track the number of units in a facility on either their program tracking or billing databases. Therefore, participant gas usage for SDG&E and SoCalGas was modeled as a function of usage in the same billing period 12 months prior, as well as the engineering estimate of total savings. This method is likely to be inferior to the per-unit method. Modeling consumption associated with both very small complexes and relatively large facilities is likely to reduce the precision of the resulting estimates. Normalizing consumption and savings to the per-unit level reduces problems of heteroskedasticity and places the consumption and savings of all facilities into the same order of magnitude.

are also necessary to calculate the 12-month lag in gas consumption for installations in 2004. The 12-month lag in gas usage controls for various factors affecting gas consumption at the site during the calendar month in question.

The model quantifies the relationship of usage to heating and cooling degree days. Increases in heating degree days, relative to the previous year's value, are expected to increase gas consumption. Increases in cooling degree days are expected to decrease gas consumption. The model exhibited significant autocorrelation. Generalized least squares was used to correct the problem.[13] The model is cast in terms of usage per dwelling unit in order to minimize heteroskedasticity.[14]

The approach uses only participant data. Given that the SAE model was estimated without nonparticipant data, results are interpreted as an estimate of gross savings. The estimation of a monthly SAE model, as the team has carried out in this analysis, includes extensive billing data for both pre- and post-installation periods of boiler controllers. These data help control for changes in the environment, such as economic fluctuations, energy crises, etc., that may influence consumption. The extensive pre- and post-information on participants is similar to including nonparticipant data in an SAE model designed to model gross realization rates.

[13] In regression analysis it is assumed that the estimated error for each observation has no correlation to the estimated errors in the other observations. When the element of time is introduced, however, this assumption may not hold. Autocorrelation occurs when the error terms from period to period show a distinct pattern indicating that there is some correlation in the errors over time. See Greene, William. *Econometric Analysis*, 2nd edition, New York: Macmillan Publishing Co., 1993 for further information.

[14] When heteroskedasticity is observed, it is generally true that as one of the variables (e.g., number of units) increases the variance of the errors also increases violating the assumption that the variance of the errors is minimized and constant for all observations.

3.

Impact Evaluation Results

3.1 Overview

This section presents the results from the model estimation for each utility to determine the therm savings achieved from the installation of boiler control measures at multifamily facilities. The analysis methodology described in Section 2 was employed to calculate utility-specific gross realization rates of therm savings for PG&E, SDG&E, and SoCalGas. The PG&E model was estimated using installations from the 2004 and 2005 program years. Since SoCalGas and SDG&E did not provide billing data that extended for the period requested (2002 through the last available date in 2006), not all installations over both program years could be included. A minimum of one year of billing data prior to the installation of a boiler controller is required for the SAE model. Specifically, the billing data received by Itron from SoCalGas begins in September 2003, and for SDG&E it begins in June 2003. This means that SoCalGas' installations before September 2004 and SDG&E installations before June 2004 could not be fully included in the SAE analysis, accounting for the exclusion of 73 out of 123 (60%) and 18 of 56 (32%) of 2004 program year sites from the analysis, respectively.

The SAE models were estimated using generalized least squares (GLS) for program years 2004 and 2005. The use of GLS allows for the recognition of the non-spherical nature of the disturbance terms, thereby enabling the model to produce linear unbiased estimators with a variance-covariance matrix (i.e., a relatively efficient estimator) that is "smaller" than traditional ordinary least squares (OLS).[15] All models presented in this section have been corrected for autocorrelation in the model's residuals.

Data Issues

The Itron team encountered difficulty as it conducted the impact analyses for the utilities. This was mostly due to a lack of sufficient data, as discussed throughout the presentation of results.

PG&E provided the team with the tracking data requested; however, all site specific tracking data for PY2005 were received relatively late on November 29, 2006. The lateness of the PY2005 tracking data was due to the receipt of prior PY2005 tracking datasets with incomplete information on the SAID numbers associated with participating facilities. A complete set of

[15] For further details on Generalized Least Squares estimation, see Greene, William. *Econometric Analysis*, 2nd edition, New York: Macmillan Publishing Co., 1993.

SAID numbers associated with boiler controller installations is needed to request/identify/use appropriate billing data and to enable site aggregation up to the facility level. Given the late receipt of the PY2005 tracking data, the project team proceeded without an update on the billing data request. The inability to update the billing request led to 22 sites being eliminated from the 104 (21%) sites listed in the PY2004-2005 tracking database due to incomplete billing records.

The tracking data provided by SDG&E and SoCalGas also appear to be incomplete. The team requested the utilities check to ensure that the team had received all account and BAID numbers associated with the boiler controllers. After checking, the utilities indicated that the numbers listed included all available identification numbers associated with the boiler control installations. The team felt, however, that it did not have all the billing data associated with the boiler controllers due to the high value of claimed savings relative to usage for several sites. Ex ante savings assume that boiler controllers reduce boiler consumption by 15%. The team decided to eliminate sites where the claimed savings exceeded 50% of natural gas consumption. These criteria led to the elimination of 11 out of 190 (6%) SoCalGas sites and 24 out of 81 (31%) SDG&E sites.

Additionally, neither Sempra Energy utility was able to provide the number of units in each multifamily complex since this is tracked neither in their billing systems nor in their tracking system.[16] The SAE model is designed to analyze average per-unit consumption, determining the realization rate of per-unit claimed savings. Using per-unit consumption and savings in the model guarantees that all dependent variables are in the same order of magnitude. Analyzing the model at the facility level allows larger sites to have substantially larger consumption while smaller facilities have relatively little consumption. Dividing by number of units allows for an analysis of similar-sized consumption.

Additional variables that would have improved the quality of the results include information on occupancy rates, whether the premises were master metered or master metered with sub-metering, the average square footage per unit, boiler type present at facilities (space heating, water, or both), and information on the existence of a previous boiler controller.[17] This

[16] PG&E tracked the number of units in both the tracking and the billing systems. Information on the number of units in a complex is useful information that could be used by the utilities as a cross check to ensure that the correct size boiler controller was requested by the applicant and installed by the contractor. For example, a site with 200 units and 20 boiler controllers would not be eligible for a large boiler controller (more than 20 units per controller). The team recommends that Sempra track these data in the future.

[17] During an interview with one of the boiler control vendors, they estimated that approximately 30% of boiler controllers are installed in facilities already equipped with boiler controllers. It is expected that a controller upgrade, such as that described by this vendor, would result in reduced savings for those particular installations, as the ex-ante estimates are based on a baseline condition without equivalent boiler controls.

information could be collected by a phone or on-site survey, or ideally during measure installation by the vendor.

3.2 PG&E Model Estimates

Table 8-3 presents the estimates for the PG&E SAE model estimated for the multifamily complexes in PG&E's territory that had boiler control measures installed during program years 2004 or 2005. The gross realization rate of therm savings from this program is the coefficient on the engineering estimate of savings, (BCSavings), which is equal to 12%.

Table 8-3: PG&E Monthly SAE Model for Boiler Controllers, Program Years 2004-2005

Variable	Parameter Estimate	T-statistics
Intercept	0.71177	6.65
$Therm_{T-12}$	0.89043	80.76
BCSavings	-0.12253	-3.08
ΔHDD	0.00672	11.10
ΔCDD	-0.00432	-4.72
HDD_{T-1}	0.00076348	1.63
CDD_{T-1}	-0.00067887	-0.91
$\left(\frac{HDD_{iT} - HDDNA_i}{HDDN_i}\right) \times Therm_{T-12}$	0.11541	2.24
Winter04	0.30523	1.21
Winter05	-0.11669	-0.64
Winter06	-0.35420	-2.13
Oakland	1.75	4.46
San Francisco	1.01554	2.05
Red Bluff	-0.03902	-0.21
Sacramento	-0.02737	-0.13
Santa Rosa	0.52021	0.99
Adjusted R-Squared = 0.9128		

The impact of the locational variables is relative to San Jose.

As the results show, dummy variables were included to create a fixed effects model in order to control for season/time as well as locational differences. Results for these variables were statistically insignificant with the exception of the Winter06 season/time variable and the Oakland and San Francisco location variables.

The estimated realization rate for boiler controllers installed in PG&E's service territory was much lower than expected, even after an attempt was made to clean the data for anomalous bills. The low estimated realization rate may be due to a low actual value, the poor quality of data received from the utility, and/or limited time and effort afforded to the evaluation team to clean the provided data. The late arrival date of data did not allow the team to update the billing request or to adequately clean the data for errors or estimates in gas meter readings or for possible mistakes in the date of controller installation.[18]

The realization rate may be much lower than anticipated if a large number of boilers was previously controlled or if the assumptions used to determine the a priori estimates differ substantially from the actual boiler characteristics. To determine the source of the a prior estimate, the team turned to the 2004/2005 Program Year Multifamily Work Papers. These papers referenced the 2001 SoCalGas Work Papers as the source of the boiler controller estimate. The team was not able to locate the 2001 SoCalGas Work Papers. The 2006 Program Year SoCalGas Work Papers, however, lists a priori savings estimates of 34 therms per apartment unit, consistent with the 2004/2005 program year estimate of a 15% savings on boiler consumption of 231 therms per unit (0.15×231 therms = 34.65 therm savings per unit). The 2005 boiler controller savings are derived using a DOE-2 simulation on an apartment building constructed post 1970.

The team compared the 2001 Work Paper's boiler therm usage of 231 therms per apartment unit to the 2004 Residential Appliance Saturation Survey (RASS) estimate of whole house gas consumption for an apartment in a 5+ unit apartment complex.[19] The RASS estimate of whole house gas consumption was 232 therms per unit per year.[20] The Work Paper assumption that boilers consume 231 therms per unit per year appears slightly high unless the Work Papers assume that all boilers are space heating boilers. Itron was not provided with information on whether the boilers were space heating, water heating, or both. This information is crucial to the calculation of a prior yearly savings and to the distribution of yearly savings into monthly savings estimates.

[18] There is no a priori data to indicate that the sites eliminated due to insufficient billing data for PG&E sites biased the results in any maner.

[19] The 5+ unit per-unit consumption was chosen as the reference consumption to simulate those units most likely to be included in a multifamily unit with a boiler.

[20] The RASS estimate of whole house gas consumption was limited to non-master metered homes. It is likely that most boiler controllers are installed in master metered units. Consumption for an individual metered house is likely to be less than for a master metered home.

The per unit boiler therm usage of 231 therms was also compared to the per unit gas consumption for PG&E sites with boiler controller installations in 2005. The average 2004 usage for sites in Oakland was 156.7 therms, 192.5 for Sacramento, 369.3 for San Francisco, 187.5 for San Jose, and 159.5 therms for Santa Rosa. Given the very low gas consumption for all locations other than San Francisco, it is highly likely that either the ex ante engineering estimates are high, the tracking data on number of apartment buildings is high, or most of the boilers in locations other than San Francisco are limited to water heating boilers.

Vendor-Specific Realization Rates

In addition to the above SAE model, the Itron team estimated the model separately for the two vendors who conducted the installations at the multifamily sites in PG&E's territory. This analysis was completed to determine whether there is a difference in the realization rate across vendors. Table 8-4 presents a comparison of the estimated rates.

Table 8-4: Estimated Realization Rates by Vendor in PG&E Territory

Vendor	Estimated Realization Rate	T-Statistic
Vendor A	3%	-0.55
Vendor B	16%	-6.86

The estimated realization rate for Vendor B was 16%, substantially higher than the 3% realization rate for Vendor A. Analysis of the data indicates that the ratio of claimed savings to consumption for large boiler controllers was higher for Vendor A (0.28) than for Vendor B (0.10). The Residential Multifamily Rebate Program PY2004/PY2005 Work Papers estimate that controllers save 15% of usage. The higher claimed savings for Vendor A will lead to an estimated lower realization rate if savings are truly less than or equal to 15%.

