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# 2010 Load Impact Evaluation for Pacific Gas and Electric Company's Smart AC Program

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**Final Report**

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## Table of Contents

# 1 Executive Summary

This report documents the load impact analysis, methodology and results for the Pacific Gas and Electric Company (PG&E) SmartAC™ program for residential and non-residential customers.

PG&E's SmartAC™ program involves the installation of programmable communicating thermostats (PCTs) and/or direct load control switches (switches) in households and small/medium businesses with central air conditioning (AC). The control devices allow AC to be cycled or thermostats to be adjusted when an event is triggered, thereby reducing energy demand associated with AC load. The standard cycling strategy for load control switches is 50% for residential customers and 33% for non-residential participants. The standard temperature adjustment for customers with PCTs is 2 degrees in the first event hour and 1 degree in each of the following two event hours for residential customers. For non-residential customers, the standard operational strategy involves a 1 degree adjustment in each of the first three event hours.

SmartAC events can only be called under emergency or in anticipation of emergency conditions between May 1st and October 31st and for an event period of 6 hours or less for no more than 100 hours per season. One territory-wide test event was called in 2010, on July 16th. Devices were controlled from 2 PM to 6 PM. Residential customer enrollment on SmartAC on July 16th was roughly 137,000 accounts, and non-residential customer enrollment was roughly 2,500 accounts.

Under contract to PG&E, FSC selected a sample of SmartAC participants and installed end-use loggers on the air conditioning units for these households to obtain data for use in both ex post and ex ante load impact analysis for 2010. Multiple events were called for this research sample under various weather conditions, device operational strategies and event durations. The load impact estimates presented here are based on analysis of this logger data. The sample was reweighted to properly represent the distribution of SmartAC customers across climate regions.

In addition to estimating load impacts, FSC also analyzed the degree to which SmartAC control devices received the signal to reduce load. FSC also conducted a survey of SmartAC customers following an M&E event to assess the degree to which the customers felt discomfort due to the event. A control survey on SmartAC customers who did not experience the event was also conducted.

## 1.1 Residential SmartAC Ex Post Load Impact Summary

Table 1-1 shows the average impact per customer for each load research event along with average temperature over the event period for the residential SmartAC population. Each event began at 2 PM, and all but two of the last three lasted until 6 PM. Those two ran until 8 PM. The largest impact occurred on August 25th, which had an estimated impact of 0.44 kW per customer. Not coincidentally, August 25th was a very hot day, following immediately after another very hot day.

The overall average event effect of 0.22 kW with an average event temperature of 93 degrees is similar to both the 2009 and 2010 average ex post result. The 2009 result was based on an estimate from a single event on September 10, 2009. The average effect was 0.19 kW during an event with an average temperature of 93 degrees. The average M&E event temperature in 2008 was also 93 degrees and the average event impact that year was 0.26 kW.

**Table 1-1:**
**Average Residential per Account Reference Loads, Impacts and Temperatures During Event Hours on 2010 Event Days**

| Event Date | Event Hours | Average Reference Load (kW) | Average Event Impact (kW) | Percent Impact (%) | Average Temperature |
|---|---|---|---|---|---|
| 6/23/2010 | 2 PM-6 PM | 0.46 | 0.11 | 24 | 86 |
| 6/28/2010 | 2 PM-6 PM | 1.23 | 0.36 | 29 | 97 |
| 7/9/2010 | 2 PM-6 PM | 0.43 | 0.09 | 21 | 86 |
| 7/15/2010 | 2 PM-6 PM | 1.13 | 0.30 | 27 | 97 |
| 7/16/2010 | 2 PM-6 PM | 1.18 | 0.30 | 25 | 95 |
| 7/22/2010 | 2 PM-6 PM | 0.44 | 0.09 | 20 | 88 |
| 8/2/2010 | 2 PM-6 PM | 0.45 | 0.11 | 24 | 88 |
| 8/16/2010 | 2 PM-6 PM | 0.42 | 0.10 | 24 | 88 |
| 8/24/2010 | 2 PM-6 PM | 1.29 | 0.40 | 31 | 103 |
| 8/25/2010 | 2 PM-6 PM | 1.36 | 0.44 | 32 | 102 |
| 9/1/2010 | 2 PM-6 PM | 0.56 | 0.18 | 32 | 93 |
| 9/2/2010 | 2 PM-6 PM | 0.76 | 0.29 | 38 | 97 |
| 9/27/2010 | 2 PM-8 PM | 0.78 | 0.22 | 28 | 94 |
| 9/29/2010 | 2 PM-8 PM | 0.94 | 0.20 | 21 | 94 |
| 9/30/2010 | 2 PM-6 PM | 0.55 | 0.10 | 18 | 87 |
| Average | n/a | 0.80 | 0.22 | 28 | 93 |

The average customer impact of 0.22 kW represents a 28% load reduction. The percent reduction across event days ranged from a low of 18% to a high of 38%. Clearly, these impacts are significantly less than the target reduction of 50% based on the 50% cycling strategy that is employed for residential participants. Most residential control devices use an adaptive cycling algorithm that is intended to reduce load in direct proportion to the cycling percentage, however it appears that most residential customers in the M&E sample were subjected to simple cycling rather than adaptive. This would mean that those customers would produce zero load impact at temperatures where their AC units were operating at less than a 50% duty cycle. Control device failure to receive or respond to the event signal is another possible cause of differences between the target and actual reduction, but an independent assessment of such problems indicates that they are relatively minor among residential customer participants (roughly equal to 7% of devices). This would suggest that improvements in the adaptive cycling performance could significantly improve impact estimates.

## 1.2 Non-residential SmartAC Ex Post Load Impact Summary

Table 1-2 shows each event date with average per AC unit event impacts and average temperature during the event hours for the non-residential SmartAC population. Each event began at 2 PM and ran until 6 PM except the second-to-last event, which ran until 8 PM. The largest impact occurred on July 15th, which had an estimated impact of 0.22 kW per AC unit. The average impact across all events is 0.11 kW per AC unit, or roughly 7% of AC load.

The target reduction for non-residential customers is 33%. As will be discussed further, event impacts in Table 1-2 are influenced dramatically by control failure, which refers to the AC load-control switch or PCT not receiving or reacting to the radio signal that starts an event. This can occur for several reasons, discussed in a later section. Average control failure in the non-residential SmartAC load-research sample was over 50% for the summer of 2010. Switches employing simple cycling rather than adaptive cycling may also play a role in low impacts among non-residential customers.

**Table 1-2:**
**Average Non-residential per AC Unit Reference Loads, Impacts and Temperatures During Event Hours**

| Event Date | Event Hours | Average Reference Load (kW) | Average Event Impact (kW) | Percent Reduction (%) | Average Temperature |
|---|---|---|---|---|---|
| 6/23/2010 | 2 PM-6 PM | 1.22 | 0.12 | 10 | 80 |
| 6/25/2010 | 2 PM-6 PM | 0.95 | 0.09 | 9 | 76 |
| 6/28/2010 | 2 PM-6 PM | 1.88 | 0.09 | 5 | 89 |
| 7/9/2010 | 2 PM-6 PM | 1.22 | 0.14 | 11 | 80 |
| 7/15/2010 | 2 PM-6 PM | 1.94 | 0.22 | 11 | 90 |
| 7/16/2010 | 2 PM-6 PM | 1.88 | 0.18 | 10 | 87 |
| 7/22/2010 | 2 PM-6 PM | 1.19 | 0.14 | 12 | 82 |
| 7/28/2010 | 2 PM-6 PM | 1.04 | 0.11 | 11 | 78 |
| 8/2/2010 | 2 PM-6 PM | 1.26 | 0.10 | 8 | 81 |
| 8/5/2010 | 2 PM-6 PM | 1.16 | 0.08 | 7 | 77 |
| 8/16/2010 | 2 PM-6 PM | 1.21 | 0.10 | 8 | 82 |
| 8/24/2010 | 2 PM-6 PM | 2.12 | 0.00 | 0 | 98 |
| 8/25/2010 | 2 PM-6 PM | 2.37 | 0.20 | 8 | 94 |
| 9/1/2010 | 2 PM-6 PM | 1.54 | 0.05 | 3 | 91 |
| 9/2/2010 | 2 PM-6 PM | 1.93 | 0.19 | 10 | 91 |
| 9/27/2010 | 2 PM-6 PM | 1.72 | 0.07 | 4 | 94 |
| 9/29/2010 | 2 PM-8 PM | 1.67 | 0.03 | 2 | 88 |
| 9/30/2010 | 2 PM-6 PM | 1.45 | 0.07 | 5 | 83 |
| Average | n/a | 1.54 | 0.11 | 7 | 86 |

## 2 SmartAC Program and Population Overview

PG&E's SmartAC™ program involves the installation of programmable communicating thermostats (PCTs) and/or direct load control switches (switches) in households and small/medium businesses with central (or packaged) air conditioning (AC). The control devices allow AC equipment to be cycled or thermostats to be adjusted when an event is triggered, thereby reducing energy demand associated with AC load. The standard cycling strategy for switches is 50% for residential customers and 33% for non-residential participants. The standard temperature adjustment for customers with PCTs is 2 degrees in the first event hour and 1 degree in each of the following two event hours for residential customers. For non-residential customers, the standard operational strategy involves a 1 degree adjustment in each of the first three event hours. SmartAC events can only be called under emergency or in anticipation of emergency conditions between May 1st and October 31st and for an event period of 6 hours or less for no more than 100 hours per season. One territory-wide test event was called in 2010, on July 16. Devices were controlled from 2 PM to 6 PM.

Table 2-1 shows the number of active, enrolled customers and devices on July 16, 2010 (the system-wide event day) by customer type, device type and local capacity area (LCA). It is important to distinguish between enrolled customers and enrolled devices, as many customers, especially non-residential customers, have multiple AC units and, therefore, multiple control devices. Some accounts even have both kinds of control device associated with separate AC units.

As seen in Table 2-1, the majority of SmartAC customers and devices are associated with residential households. Indeed, the residential segment comprises 98% of all SmartAC customers, 99% of switches and 86% of PCTs. Non-residential accounts have roughly 2.2 devices per customer, whereas residential accounts average 1.1 devices per customer.

Since the 2009 program year evaluation, the number of residential accounts and devices has grown by 9% each. Although the number of non-residential customers is much smaller than the number of residential customers, it has grown substantially since last year's report due to increased marketing in that segment. In September 2009, there were approximately 1,000 non-residential SmartAC customers. By July 2010, more than 2,400 accounts were enrolled.

As was the case a year ago, the Greater Bay Area LCA makes up the largest share of SmartAC accounts, followed by Greater Fresno. Both of these LCAs account for smaller proportions than they did last year. The number of residential customers in the Kern LCA grew more than 100% from 1,500 in 2009 to over 3,500 in 2010.

**Table 2-1:**
**SmartAC Active Accounts and Control Devices**
**July 16, 2010 Event Day**

| Customer Class | Local Capacity Area | PCTs | Switches | Accounts |
|---|---|---|---|---|
| Non Residential | Greater Bay Area | 1,684 | 197 | 944 |
| | Greater Fresno | 725 | 202 | 372 |
| | Kern | 146 | 9 | 69 |
| | Mission | 2 | 0 | 1 |
| | Northern Coast | 328 | 53 | 205 |
| | Sierra | 329 | 63 | 205 |
| | Stockton | 330 | 103 | 182 |
| | Other | 1,029 | 138 | 467 |
| | Total | 4,574 | 765 | 2,446 |
| Residential | Greater Bay Area | 7,946 | 35,530 | 38,544 |
| | Greater Fresno | 6,579 | 19,293 | 23,473 |
| | Kern | 2,434 | 1,805 | 3,561 |
| | Northern Coast | 1,433 | 5,434 | 6,409 |
| | Sierra | 2,325 | 13,632 | 13,787 |
| | Stockton | 2,413 | 9,919 | 11,337 |
| | Other | 4,263 | 16,527 | 19,198 |
| | Total | 27,393 | 102,140 | 116,309 |

## 2.1 Report Organization

The remainder of this report is organized as follows. Section 3 describes the load research sample design and the experimental operation of the sample that generates the end use load data used in the analysis. It also summarizes some of the control failures and other issues that were identified during the research. Section 4 summarizes the ex post evaluation. This is a detailed section that describes the methodologies used, the validation tests performed and ex post evaluation results. Section 5 contains the ex ante impact estimates. Section 6 presents the results of a post-event survey that was performed to assess whether the SmartAC program has any significant impact on customer comfort. The survey also assessed customer satisfaction with the program and with PG&E in general. Detailed tables presenting ex post and ex ante impact estimates that conform to the requirements of the CPUC Load Impact Protocols are provided to PG&E for filing along with this report.

# 3 M&E Sample and Experimental Design

This section details the recruitment, addressing verification, logger installation and retrieval effort for the M&E sample. It also discusses the different control strategies employed in the M&E sample during test events. Different strategies were used on sub-samples of customers and on different event days in order to examine how event impacts vary with control strategy.

## 3.1 M&E Recruitment and Logistics

### 3.1.1 Customer Recruitment

Customer recruitment occurred in two stages—residential recruitment occurred in March and non-residential recruitment in April. Non-residential recruitment was intentionally delayed because the non-residential population was growing rapidly. Waiting as long as possible to recruit the non-residential M&E sample allowed the sample to be as representative as possible of the full population.

For residential customers, a stratified random sample of 3,200 customers was drawn from the SmartAC population for recruitment to use for recruiting 320 customers into the M&E sample. The sample was stratified based on local capacity area, to ensure representation across different regions. Recruitment proceeded with a letter followed by a recruitment phone call. Customers were offered a $30 incentive check to participate in the M&E sample and recruitment was completed after one week of phone calls.

For non-residential customers, a random sample of 3,000 customers was drawn, stratified by climate region (R, S, T and X) and industry. The five industrial segments were:

- Institutions & Schools;
- Offices & Services;
- Restaurants;
- Retail Stores; and
- Other.

Non-residential recruitment proceeded in the same fashion as for residential customers with a letter followed by a phone call. Non-residential recruitment required 10 days of phone calls to reach the desired sample size of 300 customers.

For both residential and non-residential customers, the recruitment effort was stratified based on the same variables as the recruitment sample so that recruiters attempted to fill stratification cells with customers. Once a cell was full, recruiters would no longer call customers in that cell.

Following recruitment, the next step was to communicate with each of the M&E sample participants' control devices instructing it to recognize signals aimed specifically at the M&E sample.[1] This was important because the M&E sample would be operated numerous times over the course of the summer, while the overall SmartAC Program would not.

[1] In the jargon of the current load control contractor, this is known as setting the splinter for the device.

### 3.1.2 Logger Installations and Data Collection

Residential logger installations took place from March 15 to March 26. In total, 336 loggers were installed (due to some homes having two AC units enrolled in SmartAC), with 278 (83%) being placed on central AC with DLC switch control devices, and the balance on PCT controlled units. In the non-residential sample, 326 total loggers were installed, with 247 (76%) placed on PCTs and the remainder on AC units with switches.

Installers encountered 18 situations where pursuing the logger installation was not appropriate and deemed a "walk-away." For non-residential customers, walk-aways were much more common, as shown in Table 3-1. This caused non-residential installation to last almost a full month, from May 11 to June 8. In these walk-away situations, the installer would contact FSC and request a replacement recruit from the same stratification cell as the walk-away customer.

**Table 3-1: Summary of Reasons Why Initial Sample Recruits Were Abandoned**

| Reason for Abandonment | Number of Accounts |
|---|---|
| **Residential Participants** | |
| With a control device that had not received the instructions to recognize M&E control signals (the splinter had not been set)[2] | 7 |
| With a missing or disconnected DLC switch[2] | 4 |
| With a faulty DLC switch (no probability of responding to a DLC radio signal)[2] | 3 |
| With access issues (the technician could not physically get close enough to the unit) | 2 |
| Where the technician could not scan the DLC device | 1 |
| AC unit not operable[2] | 1 |
| **Non-residential Participants** | |
| With a control device with only a splinter 1 (non-M&E) address[2] | 55 |
| With a missing PCT[2] | 16 |
| With PCTs with no memory to be scanned | 7 |
| With a faulty AC (no probability of responding to a DLC radio signal)[2] | 7 |
| With access issues (the technician could not physically get close enough to the unit) | 7 |
| With a faulty PCT (no probability of responding to a DLC radio signal)[2] | 6 |
| other | 5 |
| With a missing or disconnected DLC switch [2] | 4 |
| where the customer changed their mind and opted out of the sample | 3 |

[2] In these cases, FSC provided PG&E with a list of the involved central AC units so that PG&E could remove them from the SmartAC rolls.

