The Reliability of Natural Gas Savings from Multifamily Boiler Controls

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ABSTRACT

Recently, the level of natural gas savings established in goals for many gas utilities has increased. However, some natural gas energy efficiency measures have not been evaluated recently. They deserve careful attention prior to utilities' relying on the deemed savings values associated with these measures, because deemed savings from test conditions or simulations may differ substantially from savings achieved in field conditions.

This paper presents the results from two evaluations of the natural gas savings associated with retrofitting multifamily boilers with boiler controllers. It discusses the quality and types of data available. One of the evaluations used pre- and post-billing data pooled across multifamily sites and time in a statistically adjusted engineering (SAE) model. Given the data available, the SAE billing analysis was limited to using gas consumption, the time of installation, and weather data to determine the impact of the controller. Significant data quality issues may have affected the evaluation findings. The second analysis collected refined data from site-specific analysis of pre- and post-installation consumption means. The savings realization results from these two very different analyses were remarkably similar; neither supported the deemed savings values.

The paper also discusses lessons learned from these analyses. The second analysis extended beyond a determination of the measure-level savings, including the influence of alternative strategies, their energy savings, and the importance of increased expertise on the part of the installer and oversight by the utilities. The paper reviews the evaluation results, the suggestions for installation criteria, training protocols, and system repair and commissioning recommendations.

Background

Pacific Gas & Electric (PG&E), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E) provided incentives to contractors to install boiler controls on central domestic hot water systems in multifamily buildings during program years 2004-2005 and program years 2006-2008. The first evaluation of the savings associated with these measures was completed in winter 2006 (Itron 2007). SDG&E and SCG, however, were concerned that the results of the evaluation may have been hampered by the lack of site-specific survey data and issues with the IOU tracking and billing data. SDG&E and SCG asked the Energy Division if they could undertake an additional evaluation, under their Process Evaluation studies, and hire KEMA as the contractor. The Energy Division agreed to SDG&E and SCG's request, authorizing the additional study to determine if boiler controls in multifamily buildings could provide significant reliable savings. The second evaluation of boiler controls was managed by SDG&E and completed in early 2008 (KEMA 2008).

This paper compares the evaluation strategies and results of the first evaluation of the 2004-2005 multifamily boiler control program and the evaluation of the 2006-2007 SDG&E and SCG boiler control

program. First, the data sources, data limitations, and results from the SAE billing analysis for the 2004-2005 program are discussed. Following a discussion of the findings and limitations of the first study, the paper discusses the methods and findings from the evaluation of SDG&E's and SCG's 2006-2007 multifamily boiler control installations. The paper concludes with possible strategies to help limit the uncertainties associated with the savings from boiler controls.

Analysis Methodology from the 2004-2005 SAE Billing Analysis

The approach used to estimate realized savings for the 2004-2005 multifamily boiler control measure relied on a traditional SAE billing analysis framework. The analysis team requested monthly billing data for participants from 2002-2006, monthly weather data associated with the billing data and climate zones covered by the analysis, and program tracking data for the participants in the 2004-2005 multifamily program where boiler controllers were installed.[1] The analysis was conducted at the facility level, necessitating the aggregation of billing data to this level. The program tracking data were reviewed to ensure that they included information on the utility serving the site, type and number of controllers installed at the site, contractor installing the controller,[2] engineering estimate of savings, account numbers associated with the installation,[3] number of apartments in the facility,[4] and installation date.

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:

$$\frac{Therm_{it}}{Units_i} = \beta_0 + \beta_1 \frac{Therm_{it-12}}{Units_i} + \beta_2 \frac{BCSAV_{it}}{Units_i} + \beta_3 \Delta CDD_{it} + \beta_4 \Delta HDD_{it} + \beta_5 W\,\text{int}er04$$
$$+ \beta_6 W\,\text{int}er05 + \beta_7 W\,\text{int}er06 + \beta_8 \frac{Therm_{it-12}}{Units_i}\left(\frac{HDD_{it} - HDDNA_i}{HDDN_i}\right) + \varepsilon_{it}$$

In the model, 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.[5] 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 the engineering estimate of savings represents the portion of the predicted impacts of the boiler controller actually detected in the bills.

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1 Unfortunately, SCG and SDG&E were not able to provide monthly billing data for 2002 or the early months of 2003. For sites installing measures in 2004, missing billing data from 2003 could impact the estimated realization rate.

2 While contractors' names are not crucial for the billing analysis, it can be helpful to determine if observed savings differ by contractor.

