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Customer Acceptance, Retention, and Response to Time-Based Rates from the Consumer Behavior Studies

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Executive Summary

Time-based rate programs[1], enabled by utility investments in advanced metering infrastructure (AMI), are increasingly being considered by utilities as tools to reduce peak demand and enable customers to better manage consumption and costs.

SGIG Consumer Behavior Studies (CBS)

Ten SGIG CBS utilities conducted 11 consumer behavior studies in accordance with research protocols established by DOE. These studies were intended to answer key questions facing decision makers on customer acceptance, retention, and response and address the cost-effectiveness of using time-based rates to achieve utility, customer, and societal objectives. Further information can be found on Smartgrid.gov.

There are several customer systems that are relatively new to the marketplace and have the potential for improving the effectiveness of these programs, including in-home displays (IHDs), programmable communicating thermostats (PCTs), and web portals. Policy and decision makers are interested in more information about customer acceptance, retention, and response before moving forward with expanded deployments of AMI-enabled new rates and technologies.

Under the Smart Grid Investment Grant Program (SGIG), the U.S. Department of Energy (DOE) partnered with several electric utilities to conduct consumer behavior studies (CBS). The goals involved applying randomized and controlled experimental designs for estimating customer responses more precisely and credibly to advance understanding of time-based rates and customer systems, and provide new information for improving program designs, implementation strategies, and evaluations. The intent was to produce more robust and credible analysis of impacts, costs, benefits, and lessons learned and assist utility and regulatory decision makers in evaluating investment opportunities involving time-based rates.

To help achieve these goals, DOE developed technical guidelines to help the CBS utilities implement experimental designs that would provide more accurate estimates of customer acceptance, retention, and response. The guidelines were also intended to help the utilities identify the key drivers motivating customers to join programs and take actions to change their

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[1] Time-based rates are electricity prices that vary with time and are intended to provide consumers with price signals that better reflect the time-varying costs of producing and delivering electricity.

electricity consumption behaviors. In addition, DOE provided a team of technical experts to help each utility focus their study efforts to better address long-term objectives.

There were ten CBS utilities conducting eleven studies. They comprised a generally representative group of utility types, sizes, and regions of the country. As shown in Table ES-1, each of the CBS utilities evaluated at least one of four types of time-based rate programs: critical peak pricing (CPP), critical peak rebates (CPR), time-of-use (TOU) pricing, and variable peak pricing (VPP).[2] In addition to rates, the CBS utilities also evaluated a variety of non-rate elements in their studies including information and automated control technologies as well as education. Lastly, all the CBS utilities employed an opt-in (voluntary) recruitment approach to their studies, while two augmented that effort with a separate opt-out approach (where customers are automatically defaulted on time-based rates).

Table ES-1. Scope of the Consumer Behavior Studies

	CEIC	DTE	GMP	LE	MMLD	MP	NVE	OG&E	SMUD	VEC
Rate Treatments										
CPP		●	●		●	●	●	●	●	
TOU		●		●		●	●	●	●	
VPP								●		●
CPR	●		●							
Non-Rate Treatments										
IHD	●	●	●					●	●	
PCT	●	●					●	●		
Education							●			
Recruitment Approaches										
Opt-In	●	●	●	●	●	●	●	●	●	●
Opt-Out				●					●	
Utility Abbreviations: Cleveland Electric Illuminating Company (CEIC), DTE Energy (DTE), Green Mountain Power (GMP), Lakeland Electric (LE), Marblehead Municipal Light Department (MMLD), Minnesota Power (MP), NV Energy (NVE), Oklahoma Gas and Electric (OG&E), Sacramento Municipal Utility District (SMUD), Vermont Electric Cooperative (VEC)										

[2] Technically, CPR is not a time-based rate; it is an incentive-based program. For presentation purposes it is classified with the other time-based rate programs.

All of the studies are complete. This report presents results from the interim and final evaluations for all 10 of the CBS utilities.[3]

Major Findings

There are five areas that results from the CBS utilities can be grouped into:

(1) Recruitment approaches – effects of opt-in and opt-out;
(2) Pricing versus rebates – effects of CPP and CPR;
(3) Customer information technologies – effects of IHDs;
(4) Customer control technologies – effects of PCTs; and
(5) Customer response to prices – effects of TOU.

Each is discussed in turn below and summarized in Table ES-2.

Recruitment Approaches – Effects of Opt-in and Opt-out

Social scientists have long recognized a behavioral phenomenon called the “default effect” or “status quo bias” – when facing choices that include default options, people are predisposed to remain on a pre-selected (i.e., default) option rather than choose alternative options. If the status quo bias holds true, then opt-out recruitment efforts for time-based rates would result in much higher enrollment levels than opt-in approaches. On the other hand, utilities and others generally expect customers to drop out at higher rates, and peak demand reductions to be lower, under default opt-out approaches than those recruited voluntarily under opt-in.

Results from the CBS utilities show that under opt-out recruitment approaches enrollment rates were indeed much higher (92% vs. 15%) and peak demand reductions were generally lower (6% vs. 12% for TOU and 13% vs. 23% for CPP) than under voluntary enrollment methods. However, retention rates were about the same for both (90% vs. 87%). From these results, one would expect larger aggregate peak demand reductions from comparably sized populations of customers solicited for TOU or CPP using opt-out versus opt-in approaches. Also, the overall cost-benefit advantages are expected to be greater for opt-out approaches than opt-in approaches since efforts to default customers on rates require less effort than enrolling

[3] All of the CBS utilities’ evaluation reports can be accessed from the Consumer Behavior Study section of smartgrid.gov. In addition, a number of other CBS related documents relating to guidance provided to the CBS utilities as well as additional evaluation results can be found.

volunteers. We observed benefit-cost ratios greater than 2.0 for opt-out and between 0.7 and 2.0 for opt-in, depending on rate and technology combination.[4]

Prices versus Rebates – Effects of CPP and CPR

The behavioral science theory of loss aversion states that when people are presented with a choice that involves the potential of either avoiding a loss or acquiring a gain, the strong preference is to avoid the loss rather than to acquire the gain. As a result, one would expect that customers would be more likely to enroll in and remain on CPR than CPP. The perceived risk of receiving higher bills from under performance during critical events under CPP is greater than under CPR, and this could be a motivating factor that decreases enrollment and retention for CPP. However, once customers are on a rate, because the risk of potential loss from CPP is more salient than the potential gain from CPR, customers are expected to respond more to CPP.

Results from the CBS utilities support this theory as retention rates were higher for CPR (89%) than for CPP (80%) and demand reductions were generally higher for CPP (21%) than for CPR (11%), whereas the variability in average demand reductions across events was less for CPP than it was for CPR. However, when PCTs were available as an automated control strategy, the differences in average peak demand reductions between CPP and CPR were largely eliminated. This suggests that regardless of the financial incentive to respond (i.e., acquiring a gain via a rebate or avoiding a loss via pricing), PCTs can be an effective tool to mitigate a customer's loss aversion by allowing them to automate their response during the critical peak events.

[4] The SMUD benefit-cost results are based on a ten year net present value analysis. The benefits were based on the deferral value of capacity additions and avoided wholesale energy costs due to reduced loads during high cost periods or shifting usage from higher to lower cost periods. The costs were based on marketing, program administration and technology expenses. See Section 10.1 "SmartPricing Options – Final Evaluation" SMUD, September 5, 2014.

Table ES-2. Summary of Major Findings	
Area	**Major Findings – Demand Reductions & Enrollment/Retention Rates**
Recruitment Approaches – Opt-in & Opt-out	• Opt-out enrollment rates were about 3.5 times higher than they were for opt-in (93% vs. 15%). • Retention rates for opt-out recruitment approaches (85.5% in year 1 and 88.5% in year 2) were about the same as they were for opt-in (89.7% in year 1 and 91.0% in year 2). • Peak period demand reductions for SMUD's opt-in TOU customers were about twice (13% in year 1 and 11% in year 2) as large as they were for opt-out customers (6% in year 1 and year 2). • Peak period demand reductions for SMUD's opt-in CPP customers were about 50% higher (24% in year 1 and 22% in year 2) than they were for opt-out customers (12% in year 1 and 14% in year 2). • SMUD's opt-out offers were more cost-effective for the utility than their opt-in offers in all cases. • Roughly two-thirds of those who were defaulted onto SMUD's TOU rates were expected to see bill impacts of +/- $20 for the entire 4 summer months the rates were in effect. • Based on survey responses, a majority of those defaulted onto SMUD's TOU rate were satisfied with the rate, regardless of the level of bill savings achieved, but those who saw the largest bill increases were generally less interested in continuing with the rate after the study ended.
Pricing Versus Rebates – CPP & CPR	• While opt-in enrollment rates for GMP were about the same for CPP (34%) and CPR (35%), retention rates were somewhat lower for CPP (80%) than they were for CPR (89%). • Average peak demand reductions for CPP (20%) were about 3.5 higher than they were for CPR (6%), but when automated controls (PCTs) were provided, they were about 30% larger (35% for CPP and 26% for CPR).
Customer Information Technologies - IHDs	• Enrollment and retention rates were generally unaffected by offers of IHDs. • SMUD's opt-in CPP customers with IHDs (26% in year 1 and 24% in year 2) had somewhat higher peak demand reductions than those without IHDs (22% in year 1 and 21% in year 2), but these differences can be explained by pre-treatment differences between the two groups. • SMUD's opt-in TOU customers with IHDs (13% in year 1 and 11% in year 2) had somewhat higher peak demand reductions than those without IHDs (10% in year 1 and 9% in year 2), but these differences can be explained by pre-treatment differences between the two groups. • SMUD's offerings without IHDs were more cost-effective for the utility in all cases than those with IHDs.
Customer Control Technologies - PCTs	• Enrollment and retention rates were generally unaffected by offers of PCTs. • Peak demand reductions are generally higher for CPP and CPR customer with PCTs (22% to 45%) than they were for customers without PCTs (-1% to 40%). • OG&E rate offers with PCTs were more cost-effective for the utility than those without PCTs.
Customer Response to Price - TOU	• Peak period demand reductions were far less, on average, for the lowest peak to off-peak price ratios (6% for treatments with a peak to off-peak price ratio less than 2:1) than for the highest price ratios (18% for treatments with a peak to off-peak price ratio greater than 4:1). • When a CPP/CPR was overlaid on the TOU rate, the average event peak demand reduction rose to 27% when averaged over all of the treatments • When PCTs were available, the differences in average peak period demand reductions were only affected at peak to off-peak price ratios in excess of 2:1 (21% vs. 10% for price ratios between 2:1 and 3:1 and 23% vs. 15% for price ratios in excess of 4:1).

Customer Information Technologies – Effects of IHDs

Customer information technologies such as IHDs and web portals provide ways of raising customer awareness about usage levels, consumption patterns, electricity prices, and costs. By raising awareness about prices and usage patterns, utilities create opportunities for customers to better understand how usage affects their bills. With this information, utilities expect customers will have better capabilities for understanding and responding to time-based rates. When IHDs are offered by utilities to customers for free (which is frequently done to bolster participation rates) implementation costs increase, so it is important to understand if the benefits outweigh the costs of the devices.

Results from the CBS utilities show that free IHD offers did not make a substantial difference for enrollment and retention rates (+/- 1-4 percentage points). Although SMUD's peak demand reduction estimates were larger with IHDs (2-3 percentage points), this result can be attributed to pre-treatment differences between the two groups so there was not a measured IHD effect on reductions of peak demand. As a result, because the cost of providing IHDs is non-negligible, the benefit-cost ratios of rate offerings were lower when they included offers of free IHDs relative to when they were absent (0.74 vs. 1.19 for TOU and 1.30 vs. 2.05 for CPP). In addition, many of the CBS utilities reported significant challenges with this relatively new technology. Problems included very low customer connectivity rates (e.g., less than 20% were connected all the time while between 42% and 65% were never connected at all), getting the IHDs to function properly (e.g., binding to the meter to receive data) and in one case the manufacturer decided to halt production and stop support in the middle of the study.

Customer Control Technologies – Effects of PCTs

Conceptually, automated control technologies such as PCTs lower the transactional effects associated with responding to prices and critical peak events by making it easier for customers to alter their electricity consumption at specified times. As with IHDs, utility offers of free PCTs cause implementation costs to increase, so it is important to understand if the value of the additional demand reductions outweighs the costs of the devices.

Although the studies were not designed and implemented in such a way as to measure the effect of PCTs on enrollment, results from the CBS utilities show that free PCT offers did not make a major difference for retention (91% with or without PCTs). However, peak demand reductions were substantially higher when a PCT was present (22-45% reduction with a PCT vs. -1 to 40% without one) while the variability of those reductions was less, which should increase the value of such demand reductions. Unlike with IHDs, benefit-cost ratios for PCT offers were favorable (i.e., greater than 1.0). In response, one utility (OG&E) decided to roll-out a time-based rate with an offer of a free PCT to its entire residential customer class with a recruitment goal of 120,000 customers within three years.

Customer Response to Prices – Effects of TOU

Economic theory suggests that people are generally willing to buy larger quantities of a good as its price goes down. Conversely, as the price increases, people are expected to buy less of that same good. This basic relationship can be used to explain what the CBS utilities expected to happen when they introduced a TOU rate into their study: electricity consumption would be reduced in the peak period when the peak period price of electricity was raised relative to the price of electricity in the off-peak period.

The estimated demand reductions during the peak period from customers exposed to a TOU rate ranged from a low of -1% (i.e., load increased for the average customer in this TOU treatment by 1%) to a high of 29%, with an average of 15%. On average, customers responded to a greater extent (i.e., reduced their peak demand to a greater extent) when exposed to higher rather than lower price ratios. Results indicate that customers reduced demand during the peak period by 6%, on average, when experiencing a peak to off-peak price ratio less than 2:1 compared to 18% when experiencing a price ratio greater than 4:1. However, when PCTs were available as an automated control strategy, the variability of peak period demand reductions was significantly reduced and greater reductions were observed for price ratios in excess of 2:1 (21% vs. 10% for price ratios between 2:1 and 3:1 and 23% vs. 15% for price ratios in excess of 4:1). This suggests that PCTs can be an effective tool in augmenting peak period demand reductions, but only if the price ratio is high enough. When CPP/CPR was overlaid on the TOU rate, the average event peak demand reduction was 27% when averaged over all of the treatments. However, when PCTs were available, the average event peak demand reduction was 34% vs. 24% when such automated control technology was not available.

Concluding Remarks

Rigorous experimental methods were applied in these consumer behavior studies with the belief that more credible and precise load impact estimates would help resolve some of the outstanding issues hindering broader industry adoption of time-based rates for residential customers. Since none of the CBS utilities had any experience with such experimental methods, each CBS utility was provided with a small team of industry experts who provided technical assistance in the design, implementation and evaluation of each study. Besides direct engagement with each CBS utility, these Technical Advisory Groups (TAGs) also produced a library of guidance documents for the CBS utilities (publicly available on smartgrid.gov) on such diverse topics as study plan documentation, experimental design, rate and non-rate treatments, and evaluation techniques. With the help of these TAGs and the reference material they produced, many of the concerns initially raised about the application of experimental methods (e.g., that withholding or deferring exposure to the rate after a customer had agreed to participate in the study would create customer relations problems) did not materialize. In addition, TAGs helped the utilities more narrowly focus their studies on a core set of objectives that would more directly inform the utilities on suitable pricing strategies. As such, the consumer behavior study program produced results that significantly contributed to our understanding of several critical issues, as described above.

Both utilities and participating customers learned a tremendous amount about themselves and their capabilities through these studies. Although not an explicit objective of the consumer behavior studies, successful recruitment into the pricing studies hinged on the ability of the CBS utilities to effectively engage customers – many of whom had very limited experience in this arena. As such, several CBS utilities recognized the importance of performing market research during the study design phase to ensure marketing material was as effective as possible to engage customers as participants in the studies. The most successful CBS utilities continued that engagement not just during recruitment but throughout the study period itself, which included the creation of a plethora of different materials using a number of different mediums (e.g., monthly newsletters, social media campaigns of tips and tricks) that constantly sought to keep customers engaged in the study. Such efforts seemed to be quite successful, as the vast majority of customers who started the studies also completed them, expressed a high level of satisfaction in their experiences with these new rates and to a lesser extent with the new technologies, and continued taking service under the rate after the study ended, provided such opportunities were available.

The results of the consumer behavior study effort has helped the participating utilities and others to advance the application of time-based rates. Three of the ten CBS utilities allowed participants to continue taking service under the rates after their study was completed. Four of the ten CBS utilities chose to extend an offer of the rates tested in their study to the broader population of residential customers. Specifically, OG&E has enrolled approximately 116,000 of their residential customers (representing approximately 18% of their residential population) on their SmartHours program, 100,000 (86%) of which are taking service on the variable peak pricing rate tested in its CBS, and are achieving 147 MW of peak demand reduction. This voluntary SmartHours program includes the offer of a free PCT, which 90% of customers have taken. SMUD chose to make the TOU rate it tested the default for all of its residential customers, starting in 2018. More broadly, the California Public Utility Commission ordered all of the state's investor-owned utilities to make TOU the default for residential customers, citing heavily the very positive results SMUD achieved as grounds for this decision. DOE hopes the experiences and results from the CBS effort will help the industry to effectively consider the application of time-based rates for residential customers.

1. Introduction

Time-based rates, enabled by utility investments in advanced metering infrastructure (AMI), are increasingly being considered by utilities and policy makers as tools to augment incentive-based programs for reducing peak demand and enabling customers to better manage consumption and costs. In addition, there are several customer systems that are relatively new to the marketplace that have potential for improving the effectiveness of these programs, including in-home displays (IHDs), programmable communicating thermostats (PCTs), web portals, and a host of new and novel software and data applications.[5]

The electric power industry is interested in more information about residential customer preferences for and responses to time-based rates and incentive-based programs as utilities and other stakeholders propose plans for expanded deployments. Under the U.S. Department of Energy's (DOE) Smart Grid Investment Grant Program (SGIG), several utilities took part in a Consumer Behavior Study (CBS) effort in order to develop information on preferences and responses to time-based rates and incentive-based programs, including impacts, benefits, and lessons-learned that could inform utilities' and policy makers' decisions about the design and implementation of new rate and technology offerings.

1.1 Background about Time-Based Rates and Advanced Metering Infrastructure

From the early days of the electric power industry, utilities, policy makers, and academics have shown interest in time-based rates for electricity.[6] When designed correctly, such rates allow the prices that customers pay to use electricity to correspond more closely to the actual costs of producing or procuring it. For most utilities, the cost of providing electricity changes over a variety of different time dimensions: minute, hour, day, month, and season. In general, as demand for electricity increases, higher-cost power plants must be brought online to accommodate the additional demand. Furthermore, the variable nature of certain types of renewable generation technologies likewise can cause power costs to fluctuate. Figure 1 shows how different types of time-based rates can reflect to varying degrees the marginal costs of producing electricity. Although not shown in the figure, real-time pricing (RTP), in its ideal form, can perfectly reflect these marginal costs. The alternative rates shown in the figure, critical peak pricing (CPP), variable peak pricing

[5] For example, the Green Button initiative which provides a standard protocol for customers to gain access to their interval meter data.

[6] Hausman, W. J. and J. L. Neufeld (1984). "Time-of-Day Pricing in the U.S. Electric Power Industry at the Turn of the Century." The Rand Journal of Economics 15(1): 116-126.

(VPP), and time-of-use (TOU), all seek to reflect at a more aggregate level the average of the marginal cost of producing electricity during various periods of time.

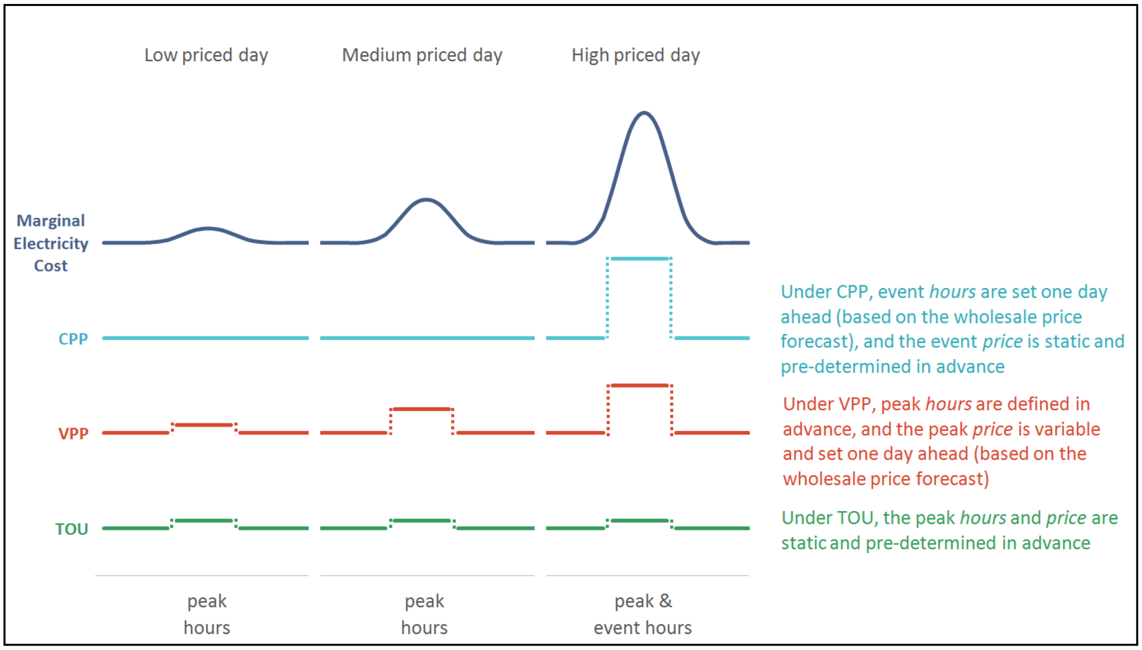

Figure 1. An Illustration of Several Time-Based Rate Designs.

Furthermore, a myriad of financial benefits inure to utilities and their ratepayers when customers take service under and respond to time-based rates. The value associated with lowering peak demands is often at its highest when reductions in consumption coincide with times that the local or regional power system is experiencing its highest level of demand (i.e., the coincident system peak demand). Such reductions in electricity demand at these times can lead to future deferrals of new investments or upgrades in electric generation, distribution and possibly transmission facilities, and/or avoidance of higher prices or demand charges from wholesale power suppliers. These results can lead to reductions in the utility's overall cost of service, which can benefit all customers when the reductions are passed on through retail rates.

In 1978, the U.S. Congress saw the value of trying to move the electric power industry towards more time-based pricing and passed The Public Utility Regulatory Policies Act[7] (PURPA). This legislation contained standards calling for states to consider adoption of TOU rates to better reflect the costs of service by charging prices that encouraged customers to shift consumption from more expensive peak to less expensive off-peak periods. In response to PURPA, many states implemented TOU rates

[7] Subtitle B asked state regulatory authorities and non-regulated electric utilities to determine whether or not it is appropriate to implement TOU rates and other ratemaking policies.

on a pilot basis to evaluate their cost-effectiveness. During the early 1980s, evaluations of those pilot programs by the Federal Energy Administration (a DOE predecessor) found that customers responded to TOU rates and successfully shifted electricity use from higher to lower cost times of day.[8] However, the costs of new meters capable of measuring consumption by time-of-day presented a barrier at that time to cost-effective implementation of TOU rates on a larger scale.

In spite of this, interest by state policy and decision makers in deployments of time-based rate programs has remained. In fact, more than 100 studies have been published that assess how customers change their consumption patterns in response to time-based rate programs, including assessments of how customer responses are helped or hindered by access to usage information from web portals and in-home displays, or by use of control technologies that automate electricity-consuming devices such as programmable communicating thermostats.[9] Results from these studies vary widely[10] and many policy and decision makers continue to ask for more detailed and more precise information about key policy questions, including:

- Does the enrollment condition (i.e., opt-in, opt-out) affect customer acceptance, retention and/or response to a time-based rate?
- Does the existence of control and/or automation technology (e.g., programmable communicating thermostat) affect customer acceptance, retention and/or response to a time-based rate?
- Does the existence of information technology (e.g., in-home display) affect customer acceptance, retention and/or response to a time-based rate?
- Do customer demographics (e.g., low-income, high usage, elderly households, college educated) play a role in customer acceptance, retention, and/or respond to a time-based rate?
- What is the persistence of participation and response over time to a time-based rate?
- What role does bill protection and/or bill guarantees have on customer acceptance, retention and/or response to a time-based rate?