For each logger installation, the field technicians also collected a significant amount of information that was recorded on an On-Site Verification Form (OVF), as well as through a series of digital photographs. The OVF included:

- Customer name, address and phone number;
- DLC control device serial number and operational status;
- Control signal strength being received by the control device;
- Information derived from interrogating the control device's memory, such as all addressing information, most importantly, the "splinter" address assigned to that device;
- AC logger serial number;
- Make, model and serial number of the AC unit itself; and
- The AC unit's kW and kVar values as measured by the technician.

### 3.1.3 Logger Retrieval and Data Downloading

Logger retrieval took place in mid-October. At that time, technicians confirmed that the logger was still functioning. Technicians also retrieved internal data from the control devices themselves, including information on whether the device was controlled during any particular hour of the summer. Of the 662 AC units where loggers were installed, technicians were successful in retrieving 615 control device memory scans. As shown below, 537 of these had useful control device memory data; this is unrelated to the number of usable sets of AC logger data, which is much larger.

### 3.1.4 Verification Protocol Components Tied to Logger Installations

As mentioned above, following the conclusion of sample recruitment for both the residential and non-residential customers, PG&E's SmartAC DR provider, Cooper, sent signals to the control devices of recruited customers to set the device to respond to M&E events. This is referred to as setting the splinter, or addressing.

As part of the installation protocols, technicians checked whether control devices had received the addressing signal. Those that did not have an appropriate splinter address in their logs would be deemed a "walk away." For residential PCT participants, technicians could only scan the PCTs associated with the homes when the owner let them in.

Once all the loggers were installed, five test events were called to verify that the devices could correctly implement a desired cycling or temperature setback strategy. These strategies are defined in Section 3-2. The test involved a small subset of each sample (23 residential participants and 16 non-residential participants), with each receiving a series of daily consecutive operations that would mimic each of the possible cycling and setback strategies associated with the M&E population. These test operations were conducted on cool days so as not to impact customer comfort. The residential gear test operations took place during the week of May 24$^{th}$, with the data being downloaded from each of the 23 control devices the following week. However, as a result of examining the data from those tests, it was determined that the Cooper UtilityPro PCT will not recognize an operation signal if it is in "heat" mode on a cool day. Bearing in mind the large proportion of the non-residential sample equipped with UtilityPros, the decision was made to wait for warmer weather to run the gear tests. Those test signals were put into the field in early September (due in large part to it being such a cool summer in 2010) and the control device data scans downloaded soon thereafter.

## 3.2 Experimental Design and Operations

Between June 1st and September 30th, 2010, air conditioners for customers in the SmartAC M&E sample were subjected to test operations under varying conditions of temperature, cycling intensity and operational duration as defined in the approved Evaluation Plan. Fourteen test operations were completed for the residential sample and 17 for the small and medium business (SMB) sample. These tests included all summer months and were scheduled across a wide range in temperature. Both residential and non-residential customers were divided into two randomly-drawn, equal-sized groups, A and B. For some test events, both groups were called using the same operational mode while for other test events, groups received different operational commands so as to detect differences in load impacts associated with different operational modes.

### 3.2.1 Program Operating Modes

During the 2010 operating/research season, the sample population was available for both emergency and testing purposes. Emergency purposes include operations requested by the CAISO or PG&E. Testing purposes include operations designed to observe load impacts under different conditions that occur over the operating season. In addition to test events, the SmartAC M&E sample was operated in a system-wide event, on July 16th.

Testing operation modes are designed to measure the impact of the program using different levels of cycling intensity and for varying durations under varying temperature conditions. Roughly 90% of residential customers in the M&E sample have DLC switches and the remaining 10% have PCTs. The cycling strategy or PCT temperature ramping strategy was operated according to the normal emergency operation, which for switches is 50% adaptive cycling and for PCTs a temperature ramping strategy of 2 degrees in the first event hour followed by an additional 1 degree in the next event hour and 1 more degree in the next hour (2, 1, 1). An extended operation was tested for the residential class using the same 2,1,1 ramping but maintaining it for six hours between 2 PM and 8 PM. Residential electric load peaks later in the day compared to non-residential customers. The extended event allowed for testing the ability of residential customers to provide load reductions into these late afternoon/evening hours.

For non-residential customers in the sample, more than 80% have PCTs while the remainder has DLC devices. For these customers, the normal cycling strategy is 33% for DLC switches and the normal temperature ramping operation for PCTs is (1,1,1). Table 3-2 summarizes the operating modes that were available during the season.[3]

[3] In the table, R refers to residential and NR to non-residential. A notch testing mode was also available for both residential and non-residential customers but was not used.

**Table 3-2:**
**Summary of Program Operating Modes**

| Operating Mode | Device Type | Control Design | Intensity | Start Time | End Time |
|---|---|---|---|---|---|
| Emergency Operation R | DLC | TrueCycle II | 50% | Variable | Variable |
| Emergency Operation NR | DLC | TrueCycle II | 33% | Variable | Variable |
| Normal Experimental Operation R | DLC | TrueCycle II | 50% | 2:00 PM | 6:00 PM |
| Normal Experimental Operation R | DLC | Standard Cycling | 50% | 2:00 PM | 6:00 PM |
| Normal Experimental Operation NR | DLC | TrueCycle II | 33% | 2:00 PM | 6:00 PM |
| Notch Test | DLC | TrueCycle II | 100% | Variable | Variable |
| Emergency Operation R | PCT | Temperature Ramp | 2,1,1 | Variable | Variable |
| Emergency Operation NR | PCT | Temperature Ramp | 1,1,1 | Variable | Variable |
| Normal Experimental Operation R | PCT | Temperature Ramp | 2,1,1 | 2:00 PM | 6:00 PM |
| Normal Experimental Operation NR | PCT | Temperature Ramp | 1,1,1 | 2:00 PM | 6:00 PM |
| Extended Experimental Operation R/NR | PCT | Temperature Ramp | 2,1,1 | 2:00 PM | 8:00 PM |
| Notch Test | PCT | Temperature Ramp | 100% | Variable | Variable |

### 3.2.2 Testing Plan and Actual Operations

The testing plan called for operations to be conducted at various temperatures between June 1st and September 30th of 2010, as seen in Table 3-4 and 3-5.[4] The reason for the difference in the operational strategy for residential and non-residential participants is that air conditioning occurs at lower temperatures for non-residential customers (due to higher internal loads), so it was deemed useful to assess load impacts at lower temperatures. Approximately 15 operations were planned for the summer. At least one operation was planned in each month of the operating season except May – with most of the operations concentrated in the July and August time periods.

There is no way to accurately predict the temperatures that will occur in any given summer in advance of the operating season. With summer 2010 proving unusually cold, FSC monitored the weather on a daily, day ahead and 10 day-ahead basis to ensure that operations took maximum advantage of temperature conditions within each month. Nevertheless, actual operations differed slightly from the testing plan. Table 3-3 describes the planned versus actual events for both residential and non-residential classes by month and Table 3-4 contains the same information based on daily high temperatures. Events were called in each month and across the temperature spectrum. With the cooler than usual summer, filling the lower temperature bins was successful, but FSC had to act opportunistically when hot weather arose

[4] Operations could have been done in May for residential customers but it was a very cool month and none were called.

to ensure sufficient observations in the higher temperature bins. This explains the higher than planned count of event operations in September, when there was a heat wave toward the tail end of the operating season.

**Table 3-3:**
**Summary of Planned versus Actual Testing Operations by Month**

| Class | Planned versus Actual | Month | | | | |
|---|---|---|---|---|---|---|
| | | June | July | August | September | Total |
| Residential | Planned | 1 | 6 | 6 | 2 | 15 |
| | Actual | 2 | 3 | 4 | 5 | 14 |
| Non-residential | Planned | 1 | 5 | 6 | 3 | 15 |
| | Actual | 3 | 4 | 5 | 5 | 17 |

**Table 3-4:**
**Summary of Planned versus Actual Testing Operations by Temperature**

| Class | Planned versus Actual | Number of Events by Temperature Bin (ºF) | | | | |
|---|---|---|---|---|---|---|
| | | 82-88 | 89-94 | 95-99 | 99+ | Total |
| Residential | Planned | 0 | 5 | 6 | 4 | 15 |
| | Actual | 0 | 5 | 3 | 6 | 14 |
| Non-residential | Planned | 3 | 4 | 4 | 4 | 15 |
| | Actual | 3 | 5 | 3 | 6 | 17 |

On four occasions half the sample was operated while the other half served as a control group. On August 24th, group A had an event while group B did not; the situation was reversed on August 25th. On September 1st, group A had an event while group B did not; again, the situation was reversed on September 2nd. On all other experimental operating days, both groups were operated. On September 27th and 29th, extended tests of six hours duration were conducted for both residential groups while non-residential customers had an extended test only on September 29th.

## 3.3 Control Device Success Rates

The load-control switches and PCTs used to activate events have internal data loggers that keep track of when the device received an event signal and record load shed minutes (how many minutes per hour the device operated). For switches operating with simple cycling, the number of operating minutes per hour should equal 60 times the cycling strategy rate—50% for a typical residential event and 33% for a typical non-residential event. For switches under an adaptive algorithm, such as True Cycle, operating minutes should be higher than these values. In an analysis not shown here, but available by request, it was found that in the M&E sample, virtually all switches operated under simple cycling for every event. It is not clear whether this would also be true of switches outside the M&E sample that may have had more hot days to allow the adaptive algorithm to work better.

For PCTs, the number of operating minutes per hour should equal 60.

A variety of issues can lead to a device not receiving a signal, but the reasons can be divided into two main categories. First, a device might not receive a signal because the signal was miss-addressed. Second, a device might not receive a signal because something blocked the signal from getting through, such as a thick wall. The second issue is thought to affect PCTs more frequently because they are located indoors while switches are located outdoors.

Table 3-5 shows the number of device loggers that were successfully downloaded and that had data for at least one event. The sample of device loggers is smaller than the M&E sample because many of the loggers did not work at all or did not work during particular periods.

**Table 3-5:**
**Number of Devices with Valid Internal Data During at Least One Event**

| | Non-Residential | | Residential | | Total | |
|---|---|---|---|---|---|---|
| | Total in Sample | Total with Data | Total in Sample | Total with Data | Total in Sample | Total with Data |
| Express Stat | 1 | 0 | 25 | 17 | 25 | 17 |
| Utility Pro | 228 | 181 | 24 | 14 | 245 | 195 |
| Switch | 72 | 70 | 282 | 255 | 354 | 325 |
| **Total** | 301 | 251 | 331 | 286 | 632 | 537 |

Table 3-6 displays the percentage of devices that report receiving the event signal for each device type and each event. Whether a device receives a signal was determined by whether the device log had recorded minutes it operated during any of the hours of the event. Further analysis indicated that it was very rare for a device to operate for only part of an event. That is, a device either operated for a whole event or it did not. The sample size underlying each event and device type fluctuates because the device data loggers are prone to large gaps in time.

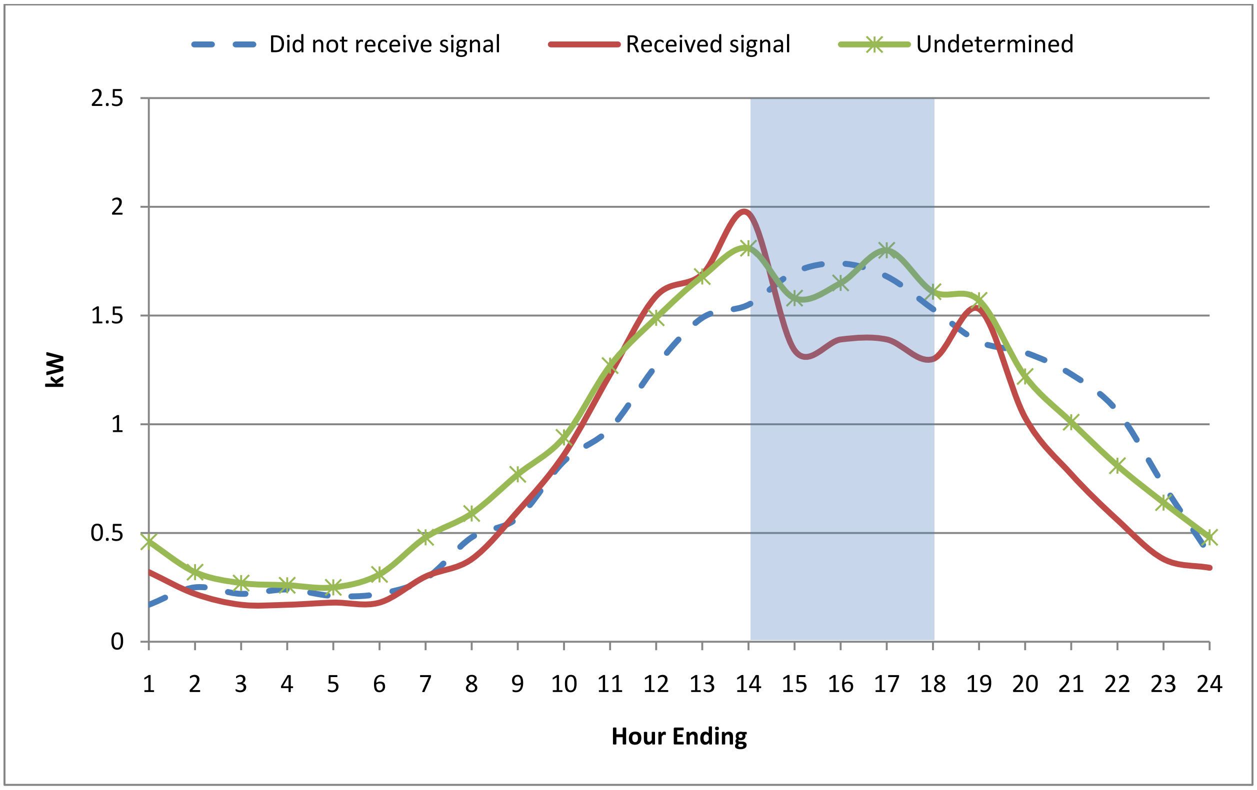
As Table 3-6 shows, residential switches have a very high rate of receiving the event signal. The other two residential device types, Express Stat and Utility Pro PCTs, each have relatively small representation in the sample. Based on an analysis of the problem conducted by PG&E's operations contractor, Cooper Power Systems, it appears that the primary cause of the poor performance of the PCTs for residential customers is poor paging reception.

Table 3-6 also shows that both types of non-residential device received fewer than half of the signals that were purportedly sent out to the non-residential M&E group during 2010. As shown in Figure 3-1, this has a large effect on event impacts. The figure shows AC load for non-residential devices known to have received the event signal on July 16th, for non-residential devices that did not receive the signal and for devices for which it could not be determined whether the signal was received. The first group shows a large event impact with the distinctive drop-off and snap-back at the appropriate times. The second group shows no event impact. The third group, presumably made up of some signal-receivers and some non-receivers, shows a muted impact. This is also evidence that the devices' internal data loggers accurately reflect whether the device received the event signal.

