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Publication Date
2009-08-12

Peer reviewed

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August 2009

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ABSTRACT

This report documents a field study of 78 small commercial customers in the Sacramento Municipal Utility District service territory who volunteered for an integrated energy-efficiency/ demand-response (EE-DR) program in the summer of 2008. The original objective for the pilot was to provide a better understanding of demand response issues in the small commercial sector. Early findings justified a focus on offering small businesses (1) help with the energy efficiency of their buildings in exchange for occasional load shed, and (2) a portfolio of options to meet the needs of a diverse customer sector. To meet these expressed needs, the research pilot provided on-site energy efficiency advice and offered participants several program options, including the choice of either a dynamic rate or monthly payment for air-conditioning setpoint control.

Overall results show that pilot participants had energy savings of 20%, and the potential for an additional 14% to 20% load drop during a 100°F demand response event. *In addition* to the efficiency-related bill savings, participants on the dynamic rate saved an estimated 5% on their energy costs compared to the standard rate. About 80% of participants said that the program met or surpassed their expectations, and three-quarters said they would probably or definitely participate again without the $120 participation incentive. These results provide evidence that energy efficiency programs, dynamic rates and load control programs can be used concurrently and effectively in the small business sector, and that communicating thermostats are a reliable tool for providing air-conditioning load shed and enhancing the ability of customers on dynamic rates to respond to intermittent price events.

Background

Electricity demand response programs have existed in California for decades. Over the past ten years, however, increasing demand response capacity has become a priority at both the state and federal levels. While a dizzying variety of demand response incentive structures exist, only two are seriously considered for the mass market: air-conditioning control (ACC) and critical peak pricing (CPP). ACC programs, which have been in operation since the 1980's, offer payments in exchange for remote utility control of air conditioning units. CPP, a newer construct made possible by advanced metering, provides time-varying price incentives for customers to reduce their own electricity use – manually or through the use of enabling technologies that can sense and respond to the variable rate.

Recent evidence indicates that small businesses have the potential to shed load during peak events. A California pilot conducted from 2003 to 2004 showed that small commercial customers with communicating thermostats dropped 13% of their peak load in response to CPP events.[1] Even so, small commercial customers can be complicated targets for demand response programs and tariffs. Customers tend to be fairly heterogeneous, have limited time and money to devote to energy management, and are skeptical about the tradeoffs between money saved and business lost. As a result, the small commercial sector has been relatively unaddressed by demand response research and underserved by demand response programs.

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[1] Charles River Associates, California's Statewide Pricing Pilot: Commercial & Industrial Analysis Update. 2006.

Research Overview

The goal for this study was to provide a better understanding of demand response issues in the small commercial context, thus allowing the design of programs that benefit both utilities and their small business customers. An initial market assessment recommended targeting offices, retail, and restaurants as good candidates for a demand response pilot. Subsequent focus groups indicated that these small business types desperately wanted help with energy efficiency advice and financing, and would be willing to sign up for a demand response program in exchange for this kind of help from the utility.

Participation in the pilot required that customers choose one of two experimental demand response tariffs – ACC or CPP – which were designed to offer equal benefits assuming similar customer load drop during events. In both cases, twelve events were to be called from 4 to 7 p.m. between June and September 2008, when the tariffs were in force. Participants choosing the ACC option stayed on their original flat rate and received a $5 or $10 monthly credit on their bill in exchange for a 2- or 4-degree thermostat setback (respectively) during the three-hour events. ACC participants were required to have thermostats installed and programmed to respond to events. Participants choosing the CPP option were put on a time-of-use (TOU) rate with a dispatchable critical peak event component, thus rewarding both daily load shifting (via TOU) and temporary load reductions during events (via CPP). Although CPP participants were not required to have communicating thermostats, about three-fourths chose to have one installed. Table 1 summarizes the experimental CPP tariff and compares it to the existing small business rate (GSN).

