# SMUD's Residential Summer Solutions Study 2011-2012

*A 2-year investigation of the effects of dynamic pricing, customer-programmed thermostat automation, utility-controlled thermostat automation, and real-time energy and cost information, on residential conservation, peak reduction, and demand response*

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# Executive Summary

The 2011-2012 Residential Summer Solutions Study examined residential customer response to an advanced energy efficiency and demand response (EEDR) program that provided participants with real-time energy information and advice along with programmable communicating thermostats (PCTs) that enabled utility or customer automation of occasional price and load control events.

The study recruited from a sample of over sixteen thousand eligible customers that were randomly assigned to one of four experimental information treatment groups: Baseline information, real-time Home information, real-time Appliance information, and a control group. As part of the participation agreement, customers were given the option to sign up for the Summer Solutions rate – an experimental time-of-use rate with critical peak events (a.k.a. a TOU-CPP rate) – and/or the automatic temperature control (ATC) option, which paid customers to allow utility control of their PCT during events. These two options created a total of four program combinations: tiered rate with customer-controlled PCT, tiered rate with utility-controlled PCT, TOU-CPP rate with customer-controlled PCT, and TOU-CPP rate with utility-controlled PCT.

Table 1 provides the basic characteristics of the Summer Solutions Study design.

**Table 1. Summer Solutions Study design summary**

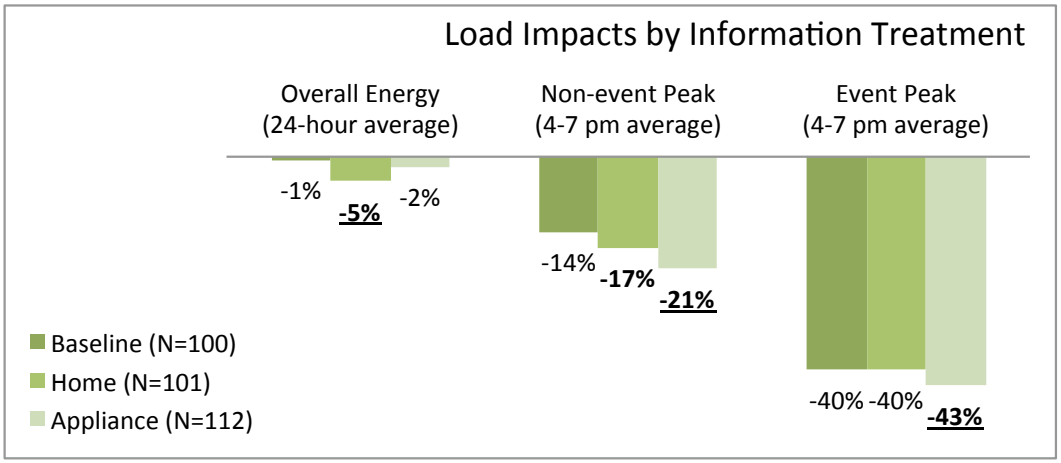
| Study Component | Description |
|---|---|
| **Peak Events** | • 12 events called 4-7pm weekdays from June through September<br>• OpenADR-compliant PCTs enabled event notification and AC automation |
| **Information Treatments** | • Baseline = PCT only<br>• Home = PCT + real-time energy use data for the home<br>• Appliance = PCT + real-time energy data for the home, AC, and 2 appliances |
| **Rate Options** | • Tiered rate = SMUD's standard residential flat 2-tier rate<br>• TOU-CPP rate = a time-of use rate with 12 critical price events per summer |
| **Automation Options** | • Customer PCT = 4°F default event offset that could be changed at any time<br>• Utility PCT = a 4°F mandatory event offset with 1 override per summer |

In both 2011 and 2012, twelve events were called on days with maximum temperatures forecast to be greater than 95°F. Participants were notified 24 hours in advance through multiple channels: email, text messaging, thermostat, and real-time energy display.

Hourly load and bill impacts for summer 2012 were estimated using a three-level mixed-effects regression model that corrected for weather and exogenous effects with the following findings.

1) **The addition of real time data, whether at the home or appliance level, provided relatively small improvements to savings** – ranging from 0-7% (Figure 1)**.** Higher savings found in the second year of this two-year study suggest that real-time data impacts may increase with time, as customers learn and act on the information. In particular, the effects on long-term investments, such as air-conditioner upgrades, are unlikely to be realized early on.

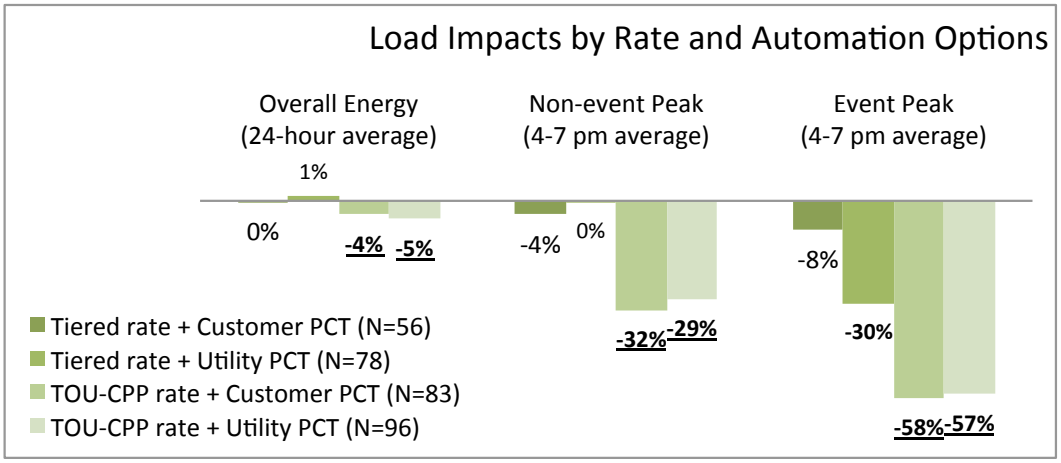
**FIGURE 1. LOAD IMPACTS BY INFORMATION TREATMENT (ΔKW)**




*Impacts significantly different from the Baseline group are marked in **bold**.*
*Impacts significantly different from both of the other two groups are underlined.*

2) **Voluntary TOU-CPP rates with customer-controlled PCT event automation outperformed tiered rates with information-only and load control programs**, having higher energy savings, non-event peak demand savings, and event peak demand savings (Figure 2).

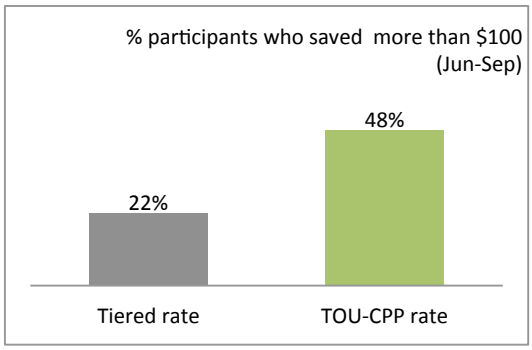
**FIGURE 2. LOAD IMPACTS BY RATE AND PCT AUTOMATION OPTION (ΔKW)**




*Impacts significantly different from the "Tiered rate + Customer PCT" group are marked in **bold**.*
*Impacts significantly different from the "Tiered rate + Utility PCT" group are underlined.*

3) **Participants on the TOU-CPP rate saved more than twice as much energy and money as did those on the standard tiered rate.** The average summer TOU-CPP savings of 460 kWh was more than twice the 190 kWh savings of those on the standard tiered rate, and more than twice as many TOU-CPP participants exceeded $100 in summer savings (Figure 3).

FIGURE 3. SUMMER 2012 PARTICIPANT BILL SAVINGS, BY RATE




4) **The use of programmable communication thermostats (PCTs) for event automation more than doubled demand savings during non-event and event peak pricing periods.** This result is based on a comparison of the Summer Solutions TOU-CPP participants to SMUD's Smart Pricing Option pilot, which moved volunteers to TOU and CPP rates without a PCT.

5) **Customer-controlled PCT automation provided the same load relief during price events as did utility-controlled PCT automation**. Both types of PCT automation showed event impacts nearing 60% for customers on the TOU-CPP rate. For customers on the tiered rate, utility-controlled automation more than tripled event response to 30% from just 8%.

6) **SMUD's system wide peak shaving capability would benefit more from a residential TOU-CPP rate than from an air-conditioning load control program.** The TOU-CPP rate had 10 times more peak savings on non-event days and twice the savings on event days (Figure 4).

FIGURE 4. RESIDENTIAL SECTOR PEAK LOAD IMPACTS: AC LOAD CONTROL VS. TOU-CPP

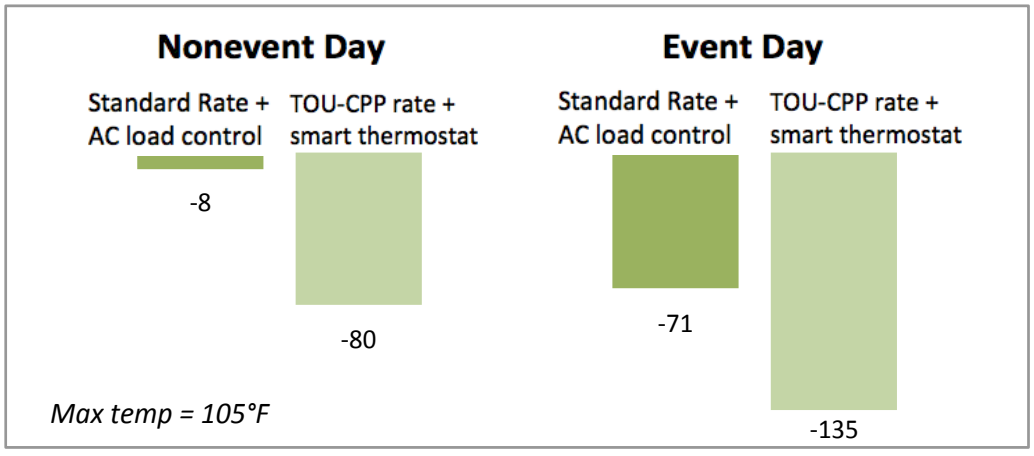


Table 2 summarizes these findings along with some of the other key results of the study.

**TABLE 2. SUMMER SOLUTIONS STUDY DETAILED RESULTS SUMMARY**

| Issue | Findings |
|---|---|
| **Recruitment & Installation** | Of the 7,000 invited customers, 6.4% returned applications and 5.2% were successfully installed. |
| **Attrition** | Of the 362 installations, 5 dropped out during their first summer and 42 were unreachable or unwilling to upgrade their equipment in the second summer. |
| **Customer Choice** | Of participants offered both the TOU-CPP rate and the AC load control option, 49% chose both, 25% chose the TOU-CPP rate only, 13% chose the AC load control option only, and 13% chose neither. |
| **Real-time Data Home vs. Appliance** | Relative to the Baseline, real-time Home information enhanced overall impacts by 4%, enhanced non-event peak impacts by 3%, and did not affect event impacts. Real-time Appliance information did not affect overall energy use, but enhanced non-event peak savings by 7%, and event peak savings by 3%. |
| **Rate: Tiered vs. TOU-CPP** | Participants on the TOU-CPP rate provided the highest energy and demand savings, exhibiting overall 2010-2012 energy savings of 4-5% and averaging 30% non-event peak demand savings. Those on the tiered rate showed no significant energy savings and just 0-4% non-event peak demand savings. |
| **Automation: Utility PCT vs. Customer PCT** | During events, participants on the TOU-CPP rate with a customer-controlled PCT dropped nearly twice as much load (58%) as did participants on the tiered rate with a utility-controlled PCT (30%). |
| **Bills: Tiered vs. TOU-CPP** | Average summer bill savings for the TOU-CPP rate was $145, while the average bills savings for those on the standard 2-tier rate was just $40. Nearly half (48%) of those on the TOU-CPP rate saved at least $100 over the course of the summer, while only 22% of those on the tiered rate achieved this goal. |
| **Event Notification** | The AutoDR event notification platform successfully initiated all 12 events. |
| **Satisfaction** | Over 90% of respondents were somewhat or very satisfied with the program. |

Based on impact findings, participant feedback, and costs, the team recommends the following key components for near-future programs at SMUD and other utilities in similar climates.

1) **Rates.**
   a) Offer residential customers at least one time-varying rate option, such as TOU-CPP.

2) **Automation.** Offer, rebate, or recommend user-friendly PCTs[1] that:
   a) enable customers to automate precooling and offsets for daily TOU peak load shifting, and
   b) enable customers to automate precooling and offsets for occasional CPP events. [2]

3) **Information**. Provide customers with:
   a) a concise summary and graphical representation of the rate (e.g. on a website or magnet)
   b) a website tool that allows customers to compare bill estimates for various rate options based on their personal historical energy use data
   c) notification of prices and events[3] (e.g. by smartphone app or thermostat), and
   d) real-time energy data for the home[4] (optional).

4) **Customer Service.** Maintain enhanced customer services, for example:
   a) a customer support call center that is well versed in the new rate and technology basics, and
   b) low-cost home energy inspections and recommendations.

The results of this study do not support the use of direct load control programs where dynamic rates are an option. The results of this study also do not support the provision or rebate of real-time energy monitors for individual appliances, due to the high cost, limited energy savings (2%), and lower customer ratings for this feature. For the near future, we recommend that utilities focus on improving the effectiveness and cost-effectiveness of the program components outlined in the list above – time-varying rates, customer-controlled PCTs, event notification, and enhanced customer services – and consider real-time energy information at the Home level a nice, but not necessary, addition to this portfolio.

[1] For a review and ranking of usability scores for communicating thermostats, see Herter & Okuneva 2013a.

[2] See SMUD's residential precooling study evaluation (Herter & Okuneva 2013b).

[3] e.g. via Internet (OpenADR), FM broadcast (RDS), smart meter (SEP), or some other cost-effective alternative.

[4] For example, via CT-based submeter, smart meter (SEP), or some other cost-effective alternative.

# 1. Introduction and Background

There is substantial activity surrounding the implementation of the Smart Grid in California and across the nation. Some of the main promises of the Smart Grid include increased system efficiencies, improved reliability, and a better informed, more involved, and happier customer base. On the ground, however, utilities are still struggling to communicate the value of the Smart Grid to their customers. In some places, there have been high profile cost overruns and outright customer revolts with respect to the communicating interval meters. Our goal in this study was to investigate the value of smart grid related information and controls in the forms of energy savings (kWh), peak load savings (kW), summer bill savings ($), and customer satisfaction, to inform future residential rate, technology, and program offerings at the Sacramento Municipal Utility District (SMUD).

Two earlier studies influenced the development of the Residential Summer Solutions Study. The first was a similar SMUD study conducted in 2008 in the small commercial sector, called the Small Business Summer Solutions Study (Herter et al., 2009). The second was a simulation effort intended to provide some evidence of the relative impacts of home and appliance energy data on residential energy use (Herter & Wayland 2009). These studies are described in further detail below.

## 2008 Small Business Summer Solutions Study

The Residential Information and Controls Pilot is the second in a series of behavioral studies initiated under a DRRC-SMUD partnership. In 2008, SMUD piloted an energy-efficiency and demand-response (EEDR) program for small commercial customers under 20 kW, offering participants two mutually exclusive program options: (1) a time-of-use rate with critical peak price events, or (2) monthly payment for remote thermostat control. Participants received programmable thermostats that not only allowed them to program daily schedules, but also to automate pre-cooling and response to the twelve critical events called during the summer of 2008.

Results, corrected for weather and exogenous effects, showed that customers reduced overall energy use by 20%, shifted 14% of their load out of the event periods, and saved 25% on their electricity bills compared to the prior summer. About 80 percent of participants said that the program met or surpassed their expectations, and three-quarters said they would probably or definitely participate again without the $120 participation incentive. These results provided evidence that energy efficiency programs, dynamic rates and load control programs could be used concurrently and effectively in the small business sector, and also provided further evidence of the effectiveness of programmable communicating thermostats for near-immediate air-conditioning demand response (Herter et al., 2009).

## 2009 Residential Information and Controls Simulation Research

Following the small commercial study, there arose an interest in finding residential applications for real-time energy use information made possible through advanced metering infrastructure (AMI). While incorporation of real-time energy use information with dynamic pricing and automated air-

conditioning control seemed a natural fit, it became clear that technologies providing these functionalities were insufficiently developed. There were many vendors and technologies addressing one or several of the functions needed for the study, but no one vendor had a technology that effectively accomplished them all.[5] Moreover, there was concern that testing a single residential energy management system would provide results that could not be extrapolated to other systems.

Instead, the research team worked with a game developer to create a simulation of a home with an energy information system. In the simulated home environment players could choose a male or female avatar. In the mornings, the spouse and two children came out of the bedrooms to perform normal family activities: watch TV, sit down at the table to be fed, or go outside. In the process they would leave the TV going, lights on, and doors open. It was the job of the player's avatar to keep the family happy by doing things like feeding them, keeping the temperature comfortable, and washing their clothes, while at the same time keeping energy costs low. Each behavior had options. A warm meal made the family happier than a cold meal, but required more energy. Doing laundry first thing in the morning before peak prices saved energy, but leaving the family hungry at the table would decrease overall happiness. Family members changed their clothes often; the longer it took between washes, the unhappier the family became. If happiness fell to zero, the three-day level had to be replayed from the beginning.

At the end of each level, the avatar was given the opportunity to use income minus energy expenditures to purchase appliance upgrades, a smart thermostat, insulation, and even solar panels. At the end of four levels, the game was over and the player received their score, which was a combination of the family Happiness score and an Energy Efficiency score. It was a quick-moving, fun game, and some customers continued to play it well beyond the data collection period.

Four different versions of the game were randomly distributed and played by about 450 SMUD participants. In version 1, players were given their electricity bill at the end of each level, to simulate the typical real-life utility practice of monthly bills. In version 2, players were also provided with real-time energy data for their virtual home. In version 3, players were given all this plus real time energy data for the key appliances. In version 4, players were given all of these things plus monthly appliance summaries. Energy use scores were then analyzed to determine differential effects of the various feedback factors on game-playing behavior. Statistical analysis showed that the group receiving Appliance-level energy information used 6% less energy than the Home and Baseline groups, while the Home and Baseline groups were statistically indistinguishable (Herter & Wayland 2009).

Although, this experiment relied on a simulated environment, it raised the question of whether real-time energy data for appliances might be more actionable than real-time energy data for the home. One of the goals of the 2011-2012 Residential Summer Solutions Study was to answer this question in the field.

[5] For a description of technologies available in 2009-2010, see HERS 2010.

# 2. Residential Summer Solutions Study Overview

## Scope and Objectives

The Residential Summer Solutions Study field-tested the effects of various information, rate, and automation options on residential customer behavior. Participation was voluntary, meaning that results are representative of a similarly implemented voluntary program.[6] The findings of this study will inform SMUD's future rate, technology, and program offerings for the residential sector.

The main objective of this study was to compare energy, demand, and bill impacts under:

- 3 randomly applied information treatments
  - baseline information (no real-time data)
  - real-time home-level data
  - real-time appliance-level energy data
- 2 self-selected rate options
  - SMUD's standard residential 2-tier rate
  - an experimental dynamic TOU-CPP rate
- 2 self-selected automation options for events
  - utility-controlled PCTs
  - customer-controlled PCTs

## Experimental Design

The study involved three randomly applied information treatment groups (Table 3). The Baseline group was provided with an OpenADR-compatible PCT that notified customers of the 12 summer events and facilitated automatic response. The Home group received the same PCT *plus* the ability to view real-time energy data for their home on their PCT and computers. The Appliance group was given the PCT and real-time home information *plus* real-time energy data for their central air conditioning and two other appliances.

**Table 3. Experimental design**

| Treatment Group | PCT + Event Notification* | Real-time Home Data | Real-time Appliance Data |
|---|---|---|---|
| Baseline | ✔ | | |
| Home | ✔ | ✔ | |
| Appliance | ✔ | ✔ | ✔ |

** All participants were given 24-hour advance notification of the 12 summer events via PCT and email.*

[6] Results are not intended to be representative of a mandatory program applied to the entire residential sector; such a scenario is impractical since customers cannot be required to install and use the technologies tested here.

All participants were given the opportunity to sign up for the "Summer Solutions rate" – an experimental time-of-use rate with critical peak price events, also known as a TOU-CPP rate. In addition, participants were given the choice between programming their own PCTs event settings or being paid to allow SMUD to control their event response. These options are described in further detail in Section 3.

## Study Area

This study takes place in the two cities of Sacramento and Folsom, California. Both cities are located in the Sacramento Municipal Utility District (SMUD) service territory, which is located in California's central valley, covering the state capital of Sacramento and surrounding suburban areas (Figure 1). SMUD is currently the nation's sixth largest community-owned electric utility in the nation, spanning 900 square miles and serving over half a million residential customers.

**Figure 5. SMUD service territory**


Sacramento weather is characterized by hot, dry summers and mild, rainy winters. On average, the maximum daily temperature exceeds 100 °F on 15 days annually. Sacramento area residents are frequently relieved from excessive late afternoon temperatures by sea breezes that blow up through the Sacramento-San Joaquin River Delta from the San Francisco Bay.

## SMUD's AMI System

In 2009, SMUD received a U.S. Department of Energy Smart Grid Investment Grant of $127.5M to implement an Advanced Metering Infrastructure (AMI) for all of its customers, and to subsequently implement large-scale demand-response and dynamic-pricing programs. SMUD began installation of their new AMI system at the end of 2009 and was nearing completion by the end of 2011.

SMUD's new residential and small commercial meters can be configured to collect energy use data at 5, 15, 30, and 60-minute intervals. SMUD currently records residential energy data hourly and uploads the interval data daily. The meters have on-board network interface cards that enable the meters to communicate with SMUD's smart grid network and also with Zigbee-enabled devices in the home. Because the Zigbee network was not enabled before the Summer Solutions Study began, Zigbee communications were not used in this study.

### Existing Residential Rates and Programs at SMUD

SMUD's rates are about 27 percent lower than rates in the surrounding utility area. SMUD's residential rate is a two-season, two-tier, inclining block rate. About half of the residential population exceeds the Tier 2 threshold of 700 kWh per month during the summer season.

At the time Summer Solutions study was designed and implemented, the only demand response program offered to SMUD's residential customers was Peak Corp, an air-conditioning load management (ACLM) program that used wireless broadcasts to signal air-compressor switches during events. In 2012, more than 100,000 (about 20%) of SMUD's residential customers received incentives of $2, $4 or $6 per event, depending upon cycling intensity, to allow the District to cycle their air conditioner during critical summer hours. The last Peak Corp event, called in 2001, was met with a considerable number of customer complaints and program dropouts. This experience plus the obsolescence of the Peak Corps technology and the availability of new control technologies prompted SMUD to consider alternative demand response options for the residential sector.

## Schedule

Table 4 outlines the major phases and tasks of the Summer Solutions Study.

**Table 4. Summer Solutions Study schedule**

| Task | Dates | Activities | Responsible Team |
|---|---|---|---|
| **Preparation** | Jan – May 2011 | • Design and test equipment<br>• Develop experimental rate, ATC option<br>• Prepare customer outreach materials | • Herter Energy, RCS<br>• Herter Energy, SMUD<br>• Herter Energy, SMUD |
| **Recruitment** | Apr – May 2011 | • Mail recruitment materials<br>• Create participant database<br>• Distribute participant materials | • SMUD<br>• Herter Energy<br>• Herter Energy |
| **Summer 2011 Field Study** | Jun – Sep 2011 | • Equipment installation<br>• Participant Surveys<br>• Events (12)<br>• Customer service and tech support | • Herter Energy<br>• Herter Energy<br>• Herter Energy<br>• Herter Energy |
| **2011 Analysis & Reporting** | Oct – Dec 2011 | • Collect billing data from SMUD<br>• End of Summer Survey<br>• Analyze data and report findings | • Herter Energy<br>• Herter Energy<br>• Herter Energy |
| **Summer 2012 Field Study** | Jun – Sep 2012 | • Equipment installation<br>• Participant Surveys<br>• Events (12)<br>• Customer service and tech support | • Herter Energy<br>• Herter Energy<br>• Herter Energy<br>• Herter Energy |
| **2012 Analysis & Reporting** | Oct – Dec 2012<br><br><br>Jan – Aug 2013 | • Collect billing data from SMUD<br>• End of Summer Survey<br>• Analyze data and submit draft report<br>• Review and comment on draft report<br>• ReRevise final report | • Herter Energy<br>• Herter Energy<br>• Herter Energy<br>• SMUD<br>• Herter Energy |

# 3. Study Components

## Participant Benefits

Benefits of the pilot included:

- *A smart thermostat*. Customers received the programmable and communicating Summer Solutions thermostat, a PCT, which provided notification of events and enabled utility or customer control of automated event response.
- *Real-time energy information*. Customers in the Home and Appliance groups had access to real-time energy information for their home and appliances, respectively. An interactive graphic display with real-time energy use and costs were available through their home computer or other home-networked devices, and a more basic display of real-time energy use values (without cost information) was available on the Summer Solutions thermostat.
- *Efficiency information.* The pilot provided participants with several sources of information on best practices and rebates.
- *Home Energy Assessments.* Free onsite home energy assessments were offered, providing participants with a checklist of inexpensive upgrades.
- *The opportunity for lower energy bills*. All participants had the opportunity to reduce their bills through efficiency improvements and conservation. Those on the Summer Solutions rate could also benefit from load shifting on non-holiday weekdays and during events.
- *The opportunity to earn $48 on the ATC option.* Participants who enrolled in the ATC option were paid $4 for allowing SMUD to control their PCT during each of the 12 summer events.
- *Other benefits*. Non-financial reasons for participating varied. For many customers, participation in a program like this is about feeling that they are doing the right thing: benefiting the environment and reducing strain on the electric grid during peak times to improve electric reliability for the community. Some customers enjoy the game of avoiding high rates, while others enjoy feeling like they are part of a team.

## Information Treatments

The Summer Solutions information and controls system was custom designed to meet the specific research needs of this study. Herter Energy worked closely with SMUD to choose a technology that best satisfied the requirements of this project. The system was required to:

1) Allow SMUD to notify thermostats of price and load control events using OpenADR
2) Display real-time information, including
   a) electricity use and costs for the home/site
   b) electricity use and costs for 110V and 220V appliances through optional submeters
   c) electricity rate information
   d) system event notifications
3) Initiate thermostat automation on receipt of a price or event signal
   a) price event offsets determined by the customer
   b) load control offsets determined by SMUD
4) Comply with SMUD's data security requirements
5) Function without reliance on Zigbee communications from the meter

The base unit of the chosen system was an Internet-connected gateway with 2-way ZWave communication to local system components, including smart thermostats, 220-volt energy monitors, and 110-volt energy monitors. In addition to aggregating and hosting data collected from these components (for viewing on the computer), the gateway retrieved event information from the OpenADR server through the Internet connection and passed it to the thermostats.

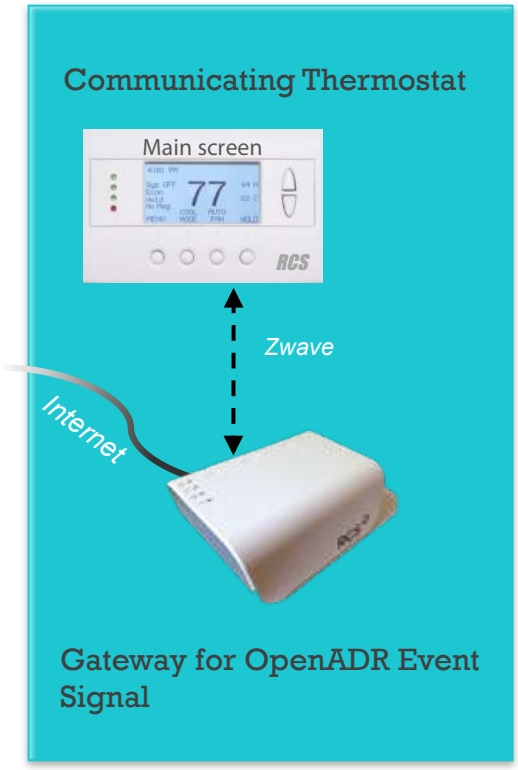
The thermostat collected and displayed real-time energy data from connected monitors. The thermostat also displayed weekday peak and event prices for participants on the dynamic rate, but aggregated cost information was not available via the thermostat.

