Using Experimental Design to Assess the Impacts of Education and Rate Design: The PEAK Plus Pilot Project

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ABSTRACT

The PEAK Plus pilot project, jointly implemented by Southern California Edison (SCE) and The Energy Coalition, was designed to quantify the incremental effects of a targeted student energy curriculum, a critical peak rate design offering, and a combination of the two. The education component was targeted at fourth graders and was designed to build on students' skills as household energy managers and demand responders. The rate design offered incentives in the form of energy bill credits for customers who curtailed peak consumption when notified by the utility. Four groups of customers (three treatment and one control group) in similar climate zones were selected for participation in the experiment. Load patterns for the four groups were analyzed using a regression model on data from May through October 2008. The results indicated the rate design had a statistically significant load impact of 0.23 kW (15.5% of reference day load) and an average of 0.5 kWh savings per household for each peak event. Education was shown to improve the effect of the rate design, as the treatment group receiving a combination of rate and education had a statistically significant net impact of 0.31 kW per event (26.8% of reference day load) and an average of 0.8 kWh per household per event. Although feedback from PEAK education participants suggests that knowledge transfer occurs between students and their parents, results regarding PEAK education by itself were inconclusive and did not show a statistically significant effect on load shifting behavior. Process evaluation results suggest that the pilot program could be improved by providing a more effective event notification system for the participants receiving education only.

Design of the Experiment

The PEAK Plus pilot project was an experiment designed to determine the incremental impact two intervention methods—PEAK education and a peak-time rebate (PTR) electricity rate—have on shifting customers' energy use during peak period. PEAK education is an energy awareness curriculum, designed and supported by The Energy Coalition (a non-profit organization), that covers four main focus areas: shifting energy use off peak demand; shrinking energy use through cutting waste; exploring renewable energy; and plugging into new technologies. These focus areas are explored through an 11-lesson series and integrated with physical science concepts and lab activities. Teachers have the option of picking which units to use, though they are required to spend a minimum of 10 hours of classroom time on material and implement Unit 1, which covers demand response concepts. While the curriculum is generally taught in the fourth grade, it can be taught from fourth to seventh grade. For the PEAK Plus pilot project, only households with fourth-grade students were eligible to participate to avoid age or grade difference bias.

The PTR rate was a peak time incentive electricity rate that provided a $0.66 credit for every kWh saved during designated "PEAK event" days. SCE notified PTR rate households of upcoming PEAK event days, generally scheduled on hot summer days, during which households were encouraged to decrease energy use between 2:00 PM and 6:00 PM. Baseline usage was calculated from the average

of the three highest daily usages between 2:00 PM and 6:00 PM in the five weekdays previous to the PEAK event. Any kWh reductions on a PEAK event day with respect to the baseline were considered saved kWh; outside of the PEAK event hours, participants were subject to a SCE's standard residential rate. The pilot project PTR rate was in effect from January 1, 2008 to December 31, 2008.

To investigate the unique impacts of each intervention approach and their potential interactive effects, the pilot used an experimental design where participant households were assigned to four study groups—three treatment groups and one control group—that received a combination of intervention methods as follows:

1. **PEAK Plus (PP):** Households who had a fourth grade child receiving the PEAK education curriculum and who also signed up for PTR rate.
2. **PEAK Only (PO):** Households who had a fourth grade child receiving the PEAK education curriculum but did not participate in the PTR rate.
3. **Rate Only (RO):** Households who signed up for the PTR rate only; these households also had a fourth-grade child who did NOT receive PEAK education.
4. **Control Group (CG):** Households did not participate in the PTR rate; these households also had a fourth-grade child who did NOT receive PEAK education.

During PEAK event days, treatment groups receiving the PTR rate were expected to decrease energy use between the hours of 2:00 PM and 6:00 PM. All groups had interval-recording meters installed at their home to monitor and record electricity use throughout the day. Table 1 provides a summary of the four groups and their corresponding intervention methods.

