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SmartPricing Options Final Evaluation

The final report on pilot design, implementation, and evaluation of the Sacramento Municipal Utility District's Consumer Behavior Study

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U.S. Department of Energy

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1.0 Pilot Project Continuation

The Department of Energy's Smart Grid Investment Grant (SGIG) offered SMUD the opportunity to test the impacts of dynamic pricing and enabling smart grid technology on peak load shaving, energy conservation, and customer satisfaction using rigorous experimental research methods. SMUD implemented the first year of the SmartPricing Options (SPO) pilot in June 2012 and second year of the pilot in June 2013. SMUD is one of eleven utilities conducting a Consumer Behavior Study (CBS), a dynamic pricing trial, funded in part by the SGIG. This report examines the implementation, operations, and load impacts of the SPO pilot after the completion of the second year.

1.1 About SMUD

SMUD is a publicly-owned electric utility governed by a seven-member Board of Directors. Serving approximately 600,000 customers and a total population of about 1.4 million, SMUD is the sixth-largest public utility in the United States. SMUD's 900-square-mile service territory encompasses Sacramento County and a small portion of Placer County.

SMUD has been providing public power to the Sacramento region since 1946, and our energy efficiency and renewable energy programs are recognized nationally for leadership and innovation. For each of the last eight years, SMUD has received the highest customer satisfaction ratings of any utility in California in the J.D. Power and Associates survey and received the second-highest score in the United States for commercial customer satisfaction in 2010.

1.2 Consumer Behavior Study Background

SMUD was awarded a $127M grant toward a $308M smart grid project from the U.S. Department of Energy (DOE) as part of the American Recovery and Reinvestment Act of 2009 (ARRA). SMUD's SmartSacramento®[1] project is a result of an effective and strategic partnership between SMUD, California State University Sacramento, State of California's Department of General Services, County of Sacramento, Los Rios Community College District, Elk Grove Unified School District, and the Sacramento City Unified School District. Together with our partners, SMUD is implementing a smart grid in Sacramento that can serve as a model for California and the rest of the United States.

[1] ®A registered service mark of the Sacramento Municipal Utility District.

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Included in SMUD's proposal to DOE was an agreement to participate in a cross-utility research effort to study the impacts of dynamic pricing in various regions. This study accounted for approximately 4% of SMUD's proposed smart grid project budget. Utility participants who conducted a consumer behavior study would not only benefit from the research opportunity within their own service territory, but the findings would be publicly available as individual utility analyses as well as an aggregate assessment across consumer behavior studies to be conducted by Lawrence Berkeley National Laboratory. Eleven utilities participated in the research effort and many studies have been completed. The research results are anticipated to be referenced by strategic planners within utilities, policy makers, technology developers and manufactures, and others in the utility space with an interest in pricing design, behavior change, and enabling technology development.

Please refer to the Interim Evaluation report of SMUD's Smart Pricing Options for a detailed description of the study background, objectives, planning and design. The interim report can be found at:

https://www.smartgrid.gov/sites/default/files/MASTER_SMUD%20CBS%20Interim%20Evaluation_Final_SUBMITTED%20TO%20TAG%2020131023.pdf

1.3 How This Report Is Organized

This report is divided into two sections and an appendix.

> *Section I: Project Operations* discusses the logistics of putting the project plan and research design into action for the second year of the pilot. Details on recruitment and first year implementation can be found in the interim evaluation report at the above link. Section 1 focuses on additional lessons learned and key takeaways in terms of pilot operations.
>
> *Section II: The Final Evaluation* is a comprehensive load impact report covering the load impacts, average impacts over the two summers, customer attrition, impact persistence, customer satisfaction, and customer choice analysis from the second summer conducted by Nexant.[2] The report is included in its entirety as it was prepared for SMUD. This section was written in a manner in which it can be extracted from this report and stand alone as an independent document. As such, it contains some brief areas of redundancy with *Section I* of this report, providing high level details for contextual value within the impact discussion.

[2] The interim report was produced by Freeman, Sullivan & Co., (FSC), which was acquired by Nexant in January 2014.

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From this point forward, when referring to SMUD's consumer behavior study, we use the pilot's marketing name, "SmartPricing Options." We also use the terms "study" or "pilot" to refer to the SmartPricing Options. The term "Consumer Behavior Study" or "CBS" refers to the overall consumer behavior study data being collected by the DOE in consultation with Lawrence Berkeley National Lab.

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SECTION I: PROJECT OPERATIONS

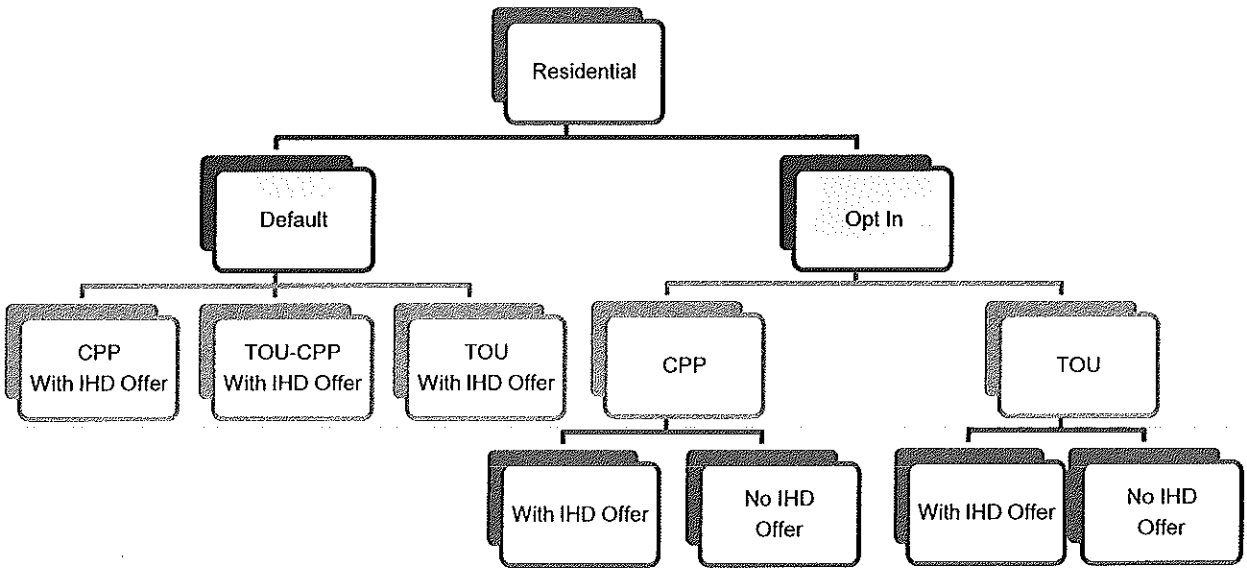
The second year of the pilot focused on operational process improvements, customer retention, and application of lessons learned from the first summer.

2.0 The Second Summer of SmartPricing Options

In early 2013, the second year of the pilot, SMUD staff began planning for improvements in the operational processes for the pilot's Conservation Days, customer services, and customer retention. From the research completed, the experiences gained and lessons learned from the first year of operations, SMUD was able to refocus on what could be done to improve communication to pilot participants and ensure customer retention.

The seven treatment groups for the pilot included a representative sample of SMUD's customer base except for the following exclusions: photovoltaic customers, air conditioning load management customers, and medical rate customers. Low income customers were included in the study population and represented 33% of study participant. The SPO treatment groups are detailed below.

Figure 1: SmartPricing Options Treatment Groups



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The experimental rate options were offered to the sample population beginning in October, 2011 and were in effect from June through September, in both 2012 and 2013. The research objectives were to determine:

1. Electric energy and demand impacts for each treatment;
2. Customer characteristics related to energy usage behaviors;
3. The role of IHDs in customers' daily electricity management;
4. Program impacts on customer bills and satisfaction;
5. Expected value of rate and IHD programs;
6. Expected market penetration for rate and enabling technology programs; and
7. Effective educational and marketing strategies for customers.

It is not uncommon in utility research to rely on quasi-experimental methods and limited sample sizes due to resource constraints, technology limitations, and concerns about negative impacts on customer satisfaction. The Technical Assistance Group (TAG) that was under contract to DOE to provide guidance for the consumer behavior studies had a much higher standard for implementation of the consumer behavior studies for all SGIG recipients. In SMUD's case, the resulting research plan included three methodologies: Randomized Control Trials (RCT), Random Encouragement Design (RED), and Within Subjects.[3]

It was important to SMUD to manage the size of the study, and the RCT and RED designs with the agreed upon statistical power required much larger sample sizes than the methods typically employed by SMUD. In an effort to manage the study's footprint on our service territory, we assigned research rigor and associated sample sizes based on the priority of the research questions that could be answered by the treatment group. This resulted in the following design:

- RED: CPP with technology offer (opt-in and default) and TOU with technology offer (default)
- RCT: TOU with and without technology offer (opt-in)
- Within Subjects: CPP without technology offer (opt-in) and TOU-CPP with technology offer (default)

[3] These terms are defined in detail in the appendix of this report on page 136.

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Ultimately, sample sizes were larger than expected after the first summer due to much higher than expected recruitment and retention rates, which allowed Nexant to conduct the evaluation using RED and RCT methods for all treatments.

SMUD had predicted that approximately 20% of pilot participants would leave before the end of the study period on October 1, 2014. It became clear in early 2013 that attrition would be greater than 20%, primarily due to customers moving from premises that were in the study. If a customer moved from a home included in the study, they were dropped from the evaluation. During the course of the two year pilot, approximately 25% of customers in the study moved, exceeding SMUD's forecasted attrition levels. These move-out rates, upon further investigation, were only slightly higher than average, which was most likely a result of the economic recession. However, dropout rates, that is, customers that elected to leave the pricing pilot, were very low across all treatment plans, ranging from 4%-9%. Because SMUD had overenrolled customers in each of the treatment groups, this attrition did not compromise the validity of the study.

SMUD focused significant attention on customer retention and improved communications regarding the pilot goals and objectives. The shift in marketing from a recruitment campaign to an educational and retention campaign allowed for a deeper dive into customer preferences and targeted marketing. Market research conducted in the first year allowed the team to identify improvements that could be made to communications. The team applied this customer feedback to marketing collateral and produced higher customer satisfaction ratings among pilot participants than during the first year. Additional information on Marketing and Market Research can be found in Section III.

By the second year of the pilot, experience was on the side of the operations team. We had learned a great deal from the challenges during the first summer and the team implemented new operational processes that improved CPP event execution, reporting, and customer service. More on these efforts can be found in Section 5, which discusses pilot operations.

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The project schedule included over 1260 tasks with start and finish dates for each task of the project. This schedule was critical for the project team to stay on task and recover from delays and surprises that are inevitable in any project.

3.0 Project Administration: Budget and Schedule

3.1 Overview

The SmartPricing Options pilot was one of the larger SGIG funded pilot projects in terms of scope, schedule and budget. The two-year pricing pilot required a seven month recruitment period and over a year and a half of planning and implementation before the pricing plans went into effect.

3.2 Details

3.2.1 Budget

The budget process at SMUD is completed annually for the upcoming year and includes a three year planning budget. The SmartPricing Budget was created in 2010-2011 and updated annually for the pilot covering 2010 through 2014.

Total Project Budget

The initial projected total costs for the pilot totaled $12.8 million. All budget figures discussed in this section include the cost of product, services, and internal labor to administer the pilot, as well as the surcharge rate used to account for organizational overhead[4]. The costs reported here are total budgets, not just SMUD's cost share of the pilot. Due to some efficiencies and overestimated support requirements, project expenditures equaled approximately $9.9 million.

As depicted in Figure 2, the two largest costs were the implementation of IHDs and the marketing activities, followed closely by evaluation and reporting. This is an interesting

[4] All budget figures reflect allowable expenses allocated in accordance with guidelines dictated by the U.S Department of Energy. Figures presented in this report do not replace or supersede any reports provided to DOE and should be considered estimates.

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point for rate implementation planning, since many of the costs associated with the evaluation and offer-specific communications may not be applicable in a standard program deployment, and it is common for the price of enabling technology to be reduced for customers by offering a rebate or incentive rather than giving the device to customers for free. While these allocated expenses were appropriate in the research study environment, they may not be applicable for actual program deployment.

The initial stages of the project were heavy in design, recruitment, technology and project management costs, some of which would not be applicable to a system-wide implementation since they concern research design, study set up, and DOE reporting. Also, the complexity of managing seven treatment groups and the redundant efforts required to support each task for each of the treatment groups would be eliminated if the program manager could market the offers without mutual exclusivity. Alternatively, much of the infrastructure that was developed to support time-variant rates and pilot oversight would be leveraged if a system-wide program rollout was deployed after the pilot period. For example, billing validation and bill presentment could be leveraged indefinitely, and project management tasks to oversee the pilot would be absorbed by program staff.

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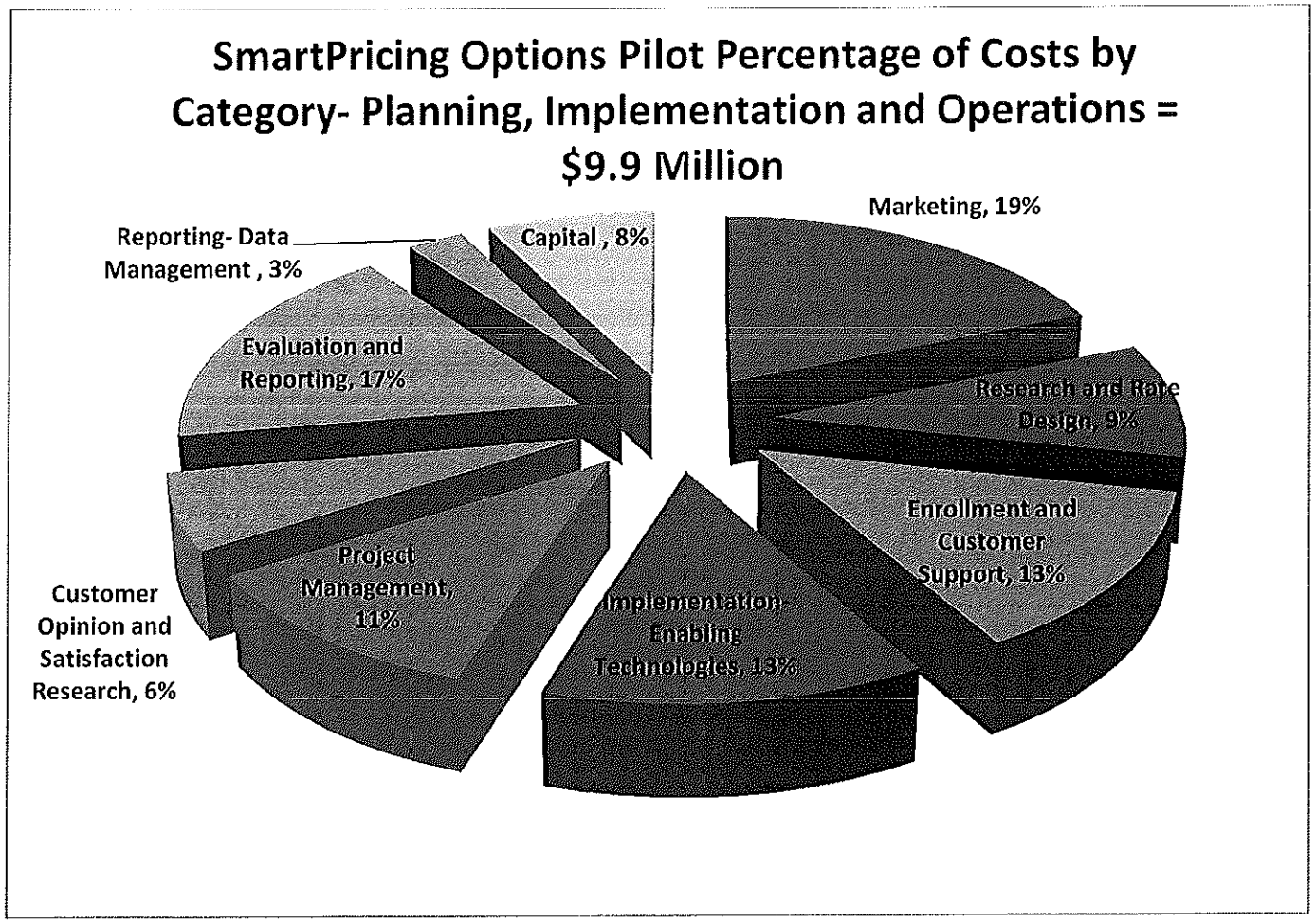
Figure 2: Actual Budget for SmartPricing Options, through May 2014



The following descriptions provide a summary of the expense types in each category and provide additional details.

MARKETING

The marketing costs for recruitment and retention through May 2014 totaled $1.9M, or 19% of the total project costs through the end of the study period. The pilot study design coupled with the diverse and comprehensive marketing effort required that the marketing team create seven versions of most marketing pieces, which was very labor intensive. The team worked with several local marketing firms to design materials that would resonate with customers and give them the tools that would help them be successful on the new pilot pricing plans.

The marketing total also includes a full time, dedicated marketing professional for 35 months during this period. Of note is the reduction in expenses for outside services

relative to the initial budget plan (total planned marketing budget was $2.8M). This reduction resulted from a change in strategy from our marketing team to exclude radio spots, billboard advertisements, and other mass marketing strategies for recruitment that were originally planned but not implemented.

A full description of the marketing plan and the components that make up these costs can be found in Section I, 7.0 Marketing, in the Interim Evaluation Report, and in Section 1, 4.0 of this Final Evaluation report.

Enrollment and Customer Support

Enrollment and customer support costs for the pilot account for approximately 13% of the total costs for the duration of the pilot, for a total of $1.3M. These costs include tasks such as customer service, billing, enrollment, un-enrollment, support for the enabling technology, and deployment of customer notifications related to the daily operations of the pilot, such as reminder postcards to call with questions or informational notifications provided for billing clarification.

The original plan had estimated hours for customer support very conservatively. However, call volumes were much lower than the original estimate and customer support labor hours were about half of what was originally planned. In addition, we were able to achieve efficiencies in the enrollment process due to automation of several transactions for enrolling customers.

Implementation and support: In Home Displays

Figure 3 compares planned costs in the original budget to the actual expenditures for the implementation of IHDs through December 2014. Significant reduction in the expenses for outside services was due to providing internal technical support for IHDs rather than utilizing outside services for that role. After careful evaluation of the proposed support services provided from an external party, we decided to keep all support for the devices in house, which resulted in large costs savings for those services, since added labor costs were offset by efficiencies in other areas.

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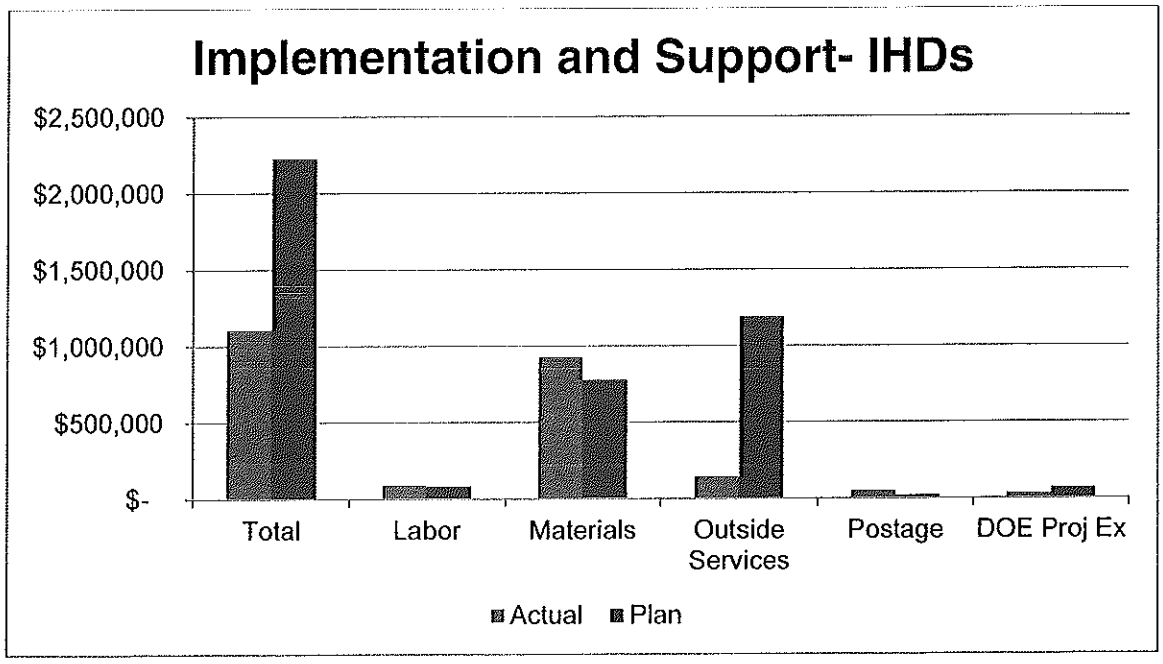
Figure 3: Implementation - IHD Costs



IMPLEMENTATION: PROJECT MANAGEMENT

Project management includes all tasks associated with keeping the project planned and implemented within scope, on schedule, and within budget. Many tasks that might otherwise be handled by a program manager in a program environment, such as running reports and validating mail lists, were also handled by the project manager, since no program manager was planned for this research project. The costs for these tasks were approximately $1.1M from the planning stages to the completion of the pilot. There were several team members billing to the project under project management based on the nature of their tasks. These tasks include development of requests for proposals for support services; development of schedules, scope, and budgets; review of all marketing materials; and data management for reporting and evaluation, among other tasks.

CUSTOMER OPINION AND SATISFACTION RESEARCH

Market research costs, totaling 6% of the total project budget, include research conducted prior to recruitment and customer opinion and satisfaction research performed before, during and after the pilot. This includes the portfolio of research projects presented in Section I, 6.0 Market Research, in the interim evaluation report and in Section 1, 4.0 of this report.

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EVALUATION AND REPORTING

When conducting a pilot, the costs of evaluating the results and answering the research questions are a major consideration when scoping the project. During the planning period, SMUD had considered both quantitative and qualitative research questions and looked at how to best plan for the expenditures throughout the pilot period. SMUD agreed to produce an interim evaluation report at the end of the first summer and a final evaluation report at the end of the second summer that looked at results from across both summers that the rates were on effect. In order to accommodate these costs across multiple years, several different budgets were established for each of the broad research areas under the pilot. The interim and final evaluations were grouped together with reporting metrics and data, and the funding was budgeted across three years, 2012 through 2014, in the Evaluation and Reporting category.

The total expenditures for the evaluation and reporting category were17% of the total budget across the three year study period and were primarily spent on outside services for consulting work completed to evaluate the pricing pilot. The detailed final evaluation report is included in Section two of this report and the interim evaluation report can be found at:
https://www.smartgrid.gov/sites/default/files/MASTER_SMUD%20CBS%20Interim%20Evaluation_Final_SUBMITTED%20TO%20TAG%2020131023.pdf.

REPORTING: DATA MANAGEMENT

Although data management is not a large part of the overall budget, it is an important task operationally and strategically. Data management and reporting accounted for 3% of the total budget. The majority of these costs included data analytics and statistical software (SAS) and labor expenses.

CAPITAL

Capital expenses include those costs required to upgrade system infrastructure to support time based rates through the Customer Information System (SAP), Meter Data Management systems, and the HAN Communication Manager. These expenditures accounted for approximately 8% of the costs through May 2014.

3.2.2 Schedule

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The SmartPricing Options project schedule was developed to accommodate implementation of a large study that included the integration of smart grid technology. The outside boundaries of the schedule were dictated by the two-year study period allowed by DOE and the start date of the grant award. DOE reportable milestones and deliverables are noted in Table 2. Customer recruitment began in late October 2011 and customers were placed on the new pricing plans on June 1, 2012.

Table 2 represents the milestone schedule covering some of the primary activities associated with the SmartPricing Options pilot.

Table 1: SmartPricing Options Schedule of Milestones

Milestone	Completion Date
White Paper summary submitted to TAG	08/09/2010
Rate Development	12/31/2010
Final Plan Submitted to DOE	03/30/2011
SMUD Board Rate Approval	03/31/2011
Development of Marketing and Educational Materials	08/01/2011
Sample Selection	09/20/2011
Begin Recruiting	10/24/2011
Select IHD	12/31/2011
Deliver IHDs	05/01/2012
New Rates In Effect	06/01/2012
Interim Evaluation	09/01/2013
Market Research – Conjoint Study	12/31/2013
Residential Attributes and Consumer Behavior Survey	10/31/2013
Market Research – End of Pilot Satisfaction Survey	1/31/2014
Final Evaluation	06/30/2014

3.3 Quality Assurance

The project manager and business unit leads created a detailed task-level schedule for the SPO using Microsoft Project. The project schedule included over 1,360 tasks with start and finish dates for each. Because the project team included representatives from each of the Customer business units and a number of middle/back office business units, the schedule was critical for the project team to stay on task and recover through delays and surprises that are inevitable in any project. During core team meetings, team members stepped through the project schedule so that each individual was accountable

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for their assigned tasks. In this way, the team identified any issues or delays and worked collaboratively to find solutions to overcome them. The project schedule was stored as a protected document on SharePoint so that all team members could view it, and it was distributed to the team each month after it was updated.

In addition to regularly managing the schedule at the team level, monthly reporting to the SmartSacramento Project Management Office was required to sync up DOE milestones from the SmartPricing Options schedule with the entire SmartSacramento schedule that is used to report to DOE. This multilevel reporting process was more work than the standard approach, but it was a valuable process in terms of accountability and forecasting due to the number of reviewers included in the process and the need to seamlessly synchronize multiple tools.

3.4 Lessons Learned and Key Takeaways

The SmartPricing Options pilot was a huge undertaking for the team to implement and manage on a very tight timeline. Managing the tasks of more than 140 contributors over the course of several years requires strict schedule oversight. It is not uncommon for project schedules to be less detailed than the schedule used for this project, but having a highly detailed schedule with a corresponding line item in the budget using the same naming conventions was extremely useful in managing tasks, budget, and resources. Using a dynamic project management scheduling software (MS Project) and budget reporting system (SAP) provided access to information that allowed for schedule and budget recovery, variance explanation, sound forecasting and on-time and under-budget delivery.

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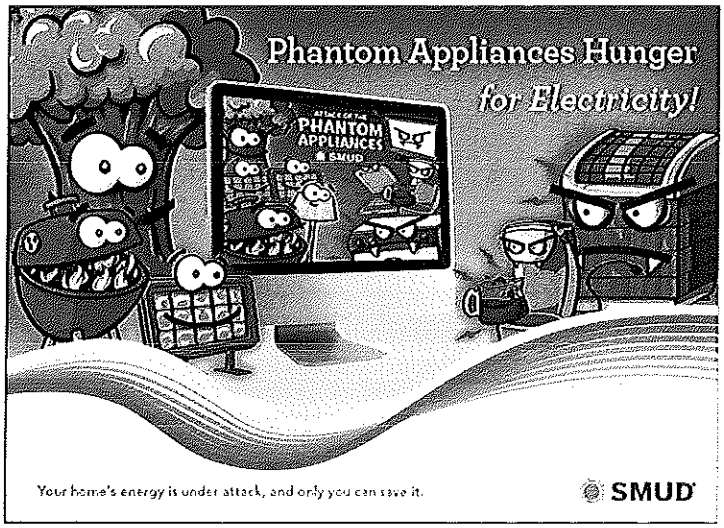
4.0 Marketing and Market Research



4.1 Overview

SMUD worked diligently to engage customers through a variety of channels and to maintain communications with pilot participants. This dedication to the customer experience not only paid off in terms of very low attrition from the pilot, but also helped customers understand pilot goals and maintain load reductions across both summers.

4.2 Details

SMUD's marketing strategy included education and retention components and leveraged multiple channels of communication with customers. The campaigns focused on four specific messages highlighting the benefits of participating in a SmartPricing Options pricing plan.

1. Get a discount on your electricity during off-peak hours;
2. Take control of your summer electricity costs;
3. Manage your energy use; and
4. Contribute to a cleaner environment.

Materials and messaging were developed based on findings from market research efforts that continued throughout the planning and implementation periods. The focus group research indicated that customers preferred images and content that were local and reflected real-life, residential activities. The marketing strategy included several dedicated photo shoots to capture the intention and feeling of SmartPricing Options. The resulting photographs, (example below), showed local families engaging in summertime activities, including family barbeques, children playing in sprinklers, and families relaxing outside. The photos also demonstrated energy-saving actions such as installing weather stripping, CFLs and using smart strips.