Over the past 15 years, the costs of interval meters and the communications networks to connect the meters with utilities and back-office systems (i.e., advanced metering infrastructure, or AMI)

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[8] Faruqui, A. and J. R. Malko (1983). "The residential demand for electricity by time-of-use: A survey of twelve experiments with peak load pricing." Energy 8(10): 781-795.

[9] Faruqui, A. and S. Sergici (2010). "Household Response to Dynamic Pricing of Electricity-A Survey of the Empirical Evidence." Social Sciences Research Network.

[10] EPRI (2012). Understanding Electric Utility Customers: What we know and what we need to know. EPRI. Palo Alto, CA.

have decreased. Recent implementation of AMI allows electricity consumption data to be captured, stored and reported at 5 to 60-minute intervals and provides opportunities for utilities and policymakers to reconsider the merits of widespread deployment of time-based rates. The benefits which may result from the application of time-based rates often times helps to justify the business case for investments in AMI. In addition to enabling time-based rates, AMI also provides new opportunities for utilities to lower costs by automating meter reading, service connections and disconnections, and tamper and theft detection. AMI can also lower electric distribution costs through improvements in outage management and voltage controls.[11]

At present, many regulators, policy makers, and other stakeholders are seeking more definitive answers to key policy questions as well as more accurate estimates of value-streams before supporting AMI investments and expanded implementation of time-based rates for residential and small commercial customers.

1.2 Overview of DOE's Consumer Behavior Studies (CBS) Program

In 2009, Congress saw an opportunity to advance the electricity industry's investment in the US power system's infrastructure by including the Smart Grid Investment Grant (SGIG) as part of the American Recovery and Reinvestment Act (Recovery Act). To date, DOE and the electricity industry have jointly invested over $7.9 billion in 99 cost-shared SGIG projects that seek to modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid and customer operations enabled by these investments. The SGIG program included more than 60 projects that involved AMI deployments with the aim of improving operational efficiencies, lowering costs, improving customer services, and enabling expanded implementation of time-based rate programs.[12]

In selecting project applications for SGIG awards, DOE was interested in working closely with a subset of utilities willing to conduct comprehensive consumer behavior studies that applied randomized and controlled experimental designs. DOE's intent for the studies was to encourage the utilities to produce robust statistical results on the impacts of time-based rates, customer information systems, and customer automated control systems on peak demand, electricity consumption, and customer bills. The intent was to produce more robust and credible analysis of

[11] DOE's Recovery Act smart grid programs have produced a number of reports and case studies documenting the impacts and financial benefits of AMI for these purposes. These can be downloaded from www.smartgrid.gov.

[12] SGIG has helped to deploy more than 16.3 million new smart meters, which represents about 32% of the 50 million smart meters that have been installed nationwide as of 2015.

impacts, costs, benefits, and lessons learned and assist utility and regulatory decision makers in evaluating investment opportunities involving time-based rates. Of the SGIG projects investing in AMI and implementing time-based rate programs, there were ten utilities that were interested in working with DOE to participate in the CBS program.

The ten CBS utilities set out to evaluate a variety of different time-based rate programs and customer systems. Concerning the former, the CBS utilities planned to study TOU, CPP, VPP, and critical peak rebates (CPR).[13] Many also planned to include some form of customer information system (e.g., IHDs) and/or customer automated control system (e.g., PCTs). Several CBS utilities evaluated multiple combinations of rates and customer systems, based on the specific objectives of their SGIG projects and consumer behavior studies. For example, one utility evaluated treatment groups with a CPP rate layered on top of a flat rate, in combination with and without IHDs. Another evaluated VPP as well as CPP layered on top of a TOU rate in combination with and without PCTs.

1.3 DOE's Technical Approach to the CBS Program

DOE's goal for all of the consumer behavior studies was for them to produce load impact results that achieve internal and ideally external validity.[14] To help ensure that this goal was met, DOE published ten guidance documents for the CBS utilities. The guidelines were intended to help the utilities better understand DOE's expectations of their studies to achieve these goals, including their design, implementation, and evaluation activities.

Specifically, several of the DOE guidance documents addressed how to appropriately apply experimental methods such as randomized controlled trials and randomized encouragement designs to more precisely estimate the impact of time-based rates on electricity usage patterns, and identify the key drivers that motivated changes in behavior.[15] The guidance documents identified

[13] Technically, CPR is not a time-based rate; it is an incentive-based program. However, for simplicity of presentation, it is classified with the other event-driven time-based rate programs.

[14] Internal validity is the ability to confidently identify the observed effect of treatments, and determine unbiased estimates of that effect. External validity is the ability to confidently extrapolate study findings to the larger population from which the sample was drawn.

[15] The experimental designs were intended to ensure that measured outcomes could be determined to have been caused by the program's rate and non-rate treatments, and not random or exogenous factors such as the local economic conditions, weather or even customer preferences for participating in a study. Most of the studies decided to use a *Randomized Controlled Trial* experimental design, which is a research strategy involving customers that volunteer to be exposed to a particular treatment and are then randomly assigned to either a treatment or a control group. A few studies chose to use a *Randomized Encouragement Design*, which is a research strategy involving two groups of customers selected from the same population at random, where one is offered a treatment while the other is not. Not all customers offered the treatment are expected to take it, but for analysis purposes, all those who are offered the

key statistical issues such as the desired level of customer participation, which was critical for ensuring that sample sizes for treatment and control groups were large enough for estimates of customer response to have the desired level of accuracy and precision. Without sufficient numbers of customers in control and treatment groups, it would be difficult to determine whether or not differences in the consumption of electricity were due to exposure to the treatment or random factors (i.e., internal validity).

To make best use of the guidance documents, DOE assigned a Technical Advisory Group (TAG) of industry experts to each CBS utility to provide technical assistance. The TAGs helped customize the application of the guidance documents as each of the utility studies was different and had their own goals and objectives, starting points, levels of effort, and regulatory and stakeholder interests. These latter factors, in conjunction with the DOE guidance documents, determined how each utility study was designed and implemented. For example, several utilities had prior experience with time-based rates and used the studies to evaluate needs for larger-scale roll-outs. Others had little or no experience and used the studies to learn about customer preferences and assess the relative merits of alternative rates and technologies.

Each CBS utility was required to submit a comprehensive and proprietary Consumer Behavior Study Plan (CBSP) that was reviewed by the TAG and approved by DOE. In its CBSP, each utility documented the proposed study elements, including the objectives, research hypotheses, sample frames, randomization methods, recruitment and enrollment approaches, and experimental designs. The CBSP also provided details surrounding the implementation effort, including the schedule for regulatory approval and recruitment efforts, methods for achieving and maintaining required sample sizes, and methods for data collection and analysis.[16]

Each CBS utility was also required to comprehensively evaluate their own study and document the results, along with a description of the methods employed to produce them, in a series of evaluation reports that were reviewed by the TAG, approved by DOE, and posted on Smartgrid.gov. Each utility was expected to file an interim evaluation report after the first year of the study and a final evaluation report at the end of the study.

treatment are considered to be in the treatment group. For more information, see **"**Quantifying the Impacts of Time-based Rates, Enabling Technology, and Other Treatments in Consumer Behavior Studies: Protocols and Guidelines" July 2013, Lawrence Berkeley National Laboratory.

[16] In several cases, utilities encountered problems during implementation (e.g., insufficient numbers of customers in certain treatment groups) that required the study's initial design as described in the CBSP to be altered to maintain a high probability of achieving as many of the study's original objectives as possible. For several utilities this meant reductions in the number of treatment groups included in the studies.

1.4 Reporting

In addition to the CBS utilities' evaluation reports, DOE funded research on a variety of topics related to this CBS effort utilizing independent analysis of data collected by the CBS utilities throughout their studies.[17] Some of these reports are for a general audience and can be found on DOE's smart grid website (smartgrid.gov). A number of other reports, which are considerably more technical in nature, can be found at Lawrence Berkeley National Laboratory's (LBNL) website (emp.lbl.gov). Finally, a small subset are highly technical and will be published in peer-reviewed academic journals.

Table 1 lists the title of each report that has already been published as a DOE report (smartgrid.gov) or an LBNL report (emp.lbl.gov) as well as when it was published.

Table 1. Prior SGIG CBS Reports

Titles	Publication Location	Publication Dates
Smart Grid Investment Grant Consumer Behavior Study Analysis: Summary of Utility Studies	Smartgrid.gov	June 2013
Residential Customer Enrollment in Time-based Rate and Enabling Technology Programs	Smartgrid.gov	June 2013
Analysis of Customer Enrollment Patterns in Time-Based Rate Programs – Initial Results from the SGIG Consumer Behavior Studies	Smartgrid.gov	July 2013
Experiences from the Consumer Behavior Studies on Engaging Customers	Smartgrid.gov	September 2014
Time-of-Use as a Default Rate for Residential Customers: Issues and Insights	Emp.lbl.gov	June 2016
Experiences of Vulnerable Residential Customer Subpopulations with Critical Peak Pricing	Emp.lbl.gov	September 2016

Those research activities that DOE continues to fund, which include an analysis of the data collected by the CBS utilities through their consumer behavior studies, will include the following topics, which will be reported separately as LBNL reports and/or as peer-reviewed journal articles:

- **Go for the Silver? Comparing Quasi-Experimental Methods to the Gold Standard**

[17] This rich dataset includes: study assignment, participation and retention data; interval meter data; survey data; customer systems data; and other data collected during the course of each study.

Randomized controlled trials (RCTs) are widely viewed as the "gold standard" for evaluating the effectiveness of an intervention. However, analysis of the effect of energy pricing has largely been conducted through quasi-experimental methodologies. Analyzing interval meter data from a subset of the CBS utilities, the true estimates obtained through the RCT will be compared with those derived from an application of quasi-experimental designs as well as from a regression discontinuity design. The goal will be to identify what might be causing any observed bias when non-RCT methods are used in this setting.

- **Understanding What Drives the Bias in Baseline Methods for Evaluating Demand Reduction**
  This research expands upon the comparison of impact estimates from experimental and quasi-experimental designs in order to delve deeper into an examination of the bias of the current best performing baseline methods in an attempt to identify the cause and implications of this bias. By analyzing interval meter data from the Sacramento Municipal Utility District's consumer behavior study, the cause of the bias can hopefully be identified: spillover, in which customers reduce demand not only during the hours that the program is designed to target, but also during other hours. The analysis will also attempt to understand the conditions under which the bias is bigger or smaller (e.g., temperature of event days; temperature of the days preceding the event; length of time between events; length of time customers have been enrolled in the CPP rate).

1.5 Data Sources

This report summarizes the major findings of DOE's SGIG-funded consumer behavior studies of time-based rates. A key source of information for the results reported herein comes from the interim and final evaluation reports that were submitted by the CBS utilities to DOE. However, not all of the utilities designed their studies to produce results that were perfectly comparable, reported information in the same way, or included metrics using the same analytical methods. When possible, this report presents aggregated results using comparable data from two or more of the utilities. Results from individual utilities are also presented where appropriate to highlight key findings. In general, the findings in this report address the following topics[18]:

[18] An assessment of bill impacts which incorporate the effects of customer response to time-based rates was not undertaken. Event driven rates are designed to be revenue neutral based on the dispatch of a specific number of events where a dramatically higher rate is in effect. If not all of those events are actually called during the study relative to the number used in designing the rate, then participating customers are highly likely to experience bill savings. This is not necessary reflective of their efforts to reduce or shift load during events, but rather an artifact of the rate design. As such, a reporting of bill impacts out of the consumer behavior studies could be misleading, since most of the studies

- The choices made by participating customers to enroll, accept, and remain involved in time-based rates. This includes information about the effects on customer choices from different forms of recruitment (i.e. opt-in versus opt-out), customer systems (i.e., IHDs and PCTs), and time-based rate offerings (i.e., CPP, CPR).
- The customer responses in terms of customer electricity demand reductions that stem from the application of different recruitment methods, customer systems, and time-based rates.
- The cost-effectiveness of the rates, programs, and customer-systems for the utility.[19]

The contents of any prior DOE-funded independent analysis of the data generated by the CBS utilities also serves as reference material for the results reported herein and is noted accordingly.

who included some form of CPP (which was a majority of the studies as will be discussed in Chapter 2) did not call all of the events for which the rate was designed for.

[19] However, there was limited information in the evaluation reports on this topic.

2. Scope and Status

Because each utility had its own unique study objectives, it is important to understand some of the details about each of the studies to more fully frame the results, and their implications. Each of the study summaries presented below contains a description of the overall SGIG project and to the study itself.[20] The Appendix contains additional information on the rates offered by the CBS utilities.

2.1 Types of Rate and Non-Rate Treatments in DOE's CBS Program

The CBS utilities evaluated a variety of time-based rates for their impact on customer acceptance, retention and response including ones that are driven by critical peak events and ones that are not. The primary objective of event-driven rates is to achieve reductions in peak (i.e., maximum) demand. Typically, utilities determine the need for critical peak events based on short-term system conditions, high forecasted wholesale market prices, or both. Participating customers receive notification of the events either on the day before or early on the critical peak event day.

The CBS utilities evaluated two primary types of event-driven rate programs: CPP and CPR. CPP designs involve increases in the price of electricity consumed during pre-determined hours (event period) on event days.[21] This higher price is overlaid onto the existing retail rate. CPR is similar to CPP except that customers are paid an incentive to reduce demand during the event period, relative to a baseline.[22]

The primary objective of non-event driven rate designs involves customers altering their consumption patterns more broadly, for example by shifting electricity consumption away from one part of the day to another. TOU rates are one of the most widely implemented types of non-event driven time-based rates and involve designs that charge customers for electricity usage based on the block of time it is consumed. Typically, this involves higher prices during a pre-determined set of

[20] Further details on the scopes of the studies can be found in "Smart Grid Investment Grant Consumer Behavior Study Analysis: Summary of Utility Studies" June 2013, Lawrence Berkeley National Laboratory.

[21] Most retail electric rates are designed to collect the same amount of revenue annually from the average customer in a class. Since CPP is designed to impose higher prices during a set number of critical peak events each year, the retail electric rate is lower on non-event days than the existing traditional utility tariff to offset the higher revenue collected during these events. This means customers have a risk for much higher bills when critical events are called (due to the higher price during events), but this would be offset by slightly lower bills the rest of the year.

[22] CPR is usually designed to overlay the incentive payment on the existing traditional utility tariff that is not changed. As such, the CPR incentive payments are typically drawn from levying slightly higher retail electric rates on all customers, not just those taking service under CPR. Because the rate increases associated with the incentive payments are spread across all customers in the class, they can be quite small on a per customer basis and are rarely noticed.

peak hours and lower prices during off-peak hours. TOU price schedules are fixed and pre-defined based on season, day of week, and time of day.

VPP, a hybrid of CPP and TOU, involves designs in which customers are charged based on the block of time electricity is consumed, but the price schedule differs based on existing power system conditions and/or wholesale market prices for that day. VPP rates are intended to encourage customers to broadly shift consumption away from peak periods, but to also accomplish greater peak demand reductions as needed when system conditions or market prices warrant.

In addition to rates, the CBS utilities also evaluated the role of customer systems including information and automated control technologies on customer acceptance, retention and response. Customer systems are thought to increase interest in acceptance of time-based rates, heighten interest in remaining on such rates, more easily respond to such rates and more generally enhance the ability of customers to manage electricity costs. Information technologies, like IHDs, more conveniently provide customers cost and energy use information, and control technologies, like PCTs, provide capabilities for customers to automate their responses to time-based rates.

The CBS utilities also evaluated different approaches to recruiting customers to participate and take service under the various time-based rates included in the studies. Many CBS utilities used an opt-in approach that sought volunteers to participate in the study. In a few cases, CBS utilities included an opt-out approach whereby customers were told they would be participating in the study unless they took action and declined.

Table 2 shows the rate and technology offerings being evaluated by the CBS utilities. The subsections that follow provide information about the scope and status of the ten utility studies.

Table 2. Scope of the Consumer Behavior Studies

	CEIC	DTE	GMP	LE	MMLD	MP	NVE	OG&E	SMUD	VEC
Rate Treatments										
CPP		●	●		●	●	●	●	●	
TOU Pricing		●		●		●	●	●	●	
VPP								●		●
CPR	●		●							
Non-Rate Treatments										
IHD	●	●	●					●	●	
PCT	●	●					●	●		
Education							●			
Recruitment Approaches										
Opt-In	●	●	●	●	●	●	●	●	●	●
Opt-Out				●					●	

Utility Abbreviations: Cleveland Electric Illuminating Company (CEIC), DTE Energy (DTE), Green Mountain Power (GMP), Lakeland Electric (LE), Marblehead Municipal Light Department (MMLD), Minnesota Power (MP), NV Energy (NVE), Oklahoma Gas and Electric (OG&E), Sacramento Municipal Utility District (SMUD), Vermont Electric Cooperative (VEC)

2.2 Cleveland Electric Illuminating Company (CEIC)

Overview. CEIC is part of FirstEnergy Services Corporation's SGIG Project which had a total budget of about $114 million (DOE's share of about $57 million) and included installation of about 34,000 smart meters, associated communications networks, and distribution automation equipment on about sixty feeders. CEIC's consumer behavior study's initial design involved about 5,000 residential customers and focused on evaluating the timing and magnitude of changes in customer peak demand and energy usage patterns in response to CPR and use of IHDs and PCTs.

Treatments. Rate treatments included the implementation of a CPR that provides a payment to customers for reducing electric demand during declared critical peak events, while the price charged by CEIC for electricity consumed at other times stays at existing flat rates. Customers received day-ahead notification of critical peak events and could receive such notification up to 15 times per year. Technology treatments included IHDs and PCTs. The PCTs involved two treatment methods:

customer control and utility control. Because several treatment groups fell short of recruitment goals, CEIC chose to focus on a smaller number of treatments to obtain more precise impact estimates. The treatments involved a flat rate with CPR that included a $0.40 per kilowatt hour rebate and either (1) a four hour event duration that could be paired with an IHD or customer-controlled PCT, and (2) a four- or six-hour event duration that could be paired with a utility-controlled PCT.

Design. The study's experimental design involved a randomized encouragement design where customers were randomly assigned to either be offered a treatment or not offered a treatment. Data from customers who were offered a specific treatment but declined the offer were included in the study with data from the customers who were randomly assigned and not offered a treatment.

Status. CEIC completed its consumer behavior study. The recruitment effort fell short of its goals and so several of the experimental cells had to be dropped to maintain, to the degree possible, statistical power in the resulting load impact estimates. The interim evaluation on results from the summer of 2012 was published in May, 2013. The final evaluation covering activities during the summer of 2013 and 2014 was published in June, 2015. Based on the results, CEIC is considering expansion of CPR offerings in the future.

2.3 DTE Energy (DTE)

Overview. DTE's SGIG project had a total budget of about $168 million (DOE's share of about $84 million) and included a system wide roll-out of 725,000 smart meters and installation of distribution automation equipment on more than fifty feeders and ten substations. DTE's consumer behavior study's initial design involved more than 6,000 residential customers and focused on evaluating customer acceptance and response to various combinations of time-based rates (TOU with a CPP overlay) and IHDs and PCTs.

Treatments. Rate treatments included the implementation of a three-period TOU rate with a CPP overlay during the peak period (weekdays and non-holidays 3 – 7 p.m.). Critical peak events were announced with day-ahead notice to participating customers. Up to 20 critical peak events could be called each year. Control and information technology treatments included the deployment of IHDs and PCTs. In addition, all customers participating in the study received web portal access, customer support, and a variety of education materials.

Design. The study's experimental design involved a randomized controlled trial with denial of treatment for the control group. A simple random sample of AMI-metered residential customers in the service territory who meet certain eligibility criteria received an invitation to opt-in to the study where participating customers could receive one of several treatments, with the understanding that this treatment is limited in supply. Customers who opted-in were surveyed to ensure they met the eligibility criteria. Those who self-identified as having central air conditioning were randomly assigned either to a control group or to receive an offer to opt-in to one of four studies, each of which includes a TOU with CPP rate design and an offer of: no technology, an IHD only, a PCT only, or both a PCT and IHD. Those who self-identify as not having central air conditioning were randomly assigned either to a control group or to receive an offer to opt-in to one of two studies, each of which included a TOU-CPP rate design and an offer of either no technology or an IHD.

Status. DTE completed its consumer behavior study. The recruitment effort fell short of its goals and so several of the experimental cells had to be dropped or consolidated to maintain, to the degree possible, statistical power in the resulting load impact estimates. The interim evaluation on the results of critical peak event days called in August, 2012 and May, 2013 was published in January, 2014. The final evaluation covering additional critical peak event days during the summer of 2013 was published in August, 2014. Based on the results, DTE is offering the TOU with CPP rate designed for the study to its entire residential population on a voluntary basis.

2.4 Green Mountain Power (GMP)

Overview. GMP (along with VEC) is part of Vermont Transco's SGIG Project which had a total budget of about $138 million (DOE's share of about $69 million) and included deployment of more than 300,000 smart meters and installation of distribution automation equipment on more than forty feeders and ten substations. GMP's consumer behavior study's initial design involved more than 3,500 residential customers and focused on evaluating customer acceptance and response to different time-based rates coupled with information feedback treatments.

Treatments. GMP implemented CPR that provided a payment to customers for reducing electric demand during declared critical peak events, while the price charged for electricity during other times stayed at the customer's existing flat rate. GMP also implemented CPP overlay that slightly lowered the customer's existing standard flat rate but augmented it with a substantially higher price during declared critical peak events. Control and information technology treatments included the deployment of IHDs. This technology provided site-level electricity consumption information and customer notification of critical peak events. Customers also received notification by email, text, and voice message and had web portal access to interval meter data, customer support, and a variety of education materials.

Design. The study's experimental design involved a randomized controlled trial with denial of treatments for the control group and pre-recruitment assignments. AMI-enabled customers who met certain eligibility criteria were randomly assigned to either one of the two control groups (differing by customer's awareness about the study and critical peak events) or one of six treatment groups. Customers assigned to the flat rate with CPP treatment were required to agree to the rate change. Customers assigned to the flat rate with CPR treatment, or one of the control groups, were told of their assignment and could opt-out.

Status. GMP completed its consumer behavior study. The interim evaluation on the results of critical peak event days called in the summer and fall of 2012 was published In November, 2013. The final evaluation covering additional critical peak event days during the summer of 2013 was published in March, 2015. Based on the results, GMP is considering expansion of time-based rate offerings in the future.

2.5 Lakeland Electric (LE)

Overview. LE's SGIG Project had a total budget of about $35 million (DOE's share of about $15 million) and included deployment of more than 120,000 smart meters and supporting communications networks. LE's consumer behavior study's initial design involved more than 2,000 residential customers and focused on evaluating customer acceptance and response to a TOU rate, under both opt-in and opt-out enrollment approaches. This study focused primarily on evaluating the timing and magnitude of changes in residential customers' peak demand and energy usage patterns due to a seasonal three-period TOU rate.

Treatments. Rate treatments included a seasonal three-period TOU rate, where the definition of the peak period (weekdays and non-holidays) differed between summer (2 – 8 p.m. April – October) and winter (6 – 10 a.m. November – March) as did the definition of the shoulder period (summer: 12 Noon – 2 p.m. April – October; winter: 10 a.m. – 12 Noon and 7 – 10 p.m. November – March). All customers participating in the study received web portal access, customer support, and a variety of education materials, including a bill calculator.

Design. The study's experimental design involved a randomized controlled trial with delayed treatment for the control group. Opt-in and opt-out enrollment approaches were evaluated. For opt-in, the pool of eligible AMI-enabled residential customers in the service territory allocated for this part of the study received an invitation to join the study and receive the rate treatment, with the understanding that the application of this treatment could be delayed by one year. Opt-in customers were then randomly assigned to either receive the rate treatment or remain on their existing inclining block rate. Those who remained on the existing rate acted as a control group during 2012 and were then offered the new rate in 2013.

For opt-out, the pool of eligible AMI-enabled residential customers in the service territory received notification that they were chosen for a study and automatically received the rate treatment. Customers who did not opt-out were randomly assigned either to receive the rate treatment or to remain on their existing inclining block rate. Those who remained on their existing rate acted as a control group during 2012, and then were placed on the new rate in 2013.

