RESPONSE OF RESIDENTIAL CUSTOMERS TO CRITICAL PEAK PRICING AND TIME-OF-USE RATES DURING THE SUMMER OF 2003

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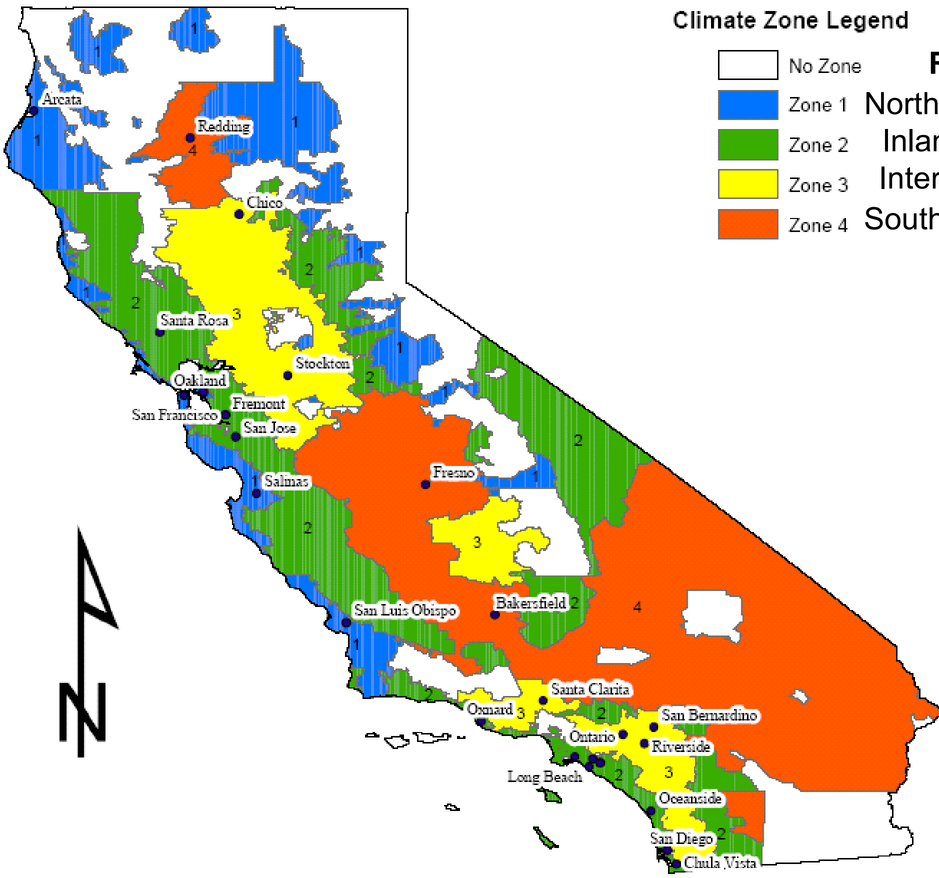
The Investor Owned Utilities in California[1] are conducting a pilot study to assess how residential and small commercial customers respond to various type of electricity pricing. The study has been undertaken as part of the California Public Utilities Commission Rulemaking 02-06-001 to better understand how customers respond to price and the impact of automated controls. Energy Commission staff obtained detailed consumption data and analyzed how residential customers responded to three different tariffs:

1. Time-of-Use Rates (TOU): Traditional On- and Off-peaking pricing with no demand response hardware.
2. Critical Peak Pricing Fixed (CPP_F): Similar to TOU pricing with the addition of a super-peak price of about 75 cents per kWh for up to 75 of the warmest hours per year. The time duration of the super-peak period is fixed between 2 and 7 p.m. Customers were not provided demand response hardware.
3. Critical Peak Pricing Variable (CPP_V): Similar to CPP_F with the exception that the super peak period can vary between 2 and 5 hours and is thus not fixed and customers were provided with automated demand response hardware.

The Time-of-Use and Critical Peak Pricing Fixed pilots were conducted throughout the state and customers divided into four different zones. **Figure 1** provides a map of these zones. Zone 1 is the coolest and Zone 4 the hottest. In reporting results later in this paper, we will use both the zone number and relative climate designation (cool, warm, hot, very hot) provided in **Figure 1**.

[1] Pacific Gas and Electric, Southern California Edison, and San Diego Gas and Electric

FIGURE 1 -- Climate Zones Used for Statewide Planning Pilot.