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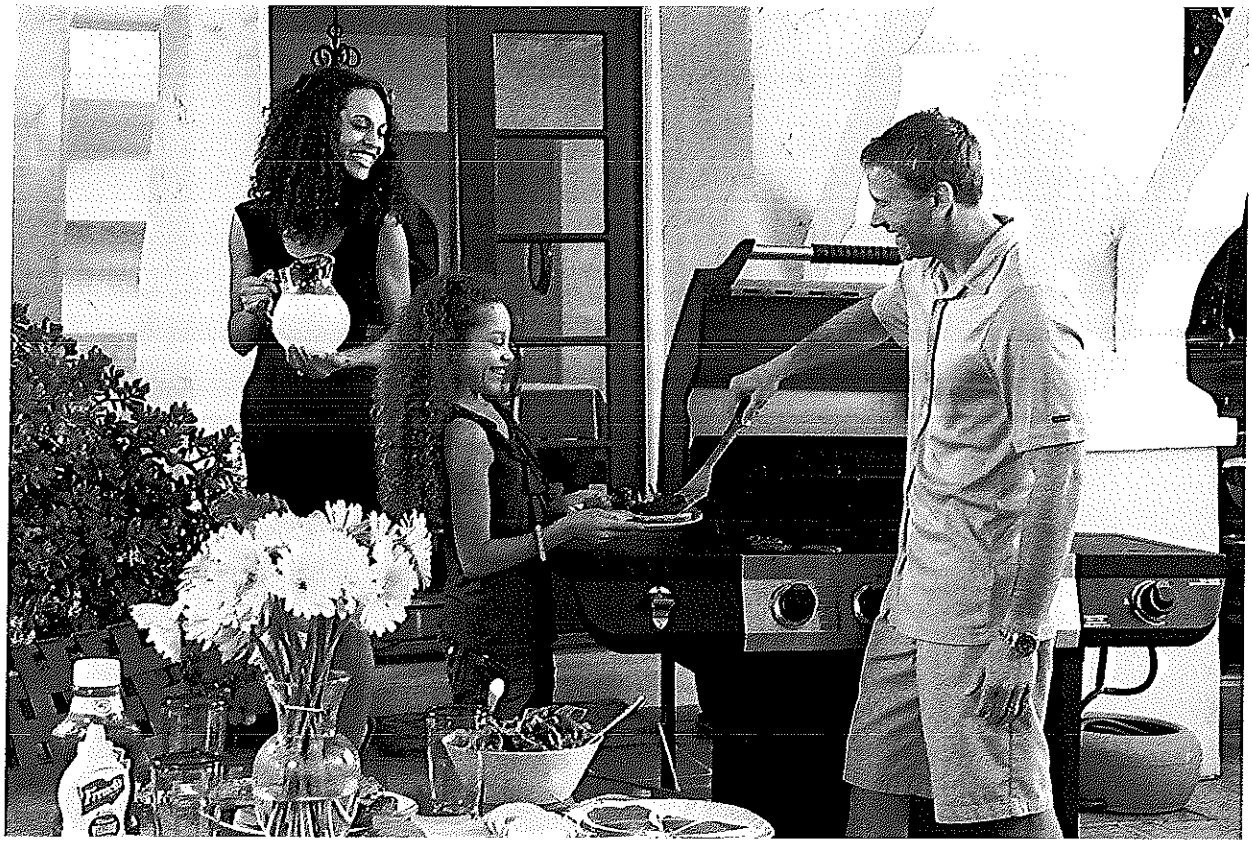

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Table 2 summarizes the communication channel schedule, including a summary of the target audience and objectives for each channel. SMUD's marketing team was aware that some channels were likely to be more effective than others; however, the team felt that it was important to optimize communications by providing access to information through a variety of channels spanning customers' personal preferences.

The mass media campaign, "Little Things, Big Potential", was conducted in the summer of 2011 and focused on increasing general awareness of energy usage, saving energy, and reducing peak load. This larger campaign allowed SMUD to test the language and images that would be used for SmartPricing Options, but also reinforced the SmartSacramento initiative to the entire SMUD population. Mass marketing for "Little Things, Big Potential" was discontinued after recruitment for the pilot began, largely because mass marketing can not be used in a RCT and RED quasi-experimental designs, since you are offering the rate plan to only a sample of the population. By discontinuing the campaign, we focused on targeted marketing for SPO to only the sample of study participants.

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Table 2: Schedule of Marketing Activities by Channel

Channel	Start Date	End Date	Target Audience	Objectives
MASS MEDIA	Jun-11	Sep-11	All residential customers	Education
DIRECT MAIL	Oct-11	Oct-14	All eligible customers	Recruitment, Education, Retention
EMAIL[5]	Mar-12	Oct-14	Opt-in and Default customers	Education, Retention
OUTBOUND CALLING	Apr-12	May-12	Eligible opt-in customers	Recruitment
DOOR HANGERS	Mar-12	Apr-12	Eligible opt-in customers	Recruitment
MICROSITES	Oct-12	Oct-14	All eligible customers	Education, Retention
FACEBOOK GROUPS	Jul-12	Oct-14	All enrolled participants	Education, Retention
PINTEREST	Jul-12	Oct-14	All enrolled participants	Education, Retention
YOUTUBE	Jul-12	Oct-14	All enrolled participants	Education, Retention

In preparing for the second summer of the pilot, SMUD's marketing team utilized information that was collected through customer feedback and surveys in developing ongoing communication materials. Although some of the customer feedback requests were items that we could not provide due to the research design constraints, such as rate comparison tools and shadow billing, we were able to provide customers with general feedback. We included average savings for SPO customers and total kWh reductions for all participants in correspondence with the customers. From customer feedback, we learned that customers wanted to know what the collective energy savings from all participants amount to in kWh and carbon offset equivalents. Customers valued information about how they were impacting the community as a whole.

Since the SmartPricing Options pilot participants only face time-based rates in the summer months, (June through September), there was a 6 month hiatus from SMUD communications regarding the pilot. In late April 2013, SmartPricing Options pilot participants were sent a reminder letter, stating that the pricing plans would go into effect again starting in a few short weeks. As a result of this letter, we had approximately 100 customers call in to de-enroll for the second summer. Drop outs had been lower up to that point and the initial up-tick in response to the letter was a concern. In retrospect, SMUD probably should have not sent the letter and only sent the "Welcome Back Kit", which provided more incentive for customers to stay in the pilot.

[5] Only enrolled customers with an email address on file received email communication. Email messages were consistent with the direct mail messages. The email notifications did not replace direct mail, rather they were sent in addition to direct mail.

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For the second summer, the marketing team prepared a "Welcome Back Kit", which closely resembled the "Welcome Kit" distributed prior to the first summer of the pilot. The kit included magnets, recipe cards, energy saving tips, information about the pricing plan, and a discount card to local restaurants and venues. The purpose of the kit was to provide engaging materials for pilot participants and to remind them that the pilot was continuing for the 2013 summer. Since marketing and communications were limited during the winter and spring months, the marketing team created a folder of marketing materials that would stand out from other mail and encourage customers to open the envelope and read the materials. The same concept was used the year before, with success; customers reported remembering receiving the welcome kits at a higher rate than any other marketing materials that were sent through direct mail.

For the second summer, the contents of the "Welcome Back Kit" were modified to encourage retention and increase customers' understanding of the pilot objectives. Customers were reminded about the pilot objectives - "SMUD is offering these time based pricing programs to reduce peak demand hot summer hours. SMUD is hoping to learn how customers use energy when on time based rates and how it impacts peak demand and energy use. During last summer, with your help, we reduced peak demand by 4 MW and reduced electricity use by 476 MWh."

4.3 Additional retention activities

For the SmartPricing Options pilot, SMUD's marketing team created the most robust retention campaign that SMUD has deployed to date. The retention campaign focused on engaging customers through various channels, including social networks, online games, infographics, email, direct mail, you-tube videos, and dedicated websites loaded with information and interactive graphics on energy use.

An example of the retention campaign is highlighted in SMUD's online game, Attack of the Phantom Appliances, which is available at http://phantomappliances.com/

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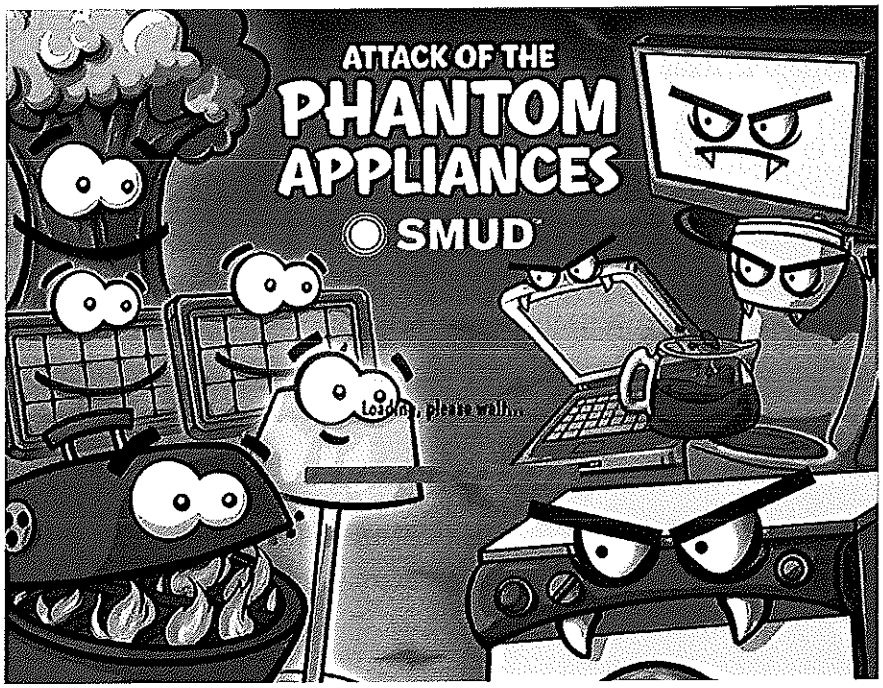

The tower defense game is peppered with quizzes that test the customer's knowledge on what it costs to operate electric appliances. The game is packed with energy saving information and energy saving heroes, such as Watson the floor lamp, who slings CFL bulbs to stop the phantom appliances as they approach your home and kitchen. If you do not place enough energy saving devices in the path of the phantom appliances, your home is overrun and you must restart the game.

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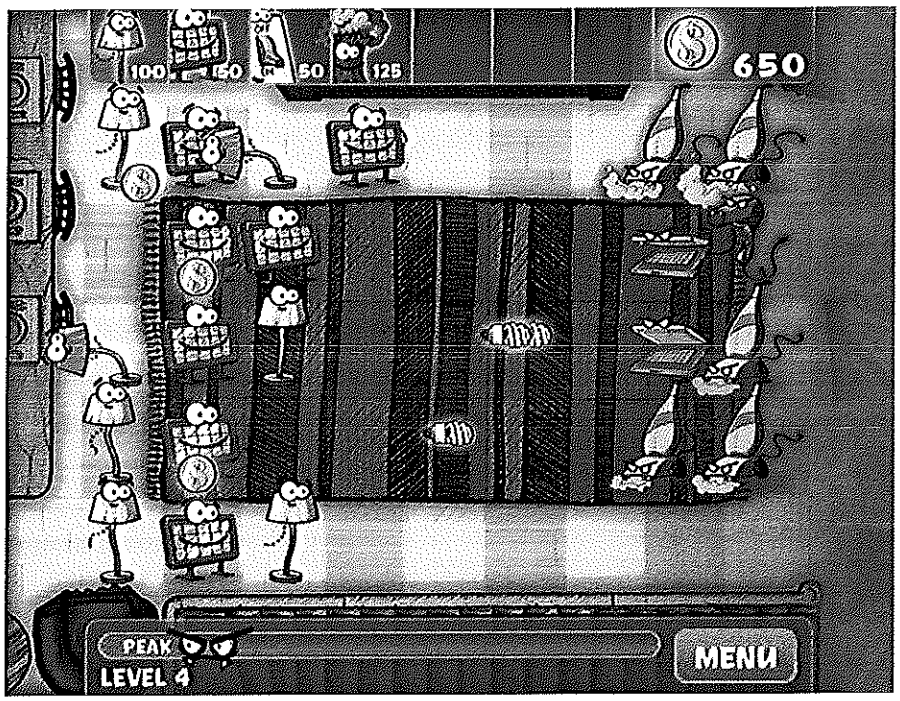

SMUD created plan specific microsites that served as an auxiliary website with independent links and address that was accessed mainly from a SMUD.org, or by directly typing the URL into a web browser. Microsites were provided for each treatment group to encourage participants to stay engaged and learn strategies to help reduce peak period usage. At the beginning of the summer of 2013, SMUD launched a sweepstakes for SPO customers to win a new grill. This effort helped drive customers to the websites to register for the sweepstakes and also provided educational information. Each microsite, a total of seven (see links below), has pricing plan specific information, but all sites are identical in content, (e.g. cost to run charts are available on all microsites, although the prices vary by treatment plan.)

Opt-In Treatment Group Sites

- Summer Weekday Value Plan w/ technology: https://www.smud.org/smartvalue
- Summer Weekday Value Plan w/o technology: https://www.smud.org/valuepricing
- Off-Peak Discount Plan w/technology: https://www.smud.org/smartdiscount
- Off-Peak Discount Plan w/o technology: https://www.smud.org/discountpricing

Default Treatment Group Sites

- Summer Weekday Value Plan w/technology: https://www.smud.org/valueoption
- Off-Peak Discount Plan w/technology: https://www.smud.org/discountoption
- Optimum Off-Peak Plan: https://www.smud.org/optimumoption

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The microsites were a platform where customers could access several other social networking sites, including Facebook, Pinterest, and YouTube. SMUD created a number of videos that were published on YouTube and focused on cooking tips during peak hours. This complimented the recipe cards that were included in the Welcome Back Kit, that provided easy and energy efficient recipes for customers to create during peak hours. The SMUD team focused on ways to make behavioral changes convenient and on providing actionable marketing materials that resonated with customers. The Pinterest page focused on activities, pet care, recipes, fun facts, and safety tips. The links below can be used to access this content.

Peak Hour Kitchen Tips:
http://www.youtube.com/watch?v=NznL9JhD6Bs&list=PL9C25A4626E0E7668&index=4

Pinterest: http://www.pinterest.com/smartpricing/

The numerous platforms that SMUD utilized to reach out and engage customers helped improve understanding of the pricing plans and the program goals of reducing peak usage. By utilizing a multifaceted campaign that employed everything from direct mail to social networks, SMUD successfully engaged customers to reduce peak demand throughout the two year pilot. As SMUD continues to roll this program out to new customers in 2014, while successfully retaining pilot participants, the marketing team will continue to use this multifaceted approach.

4.4 Market Research

The project team understood the importance of market research of customer choice and satisfaction and conducted numerous surveys over the pilot period to better understand customer preferences and satisfaction. As mentioned previously, the objectives of the pilot included understanding the customer characteristics associated with behavior, program impacts on customer satisfaction, effective educational and marketing strategies for customers, and the role of enabling technology in customers daily electricity management. As such, SMUD partnered with Nexant to conduct the End of pilot survey and a Conjoint Survey that focused on dynamic pricing. The results from those research efforts are discussed in detail in Sections 9 and 11 of the Nexant report.

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5.0 Pilot Operations and Customer Support

5.1 Overview

By the end of the first summer of the pilot, SMUD staff had gained a tremendous amount of operational knowledge and useful insights about pilot operations. This knowledge and insight were applied in the second year of operations to make improvements to conservation day (CPP event) execution and support for customers with In-home displays. The focus of this section will be on the operational improvements made to the pilot in the second summer.

5.2 Details

Conservation Day Execution (CPP Events)

One of the most challenging components of operations was notifying customers about CPP event days (referred to as Conservation Days). The notification options available to participants included email, phone call, and text messaging. SMUD continued to work with a third party vendor on the messaging campaigns for the second summer and designed a new business process and Core team to facilitate the implementation of the Conservation Days. At the beginning of the second summer, SMUD implemented several new demand response pilots to its portfolio and they all leveraged the same processes as the SPO pilot. Events across the pilots used the same "conservation days" and leveraged the same messaging vendor and settlement processes for all residential participants. This increase in volume of customers as well as the complexity of the different pilots made it critical for SMUD to make changes to the operations team responsible for the successful dispatch of these events.

Staff created a conservation day core team from across various departments that would be responsible 7 days a week for the conservation day efforts. This team was required to be available each morning throughout the summer months to execute conservation days if necessary. Each pilot project manager was responsible for messaging to their pilot's participants 24 hours prior to events and for same day execution of price messaging and temperature offsets to enabling technology in customer's homes. In addition, the Conservation Day Core team included individuals from Information technology that were tasked with monitoring the progress of messages and signals across SMUD's systems and at vendor platforms. This allowed IT staff to step in at anytime the systems were not executing properly.

The entire Core team held webinars with shared computer monitors for several hours during each event to ensure that all steps were properly executed and that systems were handling the dispatch. This differed from the first summer when there was no formal Core team and events were executed by one individual and tested for accuracy after the dispatch had occurred.

This new Core team ensured that quality assurance was happening during the dispatch and all processes had a set of eyes watching to ensure accuracy. The SMUD IT staff had direct contact with vendors in the event that messages were not properly deployed by vendor systems, which did occur during the second summer on a Sunday afternoon. Because of this new team structure, the IT team contacted the vendor and ensured that the messages were dispatched within minutes, thus avoiding another messaging mishap, like one that had occurred during the first summer. This new Core team process, although resource intensive, ultimately resulted in a successful second summer of CPP messaging to all customers.

Supporting the In-home Displays

SMUD continued to provide comprehensive support for In-home displays, (IHDs) and formalized a group in Customer Operations that was in charge of inventory, troubleshooting, and device provisioning for the IHDs. This group worked as tier 2 support, with SMUD's CSRs serving as tier 1 support. SMUD recognized the importance of having a dedicated Home Area Network (HAN) group in operations that could manage the support of HAN devices over the long term. HAN devices and enabling technology are viewed as a permanent item in SMUD's portfolio of energy information tools that will continue to become more popular.

A reminder postcard was sent to SPO participants that had elected to receive an IHD from SMUD during enrollment in the first year of the pilot. The postcard reminded customers to use the IHD again in the second summer to discover energy saving opportunities and patterns. Although SMUD had experienced a significant connectivity drop-off of devices during the winter months, the off season for the pilot, we had hoped that a reminder postcard would encourage customers to reactivate their devices for the second summer. In fact, a significant increase was observed in the number of devices that connected to the HAN network following the delivery of the postcard and the "Welcome Back Kit".

After the first year of supporting IHDs, the second year was relatively quiet. The majority of connectivity issues were addressed in the first summer. However, only 30% of the customers with IHDs actually had the devices connected to the network, during the second summer, or approximately 1,200 devices. Most of the issues that our

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support team addressed concerned replacing the rechargeable battery in the devices and re-activating the HAN radio in the meter.

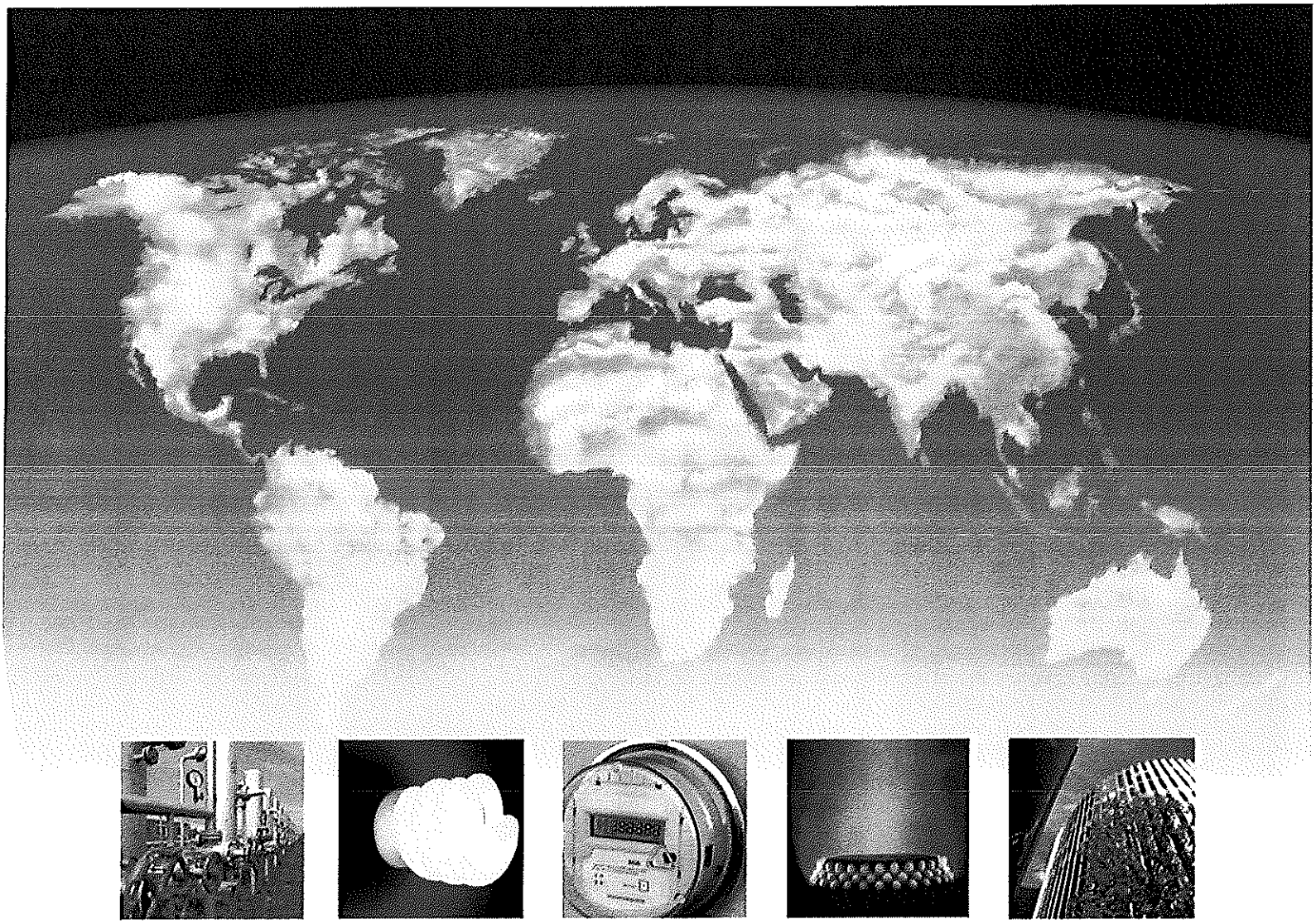
It is interesting to note that there is a population of SPO participants that have maintained connectivity of their IHD for the duration of three years now, year round, and we have named them "super users." These folks account for approximately 12% of all the IHD users.

5.3 Lessons Learned

SMUD has learned that messaging for CPP events is much more complex and requires more resources than was originally planned. A core team was created for implementing CPP events that had multi-departmental representation tasked with ensuring operational success. The accuracy of messaging is critical since it involves direct contact with customers and involves a call to action. In the first summer, there were instances of the wrong date being included in messages and wrong event numbers, all of which caused customer confusion and resulted in increased call volumes to the contact center. By ensuring that staff resources were available at every step of the execution, SMUD was able to improve the customer notification process.

Additional lessons include:

- ✓ Messaging for CPP events is complex and requires adequate staff resources to deal with quality control
- ✓ Customers were interested not only in their own savings, but also in how much everyone in the group saved (e.g., they care about the social benefits of the program)
- ✓ SMUD used pricing plan specific recruitment marketing materials, rather than mass marketing materials. This cost less, and also resulted in higher than expected enrollment rates.



SMUD SmartPricing Options Pilot Evaluation

Submitted to Sacramento Municipal Utility
Submitted By Nexant

Final Report: August 6, 2014

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1 Executive Summary

This report documents the final evaluation results for Sacramento Municipal Utility District's (SMUD) SmartPricing Options (SPO) pilot. SPO is a multi-year pricing pilot that tested three time-variant pricing plans (e.g., time-of-use, critical peak pricing and the combination of the two) and two different recruitment strategies (opt-in and default). To our knowledge, this is the first pilot in the industry that compared enrollment and load impacts on a side-by-side basis for identical customer segments based on both opt-in and default recruitment. The SPO also tested the impact of the offer of an in-home display (IHD) on customer enrollment for opt-in recruitment. The pilot research design involved both randomized control trials (recruit and delay) and randomized encouragement designs.

Opt-in recruitment began in October 2011 and marketing continued until June 1, 2012, when the new pricing plans went into effect. Default treatment groups were notified in early April 2012 that they would be placed on a new, time-variant pricing plan by June 1 unless they contacted SMUD indicating that they did not wish to be placed on the new plan. Time-variant rates were effective from June 1 through September 30 for the summers of 2012 and 2013. In between the two summers, customers reverted to their otherwise applicable SMUD tariff.

In addition to analyzing customer enrollment and load impacts, this report summarizes the results from two surveys. A conjoint survey was conducted to examine the likely impact of changes in rate attributes (e.g., price ratios, the number of rate periods, the number of event days for CPP pricing plans, etc.) on customer enrollment for opt-in pricing plans. An end-of-pilot survey was conducted to assess customer satisfaction, awareness of the attributes of each pricing plan, customer perceptions, reasons that customers stayed on the new pricing plans, IHD use and other topics of interest. The cost-effectiveness of various pricing plans under the assumption that SMUD would offer the plan to the entire residential population is also reported.

1.1 Customer Acceptance and Attrition

Customer acceptance rates for opt-in pricing plans were high by industry standards and much higher than expected for default plans, and opt-out rates were low for all plans. Table 1-1 shows the number of offers made to customers for each pricing plan, the number of customers who accepted each offer and enrollment at various points during the two year pilot. Figures 1-1 and 1-2 show the acceptance and attrition rates for each pricing plan.

As seen in Figure 1-1, acceptance rates across the four opt-in treatment groups were between 16% and 19%, which is quite high when compared with most other utility rate programs and pilots (especially considering that all recruitment was done over roughly an 8 month period, not over multiple years). Differences in acceptance rates across the four pricing plans are small. The offer of an IHD has no apparent influence on acceptance rates for CPP plans and only a slight impact for TOU plans.[1] Acceptance rates for CPP plans are slightly higher than for TOU plans and the difference for the CPP and TOU plans that did not include the offer of an IHD was statistically significant at the 95% confidence

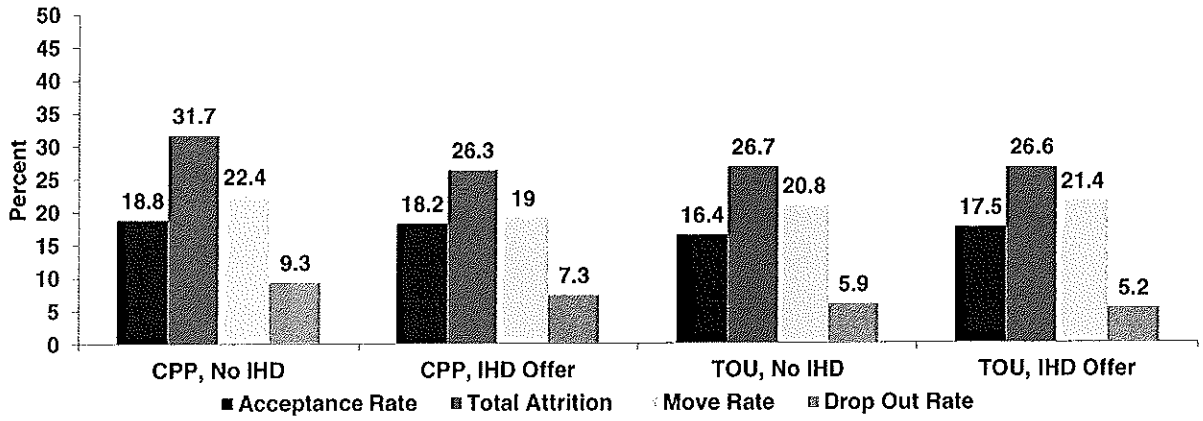
[1] The difference in acceptance rates between the TOU plan with and without the IHD offer is statistically significant at the 95% confidence level. However, when choice models were estimated that included other explanatory variables, the offer of an IHD was not statistically significant.

level. However, customers were not given a choice of multiple time-variant pricing plans, so this difference should not be interpreted as a preference for one plan over the other. Indeed, the conjoint survey that was done included choice exercises where both pricing plans were offered simultaneously. Results from this survey show that, when given a choice of both plans, customers prefer TOU to CPP by a factor of roughly 2 to 1.

Table 1-1: Offers Made and Customers Enrolled by Pricing Plan

Recruitment Approach	Rate	IHD Offer	# of Offers Made	# of Customers Accepting	# of Customers Enrolled on Date		
					6/1/12	6/1/13	9/30/13
Opt-in	CPP	No	1,187	223	212	161	147
		Yes	9,060	1,651	1,569	1,265	1,172
	TOU	No	7,500	1,229	1,157	941	877
		Yes	12,554	2,199	2,092	1,664	1,554
Default	CPP	Yes	846	701	701	566	536
	TOU	Yes	2,410	208	2,018	1,628	1,508
	TOU-CPP	Yes	729	588	588	465	431

Figure 1-1: Customer Acceptance and Attrition for Opt-in Pricing Plans

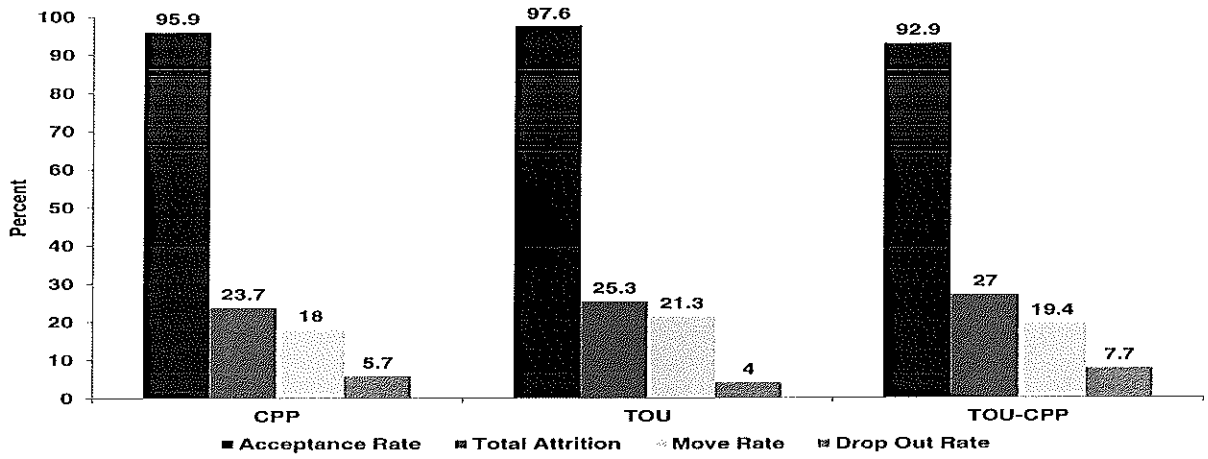


The attrition, move rates and dropout rates shown in the figure cover the period from June 1, 2012 to September 30, 2013. Total attrition ranged from roughly 21% to 27%. However, the majority of this attrition was due to customers moving. Dropout rates represent the percent of customers who actively de-enrolled over the two summers and range from a low of 5.2% for the TOU plan that included an IHD offer to a high of 9.3% for the CPP plan with no IHD offer.

