SMART GRID
INVESTMENT GRANT
CONSUMER BEHAVIOR STUDY ANALYSIS

Time-of-Use as a Default Rate for Residential Customers: Issues and Insights

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Glossary of Acronyms, Abbreviations, and Terms

AMI	**Advanced Metering Infrastructure –** All components that allow two-way communication between meters and the electric utility’s meter data management system to collect electricity usage and related information from customers and to deliver information to customers.
CA	**California**
CBS	**Consumer Behavior Study**
CBSP	**Consumer Behavior Study Plan**
CEIC	**Cleveland Electric Illuminating Company**
ComEd	**Commonwealth Edison**
CPP	**Critical Peak Pricing –** A time-based rate component that increases the price on electricity consumed for participating customers during the hours included in a declared critical event. This higher price is overlaid onto the existing retail rate. Critical events are called either on a day-ahead or in-day basis in response to forecasted or achieved, respectively, high wholesale market electricity prices, short-term system reliability problems, or both. The primary objective of this rate design is to promote reductions in the peak demand of electricity.
CPR	**Critical Peak Rebate –** A demand response program that pays participating customers for reducing electricity consumed in relation to a baseline during the hours included in a declared critical event. Critical events are called either on a day-ahead or in-day basis in response to forecasted or achieved, respectively, high wholesale market electricity prices, short-term system reliability problems, or

	both. The primary objective of this program design is to promote reductions in the peak demand of electricity.
CPUC	**California Public Utilities Commission**
DID	**Difference-in-Differences**
DOE	**Department of Energy**
DTE	**DTE Energy**
EAPR	**Energy Assistance Program**
FERC	**Federal Energy Regulatory Commission**
FOA	**Funding Opportunity Announcement**
GMP	**Green Mountain Power**
HEMS	**Home Energy Management System**
IHD	**In-Home Display**
IV	**Instrumental Variable regression**
kWh	**Kilowatt-hour**
LAC	**Los Alamos County Electric Utility**
LBNL	**Lawrence Berkeley National Laboratory**
LE	**Lakeland Electric**
MADPU	**Massachusetts Department of Public Utilities**
MMLD	**Marblehead Municipal Light Department**
MP	**Minnesota Power**
NVE	**NV Energy**

OE	**DOE Office of Energy Delivery and Electricity Reliability**
OG&E	**Oklahoma Gas & Electric**
PCT	**Programmable Communicating Thermostat**
PSE	**Puget Sound Energy**
PURPA	**Public Utility Regulatory Policies Act**
RCT	**Randomized Controlled Trial** – A research strategy in which customers who volunteer to be exposed to a treatment are randomly assigned to treatment and control conditions.
RED	**Randomized Encouragement Design** – A research design in which two groups of customers are selected from the same population at random and 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 treatment are considered to be in the treatment group.
SGIG	**Smart Grid Investment Grant**
SMUD	**Sacramento Municipal Utility District**
SVE	**Sioux Valley Energy**
TAG	**Technical Advisory Group**
TOU	**Time-Of-Use** – A time-based rate program design that charges customers for electricity usage based on the block of time it is consumed. The price schedule is fixed and predefined, based on season, day of week, and time of day. The primary objective of this rate design is to promote overall shifting of electricity away from the peak period to other periods.

2SLS	**Two Stage Least Squares regression**
VEC	**Vermont Electric Cooperative**
VPP	**Variable Peak Pricing –** A time-based rate program design that charges customers for electricity usage based on the block of time it is consumed. The price schedule is variable and differs daily, based on bulk power system conditions during that period of the day. The primary objective of this rate design is to promote targeted shifting of electricity away from the peak period to other periods.

Foreword

As far back as the 1890s, the electric industry has been debating the issue of how to efficiently and optimally charge customers for consuming electricity (Hausman and Neufeld, 1984). At that time, there were emerging but very contentious discussions among economists about the merits of pricing the new commodity differentially based on time. The challenge with such pricing schemes revolved around metering—cost-effective technology did not exist at that time to allow electricity consumption to be captured at the required level of detail. Thus, virtually all customers were charged for their electricity consumption at a rate that was time-invariant (i.e., flat).

By the 1970s, the debate had moved beyond issues of economic efficiency and instead turned towards more practical concerns about consumer behavior—could mass-market (i.e., residential and small commercial) customers manage their electricity consumption under time-based rate programs? The results of studies undertaken by the Federal Energy Administration, the predecessor to the U.S. Department of Energy (DOE), indicated such customers were, in fact, capable of managing their electricity consumption by moving it away from the expensive "peak" period to the less-expensive "off-peak" period (see Faruqui and Malko, 1983 for a meta-analysis of these experiments). In spite of this evidence, the lack of low-cost interval or period-based metering technology continued to limit the industry's ability to expand the application of time-based rate programs at the residential level through the end of the 20th century.

Over the past ten years, however, the costs of interval meters, the communications networks to connect the meters with utilities and the back-office systems necessary to maintain and support them (i.e., advanced metering infrastructure or AMI) have dramatically decreased. The implementation of AMI and interval meters by utilities, which allows electricity consumption data to be captured, stored and reported at 5 to 60-minute intervals in most cases, provides an opportunity for utilities and policymakers to once again seriously consider the merits of the widespread deployment of time-based rate programs. However, many regulators and other key policymakers have determined that more definitive answers to key policy questions must be addressed before they will fully support a paradigm shift in the way retail electricity providers charge residential and small commercial customers for consuming electricity.

The American Recovery and Reinvestment Act of 2009 included $3.4B for the Smart Grid Investment Grant (SGIG) program with the goal of creating jobs and accelerating the transformation of the nation's electric system by promoting investments in smarter grid technologies, tools and techniques (DOE, 2012). Among other topics, the Funding Opportunity Announcement (DE-FOA-0000058) identified interest in AMI projects that examined the impacts and benefits of time-based rate programs and enabling control and information technologies through the use of randomized controlled experimental designs.

Based on responses to this FOA, DOE decided to co-fund ten utilities to undertake eleven experimentally-designed Consumer Behavior Studies (CBS) that proposed to examine a wide range of the topics of interest to the electric utility industry. Each chosen utility was to design, implement and evaluate their own study in order to address questions of interest both to itself and to its applicable regulatory authority, whose approval was generally necessary for the study to proceed. The DOE Office of Energy Delivery and Electricity Reliability (OE), however, did set guidelines, both in the FOA and subsequently during the contracting period, for what would constitute an acceptable study under the Grant.

To assist in ensuring these guidelines were adhered to, OE requested that LBNL act as project manager for these Consumer Behavior Studies to achieve consistency of experimental design and adherence to data collection and reporting protocols across the ten utilities. As part of its role, LBNL formed technical advisory groups (TAG) to separately assist each of the utilities by providing technical assistance in all aspects of the design, implementation and evaluation of their studies. LBNL was also given a unique opportunity to perform a comprehensive, cross-study analysis that uses the customer-level interval meter and demographic data made available by these utilities due to SGIG-imposed reporting requirements, in order to analyze critical policy issues associated with AMI-enabled rates and control/information technology. Over the next several years, LBNL will publish the results of these analyses in a series of research reports that attempt to address critical policy issues relating to on a variety of topics including customer acceptance, retention and load response to time-based rates and various forms of enabling control and information technologies.

Executive Summary

Ninety-eight percent of residential customers in the U.S. take electricity service under flat or inclining block rates (FERC, 2012). However, for nearly 40 years, in part because of The Public Utility Regulatory Policies Act[i] (PURPA), the vast majority have been offered a time-based rate[ii] (e.g., time-of-use) on a voluntary opt-in basis. In spite of this extensive history, the majority of U.S. utilities currently have less than 2% of their residential customers taking service under such rates (FERC, 2012). Throughout this time, most residential customers had bulk usage meters. So, if they wanted to take service under a time-based rate, they had to request that the utility install a new meter, either with multiple registers or interval-based, and incur an additional monthly meter charge. In part because of this hurdle, it is likely that residential enrollment levels in time-based rates have been low.

With increased broad penetration of interval meters as part of utility investments in advanced metering infrastructure (AMI) over the past 15 years, this major barrier to more sizable adoption of time-based rates has potentially been removed.[iii] Ubiquitous interval meters introduces the opportunity to make time-based rates the default rate design for residential customers, which would be a major policy change in the United States.

Many contend that residential customers as well as utility ratepayers could benefit from such a transition to default time-based rates in a variety of ways. All residential customers would have greater opportunities to control electricity costs and bills by altering the *timing* of electricity usage, not just using less overall. In addition, utility ratepayers as a whole can benefit because time-based rates better align the prices customers face with the cost of serving them at that time, resulting in greater economic efficiency. Lastly, broad based customer response to time-based rates can contribute to improved reliability and reduce the

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

[ii] Time-based rates capture temporal differences in the cost of providing electricity. Some time-based rate designs are static where the price schedule of electricity is set months, if not years, ahead of time to capture the diurnal and/or seasonal differences in costs (e.g., time-of-use pricing). Other time-based rate designs are more dynamic, where the price schedule is set 24 hours or less ahead of time based on anticipated or actual power system conditions, high wholesale power costs, or both (e.g., critical peak pricing, real-time pricing).

[iii] Certainly a myriad of other barriers exist (e.g., the level of marketing and customer outreach, customer-focused rate design) that may keep enrollment levels low even with the introduction of AMI.

need for the utility to invest in additional generation, and possibly distribution and transmission infrastructure.

However, risks associated with such a transition have also been identified. Consumer advocates and some utilities have raised concerns that customers will be dissatisfied with the transition (e.g., upset about having to take explicit actions to remain on a flat or inclining block rate that they know and prefer) and some may be adversely affected from the change in default rates (e.g., customers who have higher electricity consumption than the average customer in the more expensive peak period, and who cannot or do not opt out for whatever reason, will see their bills increase under a time-based rate absent any response to the rate vis-à-vis a flat or inclining block rate). [iv]

Unfortunately the U.S. electricity industry has almost no direct recent experience that can be drawn upon in this debate about the proper role of time-based rates in default rate design for residential customers.[v] Instead, the only current U.S. experience (i.e., within the last 5 years) comes by way of studies of time-based rates offered under default enrollment approaches.[vi] Results from all of those studies suggest that there are subpopulations of customers that respond to default time-based rates and other groups that are likely less inclined to do so.

The purpose of this report is to provide decision makers, policy officials, and other electric power industry stakeholders, who have either committed to (e.g., California[vii], Massachusetts[viii]) or are considering (e.g., New York[ix]) transitioning residential customers specifically to time-of-use (TOU) rates as the default rate design within the next several years, with empirical evidence that seeks to better address the concerns of a variety of industry stakeholders. Using interval meter data, survey data, and other data collected

[iv] These concerns are often times raised in regards to low income, elderly or those customers with medical needs (see for example AARP et al., 2010), but certainly could apply to the rest of the population more broadly.

[v] Since our focus is on the United States, we did not include an assessment of international experience. See, for example, Faruqui et al. (2015) for a discussion of the experience in Ontario, Canada where the default rate design for residential customers is TOU.

[vi] Incentive-based demand response programs like critical peak rebate or peak-time rebate are not herein considered time-based rates. So although Baltimore Gas and Electric has defaulted all of their residential customers onto such a program, their experience is not considered as it is outside the scope of this report.

[vii] See CPUC (2015).

[viii] See MADPU (2014).

[ix] See NYDPS (2015)

during the Sacramento Municipal Utility District's (SMUD) Smart Grid Investment Grant (SGIG) co-funded consumer behavior study (CBS) that took place during the summers of 2012 and 2013, LBNL analyzed residential customers who (1) volunteered for, or (2) were defaulted into, a study in order to quantify the differences between these two recruitment methods in terms of adoption, retention, and response to TOU rates. Of particular importance from a policy perspective is an assessment of those who might be better off for having been defaulted onto the TOU rate or who might be worse off (e.g., financially worse off, unhappy having to alter their electricity consumption behavior, frustrated that their electric rate was changed) but don't switch to another rate. In particular, improving our understanding of these different subpopulations can help policy and decision makers make that transition more successful (e.g., limited customer complaints, low opt-out enrollment rates, high retention rates, and/or high customer response).

In a default environment we define three key subpopulations:

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

Within the context of SMUD's consumer behavior study, Figure ES-1 shows the relative sizes of these three subpopulations of residential customers.

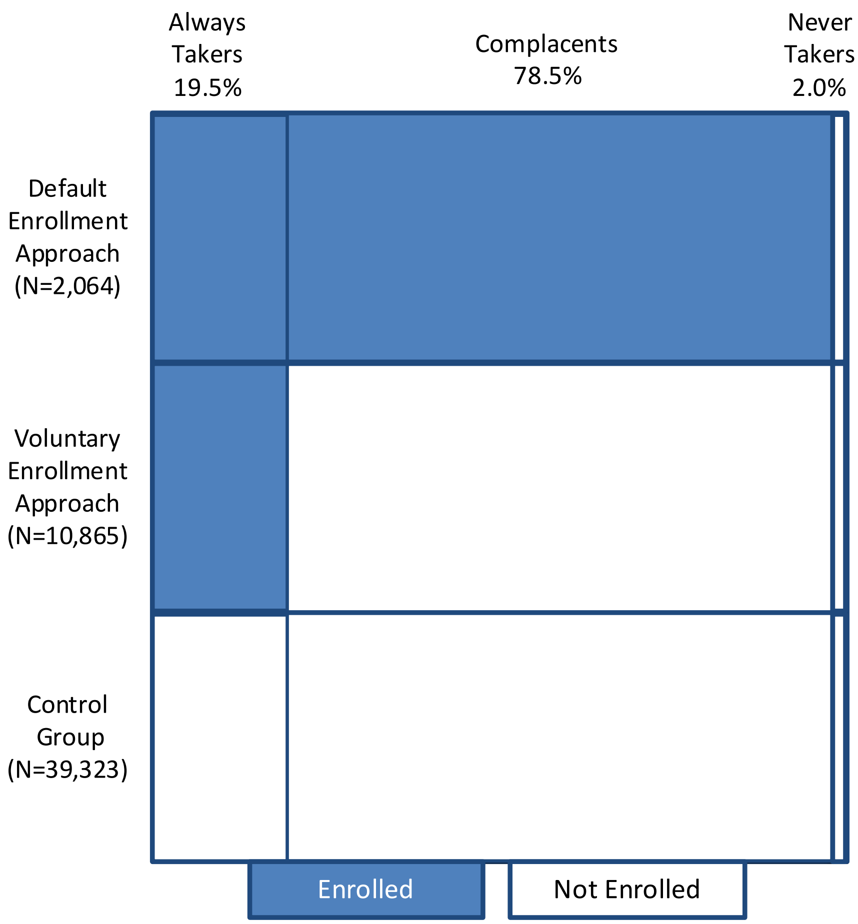

Figure ES-1. SMUD Residential Subpopulations for Analyzing Default vs. Voluntary TOU Rates

Table ES-1 summarizes the major findings of this report from analyses of these subpopulations. These findings are organized based on perceived risks that those resistant to default TOU rates have articulated.