Status. LE completed its consumer behavior study. The interim evaluation on the results from 2013 was published in February, 2015; and the final evaluation from 2014 activities was published in July, 2015. LE is currently offering the TOU rate designed for the study to its entire residential population.

2.6 Marblehead Municipal Light Department (MMLD)

Overview. MMLD's SGIG Project had a total budget of about $2.6 million (DOE's share of about $1.3 million) and included system wide deployment of about 10,000 smart meters and supporting communications networks. MMLD's consumer behavior study's initial design involved about 500 customers and focused on evaluating the timing and magnitude of changes in customer peak demand and energy usage patterns from a flat rate with CPP overlay. MMLD was also interested in assessing residential customer acceptance and retention associated with this type of rate design.

Treatments. Rate treatments included the application of a flat rate with a CPP overlay with up to a six-hour period (12 – 6 p.m.) for critical peak events on non-holiday weekdays from June through August. Customers were notified of critical peak events, which were called in conjunction with ISO New England demand response events, by 5 p.m. the day before. Participants could receive notification for up to twelve critical peak events a year during the study. All customers participating in the study received web portal access, customer support, and a variety of education materials.

Design. The study's experimental design involved a randomized controlled trial with delayed treatment for the control group. Residential customers who met certain eligibility criteria received an invitation to opt-in to a study and receive the flat rate with CPP overlay treatment with the understanding that the application of this treatment could be delayed by one year. Customers who opted in were randomly assigned to either the rate treatment or their existing flat rate, which served as the control group for the first year of the study (summer, 2011). All participating customers received the rate treatment in the second year of the study (summer, 2012).

Status. MMLD completed its consumer behavior study. The interim evaluation on results from 2011 was published in May, 2012. The final evaluation covering 2012 was published in June, 2013. Following the study, MMLD decided not to expand deployment of time-based rates in spite of the sizable peak demand reductions they produced and indicated a preference for using direct load control programs to manage peak demands.

2.7 Minnesota Power (MP)

Overview. MP's SGIG Project had a total budget of about $3 million (DOE's share of about $1.5 million) and included deployment of about 8,000 smart meters, supporting communications networks, and installation of distribution automation equipment on one of its feeders. MP's consumer behavior study's initial design involved more than 4,500 residential customers and was implemented in two phases. Phase one evaluated customer acceptance and response to different forms of information feedback. Phase two evaluated these same issues but applied to a TOU rate with a CPP overlay.

Treatments. Phase one information feedback treatments included the development of a web-portal that provided randomly assigned customers with access to consumption data at varying levels of resolution and latency: (1) monthly aggregated data provided on a monthly basis (this was the control group); (2) daily aggregated data provided on a daily basis; or (3) hourly aggregated data provided on a daily basis (required installation of a smart meter). For Phase two MP implemented a two period TOU rate that augments its existing flat rate and includes a 13 hour peak period (i.e., 8 a.m. – 10 p.m.) each weekday. In addition, MP tested the effects of overlaying, during various blocks of the peak period, a higher price on critical peak event days. Customers received day-ahead notice of critical peak events, called when a major energy event was taking place in the Midwest Independent System Operator markets or on MP's system. Participants were to be exposed to no more than 160 hours of critical peak events per year of the study.

Design. Phase one of the study's experimental design involved a randomized controlled trial with denial of treatment for the control group. All residential customers in a given geographical area who met certain eligibility criteria received an invitation to opt-in to a study where participating customers can gain access to a web portal and receive one of three information feedback treatments. Customers who opted -in were surveyed, stratified, and randomly assigned to receive one of the three web portal information feedback treatments.

Because of recruitment shortfalls, MP decided to augment the study sample. All AMI-enabled residential customers who passed up the original offer to join Phase one participants were stratified and randomly assigned to receive one of the three information feedback treatments. These customers were notified of this opportunity and allowed to opt-out of the treatment by choosing to not access the information now made available to them via the web portal.

Phase two used a within-subjects design. All customers with installed smart meters, and others who met certain eligibility criteria and had a smart meter installed, received an invitation to opt-in to a study where participants received the rate treatment for one year.

Status. MP completed both Phase one and two of its study. The interim evaluation of results from Phase one (i.e., the summer of 2012) was published in March, 2014. MP completed Phase two in the fall of 2015 and is currently finalizing its final evaluation report. Customers on the Phase two rate were allowed to continue taking service on it until the utility while the utility considers whether or not to expand time-based rate offerings in the future to the entire residential population.

2.8 NV Energy (NVE) – Nevada Power (NVP) and Sierra Pacific Power (SPP)

Overview. NV Energy's SGIG Project had a total budget of about $278 million (DOE's share of about $139 million) and included deployment of about 1.2 million smart meters, supporting communications networks, and customer systems including PCTs and web portals. NV's consumer behavior study initial design involved more than 16,000 customers in two service territories: Nevada Power (NVP) (serves about 9,000 customers) in the southern part of the state, and SPP (serves about 7,000 customers) in the northern part of the state. NV Energy's consumer behavior study's focused on evaluating the timing and magnitude of changes in residential customer peak demand and energy usage patterns due to a seasonal multi-period TOU rate with a CPP overlay. NV was also interested in assessing residential customer acceptance, retention, and response associated with enabling technologies and energy education efforts.

Treatments. Rate treatments included the application of a multi-period TOU rate that used a five-hour peak period (2 – 7 p.m. at NVP; 1 – 6 p.m. at SPP) with rates that differ depending on the time of year (shoulder summer, June and September; core summer, July and August; and winter, October – May at NVP; and core summer, July – September and winter, October – June at SPP). NV Energy was augmenting the TOU rate with a substantially higher critical peak price (TOU-CPP) during a 4-hour weekday critical peak period in the summer (June – September 3 – 7 p.m. at NVP; July – September 2 – 6 p.m. at SPP). The CPP involved day-ahead notice to participating customers when forecasted temperatures, system demand, or wholesale market prices were expected to be very high and/or when system emergency conditions were anticipated. Study participants could be notified for no more than 18 critical peak events a year for NVP and 16 for SPP.

Control and information technology treatments included the deployment of PCTs. In addition, all customers participating in the study received web portal access. Education treatments augmented the customer web portal access with a curriculum designed to educate customers about energy, energy usage, energy costs and rates, and energy management. Study participants in NV Energy's enhanced education treatments were provided with information, examples, training, and feedback through a combination of written and online materials and experiences.

Design. The study's experimental design involved a randomized encouragement design. A stratified random sample of AMI-enabled customers in the service territory who met certain eligibility criteria were assigned to one of two pools of customers: one acted as the control group (i.e., remained on the existing flat rate without receiving an invitation for the time-based rate, technology or enhanced education) while the other received an invitation to opt-in to the study where participating customers received a single specific offer of treatment that was a combination of the rate, control/information technology, and/or education material. Offers to participate were randomized from the pool of eligible customers until samples size goals were achieved. Data from a sample of customers who were offered but declined the treatments were included in the study as was data from customers in the control group who were not offered the treatments.

Status. NV Energy's completed its consumer behavior study. Its interim evaluation extensively covered market research and load impact analysis results during the first year of the study (January, 2013 – February, 2014) and was published in August, 2015. The final evaluation focused more narrowly on major takeaways from all analysis efforts during the entirety of the study period (January, 2013 – February, 2015) and was published in March, 2016. The utility transitioned all of their study participants onto their existing TOU rate and extended an offer to participate in one of the utility's demand response programs.

2.9 Oklahoma Gas and Electric (OG&E)

Overview. OG&E's SGIG Project had a total budget of about $293 million (DOE's share of about $130 million) and included system wide deployment of about 790,000 smart meters, supporting communications networks, customer systems for about 48,000 customers, and installation of distribution automation equipment on about fifty feeders. OG&E's consumer behavior study's initial design involved about 5,000 residential, and more than 1,000 small commercial customers. OG&E's study centered on evaluating the timing and magnitude of changes in residential and small commercial customer peak demand and energy usage patterns from several types of time-based rates, IHDs, and PCTs.

Treatments. OG&E tested two rate designs: a two-period TOU rate with a variable peak pricing (VPP) component and a TOU with a CPP overlay. The VPP and TOU with CPP overlay used a five-hour peak period (2 – 7 p.m.) during non-holiday weekdays in the summer (June to September). The VPP peak period price was set to one of four different pre-determined levels with day-ahead (by 5 p.m.) notice. OG&E provided customers at least two hours' notice of critical peak events and each event lasted no more than eight hours. Critical peak events were called under conditions of high expected temperatures or system demand, or to avoid system emergencies.

Control and information technology treatments included the deployment of IHDs and PCTs. In addition, all customers participating in the first year of the study received web portal access, customer support and a variety of education materials. All customers in the service territory received access to the web portal during the second year of the study.

Design. The study's experimental design involved a randomized controlled trial with denial of treatment for the control group and pre-recruitment assignment. AMI-enabled residential and small commercial customers who met certain eligibility criteria were stratified and randomly assigned to one of eight treatment groups, or to the control group. These customers received an invitation to opt-in to a study and receive one of several treatments, with the understanding that this treatment was limited in supply, but were not notified of their assignment at that time. Customers who opted-in were screened and surveyed for eligibility.

Status. OG&E completed its consumer behavior study. The interim evaluation covered activities during the summer of 2010 and was published in March, 2011. The final evaluation covers activities during the summer of 2011 and was published in August, 2012. Based on the results of the study, OG&E decided to roll-out the VPP rate programs and offer free PCTs to about 140,000 residential customers across its service territory.

2.10 Sacramento Municipal Utility District (SMUD)

Overview. SMUD's SGIG Project had a total budget of about $307 million (DOE's share of about $128,000 million) and included system wide deployment of more than 615,000 smart meters, supporting communications networks, customer systems for about 10,000 customers, and installation of distribution automation equipment on about 170 feeders. SMUD's consumer behavior study's initial design involved about 57,000 residential customers. SMUD's study focused on evaluating the timing and magnitude of changes in residential customer peak demand patterns due to various combinations of enabling technologies, different recruitment approaches (i.e., opt-in vs. opt-out), and several types of time-based rates.

Treatments. Rate treatments included the implementation of three time-based rate programs in effect from June through September: (1) a two-period TOU rate that included a three-hour peak period (4 - 7 p.m.) each non-holiday weekday; (2) a flat rate with CPP overlay; and (3) a TOU rate with a CPP overlay. Customers participating in any of the CPP overlay treatments received day-ahead notice of critical peak events that were called when wholesale market prices were expected to be very high and/or when system emergency conditions were anticipated. CPP participants could be notified of no more than 12 critical peak events during each year of the study.

Control and information technology treatments included deployment of IHDs. SMUD offered IHDs to all opt-out customers in any given treatment group and to more than half of the opt-in customers in the treatment group. All participating customers receive web portal access, customer support, and a variety of education materials.

Design. Due to the variety of treatments, the study included three different experimental designs: (1) randomized controlled trial with delayed treatment for the control group, (2) randomized encouragement design, and (3) within-subjects design. For all cases, AMI-enabled residential customers in SMUD's service territory were initially screened for eligibility and randomly assigned to one of the seven treatments or the control group.

For the two treatments included in the randomized controlled trial, recruit and delay, portion of the study, customers received an invitation to opt-in and receive an offer for a specific treatment. Upon agreeing to join the study, customers were told if they were to begin receiving the rate in the first year of the study or in the summer after the study was completed.

For two of the three treatments that were included in the randomized encouragement design, customers were told that they had been assigned to a treatment but had the ability to opt-out of this offer. Those who did not opt-out received the indicated treatment for the duration of the study. Those who did opt-out were included in the study but did not receive the indicated treatment.

For the two treatments that were included in the within-subject design, customers were told they had been assigned to either the flat rate with CPP overlay treatment or the TOU rate with CPP overlay treatment with technology. In the former case, customers only had the ability to opt-in to this specific treatment. In the latter case, customers only had the ability to opt-out of this specific treatment.

Status. SMUD completed its consumer behavior study. The interim evaluation covered activities during the summer of 2013 and was published in October, 2013. The final evaluation covered activities during the summer of 2014 and was published in September, 2014. Based on the results of their study, SMUD is consolidating all pricing tiers to produce a single flat rate for residential customers in 2018 and plans to transition all residential customers to a default TOU rate thereafter.

2.11 Vermont Electric Cooperative (VEC)

Overview. VEC (along with GMP) was part of Vermont Transco's SGIG Project which had a total budget of about $138 million (DOE's share of about $69 million) and included deployment of more than 300,000 smart meters and installation of distribution automation equipment on more than forty feeders and ten substations. VEC's consumer behavior study's initial design involved more than 3,500 residential customers and focused on evaluating the timing and magnitude of changes in customer peak demand and energy usage patterns from a three-period TOU rate with variable peak prices, enhanced customer service-based information feedback, and enabling control and information technologies.

Treatments. Rate treatments included the application of a three-period TOU rate with a variable peak pricing (VPP) component, where the peak period price changed to reflect the average ISO New England day-ahead marginal locational price of electricity for those hours for the Vermont load zone. The definition of each period differed seasonally. During the summer (April – September), the peak period covered weekdays and non-holidays 11 – 5 p.m.; the shoulder period covered weekdays and non-holidays 5 – 10 p.m.; and the off-peak period covered all other hours. During the winter (October – March), the peak period covered weekdays and non-holidays 4 – 8 p.m.; the shoulder period covered weekdays and non-holidays 11 a.m. – 4 p.m. and 8 – 10 p.m.; and the off-peak period covered all other hours. Control and information technology treatments included the deployment of IHDs, proactive customer services, and home energy management systems.

Design. The study's experimental design involved a randomized controlled trial with denial of treatment for the control group. A random sample of AMI-enabled residential customers in the service territory who met certain eligibility criteria received an invitation to opt-in to the study and receive one of several treatments, with the understanding that these treatments were limited in supply. Customers who opted-in were screened and surveyed for eligibility and randomly assigned to one of the three treatments or the control group. The study was originally designed to transition all treatment customers from their existing flat rate to VPP, while all control customers were to remain on their existing flat rate for the duration of the study.

However, due to attrition problems experienced in the first few months of the study that led to questions about the comparability of the customers in the control group to the remaining pool of treatment customers, VEC decided to alter the initial experimental design. To provide the best opportunity to estimate precise load impacts from VPP, VEC redesigned the study for the second year. This second part of study was designed such that all AMI-enabled residential customers in the service territory who met certain eligibility criteria received an invitation to opt-in and either receive the VPP treatment or remain on their flat rate (i.e., randomized controlled trial with denial of treatment for the control group).

Status. VEC completed its consumer behavior study. The interim evaluation covers activities during the summer of 2011 and is primarily a process evaluation because the difficulties with attrition and sample sizes precluded quantitative analysis. This was published in October, 2013. The final evaluation, published in September, 2015, covered the second part of the study and included results from June, 2013 through June, 2014. Future plans for implementation of time-based rates will be determined following completion of the study.

3. Recruitment Approaches

Social scientists have long recognized a behavioral phenomenon called the default effect or status quo bias –when facing choices that include default options, people are predisposed to accept the default over the other options offered. Historically, recruitment of residential customers to participate in time-based rates has almost exclusively involved opt-in approaches. This theory may help explain why utilities have been challenged for years in getting residential customers to widely accept voluntary time-based rate offers.

Today, with expanded deployment of AMI, increasing numbers of utilities and states are considering time-based rates as the default service option (opt-out). However, given limited industry experience with such recruitment approaches, especially at the residential level, there have been questions about the extent to which the default effect would apply to decisions about remaining on time-based electric rates after being placed on them.[23] Furthermore, various industry stakeholder groups have raised concerns about exposing vulnerable groups of customers (e.g., elderly and lower income) to time-based rates in a default environment.

Customer choices are key factors for the effectiveness of time-based rates in achieving their objective of reducing electricity demand during peak periods.[24] These choices include customer decisions to enroll and continue with new rates, their acceptance and use of various customer systems, such as IHDs and PCTs, and decisions to change their patterns of electricity consumption.

Two CBS utilities (SMUD and LE) have included both opt-in and opt-out recruitment approaches for treatment groups in their studies and have evaluated the impacts on enrollment, retention, and demand reductions. The other CBS utilities used opt-in recruitment approaches exclusively for all aspects of their studies.[25] In general, the CBS utilities were interested in evaluating these different enrollment approaches to answer several key questions about their efficacy, including:

- To what extent does the recruitment approach affect enrollment and retention rates?

[23] Baltimore Gas and Electric is one of the very few examples of a utility that has implemented an opt-out approach for its residential CPR program (Smart Energy Rewards). However, the CPR design results in no risk to customers who chose not to participate during declared critical events.

[24] When conducting experimental studies, the number of customers enrolled in programs needs to be large enough to produce statistically useful sample sizes. For larger-scale roll-outs, enrollment and retention levels need to be large enough to produce sufficient demand reductions to satisfy utility objectives for deferring capacity additions, or improving asset utilization.

[25] For further information on CBS enrollments see “Residential Customer Enrollment in Time-Based Rate and Enabling Technology Programs” LBNL 2013.

- What are some of the key lessons learned about customer engagement under the different recruitment approaches in the implementation of time-based rates?
- What types of bill management tools were employed and how does their application differ based on the recruitment approach?
- What are the effects on the magnitude and variability of demand reductions under different recruitment approaches?
- What are the costs and benefits of implementing time-based rates under different recruitment approaches, and under what conditions and circumstances are the offers cost-effective?
- What are the expected impacts on customer bills from implementing default time-based rates absent any load response, and is there any relationship between these expected bill impacts and participants' actual demand reductions, satisfaction and willingness to continue with the rate after the study ended?

3.1 Enrollment and Retention

If the default effect holds true, then opt-out recruitment efforts would result in much higher enrollment rates than opt-in approaches. Yet, utilities and others in the electric industry expect customers to drop out at higher rates than those recruited under opt-in approaches. Specifically, concerns have been raised that customers defaulted into time-based rates may not be aware of the consequences of their implicit acceptance of the time-based rate until they see their first bills. At that point, there is a concern that customers would be less likely to continue participating once they realize what they have been defaulted into, resulting in more drop outs, lower retention rates and lower customer satisfaction with the utility than under opt-in recruitment approaches.

Figures 2, 3a and 3b show the enrollment and retention rates (year 1 and year 2, respectively) from the SGIG consumer behavior studies by opt-in and opt-out recruitment approaches. Each bar in the figures represents a treatment group within a utility study. Figure 2 shows average opt-out recruitment approaches successfully enrolled approximately 6.2 times more participants than average opt-in recruitment approaches (93% vs. 15%) at 9 of the 10 CBS utilities.[26] This finding is generally consistent with default effect experiences from other industries, products, and services.

[26] Data from OG&E was not included in Figure 2 because comparable enrollment rates could not be determined from their mass media recruitment process. However, OG&E did collect data about customer retention by treatment group. As a result, Figures 3a and 3b include their results.

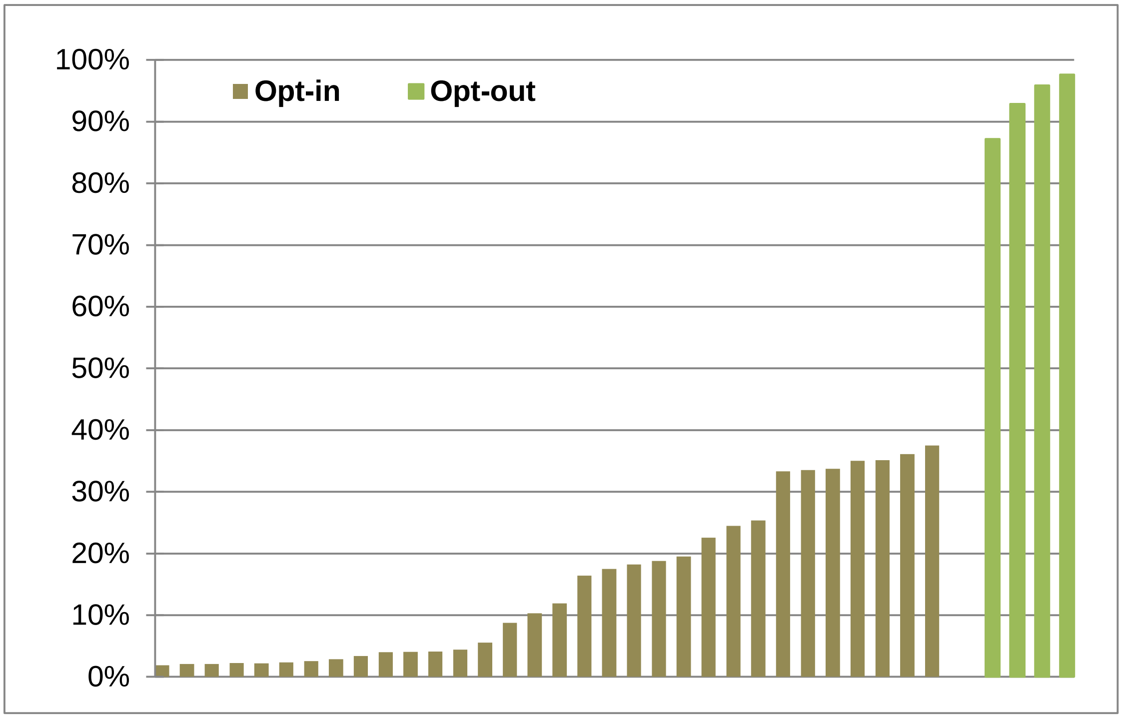

Figure 2. Enrollment Rates for Opt-in and Opt-out by Treatment Group.

Figures 3a and 3b show retention rates for year 1 (9 CBS utilities) and year 2 (5 CBS utilities),[27] respectively. Once customers joined the studies, the figures illustrate that opt-out recruitment did not result in large numbers of drop-outs during either year 1 or year 2 of the study period. In fact, retention rates were roughly the same for both opt-in and opt-out approaches, and didn't noticeably change from year 1 to year 2 of the study, as customers gained more experience with the rates. These results were contrary to the expectations of the CBS utilities.

[27] Not every CBS utility ran a two year study and some who did altered the design in the second year, in which case it was inappropriate to compare year 2 retention rates to year 1 retention rates.

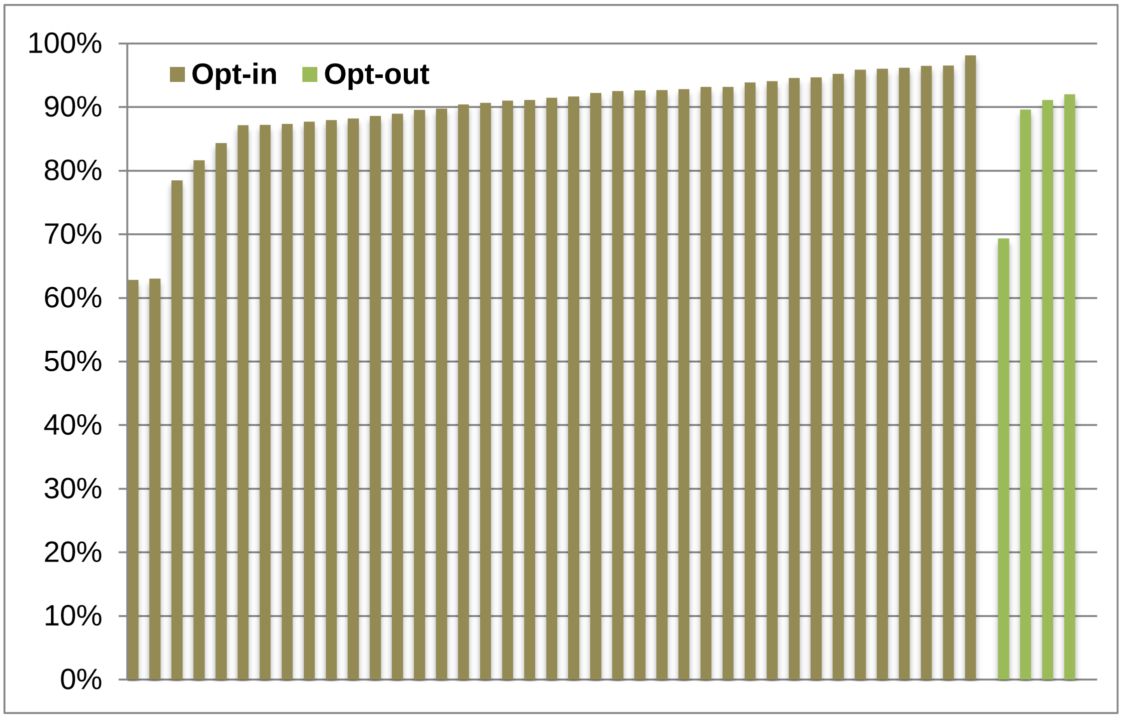

Figure 3a. Retention Rates for Opt-in and Opt-out by Treatment Group (Year 1 Only).