During both years, the OpenADR communications platform successfully initiated all 12 events. Thermostats typically responded with a delay of less than one second from the time the event was initiated at the AutoGrid program manager interface.

### Baseline Information Equipment

The Baseline group was provided with two devices: (1) a gateway and (2) an OpenADR-enabled PCT (Figure 6). Together, the system enabled event notification and air-conditioning response automation. This group was not provided with real-time energy information, thus allowing it to serve as a baseline for the two real-time energy information treatment groups.

**Figure 6. Summer Solutions equipment for the Baseline information group**

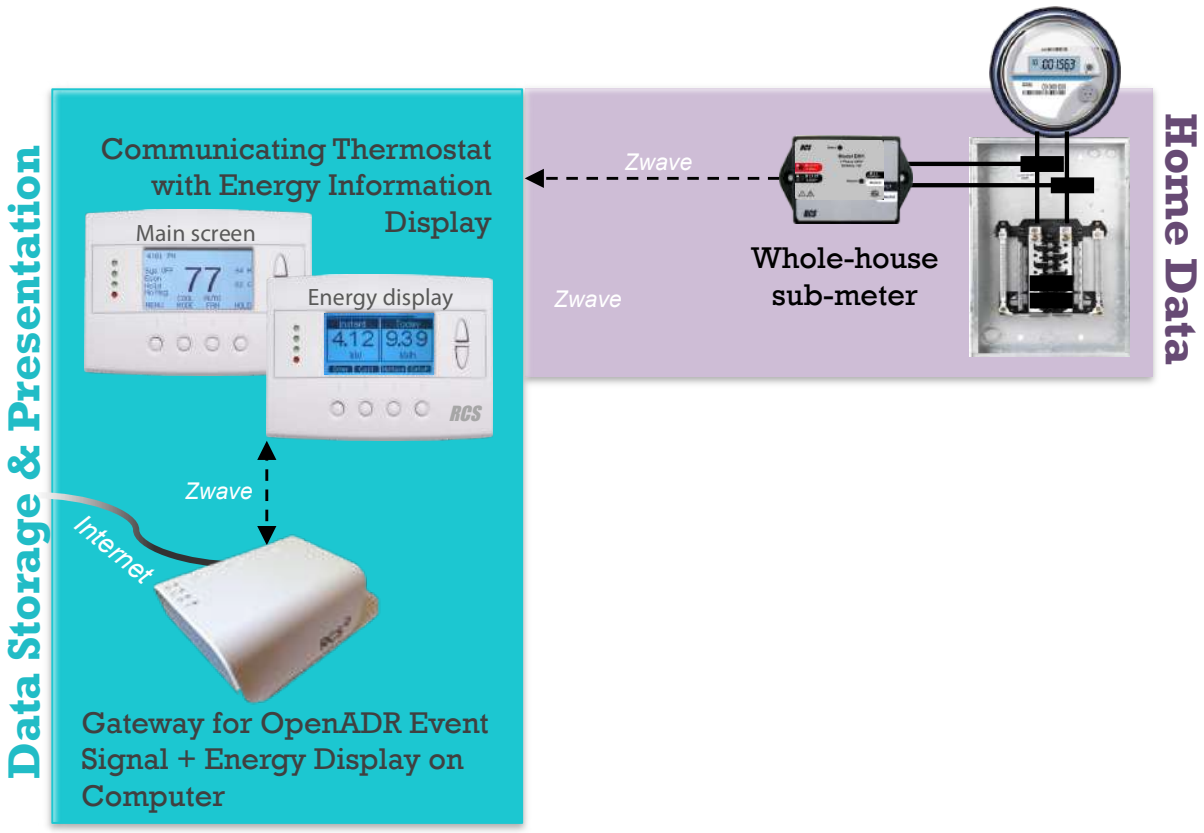



*(No real-time energy information)*

### Home Information Equipment

The Home group was provided with a gateway and smart thermostat as described above, plus a 220-volt monitor connected with current transformer clamps to the main electrical cables feeding the home (Figure 7).

**Figure 7. Summer Solutions equipment for the Home information group**

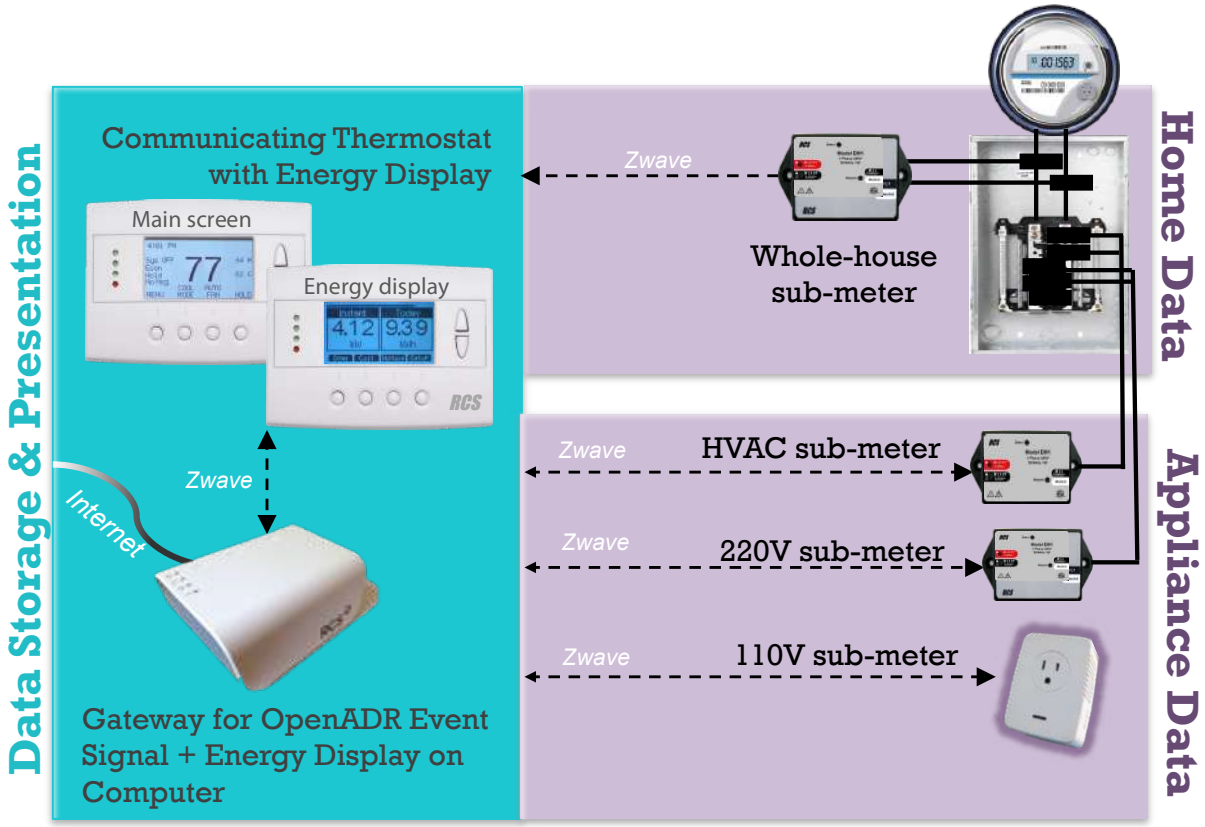



The 220-volt monitor connected at the mains used ZWave to transmit real-time home-level electricity data to the gateway and to the thermostat. Like the Baseline equipment, this system enabled event notification and air-conditioning response automation. In addition, Home group participants could view the real-time electricity use of their homes on their thermostat and detailed graphical displays of energy and cost information on the computer-based energy display hosted locally by the gateway.

### Appliance Information Equipment

The Appliance group was given a system that included all of the components of the Home system plus three additional sub-meters: one on the air conditioner, one on a 220-volt appliance of the customer's choice, and a 110-volt plug-in energy meter. Each of these transmitted real-time energy measurements to the gateway and the thermostat for aggregation and viewing by the customers.

**Figure 8. Summer Solutions equipment for the Appliance information group**



### The Summer Solutions Thermostat Interface

The Summer Solutions thermostat was designed to allow automation by either the utility or the customer through a Utility Setup menu item added to the Main Menu. For customer-controlled automation, this submenu provided an input field for the customer to choose their own event offset, from 0-10 degrees (Figure 9a). During events, the target temperature for the thermostat automatically increased by the number of degrees the customer chose for this setting. At the time of installation, the installers recommended an event offset of 4°F, and most participants did not deviate from this recommendation. For utility-controlled automation, a remotely accessible setting in the thermostat deleted the Event Offset setting from the Utility Setup menu (Figure 9b).

**Figure 9. The Utility Setup menu in the Summer Solutions Thermostat**


(a) (b) (c)

The Utility Setup screen also allowed customers to view the peak and event prices, which were also displayed on the main screen (Figure 8) from 4 to 7 p.m. on weekdays. A remotely accessible setting disabled the peak and event prices from showing on the thermostats of customers who were not on the time-varying Summer Solutions Rate (Figure 9c). The Utility Setup menu was unavailable for participants who chose the tiered rate and the utility-controlled PCT option.

The Summer Solutions thermostat also displayed real-time kW and the aggregate kWh for the day for up to four submeters. A screenshot of the thermostat's energy display is shown in Figure 8.

### The Energy Display Interface

Participants could access the Energy Display interface through an Internet browser on any device on the local area network, most commonly the home computer. At the top of each page is a header displaying the current per-kWh price, an indicator for whether there is an event in progress, and for those with energy data, the real-time home energy use and projected monthly bill.

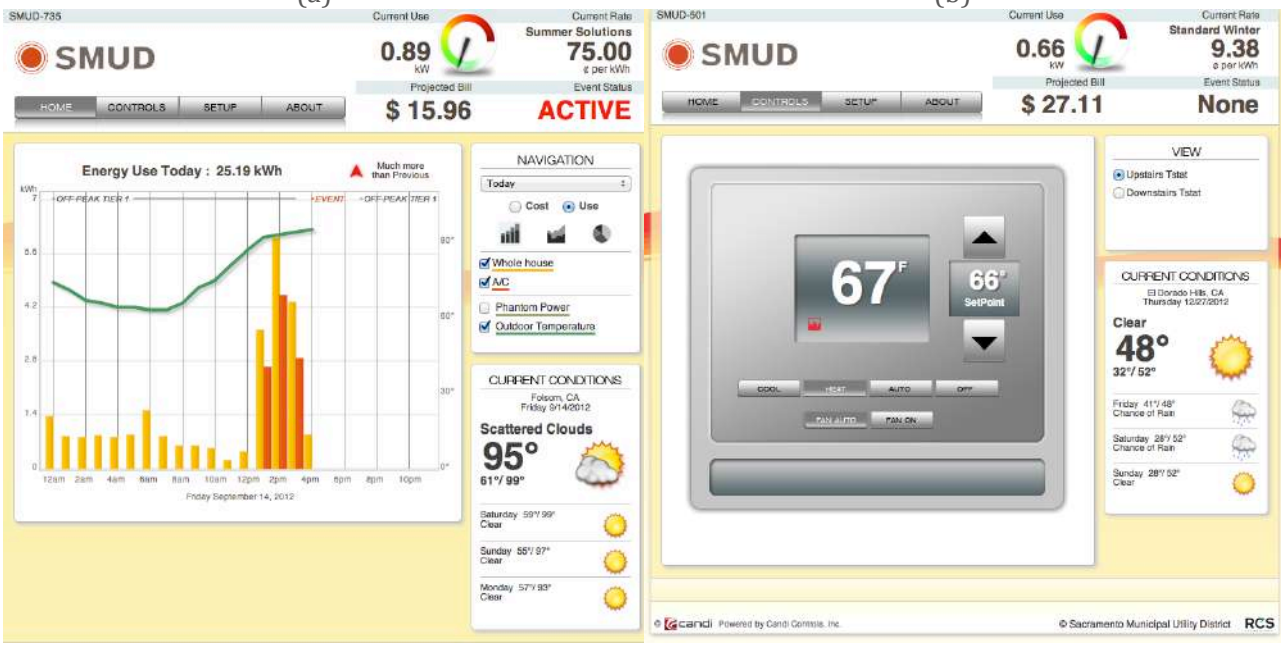
Each of the three treatment groups had a different Energy Display experience. The Baseline group had access only to the current rate, event status, and thermostat settings. The Home group could view real-time and historical energy use and costs for their home, but only the Appliance group had the full use of the system features shown in the screenshots in Figure 10. The Energy Display for the Home group graphs only the values for *Whole House*, but is otherwise identical.

The Home page (Figure 10a) graphs customer data in several user-configurable formats. The drop down to the right of the graph allows graphs in increments of seconds, minutes, hours, days, billing cycles and months. Users can switch between bar, line and pie charts, and can show or hide any combination of the individual sub-meters connected to the system.

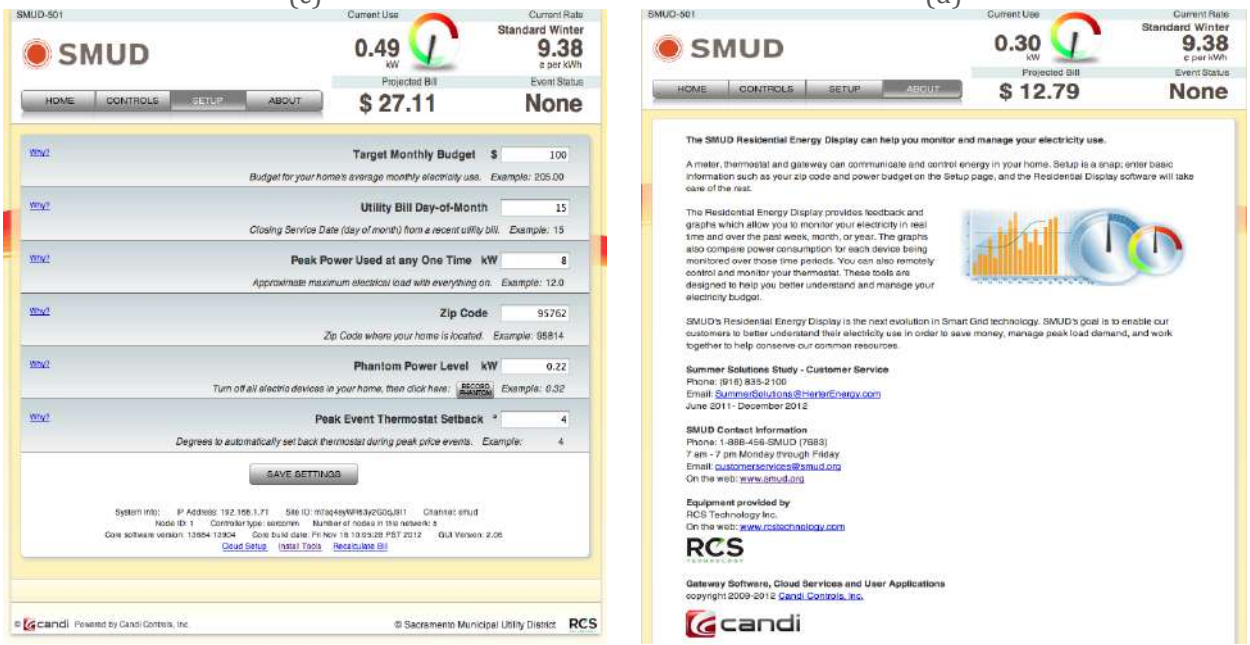
The next tab on the menu bar shows the Controls page (Figure 10b), which allows customers to view and configure controllable devices connected to the ZWave network, including thermostats and switches. On the Setup page (Figure 10c), customers can enter information specific to their home, such as target budget and zip code. Finally, the About page (Figure 10d), provides program information including contact email and phone numbers.

**FIGURE 10. ENERGY DISPLAY INTERFACE: HOME, CONTROLS, SETUP, AND ABOUT PAGES**

(a) (b)




(c) (d)




© Candi Controls

## Rate Options

The TOU-CPP rate was developed by SMUD and Herter Energy for use in this study (HERS 2011). The rate consisted of a two-period time-of-use rate with 12 peak price events (Table 5). The rate is in revenue neutral for the summer months, June to September. In the winter months, the standard residential rate applies. Participants that signed up for this rate were encouraged to save money by shifting energy use away from the On-peak and Event periods into the Off-peak period.

**Table 5. Experimental Summer Solutions rate compared to the Standard rate**

| Period | Schedule | Tier | Tiered Rate *($/kWh)* | TOU-CPP Rate *($/kWh)* | % Time |
|---|---|---|---|---|---|
| **Event** | 4:00 - 7:00 p.m. | <700 kWh | $ 0.1045 | $ 0.7500 | 1% |
| | | >700 kWh | $ 0.1859 | | |
| **On-peak** | 4:00 - 7:00 p.m. (Non-holiday weekdays) | <700 kWh | $ 0.1045 | $ 0.2700 | 8% |
| | | >700 kWh | $ 0.1859 | | |
| **Off-peak** | All other hours | <700 kWh | $ 0.1045 | $ 0.0721 | 91% |
| | | >700 kWh | $ 0.1859 | $ 0.1411 | |

On weekends, holidays and outside the 4-7 pm weekday peak period, the TOU-CPP rate is about 30% lower than the standard tiered rate, providing substantial opportunity for those on the rate to save money by shifting energy use off peak. On normal weekdays, the rate increases to 27 cents per kWh during the 4-7 pm peak. On the 12 event days, the 4-7 pm rate jumps to 75 cents per kWh.

Note that the increasing tier structure existing in SMUD's current residential rate was carried over into the TOU-CPP rate to avoid penalizing participants that ordinarily use less than 700 kWh per billing cycle. Unlike the standard rate, the tier adjustment for the TOU-CPP rate takes place only in the off-peak period, creating a total of four possible prices: Event, On-peak, Off-peak <700 kWh, and Off-peak >700 kWh.

## Automation Options

The Automatic Temperature Control (ATC) option was included to test the difference between utility and customer control of event response automation. Participants choosing the ATC option received a $4 credit on their bill for each event, during which the utility initiated a mandatory 4-degree offset that could be overridden only once per summer. Participants who did not choose this option were given a thermostat menu setting where they could program their own preferences for event response. The ATC option was available to all participants, regardless of their rate choice.

Note that customers who signed up for both the TOU-CPP rate and the ATC option were paid twice for the AC load activated under the ATC option – once by the rate and once by the ATC event incentive. Although a real utility program would not offer this double payment, we included it in this study for experimental reasons, to test the combined effect.

# 4. Field Study Activities

## Screening and Assignment to Experimental Groups

To ensure robust 2010 interval meter data, participants for this study were recruited from among the first areas receiving smart meters, located mainly in the downtown Sacramento and Folsom areas (see Figure 5). SMUD provided a database of 40,410 customers that had hourly data for the summer of 2010. These records were screened to meet the following criteria:

- Maximum of 20 hourly meter readings missing in one month
- Site address in Sacramento or Folsom
- Mailing address matches site address
- Single-family home or condominium
- Original tariff Residential Service Electric or Gas heat (RSE or RSG)
- Not on SMUD's Low-Income Energy Assistance Program Rate (EAPR) [7]

The Participation Agreement (provided in Appendix A) further required that the premises be a single family dwelling, and that the customer:

- live in and own the home
- have a residential account and a new "smart" meter
- pay his or her own SMUD bills
- have Internet access
- not plan on moving during the next 12 months
- not be on SMUD's Medical Equipment Discount Program
- not operate a child care or convalescent care business in the home

Using standard random number generation techniques, the 16,065 records that remained after screening were randomly assigned to one of four groups: (1) baseline information, (2) real-time home-level information, (3) real-time appliance-level information, and (4) control group.

[7] More than 18 percent of SMUD's residential customers are enrolled in SMUD's Energy Assistance Program (EAPR), which provides a 30-35 percent discount.

## Recruitment and Final Participant Sample

Recruitment for the Summer Solutions study took place in the spring of 2011. Letters sent by postal service were the primary strategy to inform the potential participants of the opportunity to sign up for the study. The letters informed targeted customers that the study's purpose was to test new information and technologies intended to help customers better understand their energy use and manage their energy bills, and that the information and technologies found to be most useful to participants would be considered for widespread deployment.

A different version of the invitation letter was created for each treatment group. The three versions of the letter were identical with the exception of the website link and the lines that described the equipment to be installed. The Baseline group was offered "A free state-of-the art programmable thermostat (a $100 value)"; the Home information group was offered in addition, "A free state-of-the art energy information system (a $200 value)"; and the Appliance information group, "A free state-of-the art energy information system (a $400 value)". Recruitment websites were also identical except for the page that described the equipment to be installed.

Interested customers were directed to sign and submit the Participation Agreement online or via postage-paid envelope. The agreement required that the customer choose either the Summer Solutions rate or the Standard rate, and provided a checkbox for the Automatic Temperature Control option. (A copy of the Participation Agreement is provided in Appendix A.)

Finally, the letters directed participants to their respective recruitment website, which provided basic information about the pilot. The websites provided equipment, rate and ATC information, a copy of the participant agreement, Frequently Asked Questions, and customer service contact information. Program options were described on the website as follows:

> ***Summer Solutions rate*** *- If you choose to switch to this rate, you'll receive a 30% discount during SMUD's off-peak hours. If your electricity use is flexible, you could save a significant amount of money on this rate.*
>
> ***Automatic Temperature Control program*** *- If you choose this option, SMUD will automatically increase your thermostat by 4 degrees during each of the 12 system events. In return, SMUD will credit your bill $4 per event. Under this option, installation of a program-compatible thermostat is required.*
>
> ***What happens if I don't want either option?*** *- You can still participate by having the Summer Solutions equipment installed at your home and receiving notification of system events. Under this scenario, you are not affected in any way if you choose to ignore the system events, but you can still use the equipment installed to help you be more efficient every day.*

Three waves of recruitment mailings were sent to inform three separate groups of target customers of the opportunity to participate in the pilot. All mailings included a treatment-specific invitation letter, a participation agreement, and a postage-paid envelope addressed to SMUD. Each letter directed customers to visit treatment-specific recruitment websites or contact the Summer Solutions customer service telephone line for more information.

- The first 3000 recruitment letters were sent out on April 1, 2011, offering customers the Summer Solutions equipment, rate, and ATC options. The following week, the research team began follow-up phone calls to targeted customers. After 10 days of calling, signup rates fell off noticeably and customers began voicing their displeasure at being contacted, so calling was discontinued. At that point, a reminder postcard was sent to all 3000 customers. In total, this effort resulted in 187 signups, for a total signup rate of 6.2%.
- The second wave of 1000 letters, sent to a new group of customers, generated a nearly identical response rate. There were no follow-up phone calls or post cards. This mailing completed the experimental sample cell requirements for the Summer Solutions rate.
- The last mailing to 3,000 previously uninvited customers offered only the equipment and ATC options, because the Summer Solutions rate (SS rate) treatment cells had been filled. This mailing generated a 7.0% response rate.

Table 6 summarizes the mailing schedule and results.

**TABLE 6. RESIDENTIAL SUMMER SOLUTIONS RECRUITMENT RESPONSE**

| Effort | Offer Content | Mailings | Responses | Response Rate |
|---|---|---|---|---|
| **Mailing #1** | Equipment, ATC, SS Rate | 3,000 | 153 | 5.1% |
| *- Phone calls* | | *750* | *10* | *0.3%* |
| *- Post card* | | *3,000* | *24* | *0.8%* |
| **Mailing #2** | Equipment, ATC, SS Rate | 1,000 | 50 | 5.0% |
| **Mailing #3** | Equipment, ATC | 3,000 | 209 | 7.0% |
| **Total** | | **7,000** | **446** | **6.4%** |

The final recruitment rate of 6.4% was attained through a single mailing to each potential participant. With greater marketing effort, this rate could be increased substantially. For example, opt-in rates for SMUD's 2012 Smart Pricing Option program were between 16% and 19%.

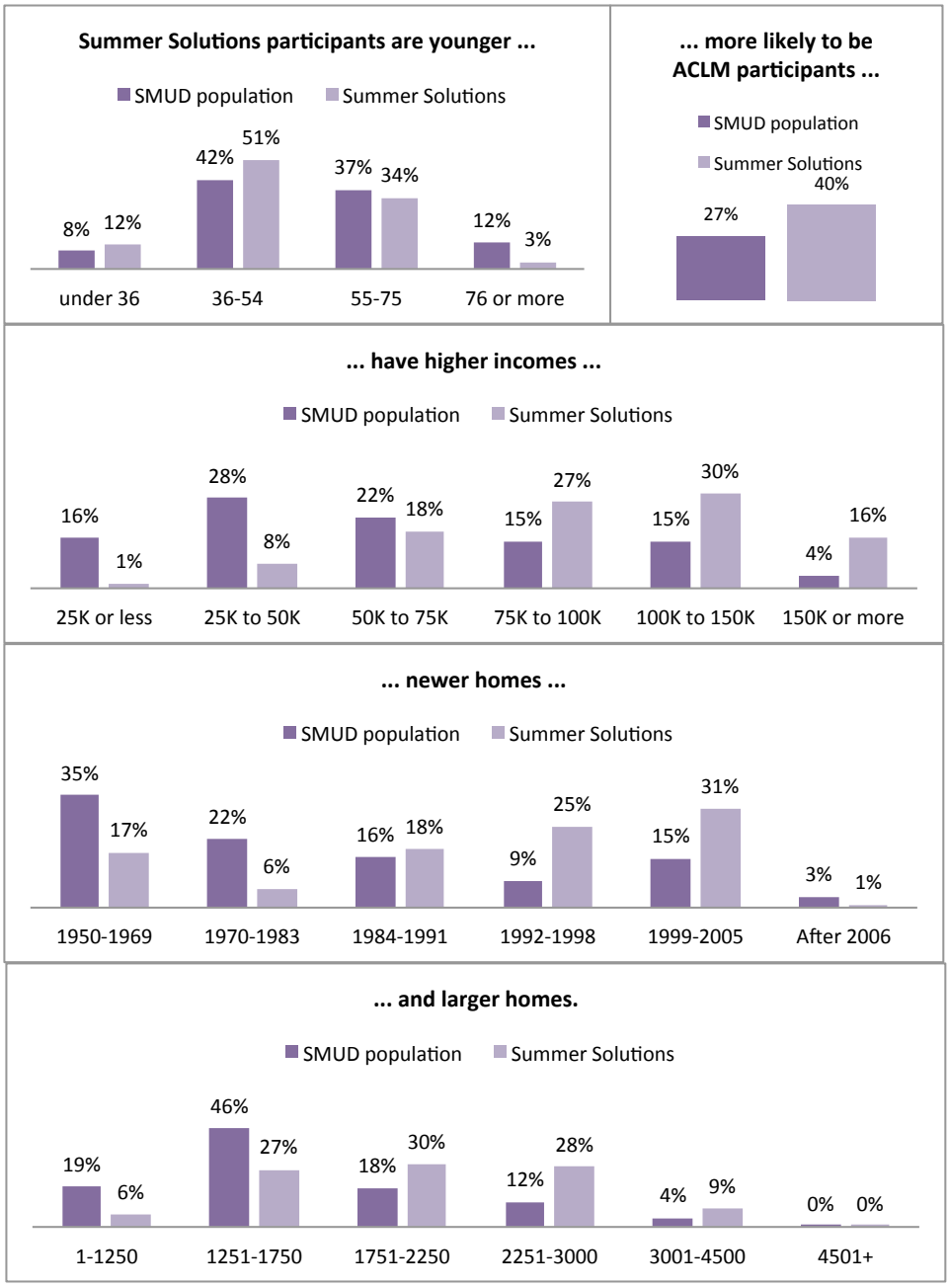
Customers were accepted in sequential order of signed participation agreement receipt. Of the 446 applicants, 362 were installed. Five installed participants dropped out during their first summer and 42 of the original 2011 participants were unreachable or unwilling to set an appointment for the equipment upgrade in the second summer. Data for two of the participants that completed the study were excluded because there were too many missing load data. The final numbers of participants in the 2012 Summer Solutions study sample frame are provided in Table 7.

