

Evaluation of Demand Responsive Pricing and Bidding Programs for Large Commercial and Industrial Customers

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ABSTRACT

This paper describes the results of load impact evaluations for 2006 and 2007 of two of the California statewide day-ahead demand response programs for commercial and industrial customers. These programs were the critical-peak pricing (CPP) rate and the demand-bidding program (DBP) operated by the three investor-owned utilities (IOUs), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and Pacific Gas and Electric (PG&E). The primary objective of the evaluation was to produce estimates of the hourly load impacts for each program and each event day, at both an aggregate level and for certain customer types. The results of the evaluation are used as input to forecasts of the expected load impacts of the programs in future years.

Introduction

This paper describes the results of load impact evaluations for 2006 and 2007 of two of the California statewide day-ahead demand response programs for commercial and industrial customers. These programs were the critical-peak pricing (CPP) rate and the demand-bidding program (DBP) operated by the three investor-owned utilities (IOUs), San Diego Gas and Electric (SDG&E), Southern California Edison (SCE), and Pacific Gas and Electric (PG&E).

The primary objective of the evaluation was to produce estimates of the hourly load impacts for each program and each event day, at both an aggregate level and for certain customer types. In addition to estimating the magnitude of hourly load impacts on event days, the evaluation was designed to address the following researchable issues:

- What was the distribution of aggregate program impacts across key customer types (*e.g.*, manufacturing, offices, retail, government)?
- To what extent did the load impacts vary across individual events?
- What does that variation say about the uncertainty of load impacts in future events?
- What was the distribution of load impacts across individual customers?

Program Descriptions

Customers enrolled in the voluntary CPP programs received a discount from the otherwise applicable rates that they pay for energy and/or demand on non-critical days, in return for paying a “critical peak” price (*e.g.*, \$0.30 to \$1.80/kWh) for energy used in pre-defined hours on a limited number of CPP “event” days. Customers enrolled in a CPP program were notified one day before a CPP event was called. By 2007, SDG&E had enrolled 233 customer accounts in CPP, SCE had enrolled 44, and PG&E had enrolled 650.

Each of the IOUs split the critical peak pricing period into two parts (seven hours—11 a.m. to 6 p.m.—for SDG&E, and six hours—12 p.m. to 6 p.m.—for SCE and PG&E). Enrolled customers are charged a “moderate” price for energy used during the first three (or four) hours of that period, and a “high” price for energy used in the last three hours of that period. SCE also offered a second CPP option targeted at large customers (greater than 500 kW), which charged the same critical price for all event hours, where the

price was higher than for the other CPP rates, in return for a substantial discount on the summer on-peak demand charge. The number of events called varied by utility. For example, SDG&E called 9 events in 2007, while SCE and PG&E called 12 events.

Customers enrolled in DBP were notified one day before a DBP event was called, and given the opportunity to submit bids for load reductions relative to a baseline load calculated by the utility, based on usage patterns on specified previous days. If a customer that submitted a bid successfully curtailed usage by at least 50 percent of its submitted bid in each hour of a DBP event, that customer received an incentive payment. Customers that submitted bids were not penalized if they curtailed usage by less than the amount needed to qualify for a payment. DBP events may extend for up to eight hours, from 12 noon to 8 p.m., though utilities have the option of designating shorter events. In 2007, SDG&E called 9 events and SCE called 22 events, while PG&E called only one test event. Enrollment was 181 customer accounts at SDG&E, 1,222 at SCE, and 1,063 at PG&E. Customers were allowed to enroll in both CPP and DBP, however CPP dominated, such that if a CPP event was called, customers enrolled in both programs could not submit a DBP bid.

Approach

Evaluation of event-based demand response programs is simplified by the fact that participating customers' own usage on non-event days during the program year of interest may be used as appropriate "control" data for estimating load reductions on event days, so long as other relevant factors such as weather are taken into account.¹ These evaluations used hourly load data for all enrolled customers for an entire summer period. The data were used at different levels of aggregation to address the various researchable issues. Data aggregated across all customers were used to estimate program-level impacts directly. Data aggregated by customer type were used to estimate the allocation of load impacts by customer type. Finally, data for individual customers were used to estimate customer-specific load impacts.²

Load impacts were estimated directly by regression analysis, where hourly load impacts were estimated as the coefficients on a series of event variables interacted with hourly indicator (dummy) variables for each hour on each event day. Numerous other variables in the equation were used to control for customers' usage patterns on an hourly and day-of-week basis, and to control for daily weather variation (the dependent variable of the regressions was the load in a given hour, ranging across all summer weekdays). The equations used separate event variables for each event, thus allowing estimation of hourly load impacts *for each event*. The estimated co-variances of the event-hour coefficients were used to develop ranges of uncertainty around the average load impact.