**Table 3-6:**
**Fraction of Devices That Operated During the Event**

| Event Date | Non-residential | | | Residential | | | | Total Weighted Average |
|---|---|---|---|---|---|---|---|---|
| | Switch | Utility Pro | Non-residential Average | Express Stat | Switch | Utility Pro | Residential Average | |
| 6/23/2010 | 0.48 | 0.37 | 0.41 | 0.88 | 0.99 | 0.13 | 0.13 | 0.88 |
| 6/25/2010 | 0.49 | 0.36 | 0.40 | - | - | - | - | - |
| 6/28/2010 | 0.50 | 0.16 | 0.28 | 0.88 | 0.97 | 0.50 | 0.96 | 0.88 |
| 7/9/2010 | 0.50 | 0.55 | 0.53 | 0.78 | 0.97 | 0.38 | 0.94 | 0.78 |
| 7/15/2010 | 0.51 | 0.50 | 0.50 | 0.89 | 0.97 | 0.57 | 0.95 | 0.89 |
| 7/16/2010 | 0.52 | 0.58 | 0.56 | 0.88 | 0.98 | 0.44 | 0.95 | 0.88 |
| 7/22/2010 | 0.51 | 0.48 | 0.49 | 0.89 | 0.97 | 0.26 | 0.94 | - |
| 7/28/2010 | 0.51 | 0.45 | 0.47 | - | - | - | - | 0.89 |
| 8/2/2010 | 0.51 | 0.36 | 0.41 | 0.83 | 0.96 | 0.13 | 0.92 | - |
| 8/5/2010 | 0.51 | 0.33 | 0.39 | - | - | - | - | 0.83 |
| 8/16/2010 | 0.49 | 0.38 | 0.43 | 0.83 | 0.98 | 0.11 | 0.94 | - |
| 8/24/2010 | 0.42 | 0.47 | 0.45 | 0.75 | 0.96 | 0.50 | 0.92 | 0.83 |
| 8/25/2010 | 0.53 | 0.52 | 0.53 | 1.00 | 0.99 | 0.00 | 0.98 | 0.75 |
| 9/1/2010 | 0.46 | 0.45 | 0.45 | 0.50 | 0.97 | 0.17 | 0.91 | 1.00 |
| 9/2/2010 | 0.55 | 0.51 | 0.53 | 0.88 | 0.99 | 0 | 0.97 | 0.5 |
| **Average** | 0.50 | 0.42 | 0.45 | 0.84 | 0.97 | 0.30 | 0.93 | 0.71 |

**Figure 3-1:
Non-residential AC Loads on July 16 for Devices According
to Whether the Device Received the Signal
(Event Window Shaded)**




Once again, an independent analysis of the underlying causes of this poor performance was conducted by Cooper Power Systems. The majority of non-residential switches with control failures are dual-stage ACs and it is believed an installation issue is at fault that may be rectified before 2011 season. For UtilityPro PCTs, 4% of the failures resulted from invalid addressing, 34% from out-of service status due to a firmware issue that is being rectified and 19% of devices have poor paging reception. Whether the problem lies with the device itself or improper installation is under investigation. These issues, and the assumed rate of control improvement, will be discussed further in the ex ante section of the report.

# 4 Ex Post Impact Analysis

As discussed in Section 2, SmartAC is an emergency program that to date has been called infrequently. Few events have dispatched the full load reduction capability of the program, though research samples have been dispatched far more frequently to better understand customer load reduction and the potential of the program for providing ancillary service in the California ISO market. This section describes the data and analysis used to produce this year's impact estimates and also provides the estimates themselves.

## 4.1 M&E Sample Dataset

The M&E sample dataset contains hourly average AC load data for the period June through September for 331 residential customers and 286 non-residential customers. Data was collected at five-minute intervals but averaged over each hour for the primary analysis. The exact dates covered by each logger vary due to installation and retrieval schedules. Both May and October were cool, so analysis is limited to June through September.

The retrieved sample for residential customers contained data from 336 loggers. Two loggers were accidentally re-launched during installation, a mistake that corrupts the logger's timestamps. Two more were missing from PG&E's residential population files for both 2009 and 2010. One logger failed to register current values. This left 331 total loggers for analysis.

Table 4-1 shows the distribution of the final residential M&E sample and the SmartAC population by LCA, CARE status and device type. The sample represents the population quite well. Population weights were calculated based on local capacity area and CARE status, which means that differences across those characteristics should be largely mitigated by the weights.

**Table 4-1: Comparison of Residential M&E sample and SmartAC Population (Percentages)**

| | Characteristic | Sample | SmartAC Residential Population |
|---|---|---|---|
| LCA | Greater Bay Area | 40 | 34 |
| | Greater Fresno | 25 | 20 |
| | Humboldt | 0 | 0 |
| | Kern | 0 | 3 |
| | Northern Coast | 10 | 6 |
| | Sierra | 10 | 12 |
| | Stockton | 0 | 10 |
| | Other | 15 | 16 |
| CARE Status | CARE customer | 17 | 28 |
| Control Device | Switch | 88 | 80 |

The retrieved non-residential sample contained data from 321 loggers. Sixteen loggers were accidentally re-launched during installation and a further 18 were accidentally turned off during installation. This reduced the sample size to 286.

Table 4-2 shows the distribution of the final non-residential M&E sample and the SmartAC population by LCA, business type and device type. The sample represents the population quite well for non-residential customers as well. Population weights were calculated based on local capacity area and industry group, which means that the small differences that do exist across those characteristics should be mitigated by the weights.

**Table 4-2:**
**Comparison of Non-residential M&E Sample and SmartAC Population (Percentages)**

| | Characteristic | Sample | SmartAC Non-residential Population |
|---|---|---|---|
| LCA | Greater Bay Area | 36 | 35 |
| | Greater Fresno | 11 | 17 |
| | Kern | 1 | 3 |
| | Northern Coast | 6 | 7 |
| | Sierra | 3 | 8 |
| | Stockton | 8 | 8 |
| | Other | 34 | 22 |
| Industry | Agriculture, Mining & Construction | 1 | 2 |
| | Manufacturing | 5 | 4 |
| | Wholesale, Transport, other utilities | 2 | 4 |
| | Retail stores | 19 | 9 |
| | Offices, Hotels, Finance, Services | 36 | 38 |
| | Schools | 7 | 7 |
| | Institutional/Government | 16 | 16 |
| | Other or unknown | 15 | 20 |
| Control Device | Switch | 25 | 15 |

## 4.2 Analysis Approach

Data from the loggers installed on the M&E sample was analyzed using multiple strategies. The primary analysis consisted of individual-AC unit level linear regressions of AC load onto variables that controlled for weather and time-of-day, day-of-week and month-of-year. A corroborating analysis was performed, taking advantage of the fact that four of the M&E events included only half of the M&E sample, with the other half serving as a control group. Each half of the sample received two of these four events. A further corroborating analysis was performed using whole-building SmartMeter data for the M&E sample and for a demographically matched control group of SmartAC customers.

The two corroborating analyses require straightforward and verifiable assumptions. This is in contrast to the regression approach, which requires reasonable, but more complicated and less-verifiable assumptions. The advantage of the regression approach is that it does not require a control group and makes very efficient use of the entire summer's data.

Each customer has a different usage pattern over time, and each customer's usage is likely to respond differently to changes in weather. This led us to estimate separate regressions for each AC unit in the sample, but using a common regression model in each case. For all AC units, the factors used to estimate usage patterns were weather variables interacted with time indicators. These allow the model to take into account different reactions to weather conditions at different times of day, times of the week and times of year. For example, a residential customer's energy usage might respond strongly to high temperatures on a Saturday afternoon when they are at home, while it might not respond at all on a Wednesday afternoon when they are at work.

The subscript *t* indicates hour of the summer. Only non-holiday weekdays were modeled because no events were called on the weekend and weekend usage behavior is quite different from weekday usage. Table 4-3 defines the variables and describes the effects they seek to identify. The regression specification was:

$$kWh_t = a + \sum_{h=1}^{24}\sum_{m=5}^{10} b_{hm}\, wacdh_t^1 \cdot I_h \cdot I_m + \sum_{h=1}^{24} \mathrm{c}_h \cdot \mathrm{wacdh}_\mathrm{t}^2 \cdot I_h +$$

$$\sum_{h=1}^{24} \boldsymbol{d_h} \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_c} + \sum_{h=15}^{22} e_h \cdot wacdh_t^1 \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_e} + \sum_{h=15}^{22} f_h \cdot wacdh_t^1 \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_{ei}} +$$

$$\sum_{h=16}^{22} g_h \cdot wacdh_t^1 \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_{es}} + \sum_{h=19}^{22} h_h \cdot wacdh_t^1 \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_{el}} + \sum_{h=19}^{22} i_h \cdot wacdh_t^1 \cdot \boldsymbol{I_h} \cdot \boldsymbol{I_{eu}} + \boldsymbol{\varepsilon_t}$$

**Table 4-3:**
**Description of AC Load Regression Variables**

| Variable | Description |
|---|---|
| $a$ | Estimated constant |
| $b - i$ | Estimated parameter coefficients |
| $I_c$ | Indicator for non-residential customers. Interacted with hourly effects so that non-residential, but not residential, customers have non-weather-sensitive parameters |
| $I_h$ | Indicator variables representing the hours of the day, designed to estimate the effect of daily schedule on usage behavior and event impacts |
| $I_m$ | Indicator variables for month of the year, designed to pick up seasonal effects |
| $I_e$ | Indicator variables designed to pick up the effects of events confirmed by device internal logs |
| $I_{eu}$ | Indicator variables designed to pick up the effects of events not confirmed by device internal logs |

| Variable | Description |
|---|---|
| $I_{ei}$ | Indicator variables designed to pick up the effects of intense events |
| $I_{es}$ | Indicator variables designed to pick up the effects of the 8/24 substation event that only hit some customers within the sample, but at different times than the M&E 8/24 event |
| $I_{el}$ | Indicator variables designed to pick the effects of events that ran for six hours rather than four |
| $wacdh^1$ | The sum of the past 24 hours cooling degree hours using a base of 75. |
| $wacdh^2$ | A weighted average of the past 3 hours' cooling degree hours with a base of 84. This is meant to capture the additional effect of particularly hot periods |
| $\varepsilon_t$ | The error term, assumed to be a mean zero and uncorrelated with any of the independent variables |

The conceptual basis for statistical analysis is that with large sample sizes, the effect of unobservable or omitted factors not related to the main effect will disappear due to the power of averaging. Presumably, many factors affect individual-customer AC usage other than what can be included in a large-scale model. In a large sample, such as hundreds of customers over three months, it is likely that the effect of these omitted factors is small. However, in smaller samples, such as one or a few customers' regression models, these omitted factors could have an important effect. This means that results for sub-samples of the dataset should be viewed with increasing caution as the sub-samples decrease in size.

A related issue is that any measure of event-impact standard error associated with these individual-AC unit regressions inherently assumes that the model has been fully and correctly specified so that the only remaining unexplained variation is completely random—meaning that it is unrelated to any variables of interest. As noted, this may be untrue at an individual-AC unit level. Moreover, statistical variation can only be calculated based on the observed events during the study period. This means that it cannot take into account the effect of weather patterns or other recurring behavior patterns that are not well-represented in the dataset, but that are likely to arise in the future. When the statistical model is asked to provide an extrapolation, there is no procedure for adjusting its uncertainty estimate upward because it's an extrapolation. Both of these issues probably lead to an under-estimation of the true level of variance that should be expected in SmartAC results—even assuming no operational changes or changes in underlying customer behavior. The degree of this under-estimation is unknown because there is no data to model it.

Given that caveat, standard errors for load impacts are calculated as

$$se = \sqrt{(stdp^2 + rmse^2)},$$

where *stdp* is the standard deviation of the prediction—i.e., the standard error associated with the fact that all coefficients are estimated values—and *rmse* is the root-mean-squared-error of the regression, or the error associated with the fact that the model has a baseline of uncertainty in it even if coefficients are estimated perfectly. The *stdp* value is calculated individually for each hourly prediction of each customer's load.

Having calculated the standard error for each customer for each hour, aggregate standard errors are calculated assuming that errors are independent across customers.  Therefore, variances can be summed to get aggregate variance.

Having calculated standard errors of predicted load, percentiles of load impact are calculated based on a Gaussian (or Normal) distribution with standard deviation equal to the calculated standard error and mean equal to the estimated load impact.  This calculation is justified by the central limit theorem.

## 4.3 Model Validation

In order for a model to be useful in the context of SmartAC, it must make accurate predictions of AC loads, primarily at high temperatures.  Three methods of validation are used to assess this capability.

### 4.3.1 In-sample Testing

First, at an individual level and an aggregate level, the model must explain a large degree of the observed variation in AC load during the summer of 2010.  This is a test of the in-sample R-squared of the model. This is the simplest test for the model to pass and it is a necessary, but not sufficient condition for the model to be useful.  A model with a high R-squared value can be developed by including a very large number of variables.  In this case, the model will appear to explain a large degree of the variation in load, but it may be highly inaccurate in predicting for conditions outside of the data the model was fit to.  This is known as over-fitting.

Although the regressions were performed at the individual AC unit level, from a policy standpoint, the focus is less on how the regressions perform for individual AC units than on how the regressions perform for the average participant and for specific customer segments.  We present measures of the variation accounted for by the model, as described by the R-squared goodness-of-fit statistic, for the individual regressions and for aggregate load.

The average R-squared among residential AC unit regressions is 63% and among non-residential AC unit regressions is 55%.  For the residential group over 75% of the regressions have R-squared values above 50% and for the non-residential group over 2/3 of the regressions have R-squared values above 50%. This means that even at an individual level, the model's variables account for over half of the variation in load for the bulk of the population.

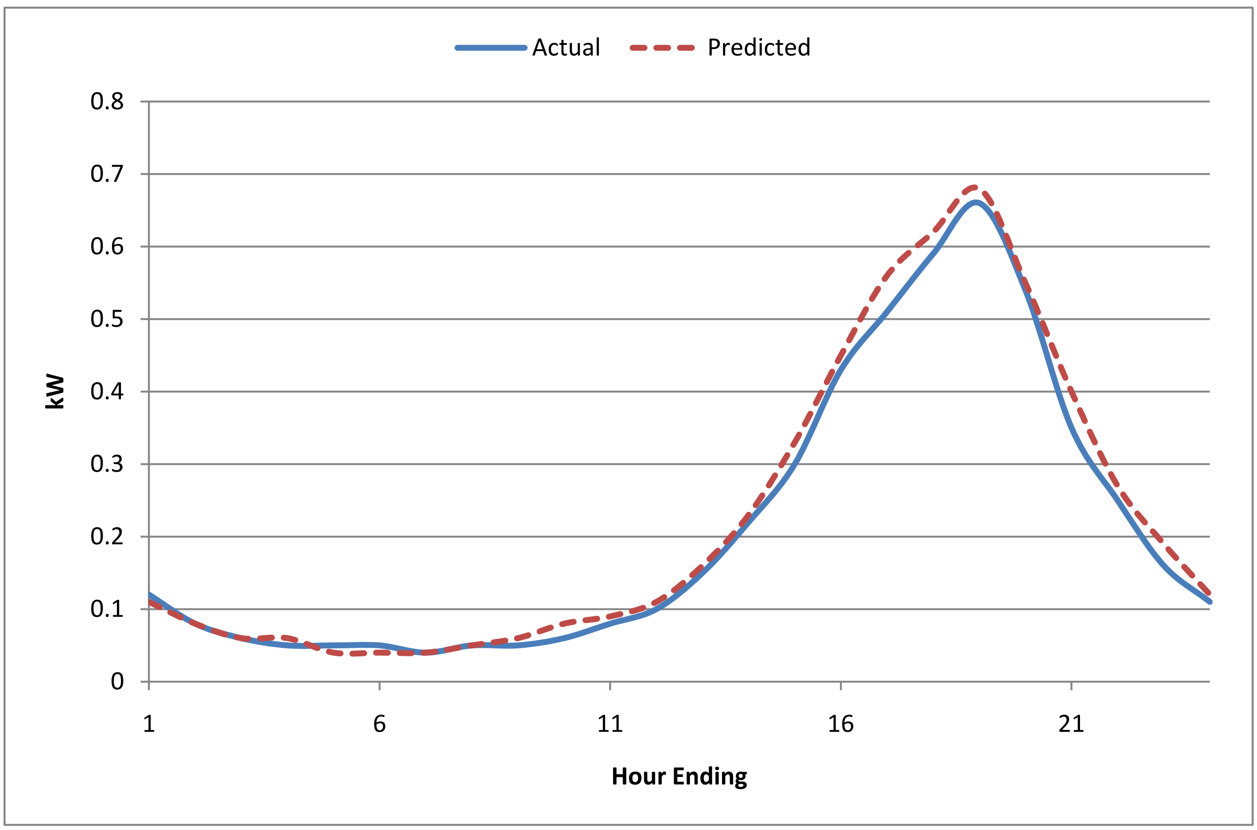
At an aggregate level over the hours of the summer, each model accounts for 97% of the variation in AC usage in both the residential and non-residential M&E samples.  During the hours of 1 PM to 6 PM, the ex ante event hours, the model R-squared values are 97% for residential units and 89% for non-residential units.  Restricting the data further to the hours 1 PM to 6 PM with temperatures above 90 degrees, the R-squared values are 89% and 87% for residential and non-residential AC units, respectively.

### 4.3.2 Out-of-Sample Testing

As a second and more stringent test, the model must do well in out-of-sample testing on days included in the 2010 dataset.  The procedure for out-of-sample testing consisted of running the regression models multiple times, each time holding back some of the hot non-event days of the summer from the estimation. Then predicted loads were compared to actual loads on the days held back. This is a true test of the regression model's predictive power for weather conditions actually observed during the summer of 2010.