Figure 1-2 summarizes the acceptance and attrition rates for the default pricing plans. The acceptance rate equals the percent of customers who were notified that they would be placed on the new pricing plan and who did not notify SMUD that they wished to opt-out prior to being placed on the plan. As

seen, only roughly 3% to 7% of customers chose not to go on the new pricing plan. This acceptance rate was much higher than the 50% rate that SMUD had planned for. Over the next two summers, an additional 4% to 8% of enrolled customers dropped out, and between 18% and 22% moved. The dropout rates for opt-in plans were actually higher than for the default plans. This likely reflects a lower level of awareness and engagement by default customers compared with opt-in customers, as evidenced by findings from the end-of-pilot survey reported later.

Figure 1-2: Customer Acceptance and Attrition for Default Pricing Plans



Choice models were estimated to determine whether opt-in and opt-out rates were correlated with customer characteristics. The primary variables examined were participation in other SMUD programs, the magnitude of the reduction in customers' bills from going on the rate without changing usage (e.g., the magnitude of the "structural win" from going on the rate) and participation in SMUD's low income tariff, known as the Energy Assistance Program Rate (EAPR). In general, opt-in rates were higher and dropout rates were lower for EAPR customers, structural winners and customers enrolled in other SMUD programs for most pricing plans.

1.2 Load Impacts

Table 1-2 summarizes the average peak-period load reductions across the two summers for each pricing plan. The first three numerical columns show the impacts averaged across the 23 days on which critical peak prices were in effect. Values for CPP days are shown for both CPP and TOU pricing plans so that an apples-to-apples comparison can be made for those two rate options under the same set of weather conditions. The last three columns in the table show the peak period load reductions across the average weekday for both summers for the TOU pricing plans. These values include impacts on days when events were and were not called for the CPP pricing plans.

Table 1-2: Peak Period Load Reductions for All Pricing Plans

Group	CPP Day Impacts			Average Weekday Impacts		
	Impact	Reference Load	% Impact	Impact	Reference Load	% Impact
Opt in TOU, IHD Offer	0.32	2.38	13.3%	0.21	1.79	11.9%
Opt in TOU, No IHD Offer	0.23	2.24	10.1%	0.16	1.72	9.4%
Opt-in CPP, IHD Offer	0.64	2.53	25.1%	n/a	n/a	n/a
Opt-in CPP, No IHD Offer	0.49	2.33	20.9%	n/a	n/a	n/a
Default TOU, IHD Offer	0.15	2.47	5.9%	0.11	1.86	5.8%
Default CPP, IHD Offer	0.36	2.56	14.0%	n/a	n/a	n/a
Default TOU-CPP, IHD Offer	0.31	2.54	12.3%	0.17	1.91	8.7%

A key conclusion is that the absolute and percent impacts per customer are roughly half as large for default plans compared with the same opt-in pricing plans. Another key conclusion is that, under CPP event-day weather conditions, average load reductions for CPP pricing plans are roughly twice as large as for TOU pricing plans. Importantly, the fact that average impacts are roughly half as much under default plans compared with opt-in plans does not mean that aggregate impacts would be smaller under default plans. Indeed, quite the opposite is true. When the differential enrollment rates are factored into the equation, default plans offered to the same population of customers as opt-in plans are likely to produce much higher aggregate load reductions. For example, the aggregate load reduction in the initial summer of an opt-in CPP pricing plan that included the offer of an IHD would equal 11.6 MW if offered to 100,000 customers.[2] The same plan offered on a default basis would produce 34.5 MW of load reduction, nearly three times more than for the opt-in plan. Similarly, if the TOU plan with an IHD offer was marketed to 100,000 customers on an opt-in basis, the load reduction on the average weekday would be 3.7 MW (and 14.7 MW on the average CPP day). When offered on a default basis, the estimated load reduction is 10.8 MW, once again roughly three times as large as for the opt-in plan.

Other key findings from the load impact analysis include the following:

- For 6 of the 8 pricing plans, average load reductions per customer were not statistically significantly different across the two summers – that is, load impacts persisted over two years – after controlling for movers. For the opt-in TOU plan with the IHD offer, impacts fell from 0.26 kW in the first summer to 0.20 kW in the second and this difference was statistically significant. For the default CPP pricing plan, impacts increased from 0.31 kW to 0.42 kW, and this difference was statistically significant.
- For default TOU pricing plans, EAPR and non-EAPR customers produced very similar absolute and percent reductions. For default CPP and for all opt-in pricing plans, average load reductions for EAPR customers were less than for non-EAPR customers.
- Absolute load reductions increase by as much as a factor of 10 across customers segmented into quartiles based on summer usage. This suggests that any opt-in program will likely be much more cost-effective if focuses its marketing resources primarily on large users.

[2] 11.6 MW = (100,000x.18.2x.64kW)/1,000

- Energy savings were small or statistically insignificant for all pricing plans. Three pricing plans showed statistically significant energy savings across the summer. Savings for the default TOU plan equaled 1.3%, for the opt-in CPP plan (with IHD offer) savings equaled 3.5% and for the default CPP plan, savings equaled 2.6%.
- A structural economic model of demand was estimated so that load impacts could be predicted for prices other than those tested in the SPO. The estimated price elasticities were comparable to those found through other pricing pilots, including California's Statewide Pricing Pilot.[3] Based on the estimated demand model, increasing critical peak prices by roughly 60% over SPO price levels (from $0.75/kWh to $1.20/kWh) would increase the percent load reduction during the peak period by roughly 20% for both opt-in and default CPP pricing plans. For TOU pricing plans, a 55% increase in peak period prices, all other things equal, would increase the percent load reduction by 30 to 40%.

1.3 The Influence of IHDs

The SPO was designed to assess the impact of the offer of an IHD on customer acceptance of opt-in pricing plans. As discussed above, the offer of an IHD did not have a material impact on acceptance rates.

Another useful investigation concerns the acceptance of and connection rates for IHDs among treatment groups that received an IHD offer. What percent of customers who received an IHD offer accepted it and what percent of those customers receiving an IHD connected the device with their meter?

Two of the opt-in treatment groups were offered a free IHD if they enrolled on the rate. Acceptance of the IHD was not a condition of going on the pricing plan. Opt-in customers could indicate at the time of enrollment whether or not they wanted an IHD. If they did, the IHD was mailed to them pre-commissioned, so that when they unpacked it and turned it on, it was supposed to automatically connect with their meter and start displaying information. All customers in the default treatment groups were offered a free IHD. Because customers were automatically enrolled unless they opted-out, there was not the same opportunity to simply "check a box" at the time of enrollment to indicate whether or not they wanted an IHD. Instead, those who wanted an IHD had to take a proactive step to request it

In summer 2012, SMUD was able to determine from the meter data management system the number of IHD devices that were connected to meters at any point in time but was not able to link those devices to individual customer accounts. However, in summer 2013, data became available that provided a daily log for each customer indicating whether or not their IHD was connected to the customer's meter.[4] As such, for the second year of the pilot, it was possible to identify customers who had their IHDs

[3] Stephen S. George and Ahmad Faruqui, *Impact Evaluation of California's Statewide Pricing Pilot*. Final Report, March 16, 2005.

[4] Reporting functionality from the HAN Communication Manager (HCM) had not been established prior to the launch of the technology and took approximately a year after go-live to established automated reporting out of HCM. However, it should be noted that the functionality was available in HCM, but SMUD had not created business requirements to set-up that functionality before the program launch, primarily because reporting on IHD connectivity had not been part of the critical path for program launch or reporting to the DOE.

connected during the entire summer, those who never had it connected during summer 2013, and those who were connected on some days and not others.

For each treatment group, Table 1-3 shows the number of customers who requested an IHD at the beginning of the pilot, the IHD acceptance rate (the number accepting divided by the number offered), the number of customers who accepted the IHD that were still enrolled at the beginning of the summer period in 2013 and, of those, the percent that had their device connected with their meter during the entire summer, the percent that were connected at some point in time during summer 2013 and the percent that were never connected in 2013. As seen in the table, roughly 96% of opt-in customers requested an IHD whereas fewer than 25% of default customers did so.

Table 1-3: IHD Acceptance and Connection Rates

Group	Enrolled 6/1/12	# That Accept IHD	Acceptance Rate	# of Customers With IHDs Still Enrolled as of 6/1/13	% Connected All the Time	% Connected Some of the Time	% Never Connected
Opt-in CPP, IHD Offer	1,569	1,498	95%	1,195	11.6%	27.4%	61.0%
Opt-in TOU, IHD Offer	2,092	2,017	96%	1,597	11.6%	22.8%	65.6%
Default TOU-CPP, IHD Offer	588	136	23%	112	18.8%	39.3%	42.0%
Default CPP, IHD Offer	701	167	24%	140	14.3%	42.9%	42.9%
Default TOU, IHD Offer	2,018	418	21%	363	18.2%	23.1%	58.7%

As seen in the last three columns in the table, roughly two thirds of opt-in customers who accepted the IHD and who were still enrolled at the beginning of the 2013 summer never had their device connected in 2013. This "never connected rate" was much lower for two of the three default groups, equal to roughly 42% for the default TOU-CPP and CPP groups. The higher connection rate for default customers compared with opt-in customers is consistent with a hypothesis that, since default customers had to take a proactive step to request the device compared with the passive "check the box" approach for opt-in customers, they were more invested in using the device once it arrived. Why the "never connected rate" for default TOU customers is closer to that of opt-in customers than it is to that of the other default groups is unclear.

The SPO was not designed to assess the impact of an IHD on demand response. However, careful observers will note in Table 1-2 that load impacts for opt-in treatments that include an IHD offer are larger than for those that don't include an IHD offer. However, it is not appropriate to attribute these differences to the offer or use of the IHD. After correcting for pre-treatment differences across treatment groups, the load impact differences are not statistically significant. Put another way, there is no evidence from the SPO indicating that IHDs significantly increase load impacts associated with time-variant pricing plans.

1.4 The Impact of Rate Attributes on Customer Acceptance

A conjoint survey was conducted to assess the impact of changes in rate attributes on customer acceptance. A conjoint survey asks respondents to select their preferred choice from among several options that vary according to selected attributes, such as peak to off-peak price ratios, the length and number of rate periods, the number of event days for CPP plans, and others. Because most rate plans implemented by utilities are revenue neutral for the average customer, when selected attributes were changed across options, prices also changed. For example, as the length of the peak period increased, the average peak period price fell since the avoided capacity costs underlying peak period prices are spread over more hours.

In order to avoid survey fatigue and so as not to influence customer behavior, the conjoint survey was not administered to SPO treatment customers. Rather, it was administered to SPO control group customers, to those who were ineligible for the SPO because they were participants in SMUD's balanced billing or direct load control programs, and to customers who were eligible for the SPO but were not included in the study. These groups were segmented and analyzed separately. 1,142 surveys were completed and the survey response rate was almost 40%. Each respondent was given 9 groups of 3 choices, for a total of 27 observations per respondent that could be used for analysis purposes. Key findings from the survey included the following:

- Acceptance rates fall as the length of the peak period increases. The percent of customers who opt-in falls by 25% to 50% as the peak period length goes from 3 to 6 hours.
- Acceptance rates are essentially the same for pricing plans that are based on 6 and 12 event days, but increasing the number of events days beyond 12 decreases acceptance rates.
- Increasing the peak-to-off-peak price ratio has only a modest impact on acceptance rates for TOU plans but has a stronger, negative impact on acceptance rates for CPP plans.
- Respondents prefer time-variant rates that do not also have a tiered structure in which prices increase as usage increases.
- Customers prefer TOU plans over CPP plans by a factor of nearly 2 to 1.
- Almost 60% of respondents said they preferred some type of time-variant rate over the standard tiered rate.
- Almost 30% of respondents would take any time-variant rate over the standard rate and another 30% would choose one time-variant option over the standard rate but not another.

1.5 Cost Effectiveness Analysis

The cost-effectiveness of each of the 7 pricing plans tested in the SPO was estimated based on the assumption that the plans were offered to SMUD's entire residential population (about 540,00 customers) and the two-year average enrollment rates and load impacts found in the SPO were observed for this larger population. Recruitment, notification and other variable costs from the SPO were used and startup and other costs were adjusted where appropriate to reflect changes that might be needed to support a larger scale operation. The primary benefit included in the analysis was avoided capacity costs resulting from lower peak period usage. Estimates were also developed for three non-SPO scenarios in which customers were defaulted onto the CPP, TOU or TOU-CPP rates but without the

offer of an IHD. Given the fact that there were no measurable incremental load reductions associated with an IHD for opt-in treatments, we assumed that enrollment rates and load reductions would be the same with and without the IHD offer. The present value of net benefits was calculated over a 10 year period.

Table 1-4 shows the NPV of benefits, costs and net benefits over a ten year period for each pricing plan. It also shows the benefit-cost ratio for each plan, based on the inputs and methods described above. The values in the table are for overall cost-effectiveness, which includes both start-up and ongoing costs, and addresses the policy question of which plan would be most cost effective if it were to be implemented from scratch. Marginal cost effectiveness estimates, which address the question of whether it is cost effective to continue to enroll more customers onto a plan once it is up and running, are discussed in Section 10.

As seen in the table, all but one of the pricing plans, opt-in TOU with an IHD offer, are cost effective, but the magnitude of net benefits vary by almost a factor of 60 between the plans with the lowest and highest positive net benefits. Of the 7 pricing plans tested in the SPO, if they were to be extended to SMUD's entire residential population, the net benefits over 10 years would range from a low of roughly -$5.5 million for the opt-in TOU plan with the IHD offer to more than $86 million for the default TOU-CPP plan with an IHD offer. Default plans are significantly more cost effective than opt-in plans and pricing plans that include the offer of an IHD are all much less cost effective than the equivalent plan that does not offer an IHD. For simulated default plans without an IHD offer, the TOU plan has the lowest net benefits but still exceeds $50 million. The TOU-CPP plan is estimated to deliver net benefits that are more than twice as large as the TOU plan. In general, all CPP plans deliver net benefits that are roughly twice as large as the equivalent TOU plan.

Table 1-4: NPV of Benefits and Costs by Pricing Plan ($ millions)

Scenario Type	Scenario	Benefit/Cost Ratio	10 Year NPV for SMUD Territory		
			Benefits	Costs	Net Benefits
Opt-in Tested	TOU, No IHD Offer	1.19	$12.1	$10.2	$2.0
	TOU, IHD Offer	0.74	$15.5	$21.0	-$5.5
	CPP, No IHD Offer	2.05	$29.7	$14.4	$15.2
	CPP, IHD Offer	1.30	$34.3	$26.3	$7.9
Default Tested	TOU, IHD Offer	2.04	$66.9	$32.8	$34.1
	CPP, IHD Offer	2.22	$142.1	$63.9	$78.2
	TOU-CPP, IHD Offer	2.49	$144.8	$58.1	$86.7
Default Simulated	TOU, no IHD Offer	4.48	$66.9	$15.0	$52.0
	CPP, no IHD Offer	4.28	$142.1	$33.2	$109.0
	TOU-CPP, no IHD Offer	4.53	$144.8	$32.0	$112.9

1.6 End-of-Pilot Survey Summary

A survey was conducted in the fall of 2013, after the end of the second summer period, to obtain input among pilot participants on the following topics:

- Customer satisfaction with SMUD and with the pricing plan customers were on;
- Awareness of the attributes of each pricing plan;
- Perceptions about the pricing plan;
- Reasons for staying on the pricing plan;
- Awareness of events for the CPP pricing plans; and
- IHD use.

The survey was sent to all customers who were enrolled on a pricing plan (including those who actively dropped out but not those who moved) as well as a sample of control group and deferred customers. The survey was conducted using both online and hard copy questionnaires. The overall response rate was 40%. Key survey findings include the following:

- Satisfaction ratings for respondents in all treatment cells, including the deferred treatment cell, were equal to or greater than satisfaction levels in the control group. Put another way, defaulting customers onto time-variant rates or using recruit and delay research methods in some cases did not negatively impact satisfaction with SMUD services.
- Customers on time variant pricing plans, including default plans, report greater agreement with the statement, "My current pricing plan is easy to understand" than do customers on the standard rate. Opt-in customers showed greater actual (not perceived) understanding of rate attributes than did customers on the standard rate and default customers showed about the same level of understanding as customers on the standard rate.
- Significantly more customers on time-variant pricing plans agreed with the statement, "My current pricing plan provides me with opportunities to save money" than did customers on the standard rate. More time-variant pricing plan customers also felt that their pricing plan was fair than did customers on the standard rate.
- Roughly 40% of customers on default time-variant pricing plans and about 57% of those on opt-in plans strongly or somewhat agreed with the statement, "My current pricing plan is better than my old pricing plan" and roughly half of all default respondents and three quarters of opt-in respondents strongly or somewhat agreed with the statement, "I want to stay on my pricing plan."
- Almost half of default and roughly two thirds of opt-in respondents strongly or somewhat agreed with the statement, "I think the Sacramento community would be better off if everybody was on my pricing plan."
- Almost 60% of default and 80% of opt-in respondents strongly or somewhat agreed with the statement, "I believe that I did something good for Sacramento by participating in my pricing plan."

2 Introduction and Pilot Overview

SMUD is located in California's Central Valley where hot summer temperatures and a very high saturation of air conditioning equipment result in peak load requirements concentrated over a relatively short number of hours. SMUD has approximately 540,000 residential customers and a peak load of roughly 3,000 MW. The top 42 hours of system load each year account for approximately 400 MW of incremental load on the system.

The primary objective of SPO is to investigate the effectiveness of AMI-enabled, time-variant pricing and enhanced information to induce behavior change in electricity consumers. Of particular interest is reduction in peak-period electricity use. By implementing time-variant pricing, SMUD seeks to:

- Provide a clear high price signal to consumers during SMUD's summer peak period;
- Encourage customers to shift loads by lowering prices during non-peak periods; and
- Assure that customers who choose not to shift, or cannot shift load, are not penalized with bills that are significantly higher than they would be on SMUD's otherwise applicable rate.

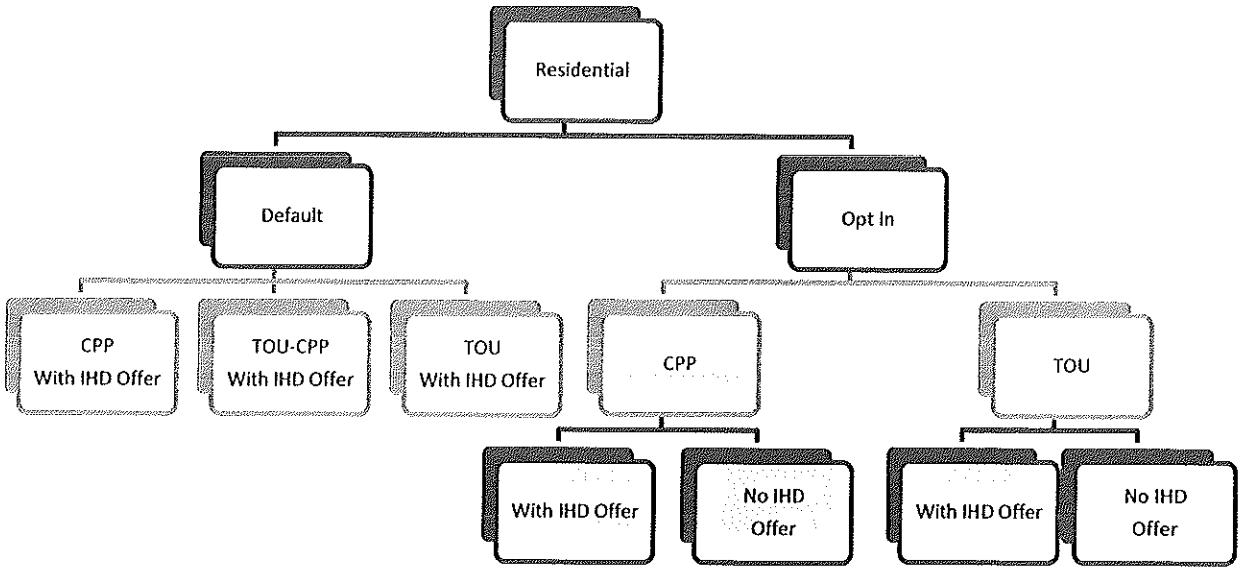
SMUD's SPO is 1 of 11 Consumer Behavior Studies funded by the U.S. Department of Energy (DOE) in an effort to assess customers' response to time-variant rates and increased access to information about electricity consumption. SPO is also one of the major components of SMUD's SmartSacramento®[5] project. The SmartSacramento smart grid project embodies SMUD's public spirit and mission to empower its customers with solutions and options that increase energy efficiency, protect the environment, reduce global warming and lower the cost to serve. When completed, SMUD's comprehensive smart grid will be a customer-centric system designed to enable informed participation by customers as well as the creation of new customer services and solutions. In addition, the project will improve the reliability and efficiency of utility operations, facilitate integration of distributed and intermittent forms of clean and renewable energy, and optimize asset utilization along the entire energy chain—from electricity generation to air conditioning units in customers' homes.

Figure 2-1 summarizes the key features of the SPO pilot, which include:

- Three rate options: time-of-use (TOU), critical peak pricing (CPP) and a TOU-CPP combination;
- Two recruitment strategies: opt-in and default (or opt-out);
- One technology offer: an In Home Display (IHD) that streams usage information to consumers in real time; and
- Three different experimental designs: randomized encouragement design (RED), randomized control trial (RCT) and within-subjects.

[5] A registered service mark of the Sacramento Municipal Utility District.

Figure 2-1: Overview of SPO Treatments



2.1 Pricing Plans

The SMUD Board of Directors approved SPO in August 2011. SPO pricing plans are applicable during the summer months of June through September. Participants revert to their otherwise applicable pricing plan schedule during non-summer months. Participating customers were first placed on the SPO pricing plans on June 1, 2012 and the pilot was scheduled to end on September 30, 2013. Given the success of the pilot and the additional learnings that can be obtained by allowing pilot participants to stay on the SPO pricing plans, SMUD has decided to allow them to do so for at least another year.

The three rate options offered through the SPO pilot include:

- **TOU Rate Option:** Participants were charged an on-peak price of $0.27/kWh between the hours of 4 PM and 7 PM on weekdays, excluding holidays. For all other hours, participants were charged $0.0846/kWh for the first 700 kWh in each billing period, with any additional usage billed at $0.1660/kWh.
- **CPP Rate Option:** Participants were charged a price of $0.75/kWh during CPP event hours, when temperatures and SMUD's system loads are expected to be unusually high. This rate option was designed under the assumption that 12 CPP events would be called each year, between the hours of 4 PM and 7 PM on weekdays, excluding holidays. Customers were notified 24 hours in advance of an event day. For all other hours, participants were charged $0.0851/kWh for the first 700 kWh in each billing period, with any additional usage billed at $0.1665/kWh.
- **TOU-CPP Rate Option:** The third and final SPO rate combines the pricing structures of the TOU and CPP rate options. The TOU-CPP off-peak electricity rate was $0.0721/kWh for the first 700 kWh in each billing period, with any additional off-peak usage billed at $0.1411/kWh. Participants were charged an on-peak price of $0.27/kWh between the hours of 4 PM and 7 PM on weekdays, excluding holidays. A CPP price of $0.75/kWh was charged to participants between the hours of 4 PM and 7 PM on CPP event days, which were planned to be called 12

times during the summer months. The 12 days are the same as those called for the CPP-only rate.

For all three SPO rate options, customers with domestic wells we given a base usage of 1,000 kWh per billing period (rather than 700 kWh). In addition, customers who were on the Energy Assistance Program Rate (EAPR) received about a 30% discount on the price they paid for all SPO rates, depending on how much energy they used. Table 2-1 summarizes the prices that were in effect by rate period during the two summers. Only the standard rate changed in 2013. All SPO pricing plans had the same prices in both summers.

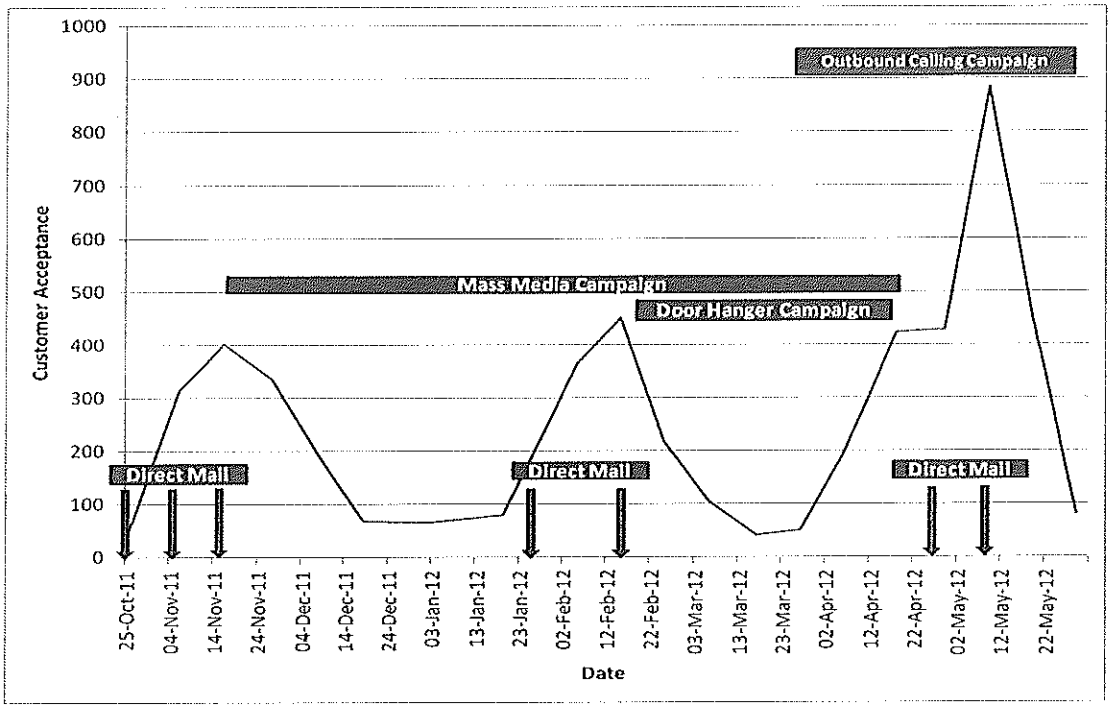
Table 2-1: Electricity Prices by Rate Period and Tariff

Category	Rate	Fixed Charge	Critical Peak	On-peak	Off-peak Base	Off-peak Base Plus	Off-peak Non-discounted Base Plus
2012							
Regular Pricing	Standard	$10.00	–	–	$0.1016	$0.1830	–
	EAPR	$3.50	–	–	$0.0660	$0.1281	$0.1830
SPO Pricing Standard	TOU	$10.00	–	$0.27	$0.0846	$0.1660	–
	CPP	$10.00	$0.75	–	$0.0851	$0.1660	–
	TOU-CPP	$10.00	$0.75	$0.27	$0.0721	$0.1411	–
SPO Pricing EAPR	TOU	$3.50	–	$0.20	$0.0550	$0.1162	$0.1660
	CPP	$3.50	$0.50	–	$0.0553	$0.1165	$0.1665
	TOU-CPP	$3.50	$0.50	$0.20	$0.0468	$0.0987	$0.1411
2013							
Regular Pricing	Standard	$14.00	--	--	$0.0955	$0.1771	--
	EAPR	$5.50	--	--	$0.05921	$0.109802	$0.1803
SPO Pricing	Same as in 2012						

2.2 Marketing and Recruitment Strategies

In the SPO pilot, SMUD examined two recruitment strategies: opt-in and default enrollment. Each customer chosen for inclusion in the pilot was randomly assigned to a treatment group and was then recruited for that specific rate/IHD offer/recruitment combination. Under the opt-in strategy, participants were invited to enroll in the pricing plan specific to their treatment group. Customers were solicited through a multi-faceted marketing campaign summarized in Figure 2-2.

Figure 2-2: Recruitment Timeline for Opt-in Treatment Cells



For opt-in treatments, the first direct mail solicitation occurred in October 2011. A second letter was sent in January to customers who had not yet enrolled. Because of concerns that some treatment cells might not reach their target enrollment rates through direct mail solicitation alone, starting in March 2012, SMUD implemented a door hanger and outbound calling campaign, which continued into May. Through these various efforts, SMUD exceeded target enrollment for all opt-in treatments prior to June 1, 2012, when customers were placed on the new rate.[6]

For default treatments, customers were placed on either the TOU, CPP or TOU-CPP pricing plan and were told to contact SMUD if they did not wish to participate. Customers were initially notified of the impending change in their pricing plan in early April 2012 and a follow-up notification occurred in early May. Welcome packets were sent to all customers on May 29, just prior to the new rates going into effect. SMUD had based the design and sampling for the SPO on the assumption that half of all default customers would drop out prior to going on the rate. In reality, the opt-out rate prior to June 1 when the default rates went into effect ranged from 3% to 7%.

The two opt-in TOU treatment groups utilized a *recruit and delay* RCT design. Two randomly selected groups of customers were chosen and recruited in the same manner. One group of volunteers was placed on the new rate on June 1 and the other group was told that their rate change would be deferred until summer 2014. The purpose of the deferred enrollment is to create a control group for each treatment group that allows for self-selection but avoids selection bias in the estimated impacts.

[6] A very small number of customers were enrolled after June 1.

Prior to soliciting participants, SMUD spent a significant amount of time and money understanding how to communicate the benefits of, and address concerns about, time-variant pricing programs and how to manage potential dissatisfaction stemming from the fact that some volunteers in selected opt-in treatment cells would have enrollment deferred for two years. From February through August 2011, SMUD conducted 25 focus groups and 4 surveys involving more than 2,000 customers to solicit input on marketing messages, naming conventions and other communication issues as input to development of the marketing and education plan.

