Realizing Demand Response Capabilities and Energy Savings in Small Commercial Retail Chain Customers

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ABSTRACT

Although small commercial customers represent a large portion of system load, they have been viewed as poor candidates for demand response and energy efficiency programs because the load at each location is small. In fact, small commercial retail chain stores can provide a cost-effective demand response and energy efficiency resource. This paper documents the equipment cost and energy impacts of a demand response enabling program funded by the California Energy Commission (CEC). Eleven retail chains installed control systems that enabled corporate energy managers to manage lighting, HVAC, and other systems remotely. While the average curtailment capability per location was only 23 kW, the average curtailment per chain was about 2.1 MW. Ten of the chains exceeded 400 kW in response to requests for load curtailment, and two chains exceeded 5 MW. The Program provided $150/kW of cash incentives for load curtailments demonstrated, not to exceed 75% of the total cost of the controls. In most cases, the subsidy was about 50%. The customers justified their portion of the cost through savings on their monthly bills. The Program enabled chain customers to standardize controls at all their facilities statewide. Additionally, the program provided technical support, which we found to be important for this group of customers. In response to a survey, customers expressed a high level of satisfaction with the Program. Customers uniformly responded that they were using or were going to use the technology installed under the Program to curtail load in response to emergencies and high prices and to better manage their equipment every day. Based on this experience, we recommend continued attention to retail chains as a demand-response and energy-efficiency resource.

Program Overview

The Small Commercial and Industrial (C&I) Demand Responsiveness (DR) Program (Program) was implemented in California in 2002 and 2003. The Program provided cash incentives and technical assistance to customers to help them install energy management and control systems for reducing their loads (most often lighting and HVAC) in response to signals from a central location. The installed equipment enables customers to reduce their peak energy use when wholesale prices rise sharply and/or system reliability is threatened (for example, when a Stage 2 or Stage 3 emergency is declared by the California Independent System Operator, ISO).

The Program targeted small C&I customers with peak loads less than 200 kW. Previous load curtailment programs typically excluded small customers in favor of much larger customer loads ranging from 500 kW to more than 1 MW. This Program examined whether small commercial customers could provide demand response resources by curtailing significant amounts of load in a reliable and cost-effective manner.

Cash Incentives to Customers

To enroll customers in the Program, we had to offer a compelling "value proposition." Discussions with customers and technology vendors revealed that the most important thing we needed to offer was the ability to achieve a financial payback of no more than two to three years on their investment in energy controls. Furthermore, the payback must be achieved reliably, with little risk. Therefore, we designed the Program to offer financial incentives that can reduce the payback period for the customer's investment in energy controls to an acceptable level. As a condition for receiving the incentives, the customers agreed to use the controls to curtail load during peak periods in response to system emergencies, high prices, or other conditions.

The financial incentive subsidized the installation of demand response technologies by providing $150 per kW of load curtailed, not to exceed 75% of the total project installation cost. To ensure that the customers bought into the systems and were committed to their proper use, we required that the customer put his own money into the project. Therefore, we decided that the Program would fund no more than 75% of the customer's project cost.

Because small C&I customers have diverse needs, the Program did not specify a single type of technology or control system. Rather, a broad range of hardware and software that enhances customers' abilities to curtail load, or that permanently reduces peak load, was eligible for Program funding.

By taking this approach, the Program struck a balance between: (1) providing financial and technical assistance to the customer to entice them to participate; and (2) putting requirements on the customer to deliver load reductions when needed. Customers found the financial incentive to be a compelling inducement for participation because the control systems enabled them to derive substantial benefits every day from energy savings and improved maintenance and operation of their building systems. Additionally, the controls make it easier for customers to curtail load in a manner that best fits with their operating practices, with as little disruption as possible. Consequently, they are more inclined to participate in future requests for emergency peak load reductions or "demand response events."