Climate Zone Legend

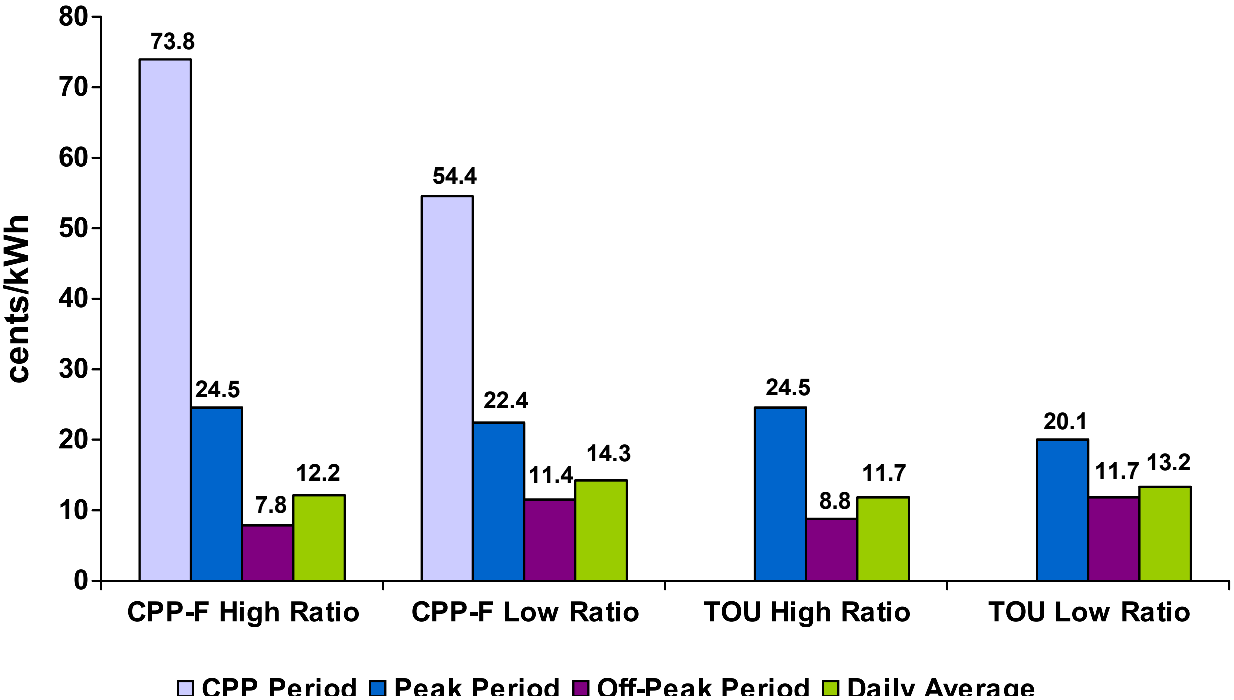
	Region	Percent of State	Climate
No Zone			
Zone 1	Northern Coastal	12%	cool
Zone 2	Inland Coastal	48%	warm
Zone 3	Interior Valleys	30%	hot
Zone 4	Southern Valleys	10%	very hot

Source: *Charles River Associates*[2]

On CPP days, super-peak prices are in effect. Non-CPP days include the remaining summer weekdays when the CPP price is not in effect but customers still face normal on-peak price. **Figure 2** provides representative retail prices.

[2] Charles River Associates were hired by the Investor-Owned Utilities to collect and analyze various aspects of this pilot study as well as to assist in its design.

FIGURE 2 -- Average Prices for Consumers on CPP_F, CPP_V, and TOU[3]



Source: *Charles River Associates*

Critical Peak Pricing Variable (CPP_V) residential tariffs were offered only in the SDG&E area.

CPP_F and TOU: CEC Methodology

To assess customer response to TOU and CPP_F tariffs, we averaged the hourly data for all customers within a specific zone and weighted these data to arrive at average hourly consumption by climate zone for TOU, CPP_F, and for the control sample. These calculations were done for both "pre-treatment" and "treatment" period dates.[4]

Thereafter comparisons were made between the control group and those customers on TOU or CPP_F tariffs. To correct for any self-selection bias, we used a difference of differences technique. This technique uses the differences in consumption between a control group and customers on the experimental

[3] A few variations that differed in on- and off-peak pricing were offered for CPP and TOU tariffs to enable elasticities to be estimated from this pilot

[4] Pre-treatment was from 6/1/03 to 6/30/03 and treatment from 7/1/03 to 10/31/03

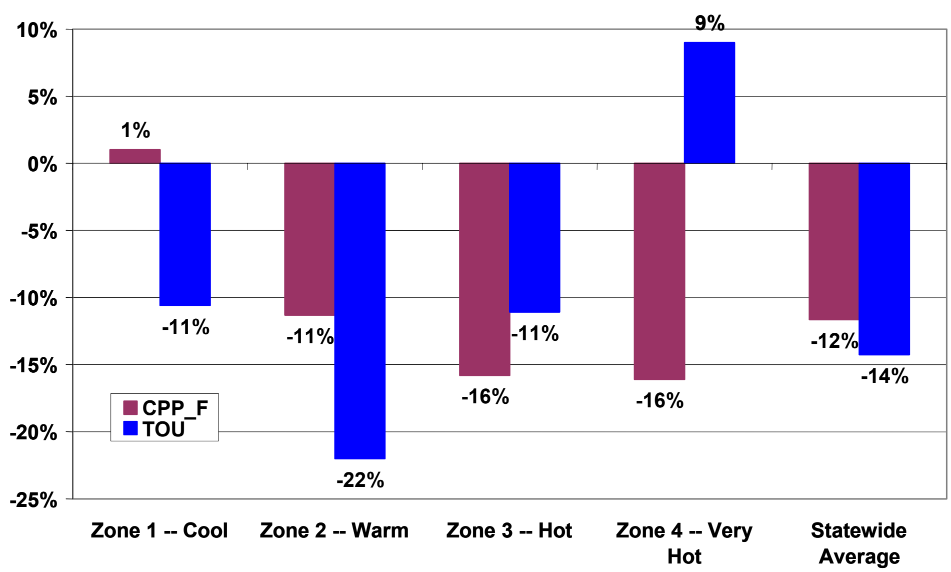
rates (CPP_F or TOU) in the pre-treatment and treatment periods and then subtracts the pre-treatment period difference from the treatment period. The purpose of these calculations is to account for the pre-existing energy use differences between the treatment and control groups.