3.3 SDG&E Model Estimates

Table 8-5 presents the estimates for the SDG&E SAE model for multifamily complexes in SDG&E's territory that had boiler control measures installed from June 2004 through the end of 2005. The gross realization rate of therm savings from this program is the coefficient on the engineering estimate of savings, (BCSavings), which is equal to 28%, however this coefficient estimate is statistically insignificant with a t-value of -1.39.

Table 8-5: SDG&E Monthly SAE Model for Boiler Controllers for Program Years 2004 and 2005

Variable	Parameter Estimate	T-statistics
Intercept	89.85416	4.10
$Therm_{T-12}$	0.89991	42.97
BCSavings	-0.28521	-1.39
ΔHDD	0.47038	2.01
ΔCDD	-0.45201	-1.77
HDD_{T-1}	-0.12712	-0.55
CDD_{T-1}	0.14592	0.57
$\left(\frac{HDD_{iT} - HDDNA_i}{HDDN_i}\right) \times Therm_{T-12}$	0.49997	3.74
Winter05	-24.82384	-0.50
Winter06	-76.07758	-1.66
Inland	-108.97938	-1.61
Adjusted R-Squared = 0.7805		

Inland is a binary variable representing inland San Diego County. Given that SDG&E provided billing data starting in June 2003, the 2004 program installations prior to June of 2004 are not included in the analysis.

Due to the significant data tracking problems associated with the SDG&E's Multifamily Boilers Program, PG&E's realization rate of 12% is considered a statewide realization rate and was used to calculate the net realized therm savings for SDG&E, presented in Section 1.

3.4 SoCalGas Model Estimates

Table 8-6 presents the estimates for the SoCalGas SAE model estimated for multifamily complexes in SoCalGas's territory that had boiler control measures installed during program years 2004 or 2005. The gross realization rate of therm savings from this program is the coefficient on the engineering estimate of savings, (BCSavings), which is equal to -16%. The t-statistic for this estimate is -1.44 and is therefore statistically insignificant.

Similar to SDG&E, there were significant data tracking problems associated with the SoCalGas Multifamily Boilers Program. For this reason, PG&E's realization rate of 12% is considered a statewide realization rate and was used to calculate the net realized therm savings for SoCalGas, presented in Section 1.

Table 8-6: SoCalGas Monthly SAE Model for Boiler Controllers for Program Years 2004 and 2005

Variable	Parameter Estimate	T-statistics
Intercept	120.90946	4.50
$Therm_{T-12}$	0.88082	104.66
BCSavings	0.16221	1.44
ΔHDD	1.56945	8.34
ΔCDD	-0.23742	-1.71
HDD_{T-1}	0.03526	0.25
CDD_{T-1}	0.07356	0.67
$\left(\frac{HDD_{iT} - HDDNA_i}{HDDN_i}\right) \times Therm_{T-12}$	0.32525	6.58
Winter05	29.17318	0.72
Winter06	-70.5601	-1.83
Los Angeles	-45.13776	-0.82
Burbank	-101.84645	-2.75
Riverside	185.18433	1.89
Adjusted R-Squared = 0.9335		

The locational binary variables are relative to Long Beach, the missing category. Given that SoCalGas provided billing data starting in September 2003, the 2004 program installations prior to September 2004 are not included in the analysis.

4.

Recommendations for Future Analysis

4.1 Overview

This section presents some of the lessons learned by the Itron team as it analyzed the impacts of boiler control installations at multifamily premises. From this endeavor, the team developed recommendations, which are presented here to ensure that future multifamily SAE models have better data available for analysis. As the team conducted this evaluation, it became clear that the results presented in this report should be interpreted with a high degree of caution. A number of difficulties were encountered, the most salient being the difficulty of obtaining all account numbers affected by the installation of the boiler controllers. This point was a problem for all three utilities, though PG&E was eventually able to satisfy this data requirement. The other major obstacle to conducting a thorough analysis was the delayed receipt of data (PG&E) and the lack of sufficient billing data that SDG&E and SoCalGas were able to provide.

4.2 Data Requirements for Analysis

Desired data for an SAE analysis includes gas consumption per unit, engineering estimates of per-unit savings from the installation of boiler controllers, monthly occupancy rates for the facilities, characteristics of the average multifamily unit in the facility, information about remodels, amenities of common areas, and weather data. If the facilities are individually metered, gas consumption per unit can be derived from the customers' bills. Alternatively, if the facilities are master metered, average monthly individual consumption can be calculated by summing all of a given facility's master meters and dividing by the number of units in the facility. Discussions with one of the vendors also indicated that some of the boilers receiving boiler controllers may have had comparable existing controllers. The replacement of an existing controller could dramatically reduce the observed bill savings relative to an uncontrolled boiler.

The following sections summarize some of the problems encountered in this analysis and data recommendations for the future.

Utility Billing and Tracking Data

Monthly billing data for the 2002-2006 period were requested from the utilities. PG&E provided data covering January 2002 to May 2006; SDG&E and SoCalGas provided billing data starting in 2003. Data from SDG&E covered June 2003 to May 2006 while SoCalGas provided billing data for September 2003 to August 2006. Given the lack of data during the early portion of 2003 for the Sempra Energy utilities, it was not possible to estimate a realization rate for controllers installed prior to June 2004 for SDG&E and September 2004 for SoCalGas. This reduced the number of multifamily facilities that could be included in these analyses (Section 3 provides details on the specific number of installations that could not be included).

Analysis of the Sempra billing data revealed that the Itron team did not receive all of the account numbers associated with SDG&E and SoCalGas installations. Several facilities in the SDG&E and SoCalGas databases had engineering estimates of therm savings that exceeded natural gas consumption of the site, as measured by the aggregation of the available consumption data. This unrealistically high level of savings was likely due to an incomplete listing of account numbers (Acct_NBR or BAID) associated with the boiler control installations. SAE models that do not include data for all impacted consumption records will lead to an underestimate of the realization rate.

Future tracking databases must include all account numbers associated with the installation of energy efficiency devices or measures if the claimed savings may be subject to billing analysis. A process that simply records an account number associated with the application is insufficient.

Multifamily Site Characteristics Data

Ideally, an SAE analysis includes several site and measure specific characteristics. Information about the design of the boiler is particularly important. To accurately calculate the ex ante engineering savings for a boiler controller, one must know the type of boiler (space heating, water heating or both), the size of the boiler, the number of units it serves, and whether it has been previously controlled. In lieu of these data, the multifamily program assumes a set level of savings for controllers installed in boilers serving a small number of apartment units (less than 20) and a large number of apartment units (more than 20). These estimates of savings are likely imprecise and could be improved by collecting data during the installation of the controller. Desired and obtainable data include the number of apartment units served by a boiler, the average square footage of units in the complex, and the previous control and the type of boiler.

Knowledge about the type of boiler is also important to estimate the ex post savings. Space heating boilers will have a very different shape for the assumed monthly distribution of savings than a water heating boiler. Without accurate information about the type of boiler, an SAE analysis cannot accurately distribute the savings across months. This problem is likely to lead to an underestimate of the realized savings.

Additional information about the occupancy, possible remodel, and change in ownership may impact the SAE results. Each of these characteristics is likely to lead to changes in consumption unrelated to the variables used to explain consumption, such as previous consumption, weather, and the engineering estimates of savings. The project team attempted to reduce the problems associated with anomalous bills by carefully analyzing the consumption records, averaging bills for missing reads, and setting other unexplainable shifts in the consumption record to missing. Ideally, these types of data would be provided through an on-site survey.

SDG&E and SoCalGas do not track the number of apartment units in a facility on either their program tracking database or their billing database. Therefore, the team modeled SDG&E and SoCalGas participant gas usage as a function of usage in the same billing period 12 months prior, as well as the engineering estimate of total savings. This method is likely to be inferior to the per-unit method. Modeling consumption associated with both very small complexes and relatively large facilities is likely to lead to imprecise estimates. Normalizing consumption and savings to the per-unit level reduces problems of heteroskedasticity and places the consumption and savings of all facilities into the same order of magnitude. Given the lack of adequate billing data and the fact that heteroskedasticity influences the efficiency but not the consistency of the estimates, the team felt that the available data did not warrant additional analysis for heteroskedasticity.

4.3 Recommendations for Future Analyses

The realization rate calculated during this analysis should be viewed with caution. The results from this study were negatively impacted by the quality and quantity of tracking and billing data received by the project team. Initial evidence, however, supports the conclusion that the ex ante engineering estimates overstates the true savings.

If the utilities want to undertake billing analysis of their multifamily programs, more effort must be undertaken to ensure that the tracking databases include all of the necessary account numbers. Inadequate tracking of account numbers is one of the most significant problems encountered during this analysis. The failure to correctly aggregate the site-level consumption data was a substantial contributor to the small estimated realization rate.

An accurate SAE realization rate for boiler controllers also requires additional data on the site, boiler, and the controller. Ideally, the controller information would include data on the existence of a previous controller and the type of boiler; this information could be easily collected at the time of installation. Without these data, it is difficult to correctly control for site-specific shifts in consumption or to accurately allocate the yearly engineering estimate of saving to their monthly distribution. An incorrect distribution will lead to a lower estimated realization rate.

Future SAE analysis of the multifamily program will require more tracking and billing data, more complete tracking data, and more on-site information. Assuming the above recommendations are carried out, the team recommends that SAE analysis be used to evaluate the savings from boiler controllers. The team believes that boiler controllers are a good measure for this type of analysis when appropriate tracking, billing, and on-site data are provided to the analysis team.

Appendix A

Additional Analyses of the Multifamily Boiler Control Measure

The results of therm savings from the installation of multifamily boiler control measures presented in the impact evaluation report were smaller than had been expected. In an effort to scrutinize these impacts, three additional analyses were undertaken.

- The team examined the difference between 2003 pre-boiler control consumption of gas and 2005 post-boiler control consumption of gas for locations at which boiler control measures were installed during 2004 in PG&E territory. The team compared assumed consumption levels to actual consumption levels and the California Statewide Residential Appliance Saturation Study[21] (RASS) whole house consumption (this analysis was restricted to PG&E due to lack of pre-consumption data for SDG&E and SCG).
- Additionally, we created individualized unit estimates of therm savings equal to 15% of the 2003 pre-installation consumption level for PG&E installations (again, analysis was restricted to PG&E due to lack of pre-consumption data for the SDG&E and SCG). An SAE analysis, similar to the one presented in the report, was conducted using these individualized unit estimates of savings instead of the engineering estimate of savings, to derive an alternative realization rate.
- Last, we ran a fixed effects SAE model that regressed current facility-level therm consumption on the previous month's consumption, a dummy variable for the time of installation for PG&E, SDG&E, and SCG, and dummy variables for each facility.

The following subsections of this appendix describe the results from these additional analyses. These results reconfirm that lower than expected therm savings were observed in participant bills following the adoption of boiler control measures at multifamily sites.

A.1 Gas Consumption Pre- and Post-Boiler Control Installations

To determine whether a detectable difference exists between the average consumption of natural gas before and after boiler control measures were installed, the monthly mean therm consumption was calculated at the facility level and the apartment unit level for PG&E

[21] KEMA, Inc. and Itron, Inc. *California Statewide Residential Saturation Study Final Report.* Prepared for the California Energy Commission. June 2004

multifamily locations. Only those sites that had boiler control measures installed during the 2004 year and had a full 12 months of consumption data for 2003 and 2005 were included in this analysis. Seven multifamily facilities were excluded from the analysis due to insufficient data, leaving 33 multifamily facilities that contain 6,913 apartment units. Table 8-7 presents the monthly average consumption of gas at the facility and apartment unit level for 2003 and 2005, the pre-and post-boiler control installation periods selected for analysis.

Table 8-7: Monthly Average Facility and Unit Therm Consumption Before and After 2004 Installation of Boiler Control Measures

	Facility (n=33)		Apartment Unit	
Year	Monthly Mean Consumption (therms)	Standard Deviation (therms)	Monthly Mean Consumption (therms)	Standard Deviation (therms)
2003	4,124.1	3,493.1	21.4	11.0
2005	4,011.2	3,391.5	20.9	11.1
Difference	112.9	-	0.5	-
% Reduction	2.7%		2.3%	

The results show a decrease in monthly therm consumption of approximately 113 at the facility level and 0.5 at the apartment unit level after boiler control measures were installed. These differences are multiplied by 12 to arrive at the annual average decrease in therm consumption before and after the installation of boiler controls. The annual average reduction in consumption of natural gas is 1,356 therms at the facility level (112.9 therms*12 months) and is 6 therms at the unit level (0.5 therms*12 months).