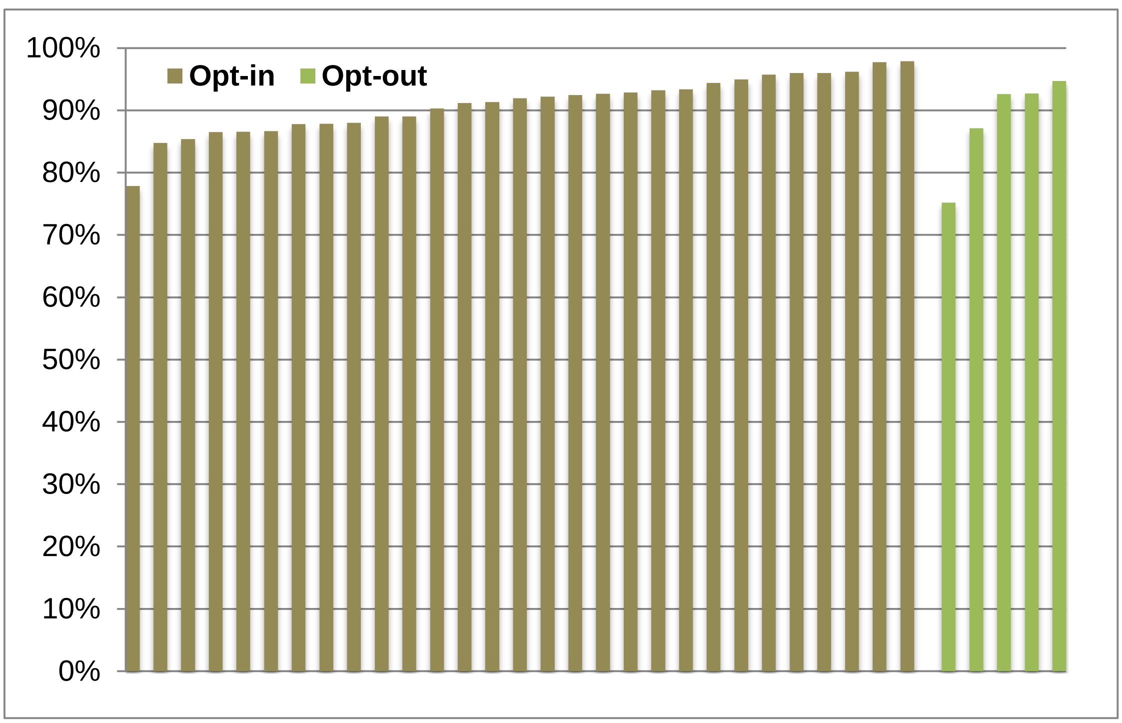

Figure 3b. Retention Rates for Opt-in and Opt-out by Treatment Group (Year 2 Only).

One of the CBS utilities (SMUD) included treatment groups to specifically evaluate the efficacy of opt-in and opt-out recruitment approaches. Figure 4 shows the effects of the different recruitment approaches on enrollment, retention, and dropout rates, and the results are consistent with the findings of the other CBS evaluations, which are shown in Figures 2, 3a and 3b.

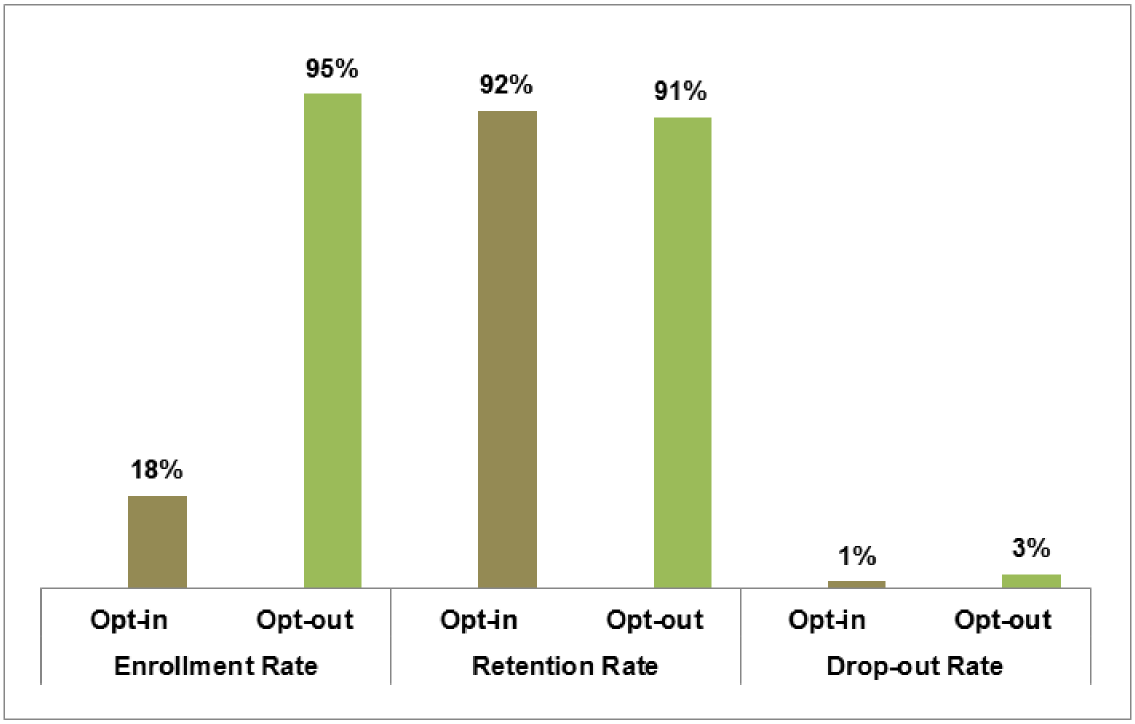

Figure 4. SMUD Enrollment, Retention, and Drop-out Rates for Opt-in and Opt-out.

3.2 Lessons Learned

Successful opt-in enrollments require extensive marketing and outreach to sufficiently raise customer awareness and successfully encourage participation in time-based rates. On the other hand, opt-out recruitment approaches do not require nearly the same level of market research to achieve high enrollment levels. However, marketing and outreach efforts are still required to make customers aware of the rate or program they are being placed into, the process they need to follow to opt-out and the actions they can take to manage the risks associated with the new rate or program. Customer engagement is essential for success under both opt-in and opt-out approaches.

In addition to opt-in and opt-out recruitment approaches, other activities implemented by the CBS utilities in two areas have particular bearing on customer enrollment and retention: (1) Education and Outreach and (2) Recruitment Strategies. Table 3 provides a summary of the lessons learned by the CBS utilities in these areas.[28]

Table 3. Summary of Lessons Learned for Opt-in Enrollments

Topics	Lessons Learned
Education and Outreach	Conduct General Customer Education
	Conduct Market Research
	Test Messages before Using Them
Recruitment Strategies	Conduct Soft Launches and Avoid Holiday Seasons
	Use Multiple Delivery Channels
	Set Realistic Expectations
	Avoid Confusing Messages

For education and outreach, which is especially important for opt-in recruitment approaches, the focus involves raising the knowledge and awareness of customers about new offerings. One challenge is that customers today have busy lifestyles and are bombarded with messages and sales pitches from many different vendors using all types of media, including newspapers, radio, television, phone lines, and the internet. The competition for a customer's attention is intense and the SGIG CBS utilities found they needed to sharper strategies and tactics to be effective.

One of the three key lessons learned for education and outreach involved needs for conducting more general customer education campaigns about utility opportunities for managing electricity demand, and customer opportunities for managing costs and bills. Methods used by CBS utilities for delivering education curricula were many and included public meetings involving small groups of customers in cities, towns, and communities; radio and newspaper advertisements; and web sites, social media and even smartphone apps.

Market research using customer surveys and focus groups was also found to be valuable in understanding customer needs and shaping effective messages. Yet, even with careful market research, the CBS utilities found it important to test messages and marketing materials before directly incorporating them into recruitment materials and sharing them widely with customers.

Successful recruitment strategies typically involve a variety of success factors including the quality and persuasiveness of invitation materials, clarity of messages, thoroughness in following up and

[28] For fuller analysis of lessons learned by CBS utilities in implementing time based rate programs see "Experiences from the Consumer Behavior Studies on Engaging Customers", U.S. DOE, September, 2014.

following through on customer questions and problems, and having the ability to anticipate and prevent common glitches from cascading into major problems.

One of the key lessons learned for effective recruitment strategies was to conduct soft launches[29] and avoid holiday seasons. Several of the CBS utilities found it important to allocate more time than was initially planned between soft and hard launches to implement fixes and make adjustments to messages. The CBS utilities also found that it is highly recommended to avoid soft and hard launches during the holiday season that stretches from mid-November through the first of the New Year. This mistake was made by at least one utility and recruitment rates were unacceptably low during that period.

The CBS utilities also found that use of both traditional (e.g., printed materials, such as letters and brochures, and telephone calls to homes and offices) and new methods (e.g., electronic materials delivered by emails, text messages to mobile phones, web sites, and social media) for delivery of messages was essential.

Setting realistic expectations for customers about the requirements of participation, performance of the devices, and potential bill savings was a key element of success as was the need to avoid the use of confusing messages.

3.3 Bill Management Tools

Several CBS utilities learned from market research that although environmental stewardship and increased reliability of the power system were important messages to promote customer participation in new rate offerings, customers were primarily interested in being able to better manage their electricity bills. Since most residential customers have only taken electric service under flat or inclining/declining block rate designs, bill management means that if they use less, then bills should go down. When time-based rates are introduced, the focus shifts away from using less overall, to shifting use from times when rates are high to times when they are lower. TOU rates, in particular, encourage customers to reduce consumption in high-priced peak periods and shift it to lower priced off-peak periods. CPP and CPR, on the other hand, encourage customers to reduce electricity use during specific hours on specific days of the year. These concepts were new to many customers and required new ways of thinking about electricity consumption and bill management.

[29] "Soft" launches refer to the release of a product, service, or program to a limited audience to gather information about usage and acceptance in the marketplace before making it generally available to a wider audience through a "hard" launch.

To help customers understand how their bills might be affected by particular time-based rate options, utilities have a variety of tools at their disposal. One is that utilities can provide web portals to customers. These internet sites allow customers to access and track their consumption and costs, often including information about how to manage both.

Another tool utilities can offer via the web portals is a bill calculator. This tool allows customers to estimate bill impacts under a variety of different rate designs. In addition, the tool allows customers to simulate how their bills might be affected from different actions (e.g., reduce X% of energy during a critical peak event or shift Y kWh from the peak to off-peak periods).

Once on a new time-based rate, utilities can also provide customers with bill comparisons (also known as shadow bills), either online or in paper form, to show how bills were affected by the new rates.[30] Lastly, utilities can provide bill guarantees[31] for customers taking service under new time-based rates.[32] The guarantees are intended to help customers adjust to new rates and protect them from adverse financial consequences associated with changing rates. Bill guarantees, however, are usually applied for limited periods of time (e.g., 6-12 months).[33]

Table 4 shows the types of bill management tools offered by the CBS utilities included in this report. The table also shows the diversity of tools offered to participating customers. For example, both LE and SMUD included opt-out recruitment approaches, but only LE provided a bill guarantee during a customer's first year on the rate. Only three utilities provided bill calculators to their customers. In general, the CBS utilities tried not to set specific expectations about bill savings during the enrollment phase of their studies. However, most of the studies did identify the opportunity to capture financial benefits (i.e., lower bills) as a reason to participate in the study.

[30] Because incentive-based programs involve a payment to a customer, the rebate is usually explicitly shown on the customer's bill. Thus, a bill comparison tool is not required to identify how a customer's financial position is affected by participation in such a program.

[31] Customers with bill guarantees usually pay the lower of two bills: the one they received under the new rate or the one they would have received under the old rate.

[32] Bill guarantees are generally not required with incentive-based programs unless they include non-performance penalty provisions.

[33] DOE strongly urged the CBS utilities to not apply a bill guarantee for the entire duration of the study, as this would not have been representative of the circumstances surrounding a broad roll-out of the rate offering to customers outside of a study setting.

Table 4. Types of Bill Management Tools					
CBS Utilities in this Report	**Web Portals**	**Bill Calculator**	**Bill Comparison**	**Bill Guarantee**	**Bill Guarantee Period**
DTE	●	●	-	-	-
FE	●	-	-	-	-
GMP	●	-	-	-	-
LE	●	-	●	●	12 months
MMLD	●	-	-	●	12 months
MNP	●	●	-	-	-
NVE	●	-	●	●	12 months
OG&E	●	-	●	●	12 months
SMUD	●	-	-	-	-
VEC	●	●	-	-	-

3.4 Demand Reductions

In addition to enrollment and retention rates, many in the electric power industry believe recruitment approaches can impact demand reductions on a per customer basis. The contention is that customers who opt-in are more likely to understand the rates they are enrolling in as well as what is expected of them to manage consumption and costs. As such, opt-in customers are generally expected to alter their consumption in some way in response to the rate. In contrast, customers who enroll under opt-out approaches may not always be making an affirmative decision: some may not have read the marketing material; some may have read it but did not understand it and never did anything to reject the offer; and others may have learned enough from the marketing material to know they were indifferent to the opportunity, thereby not eschewing it. These types of opt-out customers would not be expected to respond to the time-based rate opportunity even though they were technically enrolled.[34]

SMUD was interested in evaluating this issue and randomly assigned a subset of residential customers to different treatment groups with identical TOU rates but using different recruitment approaches (opt-in and opt-out). Figure 5 shows that per customer demand reductions for SMUD's opt-in customers in both year 1 and year 2 of their study (13% and 11% respectively) were about

[34] Commonwealth Edison's Customer Application Program (CAP) is one of the few examples in the electric industry to illustrate that this theory holds true in reality.

twice as large as they were for opt-out customers (6% for both year 1 and year 2).[35] This result supports the expectation that there are differences in motivation to reduce electricity demand for customers who volunteered to participate (opt-in) versus those placed on the rates by default (opt-out).

SMUD also evaluated identical CPP treatments that were offered to customers under both opt-in and opt-out recruitment approaches. Figure 6 shows that average demand reductions for SMUD opt-in customers over the two years the study was in effect were at least 50% higher than those measured for opt-out customers (13% vs. 12% in year 1 and 22% vs. 14% in year 2), likely due again to possible differences in motivation to reduce electricity demand for customers who opt-in, compared with those who could opt-out.

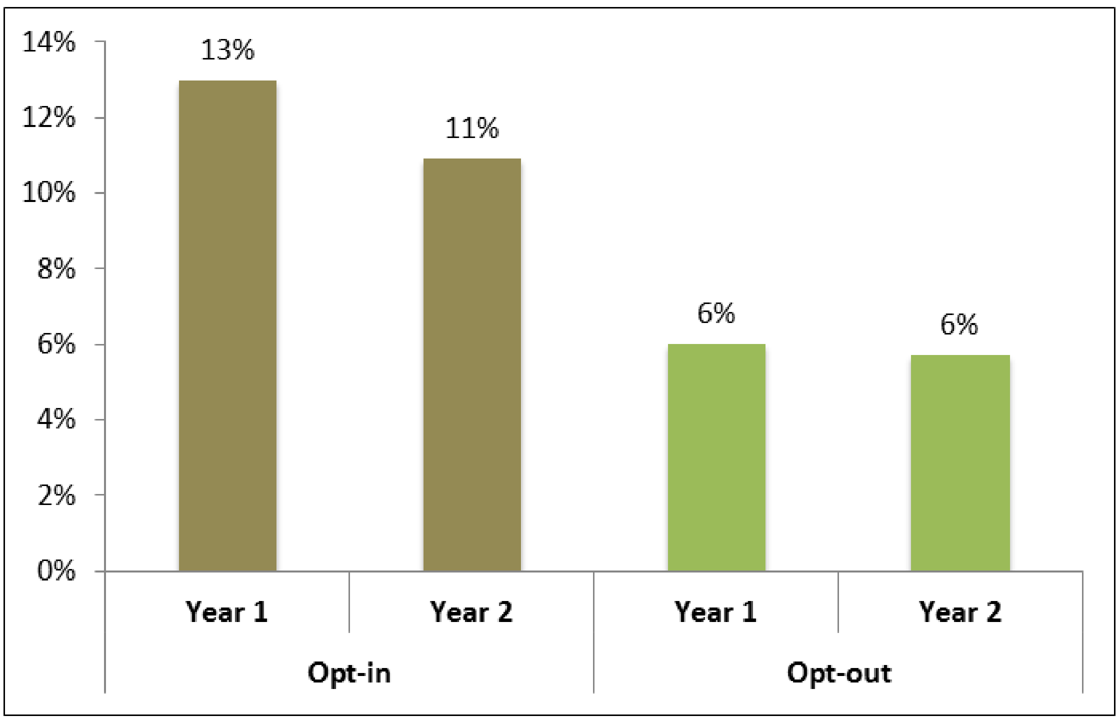

Figure 5. Percent Demand Reductions for SMUD Opt-in and Opt-out TOU Customers.

[35] The difference in these demand reduction estimates was found to be statistically significant, which means they are likely due to the rate and technology treatments rather than random factors. See pages 61 and 62 of the SMUD Interim Evaluation Report.

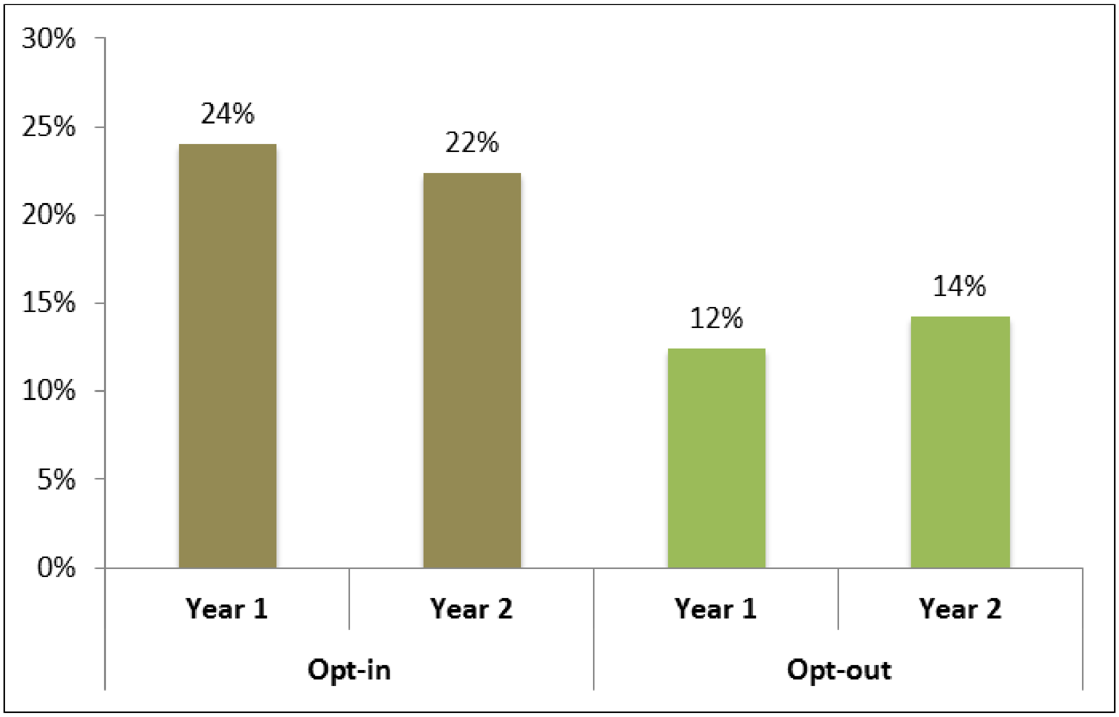

Figure 6. Percent Demand Reductions for SMUD Opt-in and Opt-out CPP Customers.

LE used a different approach to recruiting customers into their study than SMUD but did design a TOU rate that was identical for the opt-in and opt-out customers who took service under the rate in their study. Instead of initially assigning customers to receive an opt-in or opt-out enrollment solicitation, LE issued a general solicitation to its entire residential customer class to voluntarily (opt-in) participate in their TOU study. Of those who rejected this voluntary offer to participate, LE randomly selected a subset of these customers to default (opt-out) onto the TOU study.

This recruitment process may help explain the LE results for demand reductions. Opt-in customers reduced their peak period usage on average by approximately 8%. But the opt-out group did not reduce peak demand at all. Since the opt-out customers had either rejected the offer to voluntarily participate in the TOU rate, or had ignored the offer, one possible explanation is that they were far less engaged and hence less responsive than those who had volunteered.

3.5 Cost Effectiveness

Utility investments typically undergo cost-effectiveness screening by management, which serves as the foundation for regulatory filings to determine whether or not to authorize recovery of prudently incurred expenses. Utilities incur costs in the design and implementation of new time-based rates, including market research, recruitment campaigns, and sometimes some type of customer system such as IHDs and PCTs. The magnitude of recruitment efforts typically differs substantially between opt-in and opt-out approaches.

SMUD evaluated cost effectiveness to assess alternative rate and customer system (IHD) offers, and recruitment approaches, under different scenarios. As shown in Table 5, SMUD found positive benefit-cost[36] ratios for almost all of the scenario offers. However, opt-out recruitment had generally higher benefit-cost ratios for two reasons. First, they involved lower recruitment costs to achieve higher enrollment rates. Second, although each opt-out customer produced lower demand reductions in response to the time-based rates than each opt-in customer, in aggregate the opt-out customers produced much larger total demand reductions which resulted in higher benefits.

Table 5. SMUD Cost Effectiveness Analysis Results[37]

Recruitment Approach	Scenario Offer	Benefit-Cost Ratio
Opt-in	TOU, no IHD	1.19
	TOU, with IHD	0.74
	CPP, no IHD	2.05
	CPP, with IHD	1.30
Opt-Out	TOU, with IHD	2.04
	CPP, with IHD	2.22
	TOU-CPP, with IHD	2.49

3.6 Customer Bill Impacts

The results presented in this section so far show that the average residential customer defaulted onto a time-based rate generally appears willing to continue taking service on the rate and, in the case of SMUD, respond to the rate. However, this average result masks substantial diversity in underlying customer preferences and responses to new rates. In fact, one of the main concerns about defaulting all residential customers onto a time-based rate is that certain subpopulations will be adversely affected, especially financially.

[36] The SMUD benefit-cost results are based on a ten year net present value analysis with the benefits based on deferral value of capacity additions and avoided wholesale energy costs due to reduced loads during high cost periods or shifting usage from higher to lower cost periods. See Section 10.1 "SmartPricing Options – Final Evaluation" SMUD, September 5, 2014.

[37] Source: Table 10-5, page 114 "SmartPricing Options – Final Evaluation" SMUD, September 5, 2014.

Three sub-populations of customers can be defined to help clarify thinking about who might be at risk of being better off or worse off due to default time-based rates:

- **Never takers**: the set of customers that would not actively opt-in to voluntary time-based rate offers, and would actively opt-out when time-based rates are the default;
- **Always takers**: the set of customers that would actively opt-in to voluntary time-based rate offers and would not actively opt-out when time-based rates are the default; and
- **Complacents**: the set of customers who would not actively opt-in to voluntary time-based rate offers, but would not actively opt-out when time-based rates are the default.

The people who opt-in to a voluntary time-based rate would be likewise expected to not opt-out initially if defaulted onto the rate. Thus, how these ***Always Takers*** enroll in the time-based rate would likely not affect their satisfaction from taking service under it. In fact, they may benefit from a default rate in that they are automatically placed on the rate, and don't have to take the time to opt-in voluntarily.

In addition, there is a subpopulation of customers who prefer their existing rate over a time-based rate. These customers will not opt-in when solicited to voluntarily take up the time-based rate and will likewise opt-out if defaulted onto it. These ***Never Takers*** clearly express their preferences when presented with choices.