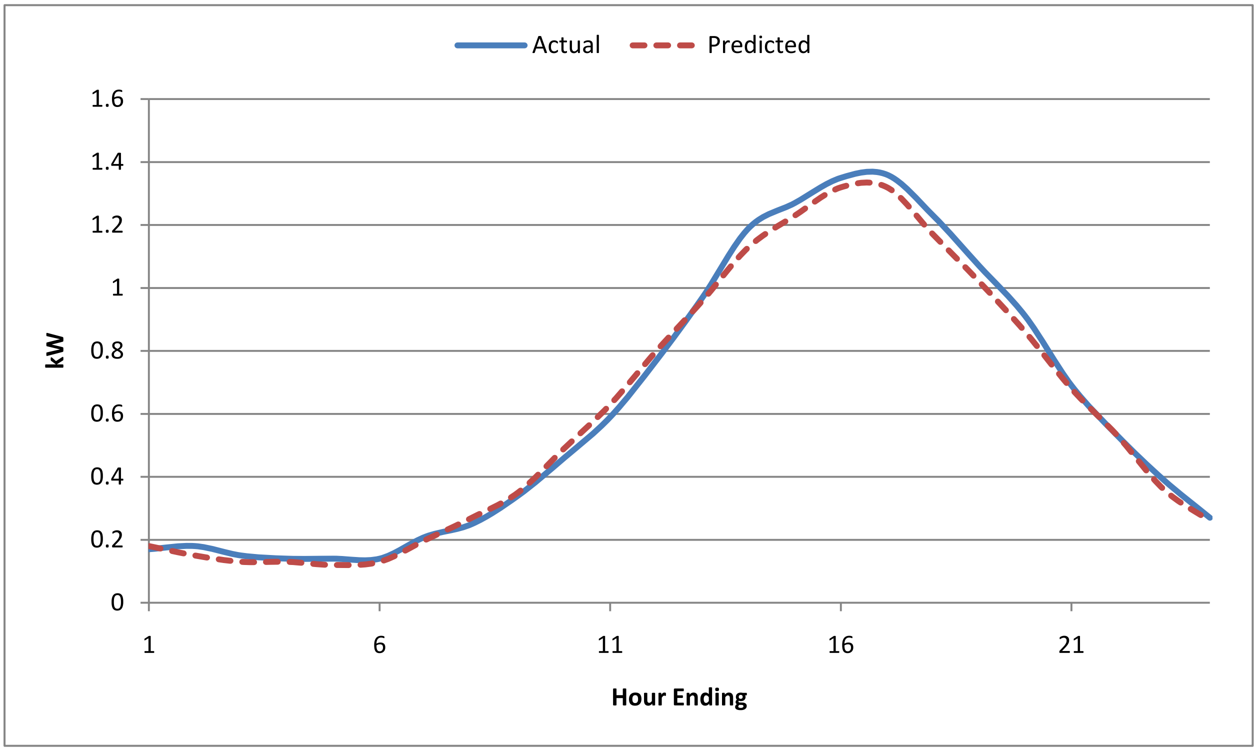
Figure 4-1 shows the actual average hourly energy use of residential AC units on five hot out-of-sample days compared to the regression-predicted average energy use. The out-of-sample days were chosen randomly among the hottest 20 non-event weekdays of the summer. The average high temperature for the 5 days was 89 degrees.[5] Figure 4-2 shows the same for non-residential AC units. The close match between predicted values and actual values reflects the ability of the regressions to predict accurately. In both cases, the predicted load is very close to the actual load. For residential customers, the predicted load is, on average, about 7% higher than actual load during the hours of 1 PM to 6 PM. For non-residential customers, predicted load is on average about 4% lower than actual load.

**Figure 4-1:**
**Average Residential AC unit Actual and Predicted Load for Out-of Sample Days**




[5] The five days are 7/22/2010, 7/29/2010, 8/19/2010, 8/20/2010 and 8/26/2010

**Figure 4-2:**
**Average Non-residential AC unit Actual and Predicted Load for Out-of Sample Days**




The final test that the model had to pass is one of general plausibility in predicting for the ex ante weather conditions. This test is less well-specified, but consists of producing reasonable AC load patterns as a function of weather, as compared to results in past years, results from other programs and general knowledge about how the program works. This reality-check test is a crucial way to test the assumptions that go into the model. The ex ante estimates that are presented in Section 5 were carefully reviewed and generally display the expected patterns across event conditions and are consistent with other studies after judgmentally accounting for expected differences due to weather conditions and other factors.

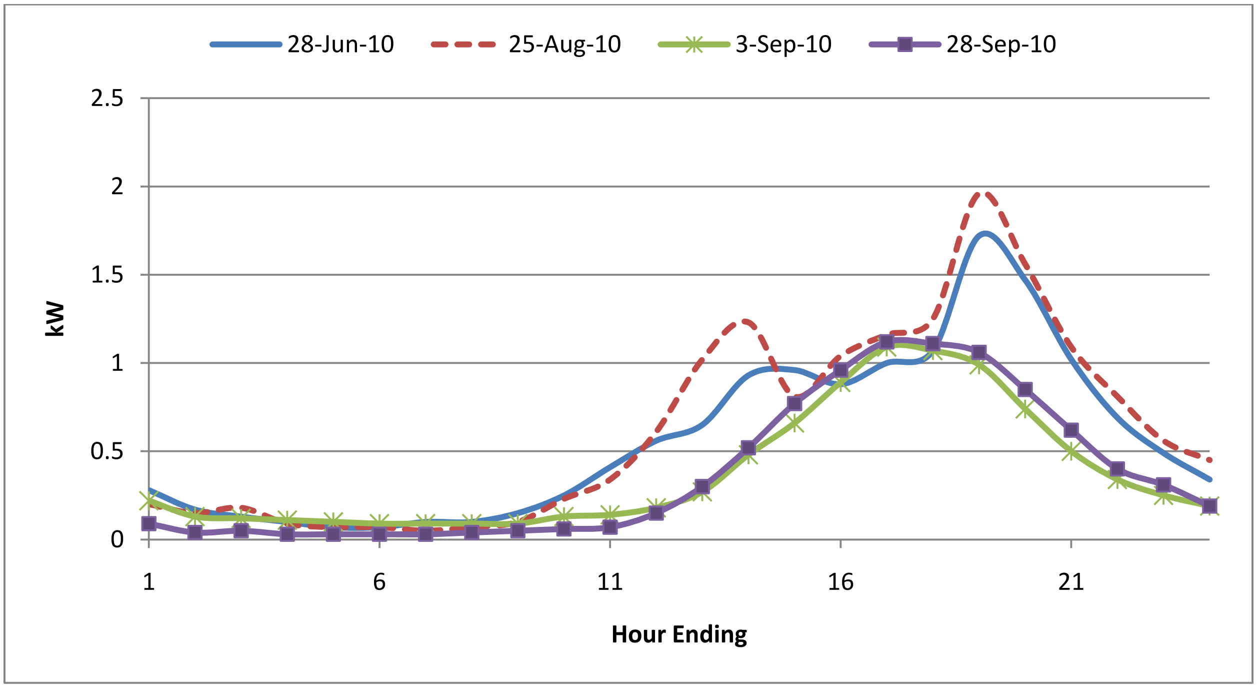
The plausibility test is particularly important because the ex ante weather conditions are mainly outside the range of non-event weather that was observed in 2010. This means that the model's predictions are extrapolations outside of the range of available data, which make them more uncertain.

The degree of extrapolation required of the model is indicated in Figure 4-3. It shows average residential load on four days: August 25th and June 28th, which were two of the highest-load event days; and September 3rd and September 28th, which were the hottest non-event days. The two event days had conditions similar to those used for ex ante predictions.

Figure 4-3 shows that load on the non-event days does not approach load on the event days. The model has to extrapolate from September 3rd and September 28th to predict what would have happened on June 28th and August 25th, had there been no event. The situation is improved somewhat by the four event days that alternated between groups A and B.  However, those days only add an average of one very hot day to each individual AC-unit regression.

The situation for non-residential customers is not as extreme in terms of the amount of extrapolation required.  Some of the non-event days have load that is similar in magnitude to the non-residential load on hot event days.  For example, among non-residential customers, load on September 28th is only a bit below what it is on August 25th, and substantially above load on June 28th.

**Figure 4-3:**
**Average AC Load for Two of the Hottest Events (July 29th and August 25th) and the Two Hottest Non-event Days (September 3rd and 10th)**




## 4.4 Air Conditioner Load Patterns

Residential air conditioner load is highly sensitive to weather conditions.  Importantly, the load reduction capability of the program is directly tied to the amount of air conditioner load.  For SmartAC, participant behavior and targeting determines the load, but it is the control device that supplies the load reduction.  In general, the cycling and control algorithms tend to provide larger percent load reductions at higher temperatures when AC run times are higher.  AC load and load reduction capability is higher for the extreme weather conditions that drive the system load peak and the need for demand response.

Figure 4-4 illustrates the sensitivity of the AC load to weather conditions for residential AC units and Figure 4-5 shows the same for non-residential AC units.  The figures show actual AC loads among the M&E sample, averaged for each hour of the day for days with high temperatures in the ranges shown.  For residential AC units, the program average AC hourly demand is almost twice as high on a day with a maximum temperature between 95 and 100 degrees than on a day with a maximum temperature between 90 to 95 degrees.  Non-residential AC loads are less weather-sensitive than residential loads.

For non-residential AC units, loads on days between 95 and 100 degrees are only about 1/3 higher than on days between 90 and 95 degrees.  Similarly, non-residential AC units have substantial AC load at temperatures below 80 degrees, while residential AC units do not.

**Figure 4-4:**
**Hourly Average AC Load for Residential SmartAC AC units by Daily Maximum Temperature**

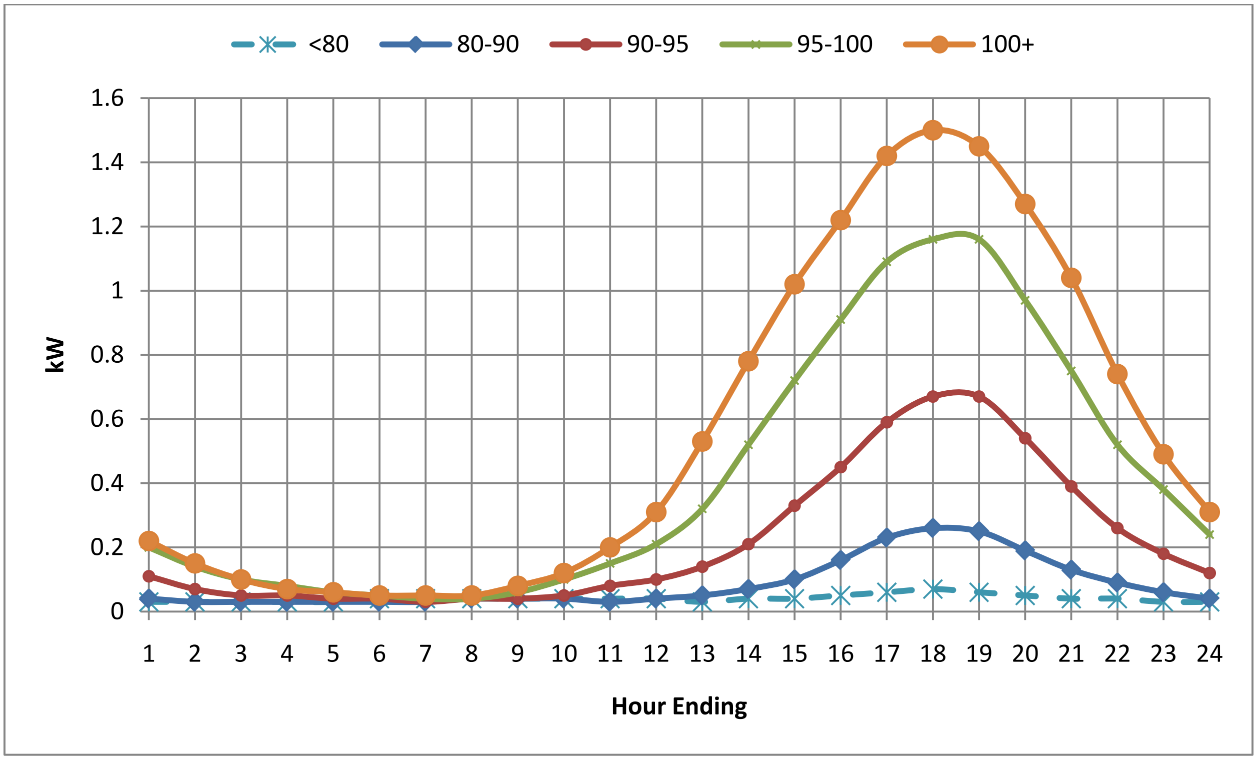
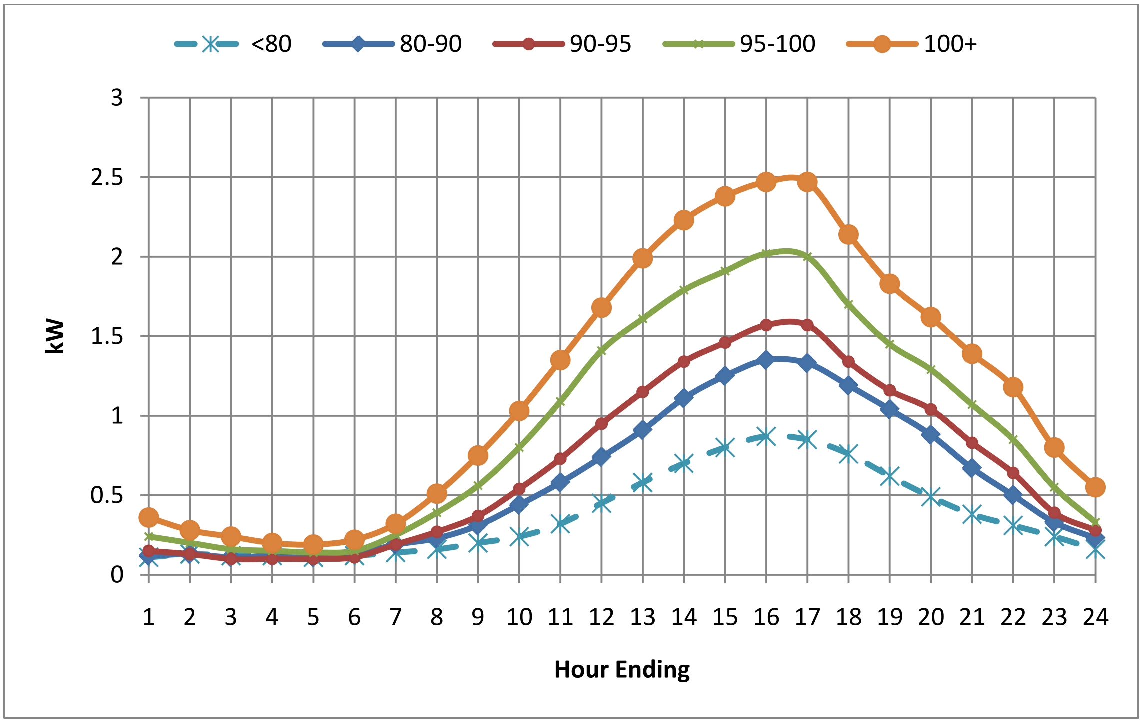


**Figure 4-5:**
**Hourly Average AC Load for Non-residential SmartAC AC units by Daily Maximum Temperature**




## 4.5 Direct Load-comparison Model

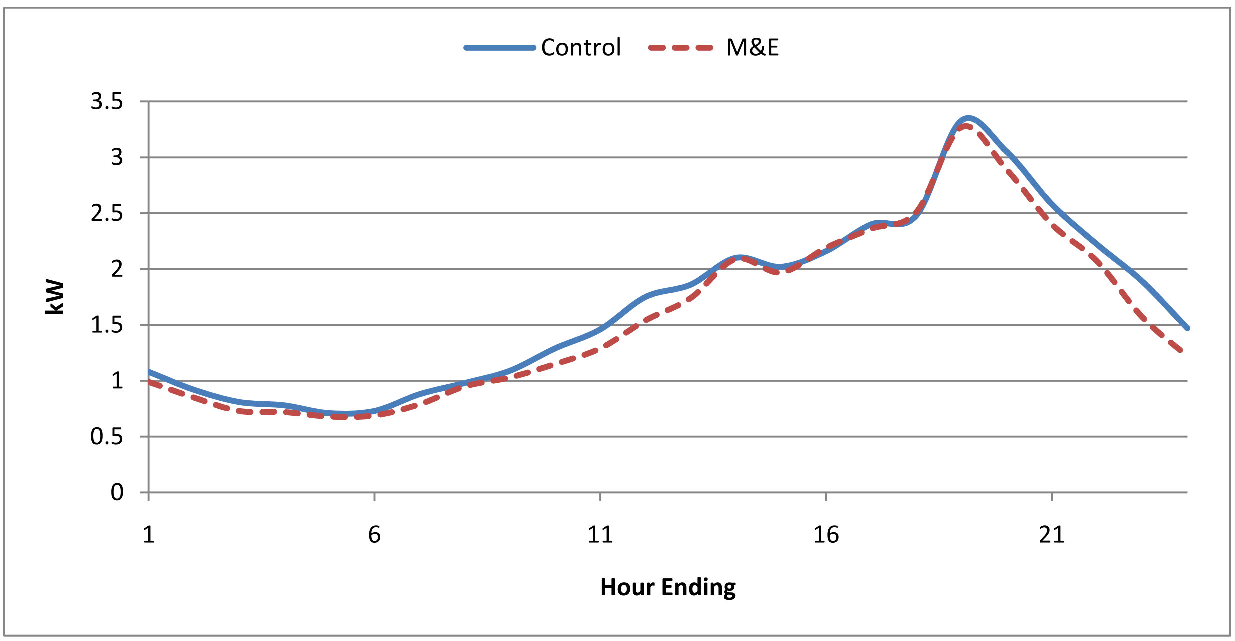
The existing data allows for two further analyses based on comparisons between M&E customers and groups of customers that did not receive particular events. These "treatment vs. control" strategies provide an independent measurement of the effect of the SmartAC events. The primary assumption behind the individual AC unit regressions is that customer load at other times of the summer with similar weather conditions provide a good prediction for what load would have been had there been no event. The primary assumption behind the comparison analyses is that the load of similar customers who did not experience events is a good estimate of what load would have been in the M&E group if there had been no event.

