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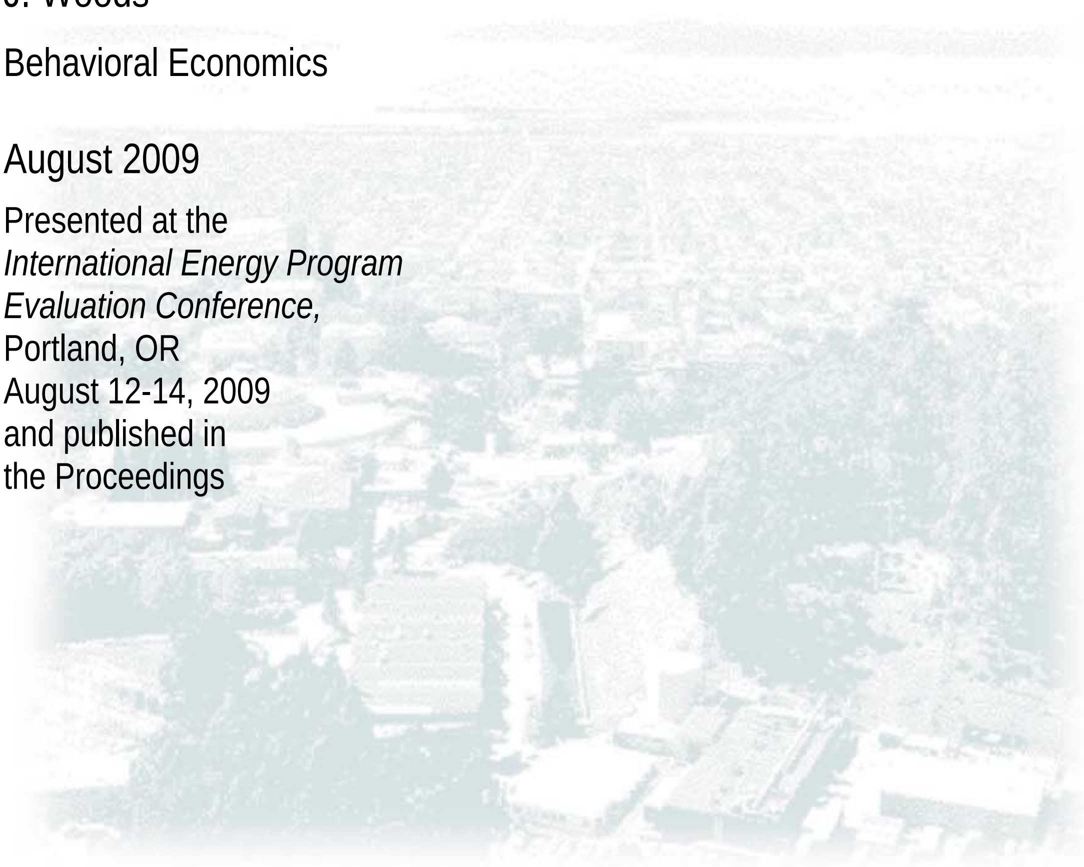

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Beyond the Price Effect in Time-of-Use Programs: Results from a Municipal Utility Pilot, 2007-2008

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ABSTRACT

This paper discusses results of a two-year collaborative research project between the authors and the Demand Response Research Center focused on behavioral response to a voluntary time-of-use pilot rate offered by the Sacramento Municipal Utilities District (SMUD) under the PowerChoice label. The project had two purposes: one was to assess the potential for increasing demand response through the introduction of enhanced information and real-time consumption feedback; the second was to better understand behavioral response to a TOU rate. Three successive waves of telephone surveys collected details about reasons for participation, actions taken, capacities and constraints to altering behavior, and a range of salient conditions, such as demographics and dwelling characteristics. Pre- and post-program interval meter data for participants and a comparison sample of households were also collected and analyzed to consider initial and season-change price effects of the rate and the effect of supplemental information treatments on response. Over half of surveyed participating households reported that they had made a great deal of effort to adjust their electricity consumption to the rate. Despite this, load data analysis revealed only minimal price effects; and, though households subjected to information treatments seemed to have learned from these treatments, load data analysis again detected only minimal effects on load. Given the currently high hopes for behavioral intervention and residential TOU rates, these unexpected results require explanation. We suggest a number of possibilities and discuss some implications for TOU programs, and for understanding demand response behavior and approaches to experiments with TOU rates.