This leaves a third group of residential customers: the group that will not opt-in to a voluntary time-based rate but neither will they opt-out when TOU is made the default rate design. These ***Complacents*** seem willing to go along with the tariff that they are placed on by the utility.

Using information from SMUD's CBS study that explicitly included both voluntary and default enrollment of residential customers onto identically designed TOU rates, Figure 7 shows a breakout of the estimated proportions of these three subpopulations in SMUD's TOU treatments with an in-home display offer. In using SMUD data to analyze these subpopulations, it was necessary to assume that the group of Always Takers observed in the voluntary enrollment experimental design (19.5% of those solicited to opt-in) would represent the same proportion of, and act similarly to, those Always Takers who could not be directly identified in the default enrollment experimental design.[38]

[38] In other fields, this additional assumption is considered to typically be valid.

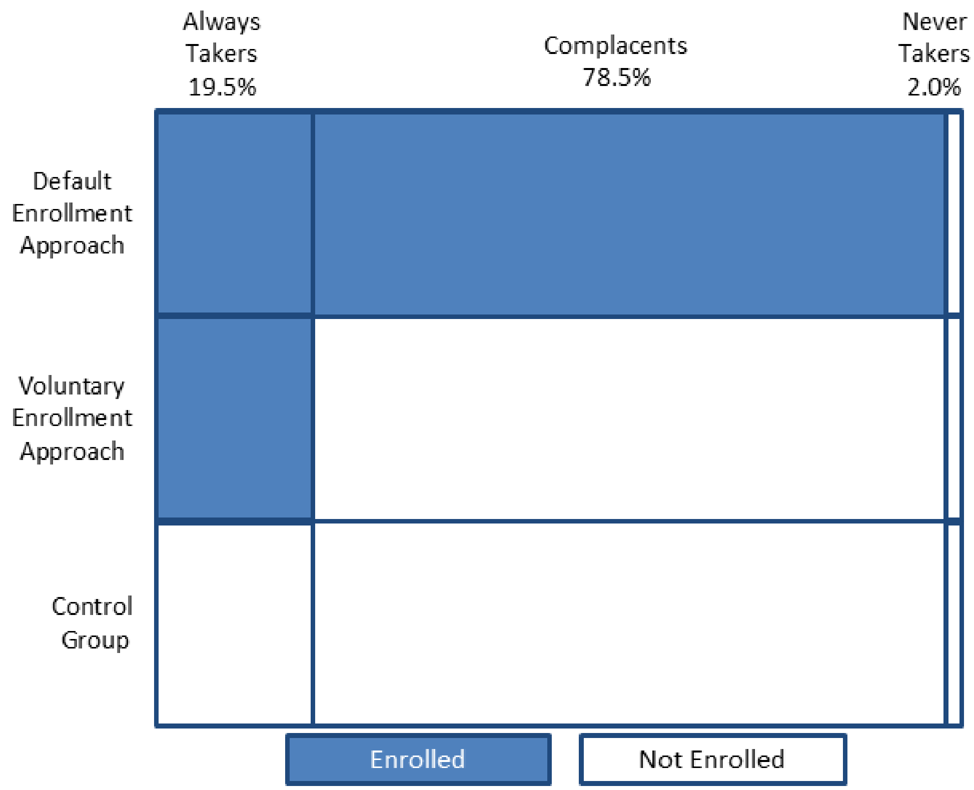

Figure 7. SMUD Residential Subpopulations for Analyzing Opt-in versus Opt-out Bill Impacts.

During the recruitment phase of the study, SMUD did not set explicit expectations with customers that each and every participant would save money by joining the study. Instead, SMUD's marketing material indicated the study's TOU rate created an opportunity for participating customers to save money by managing when they used electricity, not just how much they consumed. It is not clear if customers actually performed any calculations to assess their potential bill impacts from switching to the TOU rate, even without taking into account any change in their electricity consumption behavior.

An assessment of such predicted bill savings, based on an analysis of meter data from all of those who ultimately participated in the study under the default TOU rate, would have shown a distribution like the one in Figure 8.[39] About 22% of the Always Takers and 22% of the Complacent subpopulations, respectively, absent any response to the rate, were predicted to see +/- $5 impact on their bills over the entire four-month summer season the rate was in effect. If that range is

[39] Note that for the purposes of Figure 8 the distribution of predicted bill savings was truncated at +/-$100 per summer. There were 2 out of 12,925 customers with predicted losses greater than $100 and 22 out of 12,925 customers with predicted savings greater than $100.

expanded to +/- $10 for the full summer, 40% of Always Takers and 39% of Complacents would be predicted to see such bill impacts. Broadening the range even further to +/- $20 for the four summer months would capture a majority (66% and 67%, respectively) of both Complacent and Always Taker subpopulations. It is not clear what level of bill impact might have gotten SMUD's customers' attention to either accept or eschew participation in the study, but this similarity of impacts between the two subpopulation suggests that predicted bill impacts may not have been a key driver in the choice to participate in the study.

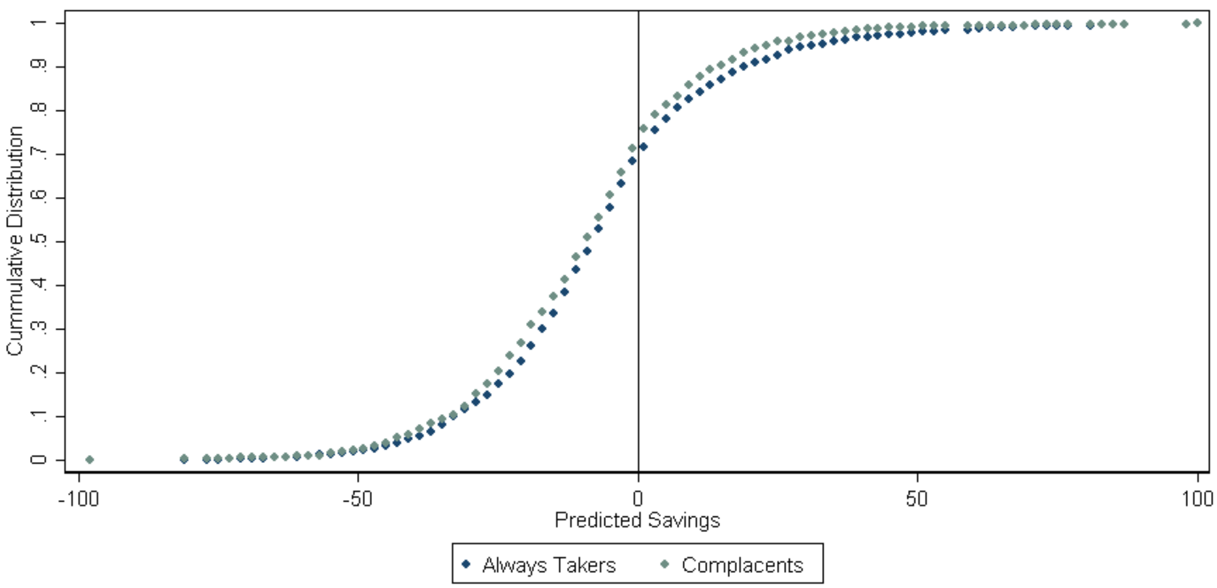

Figure 8. Distribution of Predicted Bill Savings by Customer Subpopulation.

Predicted bill impacts also have implications for the degree to which a participating customer would need to alter their electricity consumption patterns once exposed to TOU in order to achieve any positive bill savings. By breaking the Complacent and Always Taker subpopulations into smaller groups (i.e., quintiles of the predicted full summer bill savings), Figure 9 shows how the average customer in each of these subgroups reduced their peak period load during the study. Always Takers at the extremes of the predicted bill savings (i.e., those with the largest predicted bill losses or savings) exhibited a substantially larger load impact than those who might see more modest bill effects. Complacents exhibited a similar but less extreme version of this phenomenon. This suggests that for some share of both Complacent and Always Taker subpopulations, a large predicted bill impact, regardless of its direction, may increase the desire, willingness, or interest of a customer to manage their electricity consumption relative to one who anticipates that their current consumption patterns is less likely to substantively alter their bill on a TOU rate option.

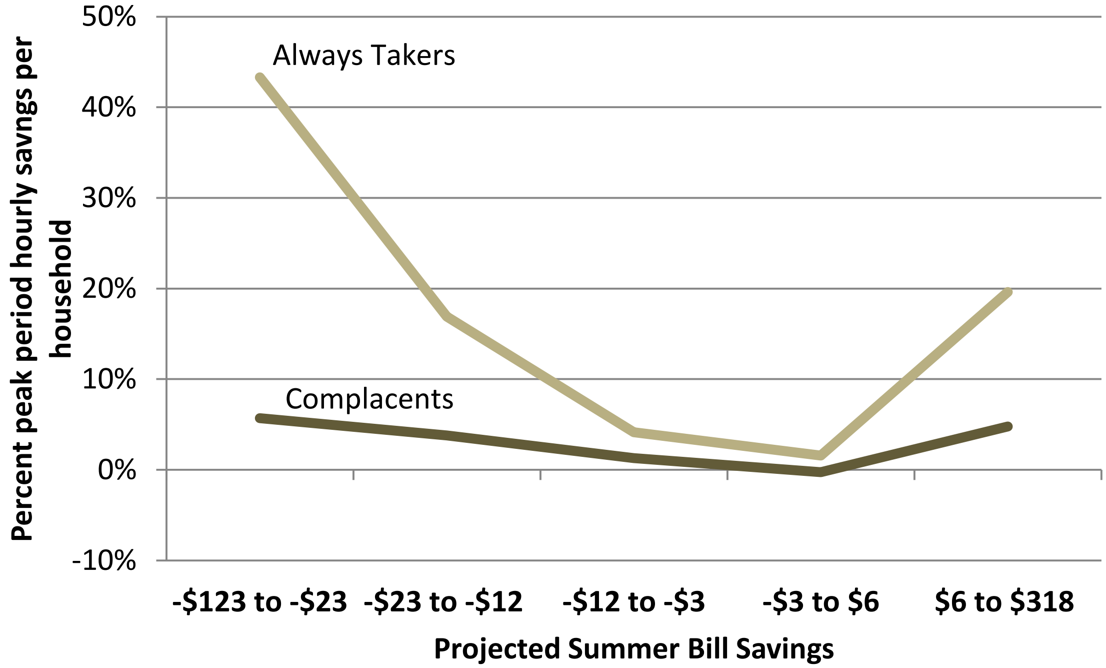

Figure 9.Peak Period Load Impacts by Quintile of Predicted Summer Bill Savings and Customer Subpopulation.

Lastly, the level of the predicted bill savings may also have implications for a participant's overall satisfaction with the default TOU rate, especially as it dictates the degree to which a customer might need to adjust their consumption to actually see a bill reduction. Based on survey responses, predicted monthly bill savings (as shown in Table 6), did not appear to be a major factor in how satisfied customers were with the default TOU rate once exposed to it. In fact, the survey respondents who were predicted to save the most by taking service under such a rate (i.e., greater than $20 for the entire summer) generally had lower satisfaction levels than those predicted to see their bills increase by $5 or more over the course of the summer (e.g., -$10 to -$5). Furthermore, the estimated level of satisfaction with the rate by Complacent survey respondents varied more widely across predicted bill savings and there appeared to be little relationship between the size of the bill impacts and the share of satisfied customers. However, there does appear to be a stronger direct relationship between the size of the predicted bill savings and the degree to which Complacent customers were interested in continuing with the rate. This finding reinforces the notion that a large share of the Complacent subpopulation were seemingly indifferent – they were reasonably satisfied with the rate, regardless of the level of bill savings they achieved, but those who likely lost the most during the study expressed an interest to not continue with the rate when given a direct opportunity to get off of it. In contrast, we see that the Always Takers who responded to the survey expressed lower levels of satisfaction with the default TOU rate as the size of the predicted bill savings increased. This result suggests that the increased effort by those Always Takers with the most to lose from participating in the study was an experience they actually found satisfying. Perhaps the more responding to the rate was required to capture bill savings, the more these customers were willing and interested in doing so. This heightened ability to manage and/or control their bills was seemingly viewed positively, especially for those with the most to gain from doing so.

Table 6. Share of Survey Responses by Subpopulation and Predicted Bill Savings

Predicted Summer Bill Savings ($)	Average Share of Survey Respondents Satisfied with the Existing Rate		Average Share of Survey Respondents Interested in Continuing with the Existing Rate	
	Always Takers	Complacents	Always Takers	Complacents
Less than - $20	94%	73%	96%	69%
-$20 to -$10	87%	92%	96%	89%
-$10 to -$5	89%	67%	92%	82%
-$5 to $5	82%	73%	94%	91%
$5 to $10	85%	100%	91%	100%
$10 to $20	72%	88%	88%	100%
Greater than $20	82%	53%	94%	92%

4. Prices versus Rebates

There is a theory in behavioral science called loss aversion, which states that when people are presented with choices that involve either avoiding a loss or acquiring a gain, the strong preference is to avoid the loss over acquiring the gain (e.g., the thought of losing $20 is more prominent than winning $20). For offers to enroll in CPP and CPR, customers are therefore expected to prefer CPR because there is no possibility of loss, whereas CPP carries the possibility of loss from higher bills.

However, once a customer is on the rate, CPP is expected to produce greater demand reductions than CPR. CPP is expected to be more motivating because customers face the punishment of a loss (through higher bills) if they do not respond, whereas response to CPR only has the benefit of a gain, and so is expected to be less motivating.

Because of the interest in finding the most efficient and cost-effective way to reduce demand during specific periods of time, several of the CBS utilities included evaluations of CPP, CPR or both in their studies. In general, the CBS utilities were interested in answering several key questions about their efficacy, including:

- How does the offer of CPP vs. CPR affect enrollment and retention rates?
- What are the effects on the magnitude and variability of demand reductions from CPP vs. CPR?

4.1 Enrollment and Retention

Utilities and others expect customers to be more likely to enroll in and remain on CPR than CPP. As discussed, the possibility of bill increase from non-performance during critical events under CPP is greater than under CPR, and this could be a motivating factor that decreases enrollment and retention.

GMP included both CPP and CPR treatments in their study and expected enrollment rates for CPR of around 80% versus 15% for CPP. GMP's recruitment experience was very different from this. As shown in Figure 11, GMP found that enrollment rates were about the same for both CPP and CPR. However, GMP did not expect differences in CPP and CPR retention rates, but actual experiences revealed slightly higher retention rates for CPR than CPP, also as shown in Figure 10.

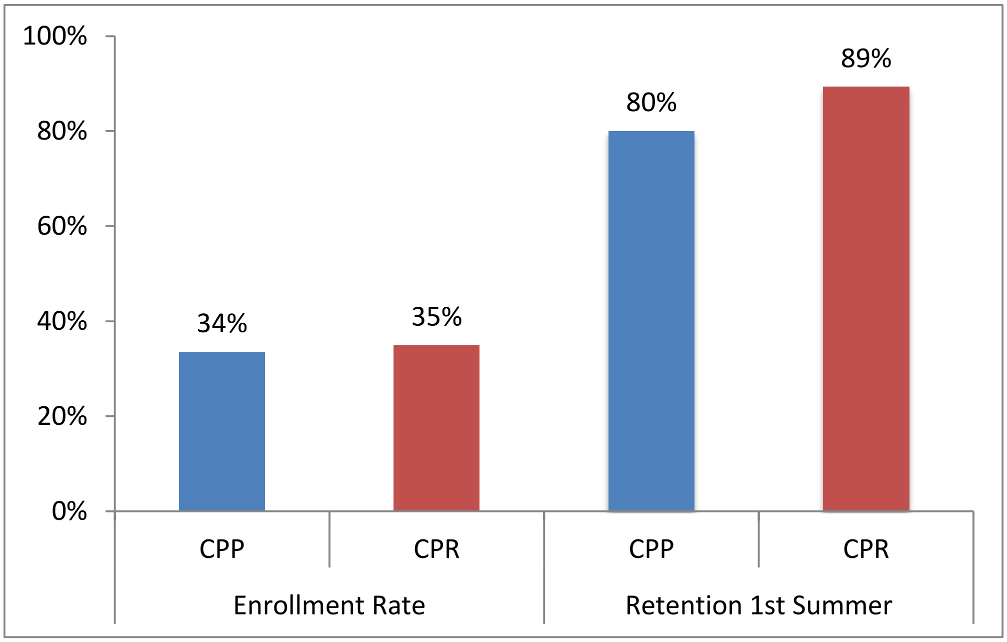

Figure 10. GMP Enrollment and Retention Rates over Time.

4.3 Demand Reductions

Because of the lower potential for higher bills associated with non-response during critical events, many of the CBS utilities expected smaller peak demand reductions for CPR than for CPP. Figure 11 shows average demand reduction during critical peak events across all CBS customers participating in CPP and CPR treatments, including both customers with and without technologies such as IHDs and PCTs. As shown, customers on CPP rates reduced demand by more than twice as much, on average, during critical peak events as those on CPR (25% vs. 11%). This result supports the expectation that demand reductions on a per customer basis under CPP would be greater than those under CPR.

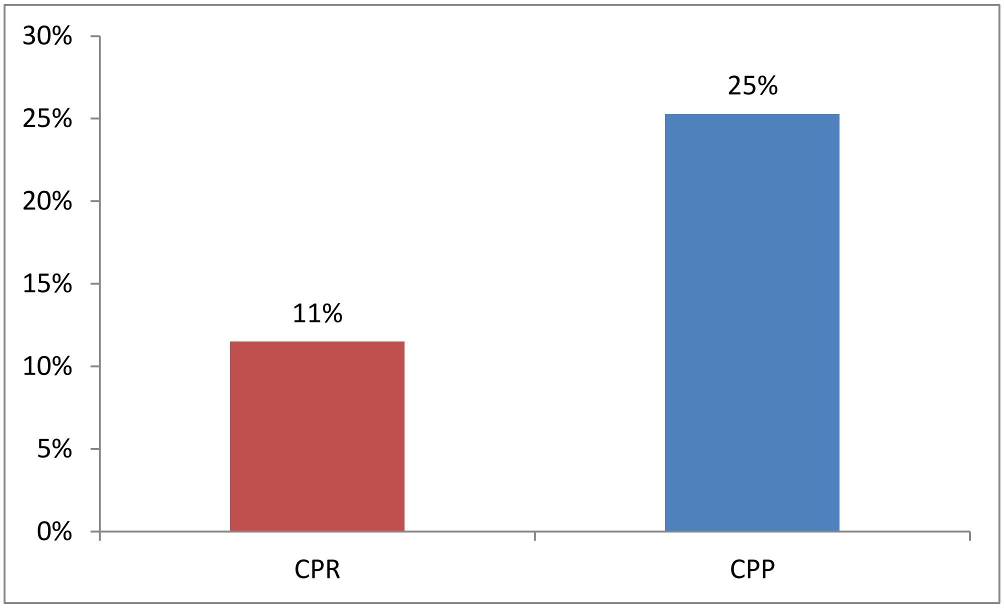

Figure 11. Average Percent Demand Reductions for CBS Customers on CPR and CPP.

However, demand reductions for both CPP and CPR were affected by the use of PCTs. These devices can be programmed to automatically control air conditioners and raise thermostat set points during critical peak events when prices are high (CPP), or when incentives are available (CPR). Each marker in Figure 12 represents one of 72 treatment groups from 8 utilities.

While Figure 11 shows CPR customers with lower demand reductions than CPP customers on average overall, Figure 12 shows that demand reductions for CPP and CPR substantially increased on average for customers with PCTs (15 and 20 percentage points, respectively). This suggests that regardless of the financial incentive to respond (i.e., acquiring a gain via a rebate or avoiding a loss via pricing), PCTs can be an effective tool to mitigate a customer’s loss aversion by allowing them to automate their response during the critical peak events.

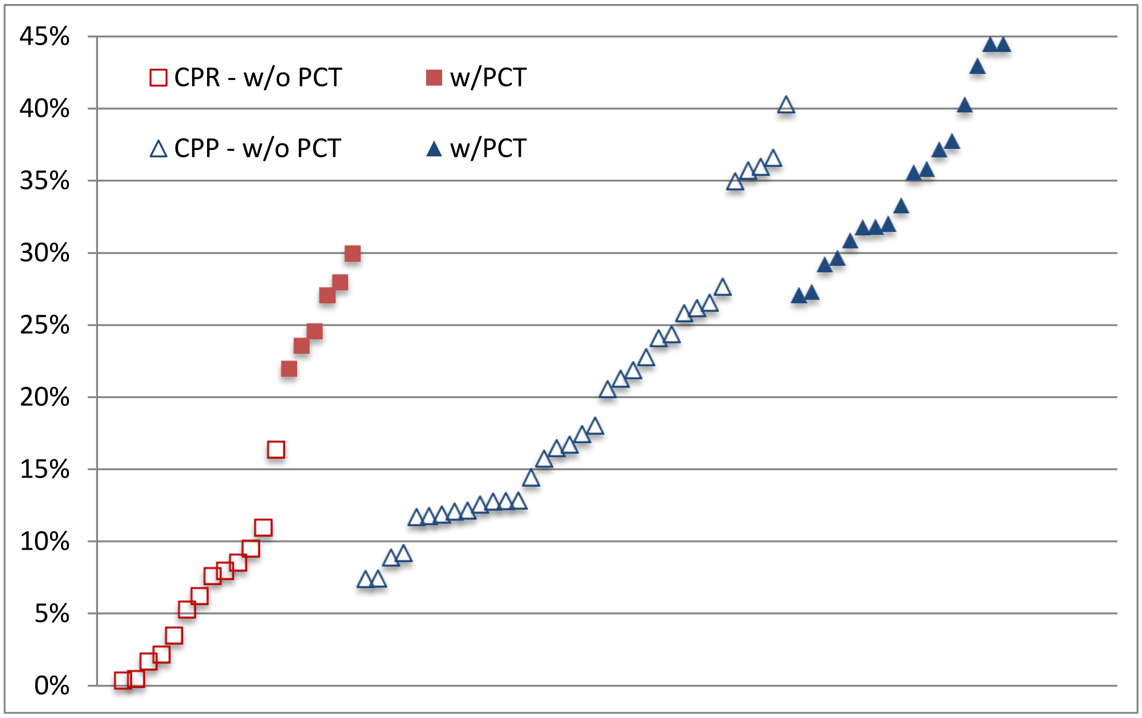

Figure 12. Average Percent Demand Reductions for Customers on CPP and CPR with and without PCTs by Treatment Group.

In addition to the magnitude of the response, system operators are concerned about the reliability and predictability of demand reductions during critical events, including possible differences between CPR and CPP. Figure 13 shows the distribution of average event demand reductions across all critical peak events for each non-PCT CPP or CPR treatment offered by GMP and OG&E, and the single CPP treatment offered by SMUD.[40] While the variability in average demand reductions across events is less for CPP than it is for CPR, demand reductions are still variable in both cases.

Using the New York Independent System Operator's definition of performance factor for its Special Case Resource program[41] (i.e., demand response resources providing capacity service during declared system reliability emergencies), customers on CPP would have had their claimed capacity capability (i.e., overall event average demand reductions) derated (or lowered) by 10% to account for variable performance. In contrast, customers on CPR would have had their claimed capacity capability reduced by three times that amount (30%).

[40] SMUD only provided event-by-event demand reductions for a single treatment cell in their evaluation reports.

[41] New York Independent System Operator (2014). Manual 4 – Installed Capacity Manual. NYISO: Rensselaer, NY. October.

This variability may be an important consideration for utilities seeking to have these resources provide capacity credits cost-effectively, and for system operators to use these rates and programs to help ensure resource adequacy.