Savings rates are estimated by dividing the difference in gas consumption before and after the installation of boiler controllers by the 2003 pre-boiler control installation consumption level and we find these to equal just under 3% at the facility level and 2.3% at the unit level. Both of these results are substantially lower than the assumed 15% savings level.

The annual therm savings listed in Table 8-7 are similar to the reported results in the impact evaluation report and they continue to reflect lower than anticipated therm savings achieved from the installation of boiler control measures at multifamily complexes. In order to gain additional perspective, the Itron team made a comparison of these annual average therm consumption values for the pre- and post-boiler control installation periods with the therm consumption values found in the RASS for multifamily complexes and the assumed savings levels in the PY2004/2005 work papers. According to the RASS table entitled, *Gas UECs and Saturations, by Residence Type, for all Households and for Homes with Gas Account Data*, whole house gas consumption is equal to 232 therms for apartment units in multifamily complexes with at least five apartment units. The estimated therm usage by conventional gas water heaters in these same types of apartment units is equal to 186 therms. The estimate of therm usage for gas water heaters represents 80% of the RASS estimate of total whole house gas consumption. The mean value of apartment-level gas consumption found in the 2003 PG&E sites reported in Table 8-7 is 257 (21.4*12) therms. Assuming that the gas boiler consumes 80% of the apartment-level gas, the approximate boiler consumption is 205 therms. In light of the RASS and PG&E data, the assumed boiler gas consumption in the program work papers of 231 appears rather high.

A.2 Apartment-Unit-Level Estimated Therm Savings for PG&E

In addition to calculating the monthly and annual average consumption of gas before and after the installation of boiler control measures at multifamily complexes, an alternative estimate of therm savings at the apartment-unit-level was calculated. The alternative was calculated by multiplying the 2003 facility pre-installation gas consumption for PG&E locations by 15%. The PY2004/2005 Work Paper assumed therm savings rate of 15%.

Once the individualized monthly unit-level therm savings was calculated for each unit, this variable, called *NewBCSavings*, was used in place of the engineering estimate of therm savings in an SAE regression analysis. A number of regressions were run, similar in structure to those described in the report.

Table 8-8 presents the coefficients estimated for one of the regressions, using the new therm savings estimate in an SAE model for multifamily complexes in PG&E's territory that had boiler control measures installed during 2004 and 2005. The coefficient on *NewBCSavings* is -0.15, which means that the actual realization rate of savings is 15% of the estimated 15% of therm savings calculated from the 2003 pre-boiler control installation consumption of the apartment units. In other words, the therm savings rate is equal to 2.25%, which is consistent with the results presented in this appendix in subsection A.1. The results from this analysis add further support to the initial SAE model findings, a relatively low realization rate for multi family boiler controllers.

Table 8-8: PG&E Monthly SAE Model for Boiler Controllers Using Alternative Estimate of Boiler Savings, Program Years 2004 and 2005

Variable	Parameter Estimate	T-statistics
Intercept	1.26	2.36
$Therms_{t-12}$	0.96	50.1
NewBCSavings	-0.15	-1.53
ΔHDD	0.017	6.86
ΔCDD	-0.008	-1.63
HDD_{T-1}	0.0003	0.18
CDD_{T-1}	-0.003	-1.75
Winter04	-0.08	-0.14
Adjusted R-Squared = 0.81		
N = 898		

A.3 Facility-Level Statistically Adjusted Engineering Analysis

The third supplemental analysis focused on estimating facility-level therm savings. Participant multifamily complexes in PG&E, SDG&E, and SCG territories (n=245) were included in a fixed effects SAE model which regressed current facility-level therm consumption on the previous month's consumption, a dummy variable for the time of installation for PG&E, SDG&E, and SCG, and dummy variables for all but one facility.[22] From this analysis, a monthly facility-level savings realization rate of -46.72 therms was estimated. The annual therm savings from all of the facilities in the analysis is estimated to equal 137,357 therms, which is calculated by multiplying the monthly realization rate of savings by 12 to make it annual, and then multiplying by 245, the number of facilities included in the analysis.

The claimed savings for the 245 sites used in this analysis was 800,007 therms. The ratio of the estimated savings (137,357 therms) to the claimed savings was 17%. This finding is consistent with the realized savings listed in the report and the two analyses listed in above.

22 Sites were deleted from this data set if the ratio of claimed savings to bills was over 50%. Eleven SDG&E sites were eliminated and 24 SCG sites were eliminated for failing this check.

8.2 SoCal Gas' Work Paper: DHW Controller for Multifamily Buildings

Demand-Controlled Set-back DHW Thermostat Controller Replacement of an Existing DHW Constant-Temperature Controller (Multifamily Residential)

Energy Efficiency Workpaper

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Prepared date: **December 19, 2005**

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PART 1 - GENERAL

1.01 MDSS MEASURE CODE: XXX

1.02 APPLICATION CODE: XXX

1.03 EQUIPMENT MEASURE(S):

A. Demand-controlled set-back domestic-hot-water (DHW) controller replacement of an existing DHW constant-temperature controller for multifamily residential applications.

PART 2 - MEASURE INFORMATION

2.01 DESCRIPTION

A. A typical equipment arrangement for this measure consists of a boiler (or generically a gas-fired hot-water generator), a storage hot-water tank (if not already part of the gas-fired hot-water generator, or colloquially a storage water heater), a recirculation pump, and a network of piping to communicate the heated domestic hot water (DHW) throughout the complex. Savings are achieved by retrofitting an existing constant-temperature controlled recirculating water heating system with a demand temperature controller that modulates its setpoint continually to meet the demand between a minimum and maximum setpoint. As demand decreases (e.g., after a morning demand due to bathing and food preparation), the temperature sensor recognizes a decrease in demand and set-backs the leaving or supply DHW temperature setpoint to a lower setting. As the day progresses and still no demand occurs the setback setpoint is continually lowered possibly to its minimum setpoint if the demand so dictates. When the demand increases, the setpoint is raised again as needed until it may ultimately return to its original "maximum" setpoint. The controller typically has built-in artificial intelligence (A/I), whereas it keeps a record of the past number of days essentially memorizing the site's actual demand-load schedule profile. This information is used to anticipate future demand needs so as to minimize a time lag in the DHW system's ability to meet a sudden demand.

2.02 MARKET APPLICABILITY

A. The target market for this measure is multifamily residential unit complexes such as apartments and town-homes that utilize gas-fired hot-water generator systems with mechanically pumped recirculation loops. Due to equipment standards, construction standards, and the age of the distribution system, this program is divided into two segments. These are the Pre1970 and the 1970 through Present segments.

B. The reason for the pre1970 construction era segment is to take advantage of the observed performance deficiencies associated with this generation. This observation was discovered from the experienced garnered from the 3rd-Party Program that implemented this measure during the mid to late 1990s. The results seemed to be excessive and outstanding. By performing oral interviews with the consultant who executed this program, a knowledge base was developed that indicated an opportunity existed that should be segmented and encouraged through this rebate program. Basically, the success the consultant experienced was driven around finding the right candidates. The criteria that qualified the right candidate was, among other conditions, old and uninsulated pipe loops, leaking valves pipes and fittings, inefficient boilers, undersized boilers. These conditions generally can be found at older constructed era complexes. This leads us to identifying the pre1970 construction era as viable market segmentation. We are also revising the terms and conditions to capture construction date information.

2.03 TERMS AND CONDITIONS

A. Only hot-water generation systems used primarily for domestic hot-water heating uses qualify. The incentive applies only to gas equipment affected by the installation of this controller (i.e., neither new construction nor fuel switching applications are eligible). Hot-water generation systems used for pools or spas do not qualify. The controller manufacture's name, equipment model number, input capacity of the hot-water generator, the output capacity or thermal efficiency rating of the hot-water generator, and year the multifamily unit complex was built must be provided. If more than half of the square-footage served by this controller is due to an addition to the complex, then use the complex addition's construction year. If requested by the Utility, customers must provide proof of purchase to the Utility.

2.04 COST EFFECTIVENESS MODELING MEASURE DATA

A. Document research and simulation models (both externally and internally developed by SoCalGas) were used in determining Annualized Natural-Gas Energy Savings associated with this technology. Research included separate studies performed by ASHRAE[i] and a second one by Robert Mowris & Associates[ii]. Simulation models offered by the Department of Energy included versions of "Equest"[iii] and "3E Plus[iv]" were also utilized. These additional tools focused on certain parameters such as industry standards for temperature set points, typical multifamily living unit water heating consumption, typical site complex size, parsing generational construction processes to identify changes that may affect the water heating load, and pipe heat loss analysis.

B. The Summary of the Cost Effectiveness is provided in Table I.

Table I - Cost Effectiveness Parameters

	Pre 1970		Post 1970	
	<30 units	>30 units	<30 units	>30 units
Summary of Key Parameters				
Total Controlled Annualized Consumption (therm/yr)	8,019	16,038	6,250	12,500
Incremental Measure Cost ($/controller)	$1,400	$1,400	$1,400	$1,400
Annual Energy Savings (therms/yr-controller)	1,125	2,250	850	1,699
Incentive ($/Controller)	$750	$1,500	$750	$1,500
Measure Lifetime (years)	10	10	10	10
Net-toGross Ratio	0.89	0.89	0.89	0.89
MDSS Measure Code	?????	?????	?????	?????
Application Code	???	???	???	???
Key Parameters for CEC Filing				
Measure No.	???	???	???	???
Incentive ($/therms saved per yr)	$0.67	$0.67	$0.88	$0.88
Gross Therm Savings (therms/yr-apt)	45	45	34	34
Payback (yrs, with rebate)	0.61	-0.05	0.81	-0.06

PART 3 - SUPPORTING CALCULATIONS AND REFERENCE DATA

3.01 CALCULATION METHODOLOGY

A. General Approach:

1. The calculation methodology uses a combination of the First Law of Thermodynamics, research, simulation, and data reduction. The combination of these pieces of information fed into the model simulation of the measure. The basic premise behind the model is to simulate the load experienced by the hot-water generator on a typical hour basis for every hour of a given day type. In this case, the given typical day types[23] are: (1) weekday; (2) Saturday; and (3) Sunday. After each hour of demand is calculated, then the energy delivered to the hot-water generator is calculated by dividing the demand experienced by the hot-water generator by its corresponding thermal efficiency. Each hour for the typical day is then summed to represent the energy consumed for their respective typical days. Each day is then prorated in accordance to their contribution to a week (e.g., the typical weekday is multiplied by 5/7—5 days per 7 day week). This typical week is subsequently postmultiplied by 52 to annualize the energy consumption. This method was used for each scenario which consists of: (1) Base case constant temperature set point, pre1970; (2) Base case constant temperature set point, 1970 to present; (3) Demand-control case modulating temperature set point, pre 1970; and (4) Demand-control case modulating temperature set point, 1970 to present.

B. Unit Energy Consumption:

1. To develop the base Unit Energy Consumption (UEC), the 2005 DEER database for water heaters for multifamily units were utilized. An attempt to prorate the UEC between the three California Investor Owned Utilities (IOUs) was implemented. The three IOUs and their respective UECs and total residential accounts are Southern California Gas Co. (SCG) with 202 therms/yr-apt. and 5 million accounts, San Diego Gas & Electric (SDG&E) with 167 therms/yr-apt. 0.8 million accounts, and Pacific Gas & Electric (PG&E) with 168 therms/yr-apt. and 4 million accounts. The most appropriate method would be to take the UEC for each IOU, postmultiply each by their respective number of multifamily units which are served by a centralized water-heating plant, and then divide this product by the summation of the total number of the multifamily units represented. This methodology would result in a weighted average UEC between the three IOUs. This data was not available, so in lieu of the number of multifamily units satisfying the above requirements, the number of residential customers within each IOU's territory was used with the assumption that the proportionality may be similar. The result is 185 therms/yr-apt. This was in turn modified to represent the appropriate UEC for the given construction era. This is explained in more detail later, however the results are presented in Table II.