Table 1. Four PEAK Plus Pilot Participant Groups

	PEAK Education	Peak Time Rebate Rate	Interval Meter
Control Group			✕
PEAK Only	✕		✕
PEAK Plus	✕	✕	✕
Rate Only		✕	✕

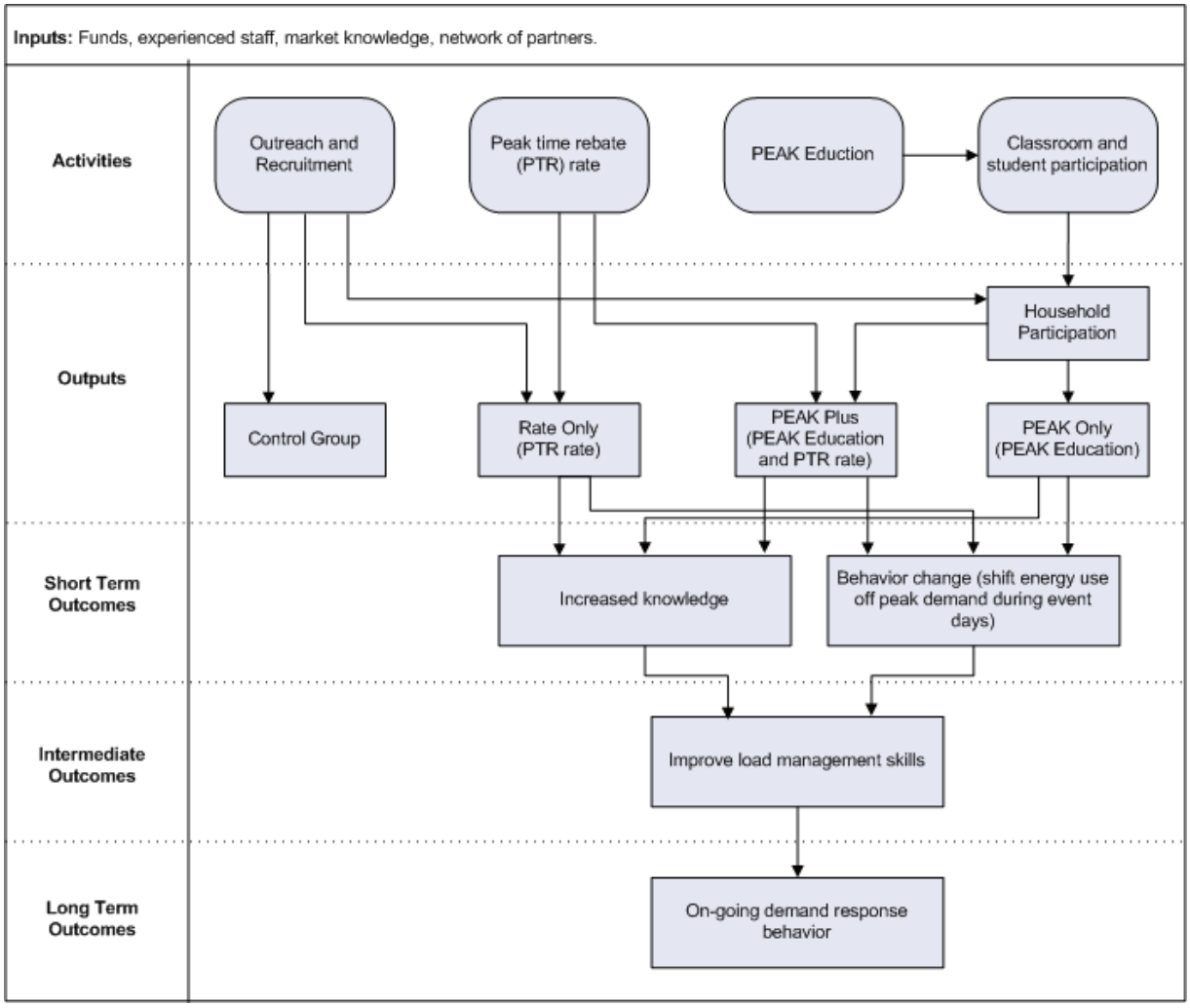
The overall objective of the PEAK Plus pilot was to quantify load impacts resulting from the three treatments. The three treatment groups were expected to have some behavioral changes and thus, reduced consumption during peak period. The combination of education and the PEAK incentive rate was expected to have the greatest amount of change as the combination of increased knowledge and price incentives was anticipated to have an additive effect on demand response.