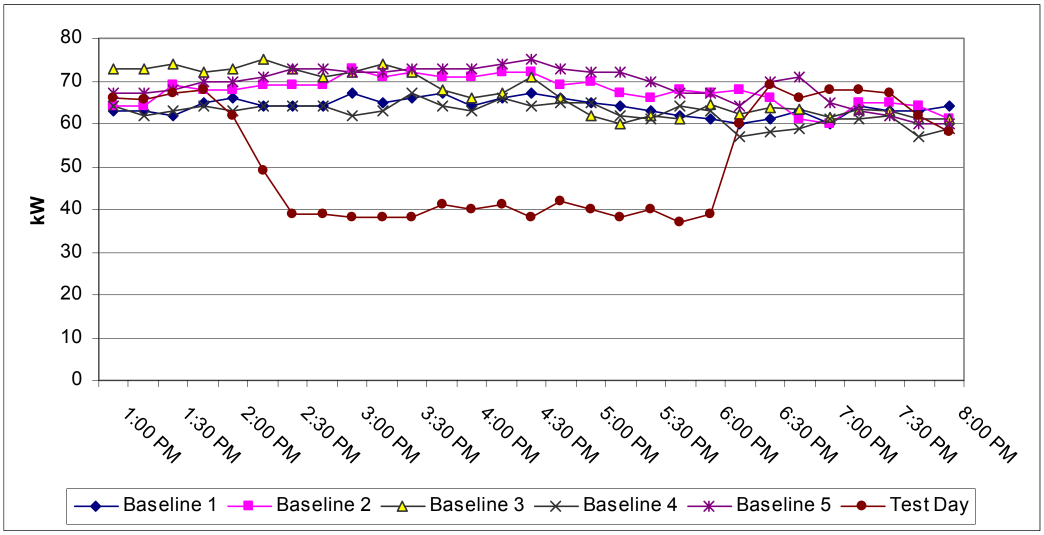
Pilot Test Requirements

A Pilot Test was conducted to measure the load curtailment capability achieved by the customer under actual operating conditions. The basic steps were: measure baseline energy consumption; measure energy consumption during the Pilot Test; and calculate the load reduction by comparing the Pilot Test measurements to the baseline measurements. The curtailment period was set as 2:00 PM to 6:00 PM, with the baseline load measured over a minimum of five days with operating conditions similar to the Pilot Test day. Using energy data for the four-hour period, the curtailment achieved was calculated as:

$$\text{Curtailment (kW)} = \frac{\text{Customer kWh Usage}_{\text{baseline}} - \text{Customer kWh Usage}_{\text{with curtailment}}}{4}$$

where **Customer kWh Usage$_{\textbf{baseline}}$** equals the baseline consumption and **Customer kWh Usage$_{\textbf{with curtailment}}$** equals the consumption during the curtailment test. Using this method, the measured curtailment is the reduction in average load for the four-hour period. Despite this apparent simplicity, a variety of issues had to be handled, including installing equipment to measure energy use at 15 minute intervals in cases where customers did not have interval meters, and improving communication system capabilities. Figure 1 presents an example graph of the load measured on five baseline days and on the test day. As shown in the exhibit, the baseline load is approximately 65 kW to 75 kW during the afternoon. During the curtailment on the test day, the load is reduced to about 40 kW, for an average reduction in this example of about 28 kW over the four-hour test period of 2:00 PM to 6:00 PM.

Figure 1. Example Graph of Pilot Test Load Data



Participating Chains

Fourteen customers implemented 17 projects, producing 24,146 kW of load reduction capability. Eleven chain customers accounted for 13 of the 17 projects, including 979 sites (see Table 1). A range of vendors was engaged by customers to install a variety of control and communication technologies. All the vendors were reasonably well known in the industry, as either established players with long histories or newer companies with new technologies. Generally, the vendors provide services to customers of all sizes, and do not focus particularly on small C&I customers with peak loads of less than 200 kW.

Nearly all the projects installed controls that enable individual building systems (lighting, HVAC) to be controlled remotely through secure web interfaces. The facility or energy manager was able to use the controls to invoke load reductions across multiple locations in California simultaneously. Table 2 lists the vendors and technologies used by each project, along with the number of sites that employed the technologies and the building systems controlled. The Venstar Surveyor EMS and Novar controls of various types were used in the most locations.