Table ES-1. Major Findings

Perceived Risks about TOU Rates as the Default Service Option	Evidence from DOE Analysis of SMUD's CBS
Lack of customer acceptance (high drop-out rates to start, and high attrition, particularly among Complacents, over time).	• Enrollment rates were five times higher under default enrollment approaches (98%) than voluntary approaches (19.5%). • Once enrolled in the new rates, drop-out rates for both Complacents (3.7%) and Always Takers (4.4%) were very low.
Insufficient changes in consumer behaviors and potentially ineffective demand response and reductions among customers defaulted onto the rate, particularly among Complacents.	• Per-customer demand reductions were about three times higher on average for the voluntary offering (16.7%) than for the default enrollment approach (5.8%). • Per-customer demand reductions were about five times higher on average for the Always Takers (16.7%) than for the Complacents (3.1%), but impacts from both groups were statistically significant. • Comparing the first to the second summer, the demand reductions of Always Takers dropped significantly (18.2% to 14.7%), while it did not for Complacents (3.4% to 2.9%), indicating that savings from Complacents were, while smaller, potentially more persistent.
Unequitable distribution of financial benefits and bill savings.	• Differences in the distribution of Always Takers and Complacents predicted summer-long bill savings, absent any response, were very similar • Two-thirds of both the Always Takers and Complacent subpopulations were expected to see their bills change no more than +/- $20 over the course of an entire summer (+/- $5/month), before taking into account any response to the TOU rate.
Unacceptably high levels of customer dissatisfaction and bill complaints that result in poor performance and low cost-effectiveness.	• There was no evidence of dramatically higher levels of dissatisfaction or complaints from customers defaulted onto the TOU rate compared to those who opted-in, nor between Complacents and Always Takers. • Utility marketing and recruitment costs for those who opted in to the voluntary enrollment study (excluding any enabling equipment costs) were fifteen times higher than for those who did not opt out of the

	default enrollment approach ($60.77 per enrollee vs. $3.99 per enrollee). • Taken all together, a default TOU for all residential customers in SMUD's service territory is estimated to produce $34M in net benefits on a 10-year present value basis with a cost-benefit ratio of 2.04 whereas a voluntary approach would create -$5.5M in net losses at a cost-benefit ratio of 0.74.

The analysis in this report suggests that, as a group, Complacents were less engaged, attentive, and informed than the other subpopulations, either unintentionally or by choice. Looking more closely, there was some subset of the Complacent population who were fully aware of the rate, engaged enough with it to undertake substantial changes in behavior to respond to it in order to achieve bill savings and were generally satisfied with their experience on the rate. However, another subset of Complacents may have been largely indifferent about the rate, not particularly concerned about being defaulted onto it, expended a modest level of effort to respond to the rate and were satisfied enough with it to keep taking service under it after the study ended, provided they didn't see large bill increases. These customers were also likely better off for having been defaulted onto the rate. Lastly, there was a subset of customers who likely were highly unengaged and inattentive. We estimate the size of this latter group to be about 20% of the entire consumer population. They were more likely unaware of the rate SMUD had transitioned them to, as they did not provide any measurable energy savings in response to the TOU rate. In this case, contrary to the others, it is possible that these inattentive Complacents were worse off for having been defaulted onto the rate.

Key Results

Result 1 Many customers seem better off being defaulted onto a time-of-use rate relative to a voluntary rate

Result 2 Only a subset of residential customers are at-risk when defaulted on to a time-of-use rate.

Result 3 Utilities should focus on reaching inattentive customers who may be worse off

This suggests that it is not the entirety of SMUD's residential customers or even the share of residential customers that are Complacents who are at-risk of being made worse off during a transition to default TOU, but rather a subset of the latter. For utilities and states considering a transition to default TOU, it is this subpopulation of customers that requires the greatest attention from policy and decision makers. The likelihood of a successful transition could improve if utilities and others consider the needs of this subpopulation of unengaged Complacents. Ideally, utilities could identify customers who are more likely to be highly inattentive before the transition to default TOU is even announced. For example, utilities could create proxies for the level of a customer's attentiveness and engagement using data gathering activities such as registration requests for on-line access to account information, logins to on-line web portals, responses to bill inserts about utility services (e.g., energy efficiency), or the frequency of customer-service calls. Customers that seem to be less attentive and less engaged could be targeted by the utility for more direct and non-traditional communication strategies. In addition, utilities could use focus groups or other types of market research to determine the best ways to reach inattentive customers so that they can be made aware of the transition, better understand their options, and more easily navigate the opt-out process.

Most importantly, our analysis also shows 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 a voluntary enrollment approach. Policy and decision making often involves tradeoffs among different perspectives and interests. Recent industry experience shows that pursuing a voluntary approach to TOU rates typically means that less than 2% of residential customers participate (FERC 2012); although with extensive, dedicated and long-term (i.e., multi-year) commitment to recruitment efforts that employ effective marketing and customer outreach strategies on the part of a utility, which are unlikely to be attained without strong regulatory support if not directives, opt-in enrollments can be as high as 50% (e.g., Arizona Public Service[x]). SMUD achieved opt-in enrollments of about 19.5% with substantial market research to get their recruitment material optimally designed to elicit participation, all within the backdrop of a utility that has high customer satisfaction ratings. In contrast, default TOU rates substantially increase the size of the customer population seemingly benefiting from the rate transition. Certainly, with this opportunity to benefit more customers comes the challenge of mitigating the problems from the subpopulation of customers that may be at risk of being made worse off by default TOU. The question for policy and decision makers is determining whether or not that effort is worthwhile, and if so, how to best mitigate that risk.

[x] See Snook and Grabel (2015)

1. Introduction

Ninety-eight percent of residential customers in the United States (U.S.) take service under flat or inclining block rates (FERC, 2012). Yet, time-based rates[1] provide an opportunity for customers and utilities alike to achieve a variety of benefits including increased opportunity for customer bill management, lower utility power production costs, deferred future generation investments, and increased utilization of existing infrastructure. Historically, implementation of time-based rates required replacement of a traditional bulk usage electro-mechanical meter with either a multi-register electro-mechanical meter or an electronic interval meter that was accompanied by a monthly meter charge. The costs of individual meter upgrades was seen by many as a barrier to broader adoption of time-based rates. Recent broad-based deployment of Advanced Metering Infrastructure (AMI) removes this metering hurdle, thereby enabling the opportunity for broader adoption of time-based rates. Currently, utilities in the U.S. have installed more than 50 million smart meters, covering over 43% of U.S. homes (Institute for Electric Innovation, 2014).

There is an on-going debate in the U.S. electric power industry about the proper role of residential time-based rates, in particular time-of-use (TOU) rates, as either a voluntary or the default rate design. One of the major concerns raised when utilities consider time-based rates has to do with whether or not there are subpopulations of customers who might be made worse off from a transition to default TOU rates. Some customers may see higher bills simply because more of their electricity is consumed in the higher priced peak period. Other customers may be able to see bill savings, but only after considerable efforts to change their consumption patterns which may leave them resentful. Other customers may be highly inattentive, only becoming aware of the transition to a default time-based rate considerably after it occurred, resulting in dissatisfaction with the utility and state regulators. However, transitioning to time-based rates as the default provide substantially more customers the opportunity to better manage their bills based on when they use electricity, not just by limiting how much they consume overall. Furthermore, broad based response to time-based

[1] Time-based rates capture temporal differences in the cost of providing electricity. Some time-based rate designs are static, where the price schedule of electricity is set months, if not years, ahead of time to capture the diurnal and/or seasonal differences in cost (e.g., time-of-use pricing). Other time-based rate designs are more dynamic, where the price schedule is set 24 hours or less ahead of time based on anticipated or actual power system conditions, wholesale power costs, or both (e.g., critical peak pricing, variable peak pricing, real-time pricing).

rates has the opportunity to reduce utility power costs as well as to defer capital investments.

Through the U.S. Department of Energy's (DOE) Smart Grid Investment Grant Program (SGIG), the Sacramento Municipal Utility District (SMUD) designed and implemented a Consumer Behavior Study (CBS) of voluntary and default TOU rates that provide useful information and insights for addressing some of the key unresolved issues concerning a transition to default residential TOU rates.[2]

1.1 Background

The vast majority of residential time-based rate programs in the U.S. have been offered to customers on a voluntary, opt-in basis for nearly 40 years, in part because of The Public Utility Regulatory Policies Act of 1978[3] (PURPA). In spite of this extensive history, the majority of U.S. electric utilities currently have less than 2% of their customers taking service under such rates (FERC, 2012). Historically, most residential customers have had bulk-usage, electro-mechanical meters. If customers wanted to take service under time-based rates, they had to request the installation by the utility of a new multi-register or interval meter and incur an additional monthly meter charge. Residential enrollment rates in time-based rate programs have been generally low in part because of this hurdle.

With increased penetration of smart meters as part of utility investments in advanced metering infrastructure (AMI) over the past 15 years, one of the barriers to expanded deployments of time-based rates has been removed. For utilities with system-wide coverage of AMI, the opportunity exists to make time-based rates the default rate design for residential customers, which they may well desire to do for reasons described below, which would be a major policy change at the state level in the United States. Several states are in the process of evaluating this approach.

There are benefits associated with the application of time-based rates. A customer can reduce their electricity bills under a time-based rate by reducing or shifting their demand to less expensive periods. Also, customers more broadly can benefit from such rates as

[2] See Appendix A for more background on the SGIG consumer behavior study effort and Appendix B for more details about SMUD's consumer behavior study.

[3] 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.

electricity costs can be more equitably distributed across the class of customers under broadly applied time-based rates, as customers who use more electricity during the most expensive times-of-day would pay more of their share of those costs. In general, aligning the prices customers pay for electricity with the full cost of providing the electricity results in greater economic efficiency. When customers reduce electricity consumption coincident with system peak demands, then such efforts contribute to improved reliability and reduce the need for the utility to invest in additional generation, and possibly distribution and transmission infrastructure.

Given these benefits, it would seem that policy-makers would be interested in applying time-based rates, and that customers might volunteer to take service under them. However, this generally has not been the case without extensive education, promotion, and encouragement from the utility.[4]

One way to encourage much more wide-scale adoption of time-based rates would be to make them the default option. There is extensive evidence that people tend to disproportionately end up on whatever option is provided to them as a default, particularly in cases when they may not have strongly defined preferences about a choice ahead of time. This phenomenon, referred to as the "default effect" or "status quo bias" has been documented in a variety of settings (e.g., organ donation, 401K contributions, car insurance).[5] Applying this phenomenon to the electricity sector suggests that there is a high likelihood that even with real benefits from voluntarily switching to a time-based rate, many consumers are unlikely to do so without being prompted in some significant way. The application of time-based rates as a default option might result in a larger set of customers willing to remain on such a rate, but would also allow them to opt-out if they have a strong preference for a flat rate.

Despite the myriad of potential benefits from a transition to time-based rates as the default service option for residential customers, there has been a lack of universal support. Consumer advocates, public utilities commissions, and many utilities have raised concerns that a substantial number of customers will be unwilling to accept default time-based rates, or might be made worse-off by them. There is of particular concern for those who are at-risk

[4] Salt River Project has over 25% of their entire residential customer population on one of two TOU rates after more than 20 years of engaging and educating customers about the merits of taking service under TOU (Institute for Energy and the Environment, 2012). Arizona Public Service has even more customers on its TOU rates (over 50% of its residential population) after almost 40 years of offering them (Snook and Grabel, 2015).

[5] For a good review see DellaVigna (2009).

for suffering higher costs and bills because they can't or won't adjust their usage, as well as for those who may simply not want to be inconvenienced by having to now manage when they use electricity, but choose not to switch to another rate.[6]

Unfortunately, there has been very little direct experience in the U.S. with default residential time-based rates[7] and therefore little empirical evidence to draw upon in order to understand the actual impact of such default rates in terms of the risks and benefits outlined above.[8] Recently, however, there is experience from several utility studies of time-based rates offered under default enrollment approaches. In addition to SMUD, there have been four other utilities in the U.S. who conducted residential time-based rate studies in the last five years that evaluated default enrollment approaches, including: (1) Commonwealth Edison (ComEd) in Chicago, Illinois (EPRI, 2011a, b); (2) Sioux Valley Energy (SVE) in Minnesota and North Dakota (Power System Engineering Inc., 2012); (3) Los Alamos County Electric Utility (LAC) in New Mexico (Ida and Wang, 2014); and (4) Lakeland Electric (LE) in Florida (Lakeland Electric, 2015).[9]

SVE, LE and LAC included evaluations of voluntary versus default enrollments, while ComEd's study focused on the latter exclusively. Three of the four studies (SVE, LAC, ComEd) evaluated critical peak pricing (CPP), while ComEd also included evaluations of other rates (i.e., day-ahead real-time pricing, TOU rates, and critical peak rebates) and LE strictly assessed a TOU rate design.