3 A complete list of impacted account numbers is necessary to ensure that the model includes all consumption associated with the boiler controllers. If impacted accounts are missing from the analysis, the model may find an inaccurate and low realization rate.

4 SDG&E and SCG were unable to provide information on the number of apartment units at a facility.

5 SDG&E and SCG 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 SCG was modeled as a function of usage in the same billing period 12 months prior, as well as the engineering estimate of total savings. 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.

Data Issues

The analysis team encountered difficulty obtaining the necessary data as it began the impact analyses. The billing data provided by SDG&E and SCG began in the summer of 2003, reducing the number of SDG&E and SCG sites with 12 months of pre-installation data. The tracking data list of site-level account numbers provided by SDG&E and SCG also appeared to be incomplete. The team requested that the utilities check to ensure that the team had received all account and meter numbers associated with the boiler controllers. The utilities indicated that the tracking data listed all account numbers associated with the boiler 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 to usage for several sites.[6] Due to the timing of the final report, PG&E was not able to provide significant post-installation billing data for sites installed late in 2005, leading to the elimination of several PG&E sites.

The failings of billing and tracking data from all three utilities led to a high percentage of sites being eliminated. The need to eliminate a substantial number of sites due to insufficient pre- or post-installation billing records speaks to the need for better coordination between the utilities and the analysis teams and the need to review the timing of reports that include SAE billing analyses. The contractors' apparent systematic under-recording of account numbers impacted by the installed measure speaks to the utilities' need to better train and supervise contractors. The utilities' lack of information on the number of apartments at a facility indicates a failure in both their billing and tracking data. These data failures must be eliminated as the energy efficiency community moves into an environment that demands proof of savings associated with rebated measures.

Additional variables that would have improved the model but were unavailable 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.[7]

SAE Regression Results

Table 1 presents the estimates for the utility SAE model parameters. The gross realization rate of therm savings from this program is the coefficient on the engineering estimate of savings, (BCSavings). The realization rate for boiler controls installed in PG&E's service territory was estimated to be 12% of the ex ante values. For SDG&E and SCG, the boiler control coefficient was not statistically significant or not statistically different from zero.

[6] 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%) SCG sites and 24 out of 81 (31%) SDG&E sites.

[7] 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.

Table 1. Monthly SAE Model for Boiler Controllers, Program Years 2004-2005

Variable	PG&E Parameter Estimates	SDG&E Parameter Estimates	SCG Parameter Estimates
Intercept	0.712*	89.854*	120.909*
$Therm_{T-12}$	0.890*	0.900*	0.881*
BCSavings	-0.123*	-0.285	0.162
ΔHDD	0.007*	0.470*	1.569*
ΔCDD	-0.004*	-0.452	-0.237*
HDD_{T-1}	0.001	-0.127	0.352
CDD_{T-1}	-0.001	0.146	0.074
$\left(\frac{HDD_{iT} - HDDNA_i}{HDDN_i}\right) \times Therm_{T-12}$	0.115*	0.500	0.325*
Winter04	0.305	-	-
Winter05	-0.117	-24.824	29.173
Winter06	-0.354*	-76.078	-70.560
Oakland	1.75*		
San Francisco	1.015*		
Red Bluff	-0.039		
Sacramento	-0.027		
Santa Rosa	0.520		
Los Angeles			-45.138
Burbank			-101.847*
Riverside			185.184*
	Adjusted R-Squared = 0.9128	Adjusted R-Squared = 0.7805	Adjusted R-Squared = 0.9335

An asterisk (*) indicates statistical significance at the 10% level. The PG&E model analyzed usage per apartment within a complex while the SDG&E and SCG models analyzed facility level usage.

The estimated realization rate was much lower than expected. The low estimated realization rate may be due to a low actual value, the poor quality of data received from the utility, or the lack of site-specific information. If a large number of boilers was previously controlled, the low realization rate may indicate that the pre-existing controls were working or that the pre-existing controls had not been broken for a long period. If the billing data for a large number of sites were incomplete due to incomplete lists of account numbers on the tracking data, the model would underestimate savings. Concerns about pre-existing boiler controls, inadequate site aggregation, and site-specific consumption issues led the analysis team to suggest that future analysis would be necessary to determine the realized savings level of boiler controls with more certainty.