Findings

CPP – Program Level

For the CPP rates, strongly significant and reasonably consistent load impacts were estimated in most cases (*i.e.*, the range of uncertainty around the average load impact was fairly tight). Load reductions as a percent of baseline loads ranged from about 2 to 10 percent for customers at SDG&E and PG&E, and

¹ This is in contrast to requiring data for "before-after" or contemporaneous control group comparisons in evaluations of non-event based programs.

² In a subsequent evaluation of load impacts in 2008, we modified the approach to focus on evaluating each enrolled customer's load impacts. While requiring estimation of numerous regression equations, this approach allowed the flexibility to aggregate load impacts by various factors, including industry type and geographical location, as well as to conduct meta-analyses of factors that influence individual customer load impacts.

from 30 to 40 percent for SCE’s CPP rate, which included a substantially higher critical price value and applied primarily to large customers. Load impacts for the demand bidding programs were generally smaller on a percentage basis and showed substantially greater variability. This was due largely to considerable variability in bidding behavior by customers in these voluntary programs, and to variability in the baseline loads of some customers, which resulted in larger standard errors of the event-hour coefficients.

Figures 1 - 3 show three sets of load values for the average CPP event for SDG&E, SCE and PG&E respectively. These are the hourly *load impacts* (where load reductions are shown as negative values, relative to the right axis), the *observed load*, and the *reference load* implied by the estimated load impacts.

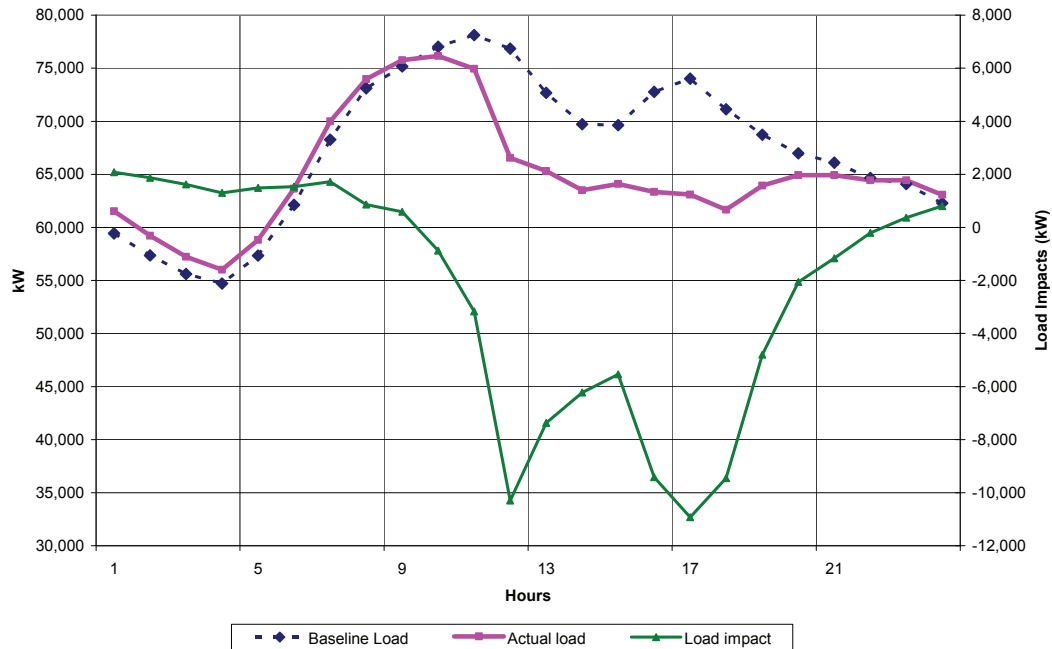


Figure 1: Reference Load, Observed Load and Load Impacts – SDG&E CPP (2007)