Data were available for many customers for both May and June, but we chose to use June only as the pre-treatment period because May data were incomplete and because, due to the mild Spring climate in most of California, May energy consumption is very unlike "summer" consumption.

CPP_F and TOU: Savings Results

Both groups of customers reduced consumption during the peak period on days designated as CPP days. **Figure 3** illustrates the percent change of CPP_F and TOU compared to the Control group. Using statewide averages, CPP_F reduced energy use in the peak period by 12% while TOU customers declined by 14%. Only CPP customers in Zone 1 – Cool and TOU customers in Zone 4 – Very Hot did not reduce demand during peak periods on CPP days.

FIGURE 3 -- CEC Results -- Percent Change Compared to Control: Peak Period on CPP Days (June only as pre-treatment period)

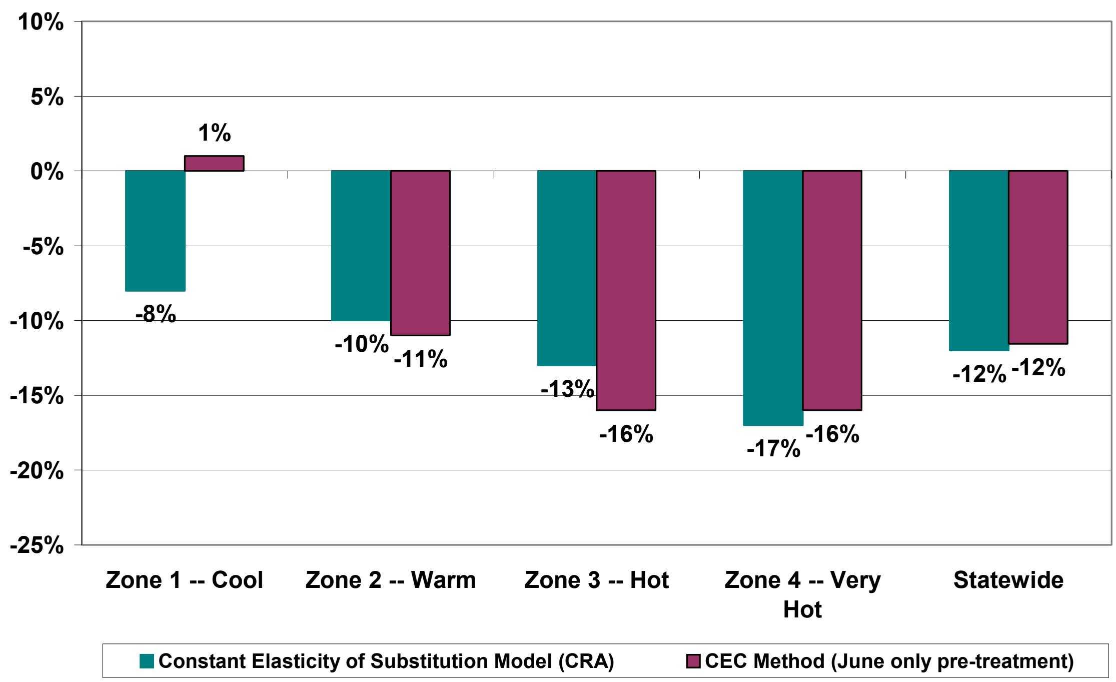


Energy savings of CPP customers in the hotter climate zones is larger than for TOU customers. However, TOU customers in Climate Zone 2 – Warm show a very large response of 22%. Later in the paper we discuss these results in more detail when we look at hourly, not just peak period, consumption.

Comparison to CRA's Results

Figure 4 compares CEC results for CPP_F customers during the peak period on CPP days to results from CRA's constant elasticity of substitution method.[5] CEC results in **Figure 4** use the same data (and are the same color) as in **Figure 3** for CPP_F. Statewide average reductions during peak period of 12% were found in using both methods, even though there are differences on a zone-by-zone basis. In our estimation all zones but Zone 1 – Cool agree reasonably well. Note that not only does absolute energy savings increase with temperature, but *percentage* savings increase as well.

FIGURE 4 – Comparison of Two Analytic Methods: Change in Consumption during Peak Period for CPP_F customers on Critical Peak Days --Summer 2003



[5] See CRA's Statewide Pricing Pilot Summer 2003 Impact Analysis for a discussion of this method.

Hourly Analysis

We have also conducted an hourly assessment of these data. We provide four figures depicting this analysis, again using June as the pre-treatment period.