[6] These concerns are often raised in regards to low income, elderly or those customers with medical needs (see for example AARP et al., 2010), but certainly could apply to the rest of the population more broadly.

[7] Since our focus is on the United States, we did not include an assessment of international experience. See, for example, Faruqui et al. (2015) for a discussion of the experience in Ontario, Canada where the default rate design for residential customers is TOU.

[8] Puget Sound Energy (PSE) instituted a time-of-use rate as the default in 2000 for its residential and small commercial customers. Although early analysis suggested customers were willing to modestly respond to the rate, programmatic changes in July of 2002 largely eradicated any financial benefit from taking service under the rate. As a result, PSE ended the program in November 2002. See Schwartz (2003).

[9] Incentive-based demand response programs like critical peak rebate or peak-time rebate are not herein considered time-based rates. So, for example, although Baltimore Gas and Electric has defaulted all of their residential customers onto such a program, their experience is not considered as it is outside the scope of this report.

LAC, LE and ComEd all experienced very high enrollment rates under default enrollment approaches (88-98%), that were much higher than those experienced under voluntary enrollment approaches.

SVE and LAC found that under a voluntary enrollment approach for CPP, customers reduced peak demand during declared events, on average, more than those under a default enrollment. Defaulted customers were, however, able to respond and reduce demand, just not as much. LE found customers who opted-in to participate in the study reduced usage in the first 5 months of the study in response to TOU rates, while the impact estimates for the defaulted customers were small and not statistically significant. An analysis of ComEd's customers that were defaulted onto the various rates was inconclusive, on average, as differences in estimated demand reductions were not statistically significant. However, a subset of ComEd's default participants (ranging from 9% to 12%, depending on the rate design) was found to produce statistically significant demand reductions.

Results from all four studies suggest that there are some subpopulations of customers under default enrollment approaches that respond to time-based rates and other subgroups that are less likely to do so. To delve into this issue more, LBNL analyzed interval meter, survey and other data collected as part of SMUD's SGIG-funded consumer behavior study.[10]

1.2 SMUD's Consumer Behavior Study

SMUD conducted one of the largest and most extensive consumer behavior studies under the SGIG program. One of the study's main goals was to better understand how the enrollment approach (voluntary vs. default) affected enrollment rates, drop-out rates, and electricity demand impacts associated with time-based rates. SMUD implemented three different time-based rate designs, all in effect during the summer months (June to September) of 2012 and 2013: (1) a two-period TOU rate with a three-hour (4-7 p.m.) peak period, (2) CPP overlaid on an underlying tiered rate, and (3) CPP overlaid on the TOU rate (see Figure 1 and Table 1).[11] Like most of the other consumer behavior studies implemented under the SGIG program, SMUD's study utilized a true experimental design (i.e., randomized control trial and

[10] Although data from Lakeland Electric's SGIG-funded consumer behavior study, which also implemented a default enrollment treatment, was available to LBNL to analyze, it was insufficient and the experimental design was not conducive to perform the same type of exhaustive and detailed analysis described herein.

[11] Only the TOU and CPP were implemented in such a way that the effect of enrollment approach (voluntary vs. default) could be analyzed.

randomized encouragement design) in order to more credibly and precisely estimate the load response to these various rates. For purposes of this report, only the customers included in the default TOU rate with IHD offer and opt-in TOU rate with IHD offer cells will be analyzed and discussed.

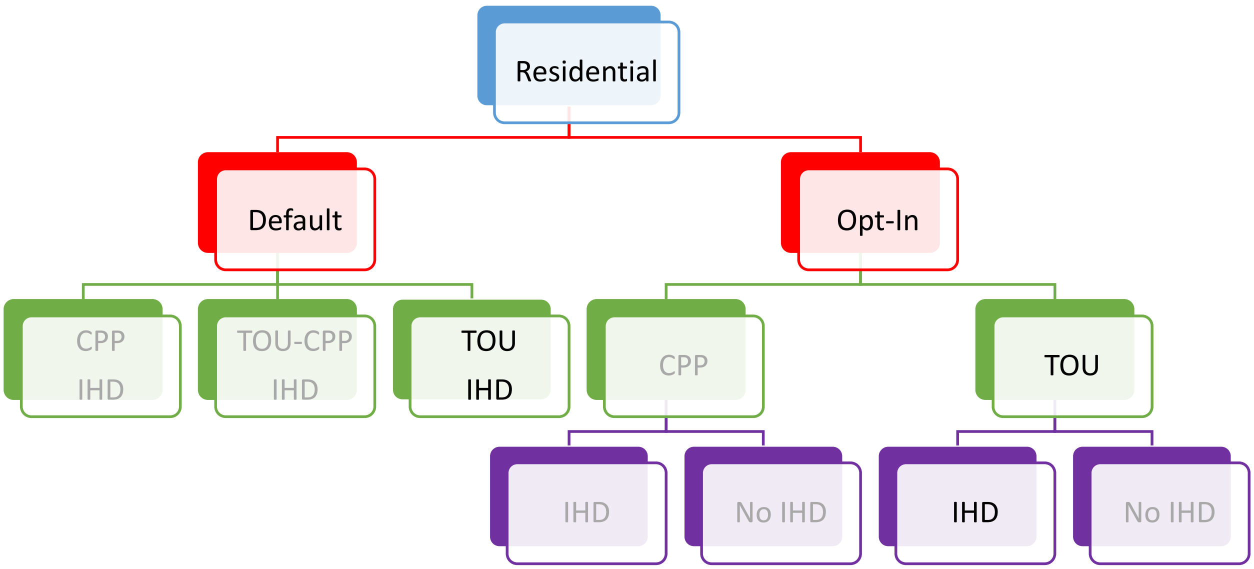

Figure 1. SMUD's Consumer Behavior Study Experimental Design

Table 1. SMUD's CBS Rate Design (¢/kWh)[12]

Period	CPP	TOU	TOU-CPP
Base (< 700 kWh)	8.51		
Base (> 700 kWh)	16.65		
Off-Peak (< 700 kWh)		8.46	7.21
Off-Peak (>700 kWh)		16.60	14.11
Peak		27.00	27.00
Critical Peak	75.00		75.00

1.3 Scope of this Report

At present, both California[13] and Massachusetts[14] have committed to transitioning residential customers to TOU rates as the default rate design within the next several years. Other states (e.g., New York[15]) have begun discussions about the viability of such a transition. Empirical analysis of SMUD's CBS data can provide information that might support the transitions in these states, while potentially contributing to discussions in similar regulatory proceedings that might occur in other states.

This analysis provides empirical evidence addressing key assumptions and preconceived notions about customer perceptions, risks, benefits and responses specifically to default

[12] Study participant on SMUD's Energy Assistance Program (EAPR) rate faced different prices than those listed in Table 1.

[13] The California Public Utilities Commission (CPUC), following a three-year examination of rate reform alternatives, ordered the state's investor-owned utilities to begin a transition to default time-of-use rates for all residential customers by 2019. See CPUC (2015).

[14] The Massachusetts Department of Public Utilities (MADPU), as part of a comprehensive suite of dockets and orders related to grid modernization, ordered the state's electric distribution companies to make a time-of-use rate with a critical peak pricing overlay the default for basic service customers following the deployment of advanced metering functionality. See MADPU (2014).

[15] As part of a proceeding that is seeking to fundamentally change the operations, roles and responsibilities of New York state's distribution utilities (i.e., Reforming the Energy Vision), the New York Public Service Commission staff wrote a white paper in 2015 that discussed the various options that could be considered to achieve broader adoption of time-based rates. See NYDPS (2015).

TOU, especially with respect to different subpopulations of residential customers transitioned to default TOU. For those states and utilities moving forward with time-based rates as default service options, this analysis can also be helpful in the design and implementation of new rates, including new strategies and techniques for addressing the needs of these different subpopulations of customers, such as those who are potentially at risk of being made worse off as a result of default TOU.

The report is organized as follows. In Chapter 2 we present the impacts of a default TOU rate at SMUD on customer acceptance, retention, demand response, bill impacts, and cost-effectiveness vis-à-vis traditional voluntary enrollment approaches. In Chapter 3, we assess how different subpopulations of residential customers are affected by a transition to default TOU. Finally, in Chapter 4 we provide a summary of the major findings and conclusions from this analysis.

2. Benefits and Risks of Default TOU Rates for Residential Customers

SMUD's consumer behavior study provides an opportunity to assess the perceived major benefits and risks of implementing default TOU for residential customers. An analysis of the data collected during their study provides information for policy and decision makers about the impacts of default rates on customer acceptance, retention, demand response, bill impacts, and cost-effectiveness vis-à-vis traditional voluntary enrollment approaches.

2.1 Potential Benefits and Risks of Default TOU

Most residential customers in the U.S. today have the opportunity to take service under TOU rates, but on a voluntary (i.e., opt-in) basis. The lack of customers signing up for these rates in large numbers (i.e., less than 2%) could be an artifact of past trends (e.g., these rate options were not always generally available, when available these rate options were poorly designed and/or ineffectively marketed) and rate economics (e.g., estimating bill savings has been challenging for a customer given the rate design and/or lack of knowledge of their own capabilities to alter electricity consumption) coupled with a tendency for consumers to stick with the status quo and/or default options (see the previous discussion of "status quo bias"). For this reason, changing the default rate structure to TOU could have several benefits. First, the variation in price from a TOU rate better reflects the increase in wholesale electricity prices as well as transmission and distribution costs due to higher demand in the peak periods. Second, on a flat rate, customers have no way of affecting the amount they pay for electricity beyond reducing use overall. In contrast, with a TOU rate, customers have an ability to adjust the timing of their consumption in a way that allows them to use the same level of services at a lower total cost. This may give customers a greater sense of control over their electricity bills. Third, because of status quo bias, making TOU a default rate in particular would be expected to increase participation in TOU without the costly recruitment efforts required to increase opt-in participation.

However, the historic low levels of voluntary participation in TOU might be an indication of a lack of awareness, interest, and/or ability to respond to this type of time-based rate design. Historically, investor-owned utilities have not had a financial incentive to vigorously pursue TOU rates for their customers, absent regulatory directives. As such, although the rates are included in their tariffs, in part due to PURPA, some contend that electric utilities have not historically rigorously marketed the rates to bolster participation levels. However, some view low participation levels less as a marketing failure on the part of the utility and more as a reflection of the fact that customers are simply not interested in taking service under a TOU rate. From the perspective of those who espouse the latter position, establishing TOU as the default rate going forward could be problematic. Customers that fail to opt-out of the pending default TOU rate during the transition stage might chose to drop-out soon after going onto the rate, resulting in substantial attrition. For customers who remain, their potential lack of awareness of a default transition in rate structure may result both in an inability to respond to the TOU rate by changing the timing of their electricity consumption, and high levels of dissatisfaction if and when they become aware of the rate change. Even if some of the remaining customers can and do respond to the rate, their load profile even after taking into account these changes may result in higher or more volatile bills than they had on the prior flat or tiered rate.

Utilities also face potential risks when implementing time-based rates as the default service option. They may contend with customer dissatisfaction if rates are poorly accepted. This can lead to low customer satisfaction ratings and an increase in customer complaints. If behavioral changes and the resulting demand impacts are smaller than expected, operation and electricity production savings to the utility may not exceed education, marketing, information and other implementation costs. In addition, utilities typically design time-based rates to collect a substantial amount of fixed costs in the higher priced peak period. As such, utilities may also experience deleterious revenue erosion if customers shift a considerable amount of load to the less expensive off-peak period.

The results from SMUD's CBS, which are expanded upon below, shows that most of these risks are not particularly substantial. In fact, SMUD's CBS showed that default residential TOU rates produced measurable benefits for both participating customers and for the utility.

2.2 Experiences with Customer Acceptance

As Figure 2 illustrates, SMUD's decision to default customers onto the TOU rate produced far higher enrollment rates than their efforts to recruit volunteers.[16] Enrollment rates were over five times larger under a default enrollment approach (98.0%) than under one that

[16] For this analysis, we consider customers that were solicited to join the TOU rate, whether voluntary or default, and also offered an in home display.

sought volunteers (19.5%) for the TOU rate.[17] SMUD reported that extensive customer outreach, education, and marketing efforts were required for achieving even this rate of voluntary enrollment. Customer recruitment costs for those who opted in to the voluntary enrollment study (excluding any enabling equipment costs) were estimated at $60.77 per enrollee. This is in comparison to $3.99 per enrollee for those who were defaulted onto the TOU rate, in spite of using nearly identical marketing material (Potter et al., 2014). As such, the significantly higher enrollment rates under default enrollment were achieved with much lower marketing and recruiting costs.

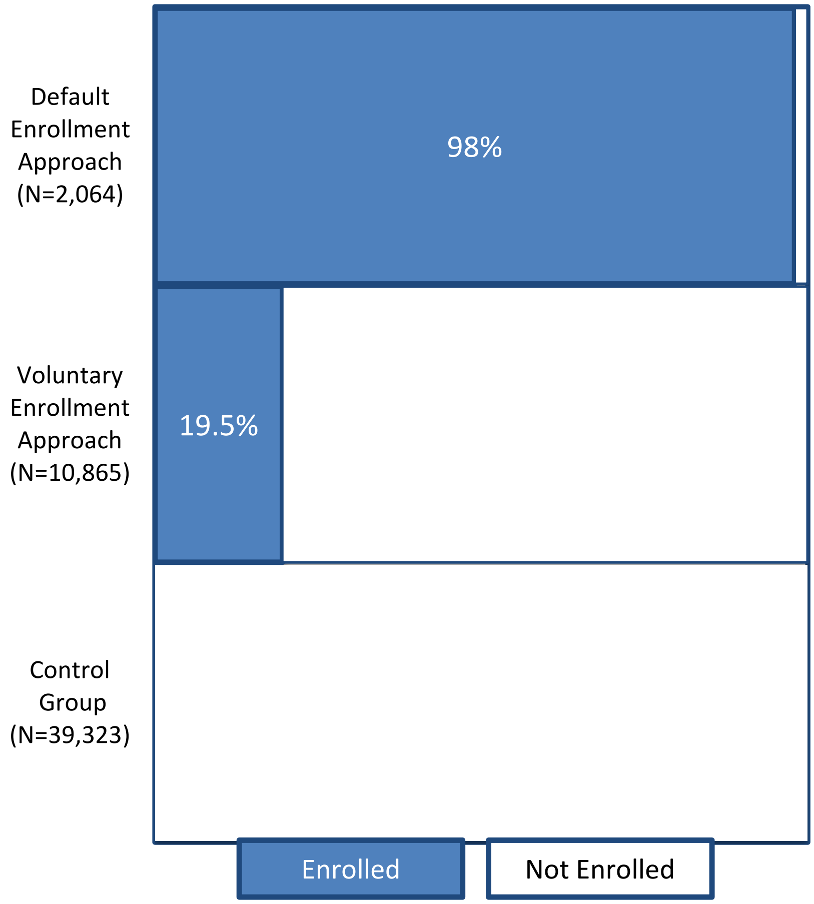

Figure 2. SMUD Enrollment Rates by Enrollment Approach

[17] These enrollment statistics reflect the share of customers enrolled in the study as of the date on which the study rates took effect (June 1st, 2012) after having omitted any customers who moved prior to that date.