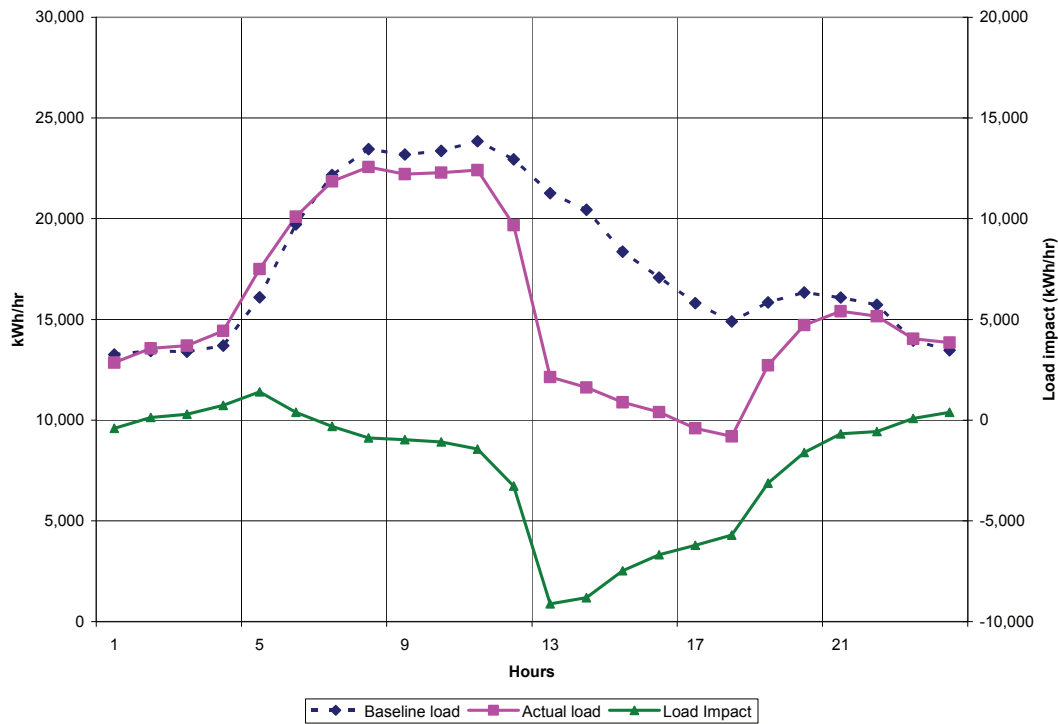


Figure 2: Reference Load, Observed Load and Load Impacts – SCE CPP (2007)

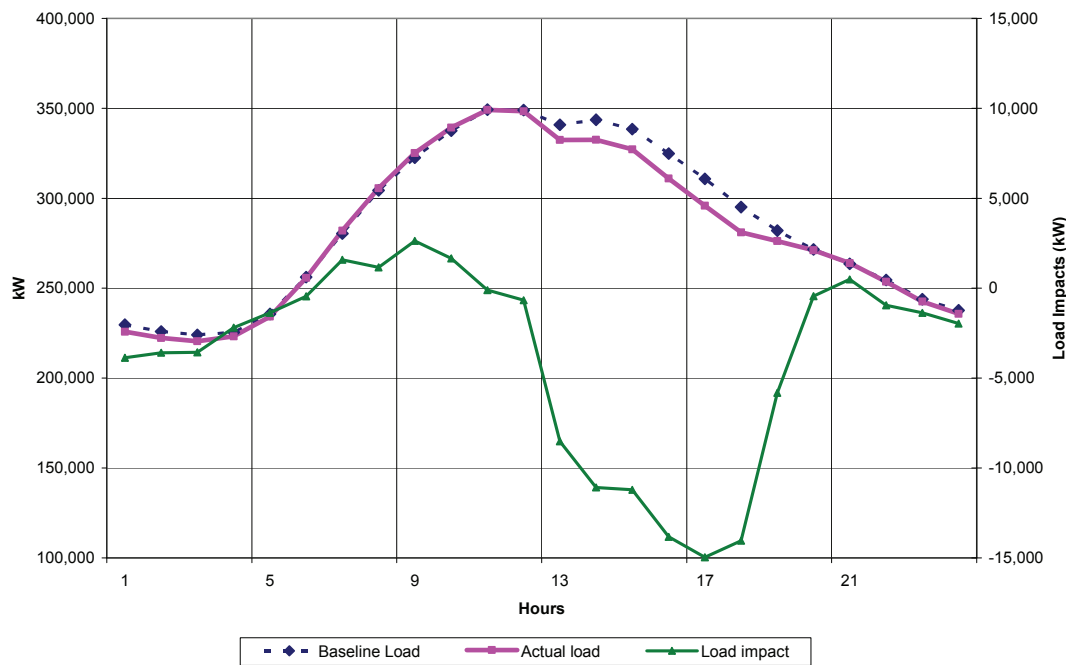


Figure 3: Reference Load, Observed Load and Load Impacts – PG&E CPP (2007)

Figures 4 - 6 show hourly load impacts for each CPP event, for SDG&E, SCE and PG&E respectively, thus illustrating the variability of load impacts across events. The load impacts at SDG&E and

SCE are seen to be reasonably consistent across events, while those for PG&E's larger number of customers vary substantially.