Based in part on the above research, SMUD used the following names for the three pricing plans tested in the SPO:

- **Summer Weekday Value Plan** for the opt-in and default TOU treatments;
- **Off-peak Discount Plan** for the opt-in and default CPP treatments; and
- **Optimum Off-peak Plan** for the combination TOU-CPP treatment, which was implemented as a default rate only.

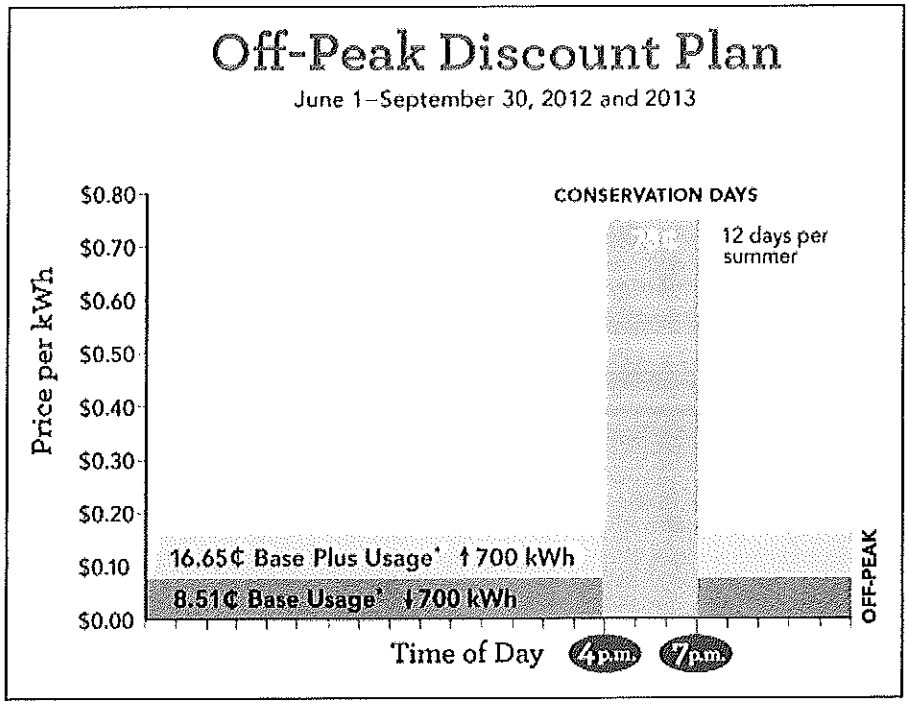
The primary messages and content used the initial solicitation letters included the following:

- The lead marketing message was that customers get a discount off the standard price during non-peak hours, which is most of the time (the amount of time varies across the three rates). The secondary message was that prices are higher for relatively few hours (e.g., only 1% of the time for the CPP rate).
- The primary message concerned "saving money on your summer electricity bills." Secondary messages included taking control and helping the environment.
- Using less electricity during peak hours, shifting usage to before 4 PM or after 7 PM and/or reducing use overall will save money.
- Additional perks include a free countertop electricity use display (for those treatment cells where IHDs are offered), access to an informational graph on My Account that shows hourly and daily usage, access to a website with energy saving tips, and discounts on activities, like movie tickets and water parks that can make using less electricity during peak hours easy and fun.

Many of these same themes were elaborated on in color brochures that were included with the solicitation letter. The cover letter itself did not provide any information about the actual prices but the brochure provided this information in the form of a graphical display. An example of the graph for the CPP Off-peak Discount Plan treatment is shown in Figure 2-3. Examples of selected marketing materials used for customer recruitment can be found in Appendix D of the interim SPO evaluation report submitted to DOE on.[7]

[7] See *SmartPricing Options Interim Evaluation*. Prepared for U.S. Department of Energy, Lawrence Berkeley National Laboratory. October 23, 2013. This report will hereafter be referenced in this document as the SPO Interim Evaluation.

Figure 2-3: Graphical Display of Off-peak Discount Plan Pricing



To help maintain the internal validity of the experiment, SMUD focused significant effort and attention on maintaining consistency in communication and educational content across treatment cells. Keeping messages and content as consistent as possible across treatment cells helps to ensure that differences in enrollment rates and electricity use across rate options and other treatment conditions are due to differences in the treatments themselves and not due to differences in messaging or communication. For example, the only differences in the initial letter sent to customers in the opt-in and default CPP treatment cells are summarized below.

The opening line in the opt-in and default letters is, respectively:

- Sign up today and you could save on your electric bills next summer!
- You're now on a new pricing plan that can help you save on your summer electricity bills!

The next sentence in the two letters, respectively, is as follows:

- You are invited to participate in a two-year SmartPricing Options pilot that can help you manage your energy bills.
- You're among the first SMUD customers to be randomly selected for a two-year SmartPricing Options pilot that can help you better manage your energy use during the summers of 2012 and 2013.

The final paragraph in the default letter indicates that customers who do not want to stay on the new plan can opt out by calling SMUD. Specifically, the letter says:

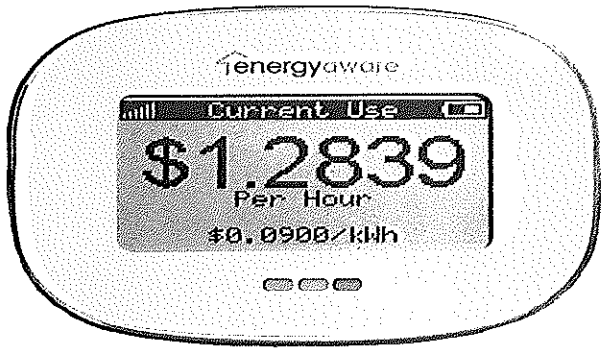
- If you would like to remain on your standard rate plan, call 1-855-736-7655. However, should you decide not to participate, you won't be able to enroll later and you will miss out on the cost savings and energy management benefits.

The final difference between the opt-in and default treatments concerned the IHD offer. The IHD was offered to some opt-in customers and not others and was offered to all default customers. Opt-in customers receiving the IHD offer could indicate their interest at the time of enrollment and nearly all customers said they would like to receive the IHD. Default customers needed to be more proactive since an enrollment transaction was not needed for the rate itself.

2.3 In Home Displays

As indicated above, IHDs were offered to selected opt-in treatment groups and to all default treatment groups. Figure 2-4 shows the IHD used in the SPO pilot. The purpose of the IHD offer was to examine its effect on customer acceptance and retention rates, program satisfaction and, where possible, electricity use.[8] For default customers, all of whom were offered an IHD, the intent was also to ensure that these customers were given tools to help them manage their energy use. Customers did not need to accept the IHD in order to participate in the pricing plan. The IHDs were preset to communicate with each customer's meter when they were turned on and were sent to customers through the mail.

Figure 2-4: In Home Display Used in SPO Pilot



Customers in the opt-in treatment cells were asked to indicate at the time of enrollment whether or not they wished to receive an IHD and almost everyone indicated they would. Customers in the default treatment cells were also asked to indicate their interest in receiving the IHD. However, default customers had to be more proactive than opt-in customers since they couldn't indicate their interest at the time of enrollment (because default customers didn't have to enroll). As a result, between 20% and 25% of default customers asked for and received an IHD.

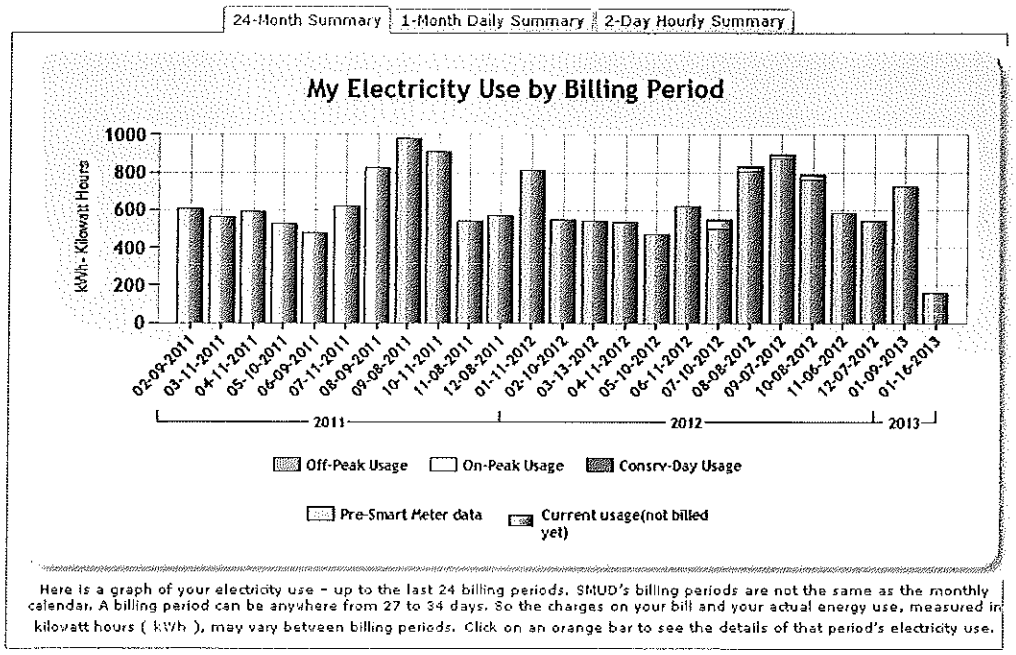
[8] As discussed in Section 1 and at greater length in subsequent sections, the SPO was designed to assess the impact of an IHD offer on electricity use, which is different from assessing the impact of an IHD on energy use.

Not all customers who received and successfully connected the IHD to their meter. In 2012, it was not possible to track IHD connection rates to individual customer accounts but this functionality became available in 2013. This allowed for a determination of the percent of customers who received an IHD in 2012 that were connected all, some or none of the time during summer 2013. Roughly one third of opt-in customers were connected at least some of the time in 2013 and between 40% and 60% of default customers that had requested an IHD were connected at least some of the time in 2013. When combined with the percent of all default customers who requested an IHD, roughly 10% to 15% of all default customers had their IHD connected at least some of the time.

2.4 Web Portal Information

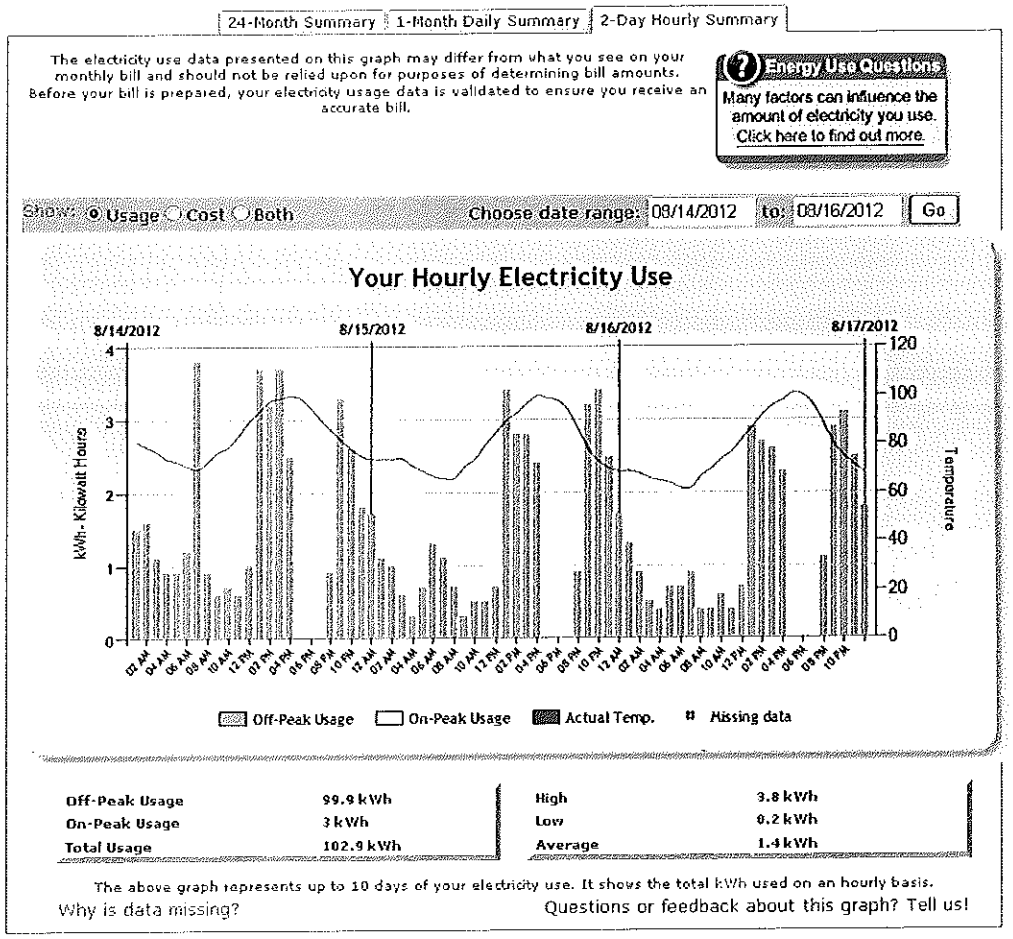
In addition to information provided in real-time through an IHD offered to some treatment groups, all pilot participants could access information about their usage profile through a web portal. Figures 2-5 and 2-6 show the landing page and the more detailed hourly information that are accessible to all pilot participants, respectively.

Figure 2-5: SPO Web Portal Landing Page on My Account[9]



[9] All SMUD residential customers have access to interval data through My Account. Data for customers on time-variant rates is formatted differently to show usage by rate period.

Figure 2-6: Hourly Usage Page for SPO Participants



2.5 Terminology

When evaluating the impact of a pricing pilot, it is important to precisely define the variables of interest. Too often, terminology can be misleading as the same term can mean different things to different people. For example, when examining marketing effectiveness, one could compare the enrollment rate at a point in time (say, on June 1 in this instance, when all customers were placed on the new rate) with the number of customers solicited. However, this ratio would under report marketing effectiveness because some customers may have moved, and therefore become ineligible for the new rate, between the time they responded affirmatively to the marketing solicitation and the time when the new rates went into effect. Similarly, someone might compare enrollment on a rate at the beginning and end of the summers and conclude (incorrectly), for example, that 10% of customers left the new rate because they didn't like it. In reality, many of those customers who left may have done so because they moved, not because they no longer wanted to be on the rate. These examples indicate why it's important to precisely define the impact measures that are reported so that reviewers do not misinterpret their meaning. Below, we define the key output variables that are reported in subsequent sections. A few additional definitions of terms are contained in the glossary in Appendix A.

- **Enrolled Customers**: Enrolled customers are customers who are on a new pricing plan at a given point in time. For opt-in rates, this group consists of customers who accepted the marketing offer, were assigned to the treatment group (rather than the control group), did not change their mind or move prior to the plan going into effect, and are still on the plan (e.g., have not dropped out or moved) at the time that the enrollment snap shot is taken. For default enrollment, enrolled customers at a point in time are customers who did not opt-out prior to or after going on the pricing plan, or did not move or leave the plan for any reason between when they were initially enrolled and when the enrollment is reported.
- **Enrollment Rate:** The enrollment rate consists of all customers who were ever actually on an SPO pricing plan for some period of time (meaning they enrolled at some point in time and did not de-enroll, opt-out or move before June 1, 2012) divided by the number of customers who were offered the plan. This is different from the customer acceptance rate, as defined below.
- **Customer Acceptance Rate:** The customer acceptance rate consists of all customers who agreed to go on a new pricing plan divided by the number of customers who were offered the plan. This value will typically be larger than the enrollment rate (and can't be less than it) as it includes everyone who signed up for a pricing plan even if they never went on the new plan.
    - For opt-in treatments, the *numerator* in the customer acceptance rate includes all customers who agreed to go on the pricing plan but who may have never done so because, for example, they moved before the plan went into effect. It would also include customers who went on the plan but later dropped out. The denominator would include all customers who received the marketing offer. This includes everyone chosen in the original sample less those who moved before the first marketing packets were sent. The customer acceptance rate is the best measure of the effectiveness of a marketing campaign.
    - For default treatments, the *numerator* of the customer acceptance rate consists of all customers who were defaulted onto the pricing plan and did not drop out prior to going on the new plan. If a customer goes on the plan and later drops out off, they would still be included in the numerator of this variable. Only customers who drop out prior to going on the plan are excluded from the numerator. The *denominator* of the customer acceptance rate for default pricing plans equals the number of customers who were defaulted onto the plan. It excludes customers who moved before June 1, 2012.
- **Decliners:** A decliner is a customer who was offered a pricing plan but declined to accept the offer. For opt-in plans, the number of decliners equals the total number of customers marketed to minus the total number of customers who accepted the offer. For default plans, the number of decliners equals the total number of customers defaulted onto the pricing plan minus those who dropped out prior to going on the plan. It does not include customers who were actually placed on the plan and then later drop out.
- **Drop outs:** Drop outs consist of customers who went on a pricing plan at some point in time, but who later requested to be taken off the plan. It does not include customers who drop out due to changing their location (e.g., moving). These are called movers. Customers who went on to MedRate or budget billing are also counted as drop outs although they may not have had a choice to stay in the SPO pilot. However, their numbers are so small that they are categorized with drop outs.
- **Movers:** Movers are customers who were either defaulted onto a new pricing plan or accepted an offer on an opt-in basis, but subsequently moved and, therefore, are no longer enrolled on

the plan. A mover may or may not have ever actually gone on the new pricing plan. For example, some customers may have accepted the new plan several months prior to the new plan going into effect and may have moved before they were placed on the pricing plan. Similarly, default customers may have not consciously declined the default option but may have moved between the time they were notified that a new pricing plan would be going into effect and when the plan actually went into effect.

2.6 Report Organization

The remainder of this report is organized as follows. Section 3 provides a summary of the analytical methods used to estimate load impacts for each pricing plan. Section 4 summarizes the load impact estimates for the four TOU pricing plans and Section 5 does the same for the CPP pricing plans. Section 6 examines the acceptance rate of IHDs for opt-in and default customers and the connection rate among those who accepted an IHD. It also examines the impact of the offer of an IHD on load reduction. The impact of the offer of IHD on acceptance of the rate plan is discussed in Section 8. Section 7 documents the estimation of demand models and price elasticities that can be used to predict the impact of changes in price levels on load reductions. Section 8 examines customer acceptance and retention rates for each pricing plan and summarizes models that were estimated that can be used to predict the likelihood of customers with various characteristics to accept and stay on each pricing plan. Section 9 summarizes the results of a conjoint survey that was conducted to determine how customer acceptance might change with variation in the attributes of opt-in pricing plans. Section 10 compares the relative cost-effectiveness of each pricing plan if it were to be rolled out to the broader SMUD population. Finally, Section 11 summarizes the findings from a detailed survey conducted among all participants after the end of the second summer to assess customer satisfaction with and perspectives on the various pricing plans and the use of IHDs.

3 Analytical Methodology for Load Impact Estimation

SMUD implemented an experimental design that encompasses multiple treatments and multiple methods of evaluation. This design enables a large number of useful analyses to be done that will help SMUD and the industry at large to make more informed decisions about time-variant pricing. Perhaps most importantly, the design allows for estimation of load impacts and acceptance rates without the risk of selection bias; this is quite rare and valuable in the realm of utility program evaluation. The discussion in this section focuses on the methods used to estimate the load impacts reported in Sections 4 and 5. The methods used to develop demand models and choice models for the various pricing plans are discussed in the report sections covering those topics.

3.1 General Approach

The fundamental step in estimating load impacts is to determine what loads would have been for treatment customers if they hadn't been exposed to the treatment; this is referred to as a reference load. SPO relied primarily on two experimental methods for developing reference loads—a randomized control trial (RCT) and a randomized encouragement design (RED). In addition, two treatments, opt-in CPP with and without an IHD offer, were designed to be analyzed using a within-subjects analysis, which constructs reference loads based on treatment customer loads during a time when the treatment is not in effect. The decision to rely on this design was based on an assumption that opt-in rates would be lower than they actually were. Because of the higher opt-in rates obtained in the study, it was possible to develop impact estimates using an RED analysis for these treatments that were originally planned to be analyzed using a within-subjects analysis. Section 9 of the SPO Interim Evaluation report compares load impact estimates developed using RED and within-subjects analysis methods, and also a third method involving the ex post development of control groups using statistical matching methods. This comparison strongly supports the use of RED/RCT methods for impact estimation whenever such methods are feasible.

An RCT refers to a research strategy in which customers who volunteer for a treatment are randomly assigned to treatment and control conditions. This method ensures that the only difference between treatment and control customers, other than small differences due to random sampling variation, is that one group receives the treatment and the other does not. An RCT design ensures that impact estimates are not affected by selection bias or other potential explanations for observed differences between the two groups of customers.

In practice, randomization can be achieved using either a *recruit and deny* process or a *recruit and delay* process. In the former, control customers are never given the treatment whereas in the latter, customers assigned to the control group are placed on the treatment after the end of the trial measurement period. Prior to that time, they act as the control group against which treatment effects are measured. SMUD used the recruit and delay method. Conceptually, the important issue is that because the groups were identical in expectation prior to the start of the experiment, the behavior of the group not on the treatment can be assumed to be an accurate representation of what the behavior of the group on the treatment would have been in the absence of the treatment. This study design was applied to two treatments: opt-in TOU and opt-in TOU plus IHD.

Load impacts can be estimated based on an RCT design by using what is called a difference-in-differences analysis. To estimate load reduction during the peak period, for example, the first difference calculation subtracts average load for the treatment group from the average load for the control group after the treatment goes into effect (in this instance, after June 1, 2012). A second difference value is calculated equal to the difference in peak period loads between treatment and control customers prior to the treatment going into effect (during the summer of 2011 in this instance). This second difference is subtracted from the first, which is why the analysis is called a difference-in-differences. The purpose of this second step is to adjust for any pretreatment differences between the control and treatment groups that might occur due to random variation in the assignment of customers to the treatment and control groups. This difference should be quite small if the treatment and control samples are large, since random error diminishes as sample sizes increase. If sample sizes are small, random error can be more impactful. Section 4 of the SPO Interim Evaluation report shows that adjustments due to random variation are small for all treatments in the SPO.

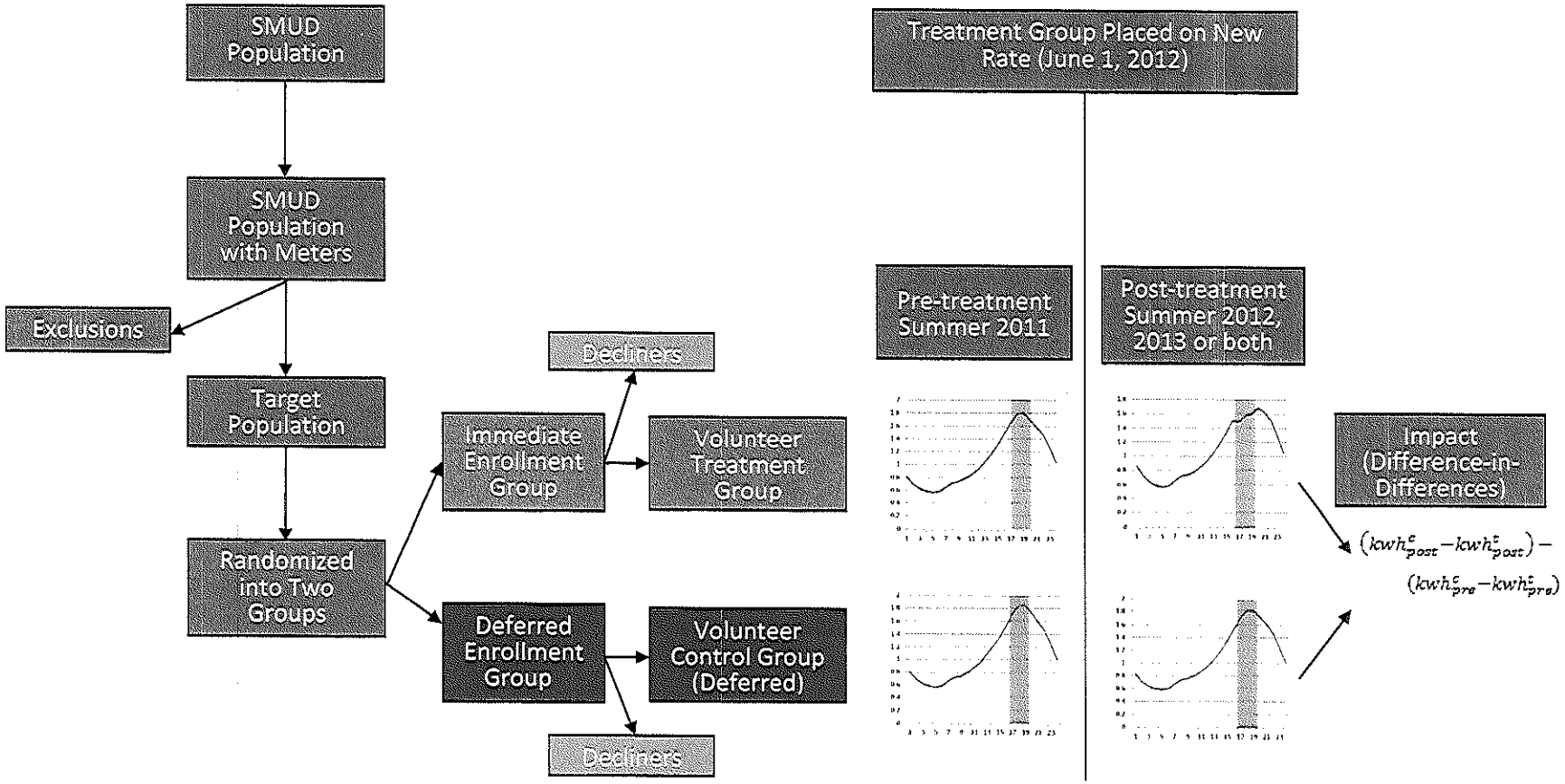
Figure 3-1 summarizes the design and evaluation of impacts using an RCT design. This approach was used for the two opt-in TOU treatments (with and without an IHD offer). Note that the randomization into either the immediate treatment or deferred treatment groups took place before customers were offered the pricing plan. Offers to customers, however, were exactly the same for both groups. Customers were blind to whether they had been pre-assigned to the immediate or deferred start as were customer service representatives (CSRs). Customers and CSRs only learned which group a customer was in after the customer accepted the plan offer.[10]

The experimental method used for the opt-out TOU treatments and for all CPP treatments is an RED. From the perspective of internal validity, an opt-in RCT and an RED are equivalent—both control equally well for selection bias and both allow one to estimate effects for those who accept the treatment, not just those that are offered the treatment. The analysis required to estimate the treatment effect on the treated using an RED requires an extra step as outlined later in this section.[11] Each requires the assumption that the offer of a treatment not taken or not received has no effect on energy consumption.

[10] The initial group of customers recruited for opt-in treatments were not told about the delay until after they agreed to participate. Some complaints from customers placed in the delayed group prompted SMUD to modify the recruitment material for all customers, both those pre-assigned to the treatment and delayed groups, to indicate that enrollment for some customers would be delayed. It is possible that a different set of customers would enroll in a program that only 50% of customers will be able to take part in immediately as compared to a program where all people who are interested are immediately enrolled. This could lead to an issue with external validity. However, this issue was unavoidable in designing an internally valid experiment.

[11] For further discussion of RCTs and REDs, see "Using Randomization in Development Economics Research: A Toolkit," by Duflo, Glennerster and Kremer. Handbook of Development Economics.

Figure 3-1: Overview of RCT Implementation and Analysis



In an RED, the behavior of two randomly-chosen groups of customers who were subjected to different levels of encouragement to take up a treatment is observed. For example, one group—the control group—could have received no offer to be on a new plan, while the treatment group could have received an invitation to enroll in a new plan. In a more complicated example, one group could have received an invitation to opt-in, while the other group could have received notification that they would be put on the rate by default unless they chose to opt-out. The key in both situations is that the two groups receive different levels of encouragement to be on the plan. The different levels of encouragement induce different participation rates between two groups that had the same expected characteristics prior to the experiment. This allows one to estimate the effect of the treatment on customers who were affected by the encouragement, as discussed below.

Using an RED design to estimate unbiased treatment effects requires the assumption that customers who are offered the treatment but decline are unaffected by the offer, and the only effect the treatment has is through the price signal (and the offer of the IHD, if applicable). Put another way, it is necessary to assume that customers who decline the offer—either on an opt-in or default basis—behave afterwards in the same way they would if they had never seen the offer. An RED analysis also assumes that customers who are placed on the rate through a default process, but would have opted in if the rate had been offered as voluntary, behave the same way no matter which way the offer was made. Some of the analyses also require the assumption that there are no customers who would accept the offer on an opt-in basis, but decline it on a default basis. Each of these assumptions seem quite reasonable. An RED was used for the following five treatments: default TOU plus IHD; default TOU-CPP plus IHD; opt-in CPP; opt-in CPP plus IHD; and default CPP plus IHD.

One fundamental difference between the analyses used for RCTs and for REDs is that with RCTs, all customers in the treatment group are enrolled and therefore assumed to be affected by the treatment and none in the control group are affected. In contrast, for REDs, the treatment group consists of all customers who received some form of encouragement toward a treatment and the control group consists of customers who received less encouragement or no encouragement. This means the RED treatment group contains many customers who are assumed to be unaffected by the treatment because they declined. This introduces a potential for confusion in terminology when discussing REDs because it is often convenient to consider the treatment group of an experiment to be the group of all customers who are directly affected by the treatment of interest (e.g., all customers who actually enroll).