Introduction

Between May 2007 and April 2009, Research Into Action, Inc. and Sacramento Municipal Utility District (SMUD) worked together to conduct research on a set of SMUD customers who voluntarily signed on to a time-of-use (TOU) rate pilot program launched under the PowerChoice label. This research project, funded by the California Public Interest Energy Research (PIER) program's Demand Response Research Center (DRRC) and supported by SMUD, had the goal of exploring the behavioral dynamics upon which successful demand response (DR) depends. To do so, we assessed customer response and the potential for increasing demand response through the introduction of enhanced information and real-time consumption feedback. This paper summarizes results of that project in light of other work on residential TOU.

The idea of TOU rates is nearly as old as the electricity industry. In the late 19th and early 20th century, the U.S. utility industry deliberated on both demand charges and time-of-day rates (Hausman & Neufeld 1984). Demand charges for large customers became firmly established by 1912, but time-of-use rates did not; by 1920, virtually none were offered (Hausman & Neufeld 1984).[1] Around the time of the energy crises of the 1970s, however, a number of utilities offered rates on an experimental basis in the

[1] *Time-of-use* as used here is also termed *time-of-day*, especially in older studies. It refers to a rate with different unit prices for different blocks of time, as defined in Faruqui & Earle (2006), as distinct from other time-based rates (such as *critical peak pricing*). Many utilities offer other seasonal rates, of course, which are also time-differentiated.

residential sector (Faruqui & Earle 2006; Sexton et al. 1989). The Public Utilities Regulatory Policies Act of 1978 also set requirements for considering time-of-use rates, for which the Energy Policy Act of 2005 (EPACT 2005) specified additional standards (U.S. DOE 2006). Evaluations for a number of these experimental rates showed that households were price responsive to the TOU rates they experienced (Aigner 2005; U.S. DOE 2006). However, due to issues of experimental design or practice and fundamental difficulties in transferring the results from one case to another, no clear picture emerged of how much response should be expected for residential customers under given circumstances (Aigner 1985; Taylor 1985). This seems to remain largely true today; and though several recent studies report that residential customers shift load in response to TOU rates, others do not (Alexander 2007).

Some utilities outside the United States have mandatory TOU rates for residential customers, but most, if not all, residential TOU rates in the United States are voluntary. Citing an EPRI study, King (2001) notes that over half of 123 U.S. investor-owned utilities (IOUs) offer TOU rates to their residential customers, but less than one percent of the customers subscribes to the TOU rates.[2] Thus, though residential TOU rates are sound from certain conceptual standpoints (Energy & Environmental Economics 2006), few consumers adopt the rates when offered.

These background conditions may be changing. Many million residential customers in the United States and Canada are scheduled to receive "smart meters" in the coming years. These meters will make it much easier for utilities to implement new rate structures, including TOU rates. A key expectation is that time-varying rates will become more common and, in some situations, mandatory for residential, as well as commercial, customers. This literature sets a broader context for the current project.

Methodology

With recent exceptions (Ontario Energy Board 2007; Pederson 2007; Tiedemann 2007), most past studies on residential demand response have examined only aggregate load effects under TOU rates. This project was designed to not only examine load effects, but to also consider the *how* and *why* of residential customer ability and willingness to engage in demand reduction behaviors, and to link this social and behavioral view to observed changes in demand.

Research Design

The research project used a customer *concerns, capacities, and conditions* (3-Cs) framework (Lutzenhiser et al. 2002) to aid in developing questions and to interpret what individuals and their households did in response to the rate. Within this basic framework, the project tested whether giving customers extra information and encouragement tailored to the TOU rate actually increased their response. Two information interventions were tested: one a series of communications delivered by mail; the second, a real-time electricity-use feedback monitor. The analysis relied on a combination of interval load meter data and three successive surveys of the TOU rate participants. Load interval meter data were also obtained for SMUD's Load Research Sample—108 households that served as the control group for load-related analyses.

The Enhanced Information Treatment. This treatment was administered to a randomly selected set of participants, comprising about half of the total PowerChoice participant population who had begun on the rate in summer 2007.[3] The enhanced information consisted of a series of "newsy" (content rich) letters sent

[2] Another recent survey of TOU and DR rates, covering the past and current offerings of 65 U.S. and international utilities, found that 50 of these utilities (41 of 50 in the U.S.) offered residential TOU rates (Energy & Environmental Economics 2006).