2.3 Experiences with Customer Retention

In contrast to some expectations, SMUD did not experience high levels of attrition among the customers defaulted onto residential TOU rates. In fact, Figure 3 shows that drop-out rates were very low for those defaulted onto the rate (only 3.9% dropped out overall), and lower overall for those in the default group than for those in the voluntary group (4.4% dropped out overall).[18]

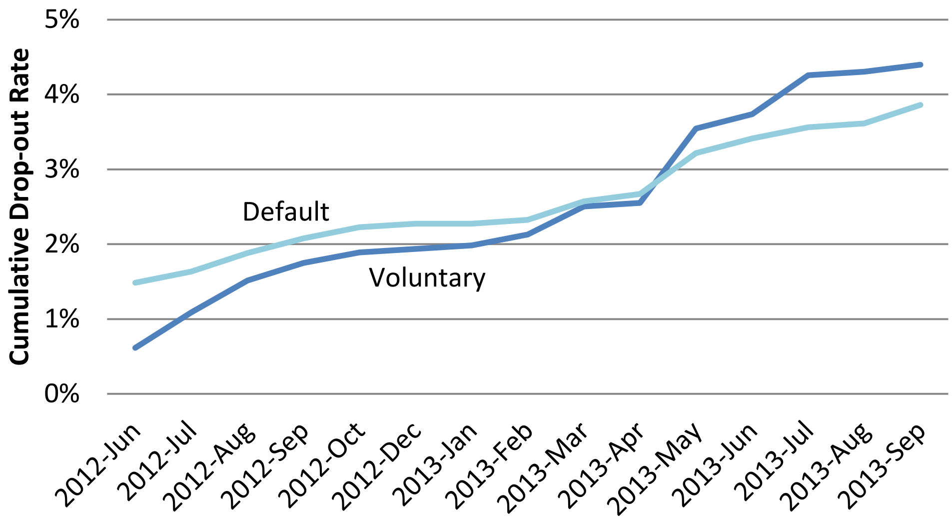

Figure 3. SMUD Drop-out Rates for Default and Voluntary Groups

An analysis of responses to SMUD's End-of-Pilot customer satisfaction survey found little difference between survey respondents who volunteered and those who were defaulted onto the rate concerning difficulties faced when adapting to the new rates.[19] However, default customers were more likely to indicate that they didn't understand or know about the new rates compared to those who volunteered. This may provide part of the explanation of why retention rates were higher for the default TOU group – they didn't bother to read the material SMUD sent indicating they were to be defaulted onto this new rate as part of a study. It is worth pointing out that this lack of awareness does not necessarily mean that customers were unhappy with being defaulted onto the rate. It is possible that they received the

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[18] Attrition was measured relative to the size of the enrolled group as of June 1st, 2012 (the effective date of the study's rates).

[19] A copy of the End-of-Pilot customer satisfaction survey instrument as well as the results of its administration can be found in Appendix G of SMUD's final evaluation report (Potter et al., 2014).

information from SMUD, spent very little time reading that material only to decide that they were basically indifferent about being on the new or old rate. In essence, these customers may have been decided that it wasn't worth any additional effort to make themselves more aware of the details at the time of enrollment, but also not worth attempting to get off of the rate during the study.

2.4 Experiences with Customer Load Impacts

As may have been expected, the average customer response rates were lower for customers defaulted onto the TOU rate than for those who volunteered.[20] As shown in Figure 4, average peak period demand reductions per household for volunteers were about three times larger than for those defaulted onto the rate (16.7% vs. 5.8%; the difference is statistically significant, and each estimate on its own is statistically significant).

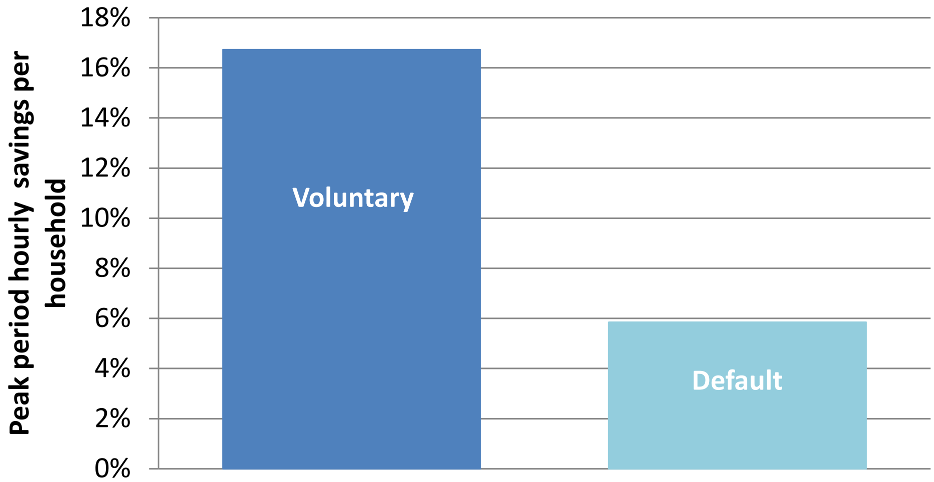

Figure 4. SMUD Average Peak Period Savings Estimates for Default and Voluntary Groups

SMUD was not only interested in the level of average response from the default and voluntary groups but also what level of aggregate response would occur if such opportunities were made available to the entire residential class. The per household estimated results can therefore be used to extrapolate the level of peak period demand reduction that could occur if TOU was made the default for all roughly 545,000 of SMUD's residential customers vs. if

[20] See Appendix C for more details on the econometric load impact analysis.

all roughly 545,000 of SMUD's residential customers were asked to opt-in to a voluntary TOU rate.[21] Under this scenario, the larger number of customers who enrolled and responded under default recruitment more than outweighs the larger per customer response of the smaller number of volunteers. As shown in Figure 5, a default TOU rate applied across the SMUD service territory would produce 5.7% (58.2 MW) aggregate peak period load reduction while a voluntary TOU offering would only produce 3.3% impact (33.2 MW).

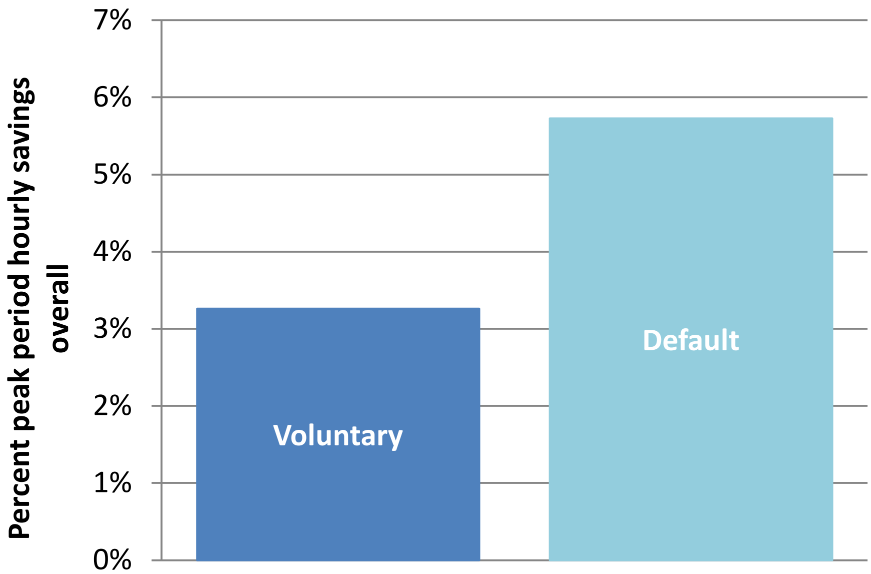

Figure 5. SMUD Aggregate Peak Period Savings Projections by Enrollment Approach for 545,000 Residential Customer Population

SMUD's survey of default and voluntary participant groups show that the vast majority of survey respondents indicated that it was not difficult to make changes in their electricity consumption patterns in response to the TOU rate. Figure 6 shows the percentage of survey respondents that undertook various actions to lower their peak period electricity usage. For nearly every action, a larger share of those who volunteered for the rate stated they undertook the action than those who were defaulted onto it. However, a majority of both types of customers who responded to the survey indicated they undertook relatively simple load shifting behaviors, such as adjusting when they did their laundry and dish washing to

[21] The average monthly residential customer count for 2015 in SMUD's service territory was 546,155. To simplify the calculations, we chose to round this down to 545,000 customers.

off peak times. In addition, well over 35% of those survey respondents defaulted onto the rate and over 48% of those who volunteered undertook actions to reduce or eliminate air conditioning use during the peak period, steps which were likely to produce much more significant peak electricity savings. [22]

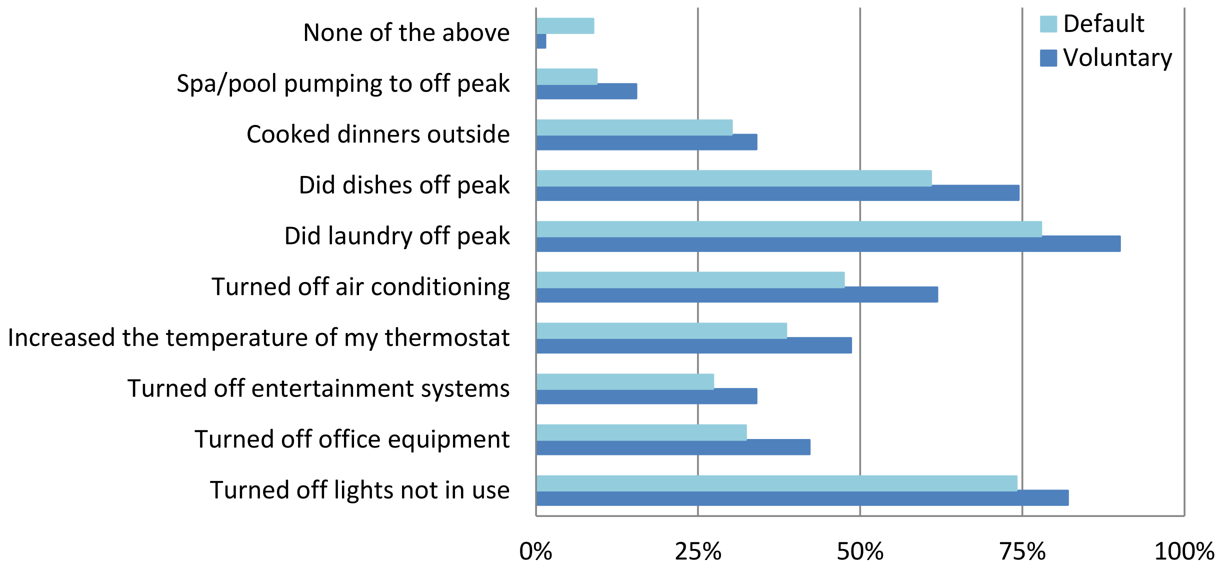

Figure 6. SMUD Survey Responses of Actions Taken by Study Participants to Lower Electricity Consumption During Peak Hours

2.5 Experiences with Customer Bill Savings

When taking service under TOU rates, the timing of when customers consume electricity matters for electricity costs and bills, whereas on flat or inclining block rates it does not. Because rates are typically designed for the average customer's load shape, moving from flat or inclining block rates to TOU rates will likely make some customers' bills larger. However, the converse is also true; those customers who consume less electricity during peak periods than the average customer may experience lower bills under a TOU rate. In SMUD's study, a larger share of customers with higher peak period consumption than the average were

[22] Note that the results from the End-of-Pilot customer satisfaction survey must be interpreted carefully as they are contingent on the subpopulation that responded to the survey. In addition, this response rate differed (not surprisingly) between the default (28.4% responded) and voluntary (45.0% responded) groups. This means that the survey responses may not reflect the experiences of the least engaged and attentive customers in general, which is more of a factor for the default group than the voluntary group.

solicited to join the study, both under default and voluntary enrollment approaches.[23] Because of this, the average customer, in both the default and voluntary treatment groups, were both expected to be slightly worse off financially from taking service under the rate, based on an analysis of their meter data from the summer prior to the start of SMUD's CBS applied to the study's TOU rate (see Table 2). Specifically, bills were expected to rise by 1.8 and 1.9% for those who volunteered or were defaulted onto the rate, respectively (i.e., -1.8% and -1.9% bill savings).[24]

Table 2. Predicted Bill Savings Absent Customer Response to TOU Rate and Actual Bill Savings in Response to the TOU Rate

	Predicted % Savings (using pre-treatment energy usage)	Actual % Savings (using post-treatment bills)
Default Rate	-1.9%	1.8%
Voluntary Rate	-1.8%	2.6%

Once exposed to TOU rates, customers were likely to reduce consumption in high-priced peak periods and potentially shift it to lower priced off-peak periods. As illustrated in Table 2, both the average default and average volunteer participant attained no measurable bill losses during the study relative to the control group – suggesting that on average customers took sufficient action to shift usage from the higher priced period to the lower priced period to offset the initially predicted bill losses from changing to the TOU rate.[25]

2.6 Experiences with Cost Effectiveness

With lower recruitment costs and higher *aggregate* demand reductions under default enrollment approaches, SMUD's cost-effectiveness analysis showed higher benefit-cost ratios and 10-year net present value for default versus voluntary enrollments, as shown in Table 3.