**TABLE 7. EXPERIMENTAL SAMPLE**

| Information Treatment | Tiered rate + customer PCT | Tiered rate + utility PCT | TOU-CPP + customer PCT | TOU-CPP + utility PCT | Total Sample |
|---|---|---|---|---|---|
| **Baseline** | 11 | 30 | 33 | 26 | **100** |
| **Home** | 24 | 27 | 21 | 29 | **101** |
| **Appliance** | 21 | 21 | 29 | 41 | **112** |
| **Total** | 56 | 78 | 83 | 96 | **313** |

Customers that signed up for the Summer Solutions study were significantly different from the general population on several variables. On average, they were younger, more likely to be Peak Corps (ACLM) participants, and had higher incomes and newer, larger homes (Figure 11). Because this study is intended to estimate the impacts of a voluntary program, these differences describe the types of customers that are likely to sign up for a similar offering, and do not impact the external validity of the final results – as long as the original sample population is similar to SMUD's general population. For example, this program was offered only to homeowners and customers not on SMUD's low-income rate, so one would expect average participant incomes to be higher.

**FIGURE 11. SUMMER SOLUTIONS PARTICIPANT DEMOGRAPHICS**



## Equipment Installation and Technical Support

The 2011 Summer Solutions equipment installations began as soon as participation agreements were received in April 2011, and were completed by June 2011. The 2012 equipment installations and upgrades began in May 2012 and were completed by June 2012.

It was critical that the equipment installers had clear instructions, were capable of answering basic questions and consistently forwarded program concerns to customer service. To help ensure this, all customer-facing contractors were provided with customer interaction training and a detailed checklist for the installers to follow at each home. Prior to customer installations, beta installations were performed to confirm installer skills, test the checklist process, and practice customer interactions.

The installation team included licensed electricians to install the current transformers in the service panels, HVAC technicians to install and test the thermostat, and network technicians to set up the gateway, thermostat and submeters on the home network. Installation was complicated by three different equipment configurations and four different program options. To facilitate timely and accurate installation, installers were provided with a detailed checklist, shown in Figure 12. After installation, participants were sent an email to solicit feedback on the process and participant understanding of how to access and use the new equipment.

About 7% of meter panels were unable to accept the current transformers (CTs) needed to provide occupants with real-time data for their home. This barrier is expected to be resolved if and when the Zigbee radios in SMUD's advanced meters are enabled for direct broadcast of real-time data into the home.

While the Summer Solutions equipment worked well enough in aggregate, the system did not work as intended in all of the homes all of the time. Throughout the summer, almost all of the service calls and technical support site visits were directly related to equipment problems.

FIGURE 12. DETAILED CHECKLIST FOR INSTALLERS

# SMUD's Summer Solutions Study
# Installation Checklist for Contractors


**WHEN YOU ENTER**

- ☐ Hand the customer their personalized **Welcome Packet**
- ☐ Lay down painters plastic where a mess might occur

**THERMOSTAT** *(all customers have the option to receive a thermostat)*

- ☐ **Schedules** - requires customer input -
- ☐ **User Settings**
  - Set Clock and Date
  - Set Screen Timeout to zero
- ☐ **Utility Settings**
  - Set Event Offset – *(recommend 4 degrees)* - requires customer input -
  - Energy Usage → Setup
    - Tstat - no nodes
    - Home – set up the WH node and verify that the stat is receiving Whole House data
    - HEMS – set up all 4 nodes (WH+HVAC+220V+110V); verify stat is receiving data
- ☐ **Hidden Settings**
  - For customers in the Automatic Temperature Control program, set the hard 4° offset

**ENERGY DISPLAY** *(Only Home and HEMS customers can view the computer Energy Display)*

- ☐ Connect the **Gateway** to the Internet
  - bookmark its IP address
- ☐ Link **ZWave** Devices
  - label appropriately (e.g. Whole House, Thermostat, Spa, Plug-in)
  - allow the customer to choose the location of the 110V plug-in monitor - customer input -
  - At the Installer Screen, verify that each ZWave device is communicating
  - verify that the Gateway is receiving valid meter data at "*(IP Address)*/installer/energy"
- ☐ **SETUP**: Enter required information - customer input -
- ☐ **Customer Education** - customer input -
  - **HOME**: Explain the graph and show different views with drop down menus
  - **DEVICES**: (HEMS only) Explain the pie chart and show different views
  - **CONTROLS**: Show the customer how they can review and change their thermostat.
  - Encourage customers to contact customer service if they have more issues or questions.
    - SummerSolutions@HerterEnergy.com or 916-835-2100

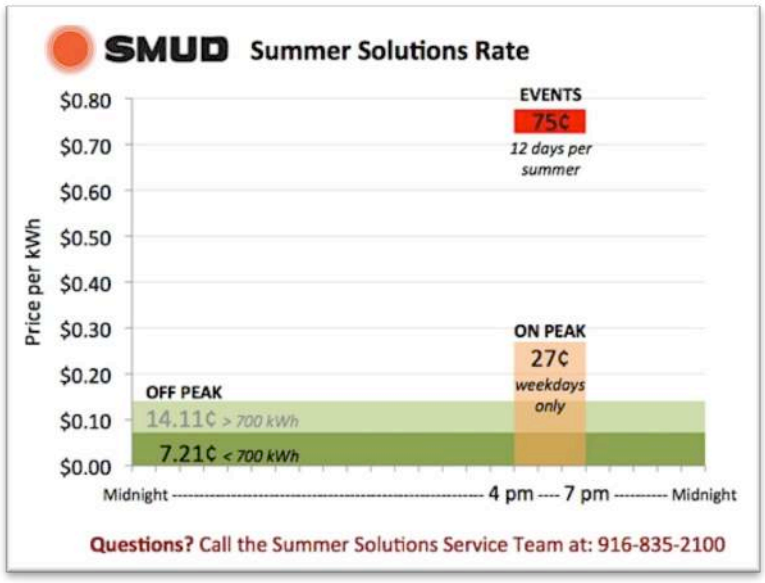
**BEFORE YOU LEAVE**

- ☐ Confirm that customers know how to access their Energy Display (if they have one)
- ☐ Clean or tidy any areas affected by the installation process
- ☐ Thank them for their time and apologize for any inconvenience

## Participant Education and Support

Program materials were handed to participants at the time of the equipment installation. Participants on the Summer Solutions rate received a refrigerator magnet illustrating the experimental rate (Figure 13). All participants were provided with a Quick Start Guide, tailored for their particular equipment and program choices (Figure 14). At the end of the installation appointment, the installer worked with participants to program the PCT as desired, and provided a brief tour of the thermostat programming options.

**Figure 13. Summer Solutions rate magnet**




Customer service support was provided through a dedicated phone line and email address staffed by Herter Energy during normal business hours. The customer service team was responsible for providing the first level of support for all questions and problems, including both programmatic and technical issues, handling basic issues that could be addressed by phone and delegating higher-level technical issues to equipment specialists.

In addition to personal attention provided by the installers and the research team, participants were provided several opportunities to review information about the pilot and actions they could take as participants.

A website was created to provide basic information about the pilot, including links to participant materials and surveys, frequently asked questions, a discussion board, equipment information, rates information, links to rebates and energy saving tips and customer service contact information.

Email notification one day prior to each of the 12 events throughout the summer reminded participants of specific strategies that could be taken to reduce energy consumption during the event on the following day.

## FIGURE 14. SUMMER SOLUTIONS QUICK START GUIDE

# Summer Solutions
## Quick Start Guide

Welcome to SMUD's Summer Solutions Study!

Please take a few moments to review this guide. In it are the essentials to get the most out of your participation this summer.

1. Study Basics: The Summer Solutions study will run from June 1 through September 30, 2011. As part of the study, you'll be provided with advice and equipment to help manage your energy use.

2. Participant Website: This site will provide educational resources, rate information, equipment user guides, a discussion board, and answers to frequently asked questions:

   **http://www.smud.org/en/SS/Participant**

3. Discussion Board: Here's where you can ask questions and share your experiences with other participants and the Summer Solutions service team.

4. Rate Magnet: If you signed up for the Summer Solutions rate, the welcome packet includes a rate magnet. Place your magnet somewhere in the home at eye level (we suggest the refrigerator) and refer to it during the summer.

5. System Events: There will be 12 System Events this summer on weekdays between 4 pm and 7 pm. During these hours, we are asking customers to reduce system costs by lowering their home energy use. If you signed up for the Summer Solutions rate, these savings are passed on to you with a 30% discount on Off Peak rates.

6. Thermostat: The Summer Solutions thermostat is a tool you can use to program in your energy savings during Events and every day. A User Guide is available on the participant website.


7. Energy Display: The Summer Solutions installer provided you with a link to a computer application that allows you to view your home's real-time energy use and costs from a web browser. A User Guide is available on the participant website.

8. Customer Service: If you have any questions, feel free to contact the Summer Solutions Support Team. They are available Monday through Friday from 9 am to 4 pm, by email or phone:

   **SummerSolutions@HerterEnergy.com**

   **(916) 835-2100**

Home 4/4/11

## Home Energy Assessments

The Summer Solutions Home Energy Assessments – one-hour on-site assessments of low-cost energy efficiency opportunities – were provided free of charge as a benefit of the program. At the end of the visit, these participants were provided with a checklist of action items, most of which could be completed by the homeowner at little to no cost (Figure 15). By the end of summer 2012, more than 40% of the participants had taken advantage of this offering.

**Figure 15. Summer Solutions Home Energy Assessment Checklist**

Summer Solutions HOME ENERGY ASSESSMENT CHECKLIST

*Unless otherwise indicated, the homeowner or a skilled professional can complete the following efficien*

| ✓ | ENVELOPE + DUCTS | Ventilation | Insulation | Penetration | Notes |
|---|---|---|---|---|---|
| | Ducts | | ☐ Insulate [1] | ☐ Metal tape/mastic [1] | |
| | Attic | ☐ Vent/turbine/attic fan [1] | ☐ Insulate to R38 (12") [1] | | |
| | Attic hatch | | ☐ Insulate to R38 (12") | ☐ Weather strip | |
| | Ceiling | ☐ Whole house fan [1] | | ☐ Foam or tape/mud | |
| | Walls | | ☐ Insulate to R13 (4") [2] | ☐ Foam or tape/mud | |
| | Windows | | ☐ Replace [2] ☐ Cover | ☐ Caulk | |
| | Doors | | ☐ Replace [1] | ☐ Weather strip | |
| | Fireplace | ☐ Close flue when unused | ☐ Insulate [2] | ☐ Seal [2] | |
| | Floor | | | ☐ Foam | |
| | Crawl space | ☐ Vent [1] | ☐ Insulate to R19 (6") [1] | | |

1 = services of a skilled professional or contractor are recommended; 2 = services of a licensed contractor are recom

| ✓ | APPLIANCES | Schedule | Efficiency | Temperature | Notes |
|---|---|---|---|---|---|
| | HVAC + thermostat | ☐ Avoid 4-7 pm | ☐ Replace [2]<br>☐ Clean coils<br>☐ Clean/change filter | ☐ Summer 78°F or higher<br>☐ Winter 68°F or lower<br>☐ Night/away offset ±10°F | |
| | Water heater | ☐ Avoid 4-7 pm [(2)] | ☐ Replace [2] ☐ Blanket | ☐ 120°F or lower | |
| | - water pipes | | ☐ Insulate first 2-5 feet | | |
| | Refrigerator | | ☐ Replace ☐ Clean coils | ☐ As recommended | |
| | - refrigerator in garage | | ☐ Remove ☐ Unplug | ☐ As needed | |
| | Pool pump | ☐ Avoid 4-7 pm | ☐ Replace [2] | | |
| | Pool heat | ☐ Avoid 4-7 pm | ☐ Replace [2] ☐ Cover | ☐ 78°F or lower | |
| | Spa pump | ☐ Avoid 4-7 pm | ☐ Replace [1] | | |
| | Spa heat | ☐ Avoid 4-7 pm | ☐ Replace [1] ☐ Cover | ☐ 101°F or lower | |
| | Light bulbs | | ☐ Replace with CFLs, LEDs | | |

1 = services of a skilled professional or contractor are recommended; 2 = services of a licensed contractor are recom

## Event Schedule and Weather

The summer of 2011 was unusually cool for the Sacramento region. In a typical summer, there are 15 days in which the maximum daily temperature exceeds 100°F – but in 2011, just one day exceeded 100°F at two of the three weather stations. Despite the cooler weather, the research team called all 12 events, trying to keep a good distribution of event days and non-event days across the available temperature spectrum and days of the week (Table 8). In 2012, four of the twelve events exceeded 100°F at all three weather stations (Table 9).

**Table 8. 2011 Event schedule and maximum daily temperatures**

| Event # | Date | Day | Sacramento West | Sacramento East | Folsom |
|---|---|---|---|---|---|
| 1 | 8/17/11 | Wednesday | 92 | 95 | 94 |
| 2 | 8/23/11 | Tuesday | 94 | 96 | 95 |
| 3 | 7/28/11 | Thursday | 96 | 99 | 97 |
| 4 | 7/8/11 | Friday | 95 | 98 | 97 |
| 5 | 7/21/11 | Thursday | 94 | 97 | 95 |
| 6* | 8/25/11 | Thursday | 94 | 96 | 94 |
| 7* | 8/29/11 | Monday | 93 | 95 | 93 |
| 8 | 9/6/11 | Tuesday | 96 | 98 | 96 |
| 9 | 9/7/11 | Wednesday | 96 | 99 | 97 |
| 10 | 9/2/11 | Friday | 96 | 99 | 96 |
| 11 | 9/9/11 | Friday | 103 | 102 | 99 |
| 12 | 9/19/11 | Monday | 94 | 96 | 93 |
| | Average | | 95 | 97 | 95 |

** August 25 and 29 were excluded from the analysis due to equipment failure.*

**Table 9. 2012 Event schedule and maximum daily temperatures**

| Event # | Date | Day | Sacramento West | Sacramento East | Folsom |
|---|---|---|---|---|---|
| 1 | 6/20/12 | Wednesday | 96 | 94 | 97 |
| 2 | 7/10/12 | Tuesday | 100 | 101 | 101 |
| 3 | 7/12/12 | Thursday | 103 | 103 | 103 |
| 4 | 8/2/12 | Thursday | 98 | 99 | 99 |
| 5 | 8/8/12 | Wednesday | 99 | 100 | 98 |
| 6 | 8/9/12 | Thursday | 102 | 104 | 104 |
| 7 | 8/10/12 | Friday | 103 | 105 | 105 |
| 8 | 8/14/12 | Tuesday | 96 | 95 | 98 |
| 9 | 8/15/12 | Wednesday | 96 | 96 | 98 |
| 10 | 9/12/12 | Wednesday | 92 | 93 | 92 |
| 11 | 9/13/12 | Thursday | 96 | 98 | 96 |
| 12 | 9/14/12 | Friday | 93 | 93 | 93 |
| | Average | | 98 | 98 | 99 |

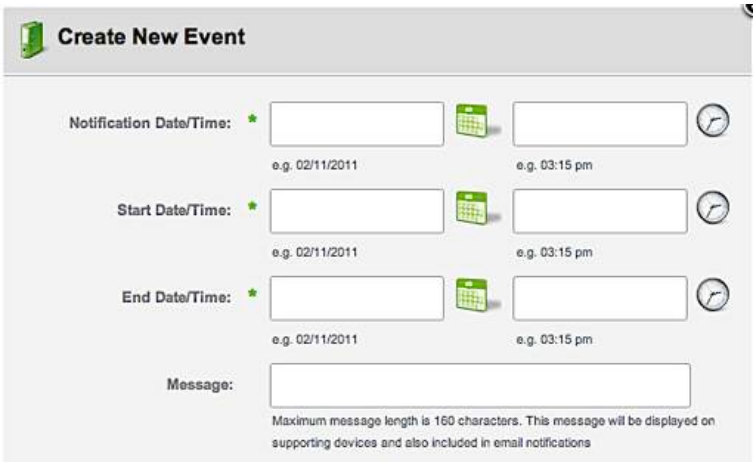
## Event Notification and Thermostatic Automation

The process of sending demand response signals to customer appliances is not new. Conventional direct load control programs for air-conditioning and water heaters have existed for decades. Likewise, programmable communicating thermostats (PCTs) have been used successfully in utility load control programs for many years. In general, the PCTs used for the Summer Solutions program provided customers with a set-and-forget tool to respond to high peak prices, and reliably delivered peak load reductions on critical peak days.

Participants were notified of all events 24 hours in advance, via email, Energy Display, thermostat, and if requested, by phone call or text message. Notification emails also provided tips for responding to the event on the following day.

The Summer Solutions equipment was OpenADR-compliant, meaning each gateway had the ability to retrieve event information from the OpenADR server via the Internet. To initiate events, the research team logged into the Demand Response Automation Server interface through a secure website, and entered program parameters for the event (Figure 16). These parameters were then available for each gateway to pull and transmit to the Summer Solutions thermostats.

**Figure 16. OpenADR interface: scheduling an event**






At 4:00 pm on the day of the event, thermostats responded to the OpenADR notification in one of two ways. The utility-controlled PCTs responded by increasing the target temperature by 4 °F, allowing one override per participant per summer. Customer-controlled PCTs responded by increasing the target temperature by the value programmed into the thermostat's "Event Offset" menu setting, described in Section 3. During installation, participants were encouraged to set this value to 4 °F or higher.

Participants who were neither on the TOU-CPP rate nor on the ATC program had no obligation or monetary incentive to respond to event signals, however, many chose to participate in events for altruistic reasons.

The OpenADR communications technology successfully notified the Summer Solutions thermostats within seconds of sending the OpenADR signal – as long as (1) the gateways were connected to the Internet and (2) the ZWave connection between the gateway and thermostat was robust. In other words, where the event notification did not reach its intended target, OpenADR was not at fault, but rather, the Summer Solutions equipment was.

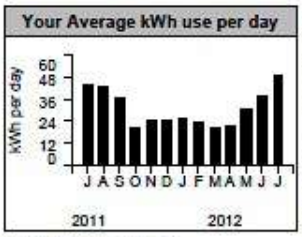
At one point in August 2011, more than half of all participant gateways suddenly disconnected from the Internet for unknown reasons. The result was that participants had to reboot their gateways to bring them back online for OpenADR event signaling, and the two affected events were removed from the analysis.

In a few homes, participants plugged their gateways into power strips and turned them off when the computer was not in use (to be efficient), thereby preventing the event signals from reaching the thermostat. One could reasonably argue that those on the ATC option who were not on the TOU-CPP rate had an incentive to unplug their gateways prior to events, to prevent the direct control of their air-conditioning while still collecting the $4 per event. However, there was no evidence to suggest that the ATC participants were any more likely to have disconnected gateways than were the non-ATC participants.

## Billing

All participants continued to receive their standard SMUD bill. Bills for participants on the TOU-CPP rate included one line per time-of-use rate period. Bills for participants on the ATC option included a line item indicating a "Bill Adjustment" for the ATC payment of $4 per event (Figure 17).

**Figure 17. Summer Solutions bill**




| ELECTRIC SERVICE CHARGES/CREDITS | USAGE | TYPE | RATE | TOTAL |
|---|---|---|---|---|
| **SmartPricing Options Optimum Off-Peak Plan** | | | | |
| Off-Peak Base Usage | 700 | Summer kWh @ | 0.072100 | 50.47 |
| Off-Peak Base Plus Usage | 711 | Summer kWh @ | 0.141100 | 100.32 |
| On-Peak Weekday Usage | 54 | Summer kWh @ | 0.270000 | 14.58 |
| On-Peak Consrv-Day Usage | 20 | Summer kWh @ | 0.750000 | 15.00 |
| Bill Adjustment: Summer Solutions* | | | | -12.00 |
| System Infrastructure Fixed Charge* | | | | 10.00 |
| Greenergy Advocate | 1,485 | kWh @ | 0.005000 | 7.43 |
| Solar Surcharge | 1,485 | kWh @ | 0.001300 | 1.93 |
| Sacramento City Tax* | | | | 14.08 |
| State Surcharge* | | | | 0.43 |
| **TOTAL ELECTRIC SERVICE CHARGES/CREDITS** | | | | **$202.24** |

## Data Collection and Surveys

Multiple types of information were collected from study participants at several points in the project. Initially, basic information was pulled from SMUD's customer database to conduct recruitment efforts. More detailed customer and building information was collected through the Participant Survey. Throughout the study, SMUD collected hourly electricity use data. At the end of the study, participant perceptions of the program were documented in their End-of-Summer Survey answers. A summary of these and other datasets and sources utilized for this study is presented in Table 10.

**Table 10. Summary of data collected**

| Source | Data | Use(s) |
|---|---|---|
| **SMUD customer database** | Name, address, phone number, rate, programs, etc. | Screening and recruitment |
| **Participant Survey** | Pre-treatment behaviors | Evaluation: Behavior changes |
| | Demographic data | Comparison to population |
| **Interval Meters** | Hourly electricity use | Evaluation: Energy impacts |
| **Weather.com** | Daily temperature forecasts | Event scheduling |
| **MesoWest.utah.edu** | Historical hourly temperatures | Evaluation: Energy impacts |
| **End-of-Summer Survey** | Satisfaction | Evaluation: Satisfaction |
| | Summer behavior | Evaluation: Behavior changes |

The study included two types of surveys: one before the first summer and one at the end of each summer. Most participants completed the online versions, while a smaller group completed paper copies that were mailed to them, or answered the questions by phone. The Participant Survey, administered prior to pilot participation, focused on building and customer characteristics and pre-summer behaviors, while the End-of-Summer Surveys, administered at the end of each summer, collected information about participants' experiences on the program. Customers who participated in both years received the End-of-Summer Survey in both 2011 and 2012. Of the 313 participants who completed the study, 298 (95%) responded to the Pre-Study Survey and 256 (82%) responded to the 2012 Post-Study Survey.

# 5. Participant Load Impacts

## Regression Analysis Brief

The regression model used in this study builds on prior work described in Herter & Wayland 2010 and Herter et al. 2013. Hourly kilowatt (kW) values, measured at each participating home, were analyzed using three-level mixed-effects models. Hourly electricity use data were regressed on year, hour, temperature, event day, and participant group variables. All impacts were estimated relative to baselines modeled using pretreatment participant loads adjusted to reflect treatment period temperatures and corrected for exogenous effects using a matched control group. The model equations, results, and other details of the analysis are provided in Appendix C.

Three types of impacts were calculated for each analysis: Overall Energy impacts, Non-event Peak impacts, and Event Peak impacts. These three values are representative of different time periods, as follows.

- ***Overall Energy impacts*** represent the average change in hourly energy use across all 24 hours of the day and all 7 days of the week, including weekends and holidays
- ***Non-event Peak impacts*** represent the average hourly change across the three peak hours, from 4 to 7 pm on *non-event* weekdays
- ***Event Peak impacts*** represent the average hourly change across the three event hours, from 4 to 7 pm on *event* weekdays

For consistency and ease of comparison, all impacts are presented in units of average kilowatt-hours per hour (kWh/h), abbreviated in most cases to kW. Positive values indicate an increase in energy use relative to the baseline, whereas negative impact values indicate energy savings. Note that the convention for presenting overall energy impacts is kWh rather than kW, but the hourly kW values presented here are easily converted to kWh through multiplication by the number of hours across the desired time period.

## Aggregate Program Impacts

This section describes the overall program impacts for all participants without regard to information treatment, rate choice, or automation control choice. Later sections will break out program effects by information treatment and program choices, respectively.

On average, the 313 Summer Solutions participants as a group showed statistically significant savings across all impact measures: 2.4% overall energy savings (-0.04 kW), 18% non-event peak savings (-0.40 kW), and 41% event peak savings (-1.24 kW).

Figure 18 illustrates the modeled baseline, non-event and event loads (kW) on a 100°F weekday with error bars indicating 95% confidence intervals. Note the substantial peak reduction on non-event weekdays, largely attributable to the 27¢/kWh peak rate for those on the TOU-CPP rate. Event days are remarkable for the appreciable load drop between 4 and 7 pm (shown as hours ending 17-

19 in the graphs), when load control and the TOU-CPP event rate of 75¢/kWh are both in effect. Note that automated PCT response is in effect only on the event days.

### FIGURE 18. AVERAGE PARTICIPANT LOADS ON A 100°F WEEKDAY

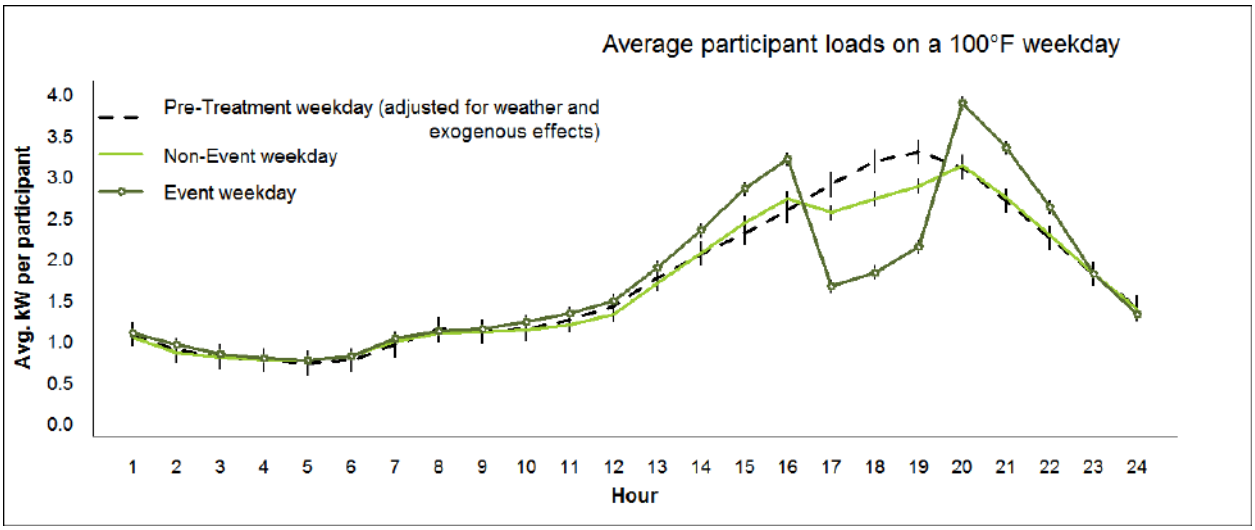
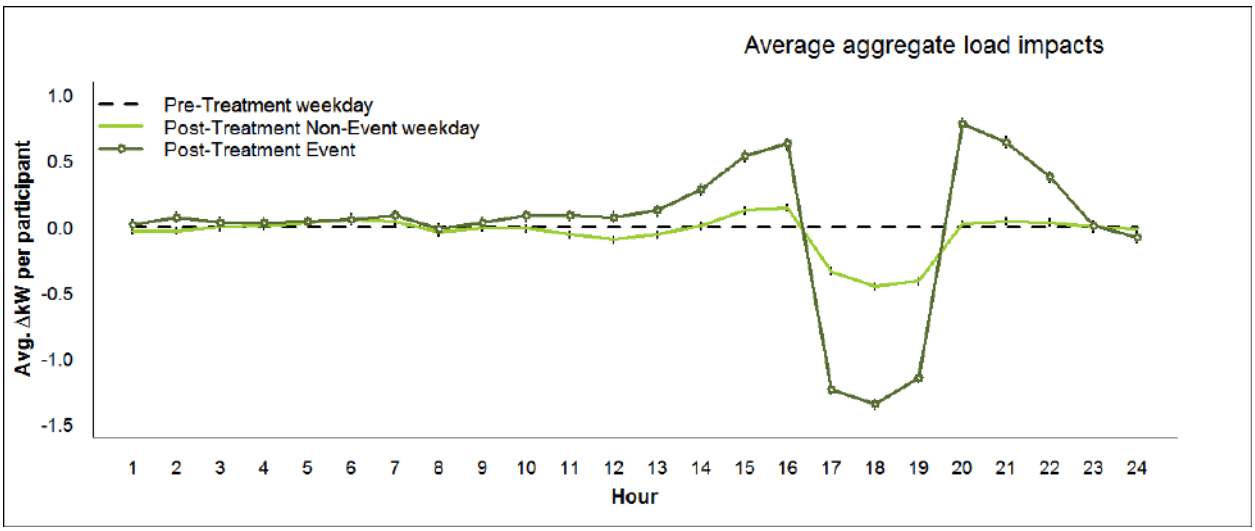



Figure 19 shows the load impacts (ΔkW) relative to the pre-treatment loads adjusted for weather and exogenous effects. On normal non-event weekdays, significant savings are clearly visible during the peak hours, with small precooling effects prior to the peak and no evidence of rebound after the peak. On event days, strong precooling effects are apparent from noon to 4 pm, when significant load savings are apparent through the end of the peak period at 7 pm. After events, a significant 3-hour rebound effect is evident.