The first comparison strategy used SmartMeter data from the 264 residential customers that were in the M&E sample and that had SmartMeters installed by the summer of 2010. SmartMeter data was also obtained for a demographically-matched group of 260 non-M&E SmartAC customers. Although the two groups were initially matched demographically based on climate region and CARE status, the best evidence that they are comparable comes from comparing load profiles. These two groups generally had comparable loads, as shown in Figure 4-6. The figure shows the average whole-house load for each group on the system-wide event day, July 16th. The two groups' loads on that day are very similar, especially during the event.

Comparing each group's average loads over the four hottest non-event days of the summer[6] also indicated that the two groups' loads generally match each other well. They do deviate somewhat, however, with the control group loads generally being higher than the treatment group loads. For this reason, a same-day adjustment was applied to the control group load for the sake of event-impact calculations. This adjustment consisted of taking the average difference between the control group and M&E group loads during the four pre-event hours, and adding that value to the M&E load during the event before calculating the event impact. For example, if the control group load was an average of 0.1 kW higher than the treatment group during the hours 10 AM to 2 PM, then we might expect that it would have continued to be roughly that much higher through the afternoon. In that case, just subtracting to calculate the event effect would overstate the effect by 0.1 kW. Instead, that 0.1 kW value is added to the M&E group load before the event-impact calculation. Several types of adjustments were tested on non-event days to see what produced the least bias. The average difference approach worked best.

As shown in Figures 4-7 and 4-8, the average difference approach produces loads and event impacts that appear very plausible. Figure 4-7 shows the treatment and control group loads on August 24th with no adjustment and Figure 4-8 shows the same loads with the adjustment. Note that for days when only half the M&E group had an event, the other half was part of the control group for that day for purposes of this analysis.

**Figure 4-6:**
**Hourly Average Whole-building Load for the M&E Residential Sample and a Matched Control Group on July 16th**




6 July 14, August 23, September 3 and September 28.

**Figure 4-7:**
**Hourly Average Whole-building Load for the M&E Group and the Control Group on August 24th, Unadjusted**

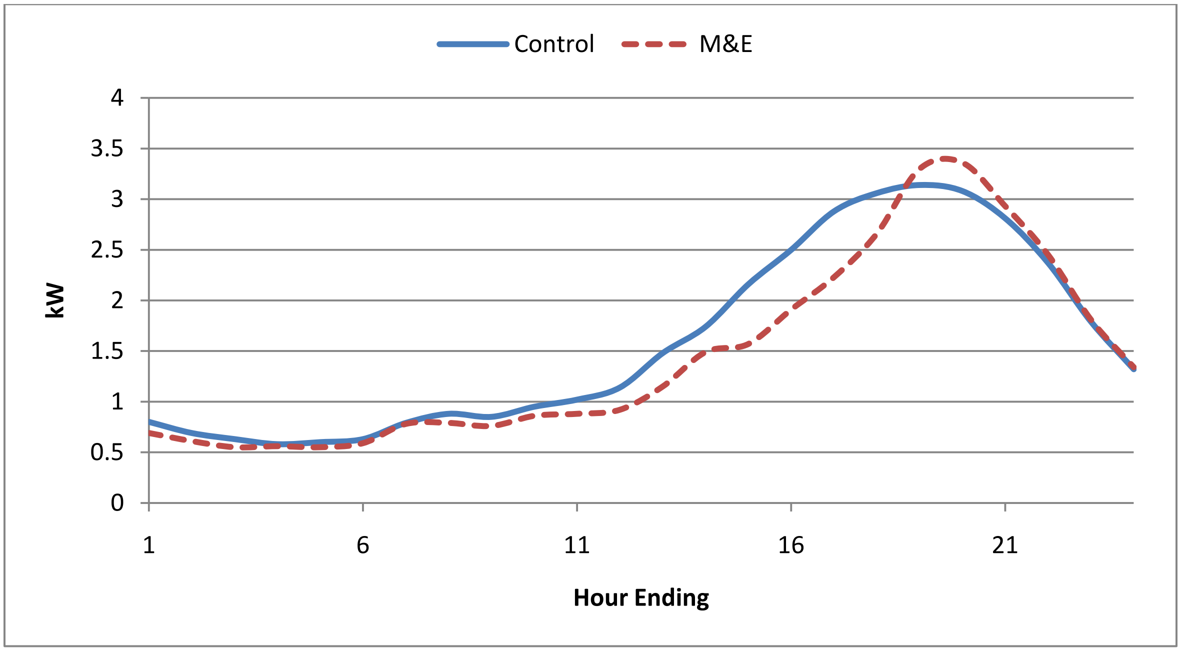
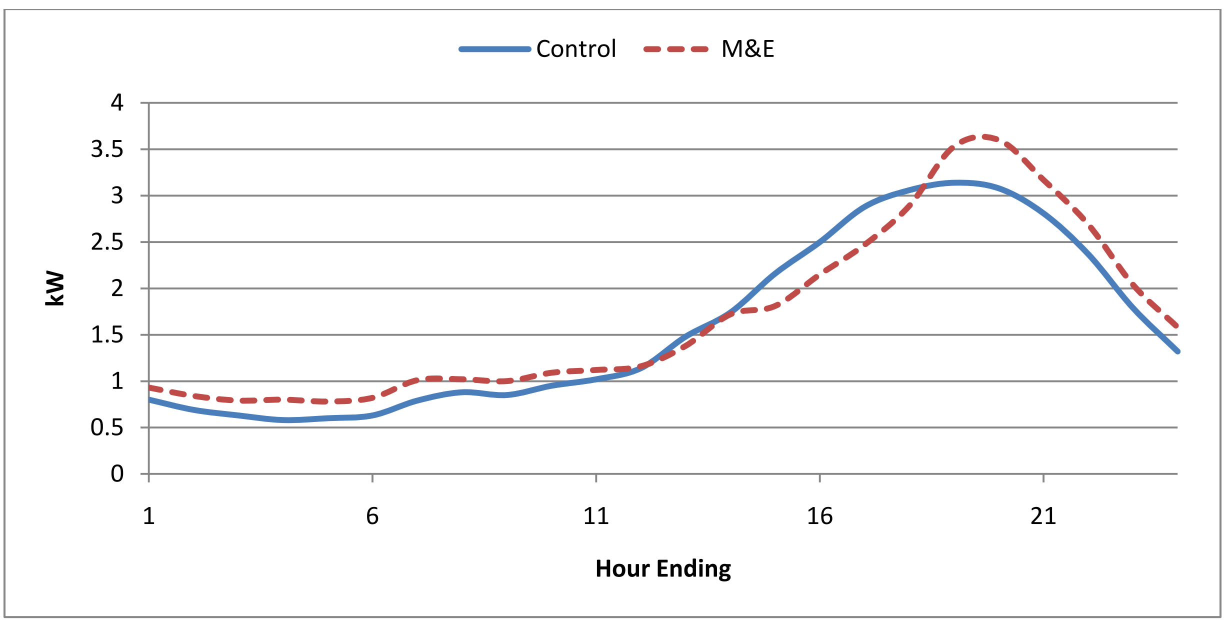



**Figure 4-8:**
**Hourly Average Whole-building Load for the M&E Group and the Control Group on August 24th, with Adjustment**




The second comparison strategy takes advantage of the fact that for four events, alternating halves of the M&E group were not called for the event. This strategy compares the AC load data between the two groups on these four event days. Although these groups were randomly chosen from within the M&E

group, group A generally had higher AC loads at high temperatures than group B.  Moreover, the loads diverge much more during the late afternoon hours than during the hours that would be used to make a same-day adjustment.  For this reason, unadjusted loads are compared directly, but individual event day impacts should be viewed with caution for this analysis in particular.  Much more likely to be accurate is the average event impact over the four relevant events.

Neither comparison analysis has been done for non-residential customers.  Although a control group was selected and the group A-B structure was in place for non-residential customers, in neither case were the loads comparable across the groups during non-event periods.  Non-residential load has much greater variability across customers than residential loads.  These strategies work for non-residential customers, but only with larger sample sizes.

Table 4-4 shows the average event impacts calculated using three strategies for the same set of customers.  The strategies are: comparing adjusted SmartMeter M&E sample loads with control group loads; comparing group A and B AC loads; and individual AC-unit regressions.  The table also shows standard errors of the event effects for each event and strategy.  The event on July 16th is not shown because all customers were affected, which means its impact cannot be calculated using either comparison method.

The SmartMeter comparison strategy has the highest standard errors, followed by the group A-B comparison, followed by the regression-based estimates.  The reason for this is that the standard errors of a calculation decrease as the sample size increases.  The regression-based estimates make use of the entire summer of load data for all customers (although some data points have a larger impact than others).  In contrast, the comparison strategies use only one day's worth of load each, albeit for all customers.  The group A-B comparison has lower standard errors than the SmartMeter comparison because the AC logger data has less variation in it than the SmartMeter data.  This makes sense because the SmartMeter data consists of AC load plus the house's non-AC load, which also has some variance.

Table 4-4 contains the differences between the event impacts calculated using the SmartMeter comparison method and the regression method, along with p-values for the differences.  The only statistically significant differences are for August 25th and September 2nd.  It is questionable how much credence to give these event impacts calculated using the comparison method because they only use one-half of the sample, and the same half for both of those events.  Also, as stated earlier, the standard errors from the regression model are not a true reflection of the error in the estimate, making the p-values likely over-estimated.

Table 4-4 also contains average impacts over the three different estimation strategies.  A standard way to combine estimates from independent studies is to weight estimates by the inverse of the squared standard errors.  However, we believe the standard errors of the regression model are understated, so we use an un-weighted average instead.

**Table 4-4:**
**Estimated Event Impacts Using Three Different Methods and the Average Impact**

| | SmartMeter Comparison (1) | | Group A-B Comparison | | AC Unit Regressions (2) | | Difference between (1) and (2) | | Average Impact |
|---|---|---|---|---|---|---|---|---|---|
| | Impact | SE | Impact | SE | Impact | SE | Difference | p-value | |
| 6/23/2010 | -0.04 | 0.13 | - | - | 0.11 | 0.032 | -0.16 | 0.23 | 0.03 |
| 6/28/2010 | 0.4 | 0.19 | - | - | 0.27 | 0.043 | 0.10 | 0.60 | 0.34 |
| 7/9/2010 | 0.17 | 0.14 | - | - | 0.09 | 0.031 | 0.08 | 0.58 | 0.13 |
| 7/15/2010 | 0.52 | 0.16 | - | - | 0.22 | 0.037 | 0.28 | 0.09 | 0.37 |
| 7/22/2010 | 0.16 | 0.13 | - | - | 0.08 | 0.030 | 0.07 | 0.60 | 0.12 |
| 8/2/2010 | 0.14 | 0.13 | - | - | 0.10 | 0.032 | 0.03 | 0.82 | 0.12 |
| 8/16/2010 | 0.19 | 0.13 | - | - | 0.09 | 0.031 | 0.09 | 0.50 | 0.14 |
| 8/24/2010 | 0.32 | 0.17 | 0.26 | 0.08 | 0.34 | 0.048 | -0.02 | 0.91 | 0.31 |
| 8/25/2010 | 0.89 | 0.20 | 0.69 | 0.09 | 0.36 | 0.086 | 0.49 | 0.02 | 0.65 |
| 9/1/2010 | 0.23 | 0.13 | 0.24 | 0.07 | 0.16 | 0.032 | 0.07 | 0.60 | 0.21 |
| 9/2/2010 | 0.61 | 0.16 | 0.54 | 0.07 | 0.23 | 0.071 | 0.35 | 0.04 | 0.46 |
| 9/27/2010 | 0.16 | 0.15 | - | - | 0.17 | 0.036 | 0.00 | | 0.17 |
| 9/29/2010 | 0.36 | 0.15 | - | - | 0.20 | 0.041 | 0.08 | 0.61 | 0.28 |
| 9/30/2010 | 0.04 | 0.14 | - | - | 0.07 | 0.041 | -0.16 | 0.23 | 0.05 |

## 4.6 SmartAC Ex Post Load Impact Results

This section presents the ex post load impacts for residential and non-residential customers for the summer of 2010. For reasons discussed in the prior section, using the impact estimates from individual customer regressions will likely understate the actual load impacts because the unusually cool summer conditions did not leave enough event-like days on which events were not called to produce accurate reference loads. As such, it was necessary to make an adjustment to the regression values, as explained below. A second adjustment was also needed because of differences in the control success rates and broken devices between the sample and the SmartAC population.

The weighted-average impacts in Table 4-4 indicate a downward bias in event impacts calculated using the regression-based method. The bias increases with temperature, which makes sense because at the higher temperatures, the regression model has to extrapolate due to a lack of hot non-event days. To account for this, the percentage difference between the average regression-based impacts and the weighted-average impacts in Table 4-4 was calculated for events with temperatures below 90° F, between 90° F and 100° F, and above 100° F. These correction factors are shown in Table 4-5.

The correction factors are applied to event impacts calculated using the regression-method for all residential M&E customers. Recall that the values in Table 4-4 are only for customers with SmartMeters, otherwise the weighted average event impacts from that table could be used directly.

No correction is done for non-residential customers. Regression-based estimates are the best estimates available. Moreover, estimation bias is a small issue for non-residential customers as compared to device control and addressing issues, which both depress current estimated impacts and add substantial uncertainty for future SmartAC non-residential impacts.

An adjustment factor was applied to both groups based on the fact that there was control and working device verification in the installation process. In the SmartAC population, more control failure and broken control devices should be expected than in the M&E sample. This correction factor was calculated as 4% for residential AC units (equal to 15 walk-aways from installation due to issues that would cause no impact out of a total of 354 AC units approached), and 21% for non-residential AC units (91/439). This means that for residential customers, impacts were adjusted downward by 4% and for non-residential customers impacts were adjusted downward by 21%.

The adjusted impacts are the ex post estimates for 2010, shown in Tables 4-6 and 4-7 (which are repetitions of Tables 1-1 and 1-2). In addition to the tables shown, a full set of ex post load impact tables satisfying the DRMEC Load Impact Protocols are available electronically.