[23] SMUD randomly assigned customers from their eligible residential class to be solicited to join either the voluntary or default study. As such, this result is not representative of some systematic effort on the part of SMUD to choose such a skewed study population, but rather due to random chance.

[24] This finding was surprising as SMUD's rate was designed to be revenue neutral to the class average customer.

[25] It is worth noting that only the Actual % Savings estimate for the default group was statistically different from zero. So, in essence, there were no measurable bill savings or losses for the average customer in the Voluntary group.

Table 3. SMUD Cost Effectiveness Results by Enrollment Approach[26]

Enrollment Approach	Benefit-Cost Ratios	10-year Net Present Values ($M)
Voluntary	0.74	- $5.50
Default	2.04	+ $34.10

[26] See Potter et al. (2014).

3. Understanding Customer Subpopulations

In totality, the results of our analysis show that the average residential customer defaulted onto SMUD's TOU rate responds to the rate and doesn't experience any measurable bill losses. However, this average result masks substantial diversity in responses to new rates and the underlying customer preferences. In fact, one of the main concerns about defaulting all residential customers onto TOU is that certain subpopulations will be adversely affected.

Here we define three subpopulations of customers that can help clarify thinking about who might possibly be made better off or might be at risk of being worse off due to default TOU rates:

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

We assume that the people who opt in to a voluntary TOU rate would be likewise expected to not opt out initially if defaulted onto the rate. Thus, we believe that the way in which these ***Always Takers*** enroll in the TOU rate would 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 to the voluntary rate.

In addition, there is a subpopulation of customers who prefer their existing rate over a TOU rate. These customers will not opt in when solicited to voluntarily take up the TOU 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 TOU 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.

Figure 7 shows a breakout of the estimated proportions of these three subpopulations in SMUD's study. In using SMUD data to analyze these subpopulations, it was necessary (but reasonable from our standpoint) to assume that the group of Always Takers observed in the voluntary enrollment experimental design 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.

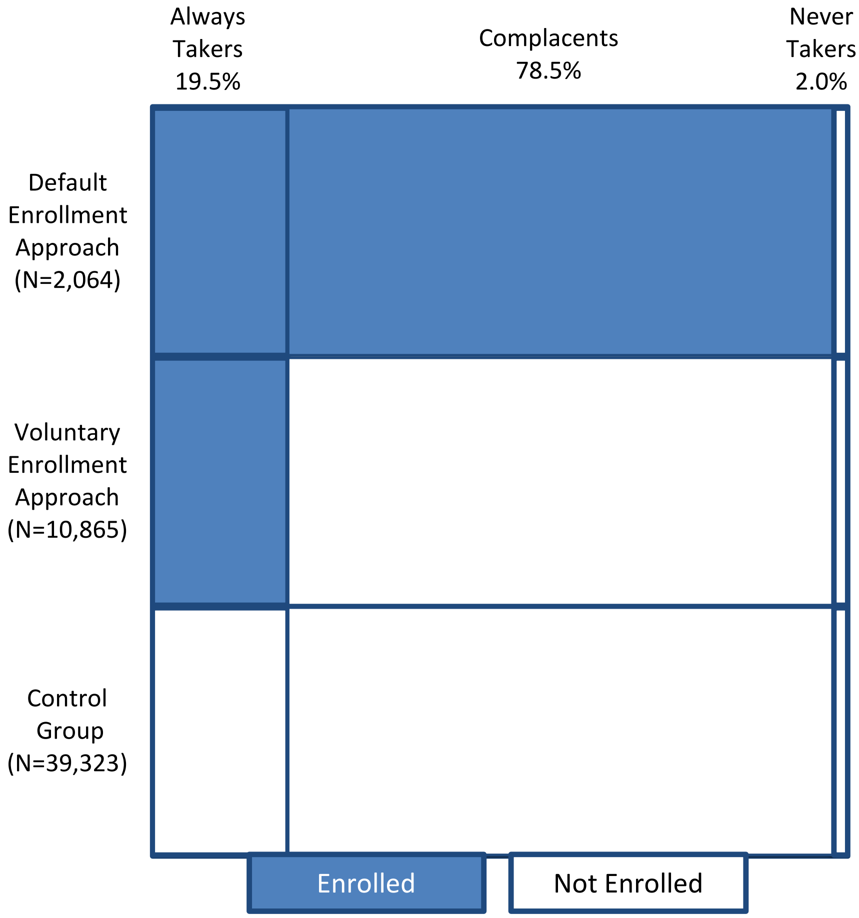

Figure 7. SMUD Residential Customer Subpopulations for Analyzing Voluntary vs. Default Enrollment

Key potential concerns one might anticipate ex-ante for the Complacent customer subpopulations under default TOU rates can be defined as follows:

- **Concerns regarding customer retention**– Complacents may not opt out initially, but once exposed to the rate, they may be more likely to drop out compared to Always Takers;

- **<u>Concerns regarding customer response</u>**– Complacents may be unlikely to respond as much (if at all) as compared to Always Takers; and
- **<u>Concerns regarding customer bill impacts</u>**– Complacents may be more likely to experience detrimental bill impacts as compared to Always Takers, if they have a more limited response.

In the following subsections we examine these three concerns in turn.

3.1 Concerns Regarding Customer Retention

One of the key concerns involves Complacents dropping out at higher rates than Always Takers. Figure 8 provides a breakdown of the drop-out rate for Always Taker and Complacent subpopulations through the course of the study and depicts a very different story. Complacents did drop out at a slightly higher rate over the first summer. However, at the beginning of the second summer we see that the rate of drop-outs for Complacents stayed relatively constant while this rate increased for Always Takers. This resulted in a larger share of Always Takers (observed to be 4.4%) dropping out overall compared to Complacents (estimated to be 3.7%).

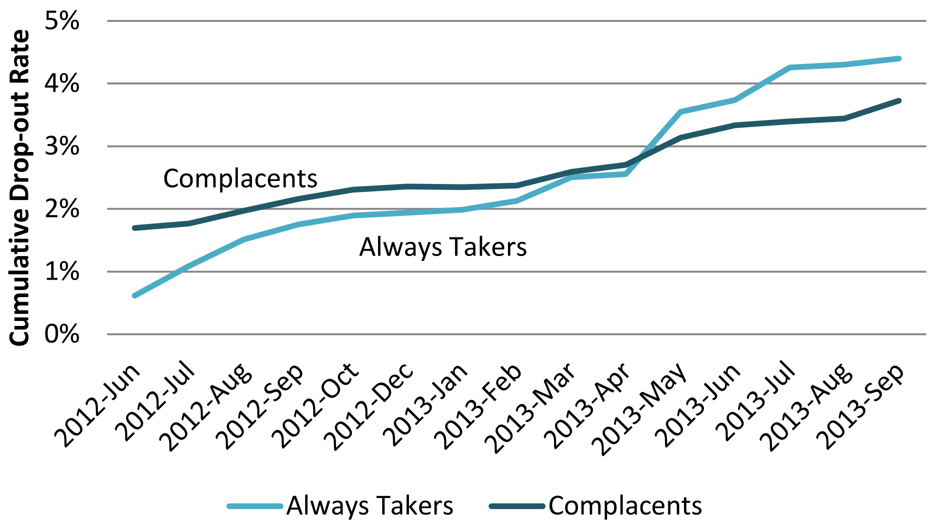

Figure 8. SMUD Drop-Out Rates by Customer Subpopulation

One explanation for this finding is that the majority of Complacents may have been satisfied with the new TOU rate once they gained experience with it. According to SMUD's End-of-Pilot customer satisfaction survey, the vast majority of survey respondents in all groups said they were generally satisfied with the new rate. A majority also indicated that they would want to stay on the new TOU rate going forward. Of survey respondents, a somewhat higher percentage of Complacents said that they did not want to stay on their TOU pricing plan (12% of Complacents vs. 6% of Always Takers who responded to the survey). In general we can conclude that, contrary to expectations, defaulting Complacents onto a TOU rate did not automatically mean high levels of dissatisfaction and in some instances seemed to actually increase satisfaction levels when customers were exposed to and understood how to use the new rate to their advantage.

However, SMUD's survey also provided evidence that Complacents were:

- Less likely to respond to the survey;
- Less likely to recognize the new TOU rates and more likely to say they were not sure about their rate when asked;
- Less likely to recall receiving the "Welcome Back" package of information from SMUD in the mail; and
- Much more likely to check the "neutral" box to most survey questions when given the option.

These survey responses (or lack thereof) suggest a few different potential reasons for the relatively low drop-out rates for Complacents. First, Complacents may have decided early in this process that it wasn't worth the mental energy and time to carefully analyze all the material sent by SMUD. These people may have learned enough from the limited time they spent reviewing the material to know they were basically indifferent to the new rate they were being put on. Thus, they were never motivated to leave the rate even though they may not have understood many of its details. Alternatively, Complacents might have decided, after their cursory perusal of the marketing material, that they didn't like the new default rate but then decided it wasn't worth the time and mental effort to get out of the study. Maybe they never got around to determining how to navigate the opt-out process or got that information but never followed through on it. Lastly, Complacents may not have been engaged enough to read any of the material sent by SMUD concerning the study and the rate transition. As such, these Complacents never attempted to get off the rate simply because they didn't know they were on it to begin with.

3.2 Concerns with Customer Response

With the potential lack of engagement, interest, and understanding among some Complacents when defaulted onto time-based rates, lower average per-customer demand reductions from them were expected.[27] Figure 9 confirms this and shows average percentage demand reductions were around five times larger for Always Takers (16.7%) as compared to Complacents (3.1%) on average across both summers of the study. The result indicates that the average Always Taker reduced their peak period hourly consumption by an estimated 18.2% on average in the first summer, while the average Complacent reduced their peak period hourly consumption by an estimated 3.4% in the first summer on average.[28] Interestingly, when comparing the impact estimates between the first and second summer of the study, we see that Always Takers peak period savings attenuated, dropping to 14.7%, resulting in a difference between the two summers that is statistically significant. On the other hand, Complacents basically maintained their level of peak period savings between the two summers (they dropped from 3.4 to 2.9% savings, but this difference is not statistically significant). This suggests that possibly the more sizable actions taken by Always Takers ended up feeling like too much over time and they eventually relaxed their efforts, while Complacents tended to take more modest actions that they were more likely to maintain.

[27] See Appendix C for more details about the econometric load impact analysis.

[28] This effect size for the Complacents in the first summer was small but statistically significant.

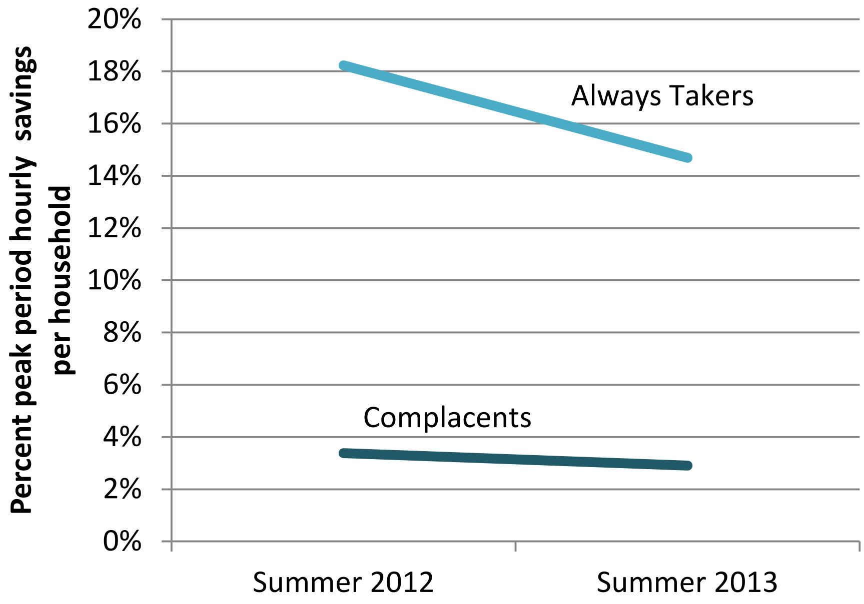

Figure 9. SMUD Average Peak Period Demand Reductions by Customer Subpopulation

From the utility's perspective, it is the aggregate demand reductions for the entire group of customers that were originally encouraged and marketed to that matters most. In the scenario discussed previously where all ~545,000 of SMUD's residential customers are defaulted onto a TOU rate, Figure 10 shows that the entire group of Complacents would provide about 2.4% (24.8 MW) of demand reductions during peak periods, while the entire group of Always Takers would provide an additional 3.3% (33.2 MW).

Collectively, these results suggest that while some Complacents may be less likely to be engaged, interested, and knowledgeable about the rate, a sizable number understood the rate well enough, were willing and able to change their consumption patterns of electricity in direct response to the default TOU rate design, and were seemingly satisfied with doing so.