Cost Effectiveness

The total project-specific cost averaged $348/kW across all 17 projects, considering the customer costs, incentive costs, and project-specific Program costs. These costs, presented in Figure 2, averaged as follows:

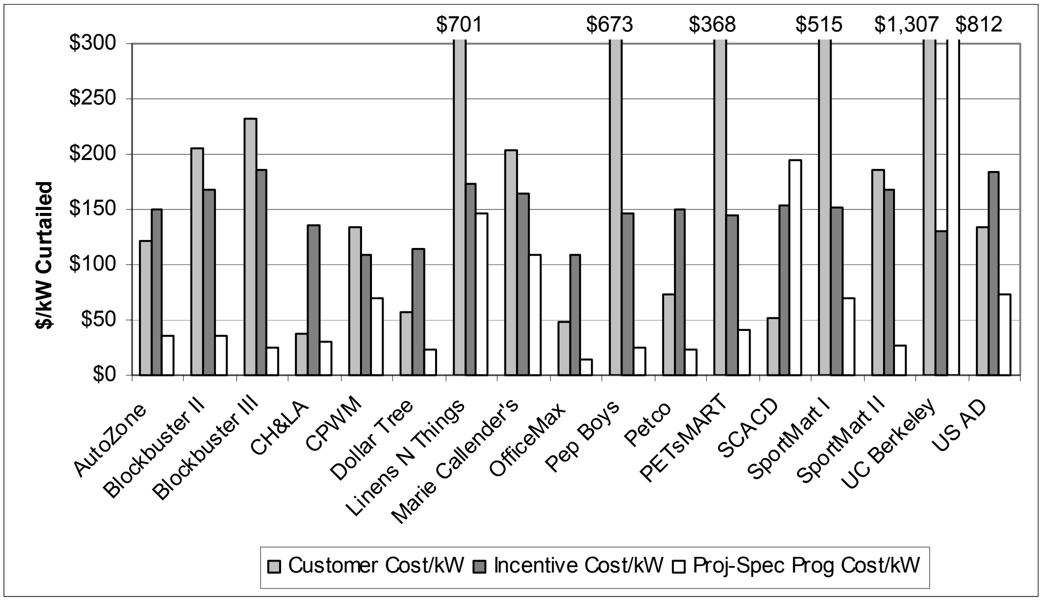
Table 1. Project Curtailment and Costs

Project/Customer	# Sites	Measured Curtailment (kW)	Customer Costs ($/kW)	Incentive Paid ($/kW)	Project-Specific Program Costs ($/kW)
Chain Stores					
AutoZone	366	6,293	$121	$150	$36
Blockbuster II	150	2,354	$205	$168	$36
Blockbuster III	75	1,093	$233	$186	$25
Cost Plus World Markets	2	116	$134	$109	$69
Dollar Tree	70	2,115	$57	$114	$23
Linens N Things	22	431	$695	$179	$146
Marie Callender's	22	758	$204	$164	$109
OfficeMax II	50	1,188	$48	$110	$14
PepBoys	22	474	$673	$147	$25
Petco	129	5,307	$74	$150	$23
PETsMART	32	1,055	$368	$144	$40
SportMart I (Gart)	17	659	$515	$152	$69
SportMart II (Gart)	22	1,249	$186	$167	$27
Chain Stores Subtotal	**979**	**23,092**	**$165**	**$150**	**$35**
Other Customers					
CH&LA	41	766	$37	$135	$31
SCACD (now USAD)	1	97	$51	$154	$194
UC Berkeley Physical Plant	1	28	$1,307	$130	$812
USAD	15	163	$134	$184	$73
Other Customers Subtotal	**58**	**1,054**	**$87**	**$144**	**$73**
Total/Average	**1,037**	**24,146**	**$162**	**$149**	**$37**