### FIGURE 19. AVERAGE AGGREGATE LOAD IMPACTS OF ALL SUMMER SOLUTIONS PARTICIPANTS



## Impacts by Information Treatment

Although this study touches on many aspects of new residential programs and technologies, the main objective of this study was to investigate the usefulness of real-time energy data at the home and appliance level. This objective is met through a three-way comparison between the load impacts of a group of participants who were given a PCT with (1) no real-time information (the Baseline information group), (2) real-time home information (the Home information group), or (3) real-time home and appliance information (the Appliance information group). The goal of this comparison was to determine whether real-time information at the Home and Appliance levels affected energy use and peak loads.

Table 11 provides the modeled load impacts for each of these three information groups. In each case, the negative kW values indicate the 2012 average hourly savings relative to a baseline generated from 2010 participant data corrected for weather and exogenous effects.

**Table 11. Average hourly load impacts (kW), by information group**

| Information Treatment Group | N | Overall Energy *(24-hour average)* | Non-event Peak *(4-7 pm average)* | Event Peak *(4-7 pm average)* |
|---|---|---|---|---|
| Baseline (none) | 100 | -0.01 (-0.6%) | -0.29 (-14%) | -1.13 (-40%) |
| Home | 101 | -0.07** (-4.6%) | -0.39* (-17%) | -1.22* (-40%) |
| Appliance | 112 | -0.03 (-1.8%) | -0.52** (-21%) | -1.37** (-43%) |

*All impacts are statistically significant (p<0.05) except Overall Energy impact for the Baseline group. An asterisk (*) indicates significant effect beyond that of the Baseline group, while a double asterisk (**) indicates significant effect beyond that of the other two groups (p<0.05).*

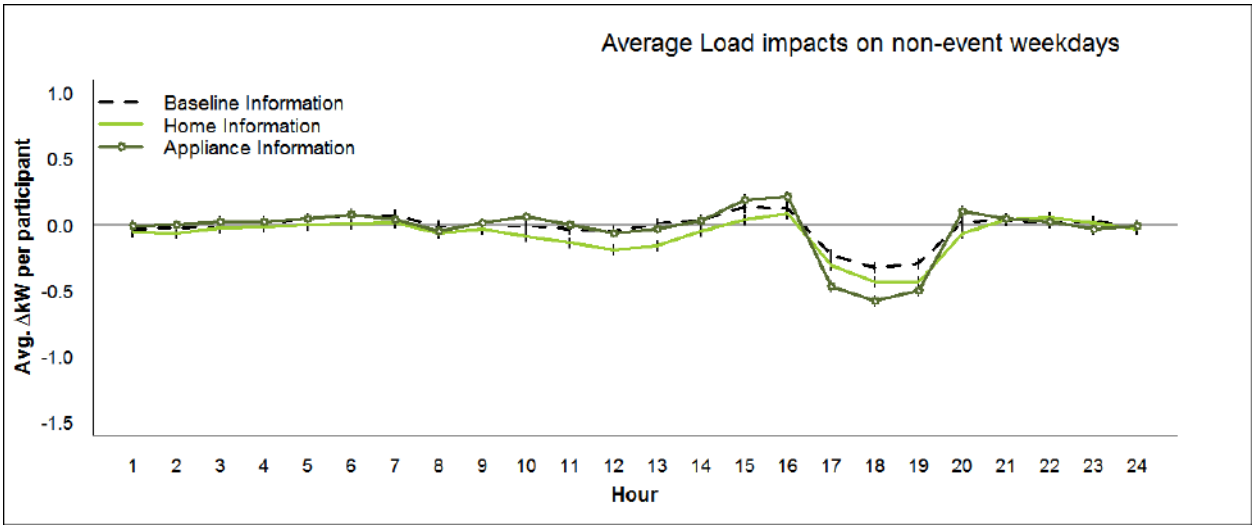
Relative to the Baseline group, real-time Home information effected additional energy savings of 0.06 kWh per hour, for an additional 4% savings. This value translates to roughly 175 kWh additional savings over the course of a 4-month summer. Interestingly, this affect was smaller for the Appliance group, who received real-time energy use data for their appliances *in addition* to the same home-level data provided to the Home group.

Non-event Peak values indicate the average hourly impacts during the post-treatment weekday peak hours of 4-7 pm. Real-time information at both the Home and Appliance levels had a significant *additional* effect on non-event peak loads, with real-time Home information providing 3% more non-event peak savings than the Baseline information, and real-time Appliance level information providing 7% more non-event peak savings than the Baseline level information.

During events, those with real-time Appliance information showed a small but statistically significantly savings of about 3% relative to the Baseline.

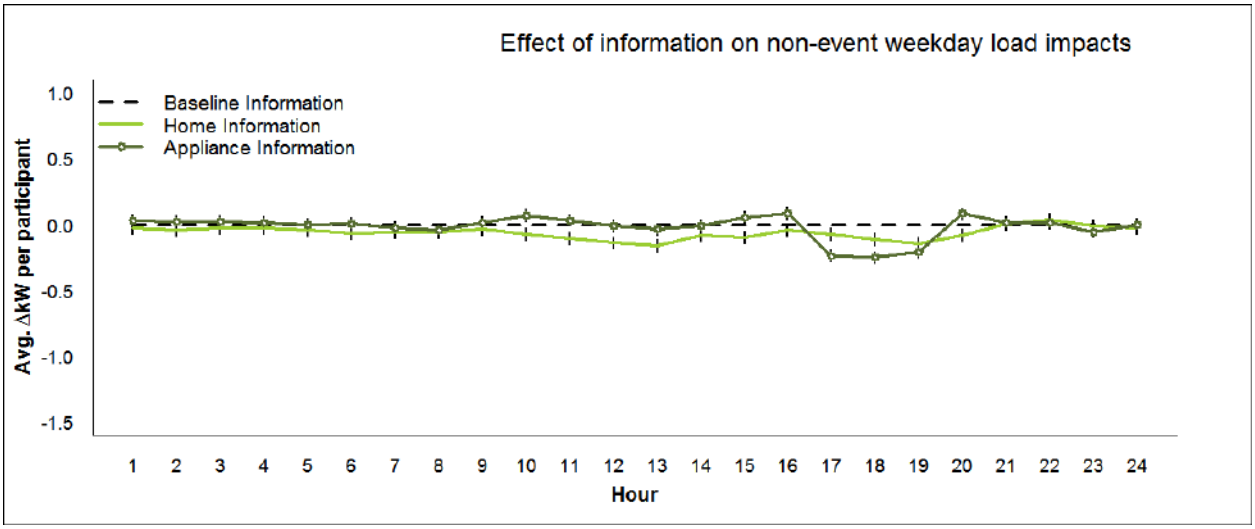
Figure 20 illustrates the hourly non-event load impacts relative to the pre-treatment weekday baseline. Compared to the Baseline group, Figure 20 shows that the Home group saved more energy during the morning hours and during the peak period, while the Appliance group saved most during the peak hours.

**FIGURE 20. AVERAGE LOAD IMPACTS ON NON-EVENT WEEKDAYS, BY INFORMATION TREATMENT**




To review these effects in more detail, Figure 21 recasts the values provided in Figure 20 using the Baseline group as the baseline, meaning that the hourly Baseline impacts have been subtracted from the Home and Appliance load shapes. In doing so, the effects of the thermostat and education are removed, leaving only the impacts of the real-time energy information treatments.

**FIGURE 21. NON-EVENT WEEKDAY LOAD IMPACT COMPARISON: HOME AND APPLIANCE INFORMATION TREATMENTS RELATIVE TO THE PCT-ONLY BASELINE**

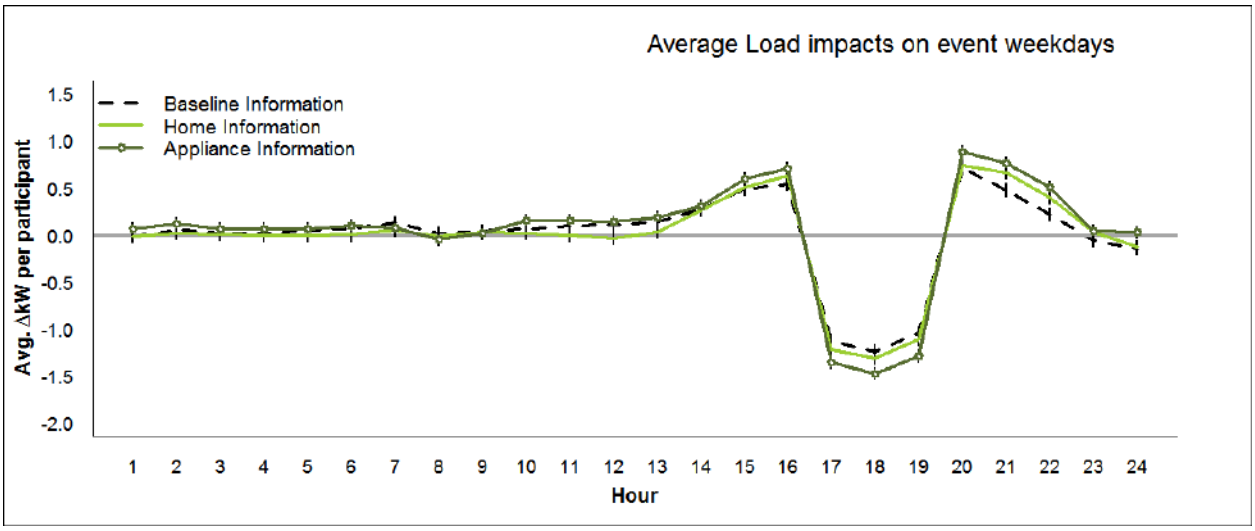


Relative to the Baseline information group, Figure 21 shows that the Home information group has modest but relatively stable savings throughout the day, continuing but not changing across the peak period. In contrast, the Appliance information group shows almost no variation from the Baseline information group until the onset of the peak period.

One possible explanation for this pattern is that those with only Home information, being less aware of individual contributions to total energy use, employ a more general strategy for keeping energy use low all the time. In contrast, those with Appliance energy data may have the knowledge required to be more precise in their load management efforts. For example, the Summer Solutions thermostats were signaled for automated response only on event days. It is possible that the Appliance group, being more aware of the significant contribution of air-conditioning loads, were more likely to use one of the four weekday temperature settings to automate avoidance of the peak every weekday, not just during events.[8] Given the uncertainties here, this topic may warrant further research.

Figure 22 illustrates hourly event load impacts relative to a pre-treatment weekday. Loads in all hours are statistically indistinguishable for the three treatment groups until the onset of the event at 4 pm (hour 17), when appliance information shows a slightly lower loads during peak.

**FIGURE 22. AVERAGE LOAD IMPACTS ON EVENT DAYS, BY INFORMATION TREATMENT**




With the addition of weekends, hourly load impacts for all summer days (not shown here) differ only slightly from the weekday impacts shown in Figure 21.

[8] The Summer Solutions thermostats provided the standard 4 temperature settings per day, rendering automation of precooling and peak offsets impossible for those using the 4 temperature settings for normal Wake, Work, Home, and Sleep periods. Future efforts would benefit from thermostats that provided at least 2 additional bins for Precool and Peak periods to allow automated response to daily peak rates.

## Impacts by Rate and Event Automation Options

Unlike the information treatments, which were randomly assigned to customers prior to recruitment, the rate and event automation options were offered in the Participation Agreement. Participants were given the option to (1) sign up for the TOU-CPP rate or stay on the standard tiered rate, and (2) allow the utility to control their PCT during events (the ATC option) or use the PCT to automate their own response to events. These two options created four program groups, listed in Table 12 along with their group size (N) and load impacts.

**Table 12. Average hourly load impact (kW), by rate and automation options**

| Program group | N | Overall Energy *(24-hour average)* | Non-event Peak *(4-7 pm average)* | Event Peak *(4-7 pm average)* |
|---|---|---|---|---|
| Tiered rate + Customer PCT | 56 | -0.00 (-0.0%) | -0.09* (-3.8%) | -0.26 (-8.2%) |
| Tiered rate + Utility PCT | 78 | 0.02 (1.3%) | -0.01 (-0.2%) | -0.88* (-30%) |
| TOU-CPP rate + Customer PCT | 83 | -0.06** (-4.1%) | -0.71*** (-32%) | -1.71** (-58%) |
| TOU-CPP rate + Utility PCT | 96 | -0.07** (-5.3%) | -0.64** (-29%) | -1.71** (-57%) |

*All impacts are statistically different from zero ($p<0.05$) except the Overall Energy impacts of the "Tiered rate + Customer PCT" group and the Non-event Peak impacts of the "Tiered rate + Utility PCT" group. An asterisk (*) indicates significant effect beyond that of the "Tiered rate + Customer PCT" group, a double asterisk (**) indicates significant effect beyond that of both "Tiered rate" groups, and a triple asterisk (***) indicates significant effect beyond all other groups ($p<0.05$).*

Most striking in this comparison are the significantly greater savings of participants on the TOU-CPP rate, shown in the last two lines of the table. These participants had greater overall energy savings than those on the standard tiered rate, and saved significantly during non-event peak periods (owing to the weekday peak rate of 27¢ per kWh), whereas those on the tiered rate saved little to nothing during the non-event peak periods.

Participants on the TOU-CPP rate also responded significantly more during events than those on the direct load control program, represented here as the Tiered rate + Utility PCT group. Since both TOU-CPP groups responded similarly, this implies that those on the TOU-CPP rate may be setting their event response higher than the 4 °F initiated by the ATC program or are contributing with end-use loads beyond just air-conditioning. Self-reported peak behaviors collected during the post study survey indicate that those on the TOU-CPP rate did more frequently report peak shifting and conservation activities (see Table 20).

Figure 23 illustrates the *weekday* load impacts of the four program groups. Those on the tiered rate show no savings compared to their weather-corrected pre-treatment loads. In contrast, those on the TOU-CPP rate show significant peak load reductions on non-event weekdays.

**FIGURE 23. RATE AND AUTOMATION OPTIONS: AVERAGE LOAD IMPACTS ON NON-EVENT WEEKDAYS**

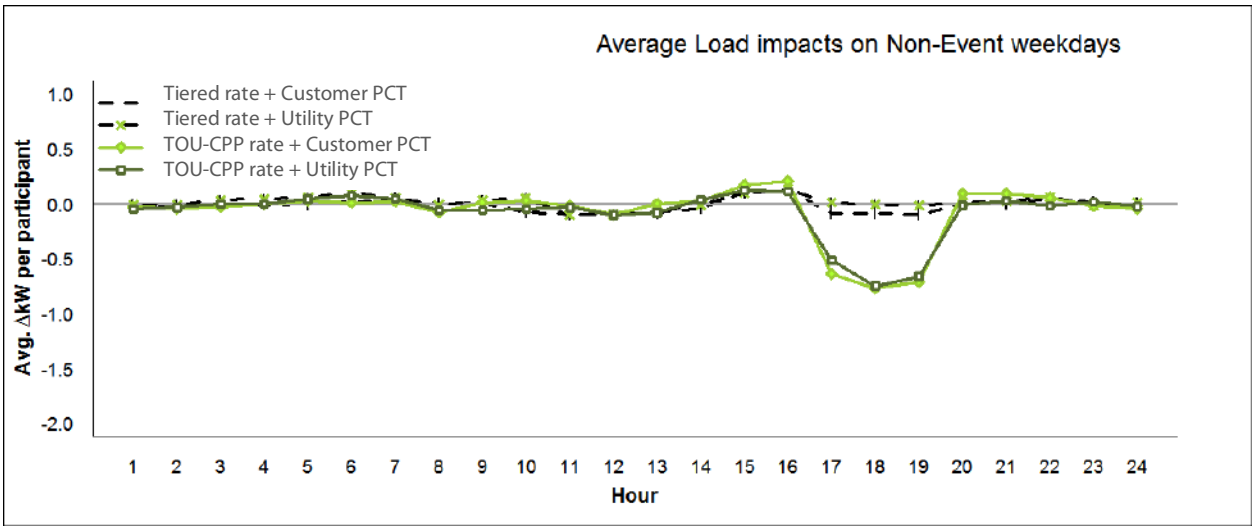
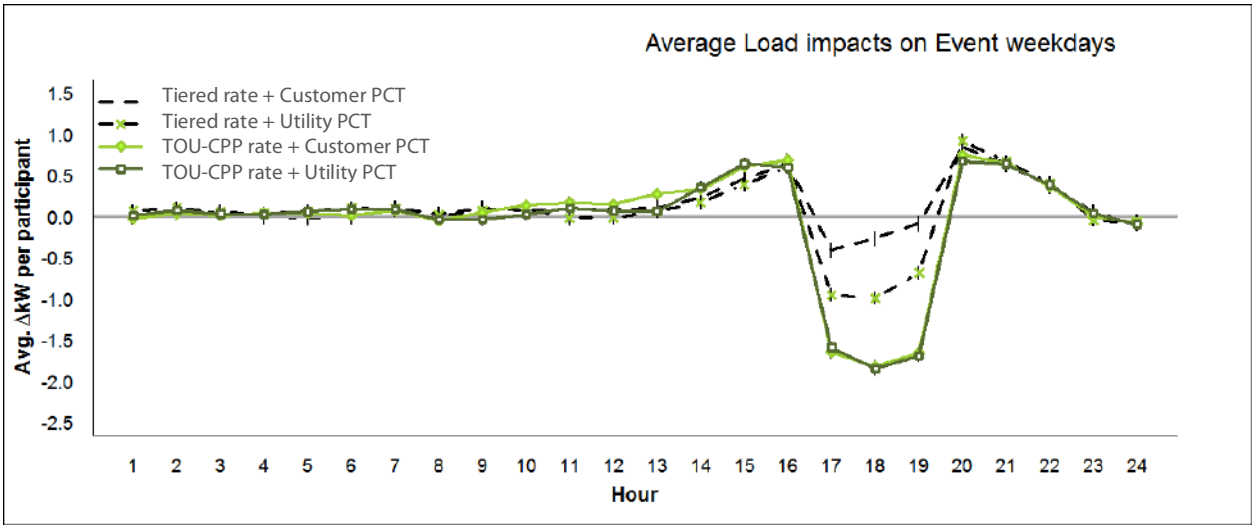



Figure 24 shows the hourly *event* day load impacts of all four groups. Those who had neither the TOU-CPP rate nor the utility-controlled PCT were provided with event notification, but had no financial incentive to reduce peak loads. Unsurprisingly, this group had the lowest response and the highest override rate, as evidenced by the swift return to normal after the first hour of the event. Those on the TOU-CPP rate had the highest event savings, achieving nearly twice the load shed of participants on the tiered rate with utility-controlled PCTs.

**FIGURE 24. RATE AND AUTOMATION OPTIONS: AVERAGE LOAD IMPACTS ON EVENT DAYS**



## Persistence of Impacts

This section describes the load impacts for the customers who participated in the Summer Solutions program in both 2011 and 2012.

Figure 25 provides impacts for each treatment in the first and second years of the Summer Solutions study (2011 and 2012) relative to 2010 baselines. For all treatments, non-event peak and event peak savings stayed level or improved in the second year. Energy savings that were earned in the first year dipped slightly in the second year for the Baseline and Home groups, but increased slightly for the Appliance group, rendering the overall energy savings for the Home and Appliance treatments statistically equal and greater than the Baseline savings in the second year. This finding is interesting because in the first year of the study, the Home group had the greatest savings, while the Baseline and Appliance groups were not statistically different.

**Figure 25. Persistence of impacts over two years, by treatment**

| Real-time information | N | Overall Energy (24-hour average) | Non-event Peak (4-7 pm average) | Event Peak (4-7 pm average) |
|---|---|---|---|---|
| Baseline | 71 | -3.9% -2.8% | -10% -14% | -38% -41% |
| Home | 74 | **-7.1%** -4.5% | **-19%** **-20%** | -38% -42% |
| Appliance | 77 | -3.3% **-3.9%** | **-21%** **-26%** | -39% **-45%** |

*Impacts significantly different from the Baseline are marked in **bold**.*
*Impacts significantly different from the other two groups are underlined.*

Figure 26 provides impacts for each of the four rate and automation program groups in the first and second years of the Summer Solutions study relative to 2010 baselines. For those on the TOU-CPP rate, non-event peak and event peak savings stayed level or improved in the second year, while peak savings for those on the Tiered rate stayed level or decreased. Energy savings that were earned in the first year dipped in the second year for all but the group on the TOU-CPP rate with utility-controlled thermostats.

**FIGURE 26. PERSISTENCE OF IMPACTS OVER TWO YEARS, BY RATE AND AUTOMATION OPTIONS**

| Real-time information | N | Overall Energy (24-hour average) | Non-event Peak (4-7 pm average) | Event Peak (4-7 pm average) |
|---|---|---|---|---|
| Tiered rate + Customer PCT | 31 | -6% -2% | -6% -3% | -5% -4% |
| Tiered rate + Utility PCT | 35 | -3% 0% | -5% -2% | **-30%** **-26%** |
| TOU-CPP rate + Customer PCT | 32 | **-7%** -1% | **-30%** **-29%** | **-51%** **-51%** |
| TOU-CPP rate + Utility PCT | 74 | **-4%** **-5%** | **-25%** **-28%** | **-53%** **-58%** |

*Impacts significantly different from "Tiered rate + Customer PCT" are marked in **bold**.*
*Impacts significantly different from "Tiered rate + Utility PCT" are underlined.*

## Extrapolation to SMUD's Residential Sector

This section describes the expected effect of a voluntary residential program with offerings similar to those of the Summer Solutions study. For simplicity, the groups with neither or both of the program options are excluded since they are unlikely to be considered for a real program.

The load impact analysis described previously allowed for development of a model that predicts average participant impacts on event and non-event days, given minimum and maximum temperature inputs. These estimates can then be extrapolated to the larger SMUD population given data inputs for the average peak load of the invited population, the percent of the residential population that is invited and eligible, and the expected participation rate.

Figure 27 shows the results of the model under the assumptions that 80% of SMUD's residential population is invited, and that 15% of those invited become participants. Note that 15% is on the lower end of what SMUD realized for their similarly designed voluntary Smart Pricing Options program. Results indicate that peak impacts on a 105°F *non-event* weekday would be about 8 MW for the load control program and 80 MW for the TOU-CPP rate.

### Figure 27. Extrapolation to residential sector loads: a 105°F non-event weekday

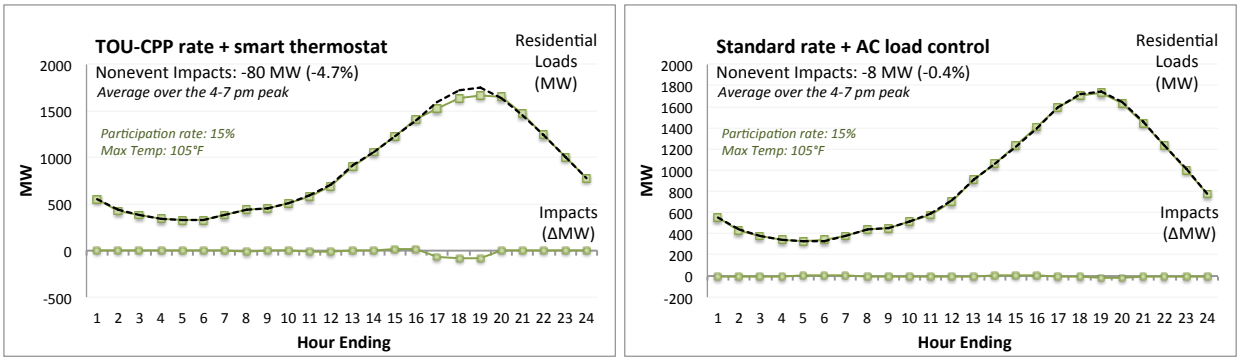
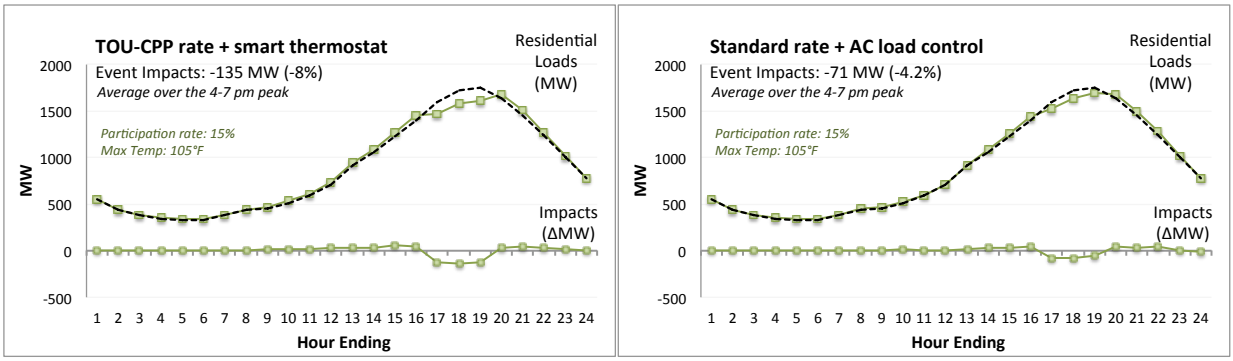



Figure 28 shows the residential impacts on an *event* weekday. Here, the TOU-CPP rate effects an average 135 MW peak load shed, while the load control program achieves just 71 MW load shed.

### Figure 28. Extrapolation to residential sector loads: a 105°F event weekday



# 6. Participant Bill Impacts

Figure 29 and Figure 30 plot summer bill impacts for those on the tiered and TOU-CPP rates, respectively. For 2011 and 2012 combined, 64% of those on the tiered rate and 80% of those on the TOU-CPP rate saved money on their summer bills. Across the four summer months, the average summer bill savings for the TOU-CPP rate was $145, while the average bills savings for those on the standard 2-tier rate was just $40.