[3] Some households were added onto the rate in late 2007, due to problems with meter installations. These late-on households therefore did not have Summer 2007 load data and were not used in the comparisons of treatment vs. non-treatment groups.

periodically throughout the project period and a refrigerator magnet with tariff details graphically presented for easy reference. This treatment was intended to provide some information on how to change behavior effectively, plus convey a normative nature of the activity using elements of Community-Based Social Marketing (McKenzie-Mohr & Smith 1999). Toward the community aspect, participants in this group were invited to respond with their own ideas and questions; some of them did.

The Monitor Treatment. This treatment was administered to 50 households who volunteered to accept and install a wireless real-time electricity-use feedback monitor.[4]

The Rate

The PowerChoice rate began in May 2007 and is scheduled to run until September 31, 2009.[5] Customers signed an agreement to participate for the two years, yet were allowed to drop off the rate with a 30-day notice. As seen in **Table 1**, the PowerChoice TOU rate was complex, specifying three seasons (four periods), three different rates per weekday (four daily periods), and two rate periods for weekend days and holidays. The ratio of peak to off-peak price was 2.5 for the Summer Season (July and August) and 1.5 for the Winter Season.[6]

Table 1. The PowerChoice TOU Rates in 2008

Rate Period	SUMMER: July and August	SWING: June and September	WINTER: October through May
Weekday Off-Peak	10 pm to Noon (9.05¢)	10 pm to Noon (8.32¢)	10 pm to 6 am (7.61¢)
Weekday On-Peak	Noon to 5 pm (17.79¢)	Noon to 5 pm (12.98¢)	6 am to 5 pm (9.74¢)
Weekday Super-Peak	5 pm to 8 pm (23.02¢)	5 pm to 8 pm (15.64¢)	5 pm to 8 pm (10.73¢)
Weekday On-Peak	8 pm to 10 pm (17.79¢)	8 pm to 10 pm (12.98¢)	8 pm to 10 pm (9.74¢)
Weekend and Holiday Off-Peak	10 pm to Noon (9.05¢)	10 pm to Noon (8.32¢)	10 pm to 6 am (7.61¢)
Weekend and Holiday On-Peak	Noon to 10 pm (17.79¢)	Noon to 10 pm (12.98¢)	6 am to 10 pm (9.74¢)

The rate also included a *consumption adjustment*, which constituted a bonus payment or an extra charge based on whether the household's monthly consumption was less or greater than 1,000 kWh. The level of the bonus or extra charge depended on how much total consumption was below or above the 1,000 kWh cutoff-point and applied to the entire bill, rather than to a block. Credits applied were up to 20% of the pre-adjusted bill; extra charges applied could range between 20% and 50% of the total pre-adjusted bill.

With these combined features, the TOU tariff was designed to encourage shifting electricity use from On-Peak to Off-Peak hours, especially in the Summer period, but also to offer a reward for lower electricity consumption overall.

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[4] Prior to receiving their monitor, volunteers were asked to sign an agreement stating their commitment to install the monitor and participant in a follow-up survey regarding their use and opinion of the monitor,

[5] In January 2008, associated with a general rate increase for SMUD residential customers, prices on the TOU rate increased.

[6] Tiedemann (2007) found a median peak to off-peak price ratio of 3.6 over 24 residential TOU rates reviewed. Thus the peak to off-peak ratio in the PowerChoice TOU rate is somewhat lower than used for many other residential TOU rates.

Recruitment

PowerChoice participants were recruited by mail and phone calls with small incentives ($25 gift certificates) offered as inducements to some customers. Of the 30,000 households contacted by SMUD, approximately 330 households signed participation agreements—about the same uptake as the average reported for residential TOU rates among U.S. IOUs which offer them (King 2001). As volunteers, participating households self-selected into the program; thus, statistically, their experience cannot be treated as representing that of households that might be recruited by other means or if a TOU rate were mandatory. This is true of any study in which participation on the rate or in the experiment is voluntary. Therefore, as with any case study, results do not necessarily represent what would happen in other situations. The volunteer participants it turned out were almost entirely single-family homes, much more likely to include an adult over age 65 (44% versus 26%), and less likely to include children (25% versus 38%) as compared to other single-family households in the SMUD service territory. Additionally, an analysis after the program began demonstrated that for the PowerChoice rate studied here, it would have been difficult for most customers to save money on the PowerChoice rate relative to the standard rate.

Load meter data were collected at 15-minute intervals from participating households, as well as for the Load Research Sample that served as a control group. Load data before the PowerChoice rate was collected for comparison, but because of problems with meter installation, this pre-rate load data was more limited than expected. To gather information on participation and behavior, three successive surveys of PowerChoice participants were conducted. **Table 2** summarizes these three surveys and their response rates.