Table 2. Technologies Used and Systems Controlled

Project/Customer	Vendor-Technology	Systems Controlled	# Sites
Chain Stores			
AutoZone	Venstar-Surveyor EMS	HVAC, Lighting	366
Blockbuster II	Comfort Systems-Novar Envoi	HVAC, Lighting, Hot Water Heater	150
Blockbuster III	Comfort Systems-Novar Savvy	HVAC, Lighting, Hot Water Heater	75
Cost Plus World Markets	Novar-Envoi	HVAC, Lighting	2
Dollar Tree	Site Controls-Novar Upgrade	HVAC, Lighting	41
Dollar Tree	Site Controls-Telsec 2000	HVAC, Lighting	29
Linens N Things	PES, Electric City-EnergySaver	Lighting	22
Marie Callender's	Site Controls-Telsec 2000	HVAC, Lighting, Refrig, Heat Lamps	22
OfficeMax II	Roth Brothers-Andover-Infinet	HVAC	47
OfficeMax II	Roth Brothers-Novar-EC	HVAC	3
PepBoys	Novar-Savvy	HVAC, Lighting	22
Petco	Novar-Savvy	HVAC, Lighting	42
Petco	Pentech-eMac	HVAC, Lighting	87
PETsMART	Novar-Savvy	HVAC, Lighting	32
SportMart I (Gart)	Osram Sylvania-TCS Systems	Lighting	17
SportMart II (Gart)	Excel Energy-ExcelSyus EMS	HVAC	22
Other Customers			
CH&LA	IES Services-Elutions Meter	HVAC, Lighting, Other	41
SCACD (now USAD)	In House System	HVAC, Lighting	1
UC Berkeley Physical Plant	In House-Barrington EMS	HVAC, Lighting	1
USAD	Venstar-Surveyor EMS	HVAC	8
USAD	Venstar-Surveyor EMS	HVAC, Lighting	7

Figure 2. Project-Specific Costs per kW



1. Customer costs are those costs incurred by the customer. These costs are the total installation costs minus the financial incentive received from the Program. The customer costs averaged $162/kW curtailed, although there was a wide range of values.
2. Incentive payment costs are the incentive payments made by the Program to the customer to reduce the customer's cost of controls and communication equipment. The incentive payment costs averaged $149/kW curtailed.
3. Project-specific Program costs are the costs incurred by the Program to implement the individual project, including technical assistance to develop the project application, tracking during project installation, assistance with the Pilot Test, and review of project documentation. The project-specific program costs averaged $37/kW curtailed. The cost varied across the projects from a high of $812/kW for the U.C. Berkeley project to a low of $14/kW for the OfficeMax project.

For most of the projects, the actual cost incurred by the customer was less than the planned cost in the project application, both in terms of cost per kW curtailed and cost per site. On average, the actual cost per kW was 90% of the planned cost in the application, and the actual cost per site was 95% of the planned cost. By these measures, the projects did not generally suffer from unexpected cost increases relative to the cost estimates in the project applications.

In addition to these project-specific costs, the Program incurred costs for activities that were not associated with specific projects. These costs averaged about $55 per kW curtailed overall for the Program and included: Program design; marketing; technical assistance to customers for projects that did not progress through to completion; and Program administration (including incentive processing and reporting). Total costs for the entire Program averaged $241 per kW curtailed.