Analysis Methodology from the 2006-2007 Customer Change Analysis

The analysis of gas savings from boiler controls installed in 2006 and 2007 relied on the collection of extensive on-site data to clarify the savings level and uncertainties associated with the 2004-2005 billing analyses. The evaluation attempted to study the variability in site-level savings by

collecting on-site information prior to and as soon as possible after the installation of the boiler controller. The evaluation built on and attempted to rectify the issues found in the previous analysis. The 2006-2007 evaluation was implemented in a way that ensured that the evaluation team was on site collecting data as soon as possible after the application was submitted. The evaluation team did not wait to receive tracking and billing data from the utility. The evaluation team and the evaluation plan were pro-active by design. The objective of the evaluation was to quantify savings and identify the on-site attributes that influence savings, enabling the utilities to modify the program to give the highest likelihood of achieving savings from the installation of boiler controllers.

While on site, the study team collected complete information on the gas accounts impacted by the controller, and was able to question site management to determine if the boiler had been previously controlled.[8] The on-site data collection effort allowed the team to collect information on the number of apartment units served by the boiler and to eliminate sites with space heating boilers.[9] The on-site data were paired with information from SCG's billing data. The analysis incorporated billing data through February 2008. The program application forms were also analyzed to provide data on the customer facility, the installing contractor, and the type of control proposed. The installing contractor was contacted to gather information on their installation practices and control strategies.

Given the low realization rate of the 2004-2005 analysis and the uncertainties associated with the previous results, the analysis team did not have the luxury of waiting to collect a long period of post-installation usage data. Given the short period of post-installation usage data, the team chose to use a customer change model. The approach compared usage by customer account for the post-installation period with the pre-installation period of the prior year. The site-level savings were calculated using the difference between the average daily pre-installation therm consumption and the average daily post-installation therm consumption. The savings were then compared on a site-by-site basis with the ex ante savings calculations to determine a realization rate. Two versions of the ex ante savings were calculated. Ex ante savings were calculated using the ex ante claimed therms per installer and the work paper assumptions on savings per apartment.[10] Given the wide range of apartments that can be served by a given controller, the work paper assumptions on savings are likely more accurate when calculated on a per-apartment basis. The utilities, however, claim savings based on a per-controller basis.

Table 2 lists the range of site-specific realization rates for SCG. The table includes information on the site number (a tracking number developed for the analysis), number of apartments in the facility, average change in daily therms for the site, annual change in therms, number of controllers installed and ex ante claimed savings per controller and for the site in total. Comparing the total site-level, claimed savings with the annual change in therms provides the site-level realization rate.

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8 If the site was previously controlled, it was eliminated from the study sites.

9 Boiler controllers on space heating boilers may have lower percentage savings due to the higher gas usage associated with space heating. It was hoped that removing these sites would eliminate this as a possible cause for the previously estimated low realization rate.

10 The per-controller savings were 1,125 therms for a controller installed in a pre-1970 building serving fewer than 30 apartment units, 2,250 therms for pre-1970 with more than 30 apartments, 850 therms for a small post-1970 building, and 1,699 for a large post-1970 building. The per-apartment ex ante savings were 45 for an apartment in a pre-1970 building and 34 for an apartment in a post-1970 building.

The average realization rate was 22.3% or 24.7%, depending on the method of calculating ex ante savings (per controller or per apartment). The remarkable finding, however, is not the average realization rate but the range of observed realization rates. Using the realization rate calculated on a per-apartment claimed savings basis, the realization rates range from a low of -77% to a high of 136%. Both the average level of savings and the highly variable savings reinforce the findings from the previous SAE billing analysis that savings from boiler controllers is substantially less than the ex ante claims and the savings are highly uncertain.