Expected short-term outcomes for the three treatment groups include increased energy knowledge and behavioral changes. Intermediate and long-term outcomes include improved load management skills and on-going demand response behavior, respectively. Figure 1 displays the logic model of the project. The pilot project's key activities included outreach and recruitment, designing the PTR rate, PEAK education, and school/student participation in PEAK education. Student participation in PEAK education in concert with program recruitment activities lead to household involvement for the PEAK Plus and PEAK Only groups. Recruitment activities lead to household participation in the Rate Only treatment group and Control Group.

PEAK Plus represents an alternative approach compared to previous program evaluation efforts. In the past, experiments such as California's Statewide Pricing Pilot have tested the effects of critical peak pricing tariffs (i.e. electricity was more expensive during peak demand). (CRA 2005) The effects of energy education on overall consumption and peak load shifting have been studied in other programs

such as the LivingWise Program sponsored by the Aquila Networks in Iowa (Cadmus 2008) and Washington State's Energy Education in Schools program (Cadmus 2008). To our knowledge, however, the joint effects of education and peak time pricing on demand response have not previously been formally investigated.

Figure 1. PEAK Plus Pilot Logic Model



Project Implementation

The pilot project was implemented by The Energy Coalition and administered by Southern California Edison (SCE). The Energy Coalition developed and supported the PEAK education component, while SCE administered the rebate rate. SCE filed the PEAK Plus project as a 2006-2008 Demand Response Program (pilot). The Cadmus Group, Inc. (formerly Quantec, LLC) was hired in 2006 to conduct a coinciding evaluation of the PEAK Plus pilot project.

Recruitment and Sample Design

The initial sample design for the project called for 200 participants in each of the four groups. A total of 709 potential participants were initially recruited—less than originally planned. Overall, PEAK Plus participant recruitment took longer than expected. Reasons for the recruitment difficulties included: 1) reaching a narrow target population; 2) engaging busy parents to learn about PEAK Plus; 3) recruiting students and families in the third grade, before they were familiar with PEAK education; and 4) reaching schools that were not affiliated with PEAK. The Energy Coalition staff, however, noted that successful recruitment strategies included recruitment at in-person events with immediate giveaways and leveraging social networks at schools.

After further participant screening, the total number of participants was 485. Applicants were disqualified for several reasons, including: applicant was participating in another SCE program (e.g. A/C Cycling Program), applicant was not the primary account holder (e.g. primary account holder's spouse signed up for PEAK Plus); household was not in SCE service territory; or applicant lived in a house on a shared meter. An additional 10% of participants were disqualified due to meter access or safety issues. Table 2 provides a summary of the recruitment goals and study sample.

Table 2: Sample Disposition

	Number of Viable Applications Received	Recruitment Goal	Sample Remaining after Screening	Sample Target
PEAK Plus	133	200	165	125
Rate Only	153	200	93	125
PEAK Only	155	200	109	125
Control Group	268	200	118	185
Total	709	800	485	560

PEAK Events

As mentioned previously, SCE announced "PEAK event" days on which participants were expected to limit energy use between the hours of 2:00 PM and 6:00 PM. SCE announced a total of 15 PEAK event days in 2008 from May to October. SCE notified PEAK Plus and Rate Only households via phone message by 3:00 PM the day prior to a PEAK event through their Outage Notification Communication (ONC) system. PEAK events were selected when the weather forecast indicated the high temperatures in downtown Los Angeles would rise above 85°F, and inland areas would reach high temperatures approximately 10 degrees hotter. Two of the PEAK events in July coincided with California ISO's peak events (state-wide peak event). In the initial plan, PEAK Only students were expected to receive PEAK event notifications via their teacher. These notifications were not implemented because students were on summer break for a majority of events, and it proved difficult to distribute notifications to teachers the day before an event as they don't have access to email or phone during the day; these challenges could have been anticipated and addressed during the design phase of the Pilot program.