Table 1. CPP tariff compared to the standard small commercial rate

Price Tier	Time Period	GSN ($/kWh)	CPP ($/kWh)	Summer Hours	% of Time
Critical peak	12 Event Days: 4–7 p.m.	$ 0.113	$ 0.572	36	1%
Super peak	Normal Weekdays: 4–7p.m.	$ 0.113	$ 0.131	219	7%
On peak	All Weekdays: 12–4, 7–10 p.m. Weekends & Holidays: 12–10 p.m.	$ 0.113	$ 0.099	965	33%
Off peak	All Other Hours	$ 0.113	$ 0.085	1708	58%

Table 2 shows the final recruitment and participant population size by business type. Of the 1,887 potential participants solicited, 158 (8.4%) responded to the solicitation, and 78 (4.2%) ultimately signed up for the pilot. Note that the participation rates for office and retail are direct results of recruitment letters only, while the participation rate for restaurants was more than doubled by face-to-face recruitment efforts initiated when it became clear that restaurant participation goals would not be met.

Table 2. Recruitment and participation metrics, by business type

Building Type	Recruitment Letters	Respondents	Participation Agreements				Participation Rate
			2°ACC	4°ACC	CPP	Total	
Office	893	67	1	11	23	35	3.9%
Retail	729	66	3	8	20	31	4.3%
Restaurant	265	25	3	1	8	12*	4.5%
Overall	1887	158	7	20	51	78	4.2%

* Includes seven participants recruited in person

In the spring of 2008, each business was visited to provide efficiency advice, install thermostats, collect in-person surveys, and educate participants. Along with information about the pilot, thermostat, and planned demand response events, participants were provided with information on appropriate efficiency measures and available efficiency rebates for their business type. From June through September 2008, twelve days with forecast high temperatures over 90°F were chosen for demand response events. Actual maximum temperatures for event days ranged from 87.7°F to 106.7°F. On the day before events, participants were notified via email, thermostat, or phone, and thermostats were notified via Radio Data Broadcast (RDS).

Multiple types of information were collected from study participants at several points in the project. A summary of the data collected during this study is presented in Table 3.

Table 3. Summary of data collected for this project

Source	Data collected	Use(s)
SMUD Customer Database	Contact information	Market assessment and segmentation Recruitment and screening
	Monthly billing data	2007-2008 energy savings analysis
Spring Survey	Business operations Building & equipment characteristics	Refine segmentation & screening
	Pre-pilot load shifting behavior	Pre/post behavior analysis
Event Surveys	Event behavior and comfort	Customer education & encouragement Participant problem resolution
Thermostat Logger	Thermostat set points (15-min)	Participant behavior vis-à-vis AC
	Indoor temperature (15-min) Compressor status (15-min)	AC unit behavior Diagnostics
	Messages/events from utility	Signal receipt confirmation
CPP bills	Monthly charges on CPP and GSN rates	Billing analysis for CPP participants
Interval Meter	Whole house electricity usage (15-min)	Critical Peak Pricing billing (SMUD) Hourly load impact analysis
CIMIS	Outdoor ambient temperatures	Event scheduling Hourly load impact analysis
Fall Survey	Satisfaction	…with tariff, thermostat, etc.
	Daily load shifting behaviors Event behaviors	Pre/post behavior analysis

Analysis of data focused around segmentation of data by building and program type. The remaining sections describe the data analysis and results.

Energy Impacts: Summer 2007 vs. Summer 2008

A regression of monthly usage (kWh) on average monthly temperature was used to estimate the weather-corrected energy savings for the 4° ACC participants, the CPP participants, and a control group of non-participants (Table 4). The 2° ACC group was not included because the sample size was small.