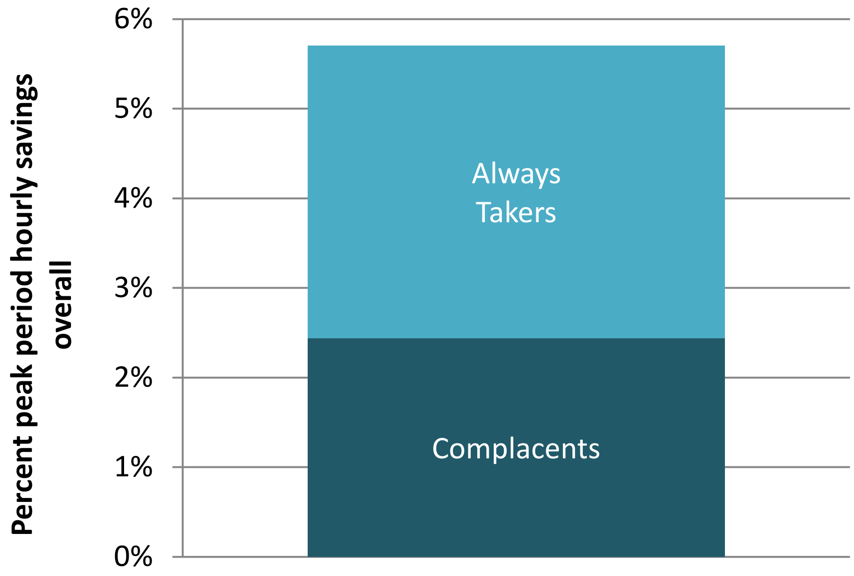

Figure 10. Aggregate Peak Period Demand Reductions by Customer Subpopulation if All of SMUD's Residential Customers were Defaulted onto TOU

3.3 Concerns with Customer 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.[29] 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 collected prior to the commencement of the study 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 11. 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 over an entire summer

[29] In fact, SMUD did not provide any customer-specific information about bill impacts during the recruitment phase of the study, nor did it provide any bill comparison tools during the study so customers could readily identify financial savings due to their participation.

on their bills in total. If that range is 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 whole summer would capture a majority (66% and 67%, respectively) of both Complacent and Always Taker subpopulation. 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 were likely not a key driver in the choice to participate in the study.

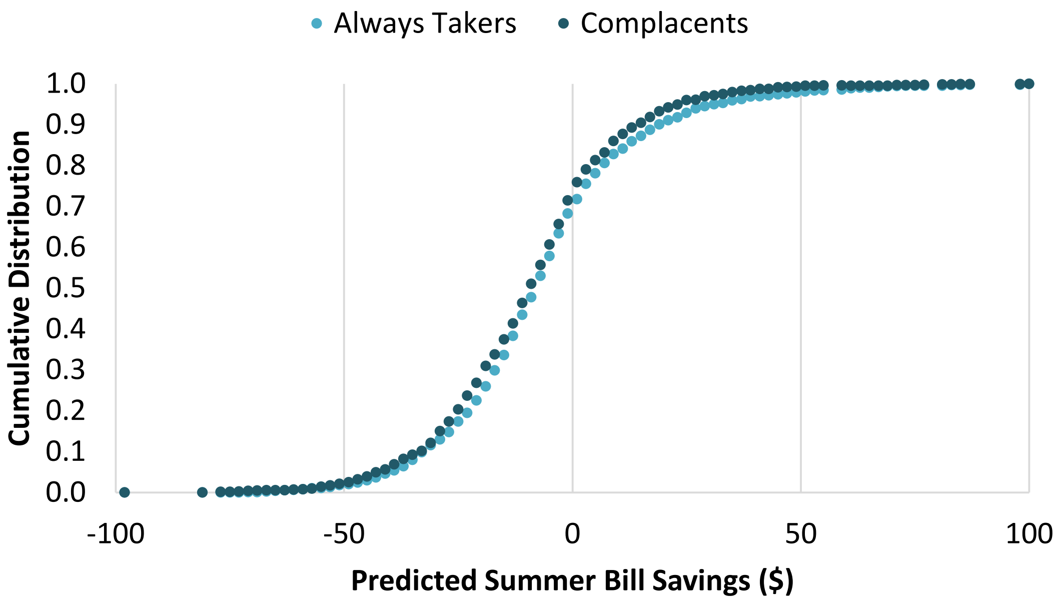

Figure 11. Distribution of Predicted SMUD Summer Bill Savings by Customer Subpopulation[30]

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 12 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

[30] Note that for the purposes of Figure 11 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.

(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.[31] One possible explanation for this is 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.

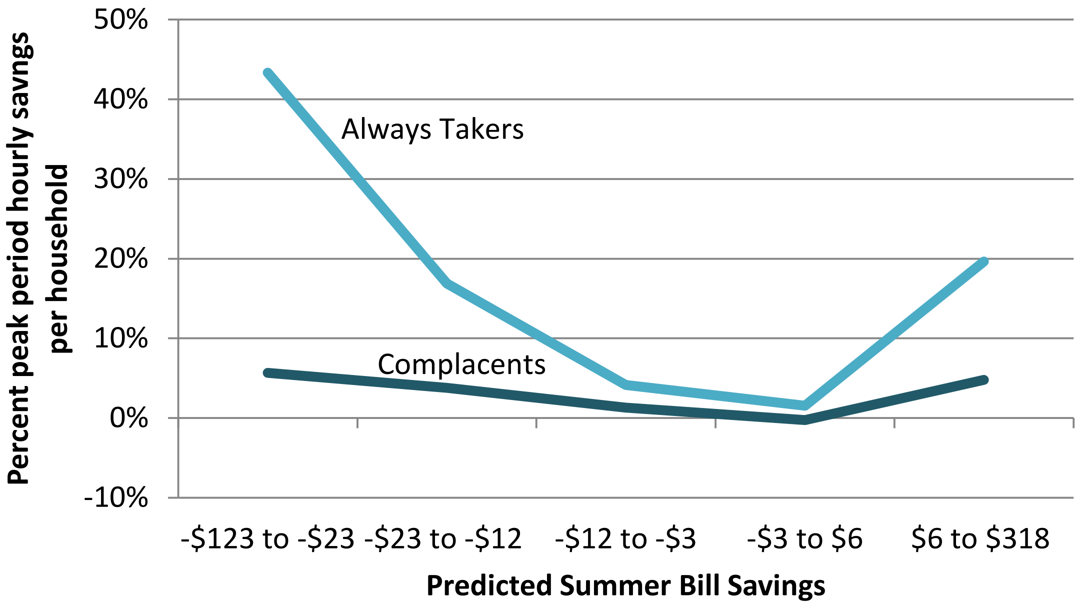

Figure 12. SMUD Peak Period Load Impacts by Customer Subpopulation and Quintile of Predicted Summer Bill Savings

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 4, did not appear to be a major factor in how satisfied customers were with the default TOU rate, once exposed to

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[31] See Appendix C for information on which peak electricity savings estimates are statistically significantly different across the quintiles of predicted bill savings for the Complacents and Always Takers.

it.[32] 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.

In contrast, there does appear to be a relationship between the size of the predicted bill savings and the degree to which Complacent customers were interested in continuing with the rate, but a rather limited relationship between bill savings and satisfaction 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. However, those who were predicted to lose 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 levels of satisfaction with the default TOU rate that increased as the size of the predicted bill savings dropped. One possible explanation for this result is 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 if the response required to capture bill savings were higher, the willingness and interest in responding was higher. This heightened ability to manage and/or control their bills may have been viewed positively, especially for those with the most to gain from doing so.

[32] No standard errors were developed as part of the analysis that relies on values in Table 4. Thus, the conclusions drawn in this section are based on a numerical comparison of these values, not a statistical one.

Table 4. Share of SMUD Survey Responses by Customer Subpopulation and Predicted Summer 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%

3.4 Identifying Inattentive Complacents

While it is difficult to directly identify which customers are attentive or not, proxies for attentiveness can be derived. In particular, utilities know whether or not a customer has ever actively volunteered for one of their programs. By constructing a proxy for attentiveness through identifying all the customers who: a) participated in one of SMUD's programs in the past; b) responded to the End-of-Pilot survey; and/or c) all customers who hooked up their in-home display as part of SMUD's study, it is possible to construct a potential estimate of the size of the attentive complacent population. Using this approach, 75% of Complacents were considered attentive and engaged. This proxy can be used to segment the Complacent subpopulation. In so doing, this definition of attentiveness can be used to see if estimated load impacts are different, which would serve as a test of the validity of this proxy. The results of such an analysis shows that, assuming the inattentive Complacents did not respond to the TOU rate (as one might expect), the attentive Complacents would have provided greater peak period load response than the overall Complacent population (about 5% vs. 3%

electricity savings). Taken in total, these results suggest that a reasonable estimate of the size of the inattentive complacent population is 25% of the overall Complacent population (which constitutes 20% of the entire SMUD population).

4. Summary of Major Findings and Conclusions

This analysis suggests that many of the previously stated concerns by consumer advocates and other industry stakeholders about a transition of residential customer to a default TOU rate did not materialize, based on experiences from SMUD's consumer behavior study. Customers defaulted onto a TOU rate initially stayed where they were placed at unexpected levels, as about 98.0% did not opt out. Once on the rate, these customers did not leave in large numbers as might have been expected; 3.9% dropped out during the study period in total. Instead, a larger share of them remained on the new rate through the end of the study than their counterparts who volunteered to participate (4.4% of whom dropped out in total). In spite of the lower per-customer demand reductions, which was expected for defaulted customers, the average defaulted customer did respond to the rate by altering their consumption of electricity to the TOU rate in a statistically significant fashion resulting in peak period demand reductions of about 5.7%. When taken in aggregate for a similar population of customers who were originally solicited to participate, SMUD's TOU rate offering was more cost effective under a default enrollment approach than a voluntary one by almost 3 to 1, in part because of lower recruitment costs.

Yet, these overall results mask the variety of underlying customer experiences across several different subpopulations. For example, there was a subgroup of residential customers that would have opted in to a voluntary TOU rate and if defaulted into the same rate would not have dropped out. This subpopulation of Always Takers should not be of particular concern to policy and decision makers as they are able to express their preferences and act on them. Likewise, the subpopulation of SMUD customers that decided to opt out of the default TOU offering (i.e., Never Takers) were following their preferences and, as such, should also not be of particular concern to policy and decision makers.[33] This leaves the remainder of the residential class – those customers who would not have opted in to the voluntary TOU rate but yet did not opt out when defaulted onto the rate. It is these Complacents that regulators, policymakers, advocates and utilities need to understand better.

The analysis in this report suggests that, as a group, Complacents were less engaged, attentive, and informed than the other two subpopulations. There was certainly some subset of the Complacent population who were fully aware of the rate, engaged enough with it to

[33] Under a default enrollment, these customers would need to go through the opt-out process which is an additional level of effort they avoid under voluntary enrollment approaches.

undertake some substantial changes in behavior to respond to it in order to achieve bill savings and were generally satisfied with their experience with the study and the rate. But another subset of Complacents may have been largely indifferent about the rate, not particularly concerned about being defaulted onto it, expended a modest level of effort to respond to the rate and were satisfied enough with it to keep taking service under it after the study ended, provided they didn't see large bill increases. These customers were also likely better off for having been defaulted onto the rate, or at least not worse off. Lastly, there was a subset of customers who likely were highly inattentive and unengaged. We estimate the size of this group to be around 25% of the Complacent population, which represents 20% of the full residential customer population. They were more likely to be unaware of the rate SMUD had transitioned them to, which also helps, in part, to explain the very low attrition rates and also low average per customer peak period response rates. In this case, contrary to the others, it is possible that these inattentive Complacents were worse off for having been defaulted onto the rate.[34]

This suggests that it is not the entirety of SMUD's residential customers or even the share of residential customers that are Complacents who are at-risk of being made worse off during a transition to default TOU, but rather a minority subset of the latter. For utilities and states considering a transition to default TOU, it is this subpopulation of customers who are potentially at risk of being made worse off that requires the greatest consideration. The likelihood of a successful transition could improve if utilities and others consider the needs of this subpopulation of inattentive Complacents. Ideally, utilities could identify customers who are more likely to be highly inattentive before the transition to default TOU is even announced. For example, utilities could create proxies, as described in the previous section, for the level of a customer's attentiveness and engagement. Customers that seem to be less attentive and less engaged could be targeted by the utility for more direct and non-traditional communication strategies. In addition, utilities could use focus groups or other types of market research to determine the best ways to reach inattentive customers so that they can be made aware of the transition, better understand their options, and more easily navigate the opt-out process if they don't want to make the transition.

[34] Although even some of these inattentive Complacents could have captured bill savings absent any change in their electricity consumption suggesting they may have actually been better off.

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Appendix A: Background on SGIG Consumer Behavior Studies

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 includes more than 60 projects that involve AMI deployments with the aim of improving operational efficiencies, lowering costs, improving customer services, and enabling expanded implementation of time-based rate programs.[35]

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 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.

A.1 Scope of the CBS Projects

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, critical peak rebates (CPR), and variable peak pricing (VPP).[36] 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

[35] When the SGIG program is completed in 2015, SGIG will have helped to deploy more than 15 million new smart meters, which represents about 23% of the 65 million smart meters that industry estimates will be installed nationwide. At that point, smart meter deployment is estimated to comprise about 45% of the electric meters in the United States.

[36] Technically, CPR is not a time-based rate; it is an incentive-based program. However, for simplicity of presentation in Table A-1, it is classified with the other event-driven time-based rate programs.

customer systems, based on the specific objectives of their SGIG projects and consumer behavior studies (see Table A-1). 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. Table A-1 provides a summary of the scopes of the CBS projects.

Table A-1. Scope of CBS Projects

	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)

A.2 DOE Guidance on CBS Projects

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.[37] 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.[38] The guidance documents identified key statistical issues such as the desired level of customer participation, which is 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

[37] 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.

[38] 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 treatment are considered to be in the treatment group. For more information, see Cappers et al. (2013)

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.[39]

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.

[39] 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.

Appendix B: Background on SGIG Consumer Behavior Studies

B.1. Overview

Sacramento Municipal Utility District (SMUD) is a summer peaking municipal electric utility with ~625,000 customers in its ~900 square mile service territory that covers much of the Sacramento, CA metropolitan area. SMUD's SGIG project (SmartSacramento) includes a consumer behavior study that evaluates customer acceptance and response to enabling technology combined with various time-based rates under different recruitment methods. The utility is targeting AMI-enabled residential customers across the entire service territory to participate in the study.