Table II - Baseline Unit Energy Consumption (UEC)

Construction Era Segment	UEC, therms/yr-apt.
pre1970	321
1970 - present	250

C. Schedules:

[23] The typical day type methodology was adopted from "eQuest" version 3.55's domestic-hot water demand schedules which are parsed in the same fashion.

1. Demand Load Schedules:
   a. 2005 Title XXIV Domestic-Hot-Water Demand Load
      i. This schedule depicts a 24 hour domestic-hot-water demand load schedule designated as a percent for each hour of a typical day. The given typical day types are: (1) weekday; (2) Saturday; and (3) Sunday. The percentage loads are presented in Table III. This schedule is based on the Domestic Hot-Water demand schedule adopted from "Equest" version 3.55 (i.e., DOE2.2 building simulation program) using its Title XXIV Compliance mode for Multifamily-Low rise complexes. Title XXIV has been adopted into the State of California Uniform Building Code (UBC) and is the current code adopted as law by most of the jurisdictions having authority within the State of California and hence the schedule is adopted as writ.

Table III - Domestic-Hot Water Demand Load Schedule, 2005 Title XXIV

Time of Day	Weekday Load	Saturday Load	Sunday Load
Mdnt -1 AM	5.00%	8.04%	8.06%
1 - 2 AM	5.00%	5.36%	5.37%
2 - 3 AM	5.00%	5.00%	5.00%
3 - 4 AM	5.00%	5.00%	5.00%
4 - 5 AM	5.00%	5.00%	5.00%
5 - 6 AM	20.00%	5.00%	5.00%
6 - 7 AM	80.00%	5.73%	5.00%
7 - 8 AM	70.25%	11.54%	5.36%
8 - 9 AM	50.00%	26.63%	8.92%
9 - 10 AM	40.25%	46.51%	19.56%
10 - 11 AM	20.00%	47.14%	26.91%
11 - Noon	20.00%	32.56%	22.74%
Noon - 1PM	20.00%	31.55%	30.26%
1 - 2 PM	29.75%	46.81%	43.32%
2 - 3 PM	50.00%	75.51%	56.75%
3 - 4 PM	50.00%	71.54%	64.55%
4 - 5 PM	70.25%	68.71%	46.94%
5 - 6 PM	70.25%	63.08%	33.68%
6 - 7 PM	40.25%	55.11%	25.32%
7 - 8 PM	40.25%	46.65%	20.65%
8 - 9 PM	20.00%	38.15%	19.95%
9 - 10 PM	20.00%	29.75%	19.95%
10 - 11 PM	10.25%	21.78%	19.02%
11 - Mdnt	10.25%	13.84%	13.54%

   b. 1970 to Present Construction Era Segment Domestic-Hot-Water Demand Load
      i. To compensate for the fact that participants in this era do not have insulated domestic-hot-water piping as is now required under Title XXIV, an attempt was made to escalate the demand load schedule values shown in Table III to reflect this fact. To estimate this additional load for this increase in energy loss, "3E Plus"4 version 3.2 created by North American Insulation Manufacturers Association (NAIMA) (i.e., DOE pipe heat loss simulation

program) was used. Results from this simulation concluded that there is an additional 11.72% load to each hour to the demand load schedule shown in Table III. The subsequent schedule is shown in Table IV.

Table IV - Domestic-Hot Water Demand Load Schedule, 1970 to Present

Time of Day	Weekday Load	Saturday Load	Sunday Load
Mdnt -1 AM	16.72%	19.76%	19.78%
1 - 2 AM	16.72%	17.08%	17.09%
2 - 3 AM	16.72%	16.72%	16.72%
3 - 4 AM	16.72%	16.72%	16.72%
4 - 5 AM	16.72%	16.72%	16.72%
5 - 6 AM	31.72%	16.72%	16.72%
6 - 7 AM	91.72%	17.45%	16.72%
7 - 8 AM	81.97%	23.26%	17.08%
8 - 9 AM	61.72%	38.35%	20.64%
9 - 10 AM	51.97%	58.23%	31.28%
10 - 11 AM	31.72%	58.86%	38.63%
11 - Noon	31.72%	44.28%	34.46%
Noon - 1PM	31.72%	43.27%	41.98%
1 - 2 PM	41.47%	58.53%	55.04%
2 - 3 PM	61.72%	87.23%	68.47%
3 - 4 PM	61.72%	83.26%	76.27%
4 - 5 PM	81.97%	80.43%	58.66%
5 - 6 PM	81.97%	74.80%	45.40%
6 - 7 PM	51.97%	66.83%	37.04%
7 - 8 PM	51.97%	58.37%	32.37%
8 - 9 PM	31.72%	49.87%	31.67%
9 - 10 PM	31.72%	41.47%	31.67%
10 - 11 PM	21.97%	33.50%	30.74%
11 - Mdnt	21.97%	25.56%	25.26%

c. Pre1970 Construction Era Segment Domestic-Hot-Water Demand Load

i. Due to this era being over 30 years old, much of the pipe and other material is in need of repair. No pipe insulation was required for these sites that were constructed in 1970 or earlier, so no heat loss compensation was performed beyond that established in Table IV. Water leaks in the system's loop due to the old piping is a factor contributing to an additional load for this era beyond that accounted for in the 1970 to present segment. In determining this extra load, we used a 2 – 6 gallon per 10 apartments per day leak rate in the system's loop. This amount of water lost would need to be replaced as make-up water and would appear as a demand load on the hot-water plant. This analysis resulted in a 2.3 – 7 % additional load. In our results we used a 5% added load to the additional 11.72% found in "1970" era. This results in a 16.72% increase for each hour to the basic demand schedule. The subsequent schedule is shown in Table V.

Table V - Domestic-Hot Water Demand Load Schedule, Pre1970

Time of Day	Weekday Load	Saturday Load	Sunday Load
Mdnt -1 AM	21.72%	24.76%	24.78%
1 - 2 AM	21.72%	22.08%	22.09%
2 - 3 AM	21.72%	21.72%	21.72%
3 - 4 AM	21.72%	21.72%	21.72%
4 - 5 AM	21.72%	21.72%	21.72%
5 - 6 AM	36.72%	21.72%	21.72%
6 - 7 AM	96.72%	22.45%	21.72%
7 - 8 AM	86.97%	28.26%	22.08%
8 - 9 AM	66.72%	43.35%	25.64%
9 - 10 AM	56.97%	63.23%	36.28%
10 - 11 AM	36.72%	63.86%	43.63%
11 - Noon	36.72%	49.28%	39.46%
Noon - 1PM	36.72%	48.27%	46.98%
1 - 2 PM	46.47%	63.53%	60.04%
2 - 3 PM	66.72%	92.23%	73.47%
3 - 4 PM	66.72%	88.26%	81.27%
4 - 5 PM	86.97%	85.43%	63.66%
5 - 6 PM	86.97%	79.80%	50.40%
6 - 7 PM	56.97%	71.83%	42.04%
7 - 8 PM	56.97%	63.37%	37.37%
8 - 9 PM	36.72%	54.87%	36.67%
9 - 10 PM	36.72%	46.47%	36.67%
10 - 11 PM	26.97%	38.50%	35.74%
11 - Mdnt	26.97%	30.56%	30.26%

2. Temperature Schedules:
   a. Make-up Water Temperature:
      i. The cold water supply temperature can range from 60°F to 70°F so an average temperature of 65°F was used.
   b. Constant Temperature Controller
      i. The constant temperature controller schedule is as the name implies, a controller that maintains a constant temperature as defined by its setpoint. The setpoint used in this evaluation is 137.5°F[V].
   c. Demand-Controlled Temperature Controller
      i. The demand-controlled temperature controller modulates its temperature setpoint between its setup setpoint and its setback setpoint. For this evaluation the setup setpoint is set equal to the constant-temperature controller's setpoint (137.5°F) and the setback setpoint is 120°F.
      ii. Selection of the setup setpoint:
         a) Although the decision for choosing to use a setup setpoint equal to the constant-temperature controller's setpoint is perhaps obvious, our research has discovered that claimed savings in previous installations include lowering the setpoint as well as savings due to the demand-temperature-tracking control. This false overstatement of energy savings has shown in itself in published papers, billing data evaluation,

and program EM&V results. The determination to use the same setpoint as the constant-temperature controller is to avoid claiming energy savings that are accomplished by simply lowering the setpoint. Although lowering the temperature is a legitimate measure in itself, this workpaper's intent is to isolate savings only associated to the controller's capabilities.

iii. Selection of the setback setpoint:

a) No study or other formal research has been performed to substantiate this setting. Instead observations have lead to this determination. Such observations include recommendations by the DOE cautioning that "setting the water temperature…below 120°F…may allow Legionella bacteria to grow,"[vi] documented projected savings estimates by installers which use 120°F as their setback setpoint, and building-design engineering practice which typically specifies a hand faucet temperature of no less than 120°F for commercial and retail installations.

iv. The Domestic-hot water temperature schedule:

a) The demand-controller setpoint schedule is expressed as a percentage where 0% equals the setback setpoint and 100% equals the setup setpoint (see Table VI). The temperature settings between 0% and 100% are determined by linearly interpolating between the two setpoints as dictated by the schedule. This schedule is based on the Domestic Hot-Water demand schedule adopted from "Equest" version 3.55 (i.e., DOE2.2 building simulation program) using its Title XXIV Compliance mode for Multifamily-Low rise complexes. As a note of reference, it is the same schedule as shown in Table III - "Domestic-Hot Water Demand Load Schedule, 2005 Title XXIV."

Table VI - Domestic-Hot Water Temperature Schedule, Demand Controller

Time of Day	Weekday Load	Saturday Load	Sunday Load
Mdnt -1 AM	5.00%	8.04%	8.06%
1 - 2 AM	5.00%	5.36%	5.37%
2 - 3 AM	5.00%	5.00%	5.00%
3 - 4 AM	5.00%	5.00%	5.00%
4 - 5 AM	5.00%	5.00%	5.00%
5 - 6 AM	20.00%	5.00%	5.00%
6 - 7 AM	80.00%	5.73%	5.00%
7 - 8 AM	70.25%	11.54%	5.36%
8 - 9 AM	50.00%	26.63%	8.92%
9 - 10 AM	40.25%	46.51%	19.56%
10 - 11 AM	20.00%	47.14%	26.91%
11 - Noon	20.00%	32.56%	22.74%
Noon - 1PM	20.00%	31.55%	30.26%
1 - 2 PM	29.75%	46.81%	43.32%
2 - 3 PM	50.00%	75.51%	56.75%
3 - 4 PM	50.00%	71.54%	64.55%
4 - 5 PM	70.25%	68.71%	46.94%
5 - 6 PM	70.25%	63.08%	33.68%
6 - 7 PM	40.25%	55.11%	25.32%

7 - 8 PM	40.25%	46.65%	20.65%
8 - 9 PM	20.00%	38.15%	19.95%
9 - 10 PM	20.00%	29.75%	19.95%
10 - 11 PM	10.25%	21.78%	19.02%
11 - Mdnt	10.25%	13.84%	13.54%

D. Constants:

symbol	value	units	description
C_v	1	BTU/lbm-°F	specific heat, constant volume
v	0.0162	ft^3/lbm	specific volume of water
c1	7.481	gal/ ft^3	conversion between ft3 and gallons
c2	60	min/hr	conversion between hours and minutes
c3	100,000	therms/BTU	conversion between BTUs and therms
c4	1,000	BTU/kBTU	conversion between 1 and 1,000 of any given units of measure