Table 4. Summer Solutions Participant Energy Savings

Business Type	Program	Average Monthly kWh		2007-2008 Difference		2007-2008 Difference Corrected for Non-Participant Change *(%)*
		Summer 2007	Summer 2008	(kWh)	(%)	
Office	None (control)	1025	976	49*	-5%	
	4° ACC	934	631	303*	-32%	-27%
	CPP	1061	668	393*	-37%	-32%
Restaurant	None (control)	3340	3252	88*	-3%	
	4° ACC	3249	2907	342	-11%	-8%
	CPP	3377	2944	432*	-13%	-10%
Retail	None (control)	1754	1716	38*	-2%	
	4° ACC	1663	1370	292	-18%	-15%
	CPP	1790	1408	383*	-21%	-19%
Average	4° ACC and CPP participants	1606	1238	369*	-23%	-20%

* Statistically significant kWh savings (α=0.05)

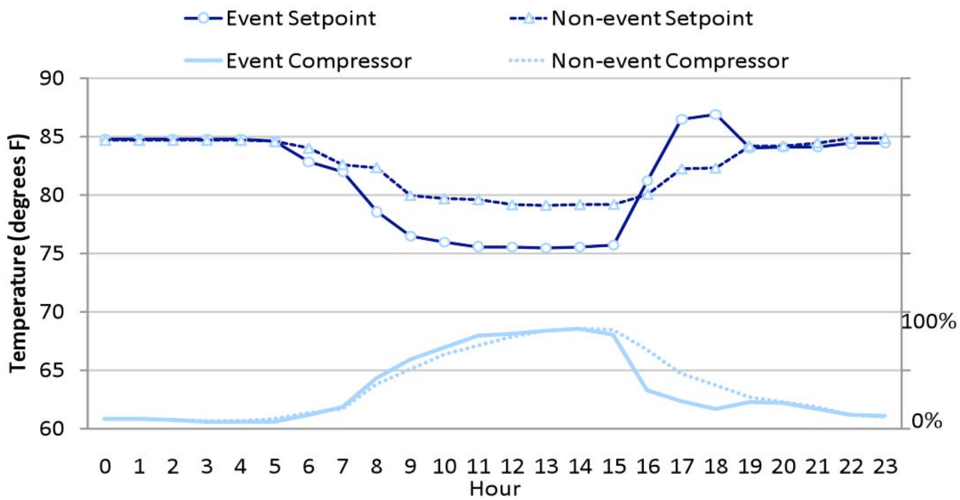
Overall, program participants used significantly less energy in 2008 than they did in 2007. Correcting for non-participant savings, the Summer Solutions program participants saved over 300 kWh *per month* on average, representing a 20% overall energy savings for the pilot. These results indicate that the pilot was successful in achieving (and surpassing) our original energy savings goal of just 5%.

Thermostat Logger Data

Thermostat logger data collected on site shows that 73% of the sent event signals were received and acknowledged by the thermostat. About one-third of the thermostats received notification for all twelve events, while about 10% received no notifications signals at all. Of the event signals received, about 5% of events were overridden by participants, meaning that after a thermostat responded to an event signal, one of the occupants of the building decreased the event setpoint by one or more degrees. As expected, fewer overrides occurred in the ACC programs (3%), because these participants were told that overrides were not allowed. Although CPP participants were told they could override their event settings at any time, overrides occurred during only 7% of CPP events.