Table 2. Summary of Response Rates to Participant Surveys

Survey	Dates	Main Purpose of the Survey	Number of Responses	Percent of TOU Households
Wave 1	August and September 2007	Collect demographic data, information on household equipment, rationale for joining PowerChoice, and baseline data on participant actions. All households currently on the rate were called.	123	58%
Wave 2	December 2007	Collect first reactions to information treatment, winter actions, and additional questions on first summer. Only Wave 1 respondents re-surveyed.	91	47%
Wave 3	September 2008	Collect post-treatment actions from all participants, details on monitor use for monitor group, and final respondent comments on the program; also to collect demographic and equipment data for households not surveyed in Wave 1. Surveys were attempted for all households still on the TOU rate.	170	72%

Note: The percentage of households on the rate varied throughout the study period.

Findings

The complete results of this project may be found in Peters et al. (2008, 2009), published by the DRRC. The report includes extensive discussion of demographics, survey results, and behaviors, as well as an analysis of consumption by self-reported level of household effort and perceived success working with the TOU rate. Specific results discussed here focus on: 1) differences in load shapes; 2) changes in consumption associated with seasonal rate changes; 3) short- and longer-term effects related to information treatments; and 4) reported behavioral response to the PowerChoice rate. First, we introduce load shape comparisons as a way to explore the overall differences between sample and comparison groups.

Load Shapes: A Way to Look at Differences

The distributions of normalized hourly loads between single-family households in PowerChoice and those in the Load Research Sample (control group) were graphically compared for each season and day type, combining data across 2007 and 2008. The median load share (percent of daily load) for each hour is marked by a horizontal line ("the waist") in the center of the corresponding "box" or "hourglass."[7] The weekday load shape comparison for the Summer season (**Figure 1**) shows that mid- and late-afternoons for the PowerChoice participants were lower and flatter than those for the control group, represented as a flattened peak period. Load shares for the mid-morning hours, from 8 am to 11 am, were correspondingly higher for PowerChoice participants than for the control group. The differences are strongest for Summer season weekdays, but are also evident for Summer weekends. On the weekend load-shape comparison (**Figure 2**), the higher load shares during the mid-morning hours suggest that some domestic chores may have been shifted to weekend mornings. Results for the two Swing season months, June and September (not shown) are both similar to the Summer season results.

These comparisons for Summer show that the load shapes of PowerChoice participants were different than for the control group, and in ways that roughly correspond to the price differentials. However, these graphical comparisons do not prove that the differences were due to *changes* that households made relative to previous patterns, as opposed to selection onto the rate. Unfortunately, the load interval data stream starts only a few weeks before most households started on the PowerChoice tariff—usually in the Spring rather than Summer season. As a result, there can be no robust comparison of PowerChoice participant household load shapes before and after the rate.

For the Winter season, however, the load shapes of PowerChoice participant households and the control sample were much more closely matched. Though not proof, the much closer match between PowerChoice participant load shapes and control sample load shapes during the Winter tariff provides some suggestion that the baseline (pre-PowerChoice) load shapes between PowerChoice and the Load Research Sample might be similar, and thus that PowerChoice participants were successfully reducing Super-Peak and Peak load shares during Summer.

Considering only single-family homes, PowerChoice participants had lower average Summer electricity consumption than the Load Research Sample. The average annual consumption in Summer 2008 for PowerChoice participants was 30.6 kWh/day, while that for the Load Research Sample was 39.4 kWh/day.

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[7] The lower and upper ends of each box represent the first and third quartile, respectively, of the distribution of load shares for the given hour; the top and bottom lines mark the 10th and 90th percentiles, respectively. Toward a proper statistical comparison, each box also shows the upper and lower confidence bound for a 90% confidence interval on the median. These are show as "notches" where the hourglass sides turn from angled to straight.