Data Collection and Analysis

To assess both the load impacts and implementation of the PEAK Plus pilot project, Cadmus conducted the following data collection and analysis activities:

- *Baseline Survey.* Conducted in January through March 2008, the baseline collected information on the participant household characteristics and energy awareness.
- *Follow-up Survey.* Conducted in November through December 2008, the follow-up survey collected information on changes in participants' household characteristics as well as their impressions and opinions of the PEAK events and/or PEAK education.
- *Teacher Interviews.* Conducted February 2009, the interviews collected feedback on PEAK curriculum, information on how PEAK is implemented in the classroom, and impressions on how students respond to demand response concepts.
- *Staff Interviews.* Conducted in both July 2007 and February 2009, the staff interviews provided insight into program implementation.

In addition to the aforementioned data collection activities, Cadmus conducted a load impact analysis using 15-minute interval load data. The 15-minutes interval load data for all households were compiled for the period of May 1 to October 31, 2008 and then aggregated to hourly and daily levels. Each household was also mapped to the nearest of six National Oceanic and Atmospheric Administration (NOAA) weather stations in SCE's service area to calculate average cooling degree days (CDD). Cadmus included only active accounts (as of October 2008) with a corresponding baseline survey in the impact analysis, resulting in a final sample of 241 households.

Summary of Results

Study Group Comparisons

The four study groups had similar household characteristics; the most notable difference among study groups was location and thus, weather patterns. Specifically, the Control Group and Rate Only participants were generally located in regions with hotter weather than the PEAK Plus and PEAK Only participants. The analysis results, shown in Table 3, also indicate higher overall baseline energy consumption for the Control Group (8,553 kWh/yr compared to the average of 7,153 kWh/yr). A precursor to the load impact analysis, these findings helped identify potential variables that needed to be controlled for during the load impact analysis.

Table 3. Average Annual Electricity Consumption, CDD, and Cooling Loads

Study Group	Mean Annual Consumption kWh/yr	Average Daily CDD	Cooling Shares (% of Total)
Control Group	8,553	3.93	22.51%
PEAK Only	7,717	2.99	18.11%
PEAK Plus	6,694	2.63	13.18%
Rate Only	7,047	3.89	19.42%

PEAK Event Implementation

Half the respondents reported they were able to change their energy use during every PEAK event; however, SCE settlement data indicated most participants behavior changes registered savings for five to seven PEAK events out of the total 15 events. During PEAK events, the most common actions

taken to reduce energy user were to turn off lights, turn off air conditioning, and shift doing laundry to off-peak time. The most common reasons for not participating in a PEAK event were the respondent was not home or the respondent claimed they did not receive notice.

Regarding satisfaction with the pilot project, most participants (77%) were satisfied with their participation in the PEAK Plus Pilot and would participate again if given the opportunity. In addition, the majority of participants indicated that it was easy to sign up for the program/PTR rate (69% respondents) and that PEAK event notifications worked well (80% respondents). Participants had difficulty recalling the PTR rate credit on their electricity bill, but, of those that recalled receiving a credit (42%), 18% said the credit was more than expected; 25% said the credit met their expectations; and 20% reported the credit was less than expected. Regardless, most participants (67%) indicated the credit motivated them to reduce energy use during PEAK events.

PEAK Education

Interviews with PEAK teachers indicated they all covered at least one demand response unit but generally did not implement all 11 PEAK units as they had limited classroom time. The natural gas and renewable energy units were the least implemented units. In general, teachers noted a lack of time was the largest barrier to implementing the complete PEAK curriculum. All interviewed teachers also indicated they taught the PEAK curriculum in spring, during the 2007-2008 school year. Though few teachers interviewed were aware of the PEAK Plus pilot project, most felt that their students understood the concept of shifting energy off peak demand.