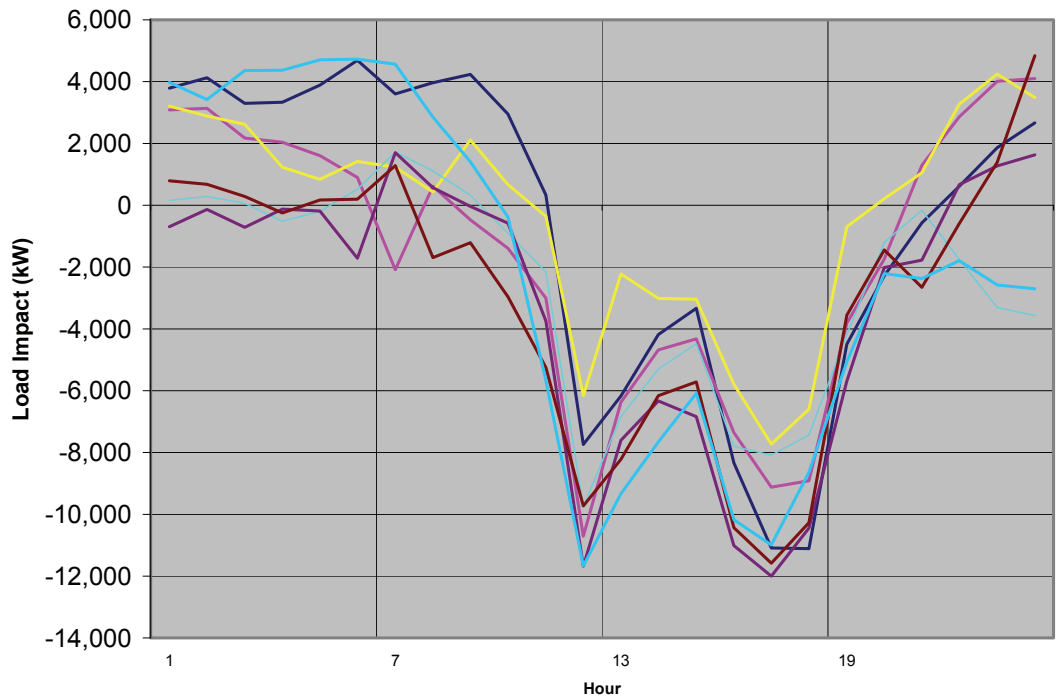


Figure 4: Variability of Event-Specific Load Impacts – SDG&E CPP (2007)