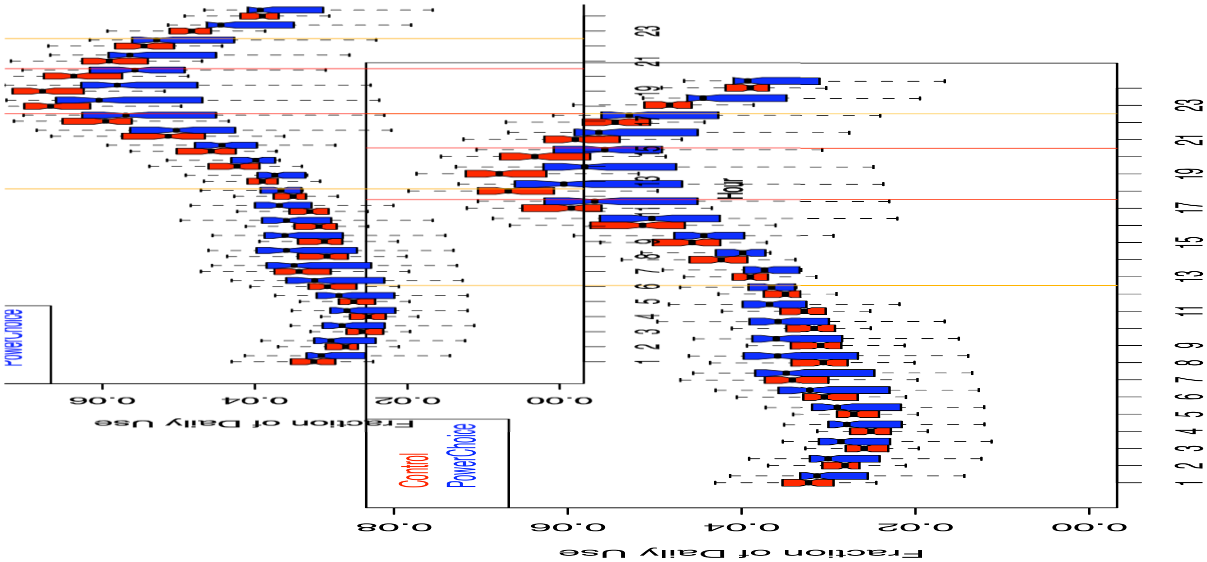

Figure 1. Normalized load shapes for Control Group and PowerChoice customers: Summer Weekday

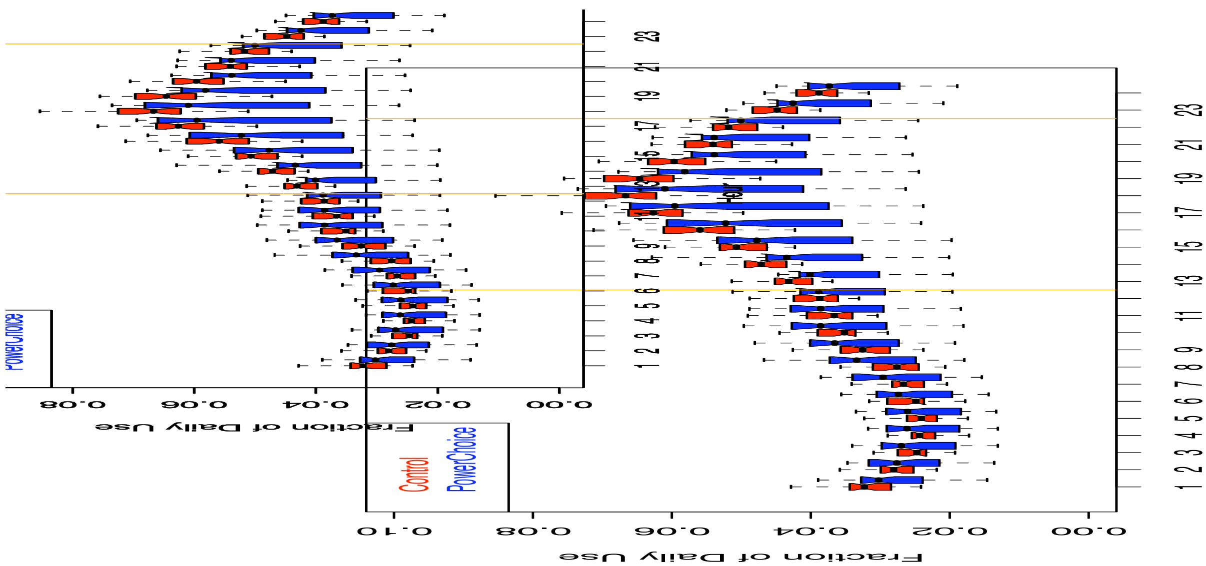

Figure 2. Normalized load shapes for Control Group and PowerChoice customers: Summer Weekend

Testing for Seasonal Price Effects

If participating households change electricity usage patterns in response to rate changes in the short-term, this response may be visible at each of the rate transition points: switching from their standard rate to PowerChoice; and then later, as the rate changes from Summer to Swing season, from Swing to Winter season, and from Winter again to Swing and then to Summer.