Each image has three frames: the left frame, average hourly consumption during the pre-treatment "CPP" days (hotter days in June); the middle frame, average hourly consumption during the treatment period CPP days; and the right frame, average hourly consumption for the control group during the treatment period compared with the difference of differences for the CPP and TOU groups. The vertical lines in each frame delineate the peak time period (2 to 7 pm).

We first discuss each frame in more detail and then point out what we consider the most interesting aspect of each figure

The left frame illustrates consumption during the six highest California ISO load days in June, 2003. During this time period, all customers were facing "flat" [6] rates since the pricing experiment did not begin until July 1, 2003. Sample size can be rather small for the data associated with this frame and confidence intervals rather large.

The middle frame provides hourly consumption on CPP days for each of the groups. There were twelve CPP days during the summer of 2003.

95% confidence intervals are provided in the left and center frames. We did not include confidence intervals in the right frame for two reasons: complexity of calculations of these and the realization that these would have been large since the pre-treatment confidence intervals are themselves rather large. This is especially the case for TOU customers, whose sample size is small because the pilot was focused more of CPP_F customers.

The right frame of each image illustrates how consumption in the TOU group and the CPP_F in each zone differ from that of the control group in each hour. These hourly patterns indicate that the maximum reduction for the CPP_F group in Zones 3 -Hot and 4 – Very Hot occurs between about 4 p.m. and 6 p.m., consistent with the CAISO peak load hours.

The figures illustrate how consumption increases dramatically from the early morning hours through the late afternoon and from cool areas of the state to very hot areas.

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[6] For the sake of convenience we refer to the typical domestic service rate as a flat, non-time varying rate. However, all residential rates used in this experiment had tiered pricing for consumption in excess of their baseline.

Figure 5 – Climate Zone 1 – Cool on "CPP" Days shows hourly consumption even over the peak time period of less the 1 kWh. During the treatment period, **Figure 5** illustrates nearly identical consumption among the three difference groups.