**Figure 29. Bill impacts for participants on the tiered rate ($ vs. %)**

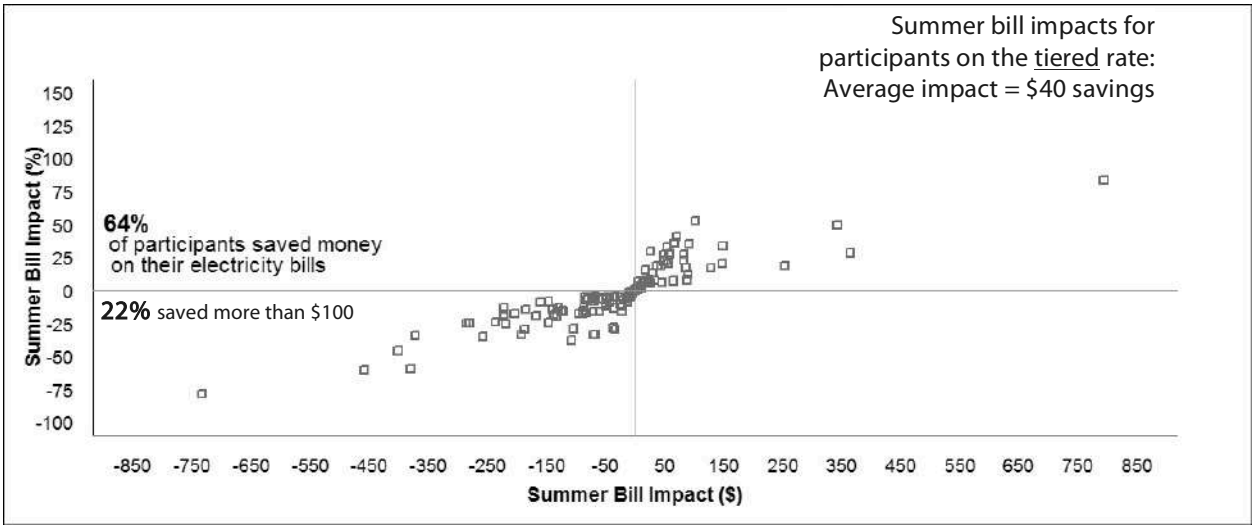
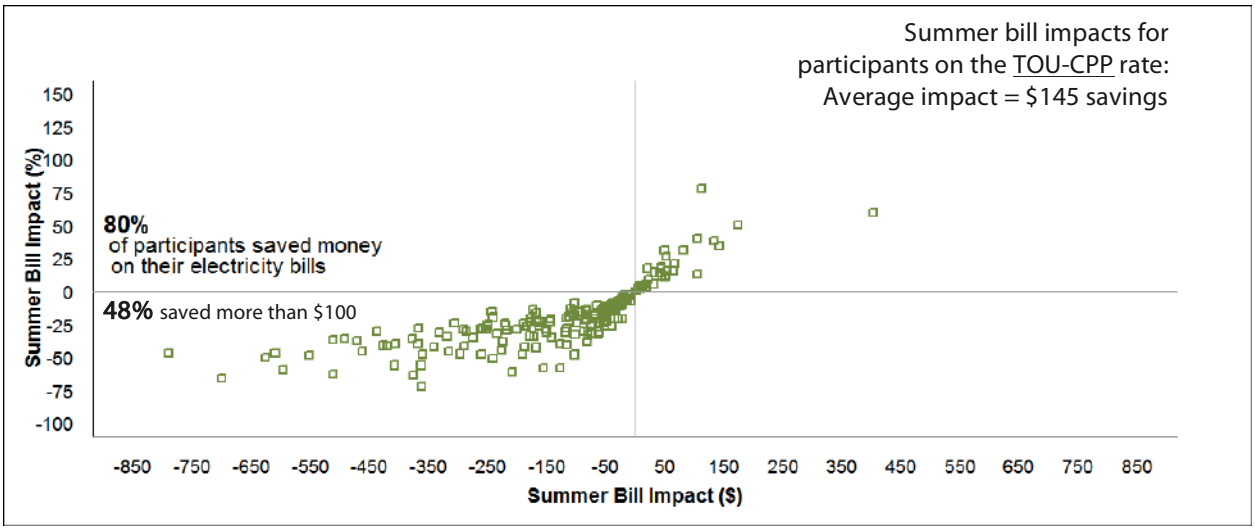



**Figure 30. Bill impacts for participants on the TOU-CPP rate ($ vs. %)**

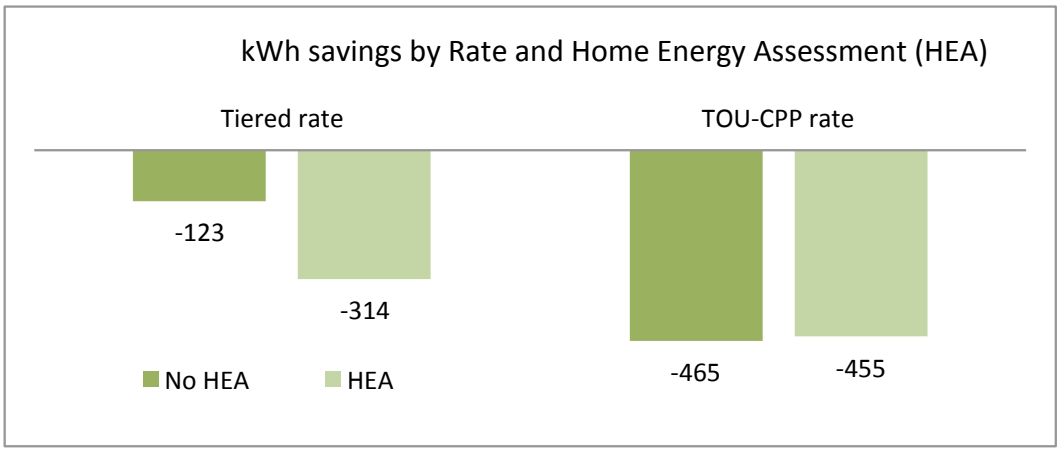


# 7. Savings Related to Home Energy Assessments

An analysis of customer specific savings indicated higher average savings for those who chose to take advantage of an optional Home Energy Assessment or HEA (See section 4). On average, those who had an HEA saved 405 kWh and $115 over the course of the summer, while those who did not have an HEA save only 299 kWh and $86 during the same period.

When this same data is considered according to rate choice, it appears that the HEA improved savings only for those on the tiered rate: with or without an HEA, TOU-CPP participants saved about 460 kWh and $146 over the summer. In contrast, those on the tiered rate who took advantage of an HEA saved significantly more money and energy than did those on the tiered rate who did not take advantage of an HEA (Figure 31).

**Figure 31. Energy savings by rate and home energy assessment**




These results could be read in two ways. This could be evidence that customers on a tiered rate can benefit significantly from the information provided in an on-site Home Energy Assessment, while those on a TOU-CPP rate are motivated enough to learn what needs to be done with or without an home energy assessment. Alternatively, since both the rate and the HEA were optional, this could be an indication that customers who were not motivated to sign up for a TOU-CPP rate or an HEA were also not motivated to save energy and money.

# 8. Preferences, Satisfaction, and Behavior

## Recruitment Rates and Program Choices

Grossly speaking, the demand response field tends to be comprised of two opposing groups: those who believe that customers will find dynamic rates unpalatable because they are confusing and punitive, and those who believe that customers will find direct load control unpalatable because it confiscates customers' control of their own appliances. This study found neither claim to be true.

As described in section 4, only the first 4,000 of the 7,000 recruitment letters mailed offered both the TOU-CPP rate and the utility-controlled PCT or "Automatic Temperature Control" option. Due to the overwhelming preference for the TOU-CPP rate over the standard tiered rate, the last 3,000 letters did not offer the TOU-CPP rate. To estimate the recruitment rates for the full set of options, then, these results consider only the response to the first 4,000 invitations.

Of the 237 customers that responded to the first 4,000 invitations, 117 (49%) chose both the TOU-CPP rate and the utility-controlled PCT, 60 (25%) chose the TOU-CPP rate only, and the remaining were split almost evenly between the 31 participants who wanted only the utility-controlled PCT (13%) and the 30 who wanted neither option (13%). This 75% signup rate for the residential TOU-CPP rate is comparable to the 65% signup rate found for the TOU-CPP rate offered in the Small Business Summer Solutions Study (Herter et al. 2009).

Table 13 shows the final signup rates for the first 4,000 invitations by treatment group and program choices. Note a slightly higher signup rate for those offered one of the two real-time energy information systems compared to those offered only the PCT. Additionally, as noted above, those choosing the TOU-CPP rate, alone or in combination with ATC far exceeded those who chose the ATC option only, or neither option (equipment and event notification only).

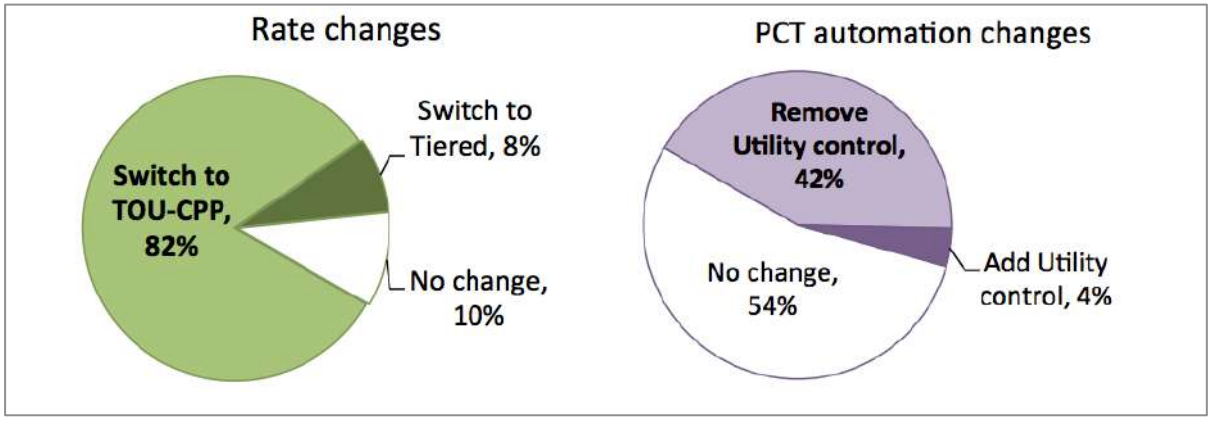
**Table 13. Response rates for the first 4000 invitations***

| | Baseline (N=1,333) | Home (N=1,333) | Appliance (N=1,334) | Average (N=4,000) |
|---|---|---|---|---|
| **Tiered rate + Customer PCT** | 0.4% | 1.1% | 0.9% | **0.8%** |
| **Tiered rate + Utility PCT** | 0.8% | 1.0% | 0.5% | **0.8%** |
| **TOU-CPP rate + Customer PCT** | 2.0% | 1.2% | 1.4% | **1.5%** |
| **TOU-CPP rate + Utility PCT** | 2.1% | 3.1% | 3.6% | **2.9%** |
| **Total** | **5.2%** | **6.3%** | **6.4%** | **6.0%** |

** The final 3,000 invitations are excluded because they did not include the TOU-CPP rate option.*

In the second year of the study, existing participants were given the option to change their original choices for rate and PCT control. Of the 222 customers that participated in both 2011 and 2012, 50 chose a different combination of rate and PCT automation options for the second year. By far the most popular change was to the TOU-CPP rate from the standard tiered rate. The second most popular switch was from the utility-controlled PCT to the customer-controlled PCT (Figure 32).

**FIGURE 32. REQUESTED PROGRAM CHANGES FOR 50 SECOND-YEAR PARTICIPANTS**



## End of Summer Survey Responses

Of the 313 Summer Solutions participants, 257 (82%) completed the End-of-Summer Survey. This section summarized some of the main findings of the survey. For a summary of all responses, see Appendix B.

### Overall Program Satisfaction

When asked to rank their satisfaction with the Summer Solutions program, 94% of participants indicated that they were very or somewhat satisfied, while 2% said they were somewhat or very dissatisfied (Figure 33). Compared to their expectations before the program began, about half indicated that their expectations were exceeded, and 5% were disappointed (Figure 34).

**Figure 33. Participants nearly all satisfied with the Program**

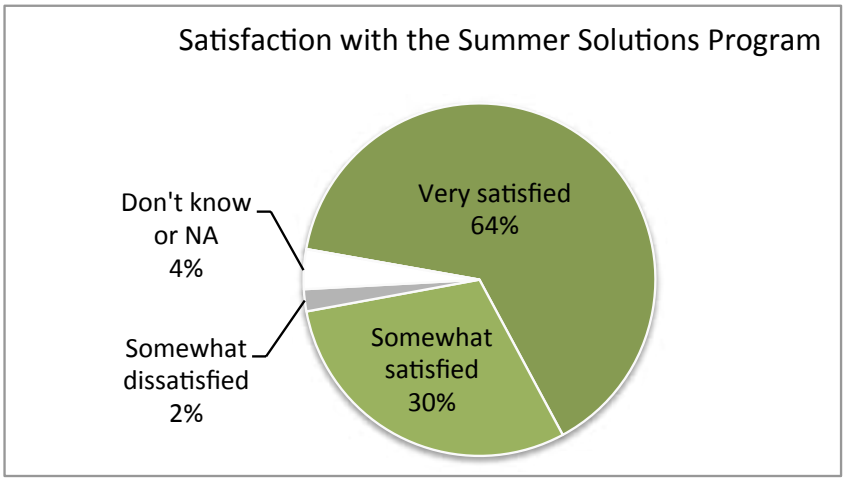
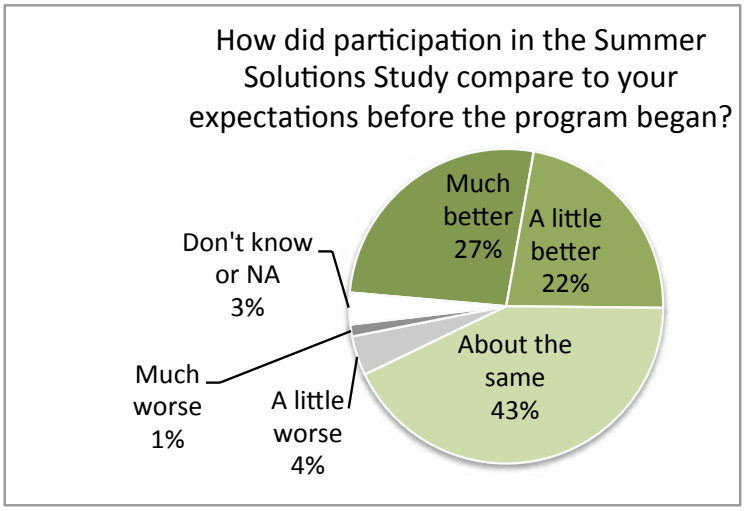


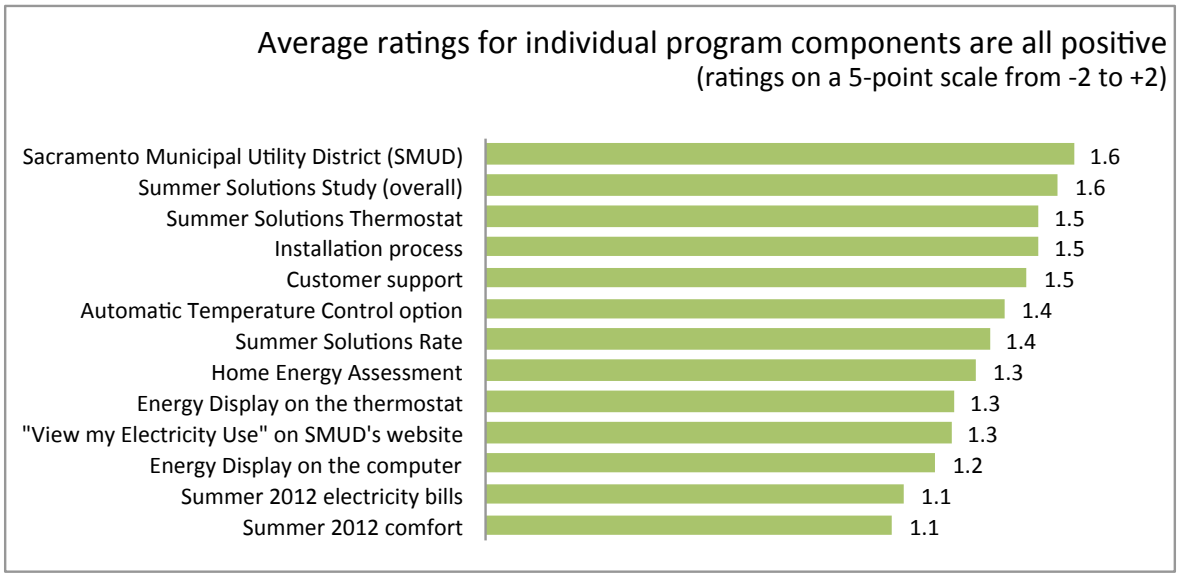

**Figure 34. Expectations were generally met or exceeded**



## Satisfaction Ratings

The end of Summer Survey asked participants to rate their satisfaction with SMUD, the Summer Solutions program, and a list of program components, as shown in Figure 35. Their ratings were assigned scores from -2 for "Very dissatisfied" to +2 for "Very satisfied." Scores for participants without experience with the rated component were excluded. For example, responses for participants who were not on the TOU-CPP rate were excluded from the average "Summer Solutions rate" score. Average scores for each component were all positive, ranging from 1.1 to 1.6.

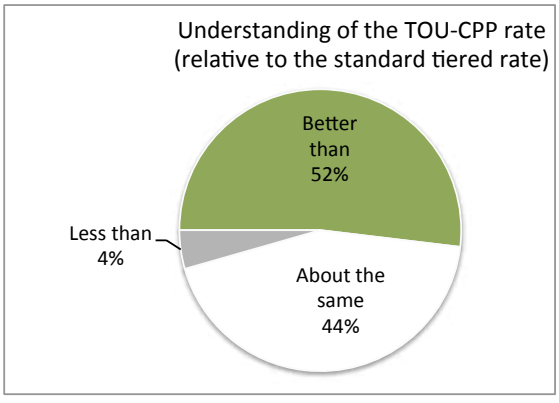
### Figure 35. Average satisfaction ratings




## Understanding of the TOU-CPP Rate

Figure 36 summarizes the responses of TOU-CPP participants asked about their understanding of the TOU-CPP relative to the standard tiered rate. More than half indicated that they understood the TOU-CPP rate better than the standard tiered rate, while 4% indicated that they understood it less than the standard rate.

### Figure 36. TOU-CPP rate more intuitive than the standard tiered rate

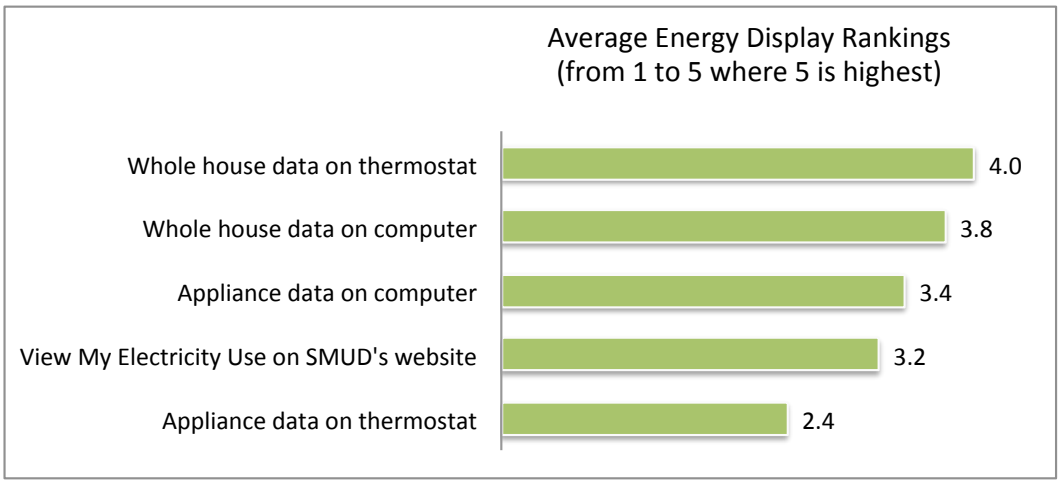


### Real-time Energy Data Displays

Figure 37 summarizes the average of the mutually exclusive rankings for different Energy Displays, where 5 is the most preferred display, 4 is the second most preferred, and so on. Rankings were excluded from participants without the display or with non-working instances of the display. Thus, rankings for "View My Electricity Use" were included only for participants who indicated that they accessed the website at least once. Rankings for "Whole house data on thermostat" and "Whole house data on computer" were included for those participants who said their energy displays accurately showed their real-time data on their thermostat or computer, respectively.

Overall, the **whole house energy use data on the thermostat** was the most preferred among participants who had access to it, followed closely by whole house data on the computer. Participants who had working access to real-time appliance data preferred the real-time data for the whole house to the real-time appliance data (see Table 20). Appliance energy data displayed on the thermostat ranked lowest wherever it was available, while SMUD's View My Energy Use came in fourth of five options overall.

**Figure 37. Average energy display rankings**



## Comfort

Participant comfort ratings were within expected ranges (Figure 38). Between 20 and 30 percent of participants said they were more comfortable during events, peaks, and overall, while more than half indicated that they were more comfortable during precooling.

Unsurprisingly, most discomfort was experienced during events, when fully 60% of participants said they were less comfortable. During weekday peaks and overall, between 30 and 40 percent of participants were less comfortable, and during precooling, 10% of participants were less comfortable. On the bright side, when asked if the discomfort was worth the savings, more than 60% said yes, and just 10% said no (Figure 39).

**Figure 38. Perceived comfort during summer 2012**

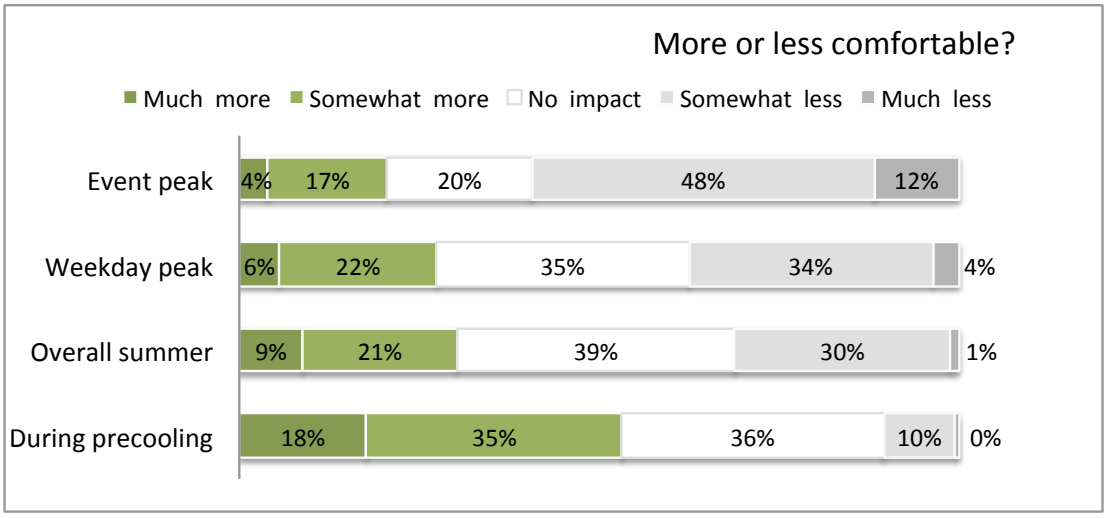
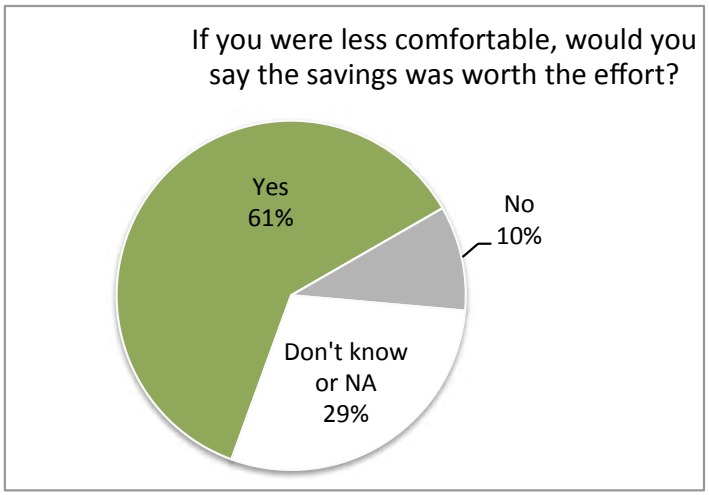



**Figure 39. Comfort-savings tradeoff**



## Conservation and Event Behaviors

Figure 40 summarizes the conservation strategies that participants said they implemented after the Summer Solutions program began.