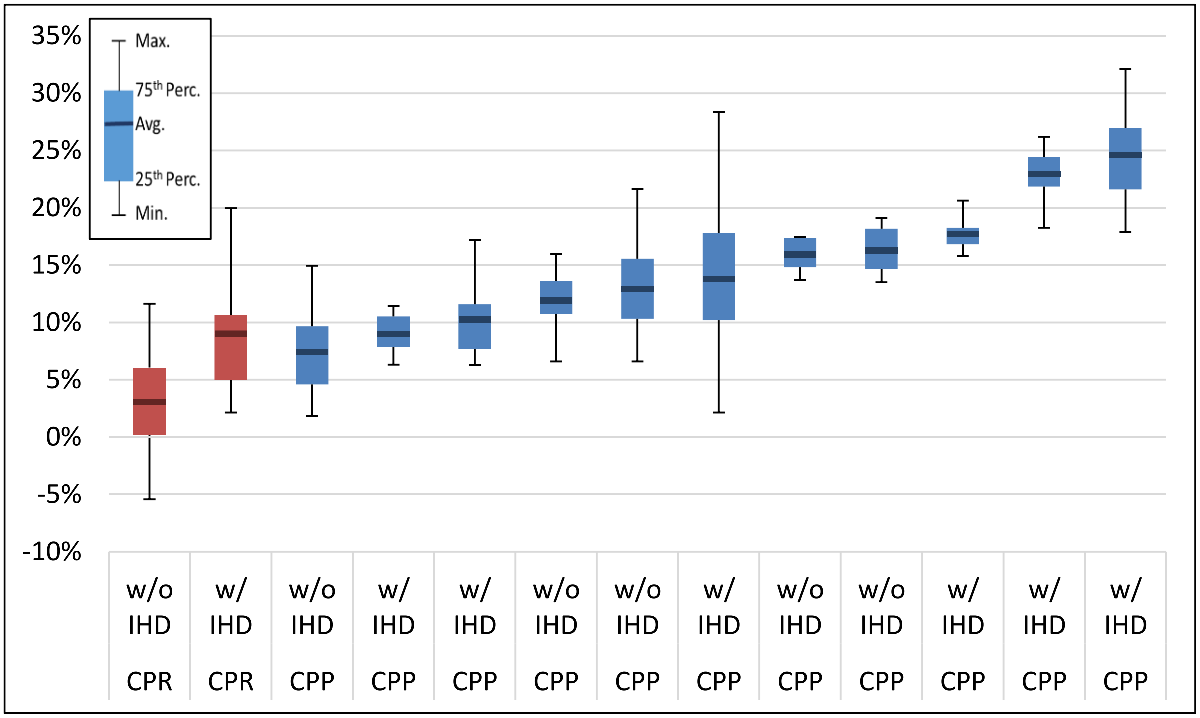

Figure 13. Variability of Per Customer Percent Demand Reductions across All Events for Customers on CPR and CPP (without PCTs) by Treatment Group.

5. Customer Information Technologies

Enabled by AMI, customer information systems are a category of devices that provide near real-time information to customers about their electricity consumption and costs. The category includes IHDs, which are small video screens that receive consumption and cost information from utilities. Several CBS utilities evaluated IHDs directly in their studies. The category also includes web portals which typically provide dashboards and analysis tools for customers to use via the internet in managing their consumption and costs. All of the CBS utilities offered web portals to customers, but none established treatment and control groups to evaluate their efficacy on customer enrollment, retention, or response.

Customer information technologies such as IHDs and web portals provide ways of raising customer awareness of usage levels, consumption patterns, electricity prices, and costs. By bringing attention to the prices and usage patterns, which otherwise might not be readily available or rarely accessed, utilities create opportunities for customers to better understand how their usage directly affects their bills. By having this information, it is expected that customers will have better capabilities for understanding and responding to time-based rates. However, when IHDs are offered by utilities to customers for free (which is frequently done as a means to attract participants and improve demand responses) program implementation costs increase, so it is important to understand if the benefits outweigh the costs of the technologies.

Many of these types of customer technologies are relatively new to the marketplace. Protocols and standards for transmitting price and consumption information to these devices are still evolving. Utilities have low levels of experience integrating the technologies and data streams into back-office systems and customers are unfamiliar with installation and operation procedures. As a result of these and other factors there are often bugs to address and learning curves to climb before performance can be fully evaluated. There are ample opportunities in this area for innovation and experimentation and many vendors are actively exploring new technologies, including software applications for mobile phones and portable computers.

Because of the potential advantages, several of the CBS utilities included evaluations of IHDs in their studies and addressed several key questions about their efficacy, including:

- What are some of the key lessons learned about IHDs in the implementation of time-based rates and incentive-based programs?
- To what extent do offers of IHDs affect enrollment and retention rates?

- To what extent do customers use offered IHDs, and what are the effects on the magnitude and variability of demand reductions?
- What are the costs and benefits of including IHDs and under what conditions and circumstances are the offers cost-effective?

5.1 Enrollment and Retention

Figures 14, 15, and 16 show the results for IHD offers on enrollment and retention rates for three CBS utilities – DTE, GMP, and SMUD. In all cases, the differences in enrollment and retention rates with and without offers of IHDs were small and did not appear to boost enrollment or retention rates, as many in industry expected they would.

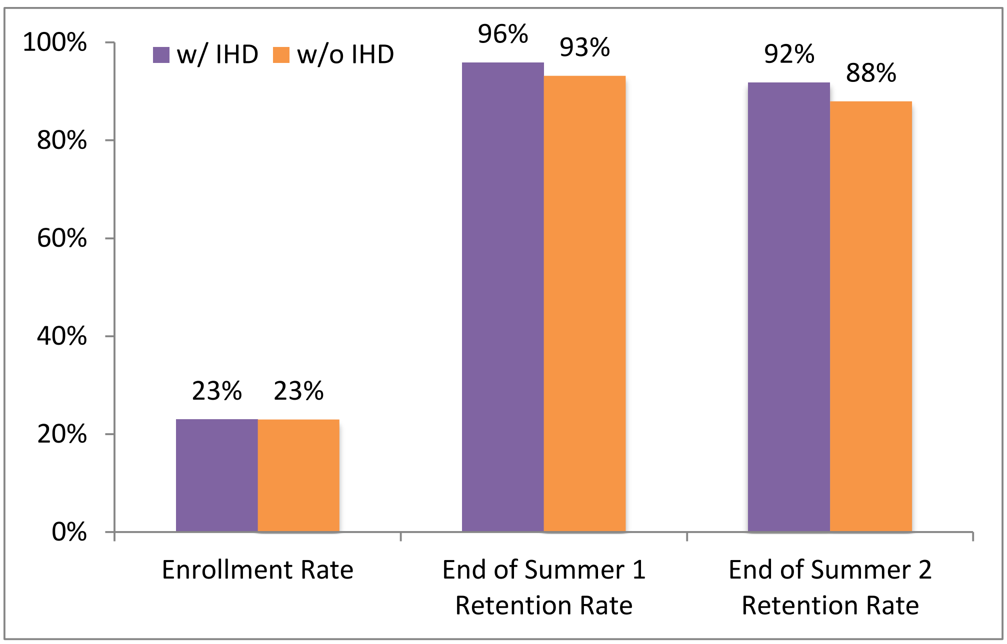

Figure 14. DTE Enrollment and Retention Rates with and without IHDs.

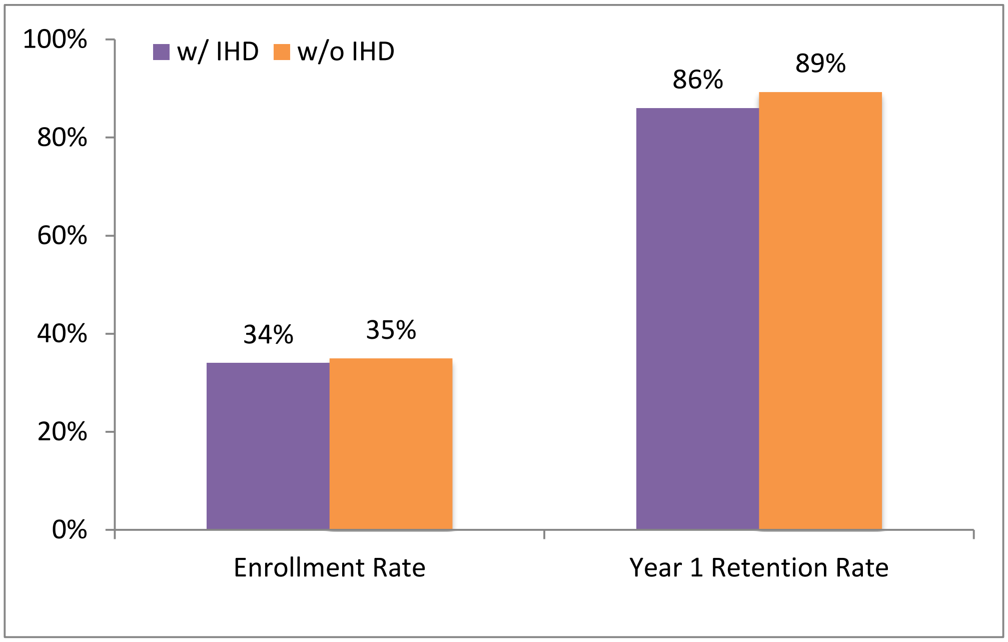

Figure 15. GMP Enrollment and Retention Rates with and without IHDs.

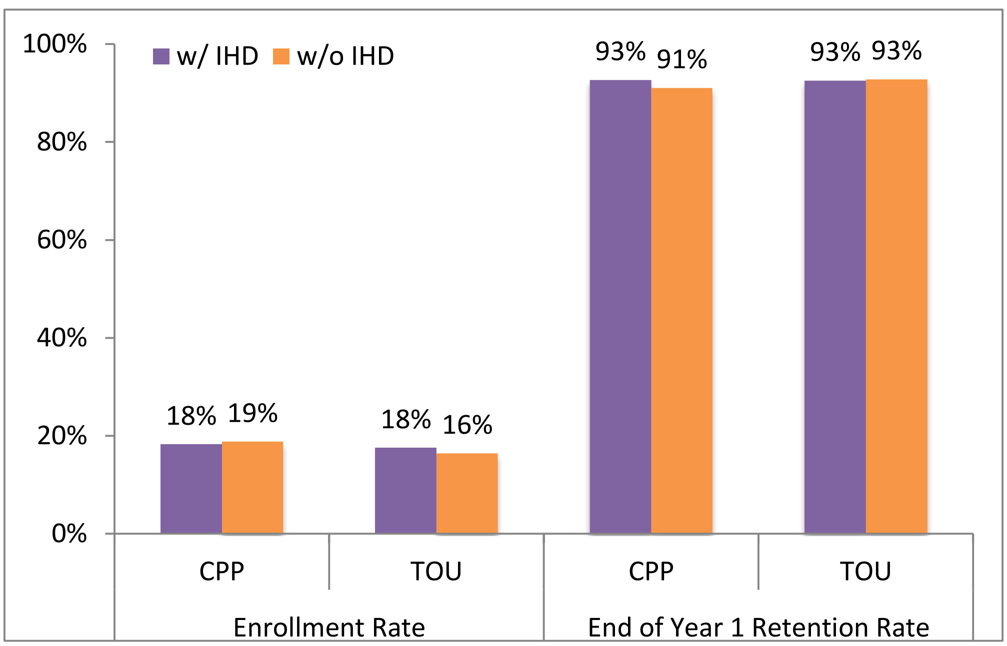

Figure 16. SMUD Enrollment and Retention Rates with and without IHDs.

5.2 Lessons Learned

Several of the CBS utilities encountered implementation problems with IHDs. Numerous instances were reported by most of the CBS utilities of equipment capabilities falling short of vendor statements and marketing material claims. For example, several utilities reported problems in getting timely servicing from vendors who had promised one level of support but delivered something less. In at least one of the studies, the vendor announced they were no longer supporting the device midway through the study and well after the devices had been installed.

SMUD tracked the connectivity of IHDs to better understand the degree to which customers were using them. Table 7 shows that less than 20% of the customers who received an IHD actually had it connected to the utility's system all the time. Instead, the majority of participants in three of the five treatment groups who received an IHD never actually turned it on and connected it to the utility's system.

Table 7: SMUD Connectivity Rates of IHDs

Treatment Group	% Connected All the Time	% Connected Some of the Time	% Never Connected
Opt-in CPP, IHD Offer	11.6%	27.4%	61.0%
Opt-in TOU, IHD Offer	11.6%	22.8%	65.6%
Default TOU-CPP, IHD Offer	18.8%	39.3%	42.0%
Default CPP, IHD Offer	14.3%	42.9%	42.9%
Default TOU, IHD Offer	18.2%	23.1%	58.7%

As a result of these experiences, several of the CBS utilities reported that:

- It is necessary to dedicate time and resources to conduct tests to ensure the equipment does what it is supposed to do, it can work with the other back office utility systems, and that servicing happens quickly and easily.
- In working with vendors, properly worded contract provisions can provide mechanisms for addressing equipment/vendor problems.
- One of the utilities tackled equipment servicing without using vendors by keeping such activities in house and said it was helpful in avoiding problems and customer frustrations with non-functional or poorly functioning equipment.
- Although customers may explicitly agree to receive these devices, some may not necessarily use them.

5.3 Demand Reductions

SMUD evaluated the effects of IHDs on demand reductions under TOU and CPP rate designs for opt-in enrollment approaches. Figures 17 and 18 show that the derived demand reductions for CPP and TOU customers were generally higher for those with IHDs than for those without IHDs, during both years of the study. However, as SMUD's evaluation report points out, these results do not suggest that the difference in the demand reduction estimates can be attributed to the effects of IHDs. According to the final evaluation report, once pre-treatment differences between the sample of customers in the two groups (with and without IHDs) are taken into account, there is no measurable effect of IHDs on demand reductions.

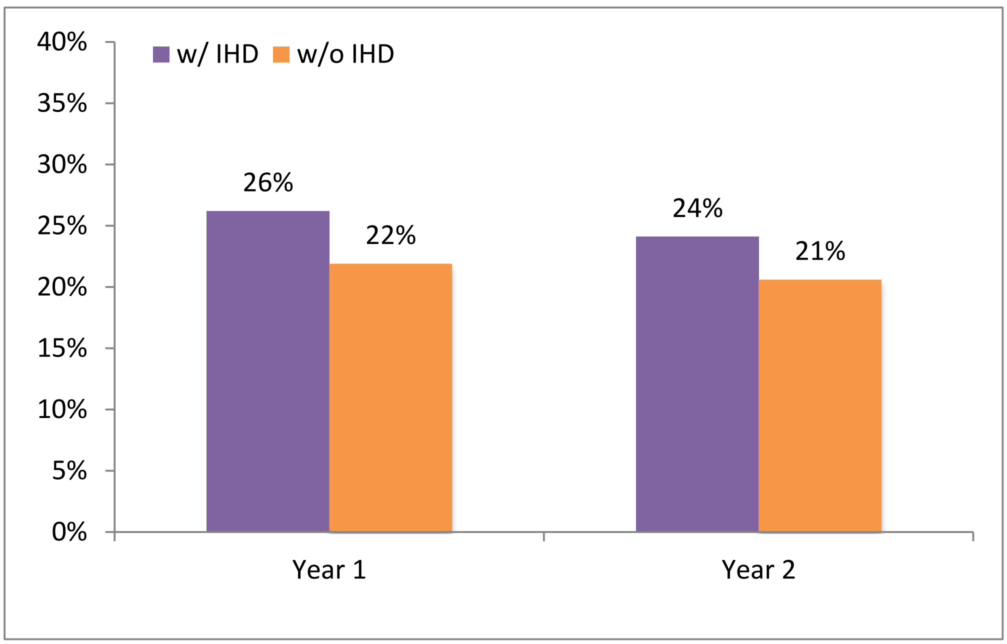

Figure 17. Average Percent Demand Reductions for SMUD's Opt-in CPP Customers with and without IHDs by Year.

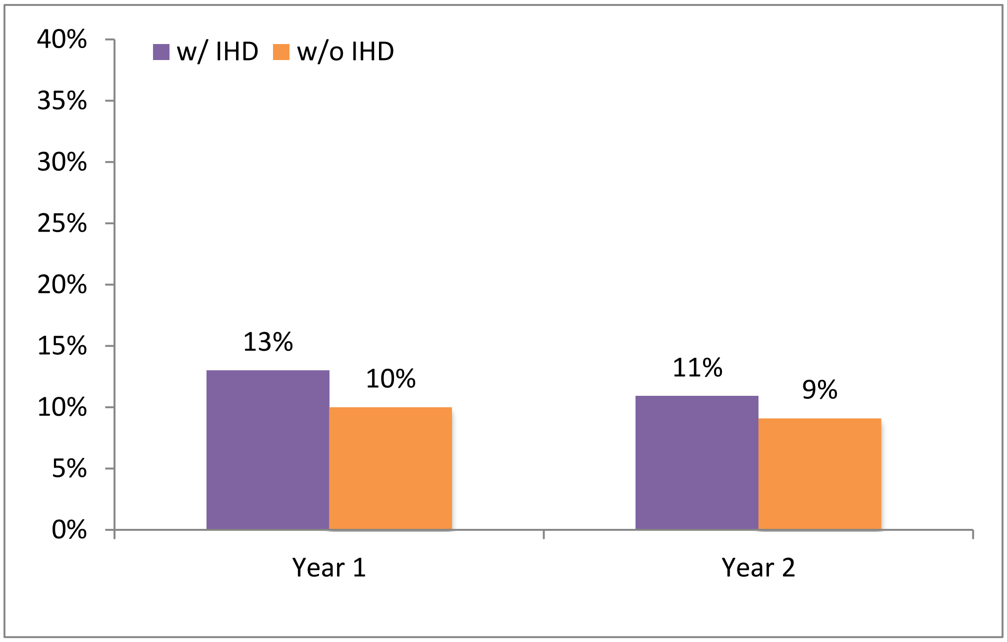

Figure 18. Average Percent Demand Reductions for SMUD's Opt-in TOU Customers with and without IHDs by Year.

In addition to understanding if IHDs can affect average levels of demand reductions, many are interested in knowing the degree to which IHDs may affect the variability of demand reductions over time. If by providing more information to customers about consumption and costs, IHDs were able to reduce variability, they would improve cost-effectiveness by increasing the levels of confidence and certainty for grid operators in the magnitude of demand reductions that involve offers of IHDs.

The data shown in Figure 19 reflect the variability of demand reductions on a per event basis from 3 CBS utilities and 13 treatment groups. On average, the level of variability of demand reductions is largely unaffected by the offer of an IHD making the results generally inconclusive with respect to the capabilities of IHDs to reduce the variability of demand reductions. Further study and analysis is needed to fully assess the role of IHDs to affect the variability of demand reductions for time-based rates and incentive–based programs.

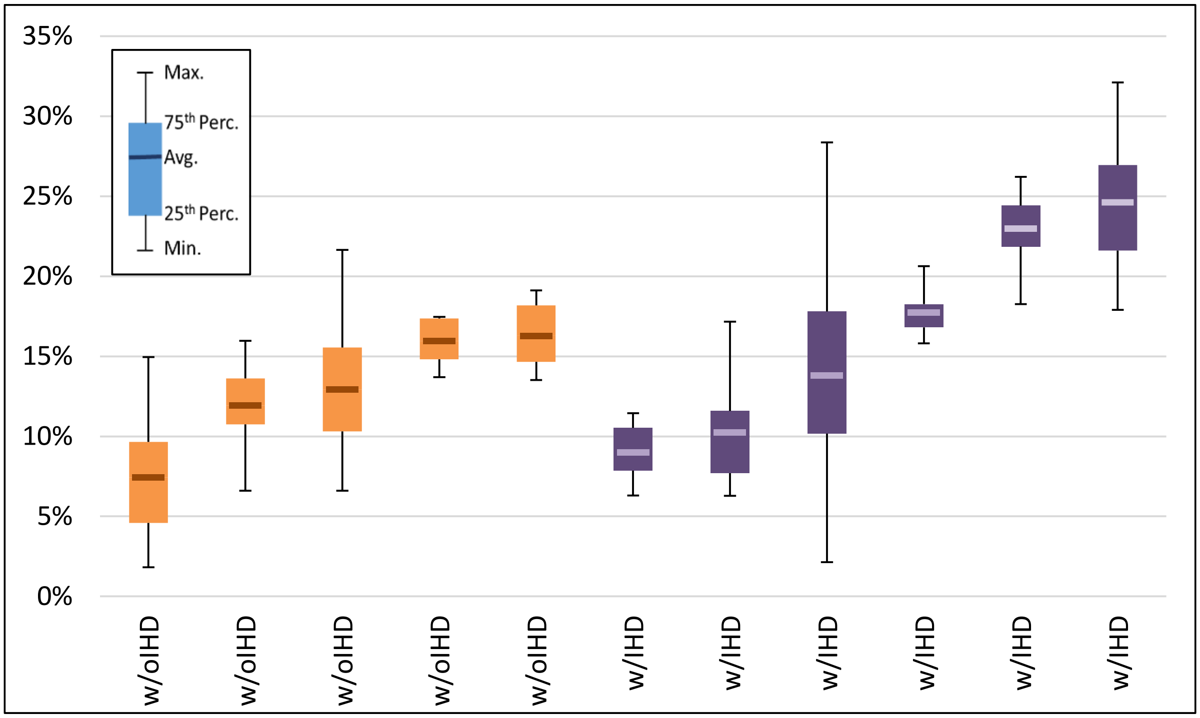

Figure 19. Variability of Per Customer Percent Demand Reductions for CPP Treatment Groups with and without IHDs by Treatment Group.

5.4 Cost Effectiveness

SMUD conducted cost-effectiveness analysis for a variety of rate offerings (TOU and CPP) with and without IHD offers. The benefit-cost ratios shown in Table 8 are consistent with the Total Resource Cost test as defined in the California Standard Practice Manual[42] and assume a 10-year time-frame that begins in 2018 and a nominal discount rate of 7.1%.

For both TOU and CPP, SMUD found higher benefit-cost ratios for scenarios without IHDs than for those with IHDs. While SMUD found that IHDs were correlated with slightly higher retention rates (1-4 percentage points) and boosted the magnitude of demand reductions by 2-4 percentage points, the costs of the devices were large enough to offset the majority of the additional benefits the IHDs generated. In the case of TOU rates, the offer of an IHD led to a result that was not cost-effective.

[42] CPUC, "California Standard Practice Manual – Economic Analysis of Demand-Side Programs and Projects" October, 2001.

Table 8. SMUD Cost Effectiveness Analysis Results for IHDs		
Recruitment Approach	**Scenario Offer**	**Benefit-Cost Ratio**
Opt-in	TOU, no IHD	1.19
	TOU, with IHD	0.74
	CPP, no IHD	2.05
	CPP, with IHD	1.30

6. Customer Automated Control Technologies

Customer automated control technologies are a category of devices that enable utilities and/or customers to automate responses to price or control signals for the purpose of altering the timing and level of electricity consumption. For residential customers, these technologies include PCTs and load controllers for air conditioners, water heaters, and swimming pool pumps. These types of technologies, especially load controllers, have been used for decades by utilities, and there is relatively more experience with their deployment than with newer customer information technologies. Several CBS utilities conducted evaluations of the efficacy of PCTs.

Conceptually, control technologies lower the transaction costs associated with responding to prices and critical peak events by making it easier for customers to reduce consumption and thereby increase the size of overall demand reductions. PCTs simplify the process of responding to critical events and/or higher priced periods by controlling air conditioner thermostat settings. However, as with IHDs, utility offers of free PCTs cause implementation costs to increase, so it is important to understand if the value of the additional demand reductions outweighs the costs of the technologies.

Because of the potential advantages several of the CBS utilities included evaluations of PCTs in their studies and addressed several key questions about their efficacy, including:

- What are some of the key lessons learned about PCTs in the implementation of time-based rates and incentive-based programs?
- To what extent do offers of PCTs affect enrollment and retention rates?
- To what extent do customers use offered PCTs, and what are the effects on the magnitude and variability of demand reductions?
- What are the costs and benefits of including PCTs and under what conditions and circumstances are the offers cost-effective?

6.1 Enrollment and Retention

Because of the way the CBS utilities designed the PCT treatments, it was not possible to assess the impacts on enrollment rates.[43] However, analysis of retention rates shows little or no impacts from

[43] Since many of the CBS utilities did not have accurate information about their residential customers' ownership of central air conditioning, it was only at the point when a customer responded to the offer to participate did the utility

PCT offers, as shown in Figures 20a and 20b, which runs counter to expectations that it would help enable customers to more easily adapt to and hence be more successful on these rates, making them more inclined to remain enrolled. The Figure 20a shows retention rates after the first year for 10 treatment groups with PCTs, compared with 33 treatment groups without PCTs. These data reflect results for 9 CBS utilities. While the overall results vary somewhat, the average retention rates with and without PCTs are about the same: approximately 90% for those with PCTs, and about 89% for those without. Likewise, Figure 20b shows retention rates after the second year for 6 treatment groups with PCTs, compared with 28 treatment groups without PCTs. These data reflect results for 5 CBS utilities and exhibit a similar pattern of retention as in year 1: 91% with PCTs and 91% without PCTs.