FIGURE 5 -- Climate Zone 1 – Cool on "CPP" Days

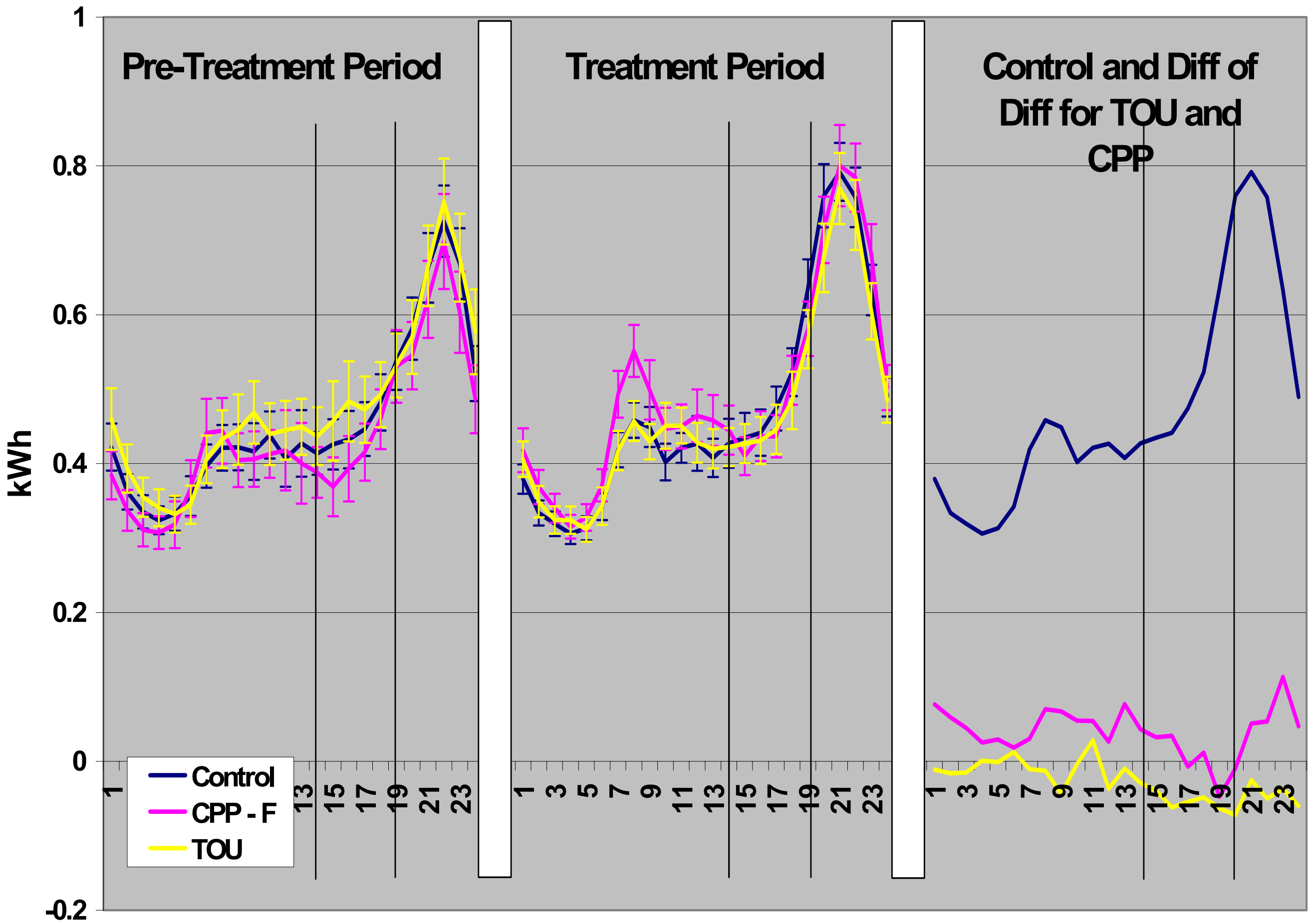
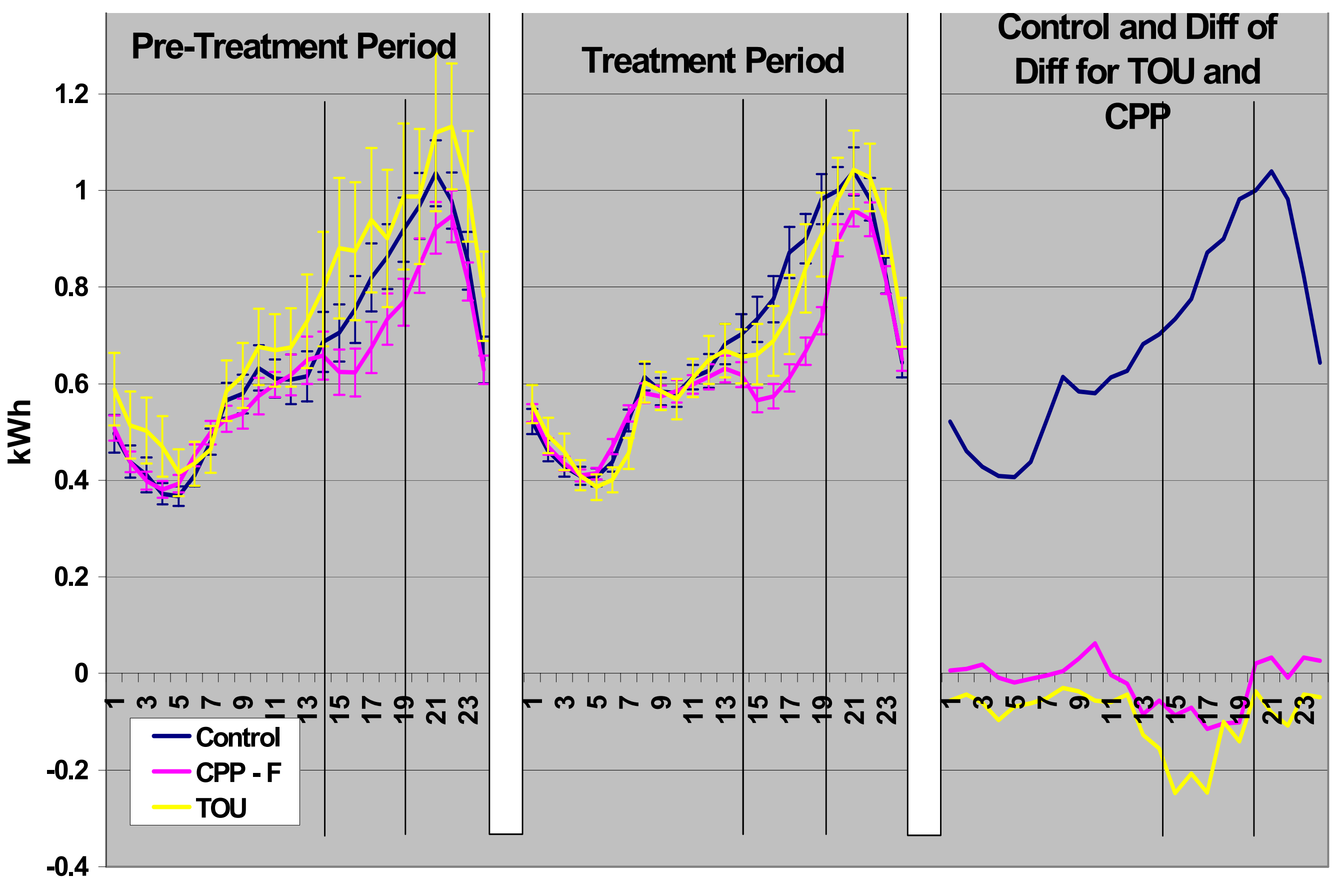


Figure 6 – Climate Zone 2 –Warm on "CPP" Days shows only a modest increase in consumption compared to **Figure 5.** However, in the peak period during the treatment period consumption of the CPP group is markedly different and lower by about .1kwh in each hour than the TOU group. However, the right frame shows TOU difference of differences consumption as less than the CPP group, due entirely to the pre-treatment period. This, of course, points out the obvious weakness of this technique when data in the pre-treatment period are limited.[7]

FIGURE 6 -- Climate Zone 2 – Warm on "CPP" Days



[7] We note here that the savings during the treatment period are great than the savings calculated using difference of differences for CPP_F customers on CPP days in all climate zones but Zone 1 – Cool.