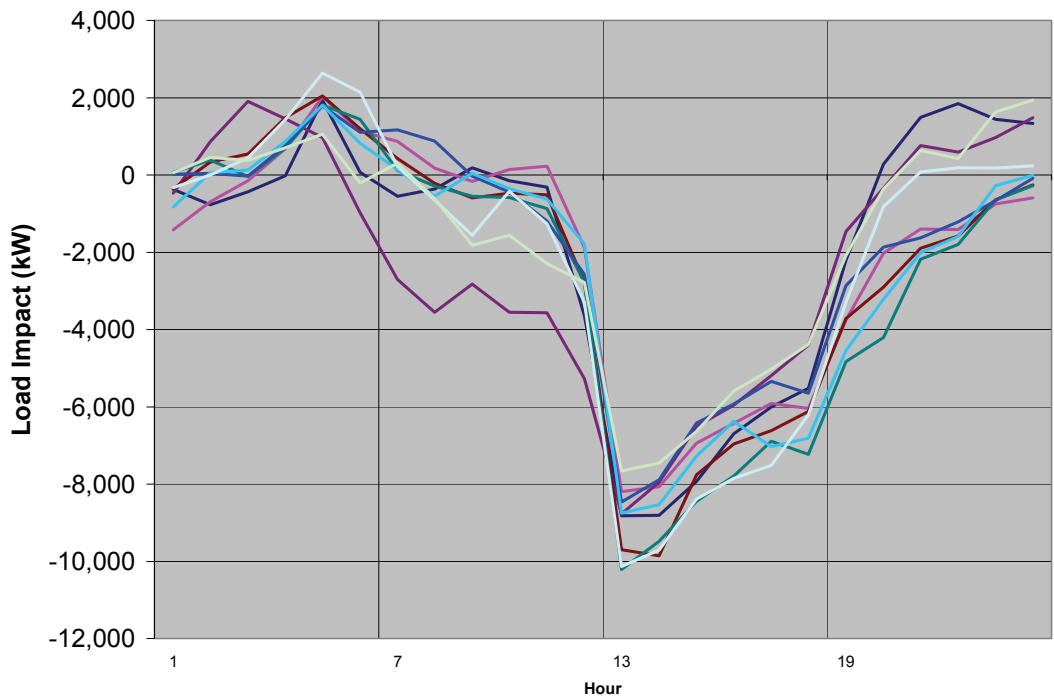


Figure 5: Variability of Event-Specific Load Impacts – SCE CPP (2007)

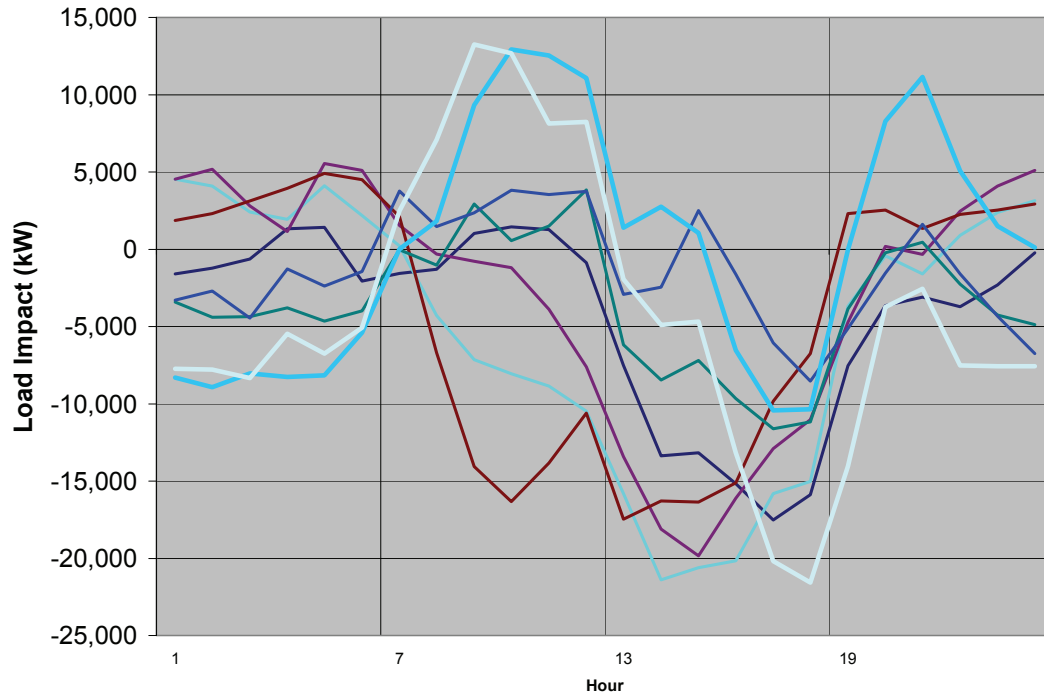


Figure 6: Variability of Event-Specific Load Impacts – PG&E CPP (2007)

DBP – Program Level

Only about 30 percent of the enrolled DBP customers tended to submit a bid when events were called, and an even smaller fraction of consistent bidders appeared to provide most of the load reductions. Figures 7 – 9 show the variability of DBP load impacts across events at the three utilities, where PG&E results are shown for 2006.