**Table 4-5:**
**Average Regression Impacts, Weighted Average Impacts and Correction Factors for Average Event Temperatures**

| Event Temperature | Average regression based impact (1) | Weighted-average impact across all methods (2) | Correction factor (2)/(1) |
|---|---|---|---|
| <90 | 0.09 | 0.11 | 1.16 |
| 90-99 | 0.19 | 0.27 | 1.42 |
| 100+ | 0.35 | 0.48 | 1.36 |

As seen in Table 4-6, the average impact per customer for each load research event along with average temperature over the event period for the residential SmartAC population. Each event began at 2 PM, and all but two of the last three lasted until 6 PM. Those two ran until 8 PM. The largest impact occurred on August 25th, which had an estimated impact of 0.44 kW per customer. Not coincidentally, August 25th was a very hot day, following immediately after another very hot day.

The overall average event effect of 0.22 kW with an average event temperature of 93 degrees is similar to both the 2009 and 2010 average ex post result. The 2009 result was estimated over just one event on September 10, 2009. The average effect was 0.19 kW during an event with an average temperature of 93 degrees. The average M&E event temperature in 2008 was also 93 degrees, and the average event impact that year was 0.26 kW.

The average impact of 0.22 kW represents a 28% load reduction. The percent reduction across event days ranged from a low of 18% to a high of 38%. Clearly, these impacts are significantly less than the target reduction of 50% based on the 50% cycling strategy that is employed for residential participants. Most residential control devices use an adaptive cycling algorithm that is intended to reduce load in direct proportion to the cycling percentage. However, in the M&E sample it appeared that virtually all switches were performing simple cycling, as mentioned in the section on control issues. This can have a major effect because many AC units will not be at a duty cycle above 50% at moderately hot temperatures. This means those units will provide zero impact. Control failures are another cause of differences between the target and actual reduction, but an independent assessment of control problems indicates that they are relatively minor among residential customer participants (roughly equal to 7% of devices). This would suggest that improvements in the adaptive cycling performance could significantly improve impact estimates.

**Table 4-6:**
**Average Residential per Account Reference Loads, Impacts and Temperatures During Event Hours on 2010 Event Days**

| Event Date | Event Hours | Average Reference Load (kW) | Average Event Impact (kW) | Percent Impact (%) | Average Temperature |
|---|---|---|---|---|---|
| 6/23/2010 | 2 PM-6 PM | 0.46 | 0.11 | 24 | 86 |
| 6/28/2010 | 2 PM-6 PM | 1.23 | 0.36 | 29 | 97 |
| 7/9/2010 | 2 PM-6 PM | 0.43 | 0.09 | 21 | 86 |
| 7/15/2010 | 2 PM-6 PM | 1.13 | 0.3 | 27 | 97 |
| 7/16/2010 | 2 PM-6 PM | 1.18 | 0.3 | 25 | 95 |
| 7/22/2010 | 2 PM-6 PM | 0.44 | 0.09 | 20 | 88 |
| 8/2/2010 | 2 PM-6 PM | 0.45 | 0.11 | 24 | 88 |
| 8/16/2010 | 2 PM-6 PM | 0.42 | 0.10 | 24 | 88 |
| 8/24/2010 | 2 PM-6 PM | 1.29 | 0.40 | 31 | 103 |
| 8/25/2010 | 2 PM-6 PM | 1.36 | 0.44 | 32 | 102 |
| 9/1/2010 | 2 PM-6 PM | 0.56 | 0.18 | 32 | 93 |
| 9/2/2010 | 2 PM-6 PM | 0.76 | 0.29 | 38 | 97 |
| 9/27/2010 | 2 PM-8 PM | 0.78 | 0.22 | 28 | 94 |
| 9/29/2010 | 2 PM-8 PM | 0.94 | 0.20 | 21 | 94 |
| 9/30/2010 | 2 PM-6 PM | 0.55 | 0.10 | 18 | 87 |
| Average | n/a | 0.80 | 0.22 | 28 | 93 |

Table 4-7 shows each event date with average per AC unit event impacts and average temperature during the event hours for the non-residential SmartAC population. Each event began at 2 PM, and all but the second-to-last ran until 6 PM. The second-to-last event ran until 8 PM. The largest impact occurred on July 15th, which had an estimated impact of 0.22 kW per AC unit. The average impact across all events is 0.11 kW per air conditioning unit, or roughly 7% of air conditioning load.

The target reduction for non-residential customers is 33%. As previously discussed, event impacts in Table 4-7 are influenced dramatically by control device communication and device failures. The average failure rate in the non-residential SmartAC load-research sample was over 50% for the summer of 2010.

Another cause of low impacts is that non-residential switches cycle at 33%. As in the residential group, it appeared that virtually all switches used simple cycling rather than adaptive cycling. This should have an even larger impact than on the residential side because it means non-residential customers with switches will provide no load reduction until their AC units have a duty cycle above 66%. That may require very hot conditions.

**Table 4-7:**
**Average Non-residential per AC Unit Reference Loads, Impacts and Temperatures During Event Hours**

| Event Date | Event Hours | Average Reference Load (kW) | Average Event Impact (kW) | Percent Reduction (%) | Average Temperature |
|---|---|---|---|---|---|
| 6/23/2010 | 2 PM-6 PM | 1.22 | 0.13 | 11 | 79 |
| 6/25/2010 | 2 PM-6 PM | 0.96 | 0.10 | 10 | 75 |
| 6/28/2010 | 2 PM-6 PM | 1.89 | 0.09 | 5 | 88 |
| 7/9/2010 | 2 PM-6 PM | 1.21 | 0.15 | 12 | 80 |
| 7/15/2010 | 2 PM-6 PM | 1.94 | 0.22 | 11 | 90 |
| 7/16/2010 | 2 PM-6 PM | 1.87 | 0.19 | 10 | 87 |
| 7/22/2010 | 2 PM-6 PM | 1.19 | 0.14 | 12 | 82 |
| 7/28/2010 | 2 PM-6 PM | 1.04 | 0.10 | 10 | 78 |
| 8/2/2010 | 2 PM-6 PM | 1.25 | 0.10 | 8 | 81 |
| 8/5/2010 | 2 PM-6 PM | 1.15 | 0.08 | 7 | 77 |
| 8/16/2010 | 2 PM-6 PM | 1.21 | 0.11 | 9 | 82 |
| 8/24/2010 | 2 PM-6 PM | 2.12 | 0.00 | 0 | 98 |
| 8/25/2010 | 2 PM-6 PM | 2.37 | 0.20 | 8 | 93 |
| 9/1/2010 | 2 PM-6 PM | 1.54 | 0.05 | 3 | 91 |
| 9/2/2010 | 2 PM-6 PM | 1.93 | 0.20 | 10 | 91 |
| 9/27/2010 | 2 PM-6 PM | 1.67 | 0.04 | 2 | 88 |
| 9/29/2010 | 2 PM-8 PM | 1.44 | 0.07 | 5 | 83 |
| 9/30/2010 | 2 PM-6 PM | 1.22 | 0.13 | 11 | 79 |
| | **Average** | 1.53 | 0.11 | 7 | 85 |

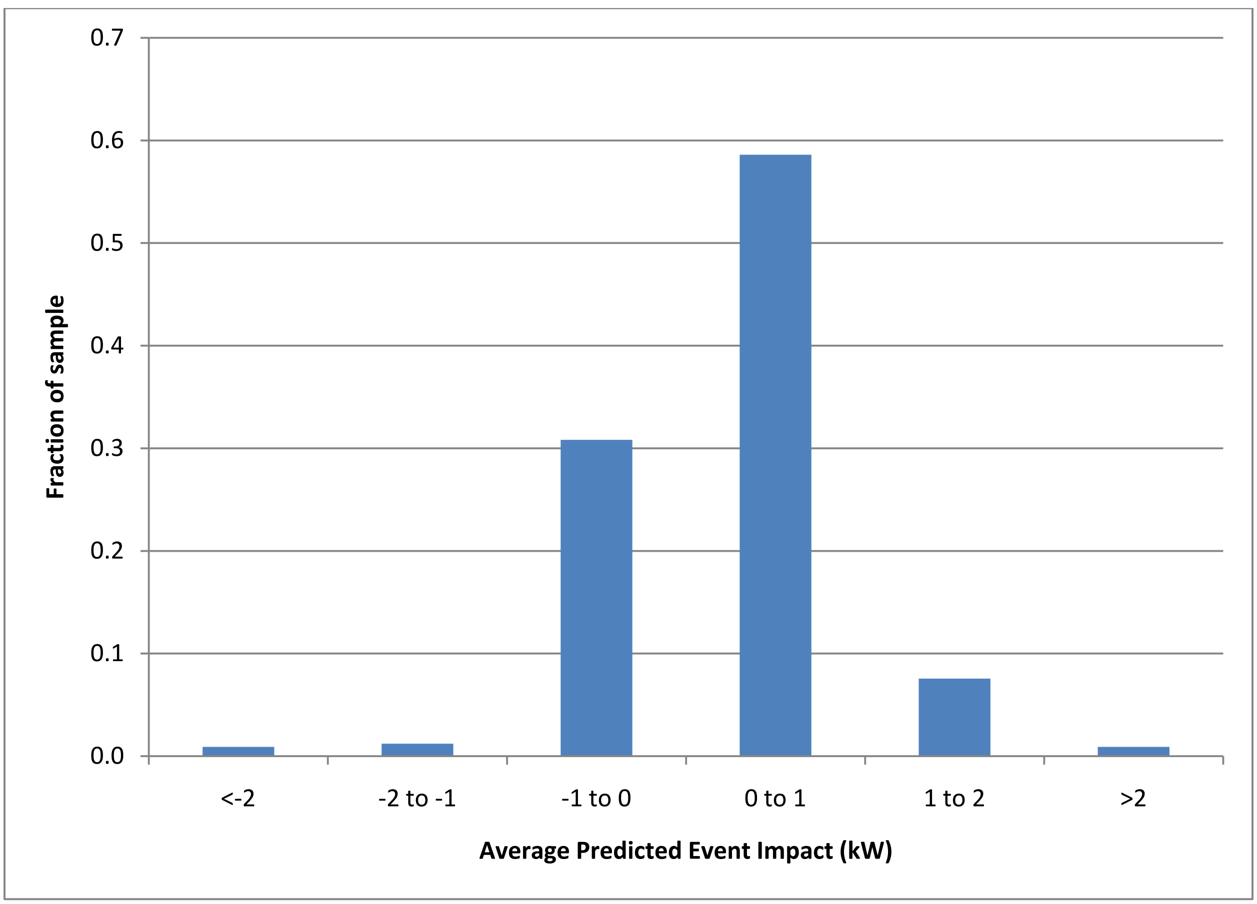
## 4.7 2010 Estimates Compared to 2008

A comparison of residential AC loads and load impacts between 2008 and 2010 revealed that average AC loads at a given temperature were about 16% lower in 2010 than they were in 2008. Ex post load impacts across events were almost identical between the two years, with the exception of three event days in 2008 that had temperatures, reference load estimates and load impact estimates larger than any event in 2010. These three events produced an upward shift in ex ante impact estimates of roughly 20% for 2008, as compared to what impact estimates would have been if those three events had been excluded. Virtually all the difference between impact estimates in 2010 and 2008 can be attributed to the combination of 16% lower AC loads and the presence of three very hot event days in the 2008 sample.

## 4.8 Distribution of Load Impacts Across Customers

Figure 4-9 shows the distribution of predicted residential event impacts for a July 1-in-2 day at 3 PM. As was discussed in the methods section, results from any given AC unit regression may not be completely reliable due to omitted factors and small samples. Another way to put this, as it relates to Figure 4-9, is that over a longer period, many customers who had small event impacts during 2010 might turn out to have high impacts overall and vice versa. However, with that caveat, Figure 4-9 suggests that a substantial number of customers in the program provide little impact, while a few customers may provide substantial impact. It is unknown whether many of these low-impact customers would provide more impact at times of very high temperature—beyond what was observed in the summer of 2010. The summer of 2010 was quite cool overall and it is quite possible that the distribution of customer impacts estimated over a hotter summer would show many more high-impact customers.

**Figure 4-9:**
**Histogram of Predicted Event Impacts for Individual Customers**



## 4.9 Load Impact Differences Across Device Types

The M&E sample was not selected to be representative of either switches or PCTs individually due to sample size constraints. Nevertheless, large differences in impacts across device type are worth investigating for the sake of improving program performance. Event impacts are reported separately for each device type in Table 4-8. Impacts in Table 4-8 are regression-based, un-weighted and have not had the bias correction detailed in Section 4-6 applied.

The results in Table 4-8 closely parallel those in Table 3-5, which gives the rate of control success for the different types of control device. This indicates that differences in event impact may partially be due to devices either receiving or not receiving event signals, rather than differences in control strategy. Residential switches tend to produce much higher impacts than PCTs, primarily because of differences in control success rates. Both types of non-residential devices have similar success rates although for different reasons, as previously discussed.

**Table 4-8:**
**Average Non-residential per AC Unit Event Impacts (kW) by Device Type**

| Event Date | Residential | | Non-residential | |
|---|---|---|---|---|
| | Switch | PCT | Switch | PCT |
| 6/23/2010 | 0.12 | 0.05 | 0.13 | 0.16 |
| 6/25/2010 | NA | NA | 0.11 | 0.05 |
| 6/28/2010 | 0.30 | 0.19 | 0.05 | 0.27 |
| 7/9/2010 | 0.09 | 0.03 | 0.16 | 0.12 |
| 7/15/2010 | 0.24 | 0.16 | 0.30 | 0.19 |
| 7/16/2010 | 0.25 | 0.14 | 0.21 | 0.20 |
| 7/22/2010 | 0.09 | 0.03 | 0.15 | 0.11 |
| 7/28/2010 | NA | NA | 0.11 | 0.07 |
| 8/2/2010 | 0.11 | 0.05 | 0.10 | 0.13 |
| 8/5/2010 | NA | NA | 0.07 | 0.11 |
| 8/16/2010 | 0.10 | 0.05 | 0.11 | 0.12 |
| 8/24/2010 | 0.34 | 0.06 | 0.16 | 0.0 |
| 8/25/2010 | 0.41 | 0.28 | 0.32 | 0.22 |
| 9/1/2010 | 0.14 | 0.06 | 0.08 | 0.07 |
| 9/2/2010 | 0.26 | 0.21 | 0.20 | 0.20 |
| 9/27/2010 | 0.16 | 0.12 | 0.06 | 0.03 |
| 9/29/2010 | 0.29 | 0.09 | 0.07 | 0.02 |
| 9/30/2010 | 0.11 | 0.12 | 0.05 | 0.04 |
| Average | 0.20 | 0.11 | 0.14 | 0.12 |

# 5 SmartAC Ex Ante Load Impacts

The SmartAC program is intended to alleviate system stress during times of very high demand. The primary purpose of this evaluation is to predict load impacts during such conditions. These ex ante predictions cover a pre-chosen set of temperature profiles meant to mimic what could be expected for monthly system peak days that might occur every other year and every tenth year. As mentioned previously, the ex ante weather conditions are mainly outside of the range of weather that was observed in 2010. This means that the model's predictions are extrapolations outside of the range of available data, which adds uncertainty. One way this has been dealt with in this report is to combine three separate analyses as was done in the ex post section. This provided a correction factor to the regression-based estimates. This correction factor is used again in the ex ante estimates.

The procedure for ex ante estimates consists of making predictions for the ex ante weather dataset using the regression models produced in the ex post analysis. The correction factor is then applied based on the average temperature during the event in the ex ante weather dataset.

Had 2010 been a hotter summer, this would be the end of the analysis. However, 2010 was fairly cool, providing little information about customer loads at high temperatures. The 2009 SmartAC evaluation was conducted using 2008 AC load data that included 5 events with temperatures near or above 100 degrees. This provides substantial additional information about the potential capacity of the program. Therefore, the ex ante impacts reported are an average of predictions calculated using 2008 data and those calculated using 2010 data and the regression model detailed in this report.

Average per customer load impacts are combined with SmartAC enrollment projections to produce aggregate predictions for the next 11 years.

## 5.1 Enrollment Projections

Enrollment projections for residential customers by local capacity area as of June of each year are presented in Table 5-1. The source for these projections is PG&E's DR Program Application for 2012-2014. FSC took the projections in the Program Application and developed a distribution of possible enrollment scenarios around them, with the values in Table 5-1 as the median projection. This distribution of scenarios was used in conjunction with the uncertainty estimates of load impact to produce aggregate uncertainty-adjusted projected load impacts that reflect estimates of both sources of uncertainty. These uncertainty-adjusted impacts are shown in the load impact tables that accompany this report.

For residential customers, program enrollment across local capacity areas is projected to remain quite stable for the forecast period.