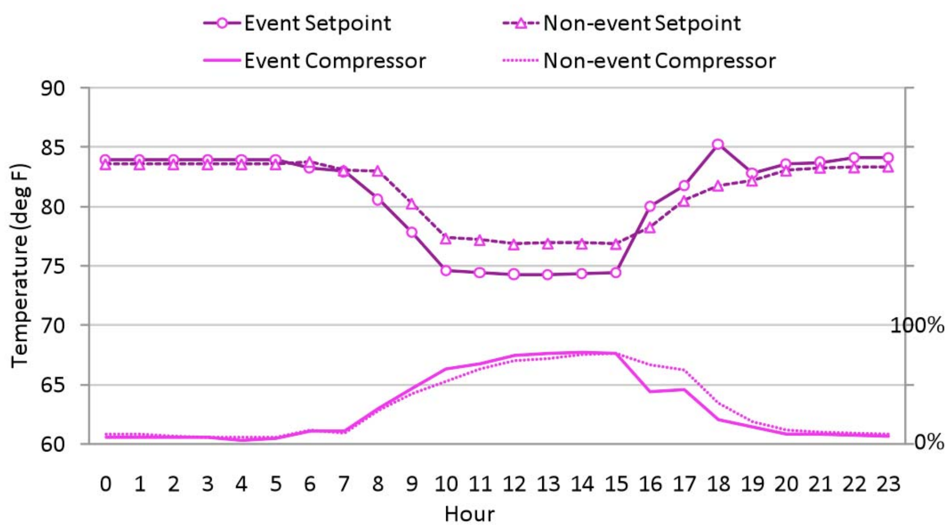
Figure 1 through Figure 3 show average setpoints and weather-normalized compressor status on event and non-event days for participating offices, retail and restaurants, respectively. For Offices and Retail, a clear shift takes place on event days. Between 8 a.m. and 4 p.m. preceding events, setpoints are about 4° lower than non-event setpoints, indicating precooling on event days. Setpoints then increase from 75° to over 85° by 7 p.m., when most offices and retail have already closed for the evening.

Figure 1. Setpoints & weather- normalized compressor status, offices



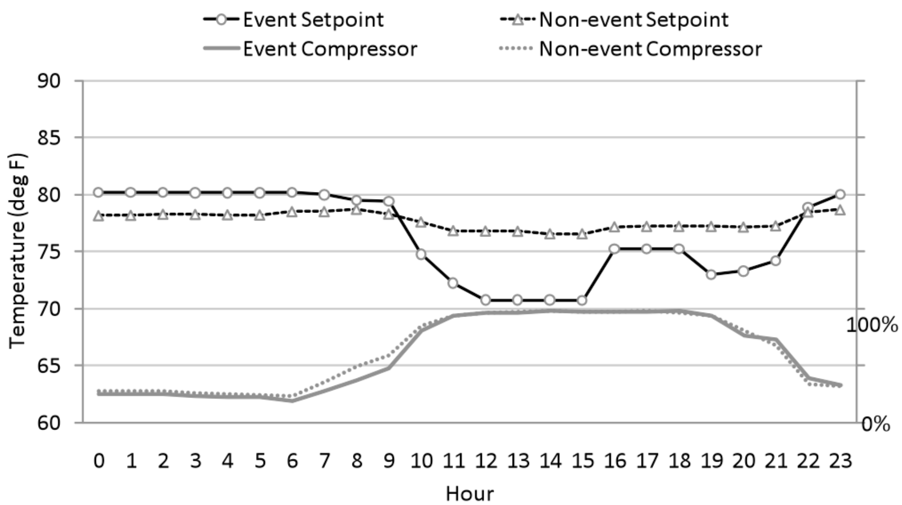
Compressor status, along the bottom of the figures, should be compared to the right axis labels, where 100% indicates that all of the compressors in the sample are running, and 0% indicates that none are running. Here, the effects of precooling on event days can barely be seen in the morning hours. In contrast, the event hours - indicated by the shading between 4 and 7 p.m. - show a marked decrease in compressor activity.

Figure 2. Setpoints and weather-normalized compressor status, retail



Logger data for restaurants paint a very different picture (Figure 3). Restaurants, like offices, attempt to precool on event days, lowering setpoints by as much as 6° before events. The new setpoints have no effect on the compressors, however, which run continuously under both scenarios. Following this "precooling," loggers show an event offset of about 4° at 4 p.m., however, the compressors are unaffected again. This provides evidence that (1) the restaurants in our participant population have undersized AC units, and (2) buildings with undersized AC units are unlikely to provide load drop during demand response events.