**Figure 40. Strategies implemented since enrolling in the program**

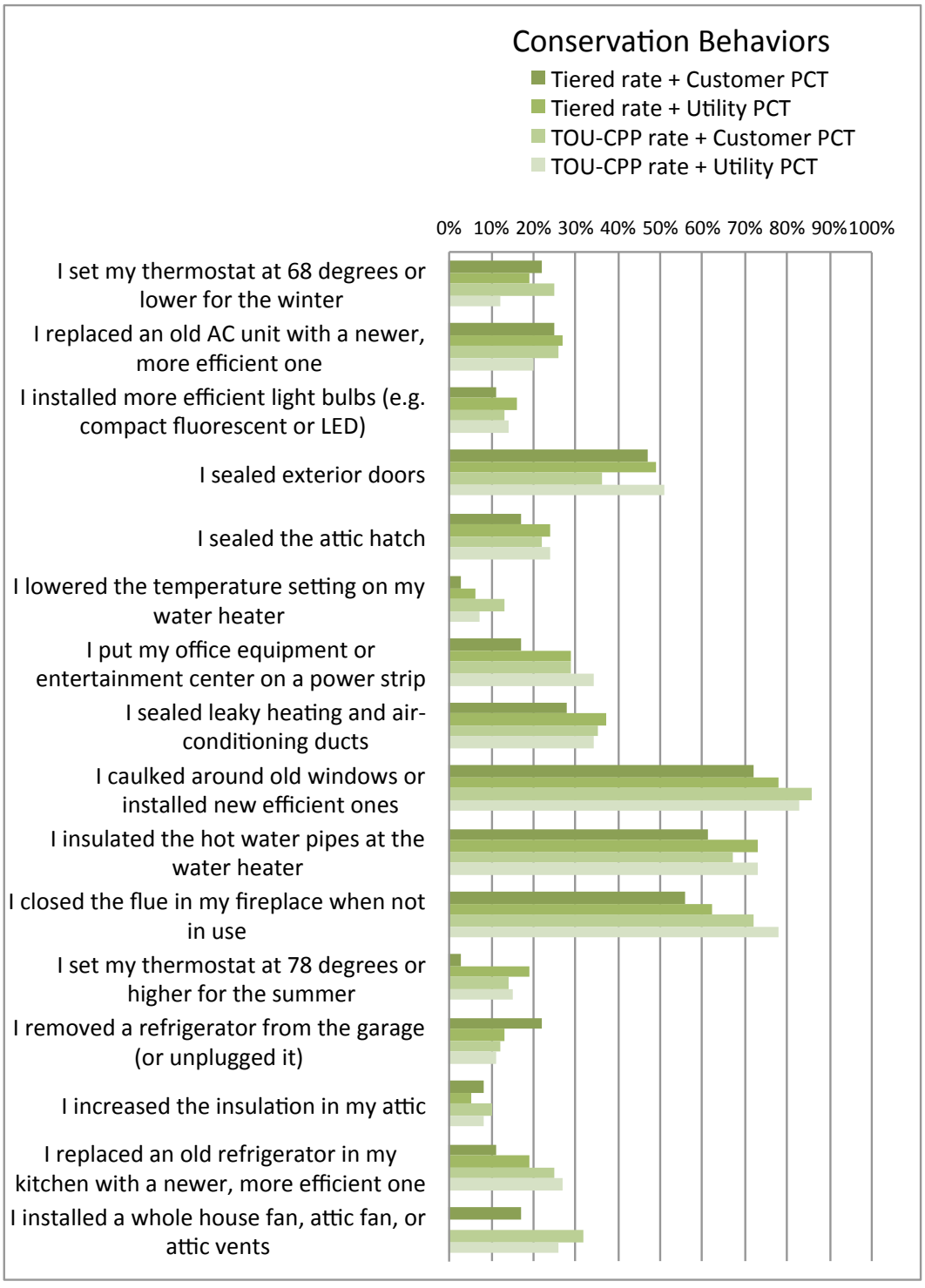
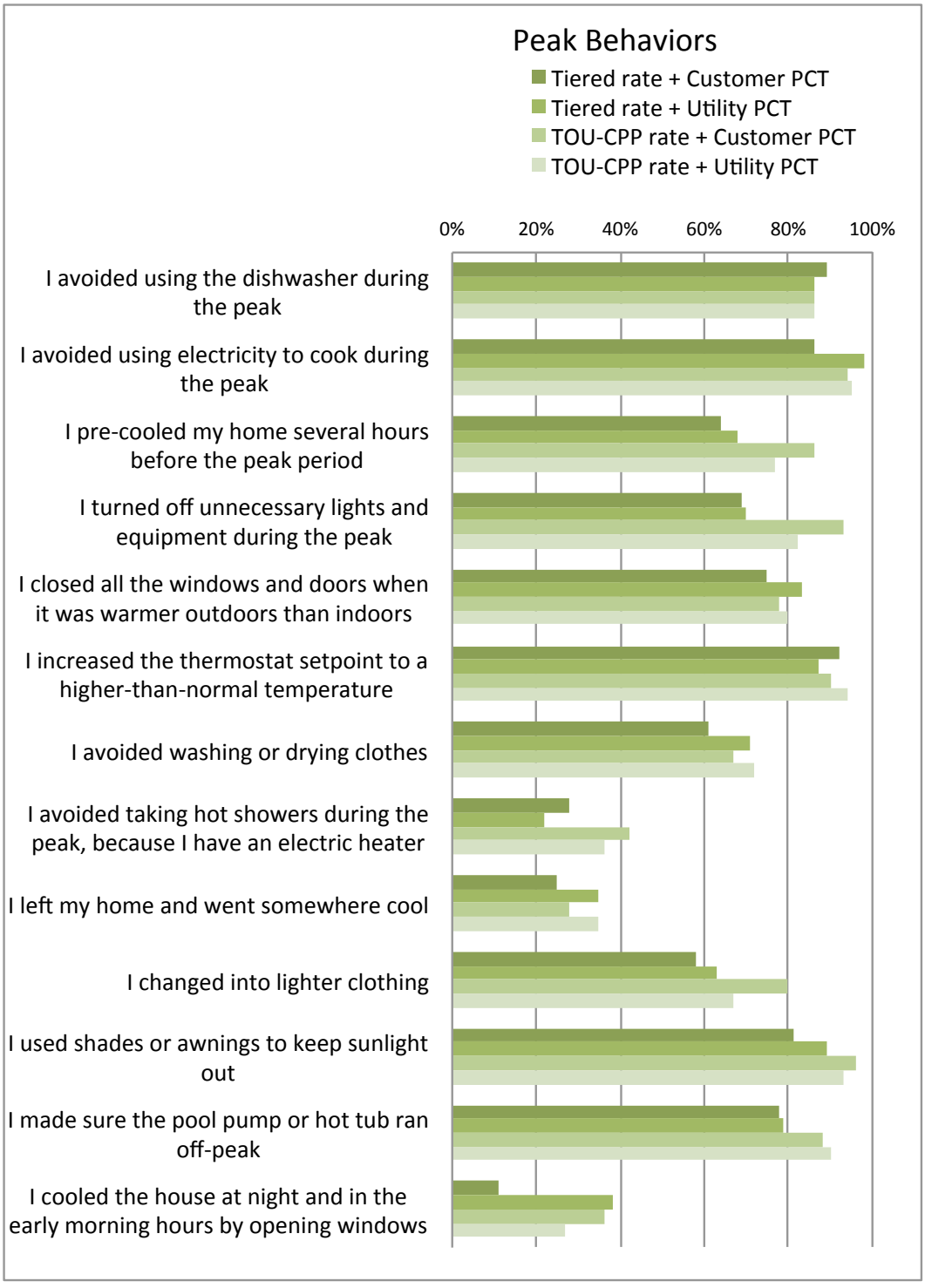


Figure 41 summarizes the strategies that participants said they commonly employed to reduce energy use during events.

**FIGURE 41. STRATEGIES COMMONLY USED TO REDUCE PEAK ENERGY USE DURING EVENTS**



## Correlating Impacts, Environment, Behavior and Opinions

This section reports the Pearson product-moment correlation coefficients (r) for correlations between customer-specific energy use, impact values, and survey answers. Customer-specific impact values for these correlations were estimated using a fixed effects model. Statistically significant values ($p<0.05$) are presented in bold font in the tables for ease of review.

Table 14 provides correlation coefficients for customer-specific energy use and impact values. Results indicate that participants with higher pre-treatment energy use had greater energy, demand, and event savings. Overall energy impacts were strongly correlated with Non-event and Event Peak impacts – meaning that those who shifted loads out of the peak period were also more likely to save energy overall. Likewise, Non-event Peak impacts were strongly correlated with Event Peak impacts – meaning that those who shifted loads out of the peak period every day were also more likely to shift loads out of the peak period on event days.

**Table 14. Correlations between energy use and program impacts (r)**

| Impact | Pre-treatment kWh Use | Overall Energy Impact | Non-Event Peak Impact | Event Peak Impact |
|---|---|---|---|---|
| Overall energy impact | **-0.27** | **1.00** | | |
| Non-event peak impact | **-0.27** | **0.66** | **1.00** | |
| Event peak impact | **-0.21** | **0.48** | **0.77** | **1.00** |
| Bill impact | **-0.52** | **0.87** | **0.73** | **0.58** |

*Values in bold font are statistically significant (p<0.05)*

Table 15 provides correlation coefficients for customer-specific impact values and pre-summer survey questions, which focus on participant home environments and demographics. Notable results include significantly negative correlations (savings) for participants with swimming pool pumps and passive solar heaters, indicating that those with swimming pools saved more than those without. Notably *absent* from the list of variables with statistically significant effects are age, income and education level.

**Table 15. Correlations between impacts and pre-summer survey questions (r)**

| # | Pre-Summer Survey Question | Pre-treatment kWh Use | Overall Energy Impact | Non-Event Peak Impact | Event Peak Impact |
|---|---|---|---|---|---|
| | City (0=Sacramento, 1=Folsom) | **0.31** | 0.02 | -0.06 | -0.09 |
| Pre1 | About how old is your home? | **-0.18** | 0.07 | **0.13** | 0.09 |
| Pre2 | About how long have you lived at this address? | -0.01 | 0.05 | 0.03 | -0.03 |
| Pre3 | What is the approximate living area of your home? | **0.55** | -0.04 | -0.09 | 0.05 |

| | | | | | |
|---|---|---|---|---|---|
| **Pre4** | About how many people occupy your home during the peak summer hours of 4-7pm? | **0.33** | 0.06 | 0.00 | 0.07 |
| **Pre5** | Is your thermostat set to RUN a preprogrammed temperature schedule? | 0.02 | 0.05 | 0.02 | -0.07 |
| **Pre8.1** | Electric water heaters | 0.10 | -0.05 | -0.03 | -0.06 |
| **Pre8.2** | Electric clothes dryers | -0.05 | 0.00 | -0.03 | -0.04 |
| **Pre8.3** | Electric cooktops | 0.00 | -0.04 | -0.04 | -0.10 |
| **Pre8.4** | Electric ovens | **0.30** | **-0.12** | -0.11 | -0.10 |
| **Pre8.5** | Refrigerators/freezers in the home | **0.22** | 0.02 | -0.06 | 0.01 |
| **Pre8.6** | Refrigerators/freezers in the garage | **0.34** | 0.02 | 0.04 | 0.04 |
| **Pre8.7** | Dishwashers | 0.07 | 0.00 | 0.05 | 0.06 |
| **Pre8.8** | Televisions | **0.37** | 0.08 | 0.01 | -0.02 |
| **Pre8.9** | Computers | **0.31** | 0.02 | 0.01 | 0.07 |
| **Pre8.10** | Swimming pool pump | **0.56** | **-0.22** | **-0.24** | **-0.19** |
| **Pre8.11** | Passive solar pool heater | **0.32** | **-0.12** | **-0.15** | -0.06 |
| **Pre8.12** | Hot tub or spa | **0.41** | 0.02 | -0.07 | -0.10 |
| **Pre8.13** | Whole-house or attic fan | 0.11 | 0.07 | 0.01 | 0.06 |
| **Pre8.14** | Central air-conditioner units | **0.30** | -0.04 | -0.01 | 0.07 |
| **Pre8.15** | Room air conditioner units | 0.02 | 0.05 | 0.02 | 0.05 |
| **Pre8.16** | Thermostats | **0.24** | -0.04 | -0.03 | **0.13** |
| **Pre11** | Age of participant | -0.04 | 0.06 | 0.02 | -0.01 |
| **Pre12** | Years of college education | -0.01 | 0.01 | -0.04 | 0.05 |
| **Pre13** | Approximate household income | -0.02 | 0.00 | 0.03 | 0.01 |
| Pre17.1 | Sacramento Municipal Utility District (rating) | -0.05 | 0.06 | 0.03 | -0.01 |

*Values in bold font are statistically significant (p<0.05)*

Table 16 provides correlation coefficients for customer-specific impact values and summer 2011 behaviors likely to affect **peak** energy use. Notable results include significant Event Peak savings for participants who precooled their homes in advance of the peak periods, and for those who increased thermostat setpoints during the peak period. Peak savings were also improved for those who avoided running laundry and dishwashers during the peak.

### TABLE 16. CORRELATIONS BETWEEN IMPACTS AND PEAK LOAD REDUCTION BEHAVIORS (R)

| | Behaviors Affecting Peak Energy Use (Post-Summer Survey) | Pre-treatment kWh Use | Overall Energy Impact | Non-Event Peak Impact | Event Peak Impact |
|---|---|---|---|---|---|
| **Post8.1** | I cooled the house at night and in the early morning hours by opening windows and/or running the whole house fan | 0.07 | -0.02 | -0.04 | -0.06 |
| **Post8.2** | I closed all the windows and doors when the outdoor temperature exceeded the indoor temperature | -0.12 | 0.02 | -0.03 | **-0.17** |
| **Post8.3** | I pre-cooled my home several hours before the peak period | 0.06 | 0.12 | -0.05 | **-0.14** |

| | | | | | |
|---|---|---|---|---|---|
| **Post8.4** | I increased the thermostat setpoint to a higher-than-normal temperature during the peak period | -0.03 | -0.06 | **-0.22** | **-0.23** |
| **Post8.5** | I used shades or awnings to keep sunlight out | **-0.19** | 0.08 | 0.06 | 0.03 |
| **Post8.6** | I turned off unnecessary lights and equipment during the peak | -0.05 | -0.07 | -0.03 | 0.02 |
| **Post8.7** | I changed into lighter clothing | **-0.14** | 0.07 | 0.12 | 0.12 |
| **Post8.8** | I left my home and went somewhere cool (e.g. a friend's house, the mall, the swimming pool) | -0.02 | -0.07 | -0.04 | -0.12 |
| **Post8.9** | I avoided taking hot showers during the peak, because I have an electric water heater | -0.17 | -0.08 | 0.08 | -0.01 |
| **Post8.10** | I avoided using electricity to cook during the peak | -0.11 | 0.01 | 0.01 | -0.10 |
| **Post8.11** | I avoided washing or drying clothes during the peak | 0.02 | -0.08 | **-0.15** | **-0.23** |
| **Post8.12** | I avoided using the dishwasher during the peak | 0.00 | -0.03 | -0.09 | **-0.15** |
| **Post8.13** | I made sure the pool pump or hot tub ran off-peak | 0.18 | -0.13 | -0.03 | -0.06 |

*Values in bold font are statistically significant (p<0.05)*

Table 17 provides correlation coefficients for customer-specific impact values and summer 2011 behaviors likely to affect **overall** energy use.

**TABLE 17. CORRELATIONS BETWEEN IMPACTS AND ENERGY CONSERVATION BEHAVIORS (R)**

| | Behaviors Affecting Overall Energy Use (Post-Summer Survey) | Pre-treatment kWh Use | Overall Energy Impact | Non-Event Peak Impact | Event Peak Impact |
|---|---|---|---|---|---|
| Post9.1 | I caulked around old windows or installed new efficient ones | -0.09 | 0.07 | 0.13 | **0.14** |
| Post9.2 | I sealed exterior doors | 0.00 | 0.08 | 0.02 | 0.04 |
| Post9.3 | I sealed the attic hatch | -0.02 | -0.10 | -0.01 | -0.05 |
| Post9.4 | I closed the flue in my fireplace when not in use | 0.05 | 0.07 | 0.09 | 0.04 |
| Post9.5 | I sealed leaky heating and air-conditioning ducts | 0.02 | 0.01 | 0.06 | -0.07 |
| Post9.6 | I increased the insulation in my attic | -0.02 | 0.04 | 0.01 | -0.01 |
| Post9.7 | I insulated the hot water pipes at the water heater | 0.00 | 0.01 | 0.00 | -0.03 |
| Post9.8 | I lowered the temperature setting on my water heater | -0.06 | 0.03 | -0.02 | 0.03 |
| Post9.9 | I set my thermostat at 78 degrees or higher for the summer | -0.03 | -0.04 | 0.04 | -0.01 |
| Post9.10 | I set my thermostat at 68 degrees or lower for the winter | 0.00 | 0.01 | 0.07 | 0.05 |
| Post9.11 | I installed more efficient light bulbs (e.g. compact flourescent or LED) | -0.02 | 0.07 | 0.01 | -0.05 |
| Post9.12 | I replaced an old AC unit with a newer, more efficient one | 0.13 | -0.03 | -0.08 | -0.12 |
| Post9.13 | I replaced an old refrigerator in my kitchen with a newer, more efficient one | 0.03 | 0.09 | **0.17** | 0.13 |
| Post9.14 | I removed a refrigerator from the garage (or unplugged it) | 0.12 | -0.14 | -0.15 | -0.03 |
| Post9.15 | I installed a whole house fan, attic fan, or attic vents | 0.11 | -0.06 | -0.09 | -0.10 |
| Post9.16 | I put my office equipment or entertainment center on a power strip and turn it off when not in use | -0.11 | 0.11 | 0.11 | 0.12 |

*Values in bold font are statistically significant (p<0.05)*

Table 18 provides correlation coefficients for customer-specific impact values and participant ratings (1-5 where 5 is highest) from the post-summer survey.

Negative correlations here, with significant effects in bold green font, imply that those who agreed strongly with the statement in questions 1.5 - 1.11, or rated highly the items in 11.1 - 11.13, also had higher savings. For example, those who agreed with the statement "I used less energy" were indeed more likely to have saved energy, having a significant correlation of -0.21 between their agreement with that statement and their overall energy impact. Participants who rated SMUD highly were also more likely to save energy during the study (r=-0.13).

**TABLE 18. CORRELATIONS BETWEEN IMPACTS AND PARTICIPANT RATINGS (R)**

| Question | Rated Study Components | Pre-treatment kWh Use | Overall Energy Impact | Non-Event Peak Impact | Event Peak Impact |
|---|---|---|---|---|---|
| Post1.5 | I used less energy | -0.03 | **-0.21** | **-0.20** | **-0.25** |
| Post1.6 | I did something good for the environment | **-0.14** | -0.10 | **-0.17** | **-0.21** |
| Post1.7 | I learned how to reduce the energy use of my home | **-0.13** | -0.02 | -0.06 | **-0.15** |
| Post1.8 | I had more control over my electricity bill | -0.09 | **-0.15** | **-0.19** | **-0.18** |
| Post1.9 | I feel better about SMUD | -0.11 | -0.12 | -0.09 | -0.09 |
| Post1.10 | I believe this program will be good for Sacramento | -0.11 | -0.03 | -0.08 | -0.08 |
| Post1.11 | I am excited to have been given the opportunity to participate | **-0.12** | -0.04 | -0.05 | -0.04 |
| Post11.1 | Sacramento Municipal Utility District | -0.08 | **-0.13** | -0.09 | -0.06 |
| Post11.2 | Summer Solutions Study (Overall) | **-0.16** | -0.03 | 0.04 | -0.06 |
| Post11.5 | Summer Solutions Rate | -0.03 | **-0.17** | **-0.22** | -0.15 |
| Post11.6 | Automatic Temperature Control option | -0.13 | -0.08 | -0.14 | **-0.19** |
| Post11.7 | Home Energy Assessment | 0.01 | -0.01 | 0.03 | 0.00 |
| Post11.8 | Summer Solutions Thermostat | -0.05 | -0.01 | -0.02 | -0.10 |
| Post11.9 | Summer Solutions Energy Display on the thermostat | -0.01 | -0.05 | 0.00 | -0.01 |
| Post11.10 | Summer Solutions Energy Display on the computer | -0.03 | -0.02 | 0.02 | -0.01 |
| Post11.11 | 'View my Electricity Use' on SMUD's My Account website | 0.00 | -0.02 | -0.05 | -0.01 |
| Post11.12 | Your summer 2012 electricity bills | -0.11 | **-0.13** | -0.01 | -0.06 |
| Post11.13 | Your summer 2012 comfort | **-0.13** | -0.08 | 0.04 | 0.03 |

*Values in bold font are statistically significant (p<0.05)*

# 9. Discussion, Conclusions, and Recommendations

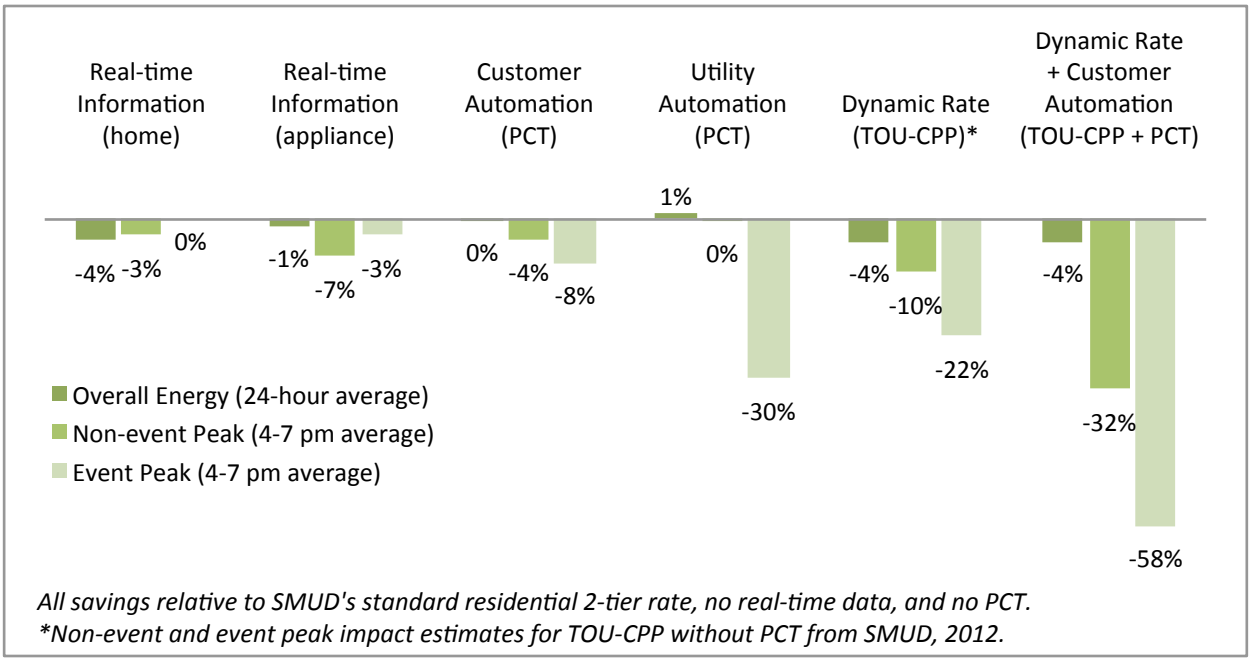
SMUD's Residential Summer Solutions study provided experimental information technology and electricity pricing to 313 participants in the summer of 2012 to test the effect of real-time home and appliance level energy information, a TOU-CPP rate, and customer or utility automation of air conditioning loads.

The study touched on a broad spectrum of utility issues including marketing, education, rate design, meter technology, appliance control, information displays, home networking, customer service, consumer behavior, conservation, efficiency, load shifting and demand response. Unfortunately, a report of reasonable length cannot provide more than a snapshot of findings from this extensive two-year endeavor. With this in mind, this section aggregates and discusses the most important findings from this study.

## Discussion: Implications for Utility Programs

This study set out to shed light on the myriad issues associated with three customer motivators and enablers of energy and demand savings that are commonly considered for residential utility programs: real-time energy information, automation of air-conditioning loads, and customer motivation in the forms of a dynamic rate or payment for load control. Combining the results found here and in other similar programs at SMUD allows us to begin to separate out the contributions of individual program components. Figure 42 shows the estimated individual and synergistic effects of information, PCT automation, and a TOU-CPP rate on residential energy and demand.

**Figure 42. Individual effects of information, automation, and dynamic rates**




*All savings relative to SMUD's standard residential 2-tier rate, no real-time data, and no PCT.*
**Non-event and event peak impact estimates for TOU-CPP without PCT from SMUD, 2012.*

These estimates indicate that energy savings on the order of 1-4% can be achieved through the provision of real-time energy data alone, while non-event peak savings can be enhanced by as much as 3% with home-level data and 7% with appliance-level data.

Currently, the provision of data at the home level is less expensive than the provision of data at the appliance level. Thus, a home-level system, while not necessarily cost-effective, is likely to be *more* cost-effective for now than an appliance-level system. In the future, advances in data disaggregation methodologies could remove this cost barrier to appliance-level data provision, however, the results of this study indicate that the added benefits of appliance level data are likely to be marginal.

Note that the effects of real-time home and appliance data beyond the first two years were not addressed in this study. The analysis of persistence described in section 5 showed that those with appliance-level data had no additional energy savings beyond the baseline in the first year, but after exposure to real-time appliance data for two years, they attained the same energy savings as did those with home-level data. Thus, depending on learning effects, longer-term exposure to real-time data could be greater than what was found here.

**While the 4% energy savings and 3% peak savings associated with real-time home energy data are statistically significant, they are dwarfed by the 4% energy savings, 32% peak savings, and 58% event savings enabled through dynamic TOU-CPP rates with PCTs.**

The group of participants who chose to stay on SMUD's standard residential 2-tier rate and did not allow SMUD to control their air-conditioning loads during events could be considered the "information only" group. They were recruited and provided exactly the same level of information, education, and event notification as the other three groups, but in the absence of a financial motivation to reduce loads (via a time-varying rate or utility load control), their energy and demand savings were unsurprisingly lackluster.

The group that stayed on the standard 2-tier rate and allowed SMUD to control their air-conditioning loads during events might be considered the standard "air-conditioning load control" group. Like load control programs at other utilities, load shed during events was significant at around 30%; however, energy and daily peak load savings did not differ significantly from zero. Thus, for utilities hoping to reduce critical peak loads without reducing daily peak or overall energy use, load control programs are a good choice.

A TOU-CPP rate alone can provide an estimated 4% energy savings relative to a tiered rate, rivaling the energy savings expected from real-time energy data. Energy, demand and bill savings were highest for participants who signed up for the experimental TOU-CPP rate, whether they controlled their own AC automation or allowed SMUD to control it for them. With peak savings nearing 30% and event peak savings at almost 60%, the TOU-CPP group on a *non-event* day had peak savings similar to the load control participants on an *event* day, and shed nearly twice as much load on an event day as those on the load control program.

## Conclusions

The main findings of this study are as follows:

1) **The addition of real time data, whether at the home or appliance level, provided relatively small improvements to savings – at least in the first two years.** Higher savings found in the second year of this two-year study suggest that real-time data impacts may increase with time, as customers learn and act on the information. In particular, the effects on long-term investments, such as air-conditioner upgrades, are unlikely to be fully captured here. Even so, the combination of real-time information with appropriate time-varying rates, as described below, is most likely to encourage the greatest energy and demand savings.

2) **Voluntary TOU-CPP rates with customer-controlled event automation outperformed information-only and load control programs**, having higher energy savings, non-event peak demand savings, and event peak demand savings.

3) **Participants on the TOU-CPP rate saved significantly more money on their summer electricity bills than did those on the standard tiered rate.** The average summer TOU-CPP bill savings of $146 was four times the $36 savings of those on the standard tiered rate. More than twice as many TOU-CPP participants exceeded $100 in summer savings.

4) **For customers on the TOU-CPP rate, the use of a PCT for event automation more than doubled demand savings during non-event and event peak periods.** This result is based on a comparison to SMUD's Smart Pricing Option pilot, which moved volunteers to TOU and CPP rates without a PCT.

5) **For customers on the TOU-CPP rate, utility-controlled PCT automation did not provide higher event response than customer-controlled PCT automation.** Both showed event impacts nearing 60%. For customers on the tiered rate, utility-controlled automation more than tripled event response to 30% from just 8%.

## RECOMMENDATIONS

Based on impact findings, participant feedback, and costs, the team recommends the following key components for near-future programs at SMUD and other utilities in similar climates.

5) **Rates.**
   a) Offer at least one residential time-of-use or dynamic rate option. TOU-CPP has been shown to be effective and accepted by customers in dozens of studies, including this one.[9] In the future, rates that better match system needs (e.g. variable-peak pricing or real-time pricing) might become desirable for customers, especially those with advanced automation options.

6) **Automation.** Offer, rebate, or recommend user-friendly PCTs[10] that:
   a) enable customers to automate precooling and offsets for daily TOU peak load shifting, and
   b) enable customers to automate precooling and offsets for occasional CPP events. [11]

7) **Information**. Provide customers with:
   a) a concise summary and graphical representation of the rate (e.g. on a website or magnet)
   b) a website tool that allows customers to compare bill estimates for various rate options based on their personal historical energy use data
   c) notification of prices and events[12] (e.g. by smartphone app or thermostat), and
   d) real-time energy data for the home[13] (optional).

8) **Customer Service.** Maintain enhanced customer services, for example:
   a) a customer support call center that is well versed in the new rate and technology basics, and
   b) low-cost home energy inspections and recommendations.

The results of this study do not support the use of direct load control programs where dynamic rates are an option. This recommendation is based on the fact that participants on the TOU-CPP rate who controlled their own event response shed twice as much load (58%) as did those on the standard direct load control program on the tiered rate (30%).

The results of this study also do not support the provision or rebate of real-time energy monitors for individual appliances, due to the high cost, limited energy savings (2%), and lower customer ratings for this feature. These results may change as home information and automation systems improve and a younger group of customers become homeowners.

For the near future, we recommend that utilities focus on improving the effectiveness and cost-effectiveness of the program components outlined in the list above – time-varying rates, customer-controlled PCTs, event notification, and enhanced customer service – and consider real-time energy information at the Home level a nice, but not necessary, addition to this portfolio.

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[9] For a summary of results from other TOU-CPP pilots, see Faruqui et al. 2012.

[10] For a review and ranking of usability scores for communicating thermostats, see Herter & Okuneva 2013a.