The research team's approach was to define a statistical model that detects changes of individual households in the PowerChoice participant group as compared to the average of the control group. Only single-family homes were analyzed for both samples. We used a *linear mixed-effect* model to relate the average kWh use of the control group linearly to the individual PowerChoice kWh, first before the rate transition and again after the transition. The relationship between the average kWh use of the control group and the PowerChoice households' kWh is modeled as a linear relationship. Each household has an estimated offset, defining how different its use is, on average, from the control group, and also two parameters that define how much an increase in use is observed for each kWh increase in use by the control group. If the relationship changes right after the transition period, then this is considered a price effect. Thus, the control group serves to calibrate changes in consumption for the PowerChoice group. This model was constructed for each of the rate periods defined on weekdays and weekends.

Initial Price Effects. To test initial price effects, when the household entered onto the PowerChoice rate, the models used on-rate observations that were within 30 days of the date the participating household went onto the PowerChoice rate. Data more than 30 days after the transition point were excluded because they are too likely to be different due to reasons other than the introduction of the PowerChoice rate. As to the pre-program period, households with less than 16 days of pre-PowerChoice data were excluded from this analysis, since otherwise there was too much statistical noise to detect effects.[8]

The statistical tests showed statistically significant price effects for transition onto the rate for only two periods: weekend mornings and weekday late evenings. **Table 3** summarizes results from the eight statistical tests.

Table 3. Initial Price Effects of PowerChoice Rate

Tariff Period (Summer/Swing Hours: June - September)	**Statistically Significant Change***
Weekday Off-Peak Early (7 am to Noon)	None
Weekday On-Peak Early (Noon to 5 pm)	None
Weekday Super Peak (5 pm to 8 pm)	None
Weekday On-Peak Late (8 pm to 10 pm)	None
Weekday Off-Peak Late (10 pm to 7 am)	Decrease
Weekend Off-Peak Early (7 am to Noon)	Increase
Weekend On-Peak (Noon to 10 pm)	None
Weekend Off-Peak Late (10 pm to 7 am)	None

* Significance tested at p=0.10.

During weekday mornings, PowerChoice customers used slightly more on weekday mornings (Off-Peak Early) after the rate started, versus before, as calibrated to usage in the control sample. This increment, while only 3% over changes in the control sample for that period, suggests that some electricity-consuming tasks—perhaps laundry, dishwashing, or cooking—may have been delayed until weekend mornings, rather than being done during the higher-price periods during the week.

During weekday late evenings (Off-Peak Late), PowerChoice customers used an average of about 3% less after the rate began than before, again as calibrated to the control sample. As one participant noted, long tasks, such as laundry, starting in the Off-Peak Late period (10 pm to 7 am) must be finished even later, making the Off-Peak Late period too late for many households to complete domestic tasks. This

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[8] Because many households had less than a month of pre-tariff load interval data available, we used a relatively short limit in order to maximize the number of households for which comparisons were possible.

consideration may have contributed to the PowerChoice participants' relatively lowered Weekday Off-Peak Late consumption.

In summary, statistical tests revealed a small increase in load for the Weekend Off-Peak period, which might be explained as load-shifting to lower-priced hours, but also a decrease in load for the evening Off-Peak period during the weekdays, with no evident theoretical explanation—perhaps because some households went to bed early or shifted chores to another period rather than start them so late. But there were no statistically significant effects suggesting a reduction in load during the Super-Peak or On-Peak periods.

There are a variety of possible explanations for this lackluster evidence on initial price effects. It is possible that the rates did not induce much change; but it is also true that the sample is small relative to the natural variability of load data, which makes changes difficult to detect. This "natural" variability includes not only weather and other temporal effects, but also normal changes in the household—such as fewer or more members, new appliances, an illness, etc. Also, even where customers were price-responsive in accordance with the TOU rate, it may have taken a while for them to react to the new rate and to learn how to adjust their loads to the various periods.

Transition Periods: Summer to Swing. The research team also tested what happened when households transitioned off the Summer rates to the lower Swing season rates—the month of September. The statistical significance of the test for each rate period is shown in **Table 4**. Here several statistically significant *increases* in consumption were detected: during Weekday Super-Peak, and both Weekend and Weekday On-Peak Early periods. These suggest some relaxation of load shifting activity or, alternatively, a basic price effect in which consumption is increased in response to lowered price. That is, since the price decreased in all rate periods, increased consumption might be expected. During the Weekday Off-Peak Late period, there was a statistically significant *decrease* in consumption, perhaps in balance to the increased consumption during Super-Peak and On-Peak periods earlier in the day, since usage in higher-price periods began to command less of a premium than it did during the Summer period.