B.2. Goals and Objectives

This study focuses on evaluating the timing and magnitude of changes in residential customers' peak demand patterns due to exposure to varying combinations of enabling technology, different recruitment methods (i.e., opt-in vs. opt-out), and several time-based rates. SMUD is also interested in learning about customer acceptance of the different time-based rates under the alternative recruitment methods.

B.3. Treatments of Interest

Rate treatments include the implementation of three time-based rate programs in effect from June through September: a two-period TOU rate that includes a three-hour on-peak period (4 - 7 p.m.) each non-holiday weekday; a CPP overlaid on their underlying tiered rate; and a TOU with CPP overlay (TOU w/CPP) (see Table B-1). Customers participating in any CPP rate treatments receive day-ahead notice of critical peak events, called when wholesale market prices are expected to be very high and/or when system emergency conditions are anticipated to arise. CPP participants will be exposed to 12 critical peak events during each year of the study.

Control/information technology treatments include the deployment of IHDs. SMUD is offering 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.

Table B-1. SMUD CBS Rate Design (¢/kWh)

Period	CPP	TOU	TOU-CPP
Base (< 700 kWh)	8.51		
Base (> 700 kWh)	16.65		
Off-Peak (< 700 kWh)		8.46	7.21
Off-Peak (>700 kWh)		16.60	14.11
Peak		27.00	27.00
Critical Peak	75.00		75.00

B.4. Experimental Design

Due to the variety of treatments, the study includes three different experimental designs: randomized controlled trial (RCT) with delayed treatment for the control group, randomized encouragement design (RED) and within-subjects design (see Figure B-1).

In all three cases, AMI-enabled residential customers in SMUD's service territory are initially screened for eligibility and then randomly assigned to one of the seven treatments or the RED control group.

For the two treatments that are included in the RCT "Recruit and Delay" study design, customers receive an invitation to opt in to the study where participating customers receive an offer for a specific treatment. Upon agreeing to join the study, customers are told if they are to begin receiving the rate in the first year of the study (i.e., June 2012) or in the summer after the study is complete (i.e., June 2014).

For two of the three treatments that are included in the RED, customers are told that they have been assigned to a specific identified treatment but have the ability to opt out of this offer. Those who do not opt out receive the indicated treatment for the duration of the study. Those who opt out are nonetheless included in the study's evaluation effort but do not receive the indicated treatment. For one of the three RED treatments, customers receive an invitation to opt in to the study where participating customers receive a specific treatment. Customers that opt in are then assigned to receive the treatment in year 1 of the study (i.e., 2012).

For the two treatments that are included in the within-subject design, customers are told they have been assigned to either the Block w/CPP treatment or the TOU w/CPP treatment with technology.[40] In the former case, customers only have the ability to opt in to this specific treatment. In the latter case, customers only have the ability to opt out of this specific treatment.

[40] The within-subjects method was designed to use no explicit control group; instead it estimates the effects of the treatment for each participant individually, using observed electricity consumption behavior both before and after becoming a participant in the study as well as on critical peak event and non-event days. However, the control group selected for the RED design may be used as a control group.

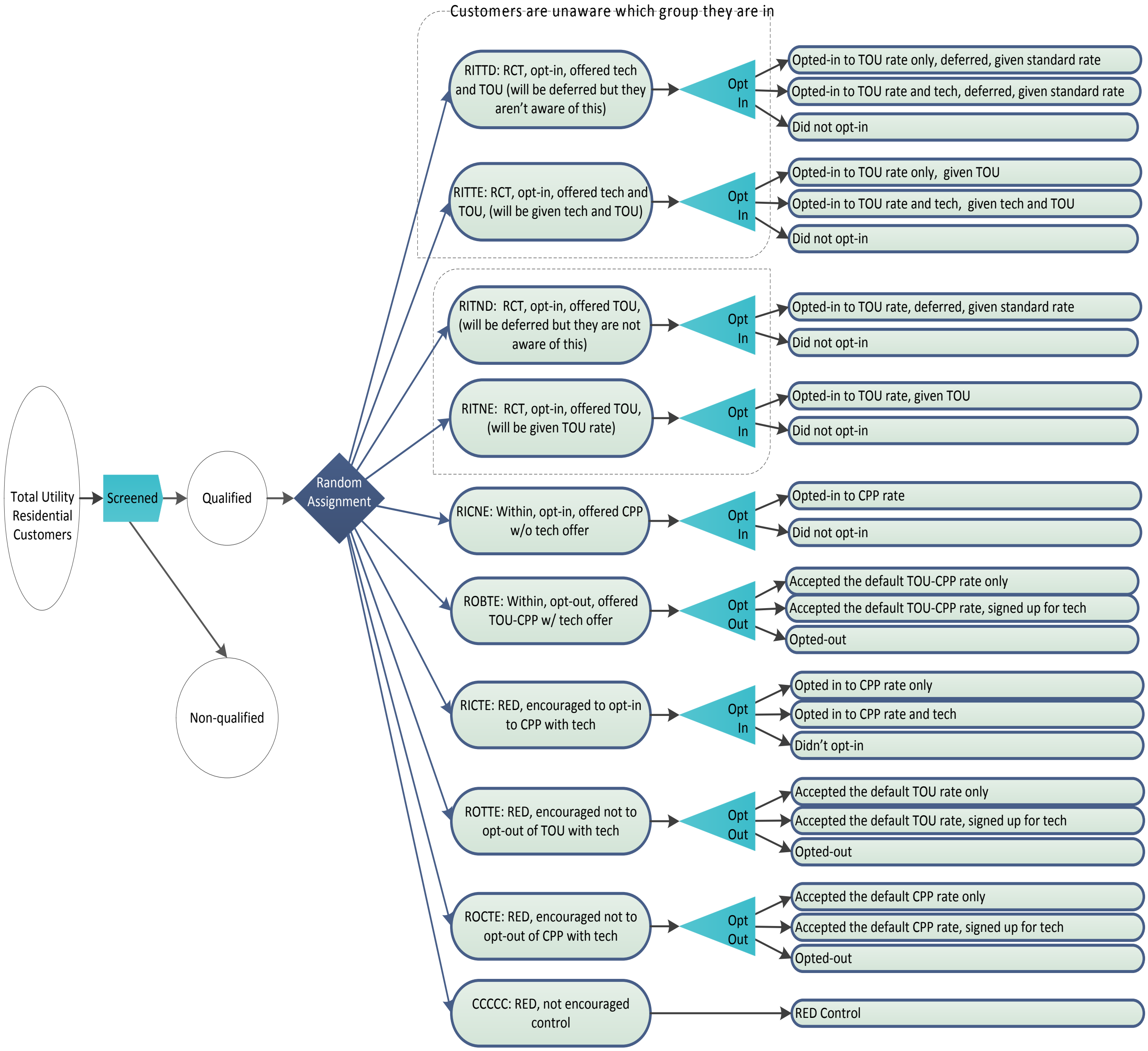

Figure B-1. SMUD Recruitment Process

Appendix C: Data Analysis and Methods

C.1. SMUD Average Peak Period Load Impacts for Default (Complacents + Always Takers), Voluntary (Always Takers), and Complacent Groups

The average peak period load impacts estimates for the two treatment groups (Default and Voluntary) were estimated using a difference-in-differences (DID) instrumental variables (IV) regression using Two-Stage Least Squares (2SLS). While whether or not a household actually experiences the study TOU electricity rates is not random (because of self-selection in or out of treatment), the assignment to a treatment group is random. We can therefore use *assignment* to treatment (or "encouragement" as it's known in the literature) as an instrument for *actual* treatment (i.e., exposure to the treatment time-of-use rate).

A separate regression is run for each treatment group (Default or Voluntary). We instrument for T_{it} with randomized assignment (or encouragement) to treatment indicator A_{it}.

$$T_{it} = \delta A_{it} + \gamma_i + \tau_t + e_{it} \qquad (1)$$

T_{it} is an indicator variable is equal to one starting on June 1st, 2012 if household i was actually enrolled in treatment and remained in the treatment group at time t, zero otherwise. A_{it} is an indicator variable equal to one starting on June 1st, 2012 if household I was encouraged to be in one of the treatment groups (random assignment to treatment), zero otherwise. The predicted values $\hat{T}_{it}$ are then used in Equation (2).

The estimating equation we use to derive the estimates in Table C1 is as follows:

$$y_{it} = \beta \hat{T}_{it} + \gamma_i + \tau_t + \varepsilon_{it} \qquad (2)$$

The variable y_{it} is hourly electricity consumption for household i in hour t; $\hat{T}_{it}$ are the predicted values generated from the regression shown in equation (1); γ_i is a household fixed effect;[41] τ_t is an hour of sample fixed effect[42]; and ε_{it} is the error term assumed to be distributed IID normal across households. In order to account for serial correlation across time observations within households, we clustered the standard errors of the estimates at

[41] In the tables that follow which show the output from the econometric analysis, the row titled "Household Fixed Effects" with a value of "Yes" indicates when these household-level fixed effects were applied.

[42] In the tables that follow which show the output from the econometric analysis, the row titled "Hour of Sample Fixed Effects" with a value of "Yes" indicates when these hour of sample fixed effects were applied.

the household level. The data used are peak hour consumption (4 pm to 7 pm) on non-holiday weekdays in both treatment summers (2012 and 2013) and in the pre-treatment summer (2011). Households in both the treatment groups and the control group are included. Coefficient β captures the average hourly treatment effect per household.

The estimates generated using this methodology for the Voluntary treatment group are shown in the first column of Table C-1. The estimates for the Default treatment group are shown in the second column of Table C-1. The third column of Table C-1 shows the estimated treatment effect of the Complacents, as isolated from the Always Takers within the Default treatment group, and was estimated using a similar, but slightly different regression.

To estimate the treatment effect for the Complacent group a regression was done using all the households from both the Voluntary treatment group and the Default treatment group (the Control group was omitted from this regression). The same estimating procedure was used as that shown in equations (1) and (2), however now, the variable T_{it} used in the first stage equation (1) is an indicator variable equal to one starting on June 1st, 2012 if household i was actually enrolled in either treatment group (Voluntary or Default) and remained in the treatment group at time t, zero otherwise. The instrument used (A_{it}) now in the first stage equation (1) is an indicator variable of whether household i was randomly assigned to the Default treatment group, zero otherwise. Therefore, the estimation isolates the effect of being in treatment, conditional on being assigned to the default group, relative to the treatment effect of the Voluntary group. In essence, it backs out the treatment effect of the Voluntary group (the Always Takers) from the treatment effect of the Default group, which includes both Always Takers and Complacents, in order to isolate the treatment effect of the Complacents alone.

Table C-1. SMUD Average Peak Period Load Impacts for Default (Complacents + Always Takers), Voluntary (Always Takers), and Complacent Groups

	Always takers (Voluntary)	Always Takers + Complacents (Default)	Complacents
Treatment Effect	-0.312***	-0.109***	-0.0580**
	(0.0301)	(0.0145)	(0.0190)
Household Fixed Effects	Yes	Yes	Yes
Hour of Sample Fixed Effects	Yes	Yes	Yes
Observations	38,335,801	31,613,593	9,879,234
Number of households	58566	48242	15138
R-squared	0.556	0.558	0.550
Average Hourly Energy Use	1.865	1.865	1.865
Standard errors clustered by household in parentheses			
*** p<0.001, ** p<0.01, * p<0.05			

C.2. Average Hourly Peak Period Demand Reductions Per Household for the Voluntary (Always Takers), Default (Always Takers + Complacents), and Complacent Groups Disaggregated Across the Two Treatment Summers

The treatment effects across the two summers were separated using a regression procedure similar to that described in equations (1) and (2), but allowing for heterogeneity between the two summers. The estimation of these effects for the Voluntary and Default treatment groups is show in equations (3), (4) and (5). Households in both the treatment groups and the control group are included. A separate regression is run for each treatment group (Default or Voluntary). The two first stage regressions are show in equation (3) and (4).

$$(T_{it} * D_{2012,t}) = \delta_{2012}(A_{it} * D_{2012,t}) + \delta_{2013}(A_{it} * D_{2013,t}) + \gamma_i + \tau_t + e_{it} \qquad (3)$$

$$(T_{it} * D_{2013,t}) = \delta_{2012}(A_{it} * D_{2012,t}) + \delta_{2013}(A_{it} * D_{2013,t}) + \gamma_i + \tau_t + e_{it} \qquad (4)$$

In equations (3) and (4), T_{it} is an indicator variable equal to one starting on June 1st, 2012 if household *i* was actually enrolled in treatment and remained in the treatment group at time *t*, zero otherwise. T_{it} is interacted with two indicator variables for the two summers: $D_{2012,t}$ is an indicator variable equal to one if time *t* is in the summer of 2012, zero otherwise, while the indicator variable $D_{2013,t}$ is equal to one if time *t* is in the summer of 2013, zero otherwise. Once again, A_{it} is an indicator variable equal to one starting on June 1st, 2012 if household I was encouraged to be in one of the treatment groups (random assignment to treatment), zero otherwise. The interaction between these indicator variables and the treatment indicator variable is instrumented for with the interaction between these two summer indicator variables and the randomized encouragement to treatment indicator A_{it}, respectively, as shown in equations (3) and (4). The predicted values from equations (3) and (4) of the two terms $(T_{it} \widehat{* D_{2012,t}})$ and $(T_{it} \widehat{* D_{2013,t}})$ are then used in the second stage regression shown in equation (5).

$$y_{it} = \beta_{2012} \, (T_{it} \widehat{* D_{2012,t}}) + \beta_{2013} \, (T_{it} \widehat{* D_{2013,t}}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (5)$$

The variable y_{it} is hourly electricity consumption for household *i* in hour *t*; γ_i is a household fixed effect; τ_t is an hour of sample fixed effect; and ε_{it} is the error term assumed to be distributed IID normal across households. In order to account for serial correlation across time observations within households, we clustered the standard errors of the estimates at the household level. The data used are peak hour consumption (4 pm to 7 pm) on non-holiday weekdays in both treatment summers (2012 and 2013) and in the pre-treatment summer (2011).