[11] See SMUD's residential precooling study evaluation (Herter & Okuneva 2013b).

[12] e.g. via Internet (OpenADR), FM broadcast (RDS), smart meter (SEP), or some other cost-effective alternative.

[13] For example, via CT-based submeter, smart meter (SEP), or some other cost-effective alternative.

# 10. REFERENCES


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# 11. APPENDICES

## APPENDIX A. PARTICIPATION AGREEMENT

SMUD
SACRAMENTO MUNICIPAL UTILITY DISTRICT
The Power To Do More.®
6201 S Street, P.O. Box 15830, Sacramento, CA 95852-1830

**Sign me up for the Summer Solutions Study!**

Customer: _____
Customer Name

_____ _____ _____
Street Address (Premises)[1] City Zip

_____ _____
Best Telephone Number E-Mail Address[2]

[1] *Address where Summer Solutions equipment will be installed.*

[2] *Email address will be used to alert you to SMUD's Summer Solutions events and also for important program information. Your information will not be shared outside those persons affiliated with this research project.*

### SMUD's Residential Summer Solutions Study – Participation Agreement

This Participation Agreement for the Residential Summer Solutions Study ("Agreement") is entered into between the Sacramento Municipal Utility District ("SMUD") and the above named customer ("Customer"), singularly referred to herein as a "Party," collectively as "Parties." The Parties agree as follows:

**1. Term.** This Agreement is effective upon the date of last execution by the Parties and shall continue until December 31, 2012, unless earlier terminated by default or by either Party on thirty (30) days prior written notice. Upon termination or expiration of this Agreement, Customer may receive electric service under any of SMUD's rate schedule(s) (e.g., otherwise applicable standard rate).

**2. Scope.** Customer agrees to participate in SMUD's Residential Summer Solutions Study, conducted jointly by SMUD, its contractor Herter Energy Research Solutions (HERS), and funding partners at the Demand Response Research Center at Lawrence Berkeley National Laboratory and the California Energy Commission. The goals of the study are to (a) give residential customers the opportunity to manage their energy use and costs, and (b) help SMUD test new residential technologies. As a condition of participating in the Summer Solutions Study, Customer agrees to remain on the program at a minimum through September 30, 2011. Participation includes allowing SMUD and its contractor to install Summer Solutions equipment at Customer's Premises, and responding to research surveys.

**3. Rate Options.** Customer must choose from one of the two rate options, the Summer Solutions Rate or the Standard Rate, to be used for the duration of the summer (June 1 through September 30, 2011). The Summer Solutions rate will involve twelve (12) events, of which customers will be notified 24 hours in advance.

***** Choose ONE of the following rate options (A or B) by initialing and checking the box *****

**A.____☐ Summer Solutions Rate + Summer Solutions Equipment**

**YES, I want to lower my bills by taking advantage of the off-peak discount of the Summer Solutions rate:**

| | | |
|---|---|---|
| **Off-Peak Base Use** | $ 0.0721 /kWh | all day on weekends and holidays + before 4 p.m. and after 7 p.m. on weekdays |
| **Off-Peak Base Plus Use** | $ 0.1411 /kWh | applies to off-peak use exceeding 700 kWh in a billing period |
| **On-Peak Use** | $ 0.2700 /kWh | 3 hours (4–7 p.m.) on normal weekdays (non-holiday, non-event) |
| **Event Use** | $ 0.7500 /kWh | 3 hours (4–7 p.m.) on 12 event weekdays—events are noticed 24 hours in advance |

Prices for the following observed holidays will be the same as the weekend prices in the same month:
- Independence Day (July 4, 2011 and 2012)
- Labor Day (September 5, 2011 and September 3, 2012)

Customer agrees to be charged and billed for electric service at the Summer Solutions rate from June 1 through September 30, 2011 and June 1 through September 30, 2012. SMUD may elect to continue this rate through September 30, 2012, change the rate for the summer period 2012, and/or discontinue the rate at the end of the study period (December 31, 2012). If SMUD changes the rate, SMUD will provide Customer with sixty (60) days prior written notice before the effective date of the amended rate. If Customer objects to the rate change, Customer may terminate this Agreement by giving thirty (30) days prior written notice.

***— OR —***

**B.____☐ Standard Rate + Summer Solutions Equipment**

**YES, I want to try the new technologies, but I'd like to keep my current rate:**

| | | |
|---|---|---|
| **Base Use** | $ 0.1045 /kWh | applies to electricity use less than 700 kWh in a billing period |
| **Base Plus Use** | $ 0.1859 /kWh | applies to electricity use 700 kWh or greater in a billing period |

**4. Automatic Temperature Control Option.**
Under either rate, Customer has the option to receive an extra $4 per event for allowing SMUD to automatically increase Customer's thermostat temperature setting by 4 degrees during events for at least 11 of the 12 events during the summer period.

***** Initial and check the box to participate in Automatic Temperature Control (Optional) *****

_____☐ **Automatic Temperature Control Payment** $4.00/event 12 event days, June-September 2011 and 2012

**YES, I will allow SMUD to automatically reset my thermostat up 4 degrees during events.**
Customer agrees to allow SMUD or its contractor to replace the thermostat (maximum of one) installed at Customer's Premises with a Summer Solutions thermostat that will automatically increase the temperature set point by 4 degrees during events. Customer is allowed to override the 4-degree setback during 1 of the 12 events for each summer season. SMUD agrees to pay Customer $4 per event for each of 12 events called and not overridden between June and September, 2011 and 2012. SMUD may elect to change the thermostat control strategy for the summer season 2012, but during no event will the setback exceed 4 degrees.

**5. Installation.** The Summer Solutions equipment (where applicable) shall be installed at Customer's Premises indicated above at the sole expense of SMUD or its contractor, who shall perform the work as soon as is reasonably practical upon approval of Customer's application. Under this Agreement, SMUD or its contractors shall have the exclusive right to install, maintain, and perform warranty services on the Summer Solutions equipment. During the term of this Agreement, under no circumstances shall Customer attempt to maintain, perform warranty services on, or remove the Summer Solutions equipment.

**6. Access to Premises.** Customer grants SMUD or its contractor the right to install and maintain the Summer Solutions equipment at the Premises. Customer also grants SMUD the right of ingress and egress on the Premises for the purposes set forth herein.

**7. Ownership.** The Summer Solutions equipment is the sole property of SMUD. At the end of the study period, the Summer Solutions equipment will remain at the Premises unless removal is requested and will become the sole property of Customer.

**8. Cost.** There is no cost to Customer for the Summer Solutions equipment, installation, and reasonably anticipated warranty services.

**9. Eligibility Requirements.** Customer must meet all the following participation and eligibility requirements:
a. Customer must have a residential account and a new "smart" meter
b. Customer must pay his or her own SMUD bills
c. Premises must be a single family dwelling that Customer lives in and owns
d. Customer must have Internet access
e. Customer must not plan on moving during the next 12 months
f. Customer must not be on SMUD's Medical Equipment Discount Program
g. Customer must not be on SMUD's Low-Income Energy Assistance Program Rate (EAPR)
h. Customer cannot operate a child care or convalescent care business in the home

**10. Incentive.** In addition to the Summer Solutions equipment, SMUD will provide through its contractor (HERS) free one-on-one energy advice, including the option for a free onsite energy evaluation for Customer's home, offering recommendations to reduce bills through efficiency improvements and peak reduction efforts.

**11. Data and Confidentiality.** Data to be collected and analyzed includes electricity use data, interaction data with a web portal and thermostat, and customer survey data including information about household appliances, energy use behaviors and demographics. SMUD, HERS and research partners will keep confidential all Customer personally identifiable information, including name, address, telephone number, email address and SMUD account number. Only summary or aggregate customer and study data, and data not associated with any identifiable customer(s), will be reported or made public as part of this research project.

**12. Rules and Regulations.** This Agreement shall, at all times, be subject to SMUD's Rules and Regulations, as amended from time to time.

**13. Warranty.** SMUD makes no warranties, implied or expressed, written or oral, with respect to the goods and services provided under this Agreement including, but not limited to, the warranties of merchantability and fitness for a particular purpose.

**14. Notices.** All written communications or notices under this Agreement shall be directed as follows:

District: Sacramento Municipal Utility District
Attn: Vikki Wood, MS A204 or summersolutions@smud.org
P.O. Box 15830
Sacramento, CA 95852-1830

Customer: As provided above.

**15. Amendments.** SMUD reserves the right, at its sole discretion, to amend the terms of this Agreement. SMUD will notify Customer in writing of the amendment at least sixty (60) days in advance of the effective date of the amendment. The amendment will become effective as of the amendment effective date stated in the notice. If Customer objects to the amendment, Customer may terminate this Agreement by giving thirty (30) days prior written notice.

**16. Applicable law.** This Agreement shall be interpreted, governed by, and construed under the laws of the State of California, as if executed and to be performed wholly within the State of California.

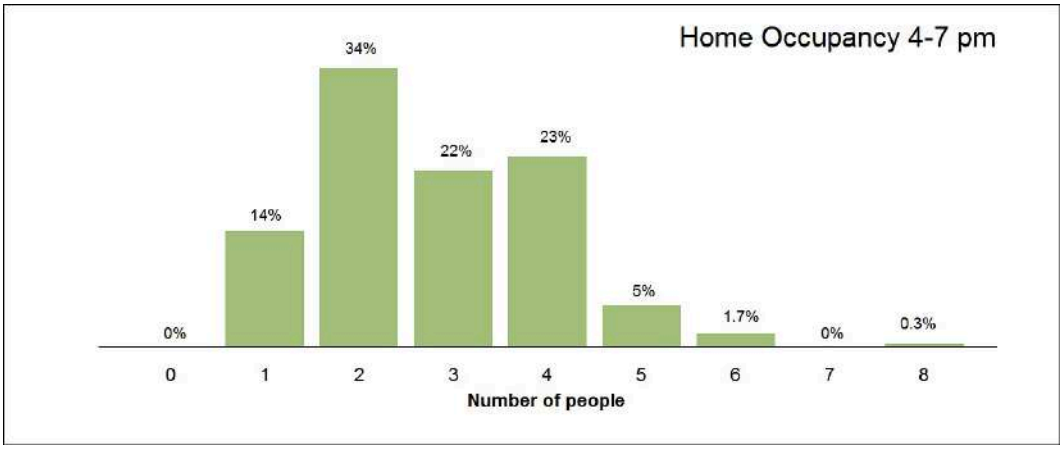
**17. Entire Agreement.** This Agreement constitutes the entire understanding between the Parties as to the subject matter hereof.

**Customer** _____ **SMUD** _____
Signature Signature

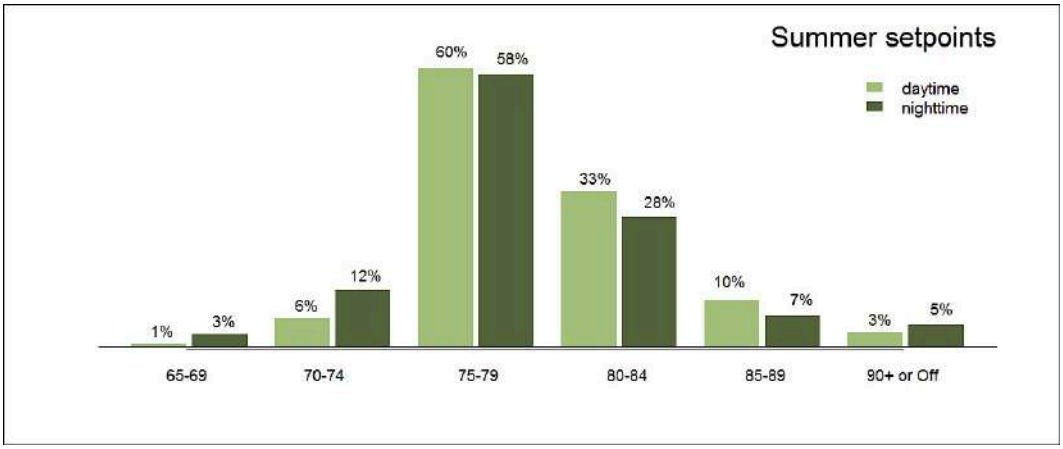
_____ _____ _____ _____
Print Name Date Print Name Date

## APPENDIX B. SUMMARY OF SURVEY RESPONSES

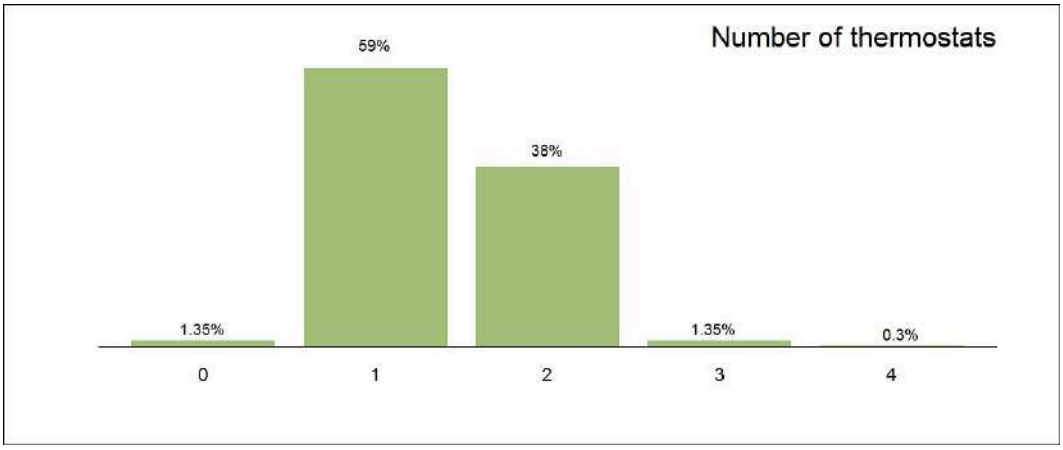
### FIGURE 43. HOME OCCUPANCY 4-7 PM



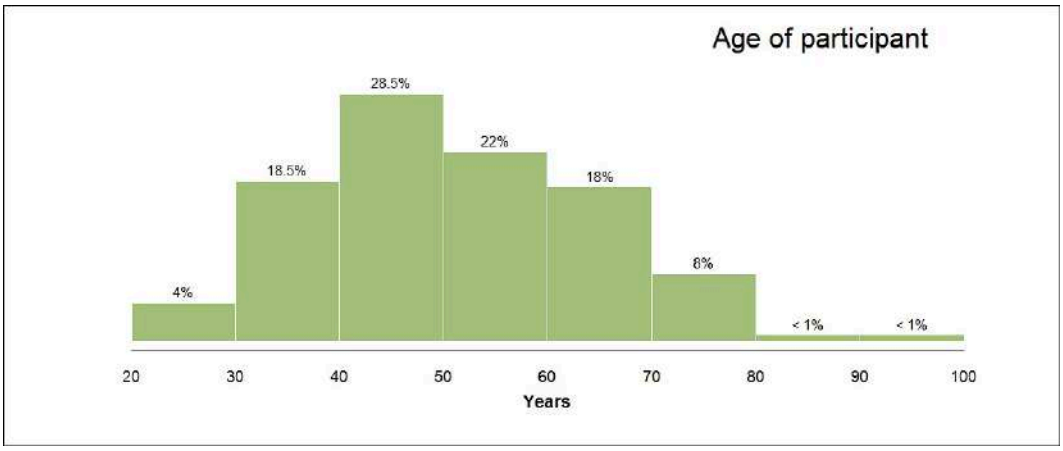

### FIGURE 44. SUMMER SETPOINTS, DAYTIME AND NIGHTTIME



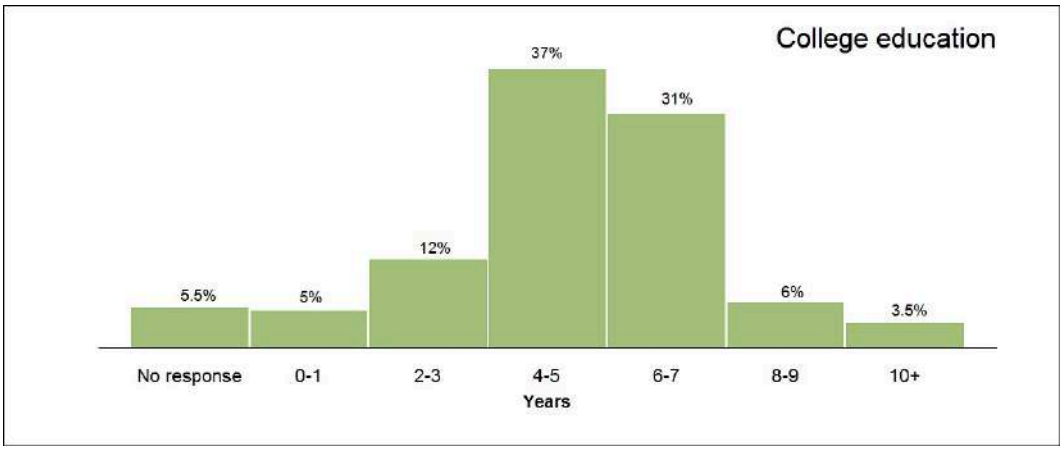

### FIGURE 45. NUMBER OF THERMOSTATS PER HOME



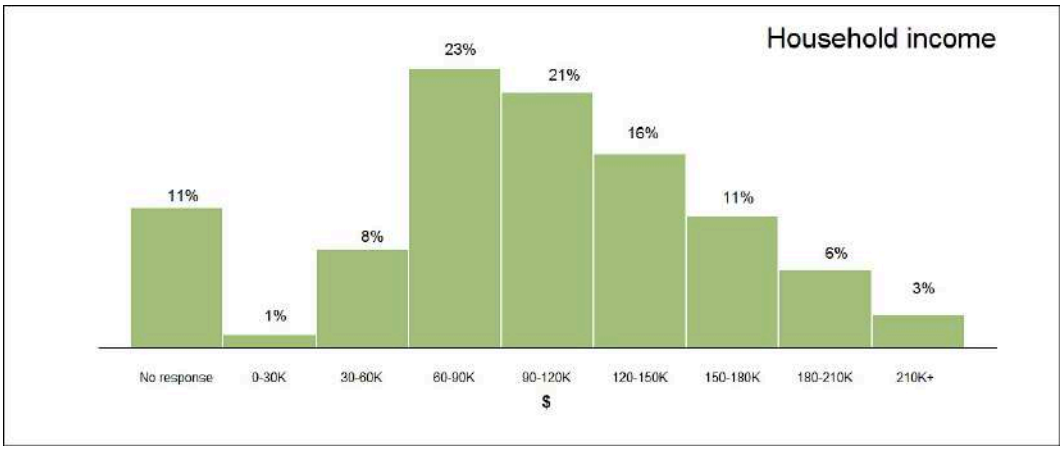
### FIGURE 46. AGE DISTRIBUTION




### FIGURE 47. YEARS OF COLLEGE EDUCATION DISTRIBUTION




### FIGURE 48. HOUSEHOLD INCOME DISTRIBUTION



The following codes are used to indicate statistical significance in tables 18 -19.

* = significantly greater than Baseline
* = significantly greater than Home
* = significantly greater than Appliance

* = significantly greater than Neither
* = significantly greater than ATC only
* = significantly greater than SS rate only
* = significantly greater than SS rate + ATC

### TABLE 19. PRE-SUMMER SURVEY RESPONSE AVERAGES, TOTAL AND BY GROUP

| # | Pre-Summer Survey | Total | Baseline | Home | Appliance | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|
| 1 | About how old is your home? | 28 | 36** | 23.3 | 24.9 | 26.4 | 28.9 | 25.8 | 29.9 |
| 2 | About how long have you lived at this address? | 10.4 | 11.7 | 10.1 | 9.5 | 9.0 | 11.1 | 11.2 | 9.9 |
| 3 | What is the approximate living area of your home? (1000 ft²) | 2.1 | 2 | 2.2 | 2.2* | 2.2 | 2.1 | 2.1 | 2.2 |
| 4 | About how many people occupy your home during the peak summer hours of 4-7 pm? | 2.8 | 2.5 | 2.8 | 3.0* | 3.1 | 2.8 | 2.7 | 2.7 |
| 5 | Is your thermostat set to RUN a preprogrammed temperature schedule? | 0.6 | 0.7 | 0.6 | 0.6 | 0.5 | 0.7 | 0.7 | 0.7 |
| 6 | What is your normal thermostat setpoint on summer weekdays? | 79.0 | 80 | 78.2 | 78.7 | 78.6 | 80 | 78.1 | 79 |
| 7 | What is your normal thermostat setpoint on summer weeknights? | 77.8 | 79.1* | 78.0 | 76.3 | 78.7 | 76.6 | 77.8 | 78.1 |
| **8 - Please indicate how many of the following electric appliances you have and use in your home. (If you do not have and use an appliance please enter 0.)** | | | | | | | | | |
| 8.1 | Electric water heaters | 0.4 | 0.3 | 0.4 | 0.4 | 0.3 | 0.2 | 0.4 | 0.5* |
| 8.2 | Electric clothes dryers | 0.7 | 0.8 | 0.7 | 0.7 | 0.8 | 0.6 | 0.8 | 0.8 |
| 8.3 | Electric cooktops | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 |
| 8.4 | Electric ovens | 0.7 | 0.6 | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.8 |
| 8.5 | Refrigerators/freezers in the home | 1.1 | 1.1 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| 8.6 | Refrigerators/freezers in the garage | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 |
| 8.7 | Dishwashers | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 8.8 | Televisions | 2.2 | 2.0 | 2.2 | 2.5* | 2.1 | 2.2 | 2.1 | 2.4 |
| 8.9 | Computers | 2.2 | 2.0 | 2.1 | 2.4 | 2.2 | 2.1 | 2 | 2.3 |
| 8.10 | Swimming pool pump | 0.3 | 0.2 | 0.3 | 0.4 | 0.2 | 0.4 | 0.3 | 0.3 |
| 8.11 | Passive solar pool heater | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 8.12 | Hot tub or spa | 0.2 | 0.2 | 0.2 | 0.3 | 0.1 | 0.3 | 0.3* | 0.2 |
| 8.13 | Whole-house or attic fan | 0.4 | 0.5 | 0.3 | 0.5 | 0.4 | 0.5 | 0.4 | 0.4 |
| 8.14 | Central air-conditioner units | 1.1 | 1.2 | 1.1 | 1.1 | 1.2 | 1.2 | 1.1 | 1.1 |
| 8.15 | Room air conditioner units | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 |
| 8.16 | Thermostats | 1.4 | 1.4 | 1.4 | 1.4 | 1.5 | 1.4 | 1.3 | 1.4 |
| **9 - Please indicate which of the following strategies you use to lower your energy use during the peak period (4-7pm) on hot summer days** | | | | | | | | | |
| 9.1 | I cool the house at night and in the early morning hours by opening windows and/or running the whole house fan | 91% | 93% | 92% | 87% | 94% | 93% | 91% | 85% |

| # | Pre-Summer Survey | Total | Baseline | Home | Appliance | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|
| 9.2 | I close all the windows and doors when the outdoor temperature exceeds the indoor temperature | 95% | 95% | 96% | 94% | 92% | 96% | 95% | 98% |
| 9.3 | I pre-cool my home (decrease the thermostat setpoint to a lower-than-normal temperature) several hours before the peak period | 36% | 22% | 25% | 40%* | 27% | 18% | 38%* | 34% |
| 9.4 | I increase the thermostat setpoint to a higher-than-normal temperature during the peak period | 48% | 52% | 39% | 53% | 29% | 49% | 60%* | 48% |
| 9.5 | I use shades or awnings to keep sunlight out | 87% | 84% | 85% | 92% | 92% | 85% | 88% | 87% |
| 9.6 | I turn off unnecessary lights and equipment | 98% | 98% | 99% | 96% | 100% | 100% | 99% | 96% |
| 9.7 | I change into lighter clothing | 86% | 87% | 95%* | 76% | 85% | 91% | 83% | 87% |
| 9.8 | I leave my home and go somewhere cool (e.g. a friend's house, the mall, the swimming pool) | 34% | 36% | 29% | 38% | 29% | 24% | 40% | 42% |
| 9.9 | I avoid taking hot showers because I have an electric water heater | 12% | 12% | 11% | 14% | 10% | 5% | 21% | 17% |
| 9.10 | I avoid using electricity to cook | 48% | 51% | 48% | 46% | 54% | 45% | 57% | 44% |
| 9.11 | I avoid tasks like laundry and dishes that can be done before or after the peak period | 87% | 89% | 88% | 84% | 81% | 88% | 85% | 93% |
| 9.12 | I set the pool pump or hot tub to run off-peak | 35% | 28% | 32% | 44% | 35% | 38% | 40% | 36% |
| **10 - Please indicate which of the following energy saving strategies you currently use.** | | | | | | | | | |
| 10.1 | I caulked around my old windows or I have new efficient ones | 53% | 54% | 53% | 52% | 48% | 59% | 56% | 49% |
| 10.2 | I sealed all doors, the attic hatch, and the fireplace flue | 38% | 37% | 38% | 38% | 25% | 41% | 44% | 38% |
| 10.3 | I sealed all heating and air-conditioning ducts and vents | 36% | 33% | 38% | 38% | 42% | 32% | 31% | 42% |
| 10.4 | The insulation in my attic is at least R38 (~12 inches high) | 52% | 49% | 62% | 45% | 58% | 50% | 60% | 49% |
| 10.5 | I insulated my hot water pipes at the water heater (at least) | 56% | 55% | 55% | 58% | 52% | 50% | 65% | 55% |
| 10.6 | I keep my water heater at 120 degrees or lower | 74% | 67% | 75% | 80% | 67% | 80% | 81% | 71% |
| 10.7 | In the winter I keep my thermostat at 68 degrees or lower | 80% | 80% | 82% | 77% | 83% | 74% | 86% | 78% |
| 10.8 | In the summer I keep my thermostat at 78 degrees or higher | 76% | 74% | 80% | 75% | 75% | 77% | 79% | 75% |
| 10.9 | I installed compact fluorescent light bulbs | 79% | 80% | 79% | 79% | 69% | 82% | 81% | 82% |
| 10.10 | I have an AC unit that is less than 10 years old | 37% | 35% | 39% | 36% | 33% | 38% | 38% | 37% |
| 10.11 | I have a refrigerator that is less than 10 years old | 74% | 71% | 75% | 77% | 75% | 84% | 78% | 65% |
| 10.12 | I do not keep a refrigerator in the garage | 60% | 67% | 58% | 54% | 54% | 65% | 67% | 53% |
| 10.13 | I have an attic fan or turbine vents to cool the attic space in the summer | 36% | 34% | 36% | 37% | 42% | 35% | 37% | 34% |
| 10.14 | I put my office equipment or entertainment center on a power strip and turn it off when not in use | 31% | 27% | 33% | 32% | 23% | 31% | 28% | 38% |
| 11 | Age of participant | 51.3 | 52.3 | 51.3 | 50.4 | 50.3 | 50.2 | 52.7 | 51.5 |
| 12 | Years of college education | 5.1 | 5.0 | 5.2 | 5.1 | 5.2 | 4.9 | 5.2 | 5.2 |
| 13 | Approximate household income ($1000) | 111 | 114 | 104 | 114 | 113 | 108 | 114 | 110 |

| # | Pre-Summer Survey | Total | Baseline | Home | Appliance | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|
| **14 - Please indicate your reasons for signing up for the Summer Solutions program. (Coded on a scale from -2 to +2)** | | | | | | | | | |
| **14.1** | Opportunity to save money | 1.2 | 1.3 | 1.2 | 1.2 | 1.3 | 1.2 | 1.2 | 1.2 |
| **14.2** | Free equipment/technology | 0.8 | 0.9 | 0.8 | 0.8 | 0.9 | 0.8 | 0.9 | 0.7 |
| **14.3** | Free home energy assessment | 0.9 | 0.7 | 0.9 | 1.0 | 0.7 | 1.0* | 1.0 | 0.6 |
| **14.4** | Opportunity to contribute to the community | 1.0 | 1.0 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 0.9 |
| **14.5** | Benefit the environment | 1.2 | 1.1 | 1.1 | 1.3 | 1.1 | 1.2 | 1.2 | 1.1 |
| **15 - Please indicate your reasons for signing up for the Automatic Temperature Control option. (Coded on a scale from -2 to +2)** | | | | | | | | | |
| **15.1** | Payment of $4 per event | 0.4 | 0.6* | 0.2 | 0.4 | 0.1 | 0.4 | 0.5 | 0.5 |
| **15.2** | No need to deal with events - SMUD does it all for me | 0.5 | 0.6 | 0.4 | 0.5 | 0.4 | 0.5 | 0.7 | 0.5 |
| **15.3** | Assurance that no-one in my house will override events | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | -0.1 | 0.1 | 0.2 |
| **16 - Please use the scale below to rate your confidence in accomplishing the following tasks. (Coded on a scale from -2 to +2)** | | | | | | | | | |
| **16.3** | Improve the energy efficiency of my home | 0.9 | 1.0 | 0.9 | 0.9 | 0.6 | 1.1 | 0.9 | 1.0* |
| **16.4** | Find information when I need help | 1.0 | 1.0 | 1.0 | 1.1 | 0.9 | 1.1 | 1.0 | 1.0 |
| **16.5** | Shifting energy use to the off-peak hours | 1.2 | 1.2 | 1.1 | 1.2 | 1.1 | 1.2 | 1.2 | 1.2 |
| **17- Please use the scale below to rate the overall performance of the following. (Coded on a scale from -2 to +2)** | | | | | | | | | |
| **17.1** | Sacramento Municipal Utility District (SMUD) | 1.2 | 1.0 | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.2 |
| **17.2** | Summer Solutions Equipment Installers | 0.6 | 0.5 | 0.5 | 0.7 | 0.6 | 0.5 | 0.5 | 0.7 |
| **18 - Please indicate your preferred methods for receiving SMUD's system event notifications. You may select as many as you wish. (All participants will receive notification by thermostat)** | | | | | | | | | |
| **18.2** | email | 86% | 85% | 86% | 87% | 83% | 88% | 88% | 85% |
| **18.3** | phone | 17% | 21% | 19% | 12% | 17% | 18% | 27%* | 9% |
| **18.4** | text message | 19% | 22% | 19% | 16% | 23% | 19% | 20% | 17% |
| **18.5** | Twitter | 1% | 1% | 2% | 0% | 0% | 3% | 1% | 1% |
| **19** | Would you like to schedule a free in-home energy assessment to help you figure out where your energy costs are going - and what you can do to fix it? | 64% | 68% | 60% | 65% | 65% | 70% | 70% | 62% |