As for PEAK education's effect on participants, many survey respondents (66%) reported their child discussed energy use with them as well as brought materials home about energy, and over half of the respondents reported their children asked them to change the way they used energy, such as install compact fluorescent lights. Most respondents indicated they made the requested changes. In addition, many respondents rated their discussions with their children to be of higher influence than the program materials.

Impact Findings

As a first step in analyzing load impacts, hourly loads were normalized to each group's total daily consumption to account for differences in total consumption among the four groups. The resulting load shapes for non-event and event days, shown in Figure 2 and Figure 3, respectively, demonstrated a clear difference in peak/off-peak load patterns among the four groups. All three treatment groups demonstrated distinct peak to off-peak load shifts during both event and non-event days. The load shift for the PEAK Plus group is particularly discernible during event days.

Figure 2. Average Daily Load Profiles – Weekdays (Excluding Event Days)

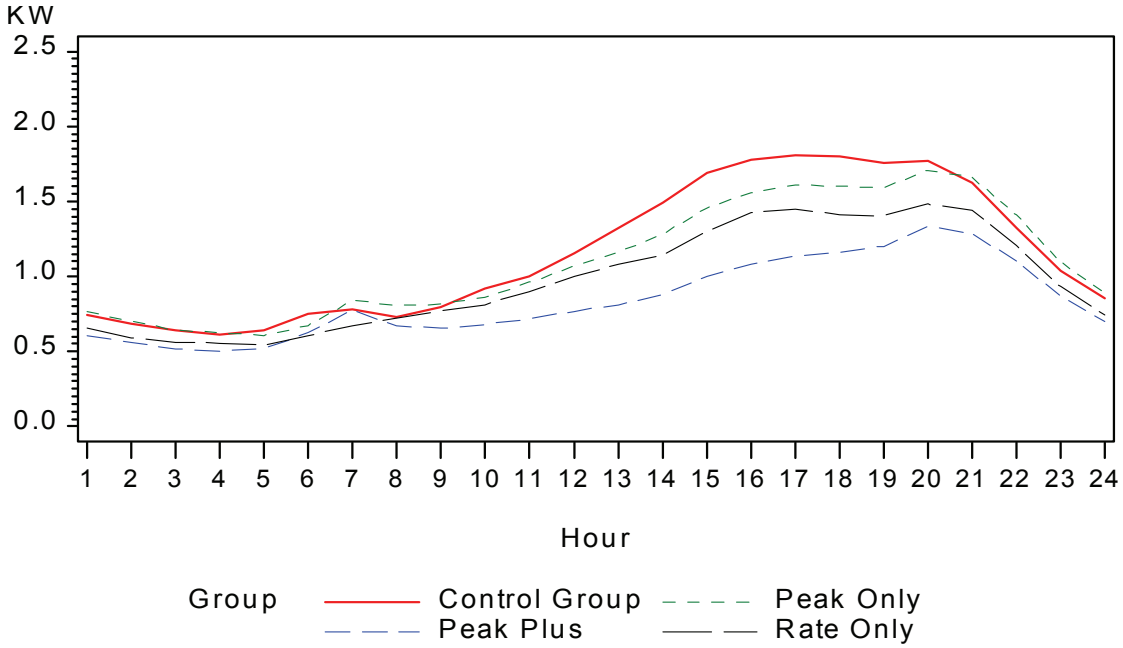
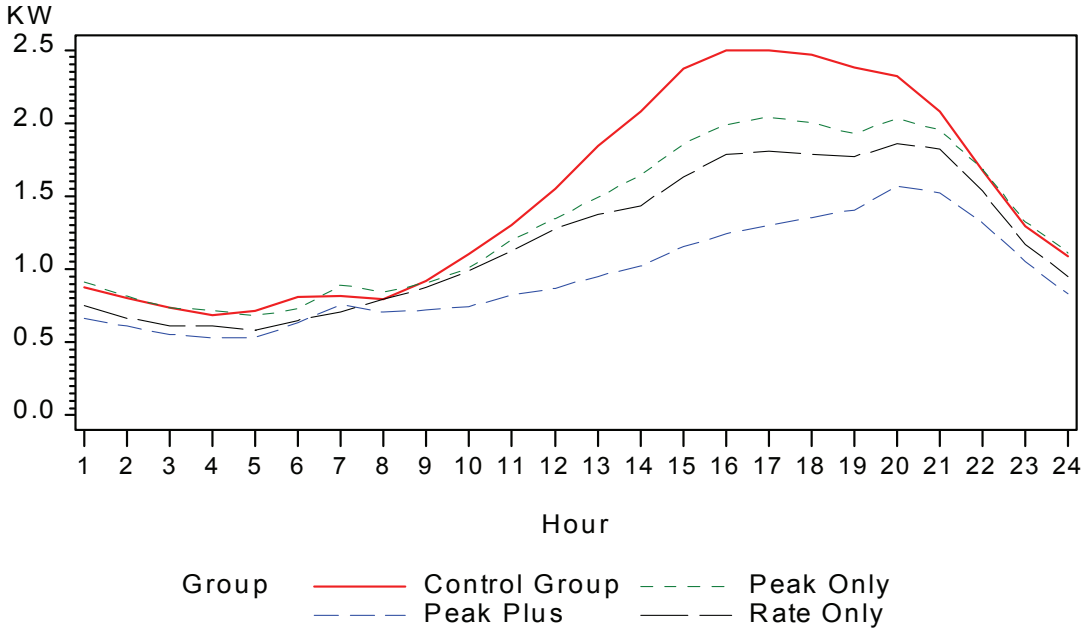