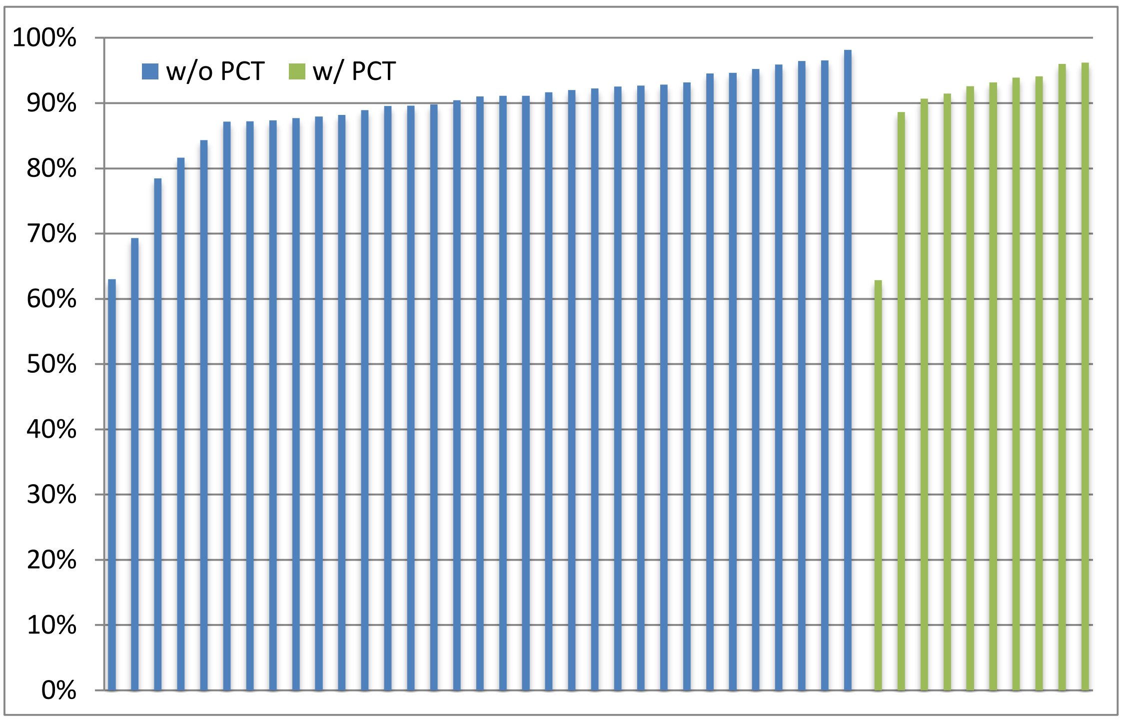

Figure 20a. Effects of PCTs on Retention Rates after the First Year of the Study by Treatment Group.

determine eligibility to participate in a PCT treatment. Any enrollment rate concerning PCTs resulting from such a recruitment process would be adversely affected by this lack of information as ineligible customers would be included in the population of customers recruited to participate in the study.

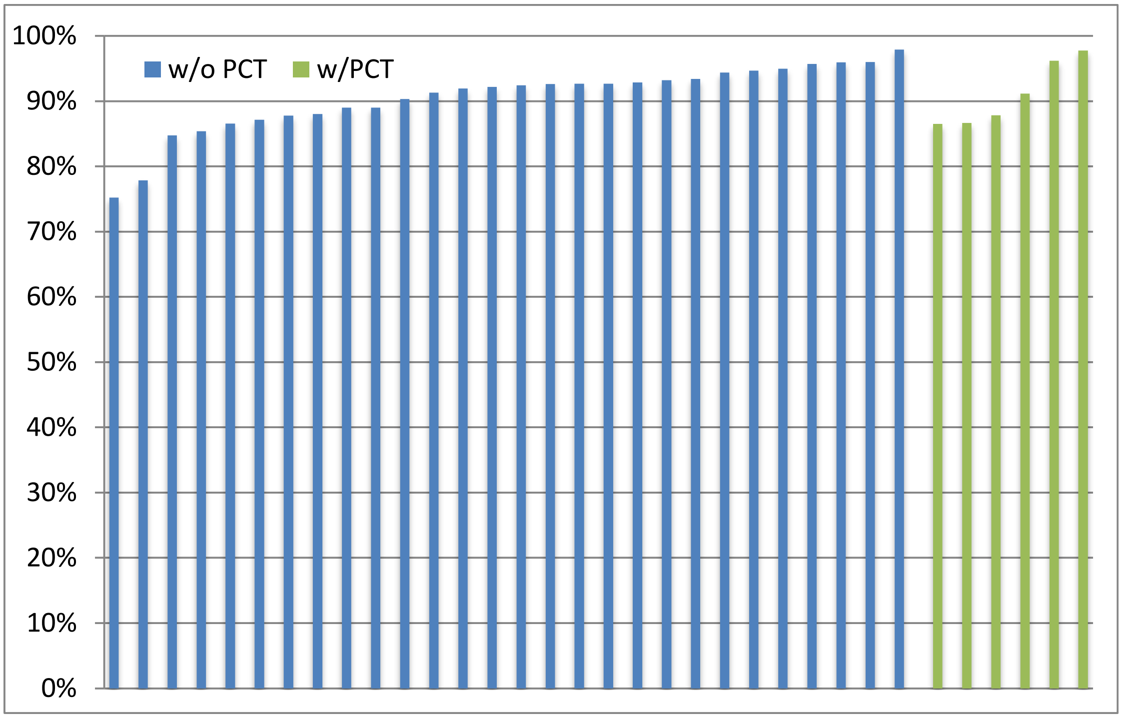

Figure 20b. Effects of PCTs on Retention Rates after the Second Year of the Study by Treatment Group.

6.2 Lessons Learned

PCTs are typically provided to customers with the understanding that utilities, not customers, will be the ones initially controlling thermostat set points during critical events. However, to promote acceptance, customers are typically given the ability to override utility controls if they are unhappy with the indoor comfort levels that result during critical peak events.

This approach relies on the theory of the default effect and is similar in concept to the application of that theory discussed in Chapter 3. In the case of PCTs, it is expected that customers, if left on their own, would be less likely to set the thermostat as high during critical events as the utility's control strategy. If the utility is able to pre-program the thermostat instead of the customer, the default bias suggests customers will be less likely to override the utility's higher thermostat control settings during events thereby maximizing the level of response.

The CBS utilities found that during the planning phases of the studies, market surveys and focus groups showed customers reluctant to have utilities in control of the PCTs during events and strongly preferred opting-in and retaining PCT control for themselves. However, once the devices were installed, and customers gained familiarity, most relaxed their concerns and allowed the utilities to control the PCTs during events after all. This lesson-learned suggests that utilities need to better address customers' initial concerns about control as these concerns are alleviated once experience is gained with the utility's control strategy for the PCTs. By doing so, it is likely more customers will be accepting of a utility-controlled PCT and thus the utility may be able to achieve higher aggregate demand reductions during all critical events.

6.3 Demand Reductions

While PCT offers did not appear to affect retention rates much, several of the CBS utilities found that demand reductions were higher for customers with PCTs than for those without. Figure 21 shows results for 8 CBS utilities encompassing 70 treatment groups and covers demand reductions for critical peak events involving CPP and CPR. The estimated demand reductions for customers with PCTs ranged from about 22% to 45%; while the estimated demand reductions for customers without PCTs ranged from about -1% to 40%.

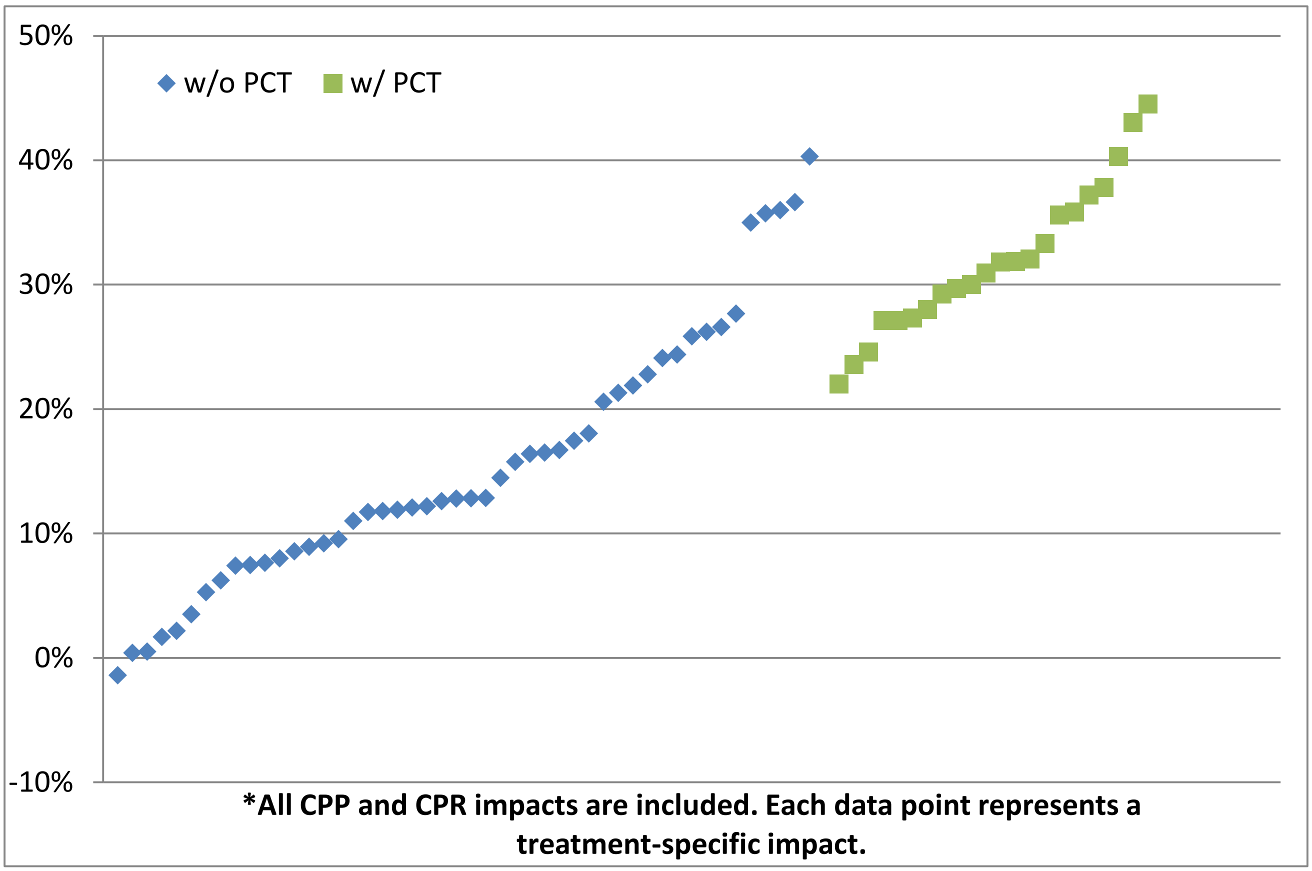

Figure 21. Average Percent Demand Reductions for Critical Event Days with and without PCTs by Treatment Group.

While PCTs generally increased the average level of demand reductions, if the devices also led to less variability in demand reductions, then the value would be increased further because of greater confidence by grid operators in the certainty of the resource. Figure 22 shows results from 3 CBS utilities and 19 CPP treatment groups. The results are generally inconclusive as certain PCT treatment groups showed less variability, while others showed greater variability. However, a separate analysis of average demand reductions for the critical peak events, and using NYISO's performance factor methodology described in Chapter 4, shows that grid operators would derate the average demand reduction 7% for CPP customers with PCTs, and 10% for CPP customers without PCTs. These results suggest that PCTs do reduce the level of variability of demand reductions associated with rates and programs, but only modestly so.

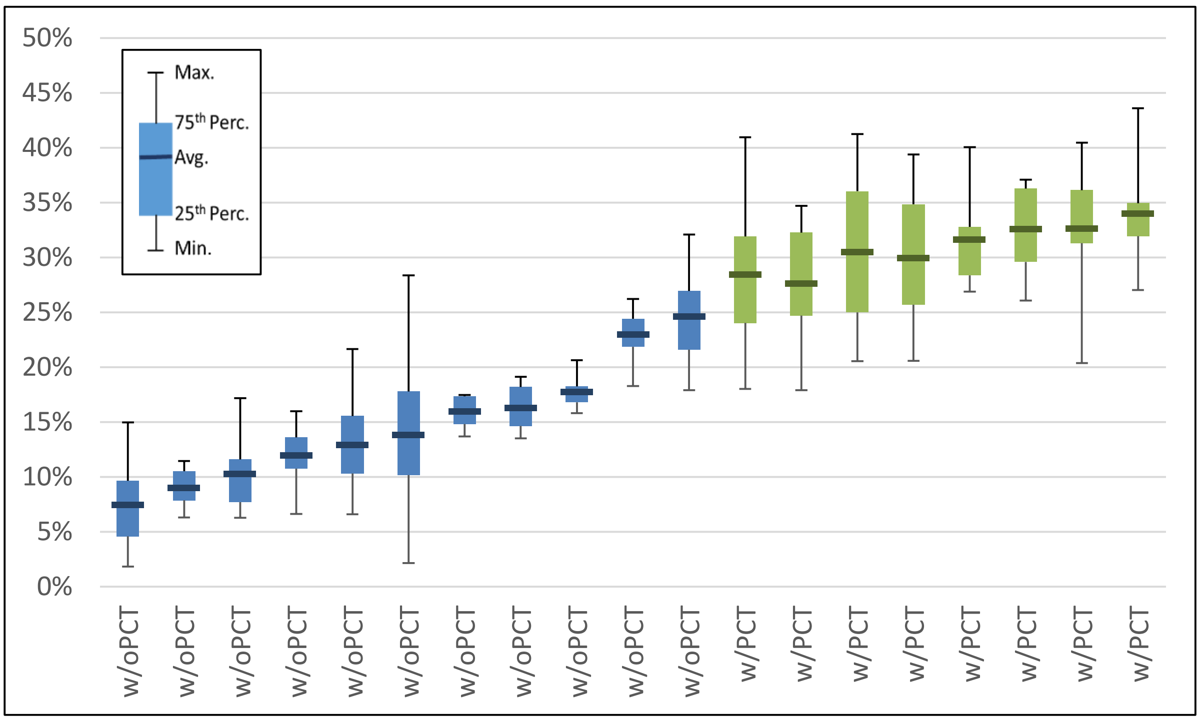

Figure 22. Variability of Per Customer Percent Demand Reductions for CPP Treatment Groups with and without PCTs by Treatment Group.

Utilities and other stakeholders are also interested in assessing the extent of anticipatory or remediation behaviors with respect to critical peak events (e.g., "pre-cooling" and "snap-back", respectively). The CBS evaluation results so far suggest there is not a clear pattern of pre-event behavioral changes on average; although these effects were observed in at least one of the individual studies. In contrast, after events, it does appear that customers with PCTs increased their electricity demand on average. This is consistent with prior studies, and is likely the result of strategies customers employ to raise thermostat set points during critical peak events and then lower the set points when the events are over.

Measuring the magnitude of this remediation (e.g., “snap-back”) effect, and the conditions under which it occurs, become increasingly important as participation in these types of demand response opportunities grows. At scale, these shifts in the timing of the maximum demand (later in the afternoon and early evening), and the need to bring on new power supplies to meet the increase in demand, will need to be forecasted accurately and subsequently managed by system operators.

6.4 Cost Effectiveness

OG&E conducted cost-effectiveness analysis of a broad roll out of its VPP rate offering which included offers of PCTs at no cost to participating customers. Shown in Table 9, the results use the standard cost effectiveness tests originally established by the California Public Utilities Commission in its Standard Practice Manual.[44] The table shows positive benefit-cost ratios in all of the standard tests. OG&E did not estimate benefit-cost ratios for simulated cases of the program without PCTs. The Total Resource Cost test results are comparable to the SMUD benefit-cost ratios for IHDs presented in Table 9. Based on these findings, OG&E filed a request, which was approved by the Oklahoma Corporation Commission, to roll-out the VPP rate offering with free PCTs under an opt-in recruitment approach with the goal of enrolling 120,000 (~20%) of its residential and small commercial customers across its service territory within 3 years.

[44] CPUC, “California Standard Practice Manual – Economic Analysis of Demand-Side Programs and Projects” October, 2001.

Table 9. OG&E Cost Effectiveness Analysis Results for PCTs[45]	
Benefit-Cost Ratios	
Participant Test	1.50
Rate Impact Measure Test	1.01
Total Resource Cost Test	1.18
Societal Test	1.18
Program Administrator Cost Test	1.11

[45] OCC (2012). In the Matter of the Application of Oklahoma Gas and Electric Company for an Order of the Commission Approving its 2013 Demand Portfolio and Authorizing Recovery of the Costs of the Demand Programs through the Demand Program Rider. Oklahoma Corporation Commission. Cause No. PUD 201200134. Order No. 605737. Attachment B, Page 5 of 18, Table 1, Row "Smart Hours Program".

7. Customer Response to Price

Economic theory suggests that people are generally willing to buy larger quantities of a good as its price goes down. Conversely, as the price increases, people are expected to buy less of that same good. This basic relationship can be used to explain what is expected to happen when a TOU rate is introduced: electricity consumption should be reduced in the peak period when the price of electricity is raised while electricity consumption should be increased in the off-peak period(s) when the price is dropped.

A number of CBS utilities were interested in better understanding how such TOU rates could more broadly affect electricity usage during the highest priced hours of each day (i.e., peak period). To this end, these CBS utilities implemented TOU rates as part of their studies.[46] A subset of them also overlaid either a CPP or CPR rate onto the TOU rate in order to assess how customers would alter their peak period demand reduction in response to the higher event price. In general, the CBS utilities were interested in answering several key questions about their efficacy, including:

- What are the magnitude of peak period demand reductions?
- What are the effects on the magnitude of peak period demand reductions from the peak to off-peak price ratio?[47]
- What are the effects on the magnitude of peak period demand reductions from the existence of a PCT?
- What are the magnitude of event demand reductions?
- What are the effects on the magnitude of event demand reductions from the existence of a PCT?

[46] Because of the overlay nature of CPP and VPP, we focused on customer response estimates on non-event days. For OG&E's Variable Peak Pricing treatments, this meant we report customer response estimates on days when the rate was set at any level except Critical. Since VEC did not separately estimate customer response on days when the price threshold was not exceeded (i.e., standard TOU peak price was in effect) vs. when it was exceeded (i.e., variable peak price was in effect), we report the customer response estimate for all days.

[47] Since so few of the CBS utilities' reported elasticity estimates from their studies, which would be a more rigorous and direct way of assessing how changes in the price of electricity affects electricity consumption, the most comprehensive way of reporting peak period demand reductions available was to segment them by the peak to off-peak price ratio.

7.1 Peak Period Demand Reductions

The CBS utilities had a varied experience with customer response during the TOU rate's peak period. Figure 23 shows results for 5 CBS utilities encompassing 67 treatment groups and covers peak period demand reductions. The estimated demand reductions ranged from a low of -1% (i.e., load increased for the average customer in this TOU treatment by 1%) to a high of 29%, with an average of 15%.

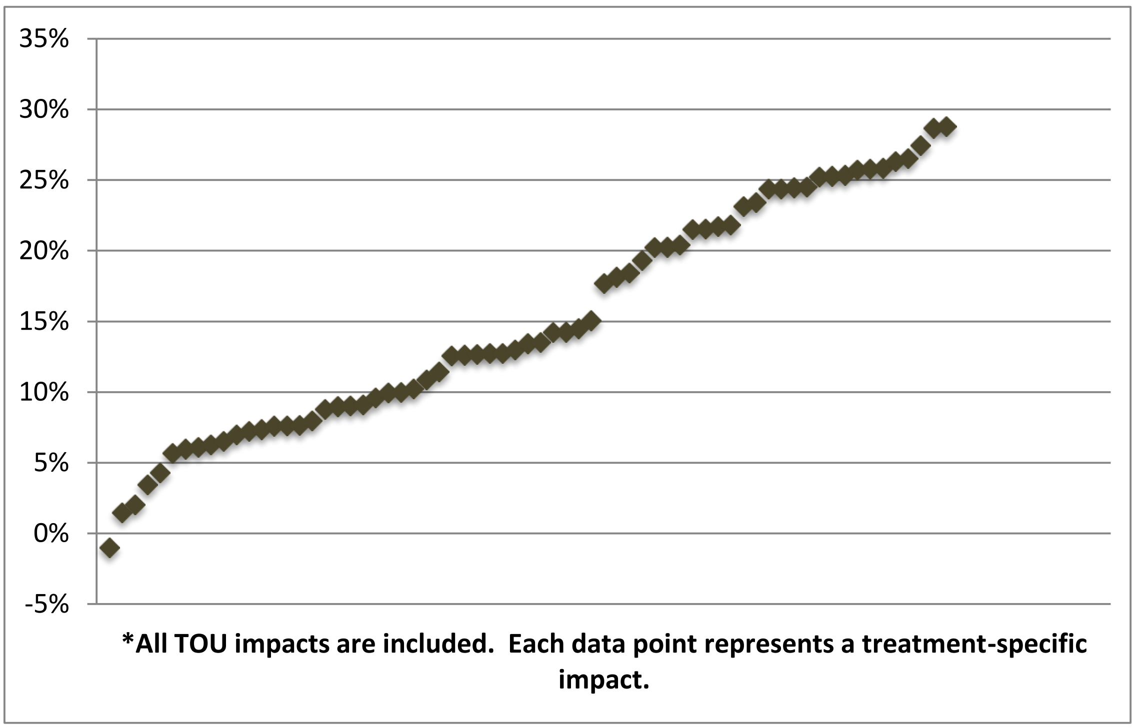

Figure 23. Average Percent Peak Period Demand Reductions by Treatment Group.

To better understand if differences in the TOU rate affected the level of peak period demand reduction, the estimated peak period demand reductions were grouped by their peak to off-peak price ratio:[48]

- Less than 2:1 price ratio;

[48] In order to compare across the different treatments, it is common to normalize the peak period price by the off-peak period price. The economic theory should still hold even if what is now being compared are price ratios and not just the price levels.

- 2:1-3:1 price ratio; and
- Greater than 4:1 price ratio.

Figure 24 shows the same average peak period demand reductions for the 67 separate TOU treatments organized by these three price ratio groupings. At the mean of each grouping, customers responded on average the least to the lowest price ratio (6% for a price ratio less than 2:1) and on average the most to the highest price ratio (18% for a price ratio greater than 4:1). However, the range of peak period demand reductions varied substantially within each price ratio grouping, at some points overlapping those from other price ratio groupings. This suggests something in addition to price may be driving differences in the observed response level.

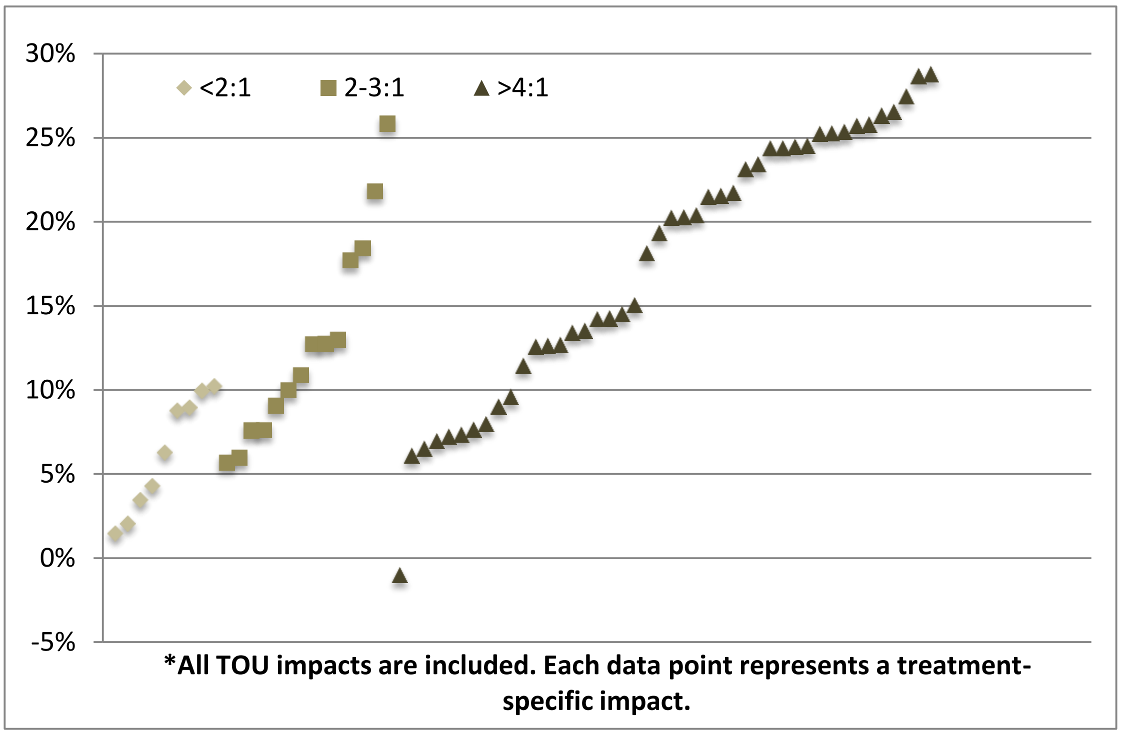

Figure 24. Average Percent Peak Period Demand Reductions by Treatment Group and Price Ratio Grouping.