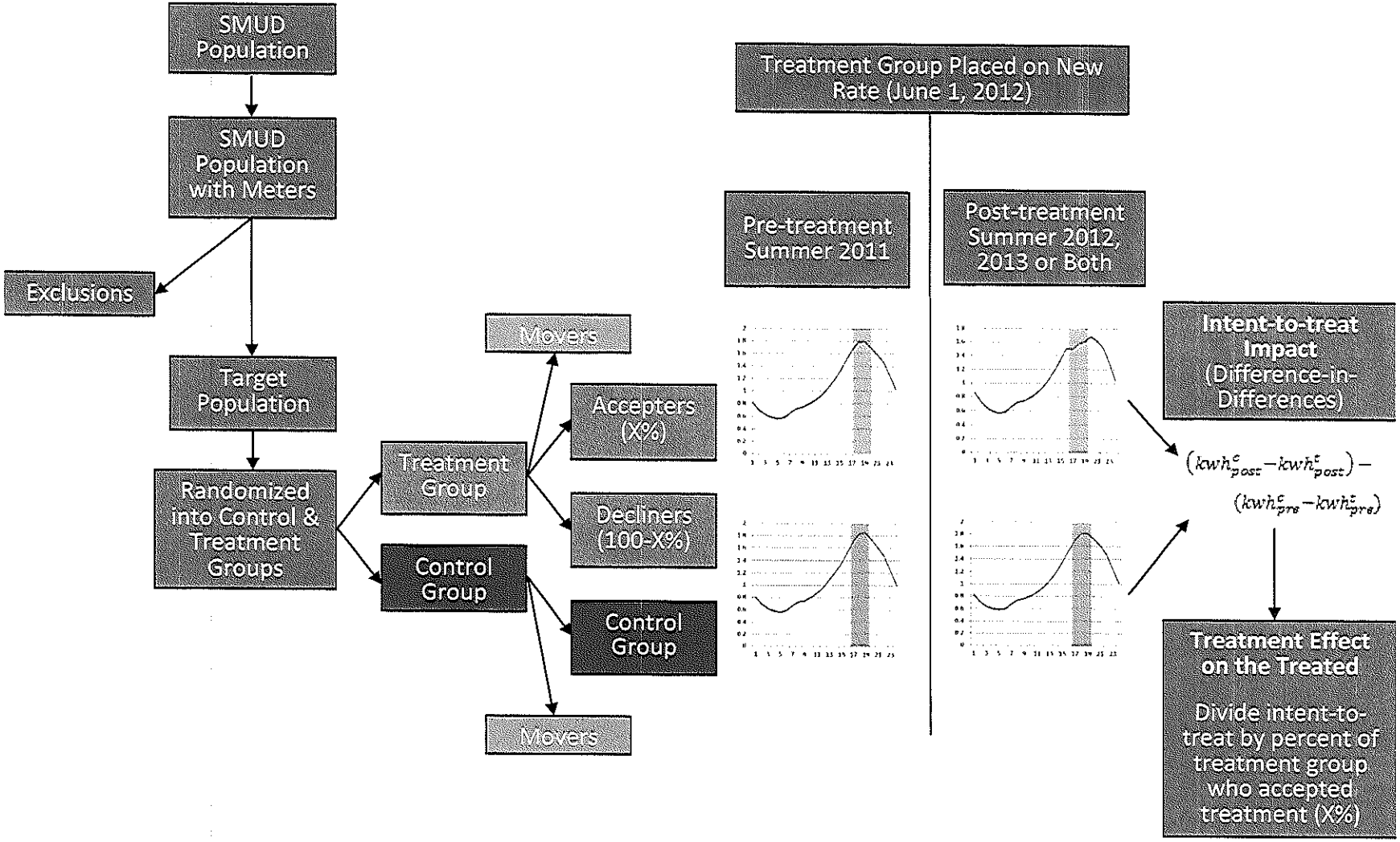
For an RED there are two treatments of interest, each vital to producing the final treatment impact estimate. First, there is the encouragement treatment, which gives an RED its name. In this case, that treatment consists of invitations to opt-in to the pricing plan (and for some the additional offer of an IHD) for opt-in cells and default assignment to a pricing plan (plus an IHD offer) for default cells. Second, there is the impact of the pricing plan itself, with or without an IHD offer. That is, the impact for those that enroll on the plan, not those that are offered the plan. In all discussions involving an RED, we adhere to the following terminology: the treatment group is synonymous with the encouraged group and refers to the group of customers who received a higher level of encouragement toward the treatment, including those who decline; takers and compliers are synonymous and refer to customers who accept the plan they are offered or defaulted onto, which does not necessarily mean they also took

the IHD offer.[12] Non-complier refers to a customer that has declined the offer, either by not opting in or by requesting not to be defaulted onto the plan. The control group refers to all customers receiving the lower level of encouragement—which typically is no encouragement.

Figure 3-2 summarizes the conceptual design and analysis of an experimental treatment using an RED. As discussed above, there are two load impacts of potential interest. One is the difference in load during, say, the peak period, between the encouraged (treatment) and non-encouraged (control) groups. As with the RCT, this analysis is based on a difference-in-differences calculation. This load impact is primarily of interest in this context because it is a necessary step to obtain the primary effect of interest, namely, the load reduction of compliers—that is, those customers in the encouraged group that actually take up the treatment. This impact is estimated by dividing the impact for the encouraged group by the percent of encouraged customers who accept the treatment offer. This is explained more fully in Section 3.2.

[12] Definitions of treatment group and control group are also included in the glossary in Appendix A.

Figure 3-2: Overview of RED Implementation and Analysis



3.2 Analysis of RCT and RED Treatment Groups

As discussed in Section 3.1, the logic underlying all RCT and RED analysis is that an unbiased reference load can be estimated by taking average loads among a group of customers with the same average pretreatment characteristics as customers who are subject to the treatment or encouragement of interest. The primary impact estimation process is referred to as a difference-in-differences analysis because the impact estimates equal the difference between loads in the treatment and control group at the time of interest (in this case, summer 2012, 2013 or both combined) minus the difference between loads in the treatment and control group during particular times prior to when the treatment goes into effect (e.g., summer 2011).

Difference-in-differences calculations can be done using regression analysis or simple averaging. Regression analysis is used here rather than simple averaging because regression allows each customer's mean usage to be modeled separately, which reduces the standard error of the impact estimates without changing their magnitude. Additionally, standard regression software allows for the calculation of standard errors for load impact estimates that correctly account for the correlation in customer loads over time.[13]

The pretreatment differences adjusted for by the regression should be as close as possible to the differences between the groups that would have been expected if the treatment had not been in place. Therefore, in all cases, the pretreatment loads included in each regression were chosen to be the loads most directly analogous to the loads during the period for which impacts were measured. For example, the pretreatment loads included in the analyses of TOU peak periods were the loads from the same groups during the peak period on weekdays from summer 2011. Similarly, the pretreatment loads used in the regressions for estimating CPP impacts were loads from the 4-7 PM peak period on weekdays with high temperatures above 90°F in summer 2011. Those days were chosen because CPP events are typically only called on hot days. It is important to note, however, that because the sample sizes are fairly large and because treatment and control group pretreatment loads are quite close in all cases, the adjustment for pretreatment differences generally has only a small impact on the results. Repeating all calculations as simple differences without pretreatment adjustments would lead to similar conclusions about the overall effect of each treatment.

The regression specification underlying all the treatment effect estimates reported from RCTs and REDs in this report is:

$$load_{it} = a_i + b_1 T_i I_1 + b_2 I_1 + u_{it} \qquad 3\text{-}1$$

The dataset used and the exact definition of each variable and parameter differs across treatment cells, as discussed below.

3.2.1 Opt-in TOU With and Without IHD Offer (RCT)

Two treatment groups were analyzed using the RCT framework—TOU and TOU plus IHD offer—and the dataset and variable definitions are the same for both. The primary analysis of interest for each

[13] More accurately, they account for the correlation in regression errors within customers over time.

treatment provides estimates of the peak period demand impact from the TOU pricing plan (or the TOU rate plus IHD plan). In this case, the dataset includes all customers who enrolled in the pricing plan, including deferred customers. The enrolled customers are the treatment group and the deferred customers are the control group. The variable $load_{it}$ in equation 3-1 contains hourly load only during the weekday peak period from 4-7 PM for summer 2011 and either summer 2012, summer 2013 or both, depending on what impacts are of interest,[14] for both treatment and control customers. The index *i* refers to customers and the index *t* refers to the time period of interest (which could be a simple hour, the average across the peak period hours, or some other period of interest).

In this version of the regression, a_i is an estimated parameter equal to the mean peak period weekday usage for each customer. The primary parameter of interest is b_1, which provides the estimated demand impact of TOU during the peak period. The parameter is the estimated coefficient on $T_i I_1$. T_i is equal to 1 for the treatment group during the treatment period (e.g., after they are placed on the pricing plan) and 0 otherwise. Finally, I_1 is the variable equal to 1 during the treatment period for all customers and 0 otherwise; this is not a parameter of primary interest, but it allows the regression to estimate the primary parameter of interest without confounding differences between treatment and control customers with differences in usage across years.

Demand impacts have also been estimated for each weekday peak period hour separately for each summer month—meaning there is a separate estimate of the TOU impact for 4-5 PM in June, 5-6 PM in June and so forth, with each estimate providing an average value over that hour for all weekdays in the respective month. This is accomplished using an identical regression specification as above, with a more limited dataset. For example, to produce the estimate for 4-5 PM in June, the dataset is restricted to contain only the hour from 4-5 PM for each weekday during June 2011 and June 2012. All other aspects of the specification remain the same and the interpretation of the variables and estimated parameters are very similar to the case of estimating the overall average effect.

Additionally, demand impacts were estimated for all non-peak periods during the summer, as described in the results section. In these cases, again, the regression specification and interpretation are the same; the only difference is that different hours were included in the regression. These sets of hours can be directly inferred from the results given. For example, to estimate the effect of TOU on the hours immediately before the peak period, the regression only includes hours immediately before the 4-7 PM peak period.

Finally, energy conservation impacts were estimated in addition to demand impacts. Energy conservation is not the primary goal of the treatments, but the treatments could lead to measurable energy savings, which could provide additional value to SMUD. Alternatively, TOU rates could lead to overall increases in usage if customers primarily shift usage from peak to off-peak periods while simultaneously increasing overall usage in response to the lower off-peak prices, which are in effect

[14] If the analysis is being done to estimate impacts for summer 2012, the data set includes data from 2011 and 2012. If the analysis is being done to estimate impacts for summer 2013, the data set includes data from 2011 and 2013. If the analysis is being done to estimate the average impact across both summers, the data set would include data from 2011, 2012 and 2013.

many more hours than higher peak period prices. Determining whether the SPO pricing plans decrease or increase usage, or leave it largely unchanged, is important for cost-effectiveness analysis.

To estimate energy conservation effects, the same specification is used but the estimation is based on monthly usage data rather than hourly or rate-period usage. The dataset includes monthly usage for June-September 2011, 2012 and/or 2013 depending on the time period of interest for the same sets of customers as in the demand impact estimates. The impacts are calculated based on differences in usage between the treatment and control groups during the treatment period and were adjusted based on differences seen in the pretreatment data, the summer of 2011. In this version of the regression, a_i is an estimated parameter equal to the mean monthly usage over pre- and post-treatment periods for each customer. The primary parameter of interest is b_1, which is equal to the estimated monthly energy savings due to TOU during the treatment period. The definitions and interpretations of $T_i I_1$ and $b_2 I_1$ are identical to the demand impact case.

3.2.2 Default TOU Plus IHD Offer and TOU-CPP Plus IHD (RED)

The rest of the TOU analyses are based on REDs rather than RCTs. There are two rates analyzed in the RED framework: default TOU and default TOU-CPP. Both of these treatments included the offer of an IHD. For the TOU-CPP rate, the analysis method summarized in this section focuses on the impact on all summer weekdays. The analysis method used to estimate the incremental effect of the CPP price is discussed in Section 3.2.3.

For both TOU default treatments, the primary analysis of interest is estimation of the peak period demand impact from the TOU rate. The regression specification in equation 3-1 does not directly provide this estimate; instead it provides an estimate of the load impact for the average customer that received an offer, not the average for customers who accepted the offer. This initial load impact estimate is often referred to as the intent-to-treat estimate. Under the reasonable assumption that non-compliers were unaffected by the offer, the intent-to-treat estimate can be transformed into the effect of the treatment on compliers by dividing the intent-to-treat estimate by the fraction of the population enrolled on the pricing plan. This scaled up effect is often referred to as the local average treatment effect. The word "local" is used to indicate that the effect is only measured for customers who responded to the encouragement. In the case where a comparison is made between an encouraged group and a control group with no one on the treatment, it is also referred to as the treatment effect on the treated. If the comparison is made between two groups that are encouraged in different ways (e.g., opt-in encouragement versus default encouragement), the local effect represents the change in usage for customers who would not have enrolled if given that option and who did not opt out from the default enrollment.

It is important to understand how equation 3-1 is used in the RED analyses because it is the first step of each such analysis. In the case of the TOU and TOU-CPP treatments, the dataset includes all customers who were offered the respective treatment (either TOU plus IHD offer or TOU-CPP plus IHD offer) and all customers in the control group. The dataset contains hourly load only during the peak period hours of weekdays from 4-7 PM for summer 2011 and either summer 2012, 2013 or both for both groups. The interpretation of the variables and estimated parameters for these two groups is essentially the same as in the TOU RCT cases above, with the important difference being that all parameters include the effect

of non-compliers and are therefore intent-to-treat estimates rather than estimates of the local average treatment effect.

Also analogous to the TOU RCT case is that estimates are developed for individual hours or non-peak periods by altering the set of hours in the regression dataset. Similarly, energy savings impacts are estimated by substituting monthly data for hourly data, in the same way described above for the TOU RCTs. Again, this produces intent-to-treat estimates which must be scaled up.

In each case, intent-to-treat estimates are scaled up to local average treatment effects by dividing by the fraction of customers enrolled at the relevant time. This is complicated somewhat by the fact that customer enrollment changes over the summer as some customers drop out of the treatment. For monthly TOU impacts, the enrollment fraction used for scaling was the average enrollment during that month among the relevant treatment group. For overall TOU impacts, the fraction used was the average enrollment fraction over the period of interest, either 2012, 2013 or both.

For impact estimation, the TOU-CPP plus IHD group can be treated identically to the TOU-only groups. The interpretation of the results must take into account the fact that these customers face much higher prices on certain days. For this reason, we also examine the effect of TOU on this group of customers, excluding CPP days. The method for doing this is to use the same regression analysis, but to exclude CPP days from the dataset.

3.2.3 Opt-in CPP, Default CPP and Default TOU-CPP (RED)

The RED analysis of CPP rates is the same as the analysis described above for TOU rates, with equation 3-1 again being the regression specification and the dataset including the full treatment and control group for each rate. This method applies to opt-in CPP with and without the offer of an IHD and default CPP and TOU-CPP, both of which included the offer of an IHD. The only difference in the analysis of the CPP rates and the TOU rates is that the pretreatment data includes only weekdays with peak temperatures above 90°F in 2011.

Again, for REDs, equation 3-1 produces the intent-to-treat estimate, which must be scaled up by the fraction of customers within the treatment group that is enrolled to produce the local average treatment effect. Due to customers leaving the rate during the summer, this fraction differs across events, and so each CPP event impact is estimated using the fraction of enrolled customers at that point during the summer. Overall, average CPP effects are scaled by the average enrollment fraction over all CPP events.

For the TOU-CPP with IHD group, the effect of the CPP rate on CPP days is estimated in the same way as the effect of the CPP treatment for the other CPP cells.

3.3 Standard Errors

In order to interpret the results of each analysis, it is important to understand not just the point estimates for each variable, but also the variance of each estimate and the associated confidence interval. For RCT analyses, the regression software automatically produces standard error estimates,

and the only complication is that those estimates must be calculated using the cluster option, which assumes that the regression errors are correlated with each other within each customer's set of errors.

For RED analyses, the first step is to estimate the standard errors of the intent-to-treat estimates, as produced by the regression with the cluster option. Those standard error estimates are then scaled up using the same scaling factor used to scale the intent-to-treat estimates themselves—the difference in the fraction of compliers between the treatment and control groups. This produces correct standard error estimates for the estimates of the local average treatment effects.

With point estimates and standard errors, confidence bands and tests of statistically significant differences can be calculated. To calculate the p-value of the hypothesis that the point estimates arise from the same distribution, we first calculate the standard error of the difference, which is the square root of the sum of the standard errors from each point estimate. Next, the ratio of the difference to the standard error of the difference is calculated. Under standard assumptions and the central limit theorem, this ratio is distributed with a Gaussian (Normal) distribution with mean zero and variance equal to one. Therefore, the p-value is determined by finding the fraction of the Gaussian distribution that is more extreme (i.e., further from zero) than the calculated ratio.[15] Because two-sided hypothesis tests are performed in all cases, this fraction is doubled and that equals the p-value. The p-value indicates the probability of observing an estimated difference that large if the two estimates came from the same distribution. Therefore, a low p-value indicates that it is unlikely that a difference that large would be observed if the two estimates came from the same distribution. In that sense, a low p-value increases confidence that the observed differences are not due to chance alone and therefore are statistically significant.

[15] Technically, a t-distribution should be used for such a test, but the t-distribution and Gaussian distribution are virtually identical for large sample tests such as this.

4 TOU Pricing Plan Impacts

This section presents the demand and energy impact estimates for the TOU and TOU-CPP pricing plans included in the SPO. The SPO design was intended to provide adequate statistical power to measure treatment effects[16] averaged over each summer for the peak period for each rate option (for TOU, TOU-CPP and CPP options). These average impacts are the primary focus of this evaluation, although sample size calculations also focused on estimating conservation effects. Other impacts of interest can be obtained from the data, including estimates by month, estimates for individual hours of the peak period, individual CPP event day effects and non-peak period effects. When reviewing these additional estimates, it should be kept in mind that the experiment was not designed to estimate these effects. As such, standard error estimates for these parameters tend to be larger. When reviewing impact estimates in the remainder of this section and in Section 5, keep in mind that the convention used is that positive impact values indicate reductions in use and negative values indicate increases.

4.1 Peak Period Load Reductions by Pricing Plan

The TOU peak period covers 4 to 7 PM on all non-holiday weekdays from June through September. During the peak period, the price per kWh for non-EAPR customers is 1.6 to 3 times higher than the off-peak price, depending on whether a customer's energy use puts them in usage tier 1 or 2. For customers on the low-income EAPR rate, the peak period price is 1.2 to 3.6 times higher than the off-peak price.

Table 4-1 shows the average estimated absolute and percentage impacts for the TOU rate options across all summer peak hours. Impacts are shown for each summer and for the two summers combined. The p-values in the last column in the table show whether the difference in impacts across the two summers is statistically significant. Table 4-2 shows the p-values for the pairwise comparisons of load impacts across pricing plans to assess whether the impact for one pricing plan is significantly different from the impact for another plan.

Looking first at the impacts in Table 4-1 averaged across the two years, the largest absolute and percent reductions are from the opt-in TOU group that was offered the IHD. The average impact for this treatment group was 0.21 kW, which equals 11.9% of the whole house reference load. The lowest absolute and percent impact was for the default TOU group (which included an IHD offer, as did all default groups), where the absolute average reduction across the two summers equaled 0.11 kW, or 5.8% of the average customer's whole house reference load. Impacts for the remaining two groups, opt-in TOU with no IHD offer and default TOU-CPP with an IHD offer, were 0.16 kW (9.4%) and 0.17 kW (8.7%), respectively. As seen in Table 4-2, the differences in peak period load impacts across the various pricing plans were statistically significant for 3 pairwise comparisons:

- the default TOU with an IHD offer and default TOU-CPP with an IHD offer, with a p-value of 0.05 (statistically significant at the 90% confidence level);

[16] See CBS Power Analysis in Appendix F of the SPO Interim Report.

- opt-in TOU with an IHD offer and opt-in TOU without an IHD offer, with a p-value of 0.07 (statistically significant at the 90% confidence level); and
- the opt-in TOU with IHD offer and default TOU with IHD offer, which was statistically different at the 99% level of confidence.

Table 4-1: Average Peak Period Load Impacts for TOU Pricing Plans for the Average Weekday

Group	Year	Average Impact per Customer (kW)	95% CI Lower[17]	95% CI Upper	Reference Load (kW)	Impact as % of Reference Load	P Value (Difference Across Years)
Opt-in TOU, No IHD Offer	2012	0.17	0.13	0.22	1.71	10.0%	0.65
	2013	0.15	0.10	0.21	1.69	9.1%	
	Average	0.16	0.12	0.21	1.72	9.4%	n/a
Opt-in TOU, IHD Offer	2012	0.24	0.20	0.27	1.80	13.1%	0.15
	2013	0.20	0.15	0.24	1.79	10.9%	
	Average	0.21	0.18	0.25	1.79	11.9%	n/a
Default TOU, IHD Offer	2012	0.12	0.09	0.15	1.87	6.2%	0.52
	2013	0.10	0.07	0.14	1.80	5.7%	
	Average	0.11	0.08	0.14	1.86	5.8%	n/a
Default TOU-CPP, IHD Offer[18]	2012	0.16	0.11	0.21	1.90	8.2%	0.63
	2013	0.18	0.11	0.24	1.85	9.6%	
	Average	0.17	0.11	0.22	1.91	8.7%	n/a

Table 4-2: P-values for Pair Wise Comparisons of Average Load Impacts Across Two Years for TOU Pricing Plans

Group	Opt-in TOU, No IHD Offer	Opt-in TOU, IHD Offer	Default TOU, IHD Offer	Default TOU-CPP, IHD Offer
Opt-in TOU, No IHD Offer	n/a	n/a	n/a	n/a
Opt-in TOU, IHD Offer	0.07*	n/a	n/a	n/a
Default TOU, IHD Offer	0.05*	0.00**	n/a	n/a
Default TOU-CPP, IHD Offer	0.90	0.13	0.05*	n/a

*Statistically significant at the 90% level; ** Statistically significant at the 99% level

[17] The 95% confidence bands are shown for load impacts in each table in this report. If the upper and lower values of the 95% confidence band bracket 0, it means that the estimated impact is not statistically significant with 95% confidence.

[18] Average weekday impacts for the TOU-CPP plan include impacts on both CPP and non-CPP days.

4.2 Impact Persistence

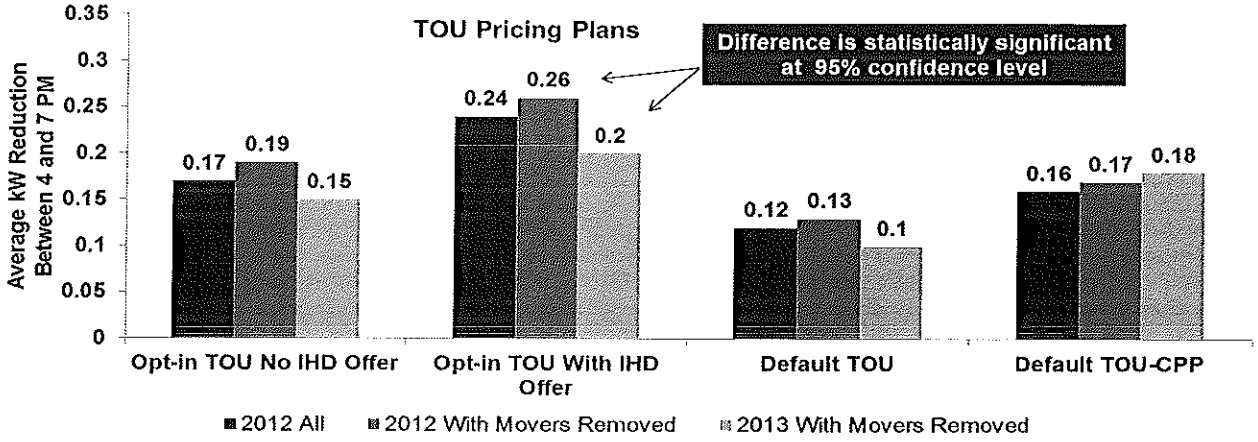
An important issue for resource planning purposes is whether load impacts from time-variant rates persist over time. As seen in Table 4-1, there are small decreases in the average impact from 2012 to 2013 for three of the four pricing plans and a small increase in the impact for the fourth pricing plan, default TOU-CPP. However, as indicated by the p-values in the last column in the table, none of these differences is statistically significant.

The above comparison of load impacts in 2012 with those in 2013, while interesting, is not the best measure of persistence because the population of participants changed across the two summers. As discussed at length in Section 8, customer attrition for most plans equaled roughly 25% over the course of the two summers, with the vast majority of this attrition resulting from customers who moved rather than from those who actively dropped out of the pricing plans. Customers who moved were dropped from their pricing plan and could not re-enroll. Since movers are more likely to live in multiple family dwellings and, therefore, be more likely to have smaller loads than those who don't move, a simple comparison of load impacts across the two summers based on the populations that are enrolled in each summer is not a valid measure of whether load impacts persist among customers who remain on a pricing plan over time, which is a more interesting question from a policy perspective. To make this comparison, load impacts were calculated for each summer based on the segment of customers who did not move over the course of the study.[19]

Figure 4-1 shows impacts for each summer for customers who did not move over the two summers. For comparison, it also shows the estimates based on the full 2012 population. As seen, the impacts for the stable population are larger for each pricing plan, which is consistent with the hypothesis that movers have smaller loads and load response than those who do not move. For three of the four pricing plans, the small differences across years for the non-mover population are not statistically significant – that is, impacts persisted across the two summers for those who were enrolled in both summers. For the opt-in TOU group with an IHD offer, there was a drop in load impacts in the second summer and the difference is statistically significant at the 95% confidence level.

[19] Active drop outs were kept in the database since dropping them would have led to a selection effect that could not be controlled for using the RED analysis methods applied in each case because there were no drop outs in the control group, just movers. Because the same percent of customers should move in both the treatment and control groups, the RED analysis is still valid when movers are dropped.

Figure 4-1: Load Impacts for Each Summer for Customers Who Did Not Move During the Study Period



4.3 Load Impacts by Month

In addition to knowing how average impacts vary across pricing plans, it is useful to observe how impacts vary across months for each plan. Table 4-3 shows the average load reductions by month for the two summers combined for each TOU pricing plan. For the three TOU only plans, September has the lowest absolute and percent load reductions across the four months, with June being the second lowest. The average impacts are highest in July for the two opt-in plans and highest in August for the default TOU plan, but the differences between July and August are not large for any of these plans. Impacts for the default TOU-CPP plan are influenced by the number of event days in each month, which is why the impacts in September are much higher than for the default TOU plan. Across the two years, there were more CPP event days in September (a total of 9) than in any other month.[20]

[20] There was 1 June event used in the analysis, 5 July events, 8 August events and 9 September events across the two years.

Table 4-3: 2012/2013 Average Load Impacts by Month for TOU Pricing Plans[21]

Month	Group	Average Impact per Customer (kW)	95% CI Lower	95% CI Upper	Reference Load (kW)	% Impact
June	Opt-in TOU, No IHD Offer	0.15	0.10	0.19	1.57	9.4%
	Opt-in TOU, IHD Offer	0.17	0.13	0.20	1.55	10.9%
	Default TOU, IHD Offer	0.10	0.07	0.12	1.75	5.5%
	Default TOU-CPP, IHD Offer	0.14	0.09	0.19	1.81	7.6%
July	Opt-in TOU, No IHD Offer	0.21	0.15	0.26	2.11	9.7%
	Opt-in TOU, IHD Offer	0.27	0.23	0.32	2.05	13.4%
	Default TOU, IHD Offer	0.12	0.08	0.15	2.17	5.5%
	Default TOU-CPP, IHD Offer	0.19	0.13	0.25	2.25	8.4%
August	Opt-in TOU, No IHD Offer	0.20	0.14	0.26	1.83	11.2%
	Opt-in TOU, IHD Offer	0.27	0.22	0.31	2.07	12.9%
	Default TOU, IHD Offer	0.14	0.10	0.18	2.15	6.5%
	Default TOU-CPP, IHD Offer	0.20	0.13	0.27	2.22	9.0%
September	Opt-in TOU, No IHD Offer	0.08	0.02	0.14	1.33	6.0%
	Opt-in TOU, IHD Offer	0.14	0.10	0.19	1.50	9.6%
	Default TOU, IHD Offer	0.07	0.04	0.11	1.61	4.5%
	Default TOU-CPP, IHD Offer	0.14	0.07	0.20	1.69	8.1%

4.4 Load Impacts by Customer Type

For opt-in pricing plans, it is useful to understand how load impacts vary across customers who might differ in selected ways such as EAPR status or overall usage. Such information can be used to develop targeted marketing strategies that can improve program cost effectiveness. Even for default plans, knowing the types of customers that produce the largest load reductions can be useful input to educational strategies that might help improve overall load reductions.

Table 4-4 shows how load impacts vary by EAPR status for the four TOU pricing plans. EAPR customers have both lower load impacts on an absolute basis and lower reference loads compared with non-EAPR customers for all four treatment groups. For the two default pricing plans, the difference in the absolute impacts between EAPR and non-EAPR customers is small and is explained completely by the difference in reference loads for the two groups since the percent reductions are almost identical. That is, EAPR customers show the same responsiveness to price as non-EAPR customers when defaulted onto a TOU pricing plan, but the absolute impacts are lower for EAPR customers because their usage is lower. For the two opt-in pricing plans, both the average absolute and percent reductions are lower for EAPR

[21] Hourly impacts by month during the peak period for the TOU pricing plans are presented in Appendix B.

customers than for non-EAPR customers. For the opt-in group with no IHD offer, the load reduction for EAPR customers is less than half as large as for non-EAPR customers even though the reference load for the two groups differed by less than 10%. For the opt-in group with the IHD offer, the absolute impacts differ by about 50% even though the reference loads differ once again by less than 10%.