In **Figure 7 Climate Zone 3 – Hot on "CPP" Days** we see a significant increase in consumption compared to the previous figure and a clear savings during the treatment period for CPP customers (middle frame of **Figure 7**). However, again due to relative consumption in the pre-treatment period, savings exhibited by CPP and TOU customers are similar in frame 3 (using difference of differences).

FIGURE 7 -- Climate Zone 3 – Hot on "CPP" Days

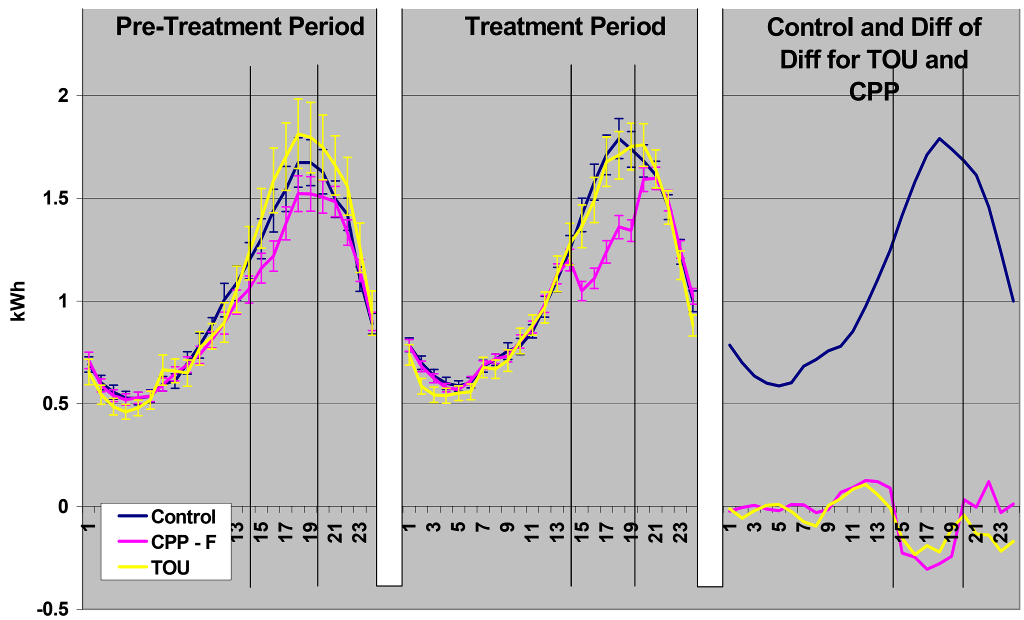
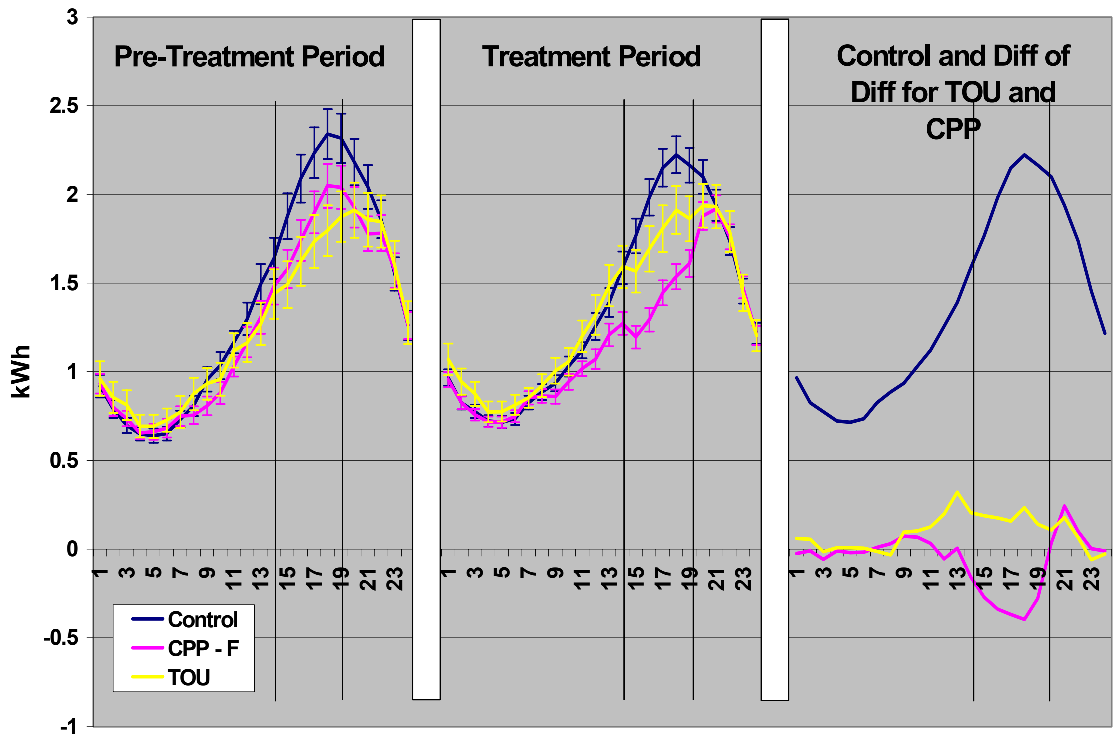