Table 2. Ex Ante and Ex Post Savings by Site Number for SCG

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-Arte Annual Savings Savings per Controller	Realization Rate
0	0	7064	1963	24	0.729	266	1	1,125	1,125	2364%	45	1,080	24.62%
0	1	6853	1960	55	-5.234	(1,910)	1	2250	2,250	-8491%	45	2,475	-77.19%
0	1	6854	1960	115	-0.821	(300)	6	2250	13,500	-222%	45	5,175	-5.79%
0	1	6945	1969	32	-1.95	(712)	1	2250	2,250	-3164%	45	1,440	-49.43%
0	1	7065	1969	193	9.095	3,320	5	2250	11,250	2951%	45	8,685	38.22%
0	1	7066	1965	132	-0.709	(259)	4	2250	9,000	-288%	45	5,940	-4.36%
0	1	7067	1964	119	8.01	2,923	3	2250	6,750	4331%	45	5,355	54.59%
0	1	7105	1968	768	41.596	15,182	13	2250	29,250	5191%	45	34,560	43.93%
0	1	7106	.	249	5.262	1,921	6	2250	13,500	1423%	45	11,205	17.14%
1	0	6949	1984	24	-0.563	(205)	2	850	1,700	-1208%	45	1,080	-19.02%
1	1	6924	1982	200	-5.154	(1,881)	1	1699	1,699	-11073%	34	6,800	-27.67%
1	1	6925	1988	84	7.091	2,588	1	1699	1,699	15234%	34	2,856	90.63%
1	1	6926	1988	60	0.28	102	1	1699	1,699	602%	34	2,040	5.01%
1	1	6928	1979	49	1.793	654	1	1699	1,699	3851%	34	1,666	39.27%
1	1	6929	1986	44	-0.339	(124)	1	1699	1,699	-728%	34	1,496	-8.26%
1	1	6931	1973	530	15.409	5,624	14	1699	23,786	2365%	34	18,020	31.21%
1	1	6950	2006	303	-1.985	(725)	5	1699	8,495	-853%	34	10,302	-7.03%
1	1	6953	1972	63	-1.295	(473)	1	1699	1,699	-2781%	34	2,142	-22.06%
1	1	6954	1974	100	12.253	4,472	1	1699	1,699	26324%	34	3,400	131.54%
1	1	6956	1980	150	2.564	936	2	1699	3,398	2754%	34	5,100	18.35%
1	1	6968	1979	374	4.311	1,574	7	1699	11,893	1323%	34	12,716	12.37%
1	1	6990	2004	140	-6.378	(2,328)	1	1699	1,699	-13702%	34	4,760	-48.91%
1	1	6996	1980	112	13.676	4,992	2	1699	3,398	14691%	34	3,808	131.09%
1	1	6997	1980	152	-0.388	(142)	2	1699	3,398	-417%	34	5,168	-2.74%
1	1	6999	1972	54	1.601	584	1	1699	1,699	3440%	34	1,836	31.83%
1	1	7000	1972	54	2.392	873	1	1699	1,699	5138%	34	1,836	47.55%
1	1	7001	1980	120	4.208	1,536	8	1699	13,592	1130%	34	4,080	37.65%
1	1	7003	1980	188	23.857	8,708	6	1699	10,194	8542%	34	6,392	136.23%
1	1	7004	1980	88	3.043	1,111	2	1699	3,398	3269%	34	2,992	37.12%
1	1	7006	1972	54	6.496	2,371	1	1699	1,699	13955%	34	1,836	129.13%
1	1	7008	1980	208	-6.111	(2,230)	6	1699	10,194	-2188%	34	7,072	-31.54%
1	1	7009	1980	209	-1.086	(396)	4	1699	6,796	-583%	34	7,106	-5.58%
1	1	7068	1973	148	0.625	228	5	1699	8,495	269%	34	5,032	4.54%
Grand Total					**132.278**	**48,281**	**116**		**216,301**	**22.32%**		**195,451**	**24.70%**

Differences in Realization Rate by Contractor and Control Strategy

Given the extensive collection of site-level data, the realization rate can also be calculated by installation contractor and by controller manufacturer and control strategy. Table 3 shows the savings by contractor. Three contractors had an average realization rage above 30%, three contractors had an average realization rate below 20%, and one contractor had a negative realization rate. Surveys of the contractors showed that all stated they were using many of the standard good practices as part of their normal installation processes. Given the observed realization rate, it is not clear if they actually systematically implement what they state.

Table 3. Ex Ante and Ex Post Therm Savings by Contractor

Contractor	Control Mfr	No. Sites	Apts	Annual Therm Savings		Realization Rate	
				Ex Ante	Ex Post	Average	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%
	Total	**33**	**5,203**	**195,451**	**48,281**	**24.7%**	

Table 4 shows therm savings by controller manufacturer and control strategy. Three brands of controllers were installed in participating sites. These data show that there is also a significant difference in the realization rates by controller manufacturer. It is not clear how much of the observed difference in the realization rate is a function of the controller, the control technology/strategy, or the installation and commissioning. Once a pattern for controlling a system was developed, the installer applied it to all subsequent systems, even though that strategy may not have been the most appropriate for all subsequent installations.

Table 4. Ex Ante and Ex Post 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%**

Table 5 shows the basic boiler control strategies in current use. The program provides incentives for demand control and temperature modulation based controllers. The controllers in the SCG sample of analyzed sites 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. 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.