Figure 3. Setpoints and weather-normalized compressor status, restaurants



Load Impacts on Event Days

The linear autoregressive model used to analyze the hourly load data estimates the hourly load (in kWh per hour) for an average customer. The model is fit using the maximum likelihood method with a lag of 1, and controls for several important factors: hour of the day, day of the week, month, cooling degree hours for the hour in question, and total cooling degree hours for the day (Equation 1).

$$Q_i = \alpha + \beta^{lag_1} \cdot Q_{lag_1} + \sum_{j=1}^{23} (\beta_j^{Hour} \cdot Hour_j + \beta_j^{EventHour} \cdot EventHour_j) + \sum_{k=1}^{3} \beta_k^{Month} \cdot Month_k + \sum_{l=1}^{4} \beta_l^{Day} \cdot Day_l + \beta^{CDH} \cdot CDH + \beta^{DayCDH} \cdot DayCDH + \epsilon_i \quad (1)$$

In Equation 1, Q_i is the kWh/hr for hour i for an average customer, α is the intercept term, and the β's are the estimated parameters. Also:

- Q_{lag1} is the kWh/hr load for the previous hour,
- *Hour* is a set of 23 dummy variables for hour of the day for non-event days,
- *EventHour* is a set of 23 dummy variables for hour of the day for event days,
- *Month* is a set of three dummy variables for month, and
- *Day* is a set of four dummy variables for day of the week.
- The two other variables are calculated from weather data, where:
- *CDH* is the number of cooling degree hours (base 75) for hour i, and
- *DayCDH* is the total cooling degree hours for the day.

The model was used to estimate average hourly event and non-event loads. Load impacts – the difference between the event and non-event loads – for a 100° reference day are presented in Table 5. These results show the greatest savings from offices and retail stores on both the CPP rate and the 4° ACC program. Overall, the model indicates an average load drop of 0.7 kW (14%) for a program with a similar distribution of participating business types and programs. Excluding Restaurants, who were unable to respond to events, load impacts averaged 20%.

Table 5. Average load drop during event periods

Business Type	Program	Average Hourly Usage (kWh/h)		Impact	
		Normal	Event	(kWh/h)	(%)
Office	4° ACC	2.1	1.3	0.8	-38%
	CPP	2.4	1.8	0.6	-24%
Restaurant	4° ACC*	8.9	8.8	0.1	-1%
	CPP	13.4	13.1	0.4	-3%
Retail	4° ACC	3.5	2.7	0.8	-22%
	CPP	5.8	5.0	0.8	-14%
Total		4.8	4.1	0.7	14%
Offices & Retail Only		3.6	2.9	0.7	-20%

* Only one participant in the sample

Bill Impacts for CPP Participants

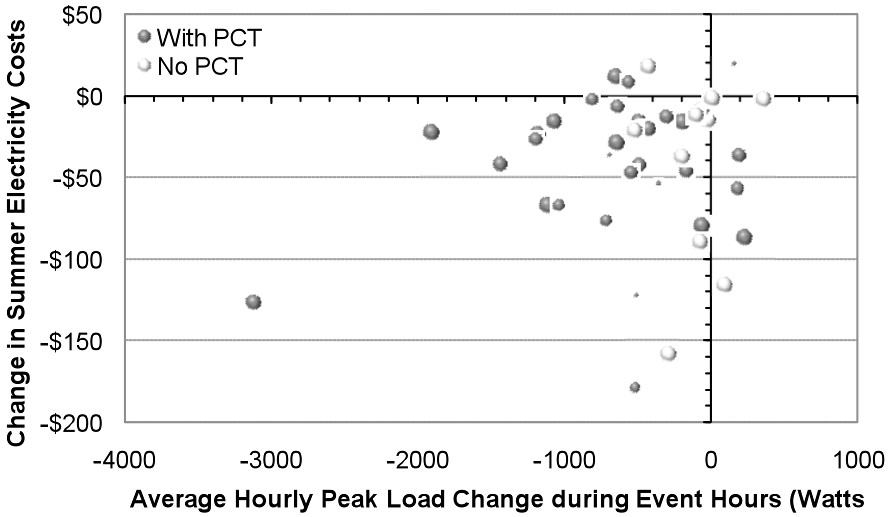
CPP bill impacts were calculated as the change in bill relative to the standard small commercial flat rate of $0.113 per kWh. All but four of the CPP participants saved money on the experimental rate, with the greatest bill savings at $178, and the greatest bill increase at $20. On average, CPP participants saved about 5% on the CPP tariff, with restaurants having the highest savings in dollar terms (Table 6).