Figure 8 Climate Zone 4 – Very Hot on "CPP" Days. TOU customers on CPP afternoons actually show an increase in consumption when the difference of differences technique is used while CPP customers show a reduction of 16%. In part, these results are due to TOU customers exhibiting less consumption than the control growth in the pre-treatment period (the first frame in **Figure 8**), highlighting one of the shortcomings of this analytic technique. Nonetheless, during the treatment period (the second image on **Figure 8**), the CPP customers show a statistically significant reduction compared to the TOU and Control groups. This is of interest since much of California's residential air conditioning load growth is expected to occur in Zone 4.

FIGURE 8 -- Climate Zone 4 – Very Hot on "CPP" Day 1



CPP_V: Methodology

In assessing the response of CPP_V customers, we did not use a difference of differences techniques. CPP_V customers have "smart thermostats" capable of receiving a signal from the utility that automatically increases the temperature settings by a few degrees. Since no signals were sent in the pre-treatment period, we decided only to compare the control group and the CPP_V customers during the treatment period.

The Critical Peak Pricing Variable experiment was conducted only in the SDG&E area in Climate Zones 2 –Warm and 3 -- Hot. Enrollment was limited to single family households with central air conditioning systems. Customers were selected from a larger group who had volunteered for SDG&E's Smart Thermostat program. As it turned out, the experiment ended up with three groups of customers:

1. A Control Group on a traditional flat rate;[8]
2. A Smart Thermostat with flat rate group who had a smart thermostat capable of receiving signals from the utility but did not have time varying rates; and
3. The CPP_V with smart thermostat group who had a smart thermostat capable of receiving signals but were on critical peak prices that varied in duration. During the CPP events these customers faced "super-peak" prices on $.57 or $.77 per kWh. **Figure 2** provides representative prices.

CPP_V: Results

Looking only at the difference in consumption during the time of the 12 CPP events in the summer of 2003, the Smart Thermostat flat rate group reduced electricity use by 23% and the Smart Thermostat CPP_V group reduced use by 48% compared to the Control Group.

[8] For those who have followed this part of the experiment closely, in this analysis the control group was selected to be the non-curtailed C07 customers.

Figure 9 illustrates the average consumption of each group on the 12 event days of summer of 2003. The data are averaged over the entire duration of the daily event which varied from 2 to 5 hours. Maximum daily temperatures also have been included above the consumption data.

As a general rule, the percentage reduction between the Control and the CPP_V groups increased as Control group consumption went up. Or said another way, CPP_V saved more energy the hotter the day when compared to the Control. Generally speaking, the results can be summarized as follows: the smart thermostat alone accounted for a reduction of 23% while the smart thermostat plus a CPP_V rate resulted in twice that level of energy savings during the peak period.