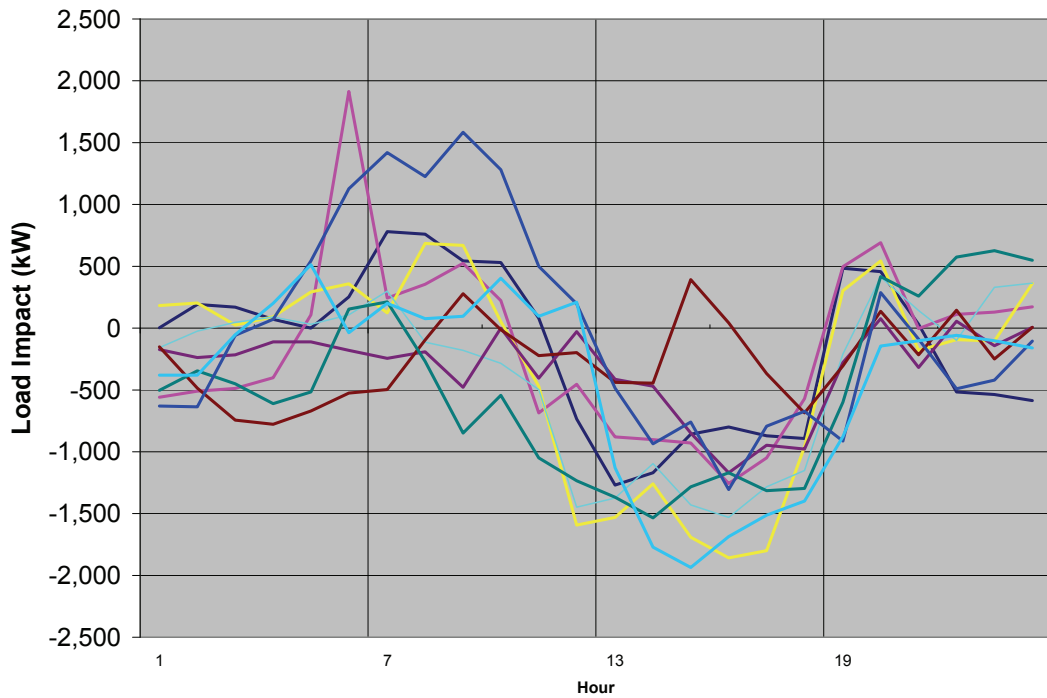


Figure 7: Variability of Event-Specific Load Impacts – SDG&E DBP (2007)

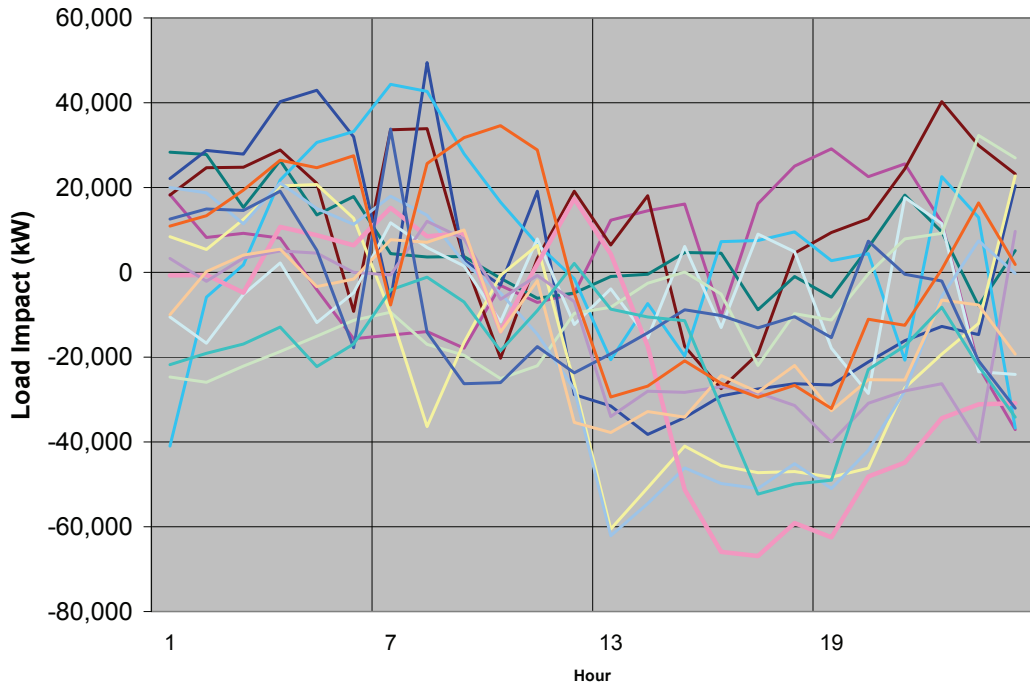


Figure 8: Variability of Event-Specific Load Impacts – SCE DBP (2007)