Several CBS utilities included the offer of a PCT with their TOU rates. The peak period demand reductions can be further segmented by the existence or absence of a PCT. Figure 25 shows the peak period demand reductions for all 67 TOU treatments organized by price ratio grouping and existence of a PCT. At the lowest price ratios (i.e., those less than 2:1), a PCT seems to make little difference in the level of peak period demand reductions. However, as the price ratio increases to more moderate levels (i.e., between 2:1 and 3:1), we see the existence of a PCT makes a considerable difference as customers exhibit dramatically larger peak period load reductions when the control technology is available (average of 21% across all treatments) relative to when it is absent (average of 10% across all treatments). When the price ratio is at its highest (i.e., greater than 4:1), the role of a PCT in driving higher peak period demand reductions is not quite as clear. Although the average peak period demand reduction for treatments with PCTs is considerably higher than the average for treatments without PCTs (23% vs. 15%), there is considerable variability across treatments both with and without PCTs.

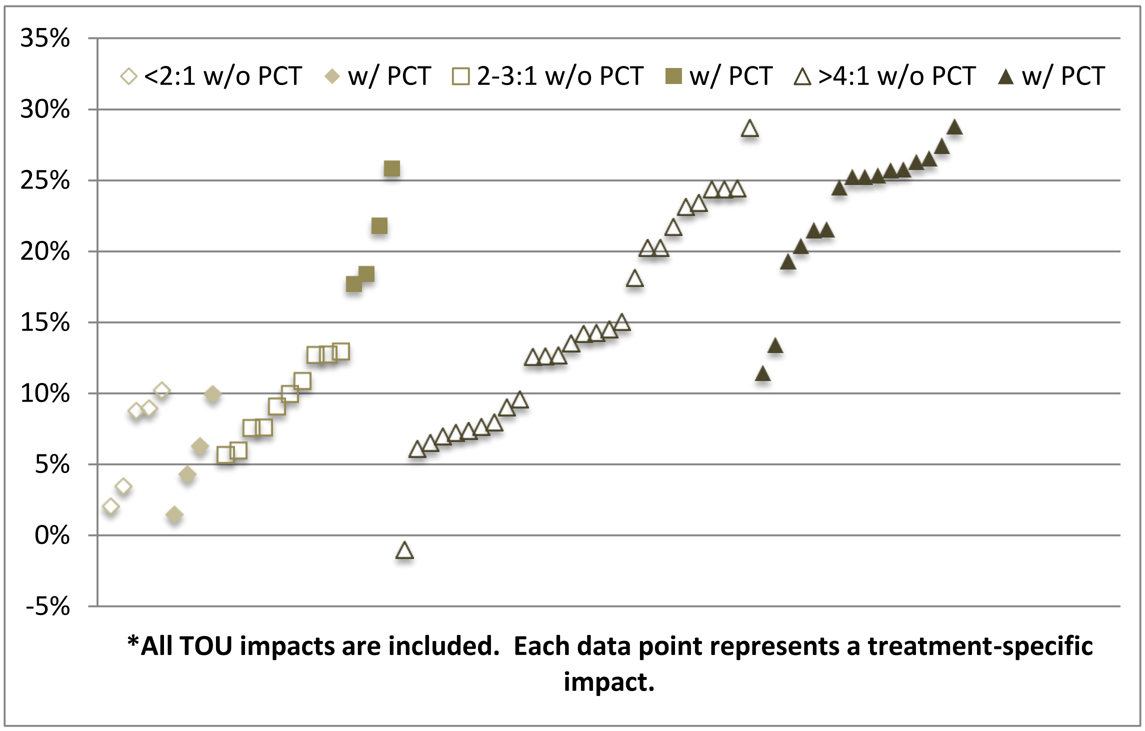

Figure 25. Average Percent Peak Period Demand Reductions by Treatment Group, Price Ratio Grouping and PCT.

7.3 Event Demand Reductions due to CPP/CPR

Four of the CBS utilities chose to overlay a CPP/CPR rate on the TOU rate to gauge the level of additional peak period demand reduction they could achieve during events relative to non-event days. Figure 26 shows results for 4 CBS utilities encompassing 23 treatment groups and covers event-only peak demand reductions. The average event peak demand reduction was 27% over all of the treatments, but ranged from 9% to 40%. This stands in contrast to non-event day peak period demand reductions, as described in Figure 23, where the average demand reduction over all treatments was 15%, with a range of -1% to 29%.

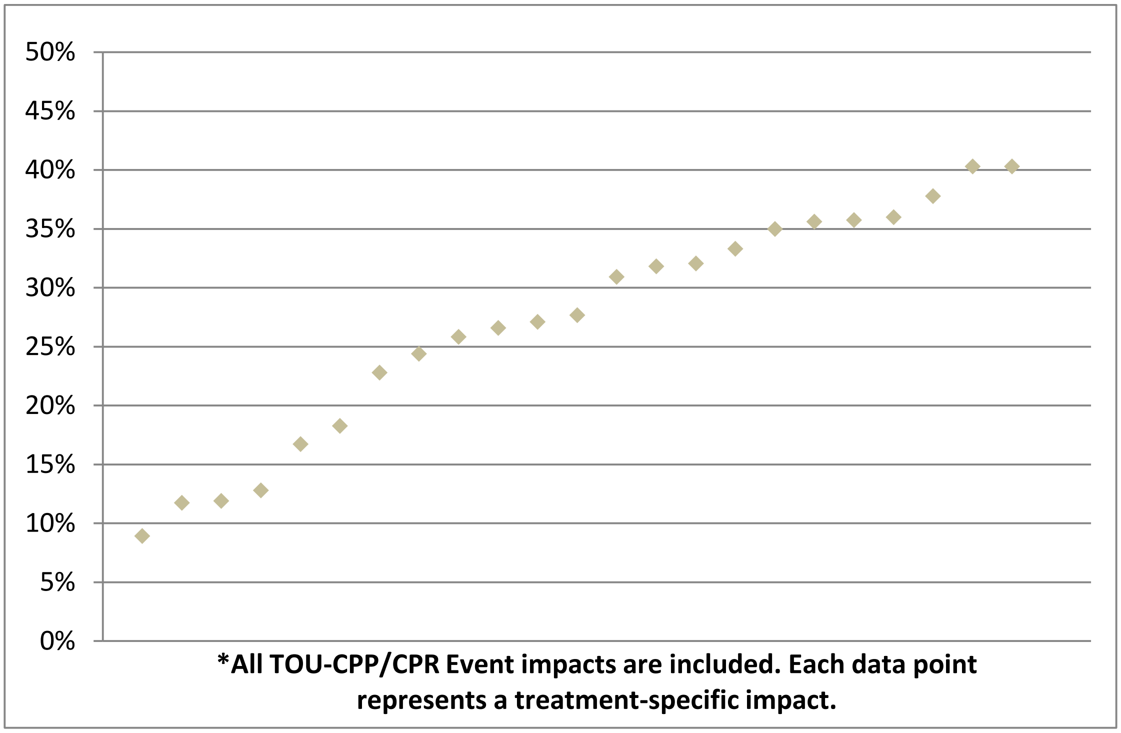

Figure 26. Average Percent Event Demand Reductions by Treatment Group.

Several of the CBS utilities also paired a PCT with their TOU CPP/CPR rate treatment. Figure 27 shows the same set of event demand reductions as portrayed in Figure 26, but this time organized by whether or not the treatment included a PCT. Consistent with the results presented in other chapters of this report, the existence of a PCT makes a difference to the response during events: 34% average demand reduction over all treatments when a PCT was present vs. 24% in the absence of a PCT.

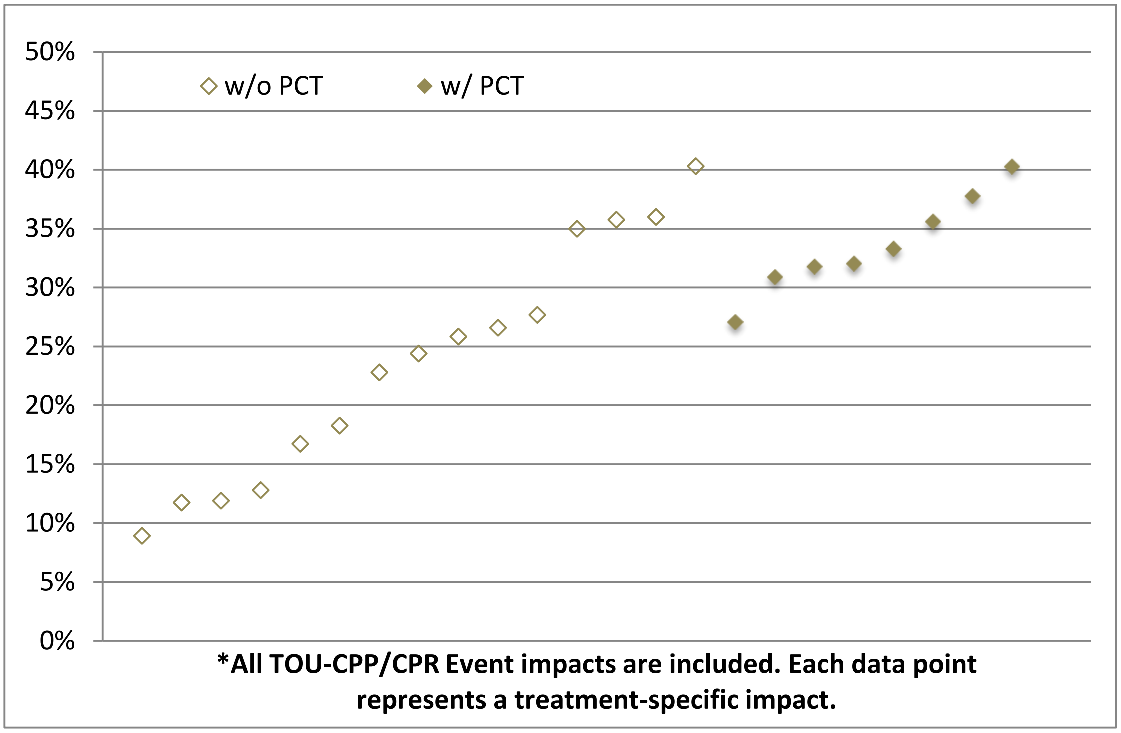

Figure 27. Average Percent Event Demand Reductions by Treatment Group with and without PCTs.

8. Conclusions

The CBS program effort produced a tremendous amount of novel insights about customer preferences for and responses to other time-based rate designs as well as information and control technology that are, at present, supportable by many regulators, policymakers and utilities.

8.1 Major Findings

Results from the CBS utilities can be grouped into five general areas:

(1) Recruitment approaches – effects of opt-in and opt-out;
(2) Pricing versus rebates – effects of CPP and CPR;
(3) Customer information technologies – effects of IHDs;
(4) Customer control technologies – effects of PCTs; and
(5) Customer response to prices – effects of TOU.

Table 10 summarizes major findings in these five areas and are each discussed in greater detail below.

Table 10. Summary of Major Findings	
Area	**Major Findings – Demand Reductions & Enrollment/Retention Rates**
Recruitment Approaches – Opt-in & Opt-out	• Opt-out enrollment rates were about 3.5 times higher than they were for opt-in (93% vs. 15%). • Retention rates for opt-out recruitment approaches (85.5% in year 1 and 88.5% in year 2) were about the same as they were for opt-in (89.7% in year 1 and 91.0% in year 2). • Peak period demand reductions for SMUD's opt-in TOU customers were about twice (13% in year 1 and 11% in year 2) as large as they were for opt-out customers (6% in year 1 and year 2). • Peak period demand reductions for SMUD's opt-in CPP customers were about 50% higher (24% in year 1 and 22% in year 2) than they were for opt-out customers (12% in year 1 and 14% in year 2). • SMUD's opt-out offers were more cost-effective for the utility than their opt-in offers in all cases. • Roughly two-thirds of those who were defaulted onto SMUD's TOU rates were expected to see bill impacts of +/- $20 for the entire 4 summer months the rates were in effect. • Based on survey responses, a majority of those defaulted onto SMUD's TOU rate were satisfied with the rate, regardless of the level of bill savings achieved, but those who saw the largest bill increases were generally less interested in continuing with the rate after the study ended.

Pricing Versus Rebates – CPP & CPR	• While opt-in enrollment rates for GMP were about the same for CPP (34%) and CPR (35%), retention rates were somewhat lower for CPP (80%) than they were for CPR (89%). • Average peak demand reductions for CPP (20%) were about 3.5 higher than they were for CPR (6%), but when automated controls (PCTs) were provided, they were about 30% larger (35% for CPP and 26% for CPR).
Customer Information Technologies - IHDs	• Enrollment and retention rates were generally unaffected by offers of IHDs. • SMUD's opt-in CPP customers with IHDs (26% in year 1 and 24% in year 2) had somewhat higher peak demand reductions than those without IHDs (22% in year 1 and 21% in year 2), but these differences can be explained by pre-treatment differences between the two groups. • SMUD's opt-in TOU customers with IHDs (13% in year 1 and 11% in year 2) had somewhat higher peak demand reductions than those without IHDs (10% in year 1 and 9% in year 2), but these differences can be explained by pre-treatment differences between the two groups. • SMUD's offerings without IHDs were more cost-effective for the utility in all cases than those with IHDs.
Customer Control Technologies - PCTs	• Enrollment and retention rates were generally unaffected by offers of PCTs. • Peak demand reductions are generally higher for CPP and CPR customer with PCTs (22% to 45%) than they were for customers without PCTs (-1% to 40%). • OG&E rate offers with PCTs were more cost-effective for the utility than those without PCTs.
Customer Response to Price - TOU	• Peak period demand reductions were far less, on average, for the lowest peak to off-peak price ratios (6% for treatments with a peak to off-peak price ratio less than 2:1) than for the highest price ratios (18% for treatments with a peak to off-peak price ratio greater than 4:1). • When a CPP/CPR was overlaid on the TOU rate, the average event peak demand reduction rose to 27% when averaged over all of the treatments • When PCTs were available, the differences in average peak period demand reductions were only affected at peak to off-peak price ratios in excess of 2:1 (21% vs. 10% for price ratios between 2:1 and 3:1 and 23% vs. 15% for price ratios in excess of 4:1).

Recruitment Approaches – Effects of Opt-in and Opt-out

Results from the CBS utilities show that enrollment rates were much higher and peak demand reductions were lower under opt-out recruitment approaches, but that retention rates were about the same for both. Because of these results, there were overall benefit-cost advantages to using opt-out approaches over opt-in. When broken down further into customer sub-populations, based on those who were assumed to have actively made a choice to accept SMUD's default offer of a TOU rate (Always Takers) and those who simply didn't eschew it (Complacents), a subset of the Complacents seemed much less engaged, attentive and informed than the other study participants.

However, extending the results to apply to SMUD's entire residential population, this suggests that it is not the entirety of the residential class or even the full share of Complacents who are at-risk of being made worse off from a transition to default TOU, but rather a subset of the latter. Most importantly, these results suggest that there is a sizable share of the residential customer class at SMUD that was seemingly better off on a default TOU rate relative to the voluntary recruitment approach.

Prices versus Rebates – Effects of CPP and CPR

Results from the CBS utilities show that retention rates were higher for CPR than for CPP and demand reductions achieved without enabling control technology were generally higher for CPP than for CPR. However, when PCTs were available as an automated control strategy, the differences in peak demand reductions between CPP and CPR were largely eliminated.

Customer Information Technologies – Effects of IHDs

Results from the CBS utilities show that free IHD offers did not make a substantial difference for enrollment and retention rates. Although SMUD's peak demand reduction estimates were larger with IHDs, this result can be attributed to pre-treatment differences between the two groups so there was not a measured IHD effect on reductions of peak demand. As a result, cost-benefit ratios of rate offerings were lower when they included offers of free IHDs. In addition, many of the CBS utilities reported significant challenges with this relatively new technology. Problems included getting the IHDs to function properly and in one case the manufacturer decided to halt production and stop support.

Customer Control Technologies – Effects of PCTs

Results from the CBS utilities show that free PCT offers did not make a major difference for enrollment and retention, but that peak demand reductions were substantially higher. Unlike with IHDs, cost-benefit ratios for PCT offers were favorable. In response, one utility (OG&E) decided to roll-out a time-based rate with an offer of a free PCT to its entire residential customer class with a recruitment goal of 120,000 customers within three years.

Customer Response to Price – Effects of TOU

Results from the CBS utilities show that customers exhibited far less peak period demand reductions, on average, to the lowest TOU price ratios (6% for treatments with a peak to off-peak price ratio less than 2:1) than to the highest TOU price ratio (18% for treatments with a peak to off-peak price ratio greater than 4:1). However, when PCTs were available as an automated control strategy, the differences in average peak period demand reductions were substantively affected at peak to off-peak price ratios in excess of 2:1 (21% vs. 10% for price ratios between 2:1 and 3:1 and 23% vs. 15% for price ratios in excess of 4:1). When CPP/CPR was overlaid on the TOU rate, the average event peak demand reduction was 27% when averaged over all of the treatments. However, when PCTs were available, the average event peak demand reduction was 34% vs. 24% when such automated control technology was not available.

8.2 Concluding Remarks

Rigorous experimental methods were applied in these consumer behavior studies with the hopes that more credible and precise load impact estimates would help resolve some of the outstanding issues hindering broader industry adoption of time-based rates for residential customers. Since none of the CBS utilities had any experience with such experimental methods, each CBS utility was provided with a small team of industry experts who provided technical assistance in the design, implementation and evaluation of each study. Besides direct engagement with each CBS utility, these Technical Advisory Groups (TAGs) also produced a library of guidance documents for the CBS utilities (which are publicly available on smartgrid.gov) on such diverse topics as study plan documentation, experimental design, rate and non-rate treatments, and evaluation techniques. With the help of these TAGs and the reference material they produced, many of the concerns initially raised about the application of experimental methods (e.g., withholding or deferring exposure to the rate after a customer had agreed to participate in the study would create customer relations problems) did not materialize. In addition, TAGs helped the utilities more narrowly focus their studies on a core set of objectives that would more readily and directly contribute to deliberations by each of the CBS utilities after the study about what to move forward with. As such, this consumer behavior study effort produced a wealth of contributory results on a number of critical issues the electric power industry was seeking information on, as described above.

Both utilities and participating customers learned a tremendous amount about themselves and their capabilities through these studies. Although not an explicit objective of the consumer behavior studies, their success hinged on the ability of the CBS utilities to effectively engage customers – many of whom had very limited experience in this arena. As such, several CBS utilities recognized the importance of performing market research during the study design phase to ensure marketing material was as effective as possible to engage customers as participants in the studies. The most successful CBS utilities continued that engagement not just during recruitment but throughout the study period itself, which included the creation of a plethora of different materials using a number of different mediums (e.g., monthly newsletters, social media campaigns of tips and tricks) that constantly sought to keep customers engaged in the study. Such efforts seemed to be quite successful, as the vast majority of customers who started the studies also completed them, expressed a high level of satisfaction in their experiences with these new rates and to a lesser extent with the new technologies, and continued taking service under the rate after the study ended, provided such opportunities were available.

It was hoped that this success would catalyze change in the electric industry both for those directly participating in these consumer behavior studies but also more broadly speaking for those totally unaffiliated with it. Three of the ten CBS utilities allowed participants to continue taking service under the rates after their study was completed. Four of the ten CBS utilities chose to extend an offer of the rates tested in their study to the broader population of residential customers. Specifically, OG&E has reached ~20% penetration of its residential class on the Variable Peak Pricing rate tested in its CBS after a little more than three years of marketing it. SMUD chose to make the TOU rate it tested the default for all of its residential customers, starting in 2018. More broadly, the California Public Utility Commission ordered all of the state's investor-owned utilities to make TOU the default for residential customers, citing heavily the very positive results SMUD achieved as grounds for this decision. DOE hopes the experiences and results from the CBS effort which have been published to date, as well as those yet to come, can help other utilities and regulators more aggressively pursue the application of time-based rates for residential customers.

Appendix – Summary of CBS Time-Based Rate Offerings[49]

KEY

CPP = Critical Peak Pricing
CPR = Critical Peak Rebate
TOU = Time of Use
IBR = Increasing Block Rate
Flat = Constant Price

All prices have been rounded to 3 decimal places.

GMP

Utility	Customer	Rate Type	Off Peak ($/kWh)	Critical Peak ($/kWh)
Green Mountain Power	Treatment	CPP	0.144	0.60
	Treatment	CPR	0.148	-0.60
	Control	Flat	0.148	0.148

DTE

Utility	Customer	Rate Type	Off Peak ($/kWh)	Mid Peak ($/kWh)	Peak ($/kWh)	Critical Peak ($/kWh)
Detroit Edison	Treatment	TOU+CPP	0.04	0.07	0.12	1.00
	Control	IBR	0.069/kWh for the first 17 kWh per day; 0.083/kWh for excess consumption over 17 kWh per day.			

FirstEnergy-CEIC

Utility	Customer	Rate Type	Off Peak ($/kWh)	Critical Peak ($/kWh)
FirstEnergy	Treatment	CPR	0.03	-0.40
	Control	Flat	0.03	0.30

[49] This summary of rate offerings are for the six CBS utilities that had produced initial or final evaluation reports at the time this report was written.

MMLD

Utility	Customer	Rate Type	Off Peak ($/kWh)	Critical Peak ($/kWh)
Marblehead Municipal Light District	Treatment	CPP	0.09	1.05
	Control	Flat	0.143	0.143

OG&E

Utility	Customer	Rate Type	Off Peak ($/kWh)	Variable Peak 1 ($/kWh)	Variable Peak 2 ($/kWh)	Variable Peak 3 ($/kWh)	Variable Peak 4 ($/kWh)	Critical Peak ($/kWh)
Oklahoma Gas & Electric	Treatment	TOU+CPP	0.042	0.23	0.23	0.23	0.23	0.46
	Treatment	VPP+CPP	0.045	0.045	0.113	0.23	0.46	0.46
	Control	IBR	0.084/kWh for consumption up to 1,400 kWh; 0.097/kWh for consumption beyond 1,400kWh					

SMUD

Utility	Customer	Rate Type	Peak ($/kWh)	Critical Peak ($/kWh)	Tier 1 ($/kWh) 0-700kWh	Tier 2 ($/kWh) 701-1425kWh	Tier 3 ($/kWh) 1426+kWh
Sacramento Municipal Utility District	Treatment	CPP	n/a	0.75	0.085	0.167	0.167
		TOU	0.27	n/a	0.085	0.166	0.166
		TOU+CPP	0.27	0.75	0.072	0.141	0.141
	Control	IBR	n/a	n/a	0.102	0.183	0.183
	Treatment EAPR	CPP	n/a	0.50	0.055	0.117	0.167
		TOU	0.20	n/a	0.055	0.116	0.166
		TOU+CPP	0.20	0.50	0.049	0.099	0.141
	Control EAPR	IBR	n/a	n/a	0.066	0.128	0.183

*EAPR stands for "Energy Assistance Program Rate", which is a program that provides discounted electricity rates to low-income residents.