Projections for non-residential customers by local capacity area are presented in Table 5-2. These values were produced by the Brattle Group in a separate report for PG&E. Enrollment growth is expected to be steady and substantial over the next five years, leading to roughly three times as many non-residential SmartAC participants in 2015 as in 2011. Proportional growth is expected to be similar across local capacity areas.

## 5.2 Non-residential Control Device Control Rates

For non-residential customers, a rate of control improvement is assumed. Table 5-3 shows the assumed rate of control success for non-residential switches and PCTs over the years 2011-2012. Control success is assumed to remain stable following 2012. These assumptions are somewhat ad hoc, but based on the presumption that most switch control problems are due to the dual-stage AC unit issues mentioned earlier and can be solved by working with the DR-provider. It is assumed that PCT signal reception issues are more difficult to solve. It is assumed that some are due to addressing issues that can be fixed almost immediately, but that others are due to thick walls and other issues unlikely to be solved in the near future.

**Table 5-1:**
**Projected Residential Enrollment Values for June of Each Year (1000s)**

| LCA | 2011 | 2012 | 2013 | 2014 | 2015-2021 |
|---|---|---|---|---|---|
| Greater Bay Area | 54 | 62 | 63 | 62 | 61 |
| Greater Fresno | 32 | 37 | 38 | 37 | 36 |
| Kern | 5 | 6 | 6 | 6 | 6 |
| Northern Coast | 9 | 11 | 11 | 10 | 10 |
| Other | 27 | 31 | 32 | 31 | 30 |
| Sierra | 19 | 22 | 23 | 22 | 22 |
| Stockton | 16 | 19 | 20 | 19 | 19 |
| Total | 161 | 189 | 192 | 187 | 185 |

**Table 5-2:**
**Projected Non-Residential Enrollment**

| LCA | 2011 | 2012 | 2013 | 2014 | 2015-2021 |
|---|---|---|---|---|---|
| Greater Bay Area | 1,485 | 2,193 | 3,159 | 4,022 | 4,365 |
| Greater Fresno | 487 | 719 | 1,036 | 1,319 | 1,431 |
| Kern | 103 | 153 | 220 | 280 | 304 |
| Northern Coast | 306 | 452 | 652 | 830 | 900 |
| Other | 719 | 1,062 | 1,530 | 1,948 | 2,114 |
| Sierra | 289 | 427 | 615 | 783 | 850 |
| Stockton | 228 | 337 | 486 | 618 | 671 |
| Total | 3,617 | 5,342 | 7,697 | 9,800 | 10,635 |

**Table 5-3:**
**Assumed Rates of Control Success for Non-residential Control Devices**

| Year | Switch | PCT | Total Average |
|---|---|---|---|
| 2011 | 0.90 | 0.70 | 0.75 |
| 2012-2021 | 0.95 | 0.80 | 0.84 |

## 5.3 Load Impacts

Aggregate and per customer load impacts are shown for residential customers in Tables 5-4 and 5-5. Due to the projected stability in enrollment and the fact that there is no projected operational change for residential customers, load impacts are predicted to be stable for the foreseeable future. The maximum expected residential load impact for 2011 is 102 MW on a 1-in-10 August day. The maximum expected per customer impact is 0.53 kW on a 1-in-10 August day. The 2012 peak hourly impact for residential customers for 1-in-10 conditions occurs during August from 4 PM to 5 PM, at which time the aggregate impact is 122 MW. For 1-in-2 conditions, the peak hourly impact occurs on the July peak day from 5 PM to 6 PM, at which time the aggregate impact for 2012 is 115 MW.

For residential customers, peak hourly impacts are lower than the impacts in the latest SmartAC Settlement Agreement (211 MW for 1-in-10 conditions) due both to lower enrollment estimates and lower per customer load impacts. The Settlement Agreement assumes mid-2012 enrollment of roughly 210,000 customers, while here the value is only 192,000. Peak hourly per customer impacts in the Settlement Agreement are estimated at just over 1 kW per customer under 1-in-10 conditions, while here they are only 0.64 kW. A similar comparison explains the discrepancy between the 1-in-2 values in the Settlement Agreement and this evaluation.

Aggregate and per customer load impacts are shown for non-residential customers in Tables 5-6 and 5-7. Non-residential average impacts are expected to increase substantially in 2011 over 2010 as operational problems are fixed, and they are expected to increase again somewhat in 2012 due to further operational improvements. The highest average expected impact for non-residential customers in 2011 is 0.65 kW on a 1-in-10 July day. The highest predicted aggregate impact for 2011 occurs on a 1-in-2 September day when the load impact is 2.0 MW. The 2012 peak hourly impact for non-residential customers for 1-in-10 conditions occurs during July from 2 PM to 3 PM, at which time the aggregate impact is 3.43 MW. For 1-in-2 conditions, the peak hourly impact occurs on the July peak day from 3 PM to 4 PM, at which time the aggregate impact for 2012 is 3.96 MW.

There are some unexpected patterns in the predicted load impacts in Tables 5-6 and 5-7. For example, the predicted impact is higher on a 1-in-2 September day than a 1-in-10 September day. This is due to the low number of actual events observed in the data and the uncertainty associated with whether many of them occurred at a customer level. The high level of control failure in the non-residential sample meant that the actual sample size of observed events was much lower than was planned for. This reduced sample size added random variation to the estimated event impacts, which led to a few counter-intuitive patterns in the final set of predictions, such as the September example above. These issues should be greatly reduced or eliminated in future years.

The CPUC load impact protocols require separate portfolio-level impacts to be developed that properly account for potential double-counting of impacts when customers may participate in more than one program that have events at the same time. In this case, customers may participation in both SmartAC and SmartRate, and those programs often have overlapping events. However, the overlap between the two programs is small enough that it will not materially affect the predicted load impacts for either of them. Therefore, the portfolio-level impacts are equal to the program-level impacts and are not reported separately.

## 5.4 Recommendations

It is recommended that PG&E attempt to solve the operational issues that lead load impacts to be lower than their potential in 2011. This includes control device problems, adaptive cycling issues and signal-receipt issues. Efforts are already underway on all three of these issues. The primary control device problem in 2010 was the malfunction of switches on dual-stage ACs, which can be due to improper installation of the control device or failure to note that the unit is dual-stage and needs to be controlled appropriately. PG&E is currently attempting to make sure that all dual-stage units are correctly identified and that control devices have been correctly installed on them.

The primary adaptive cycling issue that affected load impacts in 2010 was that virtually all cycling appeared to be simple cycling, rather than adaptive cycling. This means that, for example, if an AC unit is running at below 50% duty cycle, then a 50% cycling control strategy will have no effect. In contrast, if a unit is subject to adaptive cycling, then a 50% control strategy has a 50% load impact for any duty cycle level.

There are at least two possible reasons for the prevalence of simple cycling among units that were thought to be programmed for adaptive cycling. First, it is possible that the adaptive cycling algorithm did not have enough hot non-event days to learn each AC unit's duty cycle patterns. In such a situation, the control device performs simple cycling. If this was the case for 2010, then it may have only affected the M&E sample, as the SmartAC population only had one event, while the M&E sample had events on almost every hot day of the summer. Second, some units may not have received the signal containing the adaptive cycling algorithm. These units would use simple cycling.

Currently, PG&E is making sure that all switches are set to True Cycle II, the most up-to-date adaptive cycling algorithm. Additionally, PG&E may test Target Cycle during the summer of 2011. Target Cycle is a more advanced cycling algorithm that allows for a specific level of demand targeting in kilowatts. Finally, a new experimental design for M&E events (discussed below) will ensure that, at least for residential customers, all adaptive cycling control devices have ample learning days. This should ensure that the algorithms work to their potential.

A major signal-receipt problem in 2010 was due to the fact that PCT control signals are only sent once per event, while switch control signals are sent every half-hour during an event. This means that if a switch fails to receive the signal during one half-hour, it still has a good chance of operating for most of the event. For PCTs a missed signal leads to a missed event for the device. PG&E is currently planning to use a new control mechanism for PCTs that allows for sending a control signal every half-hour during an event. This should substantially increase signal-receipt among PCTs.

For next year's evaluation, it is recommended that the residential analysis rely wholly on SmartMeter data. SmartMeters are now installed on a sufficient portion of PG&E's SmartAC population that large, representative samples can be used to estimate load impacts. Large treatment and control groups can be used to estimate accurate ex post event impacts within days after each event. Separate, large, representative groups of customers can be called for each M&E event. This means that no particular customer experiences more than one or two events, but it is still feasible to have many M&E events. There is also the potential to better study the effects of different cycling strategies, event lengths and intensities through the use of multiple samples on a given event day. There will be some operational challenges associated with this experimental design, but they are probably surmountable.

For the non-residential evaluation, it is recommended that a larger sample size be used for the logger sample. This will allow for better estimates of event impacts. Non-residential load is highly variable across customers, and small samples can lead to significant uncertainty.

It is also recommended that SmartMeter data be used for in the non-residential evaluation. This effort will be less certain and more exploratory than the measurement effort for residential customers using SmartMeters. It is worthwhile both for identifying operational problems during the summer rather than after the summer, and for moving towards the point where the entire SmartAC evaluation can be done without the use of AC loggers.

**Table 5-4:**
**Residential SmartAC Aggregate Load Impact Estimates (MW)**
**By Weather Year, Forecast Year and Day Type**
**(Event Period 1-6 PM)**

| Weather Year | Day Type | 2011 | 2012 | 2013 | 2014 | 2015-2021 |
|---|---|---|---|---|---|---|
| 1-in-2 | Typical Event Day | 64 | 73 | 73 | 71 | 71 |
| | May Peak Day | 16 | 19 | 19 | 19 | 19 |
| | June Peak Day | 41 | 48 | 49 | 47 | 47 |
| | July Peak Day | 86 | 99 | 100 | 97 | 96 |
| | August Peak Day | 60 | 69 | 69 | 67 | 66 |
| | September Peak Day | 51 | 57 | 56 | 55 | 54 |
| | October Peak Day | 10 | 11 | 11 | 11 | 10 |
| 1-in-10 | Typical Event Day | 81 | 93 | 93 | 91 | 90 |
| | May Peak Day | 45 | 54 | 55 | 54 | 53 |
| | June Peak Day | 69 | 81 | 82 | 80 | 79 |
| | July Peak Day | 74 | 85 | 86 | 84 | 83 |
| | August Peak Day | 90 | 102 | 102 | 99 | 99 |
| | September Peak Day | 61 | 69 | 68 | 66 | 66 |
| | October Peak Day | 81 | 93 | 93 | 91 | 90 |

**Table 5-5:**
**Residential SmartAC Per Customer Average Load Impact Estimates (kW)**
**By Weather Year, Forecast Year and Day Type**
**(Event Period 1-6 PM)**

| Weather Year | Day Type | 2011-2021 |
|---|---|---|
| 1-in-2 | Typical Event Day | 0.38 |
| | May Peak Day | 0.10 |
| | June Peak Day | 0.25 |
| | July Peak Day | 0.52 |
| | August Peak Day | 0.35 |
| | September Peak Day | 0.29 |
| | October Peak Day | 0.06 |
| 1-in-10 | Typical Event Day | 0.49 |
| | May Peak Day | 0.29 |
| | June Peak Day | 0.43 |
| | July Peak Day | 0.45 |
| | August Peak Day | 0.53 |
| | September Peak Day | 0.36 |
| | October Peak Day | 0.23 |

**Table 5-6:
Non-residential SmartAC Aggregate Load Impact Estimates (MW)
By Weather Year, Forecast Year and Day Type
(Event Period 1-6 PM)**

| Weather Year | Day Type | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|
| 1-in-2 | Typical Event Day | 1.7 | 2.6 | 3.8 | 4.8 | 5.2 |
| | May Peak Day | 1.1 | 1.7 | 2.5 | 3.2 | 3.6 |
| | June Peak Day | 1.3 | 2.0 | 2.9 | 3.7 | 4.1 |
| | July Peak Day | 1.8 | 2.7 | 3.9 | 5.0 | 5.5 |
| | August Peak Day | 1.4 | 2.1 | 3.0 | 3.8 | 4.1 |
| | September Peak Day | 2.0 | 3.1 | 4.4 | 5.5 | 5.8 |
| | October Peak Day | 0.8 | 1.2 | 1.7 | 2.2 | 2.2 |
| 1-in-10 | Typical Event Day | 1.6 | 2.5 | 3.6 | 4.6 | 5.0 |
| | May Peak Day | 1.2 | 1.8 | 2.6 | 3.4 | 3.8 |
| | June Peak Day | 1.3 | 2.0 | 2.9 | 3.7 | 4.1 |
| | July Peak Day | 1.8 | 2.7 | 4.0 | 5.0 | 5.5 |
| | August Peak Day | 1.7 | 2.7 | 3.8 | 4.9 | 5.2 |
| | September Peak Day | 1.5 | 2.4 | 3.3 | 4.2 | 4.4 |
| | October Peak Day | 0.7 | 1.2 | 1.7 | 2.1 | 2.1 |

**Table 5-7:**
**Non-residential SmartAC Per Customer Average Load Impact Estimates (kW)**
**By Weather Year, Forecast Year and Day Type**
**(Event Period 1-6 PM)**

| Weather Year | Day Type | 2011 | 2012-2021 |
|---|---|---|---|
| 1-in-2 | Typical Event Day | 0.47 | 0.49 |
| | May Peak Day | 0.32 | 0.34 |
| | June Peak Day | 0.37 | 0.38 |
| | July Peak Day | 0.49 | 0.51 |
| | August Peak Day | 0.36 | 0.38 |
| | September Peak Day | 0.52 | 0.55 |
| | October Peak Day | 0.20 | 0.21 |
| 1-in-10 | Typical Event Day | 0.45 | 0.47 |
| | May Peak Day | 0.34 | 0.36 |
| | June Peak Day | 0.36 | 0.38 |
| | July Peak Day | 0.49 | 0.51 |
| | August Peak Day | 0.46 | 0.49 |
| | September Peak Day | 0.39 | 0.41 |
| | October Peak Day | 0.19 | 0.20 |

# 6 Discomfort During SmartAC Events

Following the M&E event on Monday, August 16, 2010, the Population Research Systems arm of The FSC Group conducted a post-event survey on the M&E sample of customers (the treatment group, which was called for the event) and also on a matched control group of SmartAC customers that were chosen to be demographically similar to the M&E sample but were not called on the event day. These surveys were conducted for both residential and non-residential customers. The control group is necessary in order to ascertain whether there is general discomfort on event-like days even when air conditioners are not controlled.

The surveys serve several research objectives:

- To observe how SmartAC operations affect discomfort during a four-hour M&E event. High temperatures for the day: 98° F Fresno, 94° F Sacramento, 87° F Concord; and
- To determine how discomfort varies between treatment and control groups.

The survey of treatment and control groups started immediately after the event. In total, 847 surveys were completed. Within a single day of the event, 501 were completed and within 4 days of the event 829 were completed.

The survey was similar for residential and non-residential customers. There were a total of 464 residential surveys completed and 383 non-residential surveys completed. In the residential group, there were 271 surveys completed by customers who had the event and 193 surveys by control customers. In the non-residential group, there were 193 surveys by customers who had the event and 190 by control customers.

The key discomfort questions were:

- Was there any time on Monday when the temperature in your home or place of business was uncomfortable; and
- If so, during which hours were you uncomfortable?