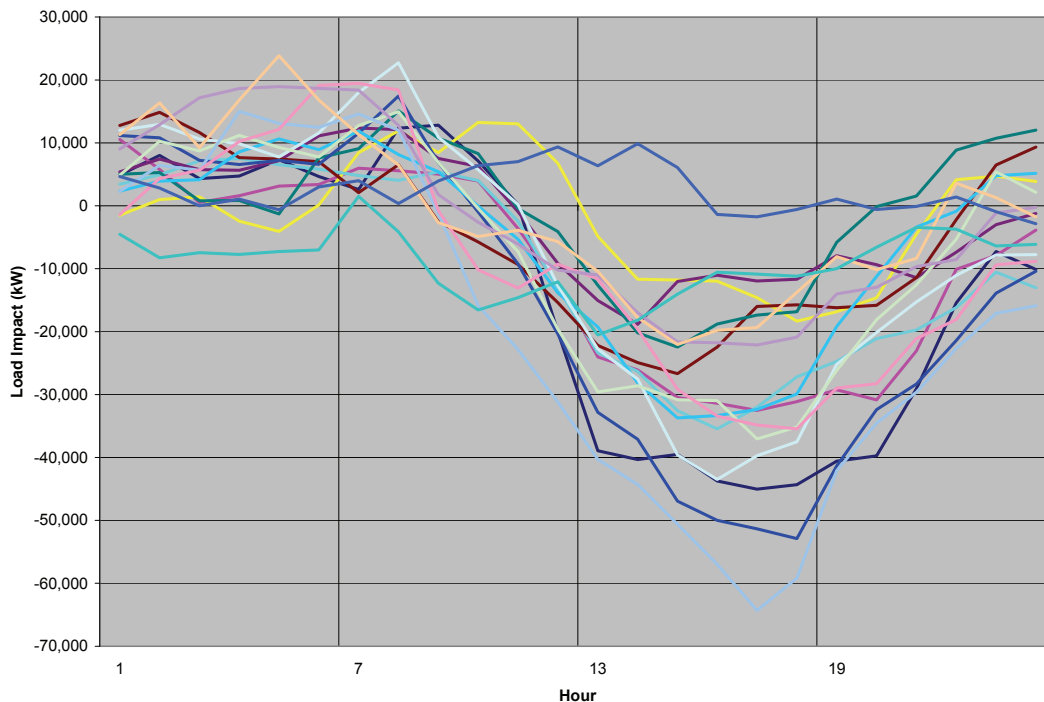


Figure 9: Variability of Event-Specific Load Impacts – PG&E DBP (2006)

CPP – Individual Customer Level

Figure 10 shows the distribution of price responsiveness (measured as percentage load impacts) across PG&E’s CPP customer accounts. These values were estimated from individual customer regressions, using equations similar to those for the aggregate load impacts. The results suggest that about 10 percent of customers were found to be considerably price responsive (*i.e.*, those observations with large negative values located close to the left axis), while another 30 percent were found to be modestly price responsive. The remaining 50 to 60 percent of customers did not respond in any significant way to the CPP rates. The positive and significant load impacts shown toward the right tail of the distribution are typical of those reported in other analyses of customer price response. We interpret them as cases of model misspecification due to omitted variables that might otherwise explain the customers’ loads on the event days. For example, many industrial customers’ loads vary on a daily basis due to production decisions that are essentially impossible for the analyst to take into account.

Figure 11 displays the same information in a different manner, illustrating the ranges of price responsiveness for eight industry types that have been used for summarizing load impact results for California’s demand response programs. For example, the chart shows that manufacturing customers demonstrate the greatest price responsiveness, while the “offices, hotels and finance” type and retail also show a number of price responsive customers.