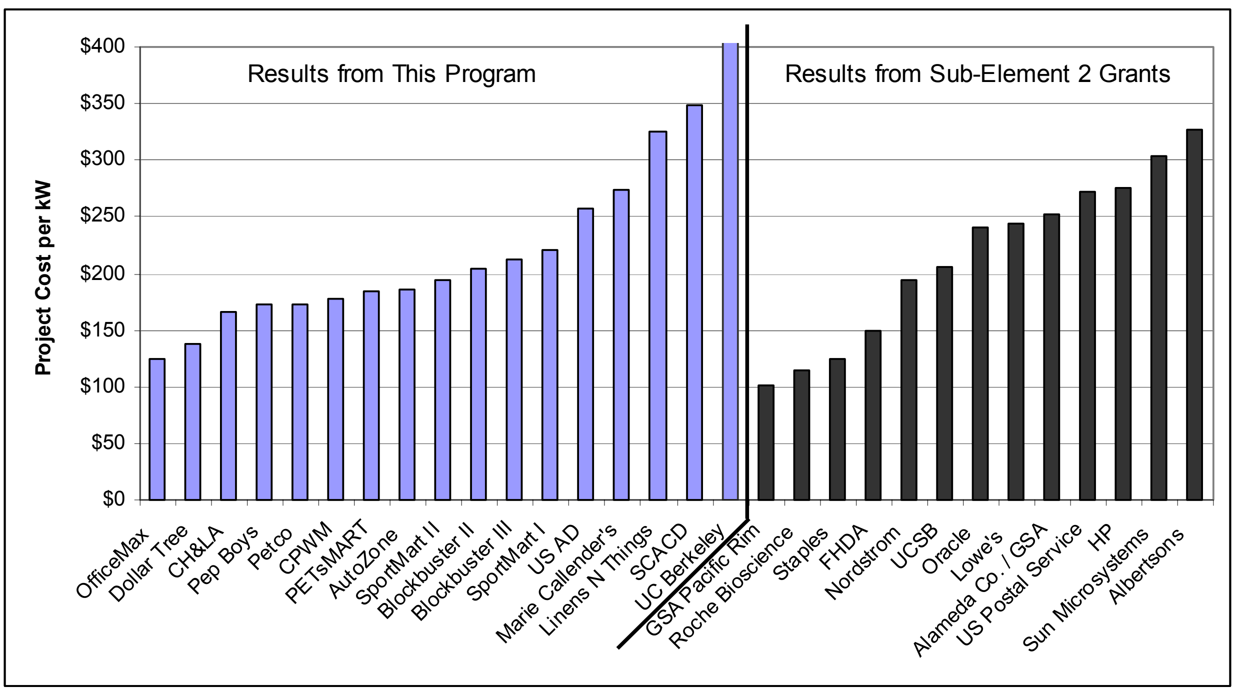
These costs can be compared to the cost of grants completed under sub-element 2 of the California Energy Commission Peak Load Reduction Programs. The sub-element 2 grants were provided to customers for installing technologies that enhanced their ability to reduce load during emergencies and periods of high prices. The curtailment capability of thirteen projects was measured along with their total costs. Generally, the peak load per site was higher in the sub-element 2 grants than in this Program.

Figure 3 compares the costs in this Program to the costs of the sub-element 2 grants. The sub-element 2 grant costs include the total costs of the grants themselves. The comparable costs from this Program are the sum of the incentive payments and the project-specific Program costs (defined above). The cost effectiveness of the sub-element 2 grants is similar to the cost effectiveness of the projects completed under this Program, as shown in Figure 3.

The total cost of the Program can be compared to the cost of new peak load resources, such as a simple cycle natural gas combustion turbine. The CEC estimates the cost of new peak load capacity in California at about $0.1571/kWh, or about $475/kW (CEC, 2003, pp. 3, D-2). By comparison, the total Program costs were $241/kW, including all marketing and administrative costs. Even if there were considerable erosion in the actual delivery of load reduction from the participating customers, the demand response resources developed under the Program are very cost competitive with the construction of new peaking capacity. Additionally, as described below, the controls installed under the Program also reduce energy usage (kWh) on an ongoing basis, providing an additional benefit that is not provided by new peaking capacity.

These comparisons indicate that small C&I chain customers are a cost-competitive source of demand response resources.

Figure 3. Cost Effectiveness Comparison with Sub-Element 2 Grants



Impacts of Curtailments on Store Operations

We conducted on-site observations at 144 sites during load curtailment, including at least 10% of the sites tested in each of the 17 projects. Through these observations, we obtained a first hand look at each of the projects, and the manner in which the curtailment was being executed. These observations not only provided documentation of the curtailments themselves, they also provided insight into the analysis of the load data collected during the curtailment.

Despite expectations that load curtailment could adversely affect shoppers in the retail stores, the on-site observations indicate that shoppers were almost completely unaffected by the load reduction tests. In only nine cases did a customer provide negative comments about the curtailment, with most of these associated with uneven lighting curtailments that created under-lit areas in individual stores. Comfort in the stores was typically maintained as HVAC units cycled on and off during the curtailment—admittedly at a higher set point. One Marie Callender's restaurant had an unacceptably high indoor temperature during the curtailment (more than 80 degrees), indicating that the curtailment settings were not properly entered at this location. Overall, this ability to curtail for up to four hours, without adversely affecting shoppers, provides participants in the Program the confidence to curtail load during emergencies and high prices.