FIGURE 9 -- SDG&E CPP_V Peak Period Average Consumption – Summer 2003

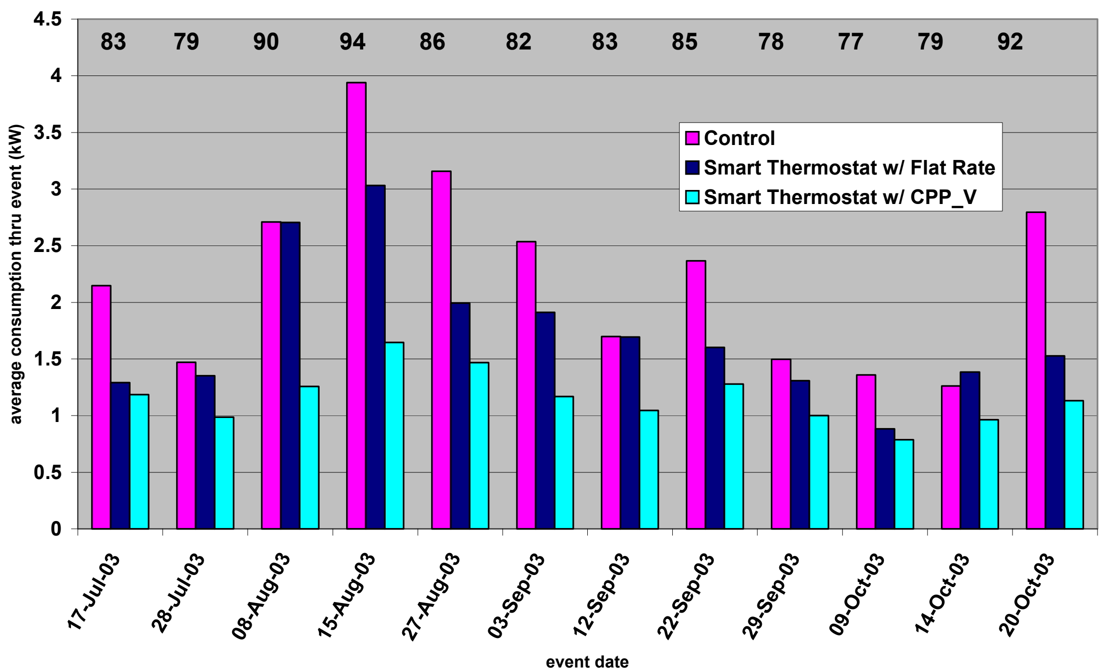
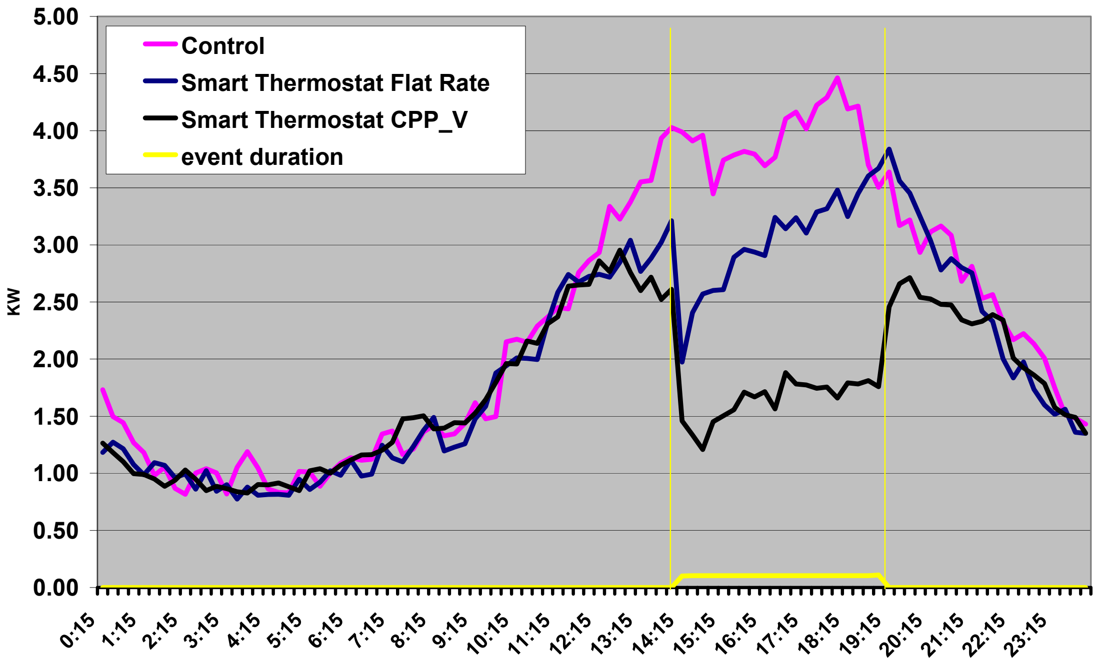


Figure 10 provides the results on a single, hot day (August 15, 2003) and illustrates average 15-minute consumption data. SDG&E set its signal at 14:00 and the event continued until 19:00. Loads for the control group steadily climbed thru the morning to about 4 kW and stayed in that range until 18:00 or so when loads started to decline. The other two groups showed the same sort of increasing loads until about 13:00 when loads leveled off somewhat. However, at 14:00 the Smart thermostat groups both exhibit a rapid reduction in load, with those on CPP_V tariffs remaining in the 1.5 to 2 kW range. Those with Smart Thermostats and flat tariffs initially drop but steadily climb to about 3.5 kW at about 18:00.

FIGURE 10 -- A Hot Day in SDG&E



Comparison to CRA's Results

CRA's results for CPP_V[9] indicate a reduction of 34% for customers on CPP_V rates with smart thermostats on event days. CEC results show a 48% reduction. It is not unexpected that the two difference methods yield slightly different results. We would be much more troubled if the results were showing large reductions in one case and increases in the other. However, since this is not the case, we can

[9] CRA uses a double-log model, see Table 1-5 of Statewide Pricing Pilot Summer 2003 Impact Analysis, 8/9/04 for details

safely conclude that the CPP_V rate with automated technology, a smart thermostat, results in savings in the range of 40%.

Conclusions

Our results for the Summer of 2003 indicate that customers do respond to price even without any automated controls. Response or expected savings is greater with automation that without. The combination of automation and a high price signal results in the largest savings. However, time varying rates, be they TOU or CPP, also result in reduction or energy savings in excess of 10% on event days.

Our analysis was conducted using data collected during the first summer of a pilot experiment that will span two summers. Additional questions that we will attempt to answer using data collected during the second summer include:

- Customer response when three event days are called in succession;
- More details on expected time duration of response and the value of such response;
- Whether aggregate or individual customer response changes during the second summer of the pilo; and,
- Finally, we will further investigate the issue of self-selection bias since as we have pointed out the difference of differences technique suffers from small sample size and large confidence intervals in the pre-treatment period.