E. Variables:

symbol	units	description
$\dot{E}$	BTU	energy content in British Thermal Units
$\dot{Q}$	BTU	heat content in British Thermal Units
T	°F	temperature in Fahrenheit
η	n/a	efficiency of given process or equipment
$\dot{m}$	lbm/hr	mass flow rate in pounds-mass per hour
$\dot{V}$	gpm	volumetric flow rate in gallons per minute

F. Equations:

1. Instantaneous Heat Load experienced by the hot-water generator:

   a. $\dot{Q}_i = \dot{m} \cdot C_v \cdot (T_{exit} - T_{enter})_i$

2. Instantaneous Energy delivered to the hot-water generator:

   a. $\dot{E}_i = \dfrac{\dot{Q}_i}{\eta}$

3. Daily Energy Consumption delivered to the hot-water generator:

a. $\dot{E}_D = \sum_1^{24} \dot{E}_i$

4. Weekly Energy Consumption delivered to the hot-water generator:

a. $\dot{E}_W = \frac{5}{7} \cdot \dot{E}_{WD} + \frac{1}{7} \cdot \dot{E}_{Sat} + \frac{1}{7} \cdot \dot{E}_{Sun}$

5. Annual Energy Consumption:

a. $\dot{E}_A = 52 \cdot \dot{E}_W$

6. Annual Energy Savings:

a. $\dot{E}_{svgs} = \dot{E}_{A_{proposed}} - \dot{E}_{A_{existing}}$

7. Mass flow rate conversion from gallons per minute to pounds-mass of water per hour:

a. $\dot{m}_i = \frac{\dot{V}_i}{v} \cdot \frac{c2}{c1}$

G. Hot-Water Generator Thermal Efficiency:

1. Pre1970 Segment:
   a. In this era boiler thermal efficiency of 72% was assumed. This is an assumption based on an attempt by SoCal Gas to blend the various era boilers existing in multifamily units. No thorough records for multifamily complexes were found to positively substantiate this value. However, if the assumption of 75% is used for comparison, then 72% is only in error by 2% well within acceptable levels. Many of these boilers and equipment will become replaced or retrofitted due to the life expectancy of 20 years of this equipment in this era.
2. 1970 to Present Segment:
   a. In this era boiler thermal efficiency of 75% was assumed. This assumption is based on the appliance standard required for hot-water boilers in the current issuance of Title XXIV. The previous issuance of Title XXIV used a minimum combustion efficiency requirement of 80%. However, the difference between the two is only due to the terminology, they are both equivalent. This means that for nearly a generation, and probably more, newer construction era multifamily complexes have boilers with a thermal efficiency at or greater than 75%.

3.02 RESULTS

A. Pre1970

1. Therm savings per apartment per year was calculated by taking the constant-temperature controller annual energy consumption in therms and subtracting from it the demand-tracking controller annual energy consumption in therms, which resulted in 45 therms/apt-yr. This value represents a 14% savings per apt-yr. For complexes with <30 residential multifamily dwelling apartments, the total annual therm savings is 45 therms/apt-yr * 25 apts = 1,125 therms/yr-controller. For complexes with ≥ 30 residential multifamily dwelling apartments, the total annual therm savings is 45 therms/apt-yr * 50 apts = 2,250 therms/yr-controller. (See Tables VII, VIII, and Table XI).

Table VII - Constant-Temperature Controller Consumption, Pre1970

Aquastat Controller									
Hour	Weekday			Saturday			Sunday		
	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load
Mdnt -1 AM	137.5	8,574.7	11,909.3	137.5	9,775.0	13,576.4	137.5	9,782.9	13,587.4
1 - 2 AM	137.5	8,574.7	11,909.3	137.5	8,716.9	12,106.8	137.5	8,720.8	12,112.2
2 - 3 AM	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3
3 - 4 AM	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3
4 - 5 AM	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3
5 - 6 AM	137.5	14,497.1	20,134.9	137.5	8,574.7	11,909.3	137.5	8,574.7	11,909.3
6 - 7 AM	137.5	38,186.8	53,037.2	137.5	8,863.0	12,309.7	137.5	8,574.7	11,909.3
7 - 8 AM	137.5	34,337.2	47,690.6	137.5	11,156.9	15,495.7	137.5	8,716.9	12,106.8
8 - 9 AM	137.5	26,342.0	36,586.1	137.5	17,114.8	23,770.6	137.5	10,122.5	14,059.0
9 - 10 AM	137.5	22,492.4	31,239.4	137.5	24,964.0	34,672.2	137.5	14,323.4	19,893.6
10 - 11 AM	137.5	14,497.1	20,134.9	137.5	25,212.8	35,017.7	137.5	17,225.4	23,924.2
11 - Noon	137.5	14,497.1	20,134.9	137.5	19,456.2	27,022.5	137.5	15,579.0	21,637.5
Noon - 1PM	137.5	14,497.1	20,134.9	137.5	19,057.4	26,468.6	137.5	18,548.1	25,761.2
1 - 2 PM	137.5	18,346.7	25,481.5	137.5	25,082.5	34,836.8	137.5	23,704.5	32,922.9
2 - 3 PM	137.5	26,342.0	36,586.1	137.5	36,414.0	50,575.0	137.5	29,007.0	40,287.6
3 - 4 PM	137.5	26,342.0	36,586.1	137.5	34,846.5	48,398.0	137.5	32,086.7	44,564.9
4 - 5 PM	137.5	34,337.2	47,690.6	137.5	33,729.2	46,846.1	137.5	25,133.8	34,908.0
5 - 6 PM	137.5	34,337.2	47,690.6	137.5	31,506.3	43,758.8	137.5	19,898.4	27,636.6
6 - 7 PM	137.5	22,492.4	31,239.4	137.5	28,359.5	39,388.2	137.5	16,597.6	23,052.3
7 - 8 PM	137.5	22,492.4	31,239.4	137.5	25,019.3	34,749.0	137.5	14,753.8	20,491.4
8 - 9 PM	137.5	14,497.1	20,134.9	137.5	21,663.3	30,087.9	137.5	14,477.4	20,107.5
9 - 10 PM	137.5	14,497.1	20,134.9	137.5	18,346.7	25,481.5	137.5	14,477.4	20,107.5
10 - 11 PM	137.5	10,647.6	14,788.3	137.5	15,199.9	21,111.0	137.5	14,110.2	19,597.5
11 - Mdnt	137.5	10,647.6	14,788.3	137.5	12,065.0	16,756.9	137.5	11,946.6	16,592.4
Σ(dE/dt), BTU/day			634,999.8			640,066.7			502,897.1

Table VIII - Demand-Tracking Controller Consumption, Pre1970

Demand Controller									
Hour	Weekday			Saturday			Sunday		
	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load
Mdnt -1 AM	120.875	6,608.5	9,178.4	121.407	7,605.2	10,562.8	121.4105	7,611.8	10,572.0
1 - 2 AM	120.875	6,608.5	9,178.4	120.938	6,725.6	9,341.1	120.9398	6,728.8	9,345.6
2 - 3 AM	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4
3 - 4 AM	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4
4 - 5 AM	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4
5 - 6 AM	123.5	11,697.7	16,246.8	120.875	6,608.5	9,178.4	120.875	6,608.5	9,178.4
6 - 7 AM	134	36,343.3	50,476.8	121.00275	6,846.2	9,508.6	120.875	6,608.5	9,178.4
7 - 8 AM	132.29375	31,871.4	44,265.9	122.0195	8,774.6	12,187.0	120.938	6,725.6	9,341.1
8 - 9 AM	128.75	23,162.8	32,170.5	124.66025	14,083.8	19,560.8	121.561	7,897.0	10,968.1
9 - 10 AM	127.04375	19,248.4	26,734.0	128.13925	21,740.8	30,195.6	123.423	11,542.3	16,031.0
10 - 11 AM	123.5	11,697.7	16,246.8	128.2495	21,995.8	30,549.7	124.7093	14,186.4	19,703.4
11 - Noon	123.5	11,697.7	16,246.8	125.698	16,289.0	22,623.6	123.9795	12,673.7	17,602.3
Noon - 1PM	123.5	11,697.7	16,246.8	125.52125	15,908.7	22,095.4	125.2955	15,425.7	21,424.6
1 - 2 PM	125.20625	15,235.7	21,160.7	128.19175	21,862.1	30,364.1	127.581	20,461.4	28,418.6
2 - 3 PM	128.75	23,162.8	32,170.5	133.21425	34,261.4	47,585.3	129.9313	25,978.8	36,081.7
3 - 4 PM	128.75	23,162.8	32,170.5	132.5195	32,452.7	45,073.2	131.2963	29,341.1	40,751.5
4 - 5 PM	132.29375	31,871.4	44,265.9	132.02425	31,181.7	43,307.9	128.2145	21,914.8	30,437.2
5 - 6 PM	132.29375	31,871.4	44,265.9	131.039	28,698.5	39,859.1	125.894	16,713.0	23,212.5
6 - 7 PM	127.04375	19,248.4	26,734.0	129.64425	25,286.6	35,120.3	124.431	13,605.7	18,896.8
7 - 8 PM	127.04375	19,248.4	26,734.0	128.16375	21,797.4	30,274.2	123.6138	11,927.9	16,566.6
8 - 9 PM	123.5	11,697.7	16,246.8	126.67625	18,429.1	25,595.9	123.4913	11,680.0	16,222.2
9 - 10 PM	123.5	11,697.7	16,246.8	125.20625	15,235.7	21,160.7	123.4913	11,680.0	16,222.2
10 - 11 PM	121.79375	8,340.9	11,584.6	123.8115	12,330.1	17,125.1	123.3285	11,352.1	15,766.8
11 - Mdnt	121.79375	8,340.9	11,584.6	122.422	9,555.8	13,272.0	122.3695	9,453.3	13,129.7
Σ(dE/dt), BTU/day			547,690.5			552,076.0			416,585.8

B. 1970 to Present

1. Therm savings per apartment per year was calculated by using the same calculations described in the Pre 1970 results. Results yielded 34 therms/apt-yr which corresponds to a 13.6% savings per apt-yr. For complexes with <30 residential multifamily dwelling apartments, the total annual therm savings is 34 therms/apt-yr * 25 apts = 850 therms/yr-controller. For complexes with ≥ 30 residential multifamily dwelling apartments, the total annual therm savings is 34 therms/apt-yr * 50 apts = 1,699 therms/yr-controller. (See Tables IX, X, and Table XI).