Figure 3. Average Daily Load Profiles – Event Days



Load impacts for each treatment group were analyzed using a regression equation, which explained variations in hourly loads during weekdays as a function of outside temperature, basic dwelling unit and household characteristics, major appliance holdings, and a binary variable representing the incidence of a critical peak day, see Equation 1.

$$kW_{hj} = \alpha + \beta_1(CDH) + \beta_2(SF) + \beta_3(HH) + \beta_4(AC) + \beta_5(EWH) + \beta_6(Event) + e \qquad \textbf{(Equation 1)}$$

Where, for each hour h (h = 1-24) and group j (j = 1-4):

kW_{hj} = hourly load during typical weekdays

CDH = cooling degree hour
SF = size of dwelling unit in square feet
HH = household size,
AC = presence of an air conditioner
EWH = presence of electric water heater
Event = hours 2:00-6:00 PM on an event day

Gross load impacts were estimated by substituting mean values of the explanatory variables in the estimated equations to calculate hourly load profiles for the event day and typical reference day for each group. Average gross impacts for each treatment group were calculated as the average difference between the event day load profile and the reference day load profile during the peak period:

$$Gross\ Peak\ Impact = Mean\ kW_{EVENT\ DAY} - Mean\ kW_{REFERENCE\ DAY} \qquad \textbf{(Equation 2)}$$

Due to climate differences among the study groups, it was also necessary to ensure the Control Group could be compared with each treatment group. To achieve this, the hourly Cooling Degree Days (CDD) of the Control Group was used in the estimated regression equations. In addition, the mean values for the treatment groups were substituted into the Control Group equations, creating a "matched" control group for each treatment group.

The gross load impact results, summarized in Table 1, indicate the PEAK Plus group had the highest mean hourly savings (0.20 kW/hour) and the PEAK Only group had the lowest savings (0.07 kW/hour). The Rate Only group also showed modest savings of 0.12 kW/hour. All three matching control groups show approximately 0.11 kW increase in their hourly loads during event days, on average.