Table 4-4: 2012/2013 Average Load Impacts by EAPR Status

Group	EAPR					Non-EAPR				
	Impact	95% CI Lower	95% CI Upper	Reference Load	% Impact	Impact	95% CI Lower	95% CI Upper	Reference Load	% Impact
Opt-in TOU, No IHD Offer	0.08	0.00	0.16	1.65	4.8%	0.20	0.15	0.25	1.76	11.3%
Opt-in TOU, IHD Offer	0.14	0.08	0.20	1.70	8.2%	0.24	0.20	0.29	1.84	13.2%
Default TOU, IHD Offer	0.09	0.04	0.15	1.64	5.7%	0.11	0.08	0.14	1.93	5.8%
Default TOU-CPP, IHD Offer	0.15	0.05	0.25	1.76	8.5%	0.17	0.11	0.22	1.96	8.5%

Another important customer characteristic of potential interest is usage. Table 4-5 shows how load impacts vary with usage. All customers on each pricing plan were stratified into quartiles based on average summer usage. Bins 1 through 4 in the table represent the lowest to the highest usage quartile. Absolute impacts increase significantly from the lowest to the highest usage bin for each treatment group, but the magnitude of the spread varies significantly across treatment groups. For example, for the default TOU plan, the difference in impacts is less than a factor of three between the lowest and the highest usage bin. However, for the default TOU-CPP group, the difference is more than a factor of 10. The variation in percent impacts is much different from the variation in absolute impacts, increasing from lowest to highest in some cases but falling in others. One thing that is clear is that for any opt-in pricing plan, targeting high usage customers will be much more cost effective than targeting low usage customers.

Table 4-5: 2012/2013 Average Load Impacts by Usage Quartile for TOU Pricing Plans (Bin 1 is the lowest usage quartile, Bin 4 is the highest usage quartile)

Group	Bins	Reference Load	Impact	95% CI Lower	95% CI Upper	Percent Impact
Opt In TOU, No IHD Offer	1	0.60	0.05	0.01	0.10	9.1%
	2	1.30	0.13	0.06	0.21	10.3%
	3	1.98	0.18	0.09	0.27	9.2%
	4	3.15	0.28	0.15	0.41	8.8%
Opt In TOU, IHD Offer	1	0.62	0.07	0.03	0.11	11.2%
	2	1.33	0.20	0.14	0.26	15.1%
	3	2.00	0.24	0.17	0.31	12.2%
	4	3.16	0.33	0.24	0.42	10.5%
Default TOU, IHD Offer	1	0.64	0.06	0.02	0.09	9.0%
	2	1.35	0.10	0.05	0.14	7.2%
	3	2.05	0.12	0.06	0.18	5.8%
	4	3.30	0.16	0.08	0.24	4.8%
Default TOU-CPP, IHD Offer	1	0.59	0.03	-0.03	0.09	4.6%
	2	1.36	0.07	-0.01	0.14	4.8%
	3	2.07	0.20	0.09	0.30	9.5%
	4	3.53	0.36	0.22	0.50	10.2%

4.5 Load Impacts Outside the Peak Period

Although the peak period hours are of primary interest, it is also useful to know what happens to electricity usage during non-peak hours for customers on the TOU pricing plans, especially those hours just before the peak period when pre-cooling might occur and right after the peak period, when a snapback effect might exist. Table 4-6 shows impacts for each of the four TOU groups for the two hours before the peak period (2 to 4 PM) and the two hours after the peak period (7 to 9 PM) across all summer weekdays for the two summers combined. The results in the table show that there are no statistically significant load reductions in the hours leading up to or following the peak period for any of the TOU pricing plans for the average weekday.

Table 4-6: 2012/2013 Average Load Impacts Before and After Peak Period for TOU Pricing Plans

Group	Average Impact Pre-Peak (2-4PM) (kW)	95% CI Lower	95% CI Upper	Average Impact Post-Peak (7-9 PM) (kW)	95% CI Lower	95% CI Upper
Opt-in TOU, No IHD Offer	-0.03	-0.07	0.00	0.00	-0.04	0.03
Opt-in TOU, IHD Offer	0.00	-0.03	0.03	0.02	-0.01	0.04
Default TOU, IHD Offer	0.00	-0.03	0.02	0.02	-0.01	0.04
Default TOU-CPP, IHD Offer	0.01	-0.03	0.06	0.02	-0.02	0.06

4.6 Energy Savings

In addition to calculating demand impacts during the TOU peak period, overall energy savings was estimated for each treatment. Table 4-7 summarizes this analysis. All four treatment groups showed energy savings of roughly 1% but only the impact estimate for the default TOU plan was statistically significant. Given the lack of load shifting seen in the prior section and the fact that the opt-in groups showed statistically significant load reductions during the peak period (as seen in Table 4-1), even the statistically insignificant impacts shown below may be taken as evidence of energy savings. With significant peak period reduction and no evidence of load shifting, the net result would need to be a modest reduction in overall energy use. Importantly, there is no evidence of an increase in overall electricity use in response to the lower off-peak prices that are in effect the majority of hours.

Table 4-7: Energy Savings for TOU Pricing Plans

Group	Design	Average Monthly Impact (kWh)	95% CI Lower	95% CI Upper	Monthly Reference Load (kWh)	Impact as % of Reference Load
Opt-in TOU, No IHD Offer	RCT	9.4	-6.8	21.6	818	1.1%
Opt-in TOU, IHD Offer		7.4	-7.9	26.7	843	0.9%
Default TOU, IHD Offer	RED	11.4	1.7	21.1	844	1.3%
Default TOU-CPP, IHD Offer		11.9	-8.6	32.4	885	1.3%

5 CPP Pricing Plan Impacts

This section summarizes the demand and energy impact estimates for the CPP pricing plans and for CPP days for the TOU-CPP pricing plan. As in Section 4, which covered the TOU treatments, the primary focus of this section is on average peak-period load impacts across all CPP events for the entire summer. We also examine how impacts vary across events and with fluctuations in temperature on event days. Impact comparisons are also made for customers who were and were not offered an IHD. As in the TOU section, additional estimates are developed for time periods that the experiment was not designed to produce, but that are nevertheless of interest.

5.1 Peak Period Load Reductions

The peak period for the CPP pricing plans is the same as for the TOU plans, 4 to 7 PM. In 2012, 12 CPP event days were called. However, on the first event day, June 20, 2012, customer notifications did not go out to everyone. As a result, the June 20 event day was not included in the analysis. For customers who did not receive notification for the June 20 event, an additional first event was called but not analyzed. This way, when the second event was called on July 10, it was the second event for all customers. In 2013, 12 events were called. Table 5-1 shows the dates, day of week and daily maximum temperature for each event day. Across the two summers, 2 events were called in June (although one was not included in the analysis for reasons stated above), 5 in July, 8 in August and 9 in September. The daily maximum temperature exceeded 90°F on all but 2 CPP days and was 95°F or greater on 16 out of the 24 event days. 5 of the 7 coolest event days occurred in September 2013.

Table 5-1: CPP Event Days for 2012 and 2013

2012 Events			2013 Events		
Date	Day of Week	Daily Maximum Temperature (°F)[22]	Date	Day of Week	Daily Maximum Temperature (°F)
20-Jun-12	Wednesday	Not Analyzed	28-Jun-13	Friday	104
10-Jul-12	Tuesday	101	2-Jul-13	Tuesday	103
12-Jul-12	Thursday	102	3-Jul-13	Wednesday	105
2-Aug-12	Thursday	99	19-Jul-13	Friday	99
8-Aug-12	Wednesday	100	15-Aug-13	Thursday	95
9-Aug-12	Thursday	103	19-Aug-13	Monday	104
10-Aug-12	Friday	103	6-Sep-13	Friday	94
14-Aug-12	Tuesday	96	9-Sep-13	Monday	101
15-Aug-12	Wednesday	95	10-Sep-13	Tuesday	87
12-Sep-12	Wednesday	92	13-Sep-13	Friday	91
13-Sep-12	Thursday	97	19-Sep-13	Thursday	91
14-Sep-12	Friday	91	30-Sep-13	Monday	78

[22] The maximum temperature reported here comes from a maximum temperature file provided by SMUD. In some cases it is slightly higher than the maximum hourly temperature in the hourly temperature file used for analysis purposes. In the comparable table in the interim report, the hourly maximum temperature was reported and it differs slightly on some days from the values reported here which is based on the data contained in the maximum temperature file provided by SMUD.

Table 5-2 shows the average impact across all CPP event hours for 2012, 2013 and the two years combined. Table 5-3 shows the p-values for each pairwise comparison of load impacts by pricing plan based on the two year average. Focusing first on the opt-in plans, the average load reductions for the opt-in CPP plan with no IHD offer was 0.49 kW, or roughly 20.9% of whole house load, and the average for the opt-in CPP plan with an IHD offer was 0.64 kW, or 25.1%. The difference in the two estimates is not statistically significant although this may primarily be due to the relatively large confidence bands around the average value for the opt-in group with no IHD offer. The sample size for this treatment group was small to begin with, with enrollment of only 212 at the start of summer 2012. By the end of summer 2013, the sample size had fallen to less than 150, which is why the confidence bands for the 2013 estimate are so large and also why they are larger for the two year average than for any of the other treatment cells. Indeed, as seen in Table 5-3, the average impact estimate across two years for the CPP plan with no IHD offer is not statistically different from any of the other three plans even though the absolute differences are roughly 50% in two cases.

Table 5-2: Load Impacts for CPP Pricing Plans

Group	Year	Average Impact per Customer (kW)	95% CI Lower	95% CI Upper	Reference Load (kW)	Impact as % of Reference Load	P Value (Difference Across Years)
Opt-in CPP, No IHD Offer	2012	0.52	0.26	0.78	2.38	21.9%	0.78
	2013	0.46	0.16	0.77	2.25	20.6%	
	Average	0.49	0.24	0.73	2.33	20.9%	n/a
Opt-in CPP, IHD Offer	2012	0.69	0.58	0.79	2.62	26.2%	0.27
	2013	0.60	0.48	0.72	2.48	24.1%	
	Average	0.64	0.54	0.73	2.53	25.1%	n/a
Default CPP, IHD Offer	2012	0.32	0.24	0.40	2.64	12.1%	0.16
	2013	0.41	0.32	0.50	2.47	16.5%	
	Average	0.36	0.28	0.44	2.56	14.0%	n/a
Default TOU-CPP, IHD Offer	2012	0.33	0.25	0.41	2.61	12.8%	0.48
	2013	0.29	0.20	0.38	2.43	11.9%	
	Average	0.31	0.24	0.39	2.54	12.3%	n/a

The default CPP plan had an average load reduction of 0.36 kW, or 14.0% of whole house load. This is roughly half as large as for the opt-in CPP plan with an IHD offer and the difference is statistically significant at the 99% confidence level. The default TOU-CPP plan produced an average reduction of 0.31 kW, or 12.3% of whole house load. The difference in impacts between the two default options is not statistically significant.

Table 5-3: P-values for Pair Wise Comparisons of Load Impacts Across CPP Pricing Plans (Based on Averages for 2012/2013 Combined)

Group	Opt-in CPP, No IHD Offer	Opt-in CPP, IHD Offer	Default CPP, IHD Offer	Default TOU-CPP, IHD Offer
Opt-in CPP, No IHD Offer	n/a	n/a	n/a	n/a
Opt-in CPP, IHD Offer	0.27	n/a	n/a	n/a
Default CPP, IHD Offer	0.33	0.00**	n/a	n/a
Default TOU-CPP, IHD Offer	0.18	0.00**	0.39	n/a

** Statistically significant at the 99% confidence level

The last column in Table 5-2 shows the results of tests for statistically significant differences across the two summers. As seen, although there were small decreases in the estimated impacts for three of the four plans, none of the differences across years are statistically significant. Section 5.2 compares impacts across years after controlling for changes in the population of participants due to customers that moved over the two summers.

Although the sample sizes used in SPO were not designed to estimate individual event day load impacts, it is still possible to do so, while recognizing that the confidence intervals around these estimates will be larger than for the average event day. Table 5-4 shows the estimated load impacts for each event day for one of the four treatments, the opt-in CPP rate with IHD offer.[23] As seen, the load impacts vary significantly across event days, from a low of 0.23 kW on the coolest day (September 30, 2013) when the maximum temperature was only 78°F, to a high of 1.0 kW on the hottest day (July 12, 2012), when the maximum temperature was 102°F. In general, load impacts are higher on hotter days than on cooler ones, although other factors such as day of week and random variation in loads mean that the relationship between temperature and load reductions is not perfectly correlated. Figures 5-1 and 5-2 show the relationship between weather and absolute and percentage load reductions, respectively. As seen, the slope of the line is much steeper when based on absolute load reductions than it is when based on percentage load reductions. Indeed, given that the reference load increases significantly with temperature, even if the percentage load reduction was constant across days, a graph of weather versus absolute load reductions would still have a positive slope. As seen in Figure 5-2, however, there is also a positive relationship between temperature and percent reduction, meaning that the average consumer on this rate reduces load more on both a percentage and absolute basis as the daily maximum temperature increases.

Another issue of interest is whether impacts drop off on the second and third day of multi-day events. In other words, do consumers tire of reducing load when it is hot several days in a row? There were two three-day event sequences across the 23 event days, both during the 2012 summer, and three two-day events, with one occurring in 2012 and two in 2013. Differences in impacts were small in four out of five multi-day sequences. The only one where the difference was relatively large was for the two-day event sequence on September 9 and 10 in 2013. However, this difference is due entirely to the drop off in

[23] Appendix C contains impact estimates for each hour of each event day for all four treatments.

temperature on the second event day, when the maximum temperature was only 87°F, compared with 101°F on the prior day. Indeed, the percentage reduction across those two days was nearly identical.

Table 5-4: Event Day Load Impacts for Opt-in CPP with IHD Offer

Date	Day of Week	Daily Maximum Temp (°F)	Load Reduction	95% CI Lower	95% CI Upper	Reference Load	% Impact
10-Jul-12	Tuesday	101	0.84	0.66	1.02	2.70	30.9%
12-Jul-12	Thursday	102	1.00	0.80	1.20	3.13	32.1%
2-Aug-12	Thursday	99	0.59	0.41	0.77	2.61	22.6%
8-Aug-12	Wednesday	100	0.69	0.52	0.86	2.63	26.4%
9-Aug-12	Thursday	103	0.84	0.65	1.03	2.97	28.2%
10-Aug-12	Friday	103	0.90	0.70	1.10	3.16	28.4%
14-Aug-12	Tuesday	96	0.70	0.53	0.87	2.66	26.3%
15-Aug-12	Wednesday	95	0.65	0.48	0.82	2.60	25.1%
12-Sep-12	Wednesday	92	0.48	0.32	0.64	2.00	23.9%
13-Sep-12	Thursday	97	0.45	0.28	0.62	2.16	20.7%
14-Sep-12	Friday	91	0.41	0.24	0.58	2.14	19.0%
2012 Average	n/a	n/a	**0.69**	**0.58**	**0.80**	**2.62**	**26.3%**
28-Jun-13	Friday	104	0.68	0.45	0.91	3.14	21.5%
2-Jul-13	Tuesday	103	0.95	0.73	1.17	3.31	28.6%
3-Jul-13	Wednesday	105	0.94	0.71	1.17	3.49	27.0%
19-Jul-13	Friday	99	0.68	0.47	0.89	2.72	25.1%
15-Aug-13	Thursday	95	0.53	0.33	0.73	2.46	21.7%
19-Aug-13	Monday	104	0.72	0.50	0.94	3.10	23.1%
6-Sep-13	Friday	94	0.46	0.27	0.65	1.90	24.4%
9-Sep-13	Monday	101	0.73	0.52	0.94	2.79	26.3%
10-Sep-13	Tuesday	87	0.55	0.36	0.74	2.04	26.9%
13-Sep-13	Friday	91	0.35	0.15	0.55	1.93	17.9%
19-Sep-13	Thursday	91	0.34	0.14	0.54	1.59	21.2%
30-Sep-13	Monday	78	0.23	0.03	0.43	1.22	18.8%
2013 Average	n/a	n/a	**0.60**	**0.48**	**0.72**	**2.48**	**24.1%**

Figure 5-1: Maximum Temperature and Absolute Load Reduction for Opt-in CPP with IHD Offer

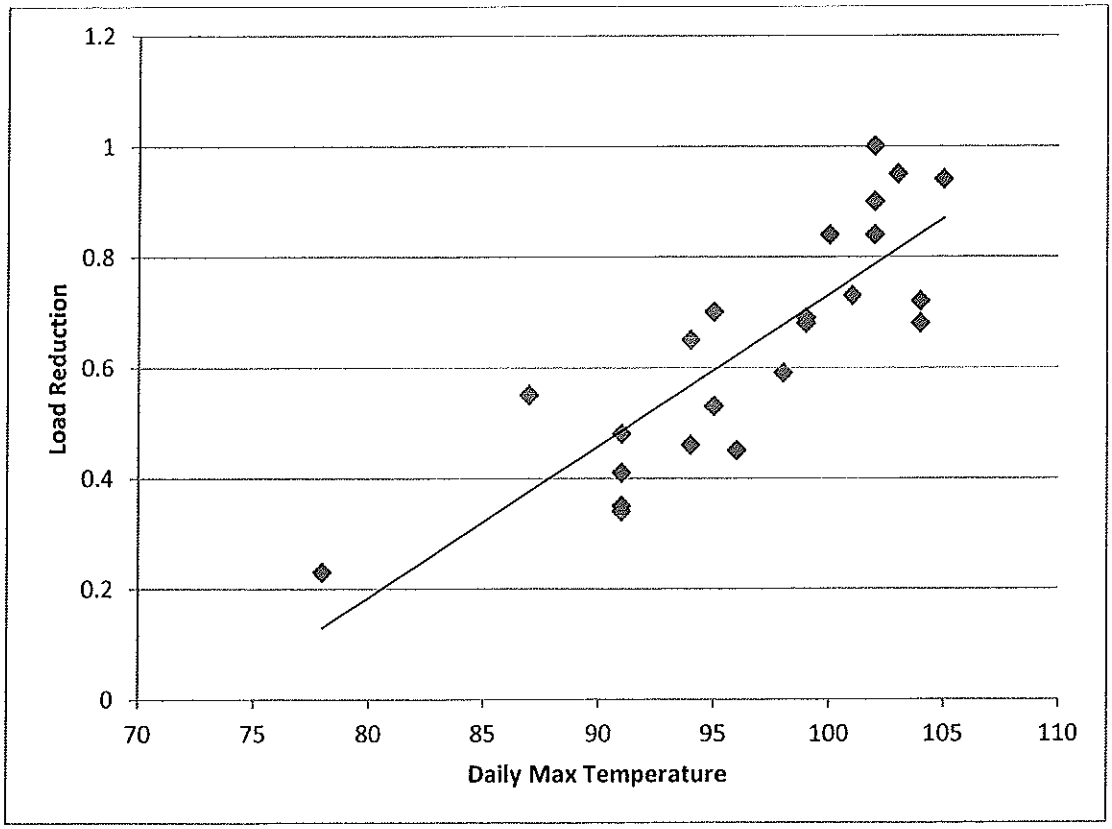
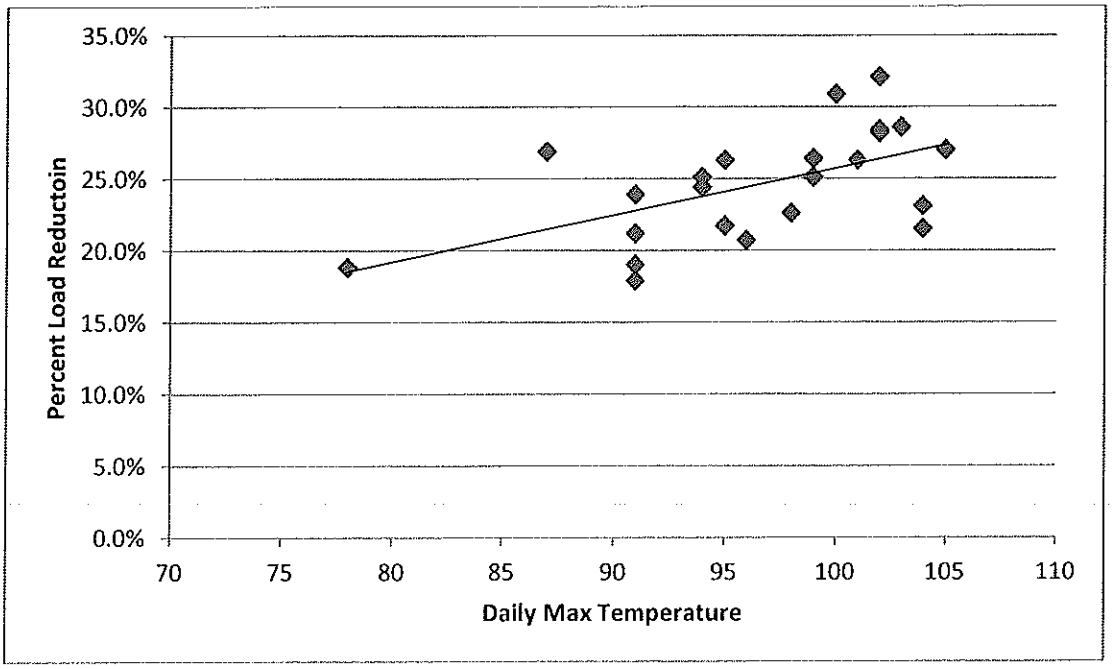


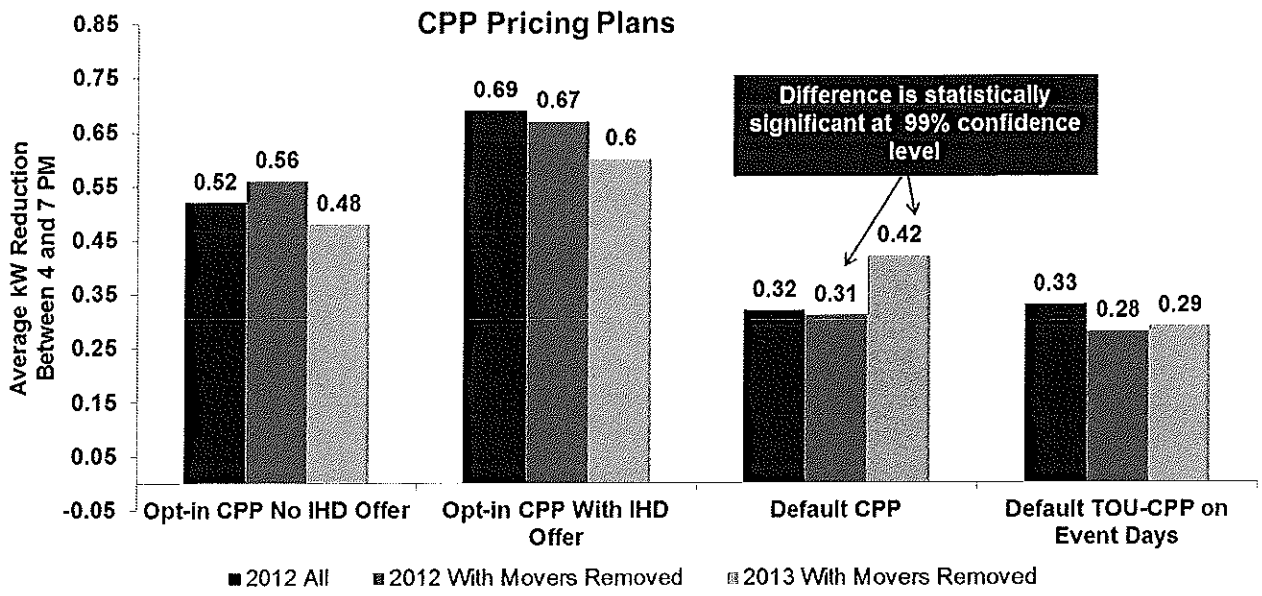
Figure 5-2: Maximum Temperature and Percentage Load Reduction for Opt-in CPP with IHD Offer



5.2 Impact Persistence

Figure 5-3 shows the load impacts for 2012 and 2013 for the population of customers who did not move over that time period. As was seen in Section 4.2 for the TOU pricing plans, after controlling for movers, differences across years were statistically significant for only one of the four pricing plans, in this case for the default CPP plan. It should be noted that the significant difference shows an increase in impacts in the second summer, not a decrease. It would appear that default customers who stayed on the pricing plan became more adept at responding to CPP event notifications than they were in the first summer.

Figure 5-3: Load Impacts for Each Summer for CPP Customers Who Did Not Move During the Study Period



5.3 Load Impacts by Customer Type

Table 5-5 shows the average load impact across event days in both years by pricing plan and EAPR status. In all cases, the impact estimates for non-EAPR customers are larger than for EAPR customers, although for the default TOU-CPP plan, the difference is relatively small. The load impact for EAPR customers for the opt-in CPP plan with no IHD offer is negative and not statistically significant. However, the sample size for this group is quite small, with 65 customers on average in summer 2012 and only 51 customers on average in summer 2013. As such, it may be inappropriate to conclude from this evidence that EAPR customers on this pricing plan are unresponsive to the CPP price signal. It may simply be that the magnitude of their price responsiveness is too small to detect given the small sample size for this group. When comparing impacts between EAPR and non-EAPR customers, it is important to note the percentage impact as well as the absolute impact. Depending on the pricing plan, there is a 10% to 35% difference in reference loads between EAPR and non-EAPR customers and this difference explains some of the difference in absolute impacts.

Table 5-5: 2012/2013 Average Load Impacts by EAPR Status for CPP Pricing Plans

Group	EAPR					Non-EAPR				
	Impact	95% CI Lower	95% CI Upper	Reference Load	% Impact	Impact	95% CI Lower	95% CI Upper	Reference Load	% Impact
Opt in CPP, No IHD	-0.03	-0.38	0.32	1.84	-1.7%	0.69	0.38	1.00	2.51	27.6%
Opt in CPP, IHD Offer	0.30	0.16	0.44	2.18	13.7%	0.76	0.63	0.88	2.65	28.6%
Default CPP-TOU	0.26	0.13	0.40	2.23	11.9%	0.32	0.23	0.40	2.60	12.3%
Default CPP	0.22	0.10	0.35	2.35	9.5%	0.40	0.31	0.49	2.61	15.2%

Table 5-6 shows the average load impacts by pricing plan and usage quartile based on average summer usage. Estimated load impacts are between 4 and 7 times larger for customers in the highest usage quartile compared to those in the lowest. Much of this variation is due to differences in the reference loads, which are between 5 and 6 times larger for high quartile customers compared to the lowest quartile group. The percentage impacts are relatively constant across usage quartiles. Once again, when comparing impacts across pricing plans, it is important to keep in mind that the opt-in sample sizes for the CPP group with no IHD is small, with only about 50 customers in each of the four usage bins. The samples sizes for all of the other plans are reasonably large, with between 150 and 350 in each bin for each pricing plan. The significant increase in the magnitude of the absolute load reductions as usage increase suggests that any opt-in program will likely be more cost effective it if targets high users unless such users are significantly less likely to enroll in the program.

Table 5-6: 2012/2013 Average Load Impacts by Usage Quartile for CPP Pricing Plans (Bin 1 is the lowest usage quartile, Bin 4 is the highest usage quartile)

Group	Bins	Reference Load	Impact	Percent Impact	95% CI Lower	95% CI Upper
Opt in CPP, No IHD Offer	1	0.72	0.16	21.9%	-0.07	0.38
	2	1.65	0.40	24.0%	-0.02	0.81
	3	2.63	0.58	22.2%	0.11	1.06
	4	4.27	1.04	24.3%	0.08	1.99
Opt in CPP, IHD Offer	1	0.83	0.26	31.3%	0.14	0.38
	2	1.76	0.53	29.8%	0.38	0.67
	3	2.68	0.72	26.9%	0.52	0.92
	4	4.06	1.05	25.7%	0.76	1.34
Default TOU-CPP, IHD Offer	1	0.68	0.11	16.3%	0.03	0.19
	2	1.45	0.16	11.2%	0.05	0.27
	3	2.22	0.35	15.8%	0.20	0.50
	4	3.75	0.59	15.6%	0.39	0.79
Default CPP, IHD Offer	1	0.73	0.15	20.6%	0.07	0.23
	2	1.50	0.23	15.3%	0.12	0.34
	3	2.42	0.41	16.7%	0.25	0.56
	4	3.90	0.62	16.0%	0.41	0.84

5.4 Load Impacts Outside the Peak Period

Table 5-7 shows the estimated impacts for the two hours immediately before and after the event period for the average event day. This analysis focuses on determining if pre-cooling behavior occurs before the event period and if a snapback effect can be observed after the event period when customers might adjust their thermostat to a cooler temperature or conduct activities that they avoided doing during the high priced event period. The values in the table for the pre-peak period represent the hours from 2 to 4 PM and the post event hours are from 7 to 9 PM. For two of the four groups, opt-in CPP with no IHD offer and default TOU-CPP, there are no statistically significant impacts in the pre-event period. In the post event period, the impacts are not statistically significant for three of the four pricing plans. Impacts in both the pre- and post-event periods are statistically significant for the opt-in CPP plan with the IHD offer. Notably, the post-treatment effect shows that the peak period reductions continue beyond the event period rather than translate into a snapback effect as is sometimes seen with load control and other demand response programs. The impact in the pre-treatment period is also statistically significant for the default CPP group. For the opt-in group with the IHD offer, the pre- and post-period load reductions, roughly 0.12 kW in both periods, are equal to about 20% of the estimated load reduction during the peak period. Similarly, the pre-event load reduction for default CPP is almost 20% of the peak period load reduction.