Table IX - Constant-Temperature Controller Consumption, 1970 to Present

Aquastat Controller									
Hour	Weekday			Saturday			Sunday		
	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load
Mdnt -1 AM	137.5	6,000.5	8,000.7	137.5	7,091.7	9,455.6	137.5	7,098.9	9,465.2
1 - 2 AM	137.5	6,000.5	8,000.7	137.5	6,129.8	8,173.0	137.5	6,133.3	8,177.8
2 - 3 AM	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7
3 - 4 AM	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7
4 - 5 AM	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7
5 - 6 AM	137.5	11,384.5	15,179.4	137.5	6,000.5	8,000.7	137.5	6,000.5	8,000.7
6 - 7 AM	137.5	32,920.6	43,894.1	137.5	6,262.6	8,350.1	137.5	6,000.5	8,000.7
7 - 8 AM	137.5	29,421.0	39,228.0	137.5	8,348.0	11,130.6	137.5	6,129.8	8,173.0
8 - 9 AM	137.5	22,152.6	29,536.8	137.5	13,764.3	18,352.4	137.5	7,407.6	9,876.7
9 - 10 AM	137.5	18,653.0	24,870.6	137.5	20,899.9	27,866.5	137.5	11,226.6	14,968.8
10 - 11 AM	137.5	11,384.5	15,179.4	137.5	21,126.0	28,168.0	137.5	13,864.8	18,486.4
11 - Noon	137.5	11,384.5	15,179.4	137.5	15,892.8	21,190.3	137.5	12,368.0	16,490.7
Noon - 1PM	137.5	11,384.5	15,179.4	137.5	15,530.2	20,707.0	137.5	15,067.2	20,089.6
1 - 2 PM	137.5	14,884.2	19,845.5	137.5	21,007.6	28,010.1	137.5	19,754.9	26,339.9
2 - 3 PM	137.5	22,152.6	29,536.8	137.5	31,309.0	41,745.3	137.5	24,575.4	32,767.2
3 - 4 PM	137.5	22,152.6	29,536.8	137.5	29,884.0	39,845.3	137.5	27,375.1	36,500.1
4 - 5 PM	137.5	29,421.0	39,228.0	137.5	28,868.2	38,491.0	137.5	21,054.2	28,072.3
5 - 6 PM	137.5	29,421.0	39,228.0	137.5	26,847.4	35,796.6	137.5	16,294.8	21,726.4
6 - 7 PM	137.5	18,653.0	24,870.6	137.5	23,986.7	31,982.3	137.5	13,294.1	17,725.4
7 - 8 PM	137.5	18,653.0	24,870.6	137.5	20,950.1	27,933.5	137.5	11,617.9	15,490.5
8 - 9 PM	137.5	11,384.5	15,179.4	137.5	17,899.2	23,865.6	137.5	11,366.6	15,155.5
9 - 10 PM	137.5	11,384.5	15,179.4	137.5	14,884.2	19,845.5	137.5	11,366.6	15,155.5
10 - 11 PM	137.5	7,884.9	10,513.3	137.5	12,023.5	16,031.3	137.5	11,032.8	14,710.4
11 - Mdnt	137.5	7,884.9	10,513.3	137.5	9,173.5	12,231.4	137.5	9,065.8	12,087.8
Σ(dE/dt), BTU/day			496,752.2			501,174.2			381,462.6

Table X - Demand-Tracking Controller Consumption, 1970 to Present

Demand Controller									
Hour	Weekday			Saturday			Sunday		
	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load	Temp (°F)	Demand Load	Energy Load
Mdnt -1 AM	120.875	4,624.6	6,166.1	121.407	5,517.5	7,356.7	121.4105	5,523.5	7,364.6
1 - 2 AM	120.875	4,624.6	6,166.1	120.938	4,729.5	6,306.0	120.9398	4,732.4	6,309.8
2 - 3 AM	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1
3 - 4 AM	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1
4 - 5 AM	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1
5 - 6 AM	123.5	9,186.2	12,248.2	120.875	4,624.6	6,166.1	120.875	4,624.6	6,166.1
6 - 7 AM	134	31,331.3	41,775.1	121.00275	4,837.5	6,450.0	120.875	4,624.6	6,166.1
7 - 8 AM	132.29375	27,308.2	36,411.0	122.0195	6,565.5	8,754.0	120.938	4,729.5	6,306.0
8 - 9 AM	128.75	19,479.0	25,972.0	124.66025	11,326.6	15,102.2	121.561	5,779.0	7,705.4
9 - 10 AM	127.04375	15,962.8	21,283.7	128.13925	18,201.4	24,268.6	123.423	9,046.8	12,062.4
10 - 11 AM	123.5	9,186.2	12,248.2	128.2495	18,430.5	24,574.0	124.7093	11,418.7	15,224.9
11 - Noon	123.5	9,186.2	12,248.2	125.698	13,305.6	17,740.8	123.9795	10,061.5	13,415.4
Noon - 1PM	123.5	9,186.2	12,248.2	125.52125	12,964.3	17,285.7	125.2955	12,530.8	16,707.8
1 - 2 PM	125.20625	12,360.3	16,480.4	128.19175	18,310.4	24,413.9	127.581	17,052.1	22,736.2
2 - 3 PM	128.75	19,479.0	25,972.0	133.21425	29,458.2	39,277.6	129.9313	22,009.8	29,346.4
3 - 4 PM	128.75	19,479.0	25,972.0	132.5195	27,831.1	37,108.1	131.2963	25,032.6	33,376.8
4 - 5 PM	132.29375	27,308.2	36,411.0	132.02425	26,687.9	35,583.8	128.2145	18,357.7	24,476.9
5 - 6 PM	132.29375	27,308.2	36,411.0	131.039	24,454.9	32,606.5	125.894	13,686.3	18,248.3
6 - 7 PM	127.04375	15,962.8	21,283.7	129.64425	21,387.6	28,516.8	124.431	10,897.7	14,530.2
7 - 8 PM	127.04375	15,962.8	21,283.7	128.16375	18,252.3	24,336.4	123.6138	9,392.6	12,523.5
8 - 9 PM	123.5	9,186.2	12,248.2	126.67625	15,227.0	20,302.6	123.4913	9,170.3	12,227.1
9 - 10 PM	123.5	9,186.2	12,248.2	125.20625	12,360.3	16,480.4	123.4913	9,170.3	12,227.1
10 - 11 PM	121.79375	6,176.8	8,235.7	123.8115	9,753.3	13,004.5	123.3285	8,876.2	11,835.0
11 - Mdnt	121.79375	6,176.8	8,235.7	122.422	7,265.7	9,687.6	122.3695	7,173.8	9,565.1
Σ(dE/dt), BTU/day			430,046.3			433,820.3			317,019.1

Table XI - Key Parameters for Multifamily Complex Domestic-Hot Water Controller

Parameter	Pre 1970		Post 1970	
	<30 units	>30 units	<30 units	>30 units
Baseline Condition				
Annualized Consumption (therm/yr-apt)	321	321	250	250
# of Multifamily Units (Apts)	25	50	25	50
Total Controlled Annualized Consumption (therm/yr)	8,019	16,038	6,250	12,500
Incremental Measure Cost				
($/controller)	$1,400	$1,400	$1,400	$1,400
Annual Energy Savings				
Savings (% of Total Controlled Load)	14%	14%	13.6%	13.6%
Savings (therms/yr-controller)	1,125	2,250	850	1,699
Gross Therm Savings (therms/yr-apt)	45.0	45.0	34.0	34.0
Gas Rate				
($/therm)	0.95	0.95	0.95	0.95
($/MMBTU)	95.00	95.00	95.00	95.00
Incentive				
($/Controller)	$750.00	$1,500.00	$750.00	$1,500.00
($/apt)	$30.00	$30.00	$30.00	$30.00
($/therms saved per yr)	$0.67	$0.67	$0.88	$0.88
Payback				
(yrs, without rebate)	1.31	0.65	1.73	0.87
(yrs, with rebate)	0.61	-0.05	0.81	-0.06

C. Simple Payback & Incremental Measure Cost

1. Simple payback with and without the energy efficient rebate and incremental measure costs compared to the energy efficiency rebate are illustrated in Figures 1 & 2. With the rebate, the payback is less than a year for both era segments and complex sizes.