Table 1. Mean Gross Load Impacts by Treatment and Matching Control Groups (Hours 14 – 17)

	PEAK Only	PEAK Only Control	Rate Only	Rate Only Control	PEAK Plus	PEAK Plus Control
KW Event	1.55	1.71	1.36	1.90	0.95	1.52
KW Non Event	1.62	1.60	1.48	1.79	1.14	1.41
Gross Impact	-0.07	0.11	-0.12	0.11	-0.20	0.11

Net load impacts for each treatment group were calculated as the difference between the gross load impact of the treatment group and the gross load impact of its matching control group, for each group *i* in hour *j* :

$$Net\ Impact_{ij} = Gross\ kW\ Impacts_{TREATMENT\ GROUP\ ij} - Gross\ kW\ Impacts_{CONTROL\ GROUP\ ij}$$

Because all matching control groups had higher loads during event days compared to reference days, net load impacts are higher than gross impacts for all three treatment groups. As shown in Table 2 and Figure 4, the PEAK Plus group had the highest net load reduction of slightly more than 0.3 kW/hour, which indicates a nearly 27% load reduction compared to the reference day. The highest hourly load impact for this group was 0.37 kW, occurring at hour 17. Load reductions for the PEAK Only and Rate Only groups were approximately 0.20 kW and 0.23 kW on average, representing 11.4% and 15.5% of reference day load respectively.

Figure 4: Estimated Net Load Impact by Treatment Group

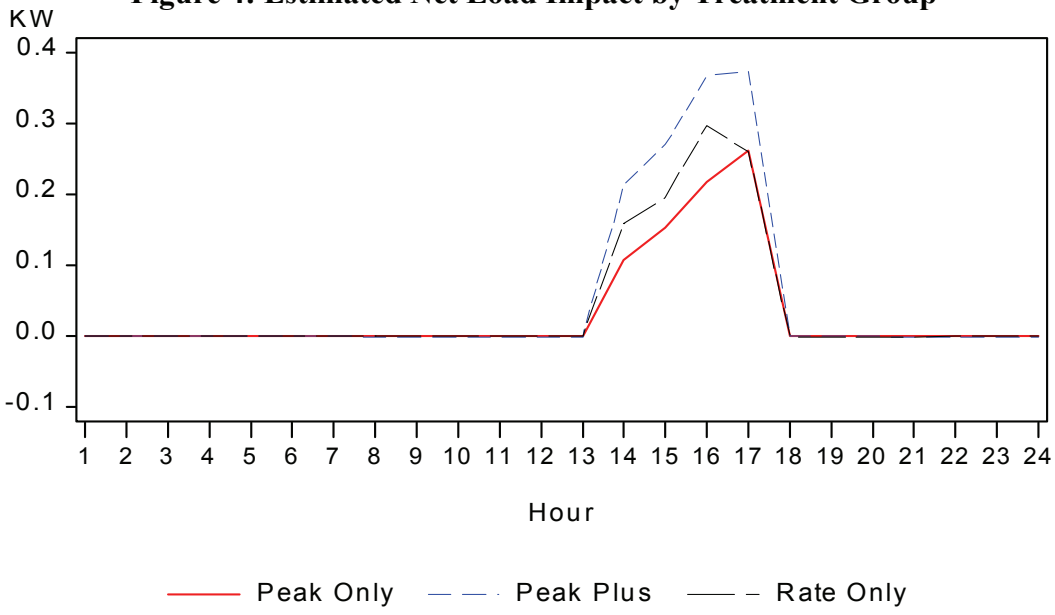


Table 2. Maximum and Average kW Peak Load Impacts

Study Group	Maximum Net Impacts (kW)	Average Net Impacts (kW)	Average Net Impacts (% of Reference Day Load)
PEAK Only	0.262	0.185	11.37%
Rate Only	0.297	0.228	15.45%
PEAK Plus	0.373	0.306	26.80%

Cadmus calculated the average electricity savings during event days for households in the Rate Only and PEAK Plus treatment groups to evaluate how the evaluation results compared with the reported savings in SCE's settlement data (record of kWh savings and credits paid for PEAK events).[1] The results, shown in Table 3, indicate the settlement data savings are significantly higher than *gross* energy savings from the evaluation. The *net* savings resulting from the evaluation, however, compared favorably with the settlement data figures.