Table 4. Price Effect for Transition from Summer to Swing (late Summer/Fall) Rate

Tariff Period (Summer/Swing Hours: June - September)	**Statistically Significant Change***
Weekday Off-Peak Early (7 am to Noon)	None
Weekday On-Peak Early (Noon to 5 pm)	Increase
Weekday Super Peak (5 pm to 8 pm)	Increase
Weekday On-Peak Late (8 pm to 10 pm)	None
Weekday Off-Peak Late (10 pm to 7 am)	Decrease
Weekend Off-Peak Early (7 am to Noon)	None
Weekend On-Peak (Noon to 10 pm)	Increase
Weekend Off-Peak Late (10 pm to 7 am)	None

* Significance tested at p=0.10.

Information Intervention Effects

The research team tested the effectiveness of the two types of information interventions: Enhanced Information Treatment (enhanced information) and Monitor Treatment (monitor), as described above. The Enhanced Information Treatment was implemented to a randomly selected set of PowerChoice participants, while monitors were distributed only to households that volunteered to accept a free monitor and to use it. A total of 50 monitors were provided in June 2008, and almost all households receiving one reported that they had successfully installed it. Both treatments were tested separately at the end of the second summer (i.e., a cumulative effect for the Enhanced Information Treatment), comparing load between the summer of 2007, before treatments began, and the summer of 2008. Note that some households received *both* treatments.

A *random effects* model was used to detect the cumulative effects of each treatment. This allowed tracking of differences in the consumption of individual households, rather than the groups in aggregate. Models for the enhanced information and monitor groups were estimated separately for each of eight different summertime periods separately (**Table 3,** above). There is an important caveat to the tests for the monitor group: strictly, the validity of inference from these statistical tests rests on the assumption that the monitor group was randomly assigned, which was not the case here.

Despite the many (16) tests, only two statistically significant differences were found. During the Weekend On-Peak period, households that received enhanced information and the monitor had slightly lower consumption than in the previous year, compared to those who had a monitor alone. And, again, during the Weekend On-Peak period, those in the monitor group had slightly reduced consumption relative to the previous year, compared to other households. So there is some evidence that the feedback monitors made a difference, though self-selection is a concern. And furthermore, when doing multiple tests, there is a good chance of getting a "false positive" result, inferring a difference when there is none.

There are several possible explanations as to why there was so little evidence of significant changes in load in response to these information interventions. Perhaps the most important to consider is the possibility that for these households, there were no real effects of the treatments, over and above effects of the rate—which itself had only minor detectable effects. In fact, as to the enhanced information, finding that information has no effect on energy consumption itself is probably more typical than not (Lutzenhiser 2002; Owens & Driffill 2006; Sexton et al. 1989). These are households that appear to be already engaged with their electricity consumption: they were among the rate households who agreed to accept the TOU rate and most reported that they pursued conservation actions on their own. Furthermore, all PowerChoice households received some information from the program—through the introductory material and through SMUD mailings to remind them of rate changes. Anyone with Internet access could also consult the SMUD consumer website, which provided general electricity conservation tips. So the information and encouragement provided in the enhanced information may not have provided much new over these baseline sources. As to the monitor group, research has generally shown that feedback using in-home monitors often reduces electricity consumption (Darby 2006). But for the current project—again, the monitor is layered on top of a rate treatment, with which households already had a year's experience.

A second possibility is that, as with the price effect, the effects of either treatment are simply quite small, and most cannot be detected due to a combination of natural consumption variability and a somewhat small sample size. This variability, relative to the expected scale of the effects of interventions, has consequences for how behavioral experiments on electricity consumption are designed. For example, collecting data on behavior is relatively time-consuming and often oriented to detecting and understanding variability, which can create some tension with the more aggregate and bottom-line oriented nature of most quantitative studies.

Behavior Findings

The surveys provided a great deal of insight into customer behavior for a residential TOU program. Perhaps explaining the reason why these customers volunteer for the program, most households surveyed said that they already conserved energy prior to volunteering for the new rate. In the first survey wave, many of the households could describe activities they had pursued and were pursuing that demonstrated this concern. We have, however, no comparable baseline for non-participants.