Table 5-7: 2012/2013 Impacts Before and After Peak Period on Event Days for CPP Pricing Plans

Group	Average Impact Pre-Peak (kW)	95% CI Lower	95% CI Upper	Average Impact Post-Peak (kW)	95% CI Lower	95% CI Upper
Opt-in CPP, No IHD Offer	0.01	-0.20	0.21	-0.11	-0.30	0.07
Opt-in CPP, IHD Offer	0.12	0.04	0.21	0.12	0.05	0.20
Default CPP, IHD Offer	0.07	0.02	0.12	0.04	-0.01	0.10
Default TOU-CPP, IHD Offer	0.04	-0.01	0.10	0.04	-0.02	0.09

From the perspective of cost-effectiveness, it is useful to know if there are spillover effects from event based tariffs on non-event days. Put another way, is there evidence that customers make behavioral adjustments that carryover to days on which the time-variant rate is not in effect. Table 5-8 shows the estimated load impacts during the peak period on nonevent days. The estimated peak period reduction on nonevent days is statistically significant for three of the four pricing plans, and is positive but insignificant for the opt-in CPP plan with no IHD offer. For two of the pricing plans, opt-in and default CPP with an IHD offer, the nonevent day impacts are roughly one quarter as large as the impacts on event days summarized in Table 5-2. For the default TOU-CPP plan, the nonevent day impacts are almost half as large as the event day impacts. The fact that the TOU-CPP impacts are as large as they are is logical since peak-period pricing is in effect on those days. However, there is no price signal in effect to drive demand reductions on nonevent days for the other two pricing plans. These results are consistent with the hypothesis that CPP customers may adjust their thermostat settings on all weekdays in order to avoid the higher event day prices and/or permanently adjust their behavioral patterns for other end uses on all weekdays.

Table 5-8: 2012/2013 Average Peak Period Impacts on Non-Event Days for CPP Pricing Plans

Group	Average Impact During Peak Hours on Nonevent Weekdays (kW)	95% CI Lower	95% CI Upper	% of Event Day Impact
Opt-in CPP, No IHD Offer	0.04	-0.13	0.21	8%
Opt-in CPP, IHD Offer	0.15	0.08	0.21	23%
Default CPP, IHD Offer	0.10	0.06	0.15	28%
Default TOU-CPP, IHD Offer	0.14	0.09	0.19	45%

An important corollary of the above findings regarding statistically significant load reductions on nonevent days is that within-subjects analysis of load impacts based only on post treatment period data would significantly understate the load impacts on event days. Such analysis, which is often used to estimate impacts for CPP programs or pilots where randomly selected control groups are not available, relies on loads on hot-nonevent days to estimate reference loads. The evidence presented here showing significant reductions on these nonevent days means that this type of analysis will produce impact estimates that are downward biased. An alternative approach to impact estimation when randomly chosen control groups are not available is to develop a control group using statistical matching methods. If the matching is based on proxy days from the post treatment period, the bias would be the same as for a within-subjects analysis. On the other hand, if pretreatment data is used for matching, no such bias would exist. A comparison of load impacts based on the RCT/RED designs used in the SPO, within-subjects analysis and statistical matching can be found in Section 9 of the SPO Interim Report.

5.5 Overall Energy Savings

Table 5-9 contains estimates of overall energy savings for customers on CPP rates. In this analysis, the monthly usage of each treatment and control group was compared for each month across the two summers. Pretreatment data from the summer of 2011 was also included to account for any differences between the groups before the treatment began. For opt-in CPP with no IHD offer and default TOU-CPP, energy savings were small and were not statistically significant. However, for both the opt-in and default CPP groups that included an IHD offer, energy savings were equal to between 2.7% and 3.6% of average monthly electricity use. This result is consistent with the prior finding that these participants had large reductions during the peak period and also showed statistically significant reductions in the pre-event period. The opt-in group also showed statistically significant reductions in the post event period.

Table 5-9: 2012/2013 Average Energy Savings for CPP Pricing Plans

Group	Design	Average Summer Energy Savings (kWh)	95% CI Lower	95% CI Upper	Monthly Reference Load (kWh)	Impact as % of Reference Load
Opt-in CPP, No IHD Offer	RED	-7.7	-68.7	53.3	758	-1.0%
Opt-in CPP, IHD Offer		30.1	3.3	56.9	856	3.5%
Default CPP, IHD Offer		22.8	6.2	39.4	864	2.6%
Default TOU-CPP, IHD Offer		11.9	-8.6	32.4	885	1.3%

5.6 TOU Impacts on CPP Event Days

When comparing load impacts and cost-effectiveness for TOU and CPP pricing plans, it is useful to examine the load reductions from TOU rates under the same weather conditions as those that occur on CPP days since load impacts for TOU rates increase with temperature. Table 5-10 shows the average impact for both CPP and TOU rates across the 23 historical event days used in the analysis. For convenience, it also shows the average impacts for TOU plans on the average weekday, which were previously shown in Table 4-1. Table 5-11 shows the results from the tests to determine whether differences across pricing plans are statistically significant. Of particular interest is whether there are statistically significant differences in peak period reductions under CPP event-like weather conditions for CPP and TOU pricing plans.

Table 5-10: Peak Period Load Reductions for All Pricing Plans

Group	CPP Day Impacts			Average Weekday Impacts		
	Impact	Reference Load	% Impact	Impact	Reference Load	% Impact
Opt in TOU, IHD Offer	0.32	2.38	13.3%	0.21	1.79	11.9%
Opt in TOU, No IHD Offer	0.23	2.24	10.1%	0.16	1.72	9.4%
Opt-in CPP, IHD Offer	0.64	2.53	25.1%	n/a	n/a	n/a
Opt-in CPP, No IHD Offer	0.49	2.33	20.9%	n/a	n/a	n/a
Default TOU, IHD Offer	0.15	2.47	5.9%	0.11	1.86	5.8%
Default CPP, IHD Offer	0.36	2.56	14.0%	n/a	n/a	n/a
Default TOU-CPP, IHD Offer	0.31	2.54	12.3%	0.17	1.91	8.7%

As seen in Table 5-10, impacts for TOU pricing plans are significantly higher on CPP days than on the average summer weekday. The ratio of load reductions on CPP days to non-CPP days ranges from a low of 1.25 for default TOU to a high of 1.91 for the opt-in TOU plan with no IHD offer. The ratios for the default TOU-CPP plan and the opt-in TOU plan with the IHD offer are 1.82 and 1.52, respectively. For three of the four pricing plans, these differences are largely due to differences in the reference loads between CPP and non-CPP days, as indicated by little change in the percentage load reductions on the two day types. For the default TOU-CPP plan, the percentage load reduction is higher on CPP days than on non-CPP days. This is logical since prices are also higher on CPP days for this pricing plan.

Table 5-11 shows the results of statistical tests to determine whether the load impacts are significantly different between TOU and CPP rates on CPP days for the relevant comparisons. As seen, CPP pricing plans produce significantly greater impacts on CPP days than TOU plans in all cases, which is to be expected since prices are significantly higher under CPP plans compared with comparable TOU plans. In each relevant comparison, the load reductions are roughly twice as large under the CPP plan compared with the comparable TOU plan.

Table 5-11: Pairwise Comparison of Load Reductions for CPP and TOU Pricing Plans on CPP Days

Group	Opt-in TOU, IHD Offer	Opt-in TOU, No IHD Offer	Default TOU, IHD Offer
Opt-in CPP, IHD Offer	0.00**	n/a	n/a
Opt-in CPP, No IHD Offer	n/a	0.05*	n/a
Default CPP, IHD Offer	n/a	n/a	0.00**

*Statistically significant at the 90% level; ** Statistically significant at the 99% level

6 The Influence of In Home Displays

SMUD's SPO was designed to assess the impact of the offer of an IHD on customer acceptance of opt-in time-variant pricing plans by marketing TOU and CPP rates with and without the offer of an IHD. This issue is analyzed in Section 8. As discussed there, the offer of a free IHD does not increase customer acceptance rates for the time-variant pricing plans included in the SPO.

Another useful investigation concerns the acceptance of and connection rates for IHDs among treatment groups that received an IHD offer. What percent of customers who received an IHD offer accepted it and what percent of those customers receiving an IHD connected the device with their meter? These issues are discussed below in Section 6.1. A related issue concerns the characteristics of customers who do and don't request an IHD when given the option and who do and don't connect the device once it is received. These issues are discussed in Section 6.2.

A third important issue is whether IHDs influence consumer electricity use. The SPO was designed to determine if there are differences in load impacts for customers who were *offered* an IHD as part of the rate offer, and those who were *not offered* an IHD as part of the rate offer. As seen in Sections 4 and 5, there is some difference in load impacts across treatment cells that did and did not include an IHD offer. However, testing the load impact of an IHD *offer* is different from testing the load impact of an IHD, because many people who were offered an IHD did not accept one and many who accepted an IHD did not use it. Given the general interest in whether or not IHDs influence usage behavior, it is likely that some readers will draw conclusions about the influence of IHDs by observing these differences. To reduce the likelihood that readers will draw incorrect conclusions about the influence of IHDs on energy use and demand response, we examine this issue in Section 6.3.

6.1 IHD Acceptance and Use

As previously discussed, two of the opt-in treatment groups were also offered a free IHD if they enrolled on the rate. Acceptance of the IHD was not a condition of going on the pricing plan. Opt-in customers could indicate at the time of enrollment whether or not they wanted the IHD. If they did, the IHD was mailed to them pre-commissioned, so that when they unpacked it and turned it on, it was supposed to automatically connect with their meter and start displaying information.

All customers selected for the default pricing plans were offered a free IHD. Because customers were automatically enrolled unless they opted-out, there was not the same opportunity to simply "check a box" at the time of enrollment to indicate whether or not they wanted an IHD. Instead, those who wanted an IHD had to take a proactive step to request it. Put another way, the transaction costs associated with requesting an IHD were higher for default customers compared with opt-in customers. In addition, customer inertia may reduce acceptance rates for default customers compared with opt-in customers who were already engaged in a transaction when asked to indicate their interest in receiving an IHD. Once requested, as with the opt-in treatment groups, a pre-commissioned IHD was mailed to customers and all that was needed to use it was to unpack it and turn it on.

In summer 2012, SMUD was able to determine from the meter data management system the number of IHD devices that were connected to meters at any point in time but was not able to link those devices to

individual customer accounts. However, in summer 2013, data became available that provided a daily log for each customer indicating whether or not their IHD was connected to their meter.[24] As such, for the second year of the pilot, it was possible to identify customers who had their IHDs connected during the entire summer, those who never had it connected during summer 2013, and those who were connected on some days and not on others.

For each treatment group, Table 6-1 shows the number of customers who requested an IHD at the beginning of the pilot, the IHD acceptance rate (the number accepting divided by the number offered), the number of customers who accepted an IHD that were still enrolled at the beginning of the summer period in 2013 and, of those, the percent that had their device connected with their meter during the entire summer, the percent that were connected at some point in time during summer 2013 and the percent that were never connected in 2013.

Table 6-1: IHD Acceptance and Connection Rates

Group	Enrolled 6/1/12	# That Accept IHD	Acceptance Rate	# of Customers With IHDs Still Enrolled as of 6/1/13	% Connected All the Time	% Connected Some of the Time	% Never Connected
Opt-in CPP, IHD Offer	1,569	1,498	95%	1,195	11.6%	27.4%	61.0%
Opt-in TOU, IHD Offer	2,092	2,017	96%	1,597	11.6%	22.8%	65.6%
Default TOU-CPP, IHD Offer	588	136	23%	112	18.8%	39.3%	42.0%
Default CPP, IHD Offer	701	167	24%	140	14.3%	42.9%	42.9%
Default TOU, IHD Offer	2,018	418	21%	363	18.2%	23.1%	58.7%

As seen in the table, roughly 96% of opt-in customers requested an IHD whereas fewer than 25% of default customers did so. As seen in the last three columns in the table, roughly two thirds of opt-in customers who accepted an IHD and who were still enrolled at the beginning of the 2013 summer never had their device connected in 2013. This "never connected rate" was much lower for two of the three default groups, equal to roughly 42% for the default TOU-CPP and CPP groups. The higher connection rate for default customers compared with opt-in customers is consistent with a hypothesis that, since default customers had to take a proactive step to request the device compared with the passive "check the box" approach for opt-in customers, they were more invested in using the device once it arrived. As

[24] Reporting functionality from the HAN Communication Manager (HCM) had not been established prior to the launch of the technology and took approximately a year after go-live to established automated reporting out of HCM. However, it should be noted that the functionality was available in HCM, but SMUD had not created business requirements to set-up that functionality before the program launch, primarily because reporting on IHD connectivity had not been part of the critical path for program launch or reporting to the DOE.

seen in Section 6.2, default customers who requested the device were much more engaged customers in that they had a higher propensity to participate in other SMUD programs. Why the "never connected rate" for default TOU customers is closer to that of opt-in customers than it is to that of the other default groups is unclear.

Although not shown in Table 6-1, it should be noted that roughly 70% of those who were connected some of the time had their devices communicating with their meters more than 50% of all summer days. Put another way, most of the customers that were connected some of the time were connected most of the time.

6.2 Customer Characteristics of IHD Users

For planning purposes, it is useful to examine the characteristics of customers who did and did not request an IHD and also the characteristics of those who had their IHD connected during the summer of 2013. Since nearly all opt-in participants requested an IHD, it was not possible to distinguish between those who did and did not request the technology for opt-in pricing plans. For default pricing plans, a binary outcome model (logit)[25] was estimated relating the likelihood of requesting an IHD to customer characteristics such as EAPR status, participation in other SMUD programs and other variables. Because the logit model is nonlinear, the estimated coefficients do not represent changes in the expected probabilities that would result from changes in the explanatory variables.[26] Such "marginal effects" provide meaningful interpretations of how different variables affect the likelihood of a given choice controlling for all other variables. For a logit model specification, marginal effects are calculated using a transformation of the parameter estimates that involves the logistic cumulative density function. Throughout the remainder of this report, the marginal effects (and not the estimated logit coefficients) are reported for all choice models.[27] The marginal effects show the change in the likelihood of the outcome variable given the presence of a particular characteristic for binary variables (e.g., participants in another SMUD program) or given a 1% change in the magnitude of a continuous variable (e.g., share of summer usage on peak).

Table 6-2 shows the marginal effects for a model relating the likelihood of requesting an IHD to customer characteristics. As seen in the first row of the table, the likelihood of requesting an IHD is 6% higher for EAPR pricing plan participants than for non-EAPR participants. There is no difference in the likelihood of requesting an IHD for CPP or TOU-CPP participants compared with TOU participants (as seen by the second and third rows in the table). The greater the share of summer electricity use that occurs during the peak hours from 4 to 7 PM, the greater the likelihood of requesting and IHD, but the magnitude of the influence is relatively small. A 10% increase in peak period usage as a percent of summer usage increases the likelihood of requesting an IHD by 1.6%. Participation in SMUD's EE

[25] Logit, probit and linear probability models were estimated and the alternative specifications produced results quite similar to those associated with the logit model.

[26] The specification of the logit model is Pr(accepting/connecting IHD) = $\exp(x'\beta)/(1+\exp(x'\beta))$, where the β terms are the coefficients to be estimated. This nonlinear specification ensures that the predicted probabilities will be between zero and one.

[27] All reported marginal effects are average marginal effects (AME) as opposed to marginal effects at the mean (MEM) or marginal effects at representative values (MER).

loan/rebate, EnergyHelp, Green Energy and MyAccount programs increases the likelihood of requesting an IHD by 6 to 9%.

Table 6-2: Likelihood of Requesting an IHD for Default Pricing Plans

Variable	Marginal Effect	Interpretation
EAPR status	0.059**	EAPR customers are 6% more likely to request an IHD than non-EAPR customers
CPP pricing plan	0.026	Participants on the default CPP pricing plan are not more or less likely to request an IHD than those on the TOU pricing plan
TOU-CPP pricing plan	0.017	Participants on the default TOU-CPP pricing plan are not more or less likely to request an IHD than those on the TOU pricing plan
Share of summer 2011 kWh consumed on peak	0.159+	Participants that use more of their total summer usage during the peak period are more likely to request an IHD
Carbon Offsets program	0.050	Participation in the Carbon Offsets program is not correlated with the likelihood of requesting an IHD
Received EE loan or rebate	0.058**	Participants in the EE load/rebate program are 6% more likely to request an IHD
EnergyHelp program	0.079**	Participants in the EnergyHelp program are 8% more likely to request an IHD
Green Energy program	0.059**	Participants in the Green Energy program are 6% more likely to request an IHD
Customer enrolled in MyAccount	0.087**	MyAccount customers are 9% more likely to request an IHD

**p<0.01; *p<0.05; +p<0.1

As was seen in Table 6-1, many customers who requested and received IHDs did not have the device connected during the summer of 2013 when connection rate data became available. Tables 6-3 and 6-4 show the marginal effects from a logit model that relates the likelihood of having the IHD connected during the summer of 2013 to customer and rate characteristics. The dependent variable equals 1 if the device was connected at any point in time during summer 2013, and 0 if it was never connected during that summer. Table 6-3 shows results for the opt-in pricing plans and Table 6-4 shows the same results for default pricing plans.

As seen in Table 6-3, EAPR customers on the opt-in pricing plans who requested an IHD were less likely to have had it connected in 2013 than non-EAPR customers. Customers on the opt-in TOU pricing plan were less likely than those on the CPP plan to have their IHD connected. Opt-in customers in the Carbon Offsets and EE loan/rebate programs were more likely to have had their IHD connected, but participants in the EnergyHelp program were significantly less likely to have had their device connected.

Participation in the Green Energy program is not correlated with the likelihood of having the IHD connected. MyAccount customers were 12% more likely to have had their IHD connected than non-MyAccount customers.

Table 6-3: IHD Connection Likelihood for Opt-in Pricing Plans (Among those requesting and receiving an IHD, the likelihood of the IHD being connected at some time during summer of 2013)

Variable	Marginal Effect	Interpretation
EAPR status	-0.103**	EAPR customers are 10% less likely to have had their IHD connected
TOU pricing plan	-0.041*	Participants on the opt-in TOU pricing plan are 4% less likely to have had their IHD connected than participants on the opt0in CPP pricing plan
Share of summer 2011 kWh consumed on peak	0.003**	Participants that use more of their total summer usage during the peak period are slightly more likely to have their IHD connected
Carbon Offsets program	0.153+	Carbon Offset customers are 15% more likely to have their IHDs connected (with confidence interval of 90%)
Received EE loan or rebate	0.066**	Participants in the EE loan or rebate program are 7% more likely to have their IHDs connected
EnergyHelp program	-0.102*	EnergyHelp participants are 10% less likely to have their IHDs connected
Green Energy program	0.022	Participation in the Green Energy program is not correlated with the likelihood of having an IHD connected
Customer enrolled in MyAccount	0.121**	MyAccount customers are 12% more likely to have their IHDs' connected

**p<0.01; *p<0.05; +p<0.1

Table 6-4 shows the marginal effects from the connection model for the default pricing plans. As with the opt-in plans, EAPR customers were less likely to have had their device connected in 2013 than non-EAPR customers. Participants in the CPP and TOU-CPP pricing plans were 15% more likely than TOU customers to have had the device connected, indicating that participants on dynamic rates may see greater value in using the IHD than those on static time-variant rate options. Customers that have higher usage on peak were slightly more likely to have had their device connected. Unlike with the opt-in plans, participation in other SMUD programs, except for MyAccount, was not correlated with the likelihood of having the IHD connected.

Table 6-4: IHD Connection Likelihood for Default Pricing Plans (Among those requesting and receiving an IHD, the likelihood of the IHD being connected at some time during summer of 2013)

Variable	Marginal Effect	Interpretation
EAPR status	-0.081+	EAPR customers are 8% less likely to have had their IHD connected
CPP pricing plan	0.147**	Participants on the default CPP pricing plan are 15% more likely to have had their IHD connected than participants on the default TOU pricing plan
TOU-CPP pricing plan	0.148**	Participants on the default TOU-CPP pricing plan are 15% more likely to have had their IHD connected than participants on the default TOU pricing plan
Share of summer 2011 kWh consumed on peak	0.005*	Participants that use more of their total summer usage during the peak period are slightly more likely to have their IHD connected
Carbon Offsets program	-0.078	Participation in the Carbon Offsets program is not correlated with the likelihood of having the IHD connected
Received EE loan or rebate	-0.014	Participation in the EE load/rebate program is not correlated with the likelihood of having the IHD connected
EnergyHelp program	-0.114	Participation in the EnergyHelp program is not correlated with the likelihood of having the IHD connected
Green Energy program	0.058	Participation in the Green Energy program is not correlated with the likelihood of having the IHD connected
Customer enrolled in MyAccount	0.163**	MyAccount customers are 16% more likely to have their IHDs' connected

**p<0.01; *p<0.05; +p<0.1

6.3 Load Impacts for Treatments With and Without an IHD Offer

As indicated previously, the SPO was designed primarily to examine the impact of the offer of an IHD on customer acceptance of time-variant rate options. The empirical evidence summarized in Section 8 shows that an IHD offer does not influence customer acceptance of the pricing plans. However, it is possible that those who accept an IHD respond more than those who do not. A comparison of load impacts for TOU and CPP plans with and without an IHD offer is a measure of the incremental effect of the offer, not necessarily the incremental impact of use of the IHD.

One estimate of the effect of the offer of an IHD on energy use can be developed by comparing the load reduction for opt-in TOU with and without an IHD offer and opt-in CPP with and without an IHD offer in

Tables 4-1 and 5-2. For the TOU case, the estimated load reduction for the opt-in TOU group receiving an IHD offer is 0.21 kW (for the two summers combined). Without an IHD offer, the impact is 0.16 kW. For the opt-in CPP plan, the estimated impacts with and without an IHD offer are 0.64 kW and 0.49 kW respectively. As seen in Table 4-2, the 0.05 kW difference for the TOU plan is statistically significant at the 90% confidence level. As seen in Table 5-3, although the 0.15 kW difference between the two groups for the CPP pricing plan is larger than the difference for the TOU plan, it is not statistically significant at the 90% confidence level, perhaps due to the small sample size for the opt-in CPP treatment with no IHD offer, which was roughly 200 in 2012 and had dwindled to roughly 150 by the end of the 2013 summer.

While it is tempting to consider these differences to equal the impact of the IHD offer on demand, and even more tempting to attribute the difference to the impact of the IHD, not just the offer, both conclusions are incorrect. The first is incorrect because the estimate does not take into account pretreatment differences between the groups that were and were not offered the IHD. Each estimate itself is internally valid and is based on a difference-in-differences regression, but the difference between the two estimates does not factor in pretreatment differences between the groups. As seen in Figures 6-1 and 6-2, there are small but meaningful differences in usage between the two groups during the pretreatment period. The difference during the peak period on the average weekday for the TOU groups is 0.06 kW and the difference for the CPP groups is 0.20 kW. When these pretreatment differences are subtracted from the observed difference during the treatment period, the estimated impact of the IHD is essentially 0 in the case of the TOU plan and is actually negative for the CPP plan. Put another way, after correcting for pretreatment differences, the offer of the IHD does not influence demand response for opt-in pricing plans.

Figure 6-1: Usage by TOU Opt-in Customers With and Without an IHD Offer

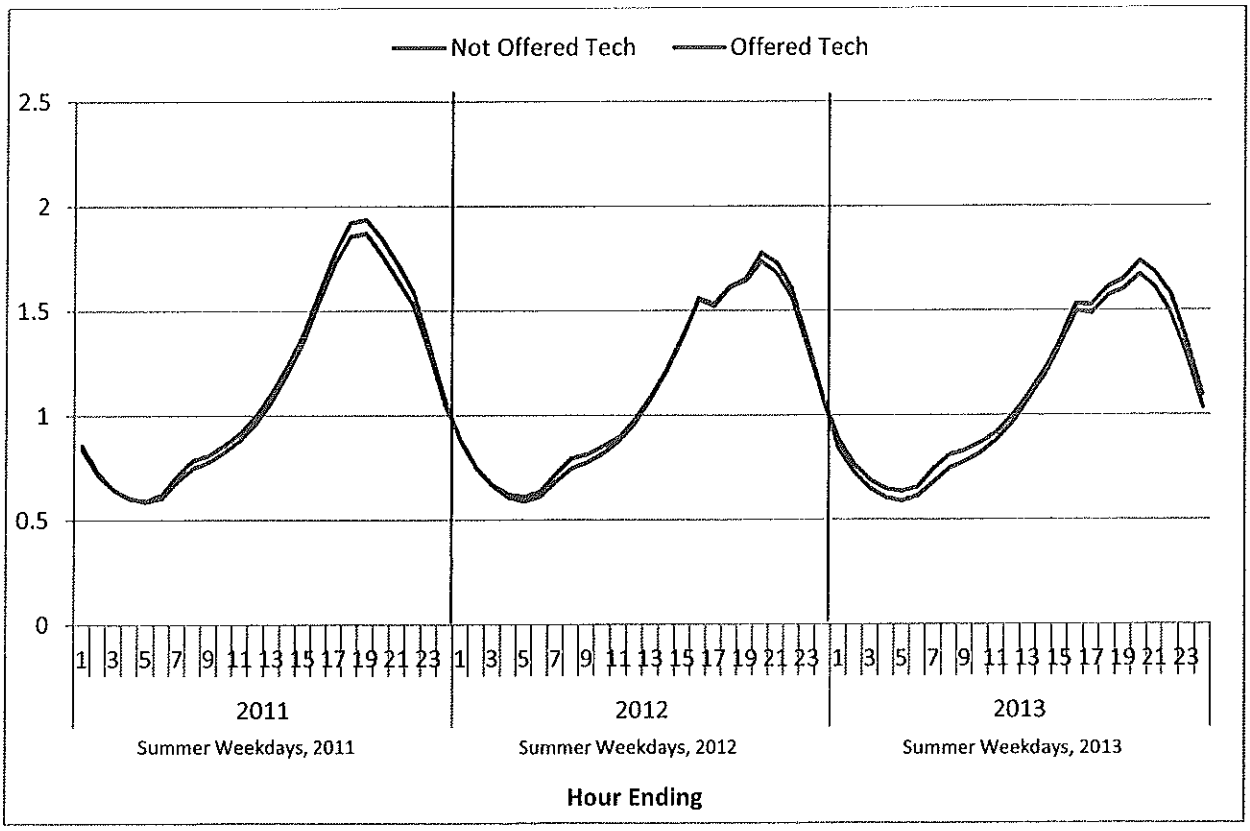
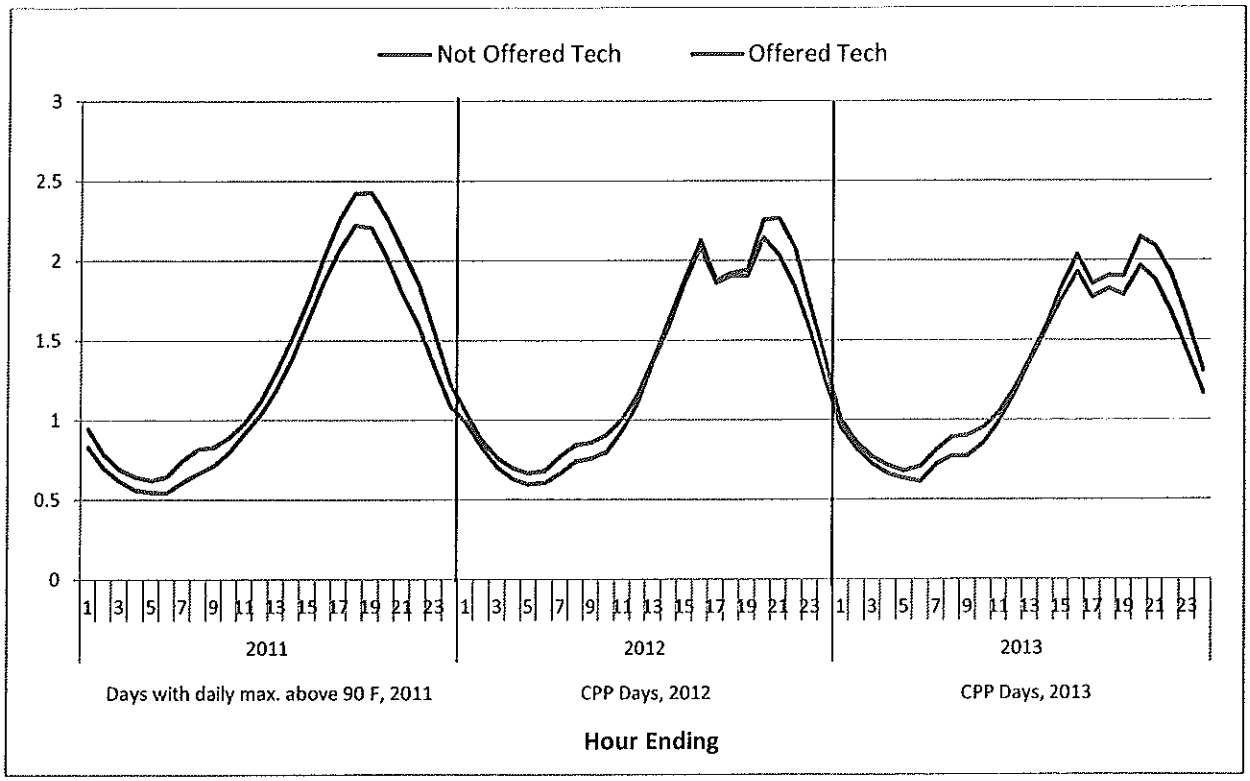


Figure 6-2: Usage by CPP Opt-in Customers With and Without IHD Offer



As previously discussed, nearly everyone in the opt-in pricing plans accepted an IHD although many did not connect it. A relevant question is whether those who did connect the device were more responsive to the price signals than those who did not. Figures 6-3 and 6-4 show hourly usage for opt-in TOU and opt-in CPP customers, respectively, during the pretreatment and treatment periods for customers that had their devices connected at least some of the time during the summer of 2013 and those that did not. Also included in the figures are loads for customers in the treatment groups who were not offered an IHD.[28]

Looking first at the opt-in TOU pricing plan (Figure 6-3), several things are noteworthy. Those who had their IHDs connected some or all of the time in 2013 had higher pretreatment peak period loads than those who did not. Those who were not connected (the largest share by far) had pretreatment loads nearly identical to TOU customers that were never offered an IHD. Connected customers were much more responsive than those who were not connected and also more responsive than those who were never offered an IHD. As evidenced by the pretreatment difference in loads, there is a strong selection effect among those who were connected. These customers are "peakier" and much more responsive than those that were not connected, but this greater responsiveness cannot be attributed to use of the IHD. While it is possible that some of this difference is attributable to the IHD, it is also possible that the entire difference is due to selection effects and that these customers are simply much more engaged in

[28] It should be noted that the pretreatment period loads for TOU customers are for the average weekday but the pretreatment loads for CPP customers are for days in which the average temperature during the peak period exceeded 90°F as these hot days are more representative of CPP event days.

managing their energy use than non-connected customers and that this engagement effect explains why they kept the IHD connected during this period and also why they responded more to the price signal.