Table 6. Mean summer bill savings by CPP participants

Business Type	Mean GSN Bill	Mean CPP bill	Mean CPP savings ($)	%
Office	$557	$529	$28	5.0%
Restaurant	$2,255	$2,149	$106	4.7%
Retail	$654	$623	$32	4.9%
All	$931	$886	$45	4.8%

Figure 4 shows the change in participant bills compared to the change in their energy usage during the event period. The shaded bubbles indicate participants that had communicating thermostats. The size of the shaded bubbles indicates the number of events that each thermostat received and responded to the event notification. The white bubbles indicate participants without thermostats, and so size is of no consequence. On average, those with communicating thermostats dropped 0.58 kW during events and saved 0.8 kWh on event days, while those without PCTs dropped 0.16 kW during events and saved 0.4 kWh on event days.

Figure 4. Summer Bill Savings vs. load change for event period

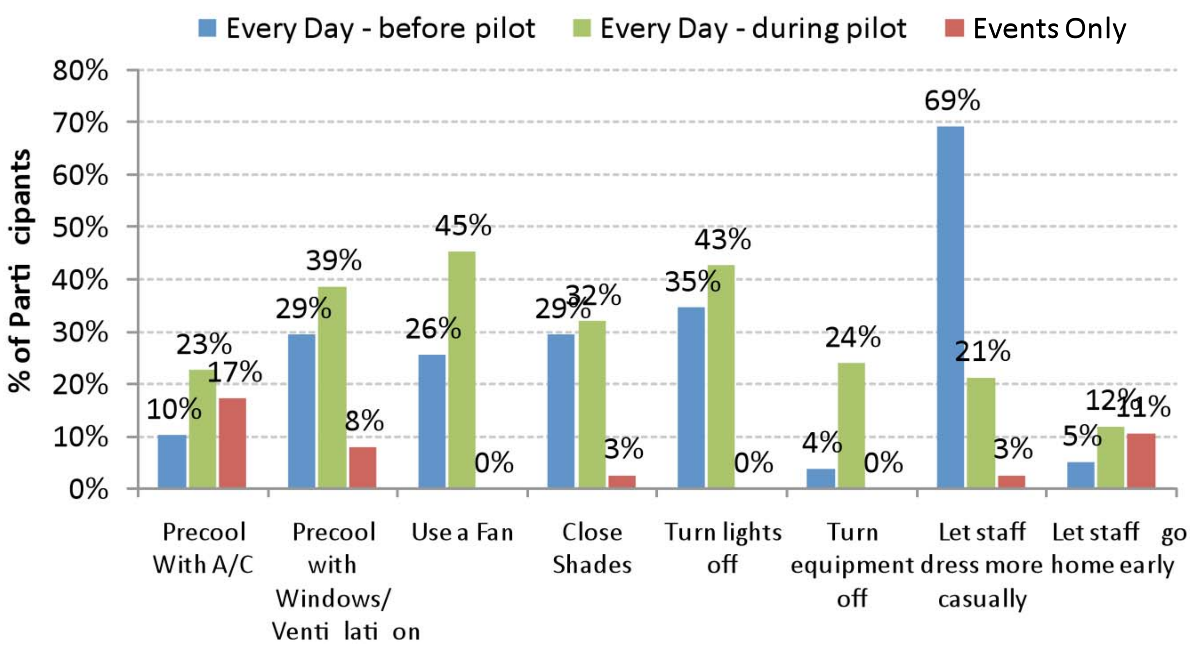


There appears to be a relatively good correlation between event response and bill savings, with all but nine of the CPP participants located in the third (bottom left) quadrant of the plot. A small group of participants saved money despite increasing their usage during event periods, while an even smaller group had higher bills despite dropping load.