Once on the rate, the second and third wave surveys found that households thought that they made greater effort to shift and to conserve under the TOU rate. Over half said that they had made a great deal of effort to adjust to the rate. For many households, this effort came through as genuine in their open-ended responses to survey questions. In fact, some survey respondents seemed to go to extreme measures, overhauling schedules for domestic tasks—like changing when they ate dinner, or staying up after 10 pm or getting up at 5 am to do laundry and other household chores. Surveyed participants also seemed clearly to understand that the rate was designed to emphasize shifting. **Table 5** provides a high-level view of what surveyed participants said they changed after joining PowerChoice.[9]

Table 5. Most Common Shifting and Conservation Actions in Response to PowerChoice (self-reports)

Activity	**Percentage Reporting a Change in Usage**
Clothes Dryer – *changed timing or used less*	91%
Dishwasher – *changed timing or used less*	68%
Central Air Conditioner – *changed hours of use, used fewer hours, or increased set-point*	63%
Installed CFLs	62%
Cooking – *changed timing, method, or foods prepared*	28%
Pool Pump – *timing or duration*	20% of all, 80% of pool owners

Something that has not been explored with customers in many past studies is whether households have the capacity to implement these activities, or whether there are constraints that take increased effort or cause more difficulties for any members of the household. A modest proportion of surveyed PowerChoice participants indicated that their attempts to change their electricity consumption to better fit the TOU rate caused some increased effort and decreased comfort and convenience (30%), as well as created tensions within the household (10%). Conservation and time-of-use shifting may be stressful to individuals and families, whether or not efforts are needed or effective from a power system point-of-view. Similar findings have been documented in a recent Swedish study on household energy conservation, which suggests that impacts from increases in household energy conservation may fall disproportionately on the women in a household (Carlsson-Kanyama & Lindén 2007). In particular, three actions were difficult for households: increasing temperatures was difficult for households with elderly, sick, or people with medical conditions; changing meal times or censuring certain electricity uses caused disagreements and strain in some families; and, while some 20% reported sometimes or always line- or rack-drying clothes, there was little to no willingness to do this among nearly 50% of the households.

The utility bill that customers received did not guide them as to whether or not they had saved or not on the rate. This was the top suggestion made by survey respondents when asked about what further information they would have liked from the utility. However, on at least some past TOU rates programs, once customers received cost comparisons, some tended to drop off the rate (Faruqui & Earle 2006); TOU bills may vary from cost premiums to savings from month-to-month and, overall, savings may often be quite modest. In the survey responses, customers had a range of suggestions about the bill format, information provided on the bill, and the rate itself—largely because they wanted to know more about the effects of their actions. Though most customers may not have had an accurate idea of whether they lost or gained on the

[9] With the exception of the data on CFL installation, which is from the Wave 2 survey, all survey results are from the Wave 3 survey (Summer 2008) and in response to direct (closed-end) questions about what activities the household changed.

rate, most offered an opinion on this issue when asked; overall, half of surveyed participants judged that they had saved money on the rate. Customers who said that they did not like the rate or the bills they received on the rate were more likely to drop off the rate. This filtering could reduce the potential benefits of the rate to the electricity system and utility; for example, higher-using consumers who balk at consumption charges probably tend to have higher peak loads that can potentially be shifted.

Whether the rate effects "wear off" with familiarity or, alternatively, that households slowly learn how to best deal with the rate, is still in question; the survey results did not indicate such a drop-off in the second year, relative to the first, and did suggest that customers continued to learn what to do. About half the households surveyed said that they made a greater effort to conserve and shift energy during the second summer than the first, and only a few said they made more effort in the first summer.

Implications of this Research

These findings suggest several recommendations for TOU programs, opportunities to understand demand-response behaviors, and investigations of demand-response behavior in TOU programs.

TOU programs need to construct rates and programs carefully, with consideration of more than the economics: billing design needs to be used to communicate the benefits and losses incurred by households; and information should be provided to customers to help them manage their activities, such as the magnet that was highly valued by those that received it. To the extent possible, rates should minimize major changes to household patterns—especially at key family times, such as mealtime.

There are some promising household end-uses that should be targeted for TOU programs: air conditioning, clothes drying, and pool-pump timing. However, the small-time behaviors that take lots of customer effort, but have miniscule effect on energy use, should not be promoted.

Further study of residential behaviors under TOU rates seems called for, since TOU rates may affect many households in the future. Such studies need to be designed to ensure acquiring adequate baseline data and sample sizes. These studies should even more clearly explore what behaviors align with target time periods to ensure the response is within customer capability and capacity. Equity considerations may also be quite important (Alexander 2007; Robinson & Rowlands 2006). Finally, the lack of volunteers for these rates needs to be understood. Is the low acceptance of rate a matter of not understanding what is entailed or are there strong barriers to such rates that need to be addressed for these programs to be successful, or is it something else?

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