The coefficients β_{2012} and β_{2013} capture the average hourly treatment effect per household in the summer of 2012 and the summer of 2013, respectively. The results of this regression for the Voluntary treatment group are shown in the first column of Table C-2, and for the Default treatment group in the second column of Table C-2. The estimates for the Complacent group are done, as in the average treatment effect case shown in Appendix C.1, by using both the treatment groups (Default and Voluntary) and not the Control group in the regression. Again, T_{it} is an indicator of whether household *i* is in treatment at time *t* (whether or not they were assigned to the Voluntary or Default treatment group), while A_{it} is now an indicator of whether household *i* was randomly assigned to be in the Default treatment group. The results for the Complacents are shown in the third column of Table C-2.

Table C-2. Average Hourly Peak Period Demand Reductions Per Household for the Voluntary (Always Takers), Default (Always Takers + Complacents), and Complacent Groups Dissaggregated Across the Two Treatment Summers

	Always Takers (Voluntary)	Always Takers + Complacents (Default)	Complacents
Summer 2012	-0.340***	-0.118***	-0.0616**
	(0.0299)	(0.0144)	(0.0190)
Summer 2013	-0.274***	-0.0969***	-0.0531*
	(0.0397)	(0.0177)	(0.0233)
Household Fixed Effects	Yes	Yes	Yes
Hour of Sample Fixed Effects	Yes	Yes	Yes
Observations	38,335,801	31,613,593	9,879,234
Number of households	58566	48242	15138
R-squared	0.556	0.558	0.550
Average Energy	1.865	1.865	1.865
Standard errors clustered by household in parentheses			
*** p<0.001, ** p<0.01, * p<0.05			

C.3. SMUD Aggregate Peak Period Load Impacts by Recruitment Method for 545,000 Residential Customer Population

The aggregate peak period load impact was estimated by taking the per-household load impact estimates from Appendix C.2, and multiplying them by 545,000*(enrollment rate) for each treatment group. So, for the Voluntary treatment group, the enrollment rate was 0.195, so the aggregate load impact predicted for 545,000 encouraged to treatment was 0.312*545,000*0.195=33,158. This was then converted to a percentage of aggregate hourly energy consumption for 545,000 households (1.865*545,000=1,016,425). This comes out to 3.3%. The same thing was done to calculate this value for the Default treatment group with an enrollment rate of 0.98 and average hourly household treatment effect of 0.109, coming out to 5.7%. You can also determine that the component of that 5.7% generated by the complacent portion of the population within the Default treatment group is 2.4%, while the Always Takers contributed 3.3% to this total savings of 5.7%.

C.4. Predicted Bill Savings Absent Customer Response to TOU Rate and Actual Bill Savings in Response to Rate by Customer Subpopulation

In order to calculate the predicted bill savings over an entire summer, the following was done. Using the standard flat rate structure, the total expenditure on electricity experienced in the pre-treatment summer of 2011 was calculated for each household. Then, this same consumption from the summer of 2011 was used to calculate how much each household would have spent that summer if they had been on the treatment TOU rate, assuming that these households hadn't changed their energy behavior. The predicted savings was calculated by subtracting the hypothetical expenditure each household would have experienced had they been on the treatment rate in 2011 from the actual expenditure they did experience during that summer on the flat rate. Therefore, if this value is positive, it means they paid more on the flat rate than they would have on the treatment rate, assuming no changes in usage. From this exercise, there is a single predicted per-summer savings value for each household. This value was then averaged across the households who enrolled in treatment in each of the treatment groups.

Table C-3. Actual Bill Savings in Response to TOU Rate by Customer Subpopulation

	Voluntary	Default
Treatment Effect	-2.992	-.2.126*
	(2.171)	(0.856)
Household Fixed Effects	Yes	Yes
Month of Sample Fixed Effects	Yes	Yes
Observations	593,018	488,993
Number of households	58,574	48,246
R-squared	0.896	0.896
Standard errors clustered by household in parentheses		
*** p<0.001, ** p<0.01, * p<0.05		

The actual bill savings were estimated using a DID 2SLS regression for the summer of 2012 and 2013 (see Table C-3). The same estimating strategy was used as was described in equation (1) and (2) above. Now, however, the y_{it} variable is the expenditure of household *i* in month *t*. The expenditure was converted from bill cycles to calendar months in order to avoid any systematic discrepancies generated based on differences in bill period start and stop dates across control and treatment groups. This conversion was done by pro-rating the total bill amount, average across all dates in that bill cycle, to each day within that bill cycle. These prorated daily expenditure amounts were then aggregated back up to the calendar month level. The results from this analysis were reported as a percent of average 2012-2013 monthly summer expenditure for the Control group ($116.6).

The distribution of predicted bill savings for the Complacents was calculated by breaking the range of observed bill savings up into $2 increment bins. Within each bin, the share of households assigned to the Voluntary and Default treatment groups appearing in each bin (b) that enrolled ($e_{V,b}$ and $e_{D,b}$, respectively) was calculated; as was the share of households enrolled in the Voluntary and Default treatment groups that appeared in each bin ($s_{V,b}$ and $s_{D,b}$, respectively). The share of Complacents households appearing in each bin that enrolled ($e_{C,b}$) is calculated directly: $e_{C,b} = e_{D,b} - e_{V,b}$.

To clarify the interpretation of these terms let me give an example. Suppose there were a total of 100 households assigned to the treatment group T. For each household, we know whether they enrolled or not, and we know what bin they are in. For simplicity, assume there are two bins (A and B). Assume there are 60 households in bin A, and 40 in bin B. Then, we observe that 30 of the households in bin A enrolled, so in that case $e_{T,A}$=0.50, while only 10 enrolled in bin B, so $e_{T,B}$=0.25. What $s_{T,A}$ captures is the share of those households that enrolled that appear in bin A, so $s_{T,A}$ =30/(30+10)=0.75 and $s_{T,B}$=10/(30+10)=0.25. These values can then be calculated for all the treatment groups. However, one more step is needed to calculate the $s_{C,b}$ values for the Complacent; these shares of enrolled Complacent households appearing in each bin (across the bins) was calculated using the following relationship.

$$s_{C,b} *(e_{C,b}/ e_{D,b})+ s_{V,b} *(e_{V,b}/e_{D,b})= s_{D,b}$$

What this is saying is that the share of all the enrolled Default households that appear in each bin ($s_{D,b}$) is a weighted average of those households that are Always Takers (identifiable as Voluntary treatment group households that enrolled, $s_{V,b}$) and enrolled Complacents (enrolled Default treatment group households that are not Always Takers, $s_{C,b}$), where the weights are determined by the enrolment rates (e) of each of these groups. All of these values are known already except for $s_{C,b}$. You can then solve out the equation for this value for each bin. The shares (s) were then added up cumulatively across all the bins to plot a graph of this cumulative distribution, as shown in Figure 11.

C.5. Drop-out rates of Always Takers and Complacents

The drop-out rates of Always Takers and Complacents were calculated using the same weighted average logic as that just described above in Appendix C.4. If the share of Always Takers that dropped out is known (because we know how many Voluntary enrollees dropped out over the course of treatment), and similarly the share of all the Default treatment group enrollees that dropped out is known, the share of Complacents that dropped out can be calculated using the fact that the Default group is made up of Always Takers and Complacents in proportions that are known based on the enrollment rates. Therefore, the drop-out rate of Complacents (r_C) can be calculated using the following relationship:

$$r_C *(e_C/ e_D)+ r_V *(e_V/e_D)= r_D$$

In this case, all the enrollment rates (e) are known, as are the drop-out rates (r) of the Voluntary (V) and Default (D) groups, so the drop-out rate of Complacents can be solved for. This was done at various points throughout the treatment period.

C.6. Peak Period Load Impacts by Customer Subpopulation and Quintile of Predicted Bill Savings

The energy savings across quintiles of predicted bill savings (defined in Appendix C.4) were estimated using the same regression approach as that presented in equations (3) and (4), only now, instead of estimating two treatment effects, five were estimated. The 2SLS regressions are show in equation (6) and (7). All variables are defined the same as in equations (1) through (5), only now $D_{k,i}$ is an indicator variable equal to one if household *i* is in percentile group *k*, zero otherwise. There are five first-stage regressions (shown in equations (6) through (10)).

$$\left(T_{it} * D_{1,i}\right) = \sum_{k=1}^{5} \delta_k \left(A_{it} * D_{k,i}\right) + \gamma_i + \tau_t + \varepsilon_{it} \quad (6)$$

$$(T_{it} * D_{2,i}) = \sum_{k=1}^{5} \delta_k \,(A_{it} * D_{k,i}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (7)$$

$$(T_{it} * D_{3,i}) = \sum_{k=1}^{5} \delta_k \,(A_{it} * D_{k,i}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (8)$$

$$(T_{it} * D_{4,i}) = \sum_{k=1}^{5} \delta_k \,(A_{it} * D_{k,i}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (9)$$

$$(T_{it} * D_{5,i}) = \sum_{k=1}^{5} \delta_k \,(A_{it} * D_{k,i}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (10)$$

The predicted values from equations (6) through (10) are then used to estimate the second stage regression shown in equation (11).

$$y_{it} = \sum_{k=1}^{5} \beta_k \,(\widehat{T_{it} * D_{k,i}}) + \gamma_i + \tau_t + \varepsilon_{it} \quad (11)$$

The variable y_{it} is again hourly electricity consumption for household *i* in hour *t*; γ_i is a household fixed effect; τ_t is an hour of sample fixed effect; and ε_{it} is the error term assumed to be distributed IID normal across households. In order to account for serial correlation across time observations within households, we clustered the standard errors of the estimates at the household level. The data used are peak hour consumption (4 pm to 7 pm) on non-holiday weekdays in both treatment summers (2012 and 2013) and in the pre-treatment summer (2011).

The coefficients β_1, β_2, β_3, β_4 and β_5 capture the average hourly treatment effect per household for households in percentile 1 (0 – 20th percentile), 2 (20th – 40th percentile), 3 (40th – 60th percentile), 4 (60th – 80th percentile) and 5 (80th – 100th percentile) of predicted bill savings, respectively. The results are shown in Table C-4.

Table C-4. Peak Period Load Impacts by Customer Subpopulation and Quintile of Predicted Bill Savings

	Always takers		Complacents	
Percentile of Predicted Bill Savings	Energy Savings	Standard Error	Energy Savings	Standard Error
0-20th	0.808***	0.0702	0.106***	0.0322
20-40th	0.315***	0.0531	0.0706*	0.0343
40-60th	0.0771	0.0562	0.0241	0.0293
60-80th	0.0291	0.0613	-0.00498	0.0344
80-100th	0.366***	0.07	0.0892*	0.04
Observations	38,335,801		9,879,234	
R-squared	0.556		0.550	
Number of households	58566		15138	
Average Energy	1.865		1.825	
Standard errors clustered at households level				
*** p<0.001, ** p<0.01, * p<0.05				

C.7. Share of Survey Responses by Subpopulation and Predicted Bill Savings

To generate the results shown in Table C-5, households were distributed into seven bins based on their predicted bill savings (defined in Appendix C.4). These bins are: losing more than \$20, losing between \$20 and \$10, losing between \$5 and \$10, gaining or losing no more than \$5, gaining between \$5 and \$10, gaining between \$10 and \$20, or gaining more than

\$20. The share of Always Taker survey respondents in each bin that answered that they were satisfied with the rate or wanted to continue on were measured directly, as those enrolled in the Voluntary treatment are considered Always Takers. Using the same methodology as that described in Appendix C.4 (summarized below), the share of Complacent households that both enrolled in the program and responded to the survey that appeared in each bin ($resp_{C,b}$) was calculated.

$resp_{C,b} * (e_{C,b} / e_{D,b}) + resp_{V,b} * (e_{V,b} / e_{D,b}) = resp_{D,b}$

$e_{V,b}$: share of Voluntary treatment group (Always Takers) in bin *b* that enrolled

$e_{D,b}$: share of Default treatment group (Always Takers and Complacents) in bin *b* that enrolled

$e_{C,b} = e_{D,b} - e_{V,b}$: share of Complacents in bin *b* that enrolled

$resp_{V,b}$: share of households enrolled in the Voluntary treatment group and responded to the survey that appeared in bin *b*

$resp_{D,b}$: share of households enrolled in the Default treatment group and responded to the survey that appeared in bin *b*

$resp_{C,b}$: share of Complacent households enrolled in the program and responded to the survey that appeared in bin *b* (solved for)

Finally, the shares of these respondents that answered that they were satisfied or wanted to continue on the rate in each bin was calculated again in the same way (results shown in Table C-5). For example, the following shows the calculation for the share of Complacent enrolled survey respondents that responded that they were satisfied with the rate ($sat_{C,b}$) in each bin *b*.

$sat_{C,b} * (resp_{C,b} / resp_{D,b}) + sat_{V,b} * (resp_{V,b} / resp_{D,b}) = sat_{D,b}$

$resp_{V,b}$: share of households enrolled in the Voluntary treatment group and responded to the survey that appeared in bin *b*

$resp_{D,b}$: share of households enrolled in the Default treatment group and responded to the survey that appeared in bin *b*

$resp_{C,b}$: share of Complacents households enrolled in the program and responded to the survey that appeared in bin *b* (solved for in prior step)

$sat_{V,b}$: share of households enrolled in the Voluntary treatment group, responded to the survey, and said that they were satisfied with the rate that appeared in bin *b*

$sat_{D,b}$: share of households enrolled in the Default treatment group, responded to the survey, and said that they were satisfied with the rate that appeared in bin *b*

$sat_{C,b}$: share of Complacent households that were enrolled in the program, responded to the survey, and said that they were satisfied with the rate that appeared in bin *b* (solved for)

Table C-5. Share of Survey Responses by Customer Subpopulation

Predicted Monthly Bill Savings ($)	Average Share of Respondents Satisfied w/ Rate		Average Share of Respondents Interested in Continuing with the TOU Rate	
	Always Takers	**Complacents**	**Always Takers**	**Complacents**
<-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%
> 20	82%	53%	94%	92%