### TABLE 20. POST-SUMMER SURVEY AVERAGES, TOTAL AND BY GROUP

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| **Post1.1** | I feel that I understand the program goals | Somewhat or Strongly Agree | 98% | 98% | 99% | 96% | 86% | 97% | 100% | 100% |
| | | Somewhat or Strongly Disagree | 2% | 1% | 1% | 4% | 11%* | 3% | 0% | 0% |
| | | Other | 0% | 1% | 0% | 0% | 3% | 0% | 0% | 0% |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| Post1.2 | I feel that I understand my electricity rate and bill | Somewhat or Strongly Agree | 95% | 96% | 93% | 96% | 97% | 92% | 94% | 97% |
| | | Somewhat or Strongly Disagree | 4% | 2% | 7% | 4% | 3% | 8% | 4% | 3% |
| | | Other | 0% | 1% | 0% | 0% | 0% | 0% | 1% | 0% |
| Post1.3 | I received adequate and competent instructions at the time of installation | Somewhat or Strongly Agree | 93% | 93% | 95% | 90% | 89% | 94% | 96% | 91% |
| | | Somewhat or Strongly Disagree | 6% | 7% | 4% | 7% | 11% | 5% | 3% | 7% |
| | | Other | 1% | 0% | 1% | 3% | 0% | 2% | 1% | 2% |
| Post1.4 | I saved money | Somewhat or Strongly Agree | 79% | 79% | 79% | 80% | 53% | 84% | 75% | 91%* |
| | | Somewhat or Strongly Disagree | 9% | 10% | 7% | 11% | 19% | 8% | 13% | 3% |
| | | Other | 11% | 11% | 13% | 9% | 28% | 8% | 12% | 6% |
| Post1.5 | I used less energy | Somewhat or Strongly Agree | 84% | 88% | 83% | 82% | 61% | 87 %* | 81% | 93 %* |
| | | Somewhat or Strongly Disagree | 9% | 6% | 9% | 12% | 22%* | 10% | 9% | 3% |
| | | Other | 7% | 6% | 9% | 7% | 17% | 3% | 10% | 3% |
| Post1.6 | I did something good for the environment | Somewhat or Strongly Agree | 90% | 94% | 88% | 88% | 75% | 98%* | 84% | 94%* |
| | | Somewhat or Strongly Disagree | 4% | 2% | 5% | 5% | 14% | 0% | 6% | 2% |
| | | Other | 6% | 4% | 7% | 7% | 11% | 2% | 10% | 3% |
| Post1.7 | I learned how to reduce the energy use of my home | Somewhat or Strongly Agree | 88% | 89% | 89% | 87% | 83% | 84% | 88% | 93% |
| | | Somewhat or Strongly Disagree | 9% | 9% | 7% | 10% | 8% | 14% | 7% | 6% |
| | | Other | 3% | 2% | 4% | 3% | 8% | 2% | 4% | 1% |
| Post1.8 | I had more control over my electricity bill | Somewhat or Strongly Agree | 82% | 74% | 88% | 84% | 72% | 73% | 81% | 9%** |
| | | Somewhat or Strongly Disagree | 13% | 16% | 9% | 15% | 14% | 22 %* | 14% | 6% |
| | | Other | 5% | 10% | 4% | 1% | 14% | 5% | 4% | 1% |
| Post1.9 | I feel better about SMUD | Somewhat or Strongly Agree | 87% | 88% | 89% | 83% | 86% | 84% | 83% | 91% |
| | | Somewhat or Strongly Disagree | 6% | 5% | 4% | 9% | 6% | 6% | 4% | 7% |
| | | Other | 8% | 7% | 7% | 9% | 8% | 10% | 13% | 2% |
| Post1.10 | I believe this program will be good for Sacramento | Somewhat or Strongly Agree | 93% | 93% | 94% | 91% | 83% | 95% | 88% | 98% |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Somewhat or Strongly Disagree | 3% | 2% | 2% | 4% | 6% | 2% | 4% | 2% |
| | | Other | 4% | 5% | 4% | 4% | 11% | 3% | 7% | 0% |
| Post1.11 | I am excited to have been given the opportunity to participate | Somewhat or Strongly Agree | 95% | 95% | 98% | 93% | 92% | 97% | 96% | 95% |
| | | Somewhat or Strongly Disagree | 3% | 5% | 1% | 4% | 3% | 2% | 4% | 5% |
| | | Other | 1% | 0% | 1% | 2% | 6% | 2% | 0% | 0% |
| Post2.1 | Participants on Summer Solutions rate (relative to the number of participants in each treatment who completed the survey). | | 61% | 59% | 55% | 70% | 44% | 24% | 0% | 0% |
| Post2.2 | I understand the Summer Solutions rate BETTER than the standard rate | | 53% | 58% | 62% | 39% | NA | NA | 49% | 53% |
| Post2.3 | I understand the Summer Solutions rate ABOUT THE SAME AS standard rate | | 43% | 42% | 33% | 53% | NA | NA | 45% | 43% |
| Post2.4 | I understand the Summer Solutions rate LESS than the standard rate | | 4% | 0% | 4% | 8% | NA | NA | 6% | 3% |
| Post3.1 | Did you have the Summer Solutions thermostat installed at your home? | | 97% | 96% | 99% | 96% | 97% | 98% | 93% | 99% |
| Post3.2 | Did the thermostat function properly? | | 90% | 90% | 93% | 88% | 94% | 92% | 86% | 90% |
| Post3.3 | Did it function properly during the events? | | 92% | 92% | 93% | 90% | 89% | 95% | 86% | 94% |
| Post3.4 | Was it easy to program the daily heating and cooling schedules? | | 88% | 82% | 90% | 92% | 97% | 89% | 88% | 85% |
| Post3.5 | Was it otherwise easy to use? | | 91% | 85% | 94% | 95% | 91% | 94% | 91% | 91% |
| Post4.1 | Does your thermostat show real-time energy use for your Whole House? | | | NA | 57% | 62% | | | | |
| Post4.2 | Would you say that it accurately shows your real-time energy data? | | | NA | 85% | 75% | 48% | 45% | 36% | 57% |
| Post4.3 | Would you say that the 'Whole House' energy data helped you lower your energy use? | | | NA | 74% | 54% | 44% | 32% | 26% | 46% |
| Post4.5 | Does your thermostat show real-time energy use for your individual appliances? | | | NA | NA | 36% | | | | |
| Post4.6 | Would you say that it accurately shows your real-time appliance data? | | | NA | NA | 37% | 46% | 33% | 28% | 38% |
| Post4.7 | Would you say that the data for individual appliances helped you lower your energy use? | | | NA | NA | 33% | 31% | 13% | 20% | 26% |
| Post4.9 | How many days would you say you consulted the Energy Display at your thermostat | | | NA | 43 | 35 | 17 | 36 | 53 | 45 |
| Post5.1 | Does your thermostat show real-time energy use for your Whole House? | | | NA | 68% | 71% | | | | |
| Post5.2 | Would you say that it accurately shows your real-time energy data? | | | NA | 79% | 74% | 52% | 58% | 43% | 57% |
| Post5.3 | Would you say that the 'Whole House' energy data helped you lower your energy use? | | | NA | 80%* | 62% | 44% | 53% | 43% | 52% |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| Post5.5 | Does your thermostat show real-time energy use for your individual appliances? | | | NA | NA | 45% | | | | |
| Post5.6 | Would you say that it accurately shows your real-time appliance data? | | | NA | NA | 42% | 46% | 47% | 48% | 41% |
| Post5.7 | Would you say that the data for individual appliances helped you lower your energy use? | | | NA | NA | 38% | 23% | 33% | 32% | 28% |
| Post5.9 | How many days would you say you consulted the Energy Display at your thermostat | | | NA | 27 | 32 | 23 | 26 | 41 | 27 |
| Post6.1 | How many days would you say you consulted 'View my Electricity Use' energy display on SMUD's My Account website? | | 8.4 | 5.7 | 9.4 | 10.1 | 4.2 | 8.5 | 14 | 5.9 |
| Post6.2 | Rate from 1 = least preferred to 5 =most preferred | Whole house data on thermostat | 4.0 | NA | 4.5 | 3.6 | | | | |
| Post6.3 | | Appliance data on thermostat | 2.4 | NA | NA | 2.4 | | | | |
| Post6.4 | | Whole house data on computer | 3.8 | NA | 3.8 | 3.8 | | | | |
| Post6.5 | | Appliance data on computer | 3.4 | NA | NA | 3.4 | | | | |
| Post6.6 | | View My Electricity Use on SMUD's website | 3.2 | 3.5 | 3.0 | 3.3 | | | | |
| Post7.1 | Did you receive email notifications about Conservation Event? | | 91% | 90% | 94% | 90% | 89% | 97% | 84% | 94% |
| Post7.2 | I read the tips | Somewhat or Strongly Agree | 84% | 84% | 88% | 80% | 72% | 87% | 80% | 90% |
| | | Somewhat or Strongly Disagree | 6% | 7% | 2% | 9% | 11% | 6% | 4% | 6% |
| | | Other | 10% | 9% | 10% | 11% | 17% | 6% | 16% | 5% |
| Post7.3 | I learned something from the tips | Somewhat or Strongly Agree | 79% | 80% | 84% | 73% | 72% | 76% | 77% | 85% |
| | | Somewhat or Strongly Disagree | 10% | 10% | 7% | 12% | 6% | 16% | 6% | 10% |
| | | Other | 11% | 10% | 9% | 15% | 22% | 8% | 17% | 5% |
| Post7.4 | I changed my behavior based on the tips | Somewhat or Strongly Agree | 72% | 73% | 77% | 65% | 67% | 68% | 70% | 77% |
| | | Somewhat or Strongly Disagree | 16% | 15% | 12% | 20% | 8% | 25% | 10% | 16% |
| | | Other | 13% | 12% | 11% | 15% | 25% | 6% | 20% | 7% |
| Post7.5 | I saved more because of the tips | Somewhat or Strongly Agree | 66% | 62% | 72% | 63% | 58% | 63% | 57% | 77% |
| | | Somewhat or Strongly Disagree | 15% | 18% | 11% | 17% | 11% | 24% | 13% | 14% |
| | | Other | 19% | 20% | 17% | 20% | 31% | 13% | 30% | 9% |
| Post8.1 | I avoided using the dishwasher during the peak | | 86% | 83% | 88% | 88% | 89% | 86% | 86% | 86% |
| Post8.2 | I avoided using electricity to cook during the peak | | 94% | 95% | 95% | 93% | 86% | 98% | 94% | 95% |
| Post8.3 | I pre-cooled my home several hours before the | | 75% | 77% | 74% | 75% | 64% | 68% | 86% | 77% |

| # | Post-Summer Survey | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|
| | peak period | | | | | | | | |
| Post8.4 | I turned off unnecessary lights and equipment during the peak | 80% | 74% | 77% | 88% | 69% | 70% | 93%** | 82% |
| Post8.5 | I closed all the windows and doors when the outdoor temperature exceeded the indoor temperature | 79% | 84% | 78% | 76% | 75% | 83% | 78% | 80% |
| Post8.6 | I increased the thermostat setpoint to a higher-than-normal temperature during the peak period | 91% | 88% | 94% | 91% | 92% | 87% | 90% | 94% |
| Post8.7 | I avoided washing or drying clothes during the peak | 69% | 71% | 76% | 61% | 61% | 71% | 67% | 72% |
| Post8.8 | I avoided taking hot showers during the peak, because I have an electric heater | 33% | 40% | 24% | 35% | 28% | 22% | 42% | 36% |
| Post8.9 | I left my home and went somewhere cool (e.g. a friend's hours, the mall, the swimming pool) | 32% | 33% | 37% | 26% | 25% | 35% | 28% | 35% |
| Post8.10 | I changed into lighter clothing | 69% | 76% | 72% | 59% | 58% | 63% | 80% | 67% |
| Post8.11 | I used shades or awnings to keep sunlight out | 91% | 90% | 93% | 90% | 81% | 89% | 96% | 93% |
| Post8.12 | I made sure the pool pump or hot tub ran off-peak | 85% | 83% | 89% | 84% | 78% | 79% | 88% | 90% |
| Post8.13 | I cooled the house at night and in the early morning hours by opening windows and/or running the whole house fan | 30% | 29% | 26% | 35% | 11% | 38%* | 36% | 27% |
| Post9.1 | I set my thermostat at 68 degrees or lower for the winter | 19% | 22% | 16% | 18% | 22% | 19% | 25% | 12% |
| Post9.2 | I replaced an old AC unit with a newer, more efficient one | 24% | 17% | 23% | 32% | 25% | 27% | 26% | 20% |
| Post9.3 | I installed more efficient light bulbs (e.g. compact fluorescent or LED) | 14% | 16% | 12% | 13% | 11% | 16% | 13% | 14% |
| Post9.4 | I sealed exterior doors | 46% | 38% | 48% | 52% | 47% | 49% | 36% | 51% |
| Post9.5 | I sealed the attic hatch | 22% | 22% | 24% | 21% | 17% | 24% | 22% | 24% |
| Post9.6 | I lowered the temperature setting on my water heater | 8% | 10% | 6% | 8% | 3% | 6% | 13% | 7% |
| Post9.7 | I put my office equipment or entertainment center on a power strip and turn it off when not in use | 29% | 26% | 34% | 27% | 17% | 29% | 29% | 34% |
| Post9.8 | I sealed leaky heating and air-conditioning ducts | 34% | 30% | 34% | 37% | 28% | 37% | 35% | 34% |
| Post9.9 | I caulked around old windows or installed new efficient ones | 81% | 79% | 82% | 82% | 72% | 78% | 86% | 83% |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| Post9.10 | I insulated the hot water pipes at the water heater | | 69% | 63% | 73% | 72% | 61% | 73% | 67% | 73% |
| Post9.11 | I closed the flue in my fireplace when not in use | | 69% | 68% | 73% | 67% | 56% | 62% | 72% | 78% |
| Post9.12 | I set my thermostat at 78 degrees or higher for the summer | | 14% | 12% | 15% | 15% | 3% | 19% | 14% | 15% |
| Post9.13 | I removed a refrigerator from the garage (or unplugged it) | | 13% | 12% | 13% | 14% | 22% | 13% | 12% | 11% |
| Post9.14 | I increased the insulation in my attic | | 8% | 9% | 11% | 4% | 8% | 5% | 10% | 8% |
| Post9.15 | I replaced an old refrigerator in my kitchen with a newer, more efficient one | | 22% | 17% | 24% | 25% | 11% | 19% | 25% | 27% |
| Post9.16 | I installed a whole house fan, attic fan, or attic vents | | 31% | 37% | 30% | 27% | 17% | 46%* | 32% | 26% |
| Post10.1 | Overall comfort during the summer months | Much more or Somewhat more comfortable | 29% | 26% | 29% | 33% | 19% | 32% | 30% | 31% |
| | | Much less or Somewhat less comfortable | 30% | 24% | 32% | 34% | 28% | 25% | 36% | 30% |
| | | Other | 41% | 50% | 39% | 34% | 53% | 43% | 33% | 33% |
| Post10.2 | Comfort before the peak period when I precooled my home | Much more or Somewhat more comfortable | 51% | 43% | 49% | 61% | 50% | 46% | 61% | 48% |
| | | Much less or Somewhat less comfortable | 10% | 10% | 16% | 5% | 3% | 13% | 9% | 12% |
| | | Other | 39% | 48% | 35% | 34% | 47% | 41% | 30% | 34% |
| Post10.3 | Comfort during the normal weekday peak periods (4-7pm) | Much more or Somewhat more comfortable | 27% | 26% | 26% | 28% | 22% | 32% | 23% | 27% |
| | | Much less or Somewhat less comfortable | 36% | 32% | 38% | 38% | 17% | 27% | 46 %* | 42% |
| | | Other | 38% | 43% | 37% | 34% | 61% | 41% | 30% | 26% |
| Post10.4 | Comfort during Conservation Events | Much more or Somewhat more comfortable | 20% | 18% | 18% | 23% | 17% | 21% | 19% | 22% |
| | | Much less more or Somewhat less comfortable | 57% | 51% | 63% | 57% | 31% | 57% | 67 %* | 60 %* |
| | | Other | 23% | 30% | 18% | 21% | 53% | 22% | 14% | 17% |
| Post10.6 | If you were less comfortable, would you say the savings was worth the effort? | | 59% | 57% | 61% | 58% | 36% | 60% | 58% | 67%* |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| **Post11.1** | Sacramento Municipal Utility District | Somewhat or Very Satisfied | 92% | 93% | 93% | 91% | 89% | 90% | 94% | 93% |
| | | Somewhat or Very Dissatisfied | 4% | 4% | 4% | 4% | 8% | 6% | 1% | 2% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.2** | Summer Solutions Study (Overall) | Somewhat or Very Satisfied | 91% | 93% | 91% | 88% | 83% | 92% | 88% | 94% |
| | | Somewhat or Very Dissatisfied | 6% | 4% | 5% | 8% | 14% | 5% | 7% | 1% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.3** | Installation process | Somewhat or Very Satisfied | 89% | 91% | 91% | 86% | 92% | 90% | 88% | 89% |
| | | Somewhat or Very Dissatisfied | 7% | 5% | 5% | 10% | 6% | 6% | 7% | 7% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.4** | Customer support | Somewhat or Very Satisfied | 84% | 77% | 89% | 87% | 78% | 86% | 86% | 85% |
| | | Somewhat or Very Dissatisfied | 12% | 20% | 7% | 9% | 19% | 11% | 10% | 10% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.5** | Summer Solutions Rate | Somewhat or Very Satisfied | 86% | 90% | 78% | 91% | NA | NA | 84% | 89% |
| | | Somewhat or Very Dissatisfied | 10% | 8% | 16% | 5% | NA | NA | 12% | 7% |
| | | Other | 5% | 2% | 7% | 5% | NA | NA | 4% | 5% |
| **Post11.6** | Automatic Temperature Control option | Somewhat or Very Satisfied | 85% | 76% | 84% | 96%* | NA | 84% | NA | 88% |
| | | Somewhat or Very Dissatisfied | 10% | 17% | 10% | 4% | NA | 13% | NA | 8% |
| | | Other | 4% | 7% | 6% | 0% | NA | 3% | NA | 5% |
| **Post11.7** | Home Energy Assessment | Somewhat or Very Satisfied | 83% | 91% | 82% | 76% | 77% | 85% | 89% | 78% |
| | | Somewhat or Very Dissatisfied | 14% | 6% | 18% | 17% | 15% | 15% | 5% | 20% |
| | | Other | 3% | 3% | 0% | 7% | 8% | 0% | 5% | 2% |
| **Post11.8** | Summer Solutions Thermostat | Somewhat or Very Satisfied | 88% | 87% | 91% | 87% | 86% | 89% | 86% | 91% |
| | | Somewhat or Very Dissatisfied | 8% | 10% | 5% | 9% | 11% | 8% | 10% | 5% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.9** | Summer Solutions Energy Display on the thermostat | Somewhat or Very Satisfied | | NA | 79% | 70% | 74% | 82% | 62% | 78% |
| | | Somewhat or Very Dissatisfied | | NA | 17% | 26% | 22% | 18% | 31% | 18% |
| | | Other | | NA | 4% | 4% | 4% | 0% | 7% | 4% |

| # | Post-Summer Survey | | Total | Baseline Info | Home info | Appliance info | Tiered rate + Customer PCT | Tiered rate + Utility PCT | TOU-CPP rate + Customer PCT | TOU-CPP rate + Utility PCT |
|---|---|---|---|---|---|---|---|---|---|---|
| **Post11.10** | Summer Solutions Energy Display on the computer | Somewhat or Very Satisfied | | NA | 72% | 77% | 74% | 82% | 71% | 73% |
| | | Somewhat or Very Dissatisfied | | NA | 24% | 18% | 22% | 18% | 21% | 22% |
| | | Other | | NA | 4% | 4% | 4% | 0% | 7% | 4% |
| **Post11.11** | 'View my Electricity Use' on SMUD's My Account website | Somewhat or Very Satisfied | 48% | 38% | 51% | 54% | 53% | 49% | 49% | 44% |
| | | Somewhat or Very Dissatisfied | 48% | 59% | 45% | 41% | 44% | 48% | 46% | 51% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.12** | Your summer 2012 electricity bills | Somewhat or Very Satisfied | 80% | 79% | 83% | 79% | 72% | 86% | 72% | 86% |
| | | Somewhat or Very Dissatisfied | 15% | 17% | 13% | 16% | 25% | 11% | 23% | 9% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post11.13** | Your summer 2012 comfort | Somewhat or Very Satisfied | 84% | 83% | 85% | 83% | 81% | 87% | 80% | 85% |
| | | Somewhat or Very Dissatisfied | 12% | 13% | 11% | 13% | 17% | 10% | 16% | 10% |
| | | Other | 4% | 4% | 4% | 4% | 3% | 3% | 4% | 5% |
| **Post12.1** | How did participation in the Summer Solutions Study compare to your expectations before the program began? | Much more or Somewhat more comfortable | 47% | 48% | 48% | 45% | 42% | 44% | 49% | 48% |
| | | Much more or Somewhat less comfortable | 5% | 7% | 4% | 4% | 3% | 6% | 10% | 1% |
| | | Other | 48% | 45% | 49% | 51% | 56% | 49% | 41% | 51% |
| **Post13.1** | I would be interested in the Summer Solutions rate if it is available in summer 2013 | | 84% | 84% | 82% | 86% | 75% | 83% | 83% | 90% |
| **Post13.2** | I would be interested in attending an evening event at SMUD presenting the study results in late 2012 | | 21% | 23% | 18% | 21% | 8% | 21% | 25% | 23% |
| **Post13.3** | I would be interested in receiving the report describing this study and its results in early 2013 | | 56% | 59% | 56% | 52% | 44% | 56% | 55% | 60% |
| **Post13.4** | I do not currently have the real-time Energy Display on my computer and thermostat, but would be interested in having it installed | | 19% | 39%** | 11% | 7% | 11% | 17% | 29% | 14% |
| **Post13.5** | I would like to have the Summer Solutions equipment removed. I understand that the thermostat can stay, but that I will no longer have access to y real-time energy use on the computer or thermostat | | 4% | 7% | 4% | 2% | 8% | 2% | 7% | 2% |

# Appendix C. Regression Models

For all analysis, hourly data for June 1, 2010 – September, 30 2010 was used as the pretreatment baseline. June 1, 2012 – September 30, 2012 was used to determine the post-treatment impacts.

## Group (Pooled) Load Impacts

The 3-level mixed effects models used to estimate group load impacts were designed to have hours nested within days and days nested within participants, with random effects for day and participant. Weekday event and non-event models include all days except weekends and holidays, while overall energy impact models include all days.

$$kw_{ijk} = \beta_{(hour)ijk} hour_{ijk} + \beta_{(CDH)ijk} CDH_{ijk} + \beta_{(MaxTemp)ij} MaxTemp_{ij} + \beta_{(hour*Treat)ijk} hour_{ijk} * Treat + r_i + r_{ij} + \varepsilon_{ijk}$$

$kw_{ijk}$: kilowatt load for customer $i$ on day $j$ at hour $k$
$hour_{ijk}$: categorical variables (1-24) indicating the hour of the day, where hour 1 spans the period from midnight to 1:00 a.m. and hour 24 spans the period from 11:00 p.m. to midnight
$CDH_{ijk}$: cooling degree hour on day $j$ at hour $k$
$MaxTemp_{ij}$: maximum temperature on day $j$
$Treat$: categorical variables for treatment or program and day type or year
$r_i$: random effects for customer $\sim N(0, \varphi_1)$, assumed to be independent for different $i$
$r_{ij}$: random effects for day $\sim N(0, \varphi_2)$, assumed to be independent for different $i$ or $j$ and of $r_i$
$\varepsilon_{ijk}$: error terms $\sim N(0, \delta^2 I)$, assumed to be independent for different $i$ or $j$ and to be independent of random effects

## Customer-specific Load Impacts

Fixed effects models were used to estimate customer specific load impacts for use in bill impacts and correlations with survey responses. Weekday event and non-event models include all days except weekends and holidays, while overall energy impact models include all days.

$$kw_{jk} = \beta_{(hour)jk} hour_{jk} + \beta_{(CDH)jk} CDH_{jk} + \beta_{(Month)jk} Month + \beta_{(MaxTemp)jk} MaxTemp_{jk} + \beta_{(hour*year)jk} hour_{jk} * DayType + \varepsilon_{jk}$$

$kw_{jk}$: kilowatt load for customer $i$ on day $j$ at hour $k$
$hour_{jk}$: categorical variables (1-24) indicating the hour of the day, where hour 1 spans the period from midnight to 1:00 a.m. and hour 24 spans the period from 11:00 p.m. to midnight
$CDH_{jk}$: cooling degree hour on day $j$ at hour $k$
$MaxTemp_{ij}$: maximum temperature on day $j$
$Month$: categorical variable indicating month (June, July, August, September)
$DayType$: categorical variables indicating event/nonevent, weekday/weekend and year
$\varepsilon_{jk}$: error terms