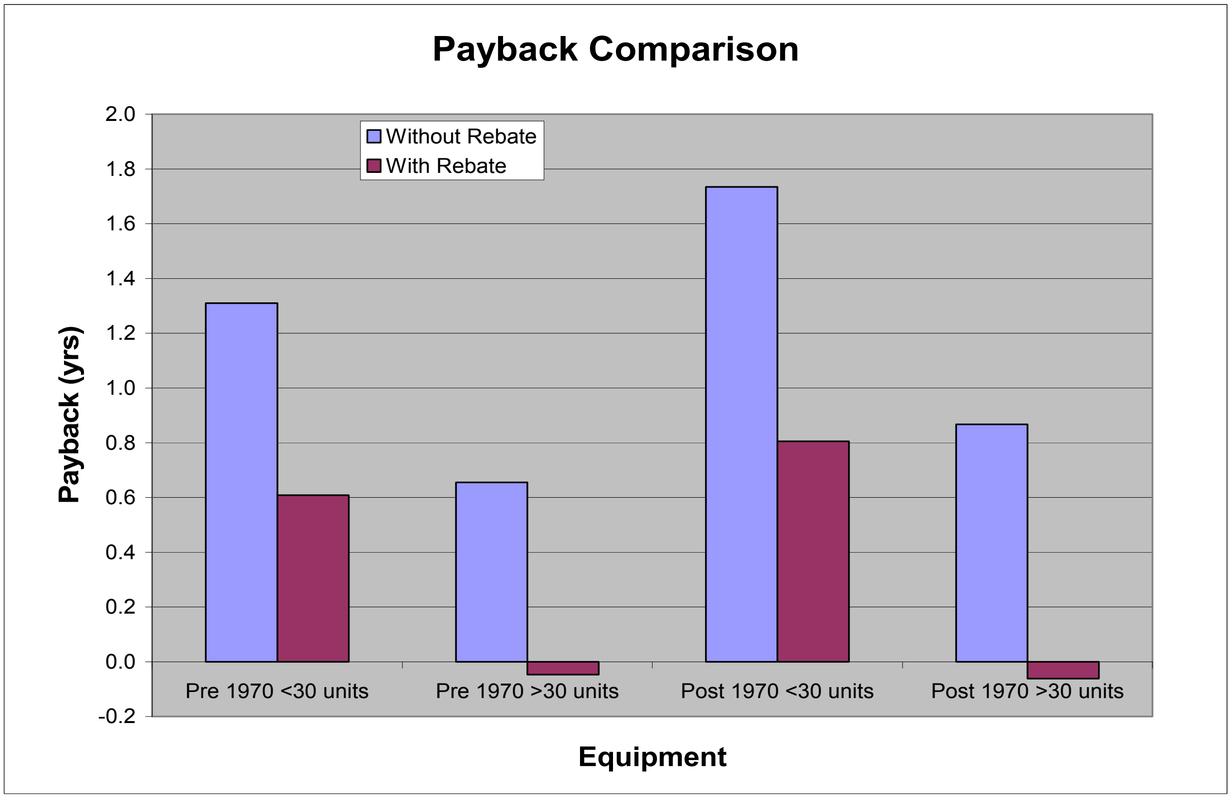


Figure 1 - Simple Payback with and without Rebate Included

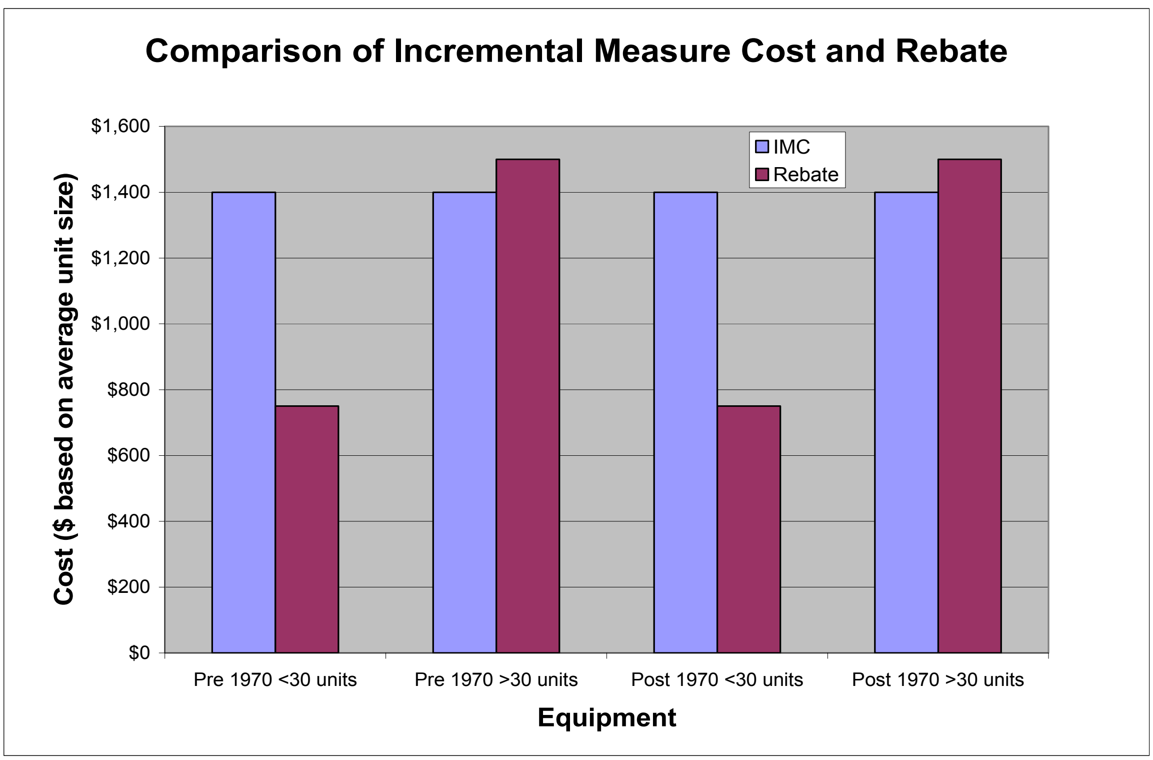
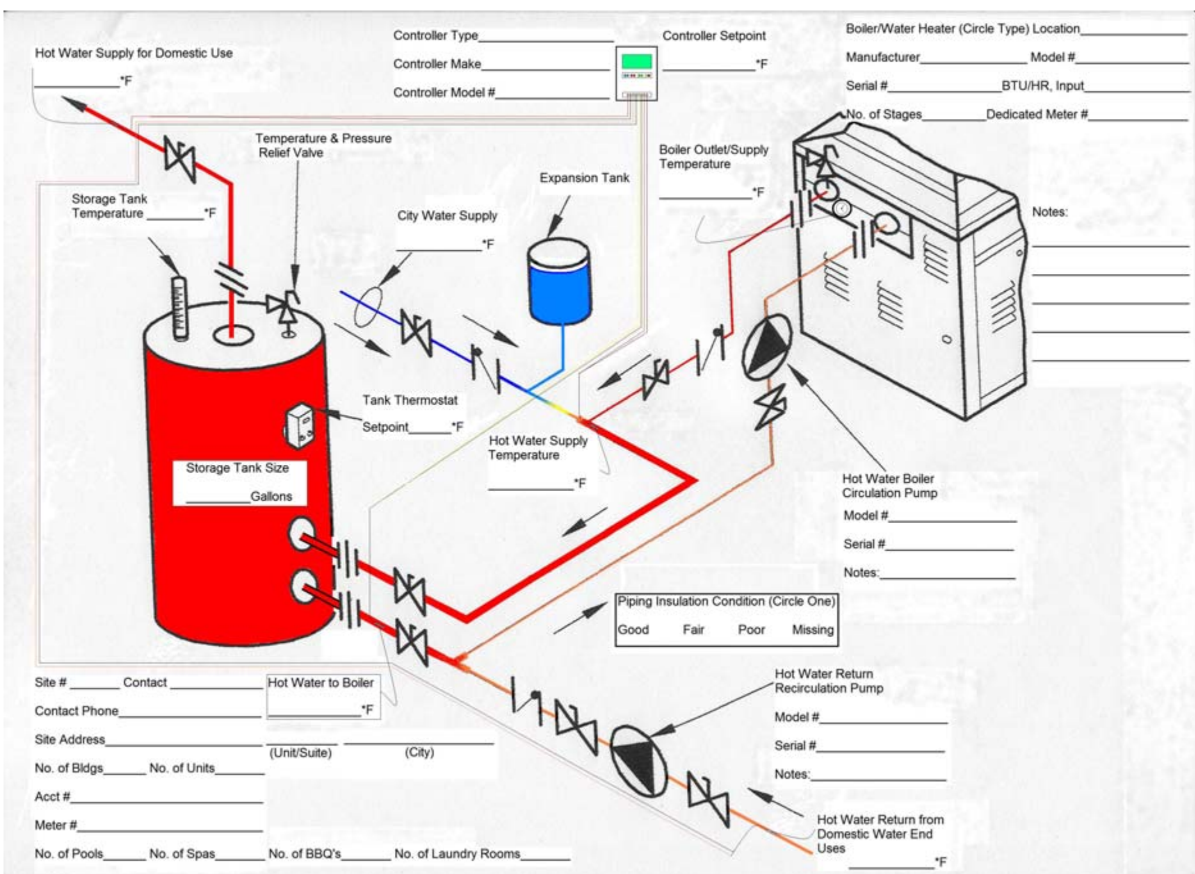


Figure 2 - Incremental Measure Cost Comparison with the Offered Rebate

PART 4 - REFERENCES

[1] Lobenstein, Bohac, Staller, Dunsworth, and Hancock; “Measured Savings from Time- or Demand-Based Temperature Controls on Service Water Heaters in Apartment Buildings”; American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Transaction—AN-92-2-3; 1992.
[1] Robert Mowris & Associates; "Evaluation Measurement and Verification Report for the Gas-Only Multifamily Efficiency Program #197-02" as prepared for SESCO, Inc.; March 2, 2004.
[1] James J. Hirsch & Associates as licensed by the U.S. Department of Energy (DOE); “Equest” software, using DOE2.2 as its calculation engine.
[1] North American Insulation Manufacturer’s Association (NAIMA) as licensed by the U.S. Department of Energy (DOE); “3E-Plus” software.
[1] IBID 2; page 10
[1] U.S. Department of Energy (DOE); “Greening Federal Facilities—An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers, Second Edition”; document number: DOE/GO-102001-1165; Section 5.3 – “Water Heating”; page 75; May 2001.

8.3 Site Inspection Form



8.4 Contractor E-Mail Survey Responses

Boiler Controller Study - Trade Ally Survey

Question	Participant A	Participant B	Participant C	Participant D	Participant E	Participant F	Participant G	Participant H
Q1. Does your company check to see if the site has/had existing energy saving controls? Do you document the pre-existing control strategy in place?	Yes, a comprehensive site survey is done before we quote savings!	Yes	Yes	Yes Yes	Yes No	(A) Yes. (B) Yes. Comments: Under the program guidelines, controls could be replaced after three years. However, our policy was to only remove controls that were no longer manufactured or serviced by the manufacturer. In a couple of circumstances controls were replaced if they had not been serviced or under a warranty program for approximately two years. This was usually due to ownership change, boiler replacement, central hot water system repairs/problems, etc.	(A) I review my database that goes back to the Pilot Bid Program in 1995. If we've installed a system I'll check whether the boiler has been changed out subsequently due to SCAQMD rules and the status of the water heater controller. I'll also physically inspect the boiler system. (B) If I survey a recent acquisition for a client and they have a water heater controller, I'll notify them via phone or e-mail of the status of that unit and any recommendations.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealers (or, in rare occasions, the customer's selected installer, either in-house or contracted.
Q2. Does your company check to see if any repairs, improvements and/or replacements of equipment and/or controls need to be made (e.g., whether or not pump is operating correctly, whether existing controls are powered, whether there are any significant leakage problems, etc.)?	As above we must have a properly operating system. We have 38 years of experience in the hot water heating and hold 7 California State contractors licenses	Yes	Yes	Yes	Yes	Yes. Comments: A full site inspection report is provided to management, with repair recommendations or alternative operation methodologies to realize full energy savings potential.	It's a prerequisite for the existing water heating system to be in good working order before the controller gets installed, otherwise the "last in first to get blamed" rule applies.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealers (or, in rare occasions, the customer's selected installer, either in-house or contracted. WE DO EMPHASIZE THAT NO CONTROLLER WILL SOLVE A SYSTEMIC PROBLEM, AND THAT ANY ADDITIONAL CONTROLLER COULD EXCERBATE AN EXISTING SYSTEMIC ISSUE.
Q3. Does your company test for and identify potentially significant cross over (hot to cold water, cold to hot water) problems?	During the initial site survey the "Delta T" or temperature difference between the supply and return temperatures are recorded. We target between 10-18 degrees F. If it's more we notify customer to repair so that the controller can function to its maximum potential.	Yes	Yes	Yes	Yes	Our company does not test for crossovers, because we are not a boiler service company; however, we identify suspected crossover problems and recommend further investigation in order to provide customer satisfaction and optimum savings.	We ask the boiler service company and the on-site maintenance personnel if there are cross-over problems.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealers (or, in rare occasions, the customer's selected installer, either in-house or contracted. We do emphasize that excessive loop loss can be indicative of cross-over, and other systemic issues and can greatly detract from the efficacy of a control. When identified, we offer suggestions on ways to correct the issue, whether done by the property, or a contractor. PTC does not perform system maintenance, but many contractors do.
Q4. Does your company use a pre-installation check list?	Yes.	Yes.	Yes.	Yes	Yes.	Yes	We do a visual inspection.	PTC has check lists and spread sheets to calculate projected savings provided to contractors. These are also used by PTC personnel when appropriate.
Q5. Does your company use a pre-start up check list?	No, it's handled at the site survey.	yes	yes	Yes	No	Yes, I think. I'm not really sure what you mean. Our procedure is better covered in your next question.	We always monitor the existing system for 3 or 4 days of normal operation before switching to the water heater controller taking over to observe potential problems.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealers (or, in rare occasions, the customer's selected installer, either in-house or contracted.

Boiler Controller Study - Trade Ally Survey

Question	Participant A	Participant B	Participant C	Participant D	Participant E	Participant F	Participant G	Participant H
Q6. Does your company ensure that the system components (e.g., boiler, pumps, sensors, controls) are operating as intended before you leave the job site?	Absolutely, it's documented.	Yes	Yes	Yes	Yes	Yes. We listen and watch the boiler or heater fire, relays operate as they should, sensors are placed appropriately for accurate readings, etc.	Yes	When we are involved, yes.
Q7. Is the system programmed with a fail safe mode?	Yes.	Yes.	Yes.	Yes	Yes.	Yes, in the fact that if the controller fails, the customer does not have to go without hot water or scalding wate We want to know if there is a probler . If the controller is unplugged, operation reverts to the original thermostat settings and mechanical controls. If the bypass mode is activated, this cuts the power to our normally closed relays, but allows us to record all data for the recirculating loop so problems with the overall system can be monitored , diagnosed and corrected	There are multiple fail-safe modes built into the computer operation, ie wires being cut, sensor failure or a circuit boa problem, the controller reverts back to normal boiler operation.	Yes. Upon failure the control reverts to the factory aquastat. The system can also be programmed for "bypass" meaning it does not control, but still data logs. This is extremely helpful in system diagnosis, and in programming for maximum savings.
Q8. When a control fails or is off does the set point change? If so, how is it maintained?	The DHW will return to a preset temperature setting provided by the original control strategy. This temperature is typically 5 degrees F above our maximum setting.	yes., boiler standards	YES- We use a safety manual re-set temperature high limit switch. This alerts the end user of a problem (no hot water) and we receive a trouble call. This also reduces liability risk of the property owner of hot water related injuries to the end users.	Yes, it reverts back to standard operation prior to installation. The standard set points are not altered when installation occurs. They are maintained by the property personnel.	The existing tank stat is set at 10f abour and takes over control.	As explained in the last question, the set-point is now the original thermostat setting. If a control fails to increase temperatures enough to meet the demand or the desired temperature cannot be reached, one could assume the control has failed and complaints will come of inadequate hot water. In rare instances it may be the controller, but more likely there is some other hindrance such as the Aquastat has been set too low (tampering with settings), a pump has failed , program settings have been changed by unauthorized staff, etc	There is a battery back up that maintains all of the information for a period of up to one year.	Programmed settings are maintained by lithium back up battery.
Q9. What method do you use to determine what the set point *should* be to satisfy the end-use?	The average return temperature is us to set the minimum set point. Also, telemetry is used to remotely monitor and adjusts the system's temperature upon usage.	safety, health codes, savings p	We physically test the water temperature at the fixtures before the controller is put on line; depending on the reading we will suggest the lowest set point (usually 120F at the fixture or lower).	All end users need basically the same hot water… between 110 and 120 degrees, however that is determined by how well the system is operating, how good the plumbing is operating etc. We use recorded data and continuous commissioning to operate and control the end users environment in order to provide safe and efficient setpoints.	Experience and preset temp	This is a process and can change as conditions change. We start with the maximum temp setting to be the existing thermostat setting. If a system is "tight" and shows minimal heat lost in the loop – say a delta t of less than 5 degrees, we can have lower minimum temperatures than a system with a 10-15 degree delta t. We also take into consideration the distance from the last living unit serve to the boiler. By checking the temperature in the unit, we can possibly set a lower minimum return than we could if we base it on the actual temperature at the return in the boiler room. Recovery, blockages, crossovers, pump failures, etc. can make temperature adjustments necessary to avoid complaints. By proactively watching these changes, we can pinpoint system problems with the control. The sophistication of the control moves temperatures between the Max and Min setpoints as required to meet desired temperatures.	The computer programs itself for desired set-points. It will determine the amount of hot water being used and adjust the temperatures proportionately within the max/min range. The health code requires a delivery temperature of 110 degrees to the tap. We try and make sure the last resident in the recirculation loop gets at around 114 degrees.	Maximum supply is typically pre-existing set point; established by historical usage. Minimum set point is 105 plus the loop loss. This is often adjusted (down) as history is available