These Pilot Tests were conducted during a period in which electricity issues were not in the news. Were the ISO to call a Stage 2 or Stage 3 alert, the general public would be made aware of the problem. We expect that during an electricity emergency, shoppers would not only be accommodating of load curtailment by retailers, they would be supportive, even if it meant reduced lighting and higher indoor temperatures. Overall, we found that the retailers participating in the Program adopted curtailment strategies that do not adversely affect their customers.

Energy Savings

The energy management and control systems installed under this Program are expected to provide benefits to customers beyond curtailment capabilities. The Program required customers to cover at least 25% of the installation costs for the systems, and in actuality, customers paid about 52% of the system costs on average. The average cost incurred by customers was about $3,800 per site.

All the project applications stated that customers expected to benefit from the control systems through reduced energy usage throughout the year, and most expected to reduce maintenance costs as well. Based on discussions with customers during the development of the project applications, they expected these benefits to pay back the customer costs of the controls within two to three years.

Most of the customers agreed to provide energy data for purposes of examining whether and to what extent the controls helped to reduce energy usage and costs on an ongoing basis. However, most of the projects were completed too recently to enable an annual energy savings analysis to be performed. Petco provided sufficient data to enable an analysis to be conducted. Linear regression was used to estimate the impact of the controls on Petco’s electricity usage, using the following equation:

$$\text{kWh} = A + B_1\,(\text{CDD}) + B_2\,(\text{HDD}) + B_3\,(\text{Dummy})$$

where:

A = intercept
B_1 = coefficient on Cooling Degree Days
B_2 = coefficient on Heating Degree Days

B_3 = coefficient on the Dummy Variable
CDD = Cooling Degree Days
HDD = Heating Degree Days
Dummy = Dummy variable indicating whether the observation is after the controls were installed (July 2002).

The regression analysis was performed separately for 26 sites with 45 months of electricity and weather data. The values for B_1 were expected to be positive, indicating that when it is hotter, more electricity is required for cooling. The values for B_3 were expected to be negative, indicating that less electricity was used on average after the controls were installed.

In all the regression analyses, the sign of the coefficients for CDD were as expected. The estimates of the coefficients on the controls Dummy variables are shown in Table 3. At 17 of the 26 sites analyzed, the coefficient on the controls Dummy variable is negative, and 11 of those are statistically significant. These negative coefficients indicate that energy consumption was reduced following the installation of the controls, after accounting for weather (using heating and cooling degree days). At nine sites the coefficient is positive, and six are statistically significant. At these sites, the analysis indicates that energy consumption increased after the controls were installed.

Based on the regression results, the impact of the controls on electricity usage was calculated as:

$$\text{Electricity Impact (\%)} = [B_3 / (\text{Average monthly kWh in 2003} + B_3)] \times 100$$

The resulting estimates of the impacts are shown in Table 3. Overall, there was a 7% reduction in energy usage at the 26 stores in the period following the installation of the controls. This estimate does not include adjustments to reflect operational changes at individual stores. For example, at the San Diego store that experienced a 15.3% increase in energy usage following the installation of controls, the HVAC units were found to be inoperative prior to the controls being installed. The units were repaired when the controls were installed. Consequently, after the installation, the units were operating and energy usage increased (as shown in Table 3). Similarly, at the Chula Vista store that experienced a 10.1% increase, new HVAC units were installed to replace non-operative units when the controls were installed. This change also contributed to increased energy usage at this site. If we exclude these two stores, the average reduction is 8.7% at the remaining 24 stores.

We also examined the impact of throwing out the top and bottom five observations to eliminate the potential impact of unusual or outlier conditions. Using the remaining 16 sites, the average savings are estimated at about 4.9%. Of interest is that stores in the same city experienced different results. For example, one store in San Jose had large savings, and another had an increase in energy usage. These differences appear to be associated with differing store configurations and possibly variations in how well the stores were operated prior to the installation of the controls. The value of the energy savings is estimated as follows.