Figure 6-3: Usage by Opt-in TOU Customers With Devices Connected and Not Connected in Summer 2013

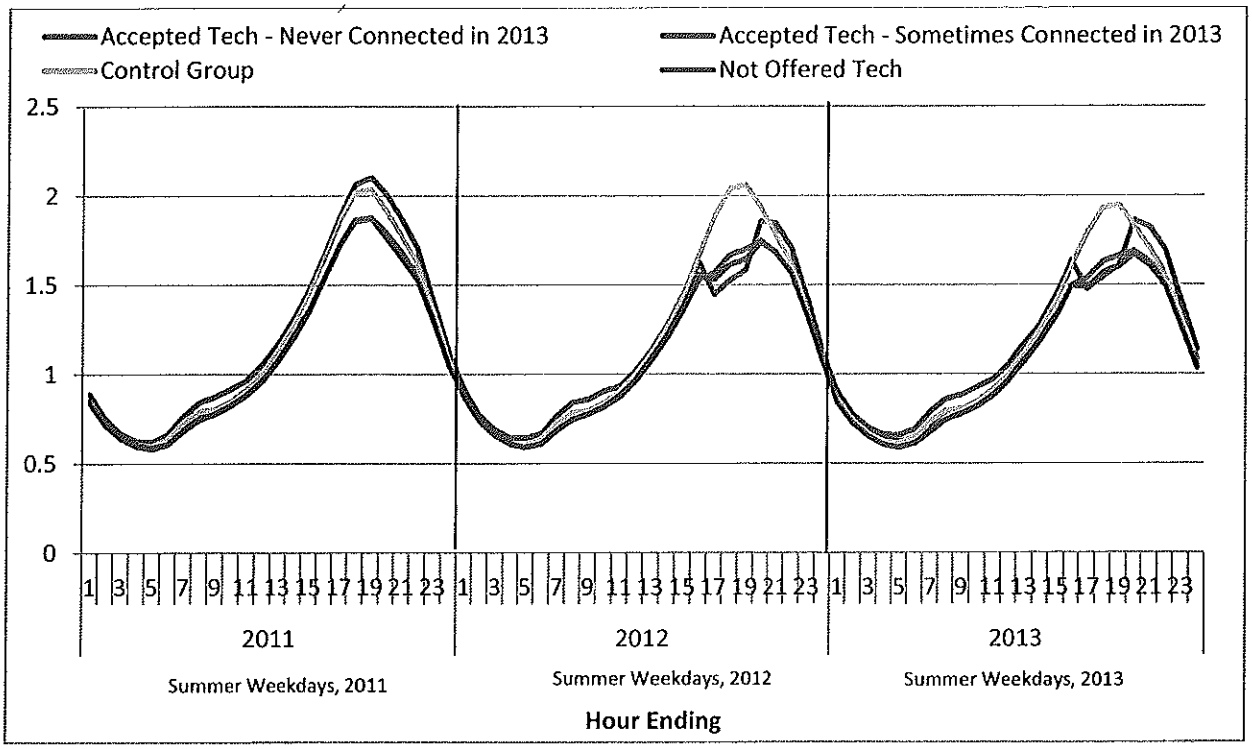
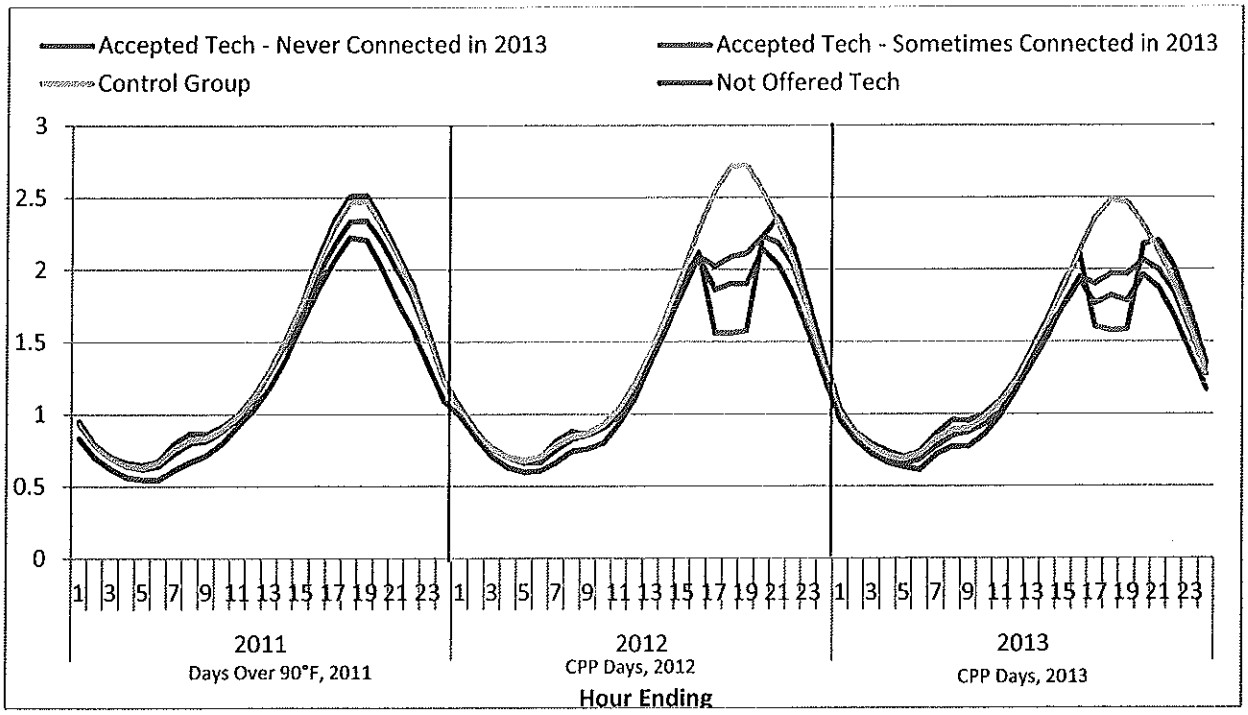


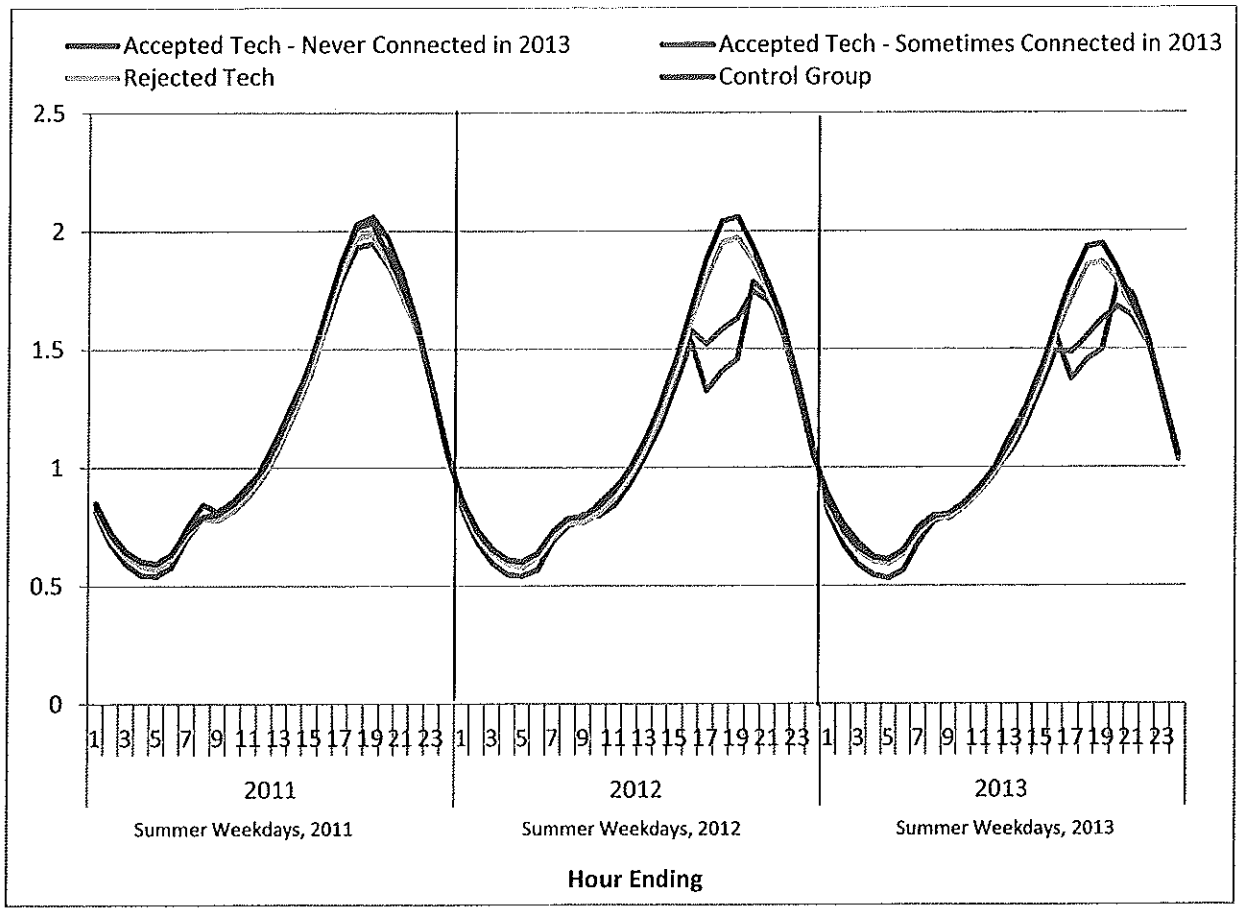
Figure 6-4: Usage by Opt-in CPP Customers With Devices Connected and Not Connected in Summer 2013



The same basic patterns observed for the opt-in TOU plan are seen for the opt-in CPP plan. Those who kept their devices connected during the summer of 2013 were much more responsive than those who did not. In this instance, however, there is a difference in the pretreatment period between those who accepted the IHD but were not connected in 2013 and those who were not offered the IHD.

Figures 6-5 through 6-8 show load shapes on the default pricing plans that were and were not connected. They also show loads for customers who rejected the offer of an IHD and for the control group for each pricing plan. As seen in Figure 6-5, customers who accepted an IHD offer were much more price responsive than those who did not. Indeed, the average response for those who did not appears to be minimal, although there is some reduction in usage during the peak period over the two years compared with the control group, but not enough to show the notch during the peak period that depicts a strong load reduction as is seen for the IHD accepting group.

Figure 6-5: Usage by Default TOU Customers who Did and Did Not Accept an IHD



Figures 6-6 and 6-7 both pertain to the default TOU-CPP plan. The first figure shows loads for the average weekday while the second represents loads on CPP days (and hot days during the pretreatment period). Figure 6-8 is for default CPP customers. In all cases, the same basic patterns are observed, the most notable being the strong selection effects at work for those who accepted an IHD and, among that group, those who were and were not connected in 2013.

Figure 6-6: Usage by Default TOU-CPP Customers who Did and Did Not Accept an IHD (Average Summer Weekday)

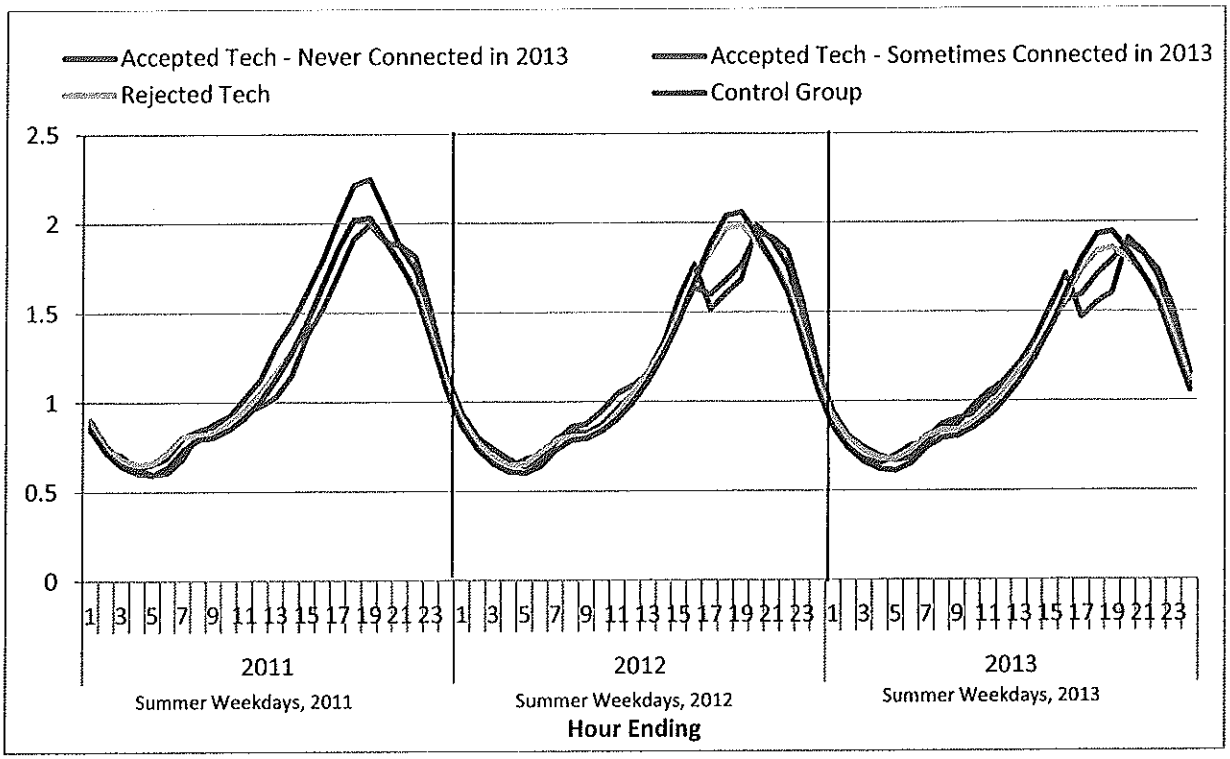


Figure 6-7: Usage by Default TOU-CPP Customers who Did and Did Not Accept An IHD (Hot, Non-event Days for Pretreatment Period)

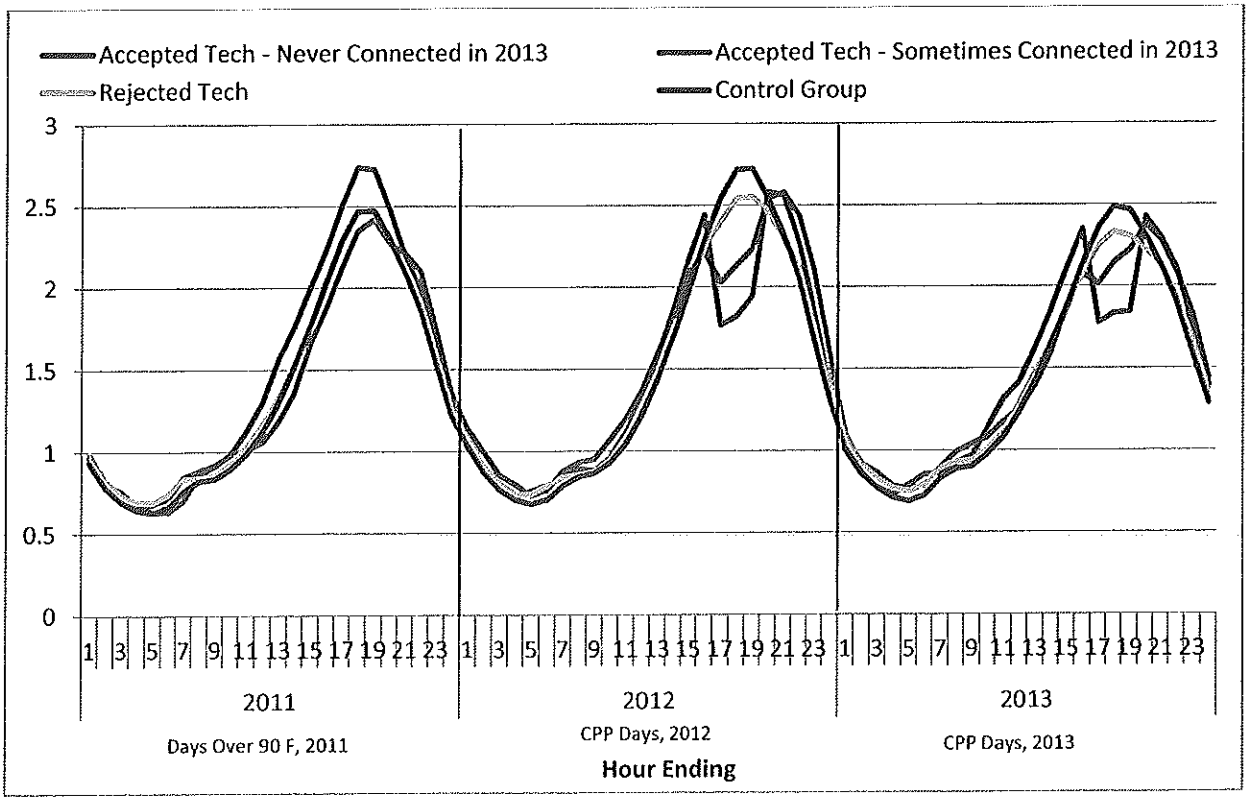
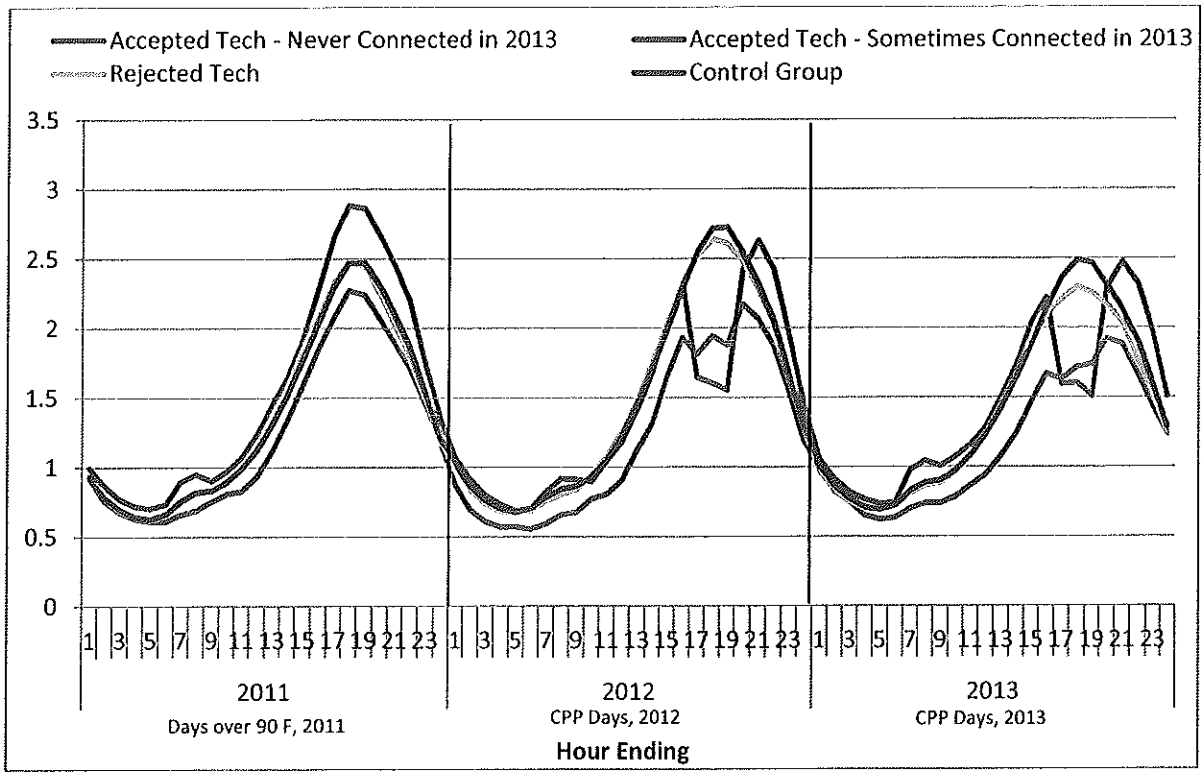


Figure 6-8: Usage by Default CPP Customers who Did and Did Not Accept An IHD



7 Price Elasticity Estimation

One of the primary goals of the SPO pilot was to determine the degree to which residential customers in SMUD's service territory respond to the price signals associated with time-varying rates. The impact estimates summarized in Sections 4 and 5 show that the average participant reduced load in response to the specific price signals tested in the SPO pilot. There is also interest in predicting how demand response might change if SMUD were to offer similar pricing plans but with different price ratios and levels than were tested in the SPO pilot. Price elasticities are a simple metric that quantifies the relationship between changes in price and changes in energy use. This section documents the development of price elasticity estimates based on the SPO results and shows how they can be used to predict changes in energy use as a function of changes in peak and off-peak prices.

7.1 Analysis Methodology

The SPO pilot was not designed specifically to estimate price elasticities for each pricing plan. A pilot designed to estimate price elasticities for a specific pricing plan would ideally involve multiple test cells, each with a different set of peak and off-peak prices.[29] This was not done in the SPO. However, by pooling customers across pricing plans, additional variation in prices can be included in the estimating database. As evidenced by the impact estimates summarized in Sections 4 and 5, price responsiveness appears to vary between customers who enroll through opt-in and default recruitment strategies. Elasticities may also vary between EAPR and non-EAPR customers. As such, the demand modeling summarized below that produces price elasticity estimates was done separately for opt-in and default plans and for EAPR and non-EAPR customers within the default and opt-in pricing plans. That is, the analysis produces four sets of price elasticities.

A structural economic model of demand is used to estimate price elasticities. The model is consistent with the neoclassical theory of utility maximization in which customers are assumed to consume the amount of electricity that maximizes their well-being subject to a budget constraint that is influenced by prices. Estimating a structural model requires the specification of a functional form for the demand equations that represent consumer preferences. In this study, the constant elasticity of substitution (CES) functional form is used. This function has been widely used in the analysis of electricity pricing experiments, including California's Statewide Pricing Pilot.[30] The CES model is comprised of two equations. The first equation expresses the ratio of peak and off-peak energy use as a function of an intercept term and the ratio of peak and off-peak prices.

$$ln\left(\frac{Q_1}{Q_2}\right) = a_{12} + b_{12} * ln\left(\frac{P_1}{P_2}\right) \quad (7\text{-}1)$$

[29] For an example of a pilot that included multiple prices for each rate option, see George and Faruqui, *Impact Evaluation of California's Statewide Pricing Pilot*. Final Report, March 16, 2005. http://www.energyarchive.ca.gov/demandresponse/documents/group3_final_reports/2005-03-24_SPP_FINAL_REP.PDF

[30] *Ibid*

where Q_i is electricity use (kWh/hour) in period *i* in and P_i is the price of electricity in period *i*. The term a_{12} is the intercept and b_{12} is the elasticity of substitution, which measures the degree of substitutability between the peak and off-peak periods for a given set of prices. Equation 7-1 captures tradeoffs in electricity consumption that occur between rate periods in the same day.

The second equation in the CES model pertains to daily electricity consumption and has the following specification:

$$ln(Q_d) = c + d * ln(P_d) \quad (7\text{-}2)$$

In this equation, Q_d is the total electricity consumed in a day and P_d is the average price for that day, which is a weighted average of the peak and off-peak prices. Equation 7-2 is often called the daily equation since it captures changes in electricity consumption at the daily level that result from changes in prices and the term *d* is the daily price elasticity.

Taken together, Equations 7-1 and 7-2 form a system of equations that can be estimated using a dataset consisting of electricity consumption for a large number of customers at the daily level in the post-treatment period (summer 2012 and summer 2013). Such a dataset was constructed using customer load data and information on each customer's experimental pricing plan. Econometric estimation adds idiosyncratic error terms to both equations and the resulting equations were then estimated jointly using seemingly unrelated regression (SUR) in Stata. As mentioned earlier, separate models were estimated for four combinations of pricing plans that vary based on whether customers were enrolled on a default or opt-in basis and whether or not they faced EAPR or non-EAPR prices.

Because of the tiered nature of the SPO rates, there is a simultaneity problem that must be addressed during the estimation process. In order to properly estimate the parameters of the model, the relationship between prices and quantities must flow in only one direction – namely the prices are allowed to influence the amount of electricity consumed in each period, but the amount of electricity consumption cannot influence the prices. With a tiered rate structure in which the price of electricity increases after a certain amount of electricity has been consumed each month, this condition is violated since the amount of electricity consumption determines the price in each period and also affects the weights that are used to calculate the average daily price.

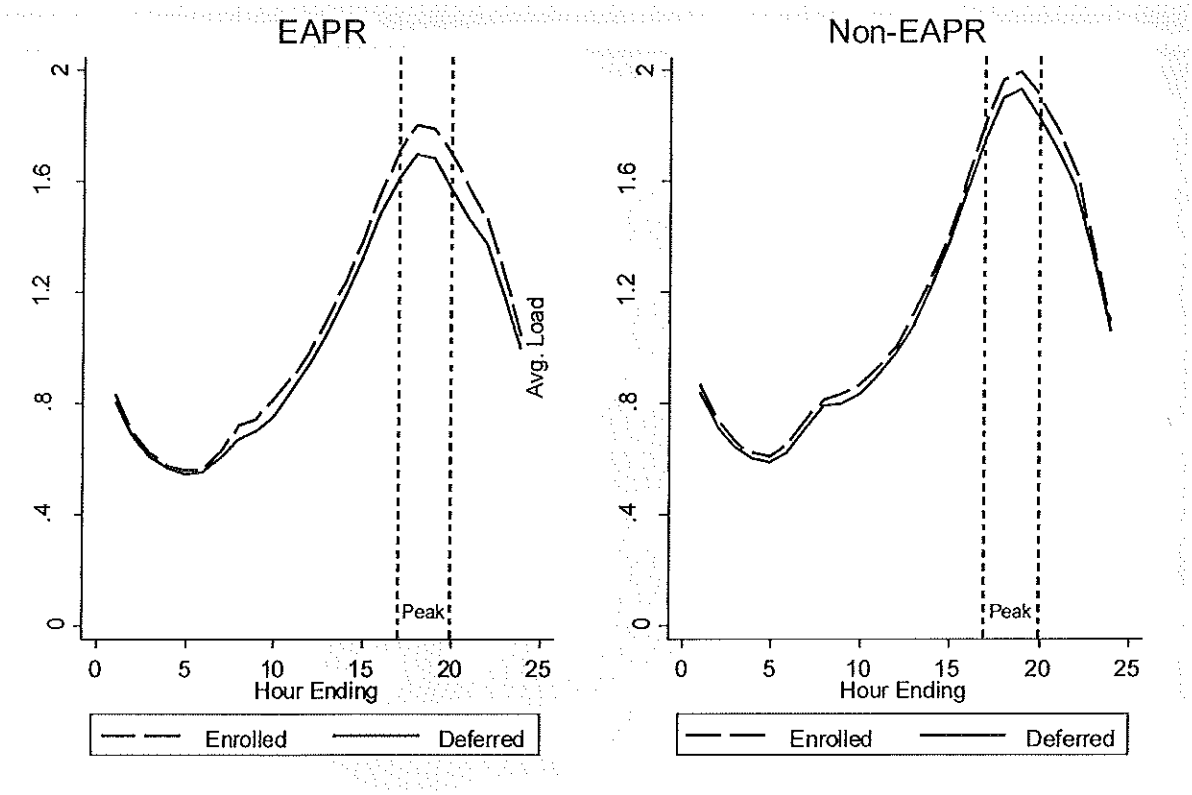
To avoid the simultaneity problem, the average electricity consumption of the relevant control group was used to determine the applicable tier for the average customer and also to weight the peak and off-peak prices used to calculate the average daily price.[31] The practical result of this solution is that all customers face only the base usage prices since the average consumption of the control groups is below the base usage threshold.

During the course of the analysis, it was discovered that pre-treatment load differences existed between customers who chose to enroll in the opt-in TOU rate and those who accepted the rate offer but were deferred (the de-facto control group). These pre-treatment loads are shown in Figure 7-1. For both

[31] These average values were calculated both on CPP and non-CPP days to allow for some difference between very hot days and more mild days.

EAPR and Non-EAPR customers, the enrolled group has noticeably higher average loads, particularly during the peak period (hours ending 17-20). The result of this pre-treatment difference in the CES model that utilizes only post-treatment data is that reductions in peak period consumption due to the increase in the peak period price appear smaller than they are in reality, which causes the model to underestimate the peak period elasticities.[32] In a similar fashion, any increases in off-peak consumption that are caused by the price change will appear larger than the change that actually occurred, which will again result in biased elasticity estimates. To correct for these problems, only the deferred control group and the opt-in CPP group were used to estimate elasticities for opt-in customers.

Figure 7-1: Pre-treatment Summer Loads for Enrolled and Deferred TOU Customers



7.2 Price Elasticity Estimates

Parameter estimates from the CES model are shown in Table 7-1. Values for the elasticities vary substantially across default and opt-in pricing plans and EAPR and non-EAPR customers. Specifically, non-EAPR customers appear more willing to shift consumption from the peak to off-peak period than EAPR customers and customers on default rates are less willing to shift than opt-in customers. These findings are consistent with those reported elsewhere. For example, in the impact evaluation of California's Statewide Pricing Pilot, CARE customers, which, like EAPR customers, qualify based on income and receive significant price discounts, showed very little price responsiveness. Similarly,

[32] This pretreatment difference was corrected for when estimating the impacts reported in Section 4 through the use of the difference-in-differences regression methodology.