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Boiler Controller Study - Trade Ally Survey

Question	ParticipantA	ParticipantB	ParticipantC	ParticipantD	ParticipantE	ParticipantF	ParticipantG	Participant H
Q10. How does the system respond to elevated water usage outside the set or learned schedule? In other words, if there is high usage when your system expects low usage, how does the system respond?	The control reads high demand by a patented algorithm and changes set print up to ensure lots of hot water.	maximum safe limi	We have had very little complaints, the controller works very well if installed correctly.	All domestic hot water systems respond the same whether they ar controlled by an external control or no control. What needs to be understood is the dynamics of a ho water heating system. The key point is that if there is immediate and unusually high demand, the heater will turn on, regardless of se point. It doesn't turn on "more", it just turns on. BUT, it will take time to heat the water and circulate it through the system. If adequate temperature is available at the faucet at the time of need it is too late, because the response of ANY system is 15-20 minutes from the time of need.	I don't know	The Pro-Temp control has many adjustable control parameters and ca be customized to fit any scenario. You are referring to the sensitivity to respond to unexpected demand. The relays cycle the boilers/heaters on/off to match the desired temperatures – which automatically adjusts between the min and max set points. An algorithm based upon boiler runtime and heat rise in each individual syste determines the desired temperature. If it takes longer to rise temps one degree it senses more demand and increases the desired set point. This set point can then increase incrementally up to the maximum setting. Conversely, if it takes less time to raise the temperature one degree, the desired temp will decrease up to the minimum supply temperature that has been programmed. The Pro-Temp does not base strategies on time of day, day of week, etc. It makes adjustments based upon real time conditions that may differ from "learned" usage profiles. Controller sensitivity can be adjusted to fit the system it is controlling.	The computer responds to usage as it occurs, it doesn't use history to operate its control logic. If it senses that a small amount of hot water is being used, ie 10 gallons vs 100 gallons, it will raise the desired set point proportionally. Figures 6 & 7 t the patent are a good illustration of the relationship between input sensor temperatures and the change in desired set-point temperatures.	A call for heat is generated when the minimum supply set point is exceeded, or the minimum return is exceeded. This happens regardless of historical data, thus there is no lac of hot water caused by independent demand.
Q11. Has your company adopted a sequence of operations that represents common practice for controlling boiler operations? If not please explain how your company's boiler operation scheme is different from common practice.	The demand controller adjusts based upon its firing history of 4 hours, 4 days and 7days thereby targeting the best temperature for the actual time of use. Certain controls schemes use the recirc pump in conjunction with the control to provide intermitten operation of pumps and varies the set points by use. More to follow at the interview.	yes	Each central hot water system and associated equipment on the surface looks the same, but underneath they vary greatly. We survey the type of equipment, past repairs & complaints and other parts of the hot water system. Only then can we suggest the installation of a hot wate controller. We make sure the customer gets the best return on their investment.	Yes	I don't understand the questions	We do not represent the common practice for sequencing and controlling multiple boilers. Common – unautomated practice work on the principle of lead/lag to stage the firing sequence of multiple boiler systems, meaning stage one or boiler one always fires first – then stage two or boiler #two fires if the desired temperature is not met. This repeats cycle after cycle and results in uneven wear on the boilers/heaters. The Pro-Temp allows us to active boilers in rotation. At 24-hour intervals primary and secondary boilers are reassigned. This can be done with up to four boilers or heaters with one controller.	The computer relies upon the change in input temperatures to determine how much hot water is being used and adjust temperatures from that information. The change in temperature is always proportionate to the amount of hot water being used.	Not sure we understand the question The controls are established on the system in essentially the same manner for all applications, and the algorithm operates in the same manner for all applications.

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Q12. Does your company use a control strategy that differentiates you from your competitors? What are its known advantages and disadvantages?	Yes, we actually monitor via satellite, cell or R.F., so that the Controller is: On line always. Adjusted if needed to "Dial" in savings. Counting Boiler run time and temperatures. Availble via any website to each customer. Alams problems to user or owner. Verifies problems are repaired.	yes, we track usage and monitor usage / savings on a monthly basis	As above, each central hot water system has its differences so each control strategy has to be fine-tuned to the requirements of each property. We have no knowledge of how our competitors come-up with their strategy. From our practice, we try our best to achieve the best possible life cycle cost of the central hot water equipment.	Yes, the known advantages are that EVERYTHING we do is transparent and available to the en user or anyone with proper credentials. Once we are installed, we are extremely "hands on" with the client. The primary difference i that with our technology, "savings" is a result of proper and efficient domestic hot water system operation. There is no black box, no smoke and mirrors. Rather the operation of the system and real time data are available online, allowing end users to validate savings, and system operations/efficiency.	No	The Pro-Temp controller advantages are (1) learned usage plus response to unexpected usage (2) time scheduling temperature boosts to override standard strategies in special circumstances, such as undersized heaters to provide satisfactory hot water service during "hours of operation" of a laundry that is a part of the recirculating system supplying living units. (3) Software upgradeable (4) full access to programming and settings at the controller (with authorized password) (5) monitoring, adjusting, alarming available remotely to end user and Pro-Temp staff. (6) Multiple boiler control strategy as described in question 10.	I'm not familiar the logic behind other manufacture's logic except for the Pro-Temp line. I used Pro-Temps extensively until the early 1990s so I'm familiar with their logic. Unless they've changed their logic, it works on a previous history and percent on time to regulate temperatures and did a good at providing thermal savings.	Yes; PTC is dynamic in its constant learning strategy; continually updating and compensating for occupancy, weather, seasons, and daylight savings time. PTC is not a "timer", which is the basis of other product. PTC is an "open" system, i.e., it can be accessed by the on-site personnel or remotely. PTC can be adjusted or repaired by property owners, PTC authorized service people, the owner's preferred contractor, or the factory. Others insist upon single point of contact. The controller can be locked or password protected to prevent unauthorized access. Because it is not a timer, it continuously updates. No pipes need to be broken or electrical interruptions There is no waste of water by cold water purges; nor maximum boiler recovery generated by dumping large quantities of cold water into the tank or boiler. Rapid thermal expansion of pipes is minimized, and high pressure purges are avoided. The pump remains as originally specified by the system designer. When appropriate, a "recovery sensor" can be utilized to proactively call for heat when large
Q13. Does your company ask the customer if they have low volume (water saving) shower heads or fixtures? .. Shower, lavatory and/or kitchen sink mixing valves?	Yes.	Yes	We only ask about mixing valves, the low flow fixtures are irrelevant because it's very hard to control the removal of these devices by the end users	Yes	Yes.	Sometimes, but it has no bearing on the operation of our controls. Apartments and hotels can tell us wha they have, but in instances that we are dealing with a homeowners association we have no way of knowing what is there.	Low-flow showerheads and aerators have been mandated in CA for many years so we assume they are already installed.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealer (or, in rare occasions, the customer's selected installer, either in-house or contracted. Most all of the PTC dealers are involved in system performance and savings, and this is a part of synergistic service. Total savings are increased when these other strategies are involved.
Q14. Does you company have or use water usage data?	We have heater only therm use which correlates to water use compared to our large database to determine abnormal usage patterns.	at times, but not frequently	Only if the customer has the requirement to do so, In this case w will educate the customer on how to do this with their utility bill	No, but we do monitor for leaks on	No	Occasionally. It can be helpful when we suspect slab leaks or want to prove additional consumption when recirc pumps fail.	No, information regarding water usage isn't pertinent to the since most properties include irrigation on the bill as well as cold & hot water and the size of irrigated areas var radically.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealer (or, in rare occasions, the customer's selected installer, either in-house or contracted. This would be tracked through the submission of fuel and water bills by the property owner. (typically by an ESCO)

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Q15. Does your company's expectations for savings change when installing controls on a boiler versus a hot water heater/tank combination? ...on a condensing boiler versus a standard efficiency boiler? ...on a boiler with internal temperature controls?	Data shows that large heating device, recirc lines, recirc pumps, and larger multi-family DHW systems tend to create a large savings in % of the fuel bill. Water heaters have a "low recovery" characteristic and therefore enhanced lowering of low use temps is not as practical to available user complaints. Therefore savings are typically 3.5% less. Condensing boiler are said to be more efficient in terms of combustion however when applied to a retrofit application of the perform equally with the standard 84% hot wate ? Our focus upon the "entire DHW system" includes standby heat losses, variable set points, and intermittent recirculation, and demand based system control. As such the condensating heater may operate at lower fuel use, but often offset by large repair bells, high initial cost, sand more on going service to maintain proper fuel mixture. All boilers have internal controls. Our control adapts to all systems	YES	Very little, because the controller reduces radiant heat loss from the system plumbing. We also make sure the existing hot water equipment has the proper energy saving devices installed (other than the controller) and are operational	Yes	No	No.	The savings for water heater controllers comes from reducing line losses in the recirculation system. Our calculation for thermal savings depends upon the outgoing temperatures and the Delta-T difference in the recirculating return line. The savings percentage is a function of hot great those line losses are, regardless of the type of water heating system. Boilers with internal controls are usually just single set-point systems operating at the same temperature 24/7.	No
Q16. Does your company record the domestic hot water set point prior to installation?	At the site survey.	YES	YES	Yes, and its validated with the client.	Yes	Yes. That becomes our original Max Supply setting. Later that number is used as "Old Supply setting" to evaluate savings based upon our flip flop test.	Yes, we try to monitor the temps for several days before control.	This is typically a dealer function. As the OEM, we typically do not become involved unless requested; or, in cases of multi-regional applications, we co-ordinate between the end customer and various regional dealer (or, in rare occasions, the customer's selected installer, either in-house or contracted. If the check list is utilized yes. If the savings calculation function is activated, absolutely. The set point can also be programmed in, without using it as part of the "savings" function.
Q17. Do you verify whether anti-scald mixing valves are installed on supply lines? If so, how does it affect your choice of control solutions?	No. Anti-scald is handled in 3 ways. First: Our control is set below or at 115-125 degrees max. Second: The boiler system mush have a safe operating control scheme as per code. Set at 5 degrees above our max. Third: All hearters are required to have a manual high limit device by CD09 Heater Safety Code. This protects anti-scald. (3rd layer) Fourth: The device has a temperature release valve at the top of the storage tank. Mixing valves historically are problematic. They also drain up cost of DHW systems with annual service cost.	YES, it doesnt	YES, during our site inspection this checked and we make appropriate recommendations based on the application.	Yes we check for it, but it does not impact the choice of control solutions, however it may alter controller programming.	None yet	If mixing valves are installed and can't be removed, we must consider to what extent we can still lower temperatures. It may not be a good application since this usually means the DHW is coming off a source which is intended for some other use such as a laundry or dishwashing in commercial environments. A more efficient way to heat the water would be to boost temperatures for those specific needs. Some replumbing may be necessary.	I haven't observed many anti-scald valves on DHW systems here in Southern California.	Yes. Inclusion of mixing valves requires a sensor placement modification, and a closer assessment of whether the system is "oversized" (not uncommon with mixing valves.) Depending on the "sizing", optimum performance requires programming for faster or slower response to calls for heat.
Additional Comments:								Some of these questions would benefit from a discussion with an experienced contractor, and /or in depth discussion of applications. There are up to 64 different programmable screens for the Pro –Temp, making maximum savings potential for many different systems and conditions.