1. Using data on square feet for each store, the energy usage averages about 20 kWh per square foot per year among the Petco stores that are reported in California in 2003. Based on the results of the analysis, the energy savings are about 0.9 to 1.3 kWh per square foot per year.

2. The cost of electricity purchased by Petco in California in 2003 was about \$0.138/kWh. Using this rate, the savings from the controls are about \$0.12 to \$0.18 per square foot.
3. For an average store of 14,000 square feet, the savings per year is about \$1,680 to \$2,520. Given the average cost to Petco of installing the controls was about \$2,500 per site, the energy savings, on average, pay back the installation costs within one to two years.

These results for Petco appear to be indicative of the financial performance of the projects overall. In response to a survey conducted at the end of the Program, nearly all the customers expressed a high level of satisfaction with the financial savings they were receiving from using the control systems. This feedback indicates that customers continue to be satisfied with the financial benefits of their investments in the energy control systems. All expected to pay back the costs of their systems within two to three years through energy savings and other operational benefits.

Table 3. Petco Energy Savings Analysis

		Regression Analysis			Electricity
Store Location	**Weather Station**	**Coefficient**	**T-Statistic**	**Adjusted R^2**	**Impact**
San Diego	San Diego	-8,882.7	-6.390	0.689	-41.5%
San Diego	San Diego	-8,260.3	-5.060	0.601	-39.5%
Santa Monica	Los Angeles	-4,716.9	-6.943	0.596	-33.4%
San Diego	San Diego	-4,124.4	-4.070	0.577	-26.8%
Coronado	San Diego	-1,801.4	-2.370	0.359	-18.9%
San Jose	San Jose	-4,122.7	-3.460	0.471	-16.6%
Montclair	Ontario	-2,475.3	-2.950	0.634	-14.8%
Modesto	Modesto	-3,185.4	-2.860	0.534	-13.9%
City of Industry	Ontario	-2,901.0	-2.606	0.616	-13.3%
Redondo Beach	Los Angeles	-1,006.0	-5.167	0.862	-9.1%
Mountain View	San Jose	-801.7	-3.214	0.863	-9.1%
San Francisco	San Francisco	-803.1	-1.219	0.569	-4.8%
Pomona	Ontario	-209.5	-0.920	0.668	-4.0%
Sacramento	Sacramento	-741.9	-0.850	0.673	-3.1%
Redding	Redding	-575.7	-0.600	0.725	-2.1%
Fresno	Fresno	-157.9	-0.070	0.543	-0.4%
Rancho Cucamonga	Ontario	-19.2	-0.026	0.715	-0.1%
Redondo Beach	Los Angeles	42.9	0.037	0.573	0.2%
San Francisco	San Francisco	594.9	1.288	0.266	3.4%
Los Gatos	San Jose	173.7	0.822	0.606	3.5%
San Jose	San Jose	2,353.0	2.000	0.607	6.0%
San Mateo	San Francisco	968.4	2.416	0.526	9.6%
Sunnyvale	San Jose	4,094.4	3.373	0.280	9.9%
Chula Vista	San Diego	2,351.5	3.190	0.612	10.1%
Cupertino	San Jose	1,323.2	4.637	0.714	10.4%
San Diego	San Diego	6,473.9	3.220	0.555	15.3%
Average					**-7.0%**

The coefficients are for the controls Dummy variables. Negative (positive) values indicate that energy usage declined (increased) after the controls were installed, after accounting for weather. See text.

Conclusions

Overall, the Program has been a successful application of a performance based incentive for small C&I customers. Companies with multiple locations value the ability to control HVAC, lighting, and other building systems remotely. The technologies that enable them to better manage energy use every day also provide a reliable and effective means for curtailing load in response to a signal. Although the load reduction at each location is small (23 kW on average), the total load reduction across all the chain store locations is significant. Additionally, our observations demonstrate that load reduction strategies can be deployed that do not adversely affect the shopping experience. Overall, we find that small commercial customers, particularly chain stores, can provide demand response resources cost effectively.

References

California Energy Commission (CEC). 2003. *Comparative Cost of California Central Station Electricity Generation Technologies,* Final Staff Report. California Energy Commission, Sacramento, California. June 5, 2003, 100-03-001F.