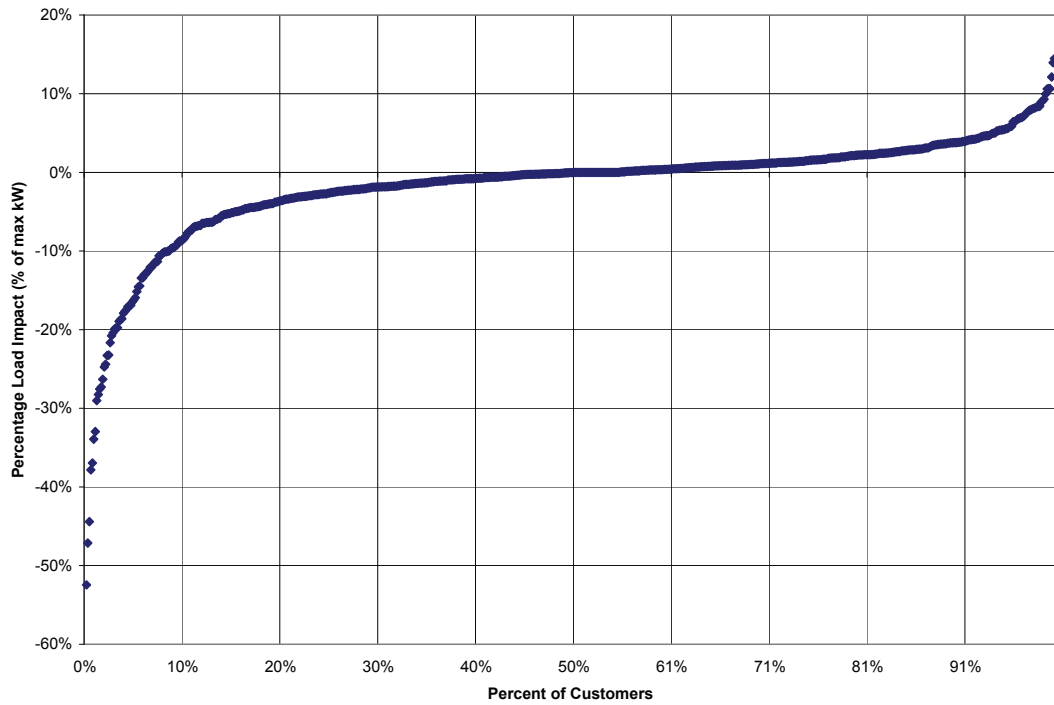


Figure 10: Distribution of Customer Price Responsiveness – PG&E CPP

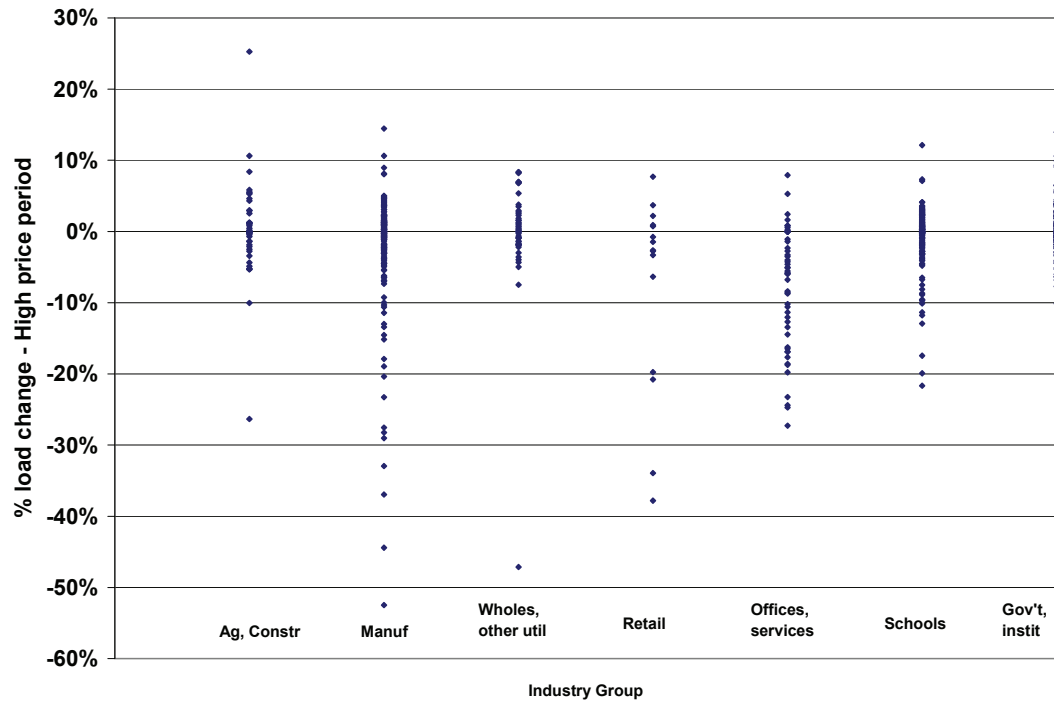


Figure 11: Customer Price Responsiveness by Industry Type – PG&E CPP

Conclusions

This evaluation demonstrates that regression analysis applied to hourly load data for participating customers of event-based programs for the overall event period (*e.g.*, summer months) enables the estimation of hourly load impacts for each event. Several notable findings were obtained, including:

- Commercial and industrial customers who volunteer for CPP rates and demand bidding programs provide significant and reasonably consistent load impacts.
- Load impacts for some programs were more consistent from event to event than others; in general, CPP load impacts were less variable than DBP load impacts.
- Load impacts on a percentage basis varied in certain expected ways, such as larger impacts for customers facing higher CPP prices and for manufacturing customers and an industry group that included municipal water utilities who have very flexible operating schedules.
- Relatively small percentages of customers (*e.g.*, 30 to 40 percent) appear to provide most of the overall load impacts.