Load Shifting and Demand Response Behavior

Figure 5 shows the percentage of participants that performed a variety of energy conservation and shifting measures every day before and during the pilot, plus the percentage of participants that performed the same actions only on event days.

Figure 5. Load shifting and conservation actions before and during the pilot



With the exception of "Let staff dress more casually",[2] the survey responses indicate that all actions were performed by a greater percentage of participants at the end of the pilot than at the beginning of pilot. In addition, all actions taken during "events only" are clearly attributable to the pilot, since events did not exist before the pilot.

Effects on Business and Comfort

In general, participants indicated that the demand response events were not very disruptive to their businesses. Overall, about 90% of participants said that the events affected their business positively or not at all, while the remaining 10% thought that the events affected businesses negatively. On average about 10% of the participants felt that the events made them uncomfortable. These statistics provide evidence that small business participants are capable of providing peak load drop with minimal disruption to their businesses.

Participant Satisfaction

About 80% of the participants were satisfied with their experience with the Summer Solutions pilot and said they would participate again next year without a participation incentive. There were no significant differences between satisfaction results for participants of different business types or in different programs.

Conclusions

The main findings of this study are as follows:

- Pilot participants used 20% less energy in summer 2008 than in summer 2007. This estimate adjusts for weather and a non-participating control group.
- On top of the 20% energy savings, pilot participants showed the ability to drop an additional 14% of their load (20% excluding restaurants) during a 100° demand response event.
- Offices and retail had the greatest kW load drop during demand response events, but all three business types had similar energy and bill savings.
- More than 90% of participants on the CPP rate benefited relative to the standard small business rate, with average bill savings of about 5% for all three business types. This is *in addition* to the bill savings resulting from the energy savings.
- On average, participants with communicating thermostats dropped 3.6 times as much load during events as did those without communicating thermostats.
- About 80% of participants said that the program met or surpassed their expectations. About three-quarters said they would probably or definitely participate again without the $120 participation incentive.

Based on these findings, we conclude that small offices and retail shops appear to be good candidates for integrated EE-DR programs. All three participating business types saved about 300 kWh per month, for an overall energy savings of 20%. With respect to demand response, the office and retail participants in this study precooled before events, increased setpoints during events, and shifted load away from the peak hours, which resulted in a 20% load drop during event hours. In contrast, small

[2] The large decrease in affirmative responses to this question is likely a result of the wording of the question – in particular the use of the word "more" without a clear reference point for comparison; i.e. this question could be taken to mean "…more casually than other days" or "…more casually than other establishments."

restaurants appear unlikely to respond to events. Despite changing thermostat settings to precool and offset on event days, the restaurants participating in this study were unable to drop load because their air-conditioning units were undersized. In general, it is probably safe to say that buildings with undersized air-conditioning units are not good candidates for dropping air conditioning load on hot days.

In conclusion, this study provides evidence that energy efficiency programs, dynamic rates and load control programs can be used concurrently and effectively in the small business sector. This study also provides further evidence that existing communicating thermostats can provide near immediate air-conditioning demand response for load control, and enhance the ability of customers on CPP rates to respond to critical events.

Acknowledgements

The work described in this report was coordinated by the Demand Response Research Center (DRRC) and funded by the California Energy Commission's Public Interest Energy Research (PIER) Program under Work for Others Contract No. 500-03-026 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231.

Thanks to everyone at the Demand Response Research Center, the Sacramento Municipal Utility District, Residential Control Systems, Inc. and eRadio, Inc. that helped make this research project a success.