In addition, a pooled model, which included indicators in the form of binary (dummy) variables for each treatment group, was specified to test the robustness of the estimated parameters of the load impact model. Overall, the results from this model specification and other slight model variations, returned coefficients and load impacts similar to those produced by the model and approach discussed earlier. The calculated kWh savings by treatment group, shown in Table 3, retain the same ordinal ranking and are only slightly smaller in magnitude than the impacts observed in the primary analysis.

[1]It is important to note that savings in the Reconciliation Report were calculated using average consumption during three out of five week days before the event as the reference for calculation of savings. In the evaluation, the non-weekend day before the event was set as the basis for calculating impacts.

Table 3. Comparison of kWh Savings with the Settlement Data (kWh Per Household Per Event)

Per Household Savings	PEAK Plus	Rate Only	PEAK Only
Comparison Model Gross (kWh)	0.7	0.4	0.3
Gross (kWh)	0.8	0.5	0.3
Net (kWh)	1.2	0.9	0.7
Settlement (kWh)[1]	1.2	1.3	NA

[1] Includes all participating households regardless if had savings

According to SCE's record settlement data, PEAK Plus participants (N=98) had lower average savings per household (2.66 kWh) than Rate Only households (2.88 kWh, N=88)), but PEAK Plus households saved more kWh overall (1556 kWh) than Rate Only households (1486 kWh). The average credit SCE paid to households per event was $1.19. The total amount of credits SCE paid over all 15 events was $2,010.

Lessons Learned

As a pilot project, PEAK Plus explored the potential impact education and a peak-time rebate rate—alone and in conjunction—have on shifting energy use off peak time. Results from this study will help implementers and planners of similar programs understand the added value of each demand response intervention. These results will also specifically inform future demand response programs and PTR rate implementation at SCE.

1. **The PTR rate had a small, measurable load impact**. Results for the Rate Only treatment group were statistically significant, with a net impact of 0.23 kW (15.5% of reference day) and an average of 0.5 kWh savings per household for each PEAK event. These results indicate that the PTR rate influenced participants, however slightly, to shift energy use during peak periods. The most common actions taken to shift energy during peak events were to turn off lights, turn off air conditioning, and do laundry during off-peak hours.
2. **Education improves the effect of the PTR rate.** Results indicate PEAK Plus participants had a higher load impact than Rate Only participants; results for the PEAK Plus participants were statistically significant and indicated a net impact of 0.31 kW per event (26.8% of reference day) and an average of 0.8 kWh per household per event. Feedback from PEAK Plus participants suggests that knowledge transfer occurred between students and their parents. Specifically, participants reported that their children shared PEAK education knowledge and energy tips with the rest of the household, though energy efficiency messages were transferred more commonly than demand response knowledge. Overall, these results suggest PEAK education complimented the PTR rate.
3. **PEAK education by itself does not affect load shifting**. Though Cadmus observed a load impact for the PEAK Only group, the effect was very small and not statistically significant, which suggests that the observed savings may have been due to natural statistical variations. This result is not surprising, as PEAK Only participants were unable to receive PEAK event notifications, which are necessary to initiate load shifting behaviors on event days, due to logistical challenges (namely there was no mechanism to deliver messages while students were on summer break). It can be argued that these challenges could have been identified at the outset of the pilot study and an alternative notification delivery mechanism could have been designed.

For future program design, Cadmus had the following recommendations:

- Allow ample time for project or program recruitment, especially when targeting a specific, hard-to-reach population. The recruitment process can be enhanced by offering immediate giveaways for signing up, and leveraging existing social networks among the target population
- Coordinate data collection and process among implementation parties to streamline program implementation.
- Conduct research at the outset of the program to determine the optimal message delivery mechanism for all treatment groups.

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