Table 5. 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 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 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 103ºF **return** temperature 24/7.	Hot water supply temperature	Local (building maintenance), with alarms

Perhaps the biggest issue identified by the site-level analysis is the wide range of realization rates for this measure and the inherent risk of obtaining energy savings with this measure as it has been implemented. Data on a number of potentially relevant parameters were collected throughout the study. With measures such as boiler controllers, the 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 system is not plumbed correctly, a controller may actually lead to increased usage. The on-site analysis and data collection 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.

Realization Rates by Type of Water Heater

Two types of water heating systems were installed at participant facilities, boilers, and water heaters. Average realization rates for each type are shown in Table 6. Most of the systems used boilers. On average, systems with boilers had a realization rate of 31.9%, 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 6. Realization Rates by Heater Type

Heater Type	Qty	Realization Rate	
		Average	Range
Boiler	24	31.9%	-77.2% to 136.2%
Water Heater	6	-8.2%	-49.4% to 24.6%
Hybrid[11]	3	11.9%	-5.6% to 43.9%

Additional Findings from the On-Site Review and the Contractor Surveys

1. The work papers assumed the set temperature was 137°F degrees. The average temperature found on site was 131°F degrees. The work papers assume a higher usage than is justified given the most recent California RASS findings.
2. The on-site analysis found several faults in the boiler system that were not addressed during the boiler control installations. For example, 70% of sites had build-up in the tank heaters, 50% of sites had dirty burner tips, and 80% of sites had uninsulated piping. These types of issues should be recorded to provide information to the utility and the site contact in a post-installation review. The repair of many of faults in the system would save energy at the site. The insulation of the piping and the installation of other energy efficiency measures would save energy at the site.
3. The on-site analysis and the contractor surveys found that there was potential for substantial issues with crossover that are not adequately understood. Crossover of hot water into the cold water or cold water into the hot water occurs because of pressure differentials when the two sets of supply lines have an open connection. Crossover at the boiler was found in only 5% of sites. The on-site analysis, however, did not check for crossover in the apartment faucets or shower fixtures. Crossover could lead to an increase in gas usage following the installation of a boiler controller.
4. The contractor that routinely performed the most complete system commissioning had the highest average realization rate among all the contractors. 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.
5. When controls are installed, various sensors are strapped to the outside of the system piping. For several installations, the wiring and connections are likely to be damaged over time by the elements and personnel.
6. Contractors determine the type of control installed. Each contractor interviewed in the study only installs one brand of control. This is an area of concern because the system configuration discovered in the field 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 installs controls that cycle the pump off when it is not needed. Prior research has shown that this is a very effective strategy for smaller multifamily systems.

[11] 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.

Conclusions

The savings observable from the installation of boiler controllers in multifamily settings is substantially less than the ex ante claimed savings. In addition, the observed savings are highly variable. If the utilities continue to rebate multifamily boiler controls, they need to revamp the program to increase the likelihood of significant observable savings. The program should attempt to pre-screen sites to try to identify those with the most energy savings potential and weed out sites with little to no (or even negative) savings potential. The following is a list of recommendations.

1. **Mandate constant monitoring and commissioning.** This would increase the expected savings, but the increase in cost might lead the measure to be non-cost effective.
2. **Develop a system to ensure a better match between the system and the type of control installed.** The system matching will require a pre-installation inspection and check list to determine and verify the type of control system best suited to the application. The utility would review the checklist prior to the installation of the control. This type of pre-installation matching of system and control would require contractors to be prepared to install more than one type of system or necessitate that contractors inform their associates when a site is better suited to a control strategy that they do not personally install.
3. **Develop a system of post installation inspections.** A post-installation inspection would verify the installation prior to the payment of a rebate and help to ensure that the installation met best practices established by the utilities.
4. **Require the contractor to report on the boiler system to the utility and the site management.** The review will note any additional boiler issues that were discovered during the inspection of the boiler system. The on-site inspections found that many sites presented possibilities for repair and retrofit that could save the site more therms than the boiler control measure and the alternatives were often more cost-effective than the installation of boiler controls. Energy efficiency programs should save energy in the most cost effective manner. Thus, if the pre-inspection on-site review finds hot water system issues that could produce more cost-effective savings than the installation of boiler controls, then these issues should have priority and be addressed first.
5. **Undertake a study to determine the impact of crossover in the apartment units on the savings from boiler controls.** The study should focus on the method of measuring the issue and mitigating the impacts of cross over on the savings potential of controllers.

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