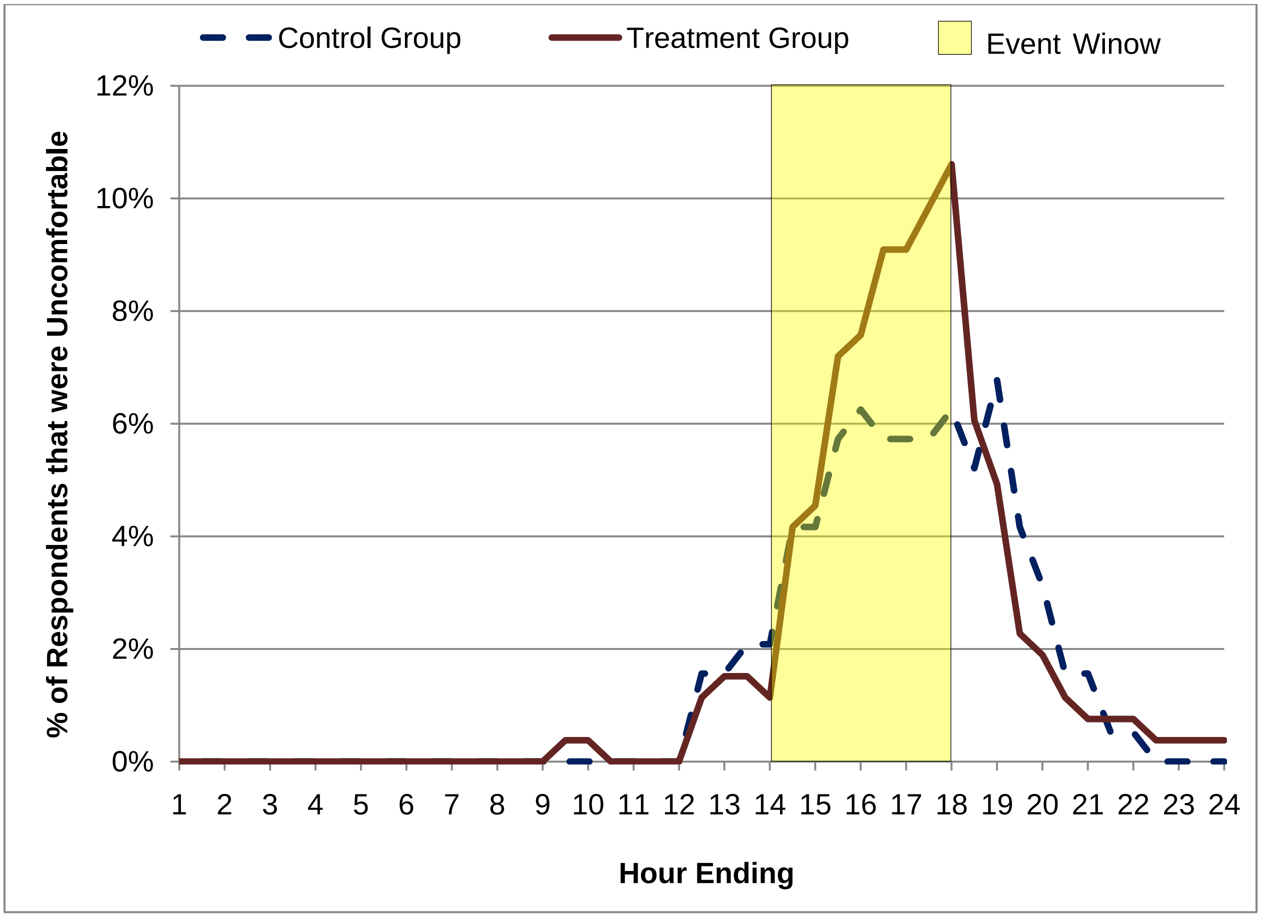
Key findings were that:

- Residential customers in the treatment group show a slight increase in discomfort relative to the control group during event hours, but the difference is not statistically significant; and
- Non-residential customers in the treatment group show an increase in discomfort relative to the control group during event hours, and the difference is statistically significant.

## 6.1 Residential Customers

For residential customers, there is a slight increase in discomfort for the treatment group during the event. 14.4% of respondents in the treatment group were uncomfortable at some point during the event, while 8.3% of respondents in the control group were uncomfortable at some point during the event. Figure 6-1 shows the levels of discomfort for each half hour of the day for each group. The peak values in Figure 6-1 are below the percentages of people who reported discomfort at any point because people could report discomfort at different times of day. Reported discomfort in the treatment group peaked at the very end of the event, while reported discomfort in the control group was fairly level from mid-way through the event until an hour or so after the event.

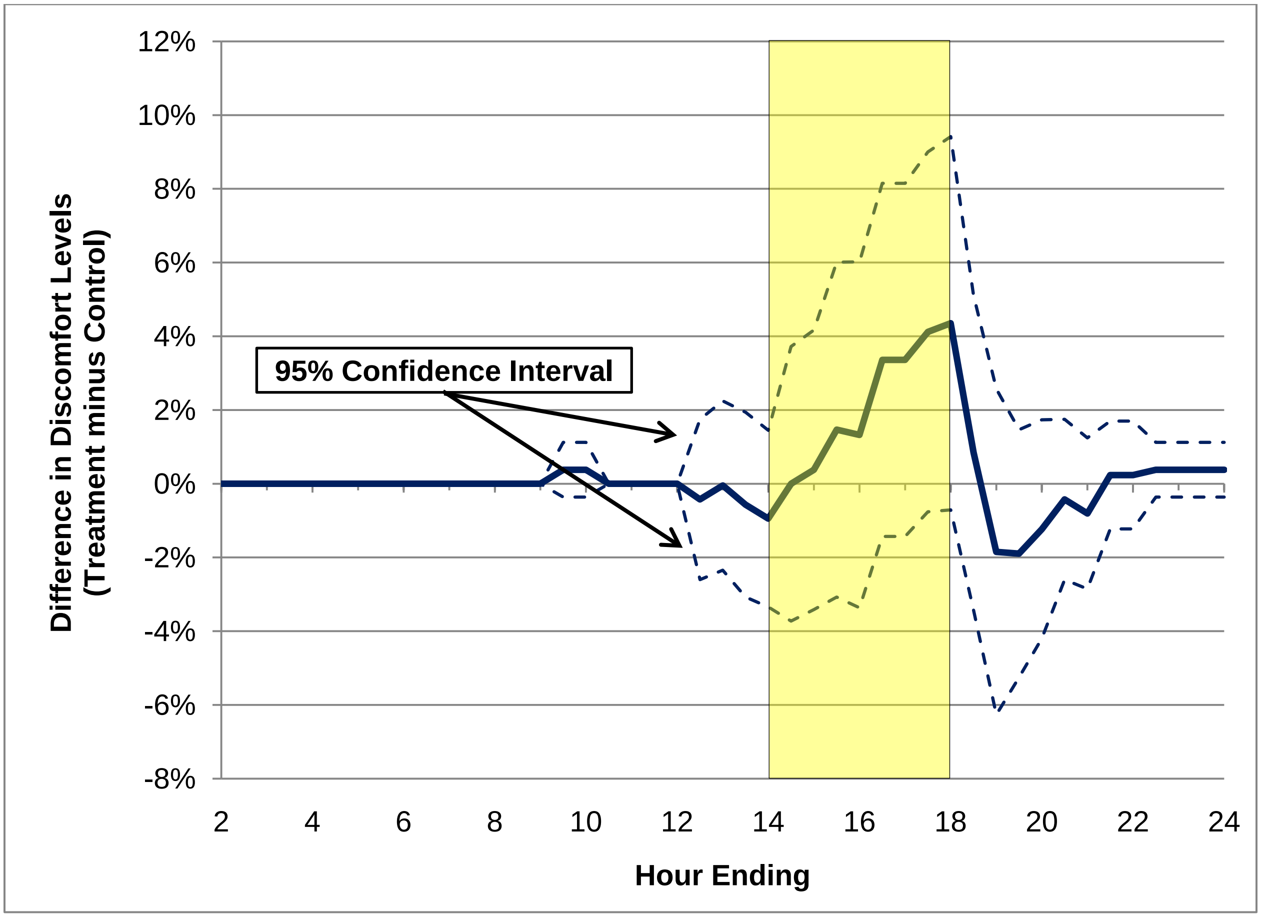
**Figure 6-1:**
**Reported Discomfort Levels in the Residential Treatment and Control Groups**




Although there is clearly a higher level of discomfort in the treatment group, it is possible that the difference is due to random variation in response. To address this question we conducted a difference-in-means test for statistical significance. A difference-in-means test determines whether or not there is a statistically-significant difference in discomfort levels between the treatment and control groups. If the 95% confidence interval around the difference does not include zero, the difference is not likely due to random variation in response.

Figure 6-2 shows the difference in means plotted for each half hour of the day, along with the lower and upper bounds of the 95% confidence interval for that difference during each half hour. As seen, the confidence interval always includes zero. This means that the difference in reported discomfort levels could well be due to random variation in responses rather than due to an actual difference in discomfort.

**Figure 6-2:**
**Difference in Means Between Treatment and Control Groups for Residential Respondents with Confidence Interval Bounds**




Customers who reported feeling discomfort at some time during the event day were asked what they thought the cause of that discomfort was. For this question, customers were allowed to list more than one possible source. There were a total of 84 responses among residential customers to this question (among 64 who reported feeling discomfort at some point). Only seven of the responses were that, "PG&E was controlling my air-conditioner." Customers do not appear to strongly blame the SmartAC program for discomfort they feel on event days. It is also worth noting that these seven responses all came from the treatment group. There were no false positive responses to this question (a false positive is when a customer attributes discomfort to SmartAC even though the AC is not being controlled).

In addition to the questions about discomfort level, the survey contained several questions about the respondents' homes and the demographics of the respondents. The responses to these questions are summarized in Table 6-1 through Table 6-7. The primary conclusion to draw from these tables is that the treatment group and control group have similar distributions for all these variables. This provides confidence that conclusions about discomfort and customer satisfaction that we draw from survey responses are not likely to be due to underlying differences between the control group and treatment group. Also note that survey respondents tend to be fairly old compared to the population—the average

age is above 60 for both the treatment and control groups. This response bias is typical of telephone surveys.

**Table 6-1:**
**"Please tell me which of the following types of buildings best describes your home?"**
**(Answers are percentages)**

| Type of Home | Control Group | Treatment Group | Total |
|---|---|---|---|
| Single family detached house | 90.7 | 86.7 | 88.4 |
| Townhouse | 3.6 | 5.2 | 4.5 |
| Duplex | 1.0 | 1.1 | 1.1 |
| Apartment | 1.0 | 2.6 | 1.9 |
| Condominium | 1.6 | 3.0 | 2.4 |
| Mobile home | 2.1 | 1.1 | 1.5 |
| Other (specify) | 0.0 | 0.4 | 0.2 |

**Table 6-2:**
**"How many bedrooms does your home have?"**
**(Answers are percentages)**

| Number of Bedrooms | Control Group | Treatment Group | Total |
|---|---|---|---|
| 1 | 1.0 | 1.9 | 1.5 |
| 2 | 11.9 | 15.1 | 13.8 |
| 3 | 41.5 | 42.4 | 42.0 |
| 4 | 29.5 | 29.5 | 29.5 |
| 5 | 6.2 | 5.5 | 5.8 |
| 6 | 1.0 | 1.1 | 1.1 |
| 7 | 0.0 | 0.7 | 0.4 |
| **Refused** | 8.8 | 3.7 | 5.8 |
| **Average number of rooms** | 3.0 | 3.2 | 3.1 |

**Table 6-3:**
**"About how many square feet of living space is your home?"**

| Group | Median | Standard Deviation |
|---|---|---|
| Treatment | 2000 | 796 |
| Control | 1800 | 863 |
| **Total** | 1900 | 837 |

**Table 6-4:**
**"Please stop me when I reach the category that best describes your household's income."**

| Group | Median | Standard Deviation |
|---|---|---|
| Treatment | Between 60 and 65 | 70 |
| Control | Between 60 and 65 | 70 |
| **Total** | Between 60 and 65 | 70 |

**Table 6-5:**
**"Which of the following is the highest level of education you have completed?"**
**(Answers are percentages)**

| Education Level | Control Group | Treatment Group | Total |
|---|---|---|---|
| 8th grade or lower | 1.6 | 1.1 | 1.3 |
| High school | 16.1 | 12.6 | 14.0 |
| Associates degree, vocational degree | 22.3 | 28.8 | 26.1 |
| Four year college degree | 29.5 | 30.6 | 30.2 |
| Graduate or professional | 27.5 | 25.5 | 26.3 |
| Don't know/Not sure/C | 0.5 | 0.0 | 0.2 |

**Table 6-6:**
**"Including yourself and children, how many people live in your home at least six months of the year?"**
**(Answers are percentages)**

| Number of People | Control | Treatment | Total |
|---|---|---|---|
| 1 | 17.0 | 25.8 | 22.2 |
| 2 | 41.0 | 46.6 | 44.3 |
| 3 | 16.5 | 12.3 | 14.0 |
| 4 | 15.4 | 10.1 | 12.3 |
| 5 | 5.9 | 4.5 | 5.0 |
| 6 | 2.1 | 0.4 | 1.1 |
| 7 | 1.6 | 0.4 | 0.9 |
| 8 | 0.5 | 0.0 | 0.2 |
| Average number of people | 2.7 | 2.2 | 2.5 |

**Table 6-7:**
**"What is Your Age?"**

| Group | Median | Standard Deviation |
|---|---|---|
| Treatment | 65 | 14 |
| Control | 62 | 16 |
| **Total** | 64 | 15 |

Finally, the survey asked about satisfaction with PG&E and SmartAC. Before they were asked about discomfort, customers were asked, "Considering all aspects of the electricity service you receive from PG&E, are you…?" with four possible answers. These answers are shown in Table 6-8. In both the treatment and control groups, the fractions of customers saying they are somewhat or very dissatisfied are less than 9%.

**Table 6-8:**
**Satisfaction Levels with PG&E Electric Service**
**(Answers are Percentages)**

| Satisfaction Level | Control Group | Treatment Group | Total |
|---|---|---|---|
| Very satisfied | 43.0 | 53.5 | 49.1 |
| Somewhat satisfied | 49.7 | 38.0 | 42.9 |
| Somewhat dissatisfied | 6.2 | 7.0 | 6.7 |
| Very dissatisfied | 1.0 | 1.5 | 1.3 |

If customers stated they were somewhat or very dissatisfied, they were asked what they disliked. These responses are shown in Table 6-9. Note that customers were allowed to list more than one reason and Table 6-9 includes all answers. Because few customers indicated dissatisfaction, this table has few responses. Raw counts are shown rather than percentages. Of the 18 "other" responses, 6 mention SmartMeter complaints and the rest are unique in the survey.

**Table 6-9:**
**Reasons for Dissatisfaction**
**(Counts)**

| | Treatment | Control | Total |
|---|---|---|---|
| Too costly | 9 | 15 | 24 |
| Unreliable | 1 | 0 | 1 |
| Poor response to service requests | 4 | 1 | 5 |
| Billing issues | 1 | 4 | 5 |
| Other (specify) | 7 | 11 | 18 |

Following the discomfort questions, customers were asked about their satisfaction with SmartAC. These questions were asked after the discomfort questions to avoid biasing the discomfort responses.

Responses to the question, “In general, how satisfied are you with your experience in the SmartAC program?” are shown in Table 6-10. Satisfaction levels with the SmartAC program are similar to satisfaction levels with PG&E electricity service, and are similar across the treatment and control groups. In both the treatment and control groups, the fractions of customers saying they are somewhat or very dissatisfied are less than 7%.

**Table 6-10:**
**Satisfaction Levels with SmartAC Program**
**(Answers are Percentages)**

| Satisfaction Level | Control Group | Treatment Group | Total |
|---|---|---|---|
| Very satisfied | 49.2 | 55.7 | 53.0 |
| Somewhat satisfied | 44.0 | 38.4 | 40.7 |
| Somewhat dissatisfied | 4.7 | 3.7 | 4.1 |
| Very dissatisfied | 2.1 | 2.2 | 2.2 |

If customers stated that they were somewhat or very satisfied, they were asked what they liked. These responses are shown in Table 6-11. Note that customers were allowed to list more than one reason and the table includes all answers. Raw counts are shown rather than percentages. The 19 “other” responses did not show a pattern towards any particular type of response.

**Table 6-11:**
**Reasons Respondents Like SmartAC**
**(Counts)**

| Reasons for Liking | Control | Treatment | Total |
|---|---|---|---|
| Getting a $25 rebate/incentive from PG&E | 11 | 19 | 30 |
| Getting a new/better/programmable thermostat | 8 | 16 | 24 |
| Helping PG&E avoid power shortages/outages | 29 | 54 | 83 |
| Helping fight global warming/climate change | 1 | 3 | 4 |
| Helping the environment | 6 | 16 | 22 |
| Saving my energy | 22 | 35 | 57 |
| Saving money on my electric bill | 18 | 29 | 47 |
| It is easy / Takes cares of itself | 14 | 30 | 44 |
| Never or seldom causes discomfort or inconvenience | 53 | 80 | 133 |
| Other (specify) | 7 | 12 | 19 |
| Don't know | 51 | 50 | 101 |

If customers stated that they were somewhat or very dissatisfied, they were asked what they disliked. These responses are shown in Table 6-12. Note that customers were allowed to list more than one reason and Table 6-12 includes all answers. For this reason, raw counts are shown rather than percentages. Because few customers indicated dissatisfaction, this table has few responses. Of the 16 “other” responses, 4 mention higher bills, 3 mention not understanding the program and 3 mention technical problems with their AC or thermostat. The rest are unique issues in the survey.

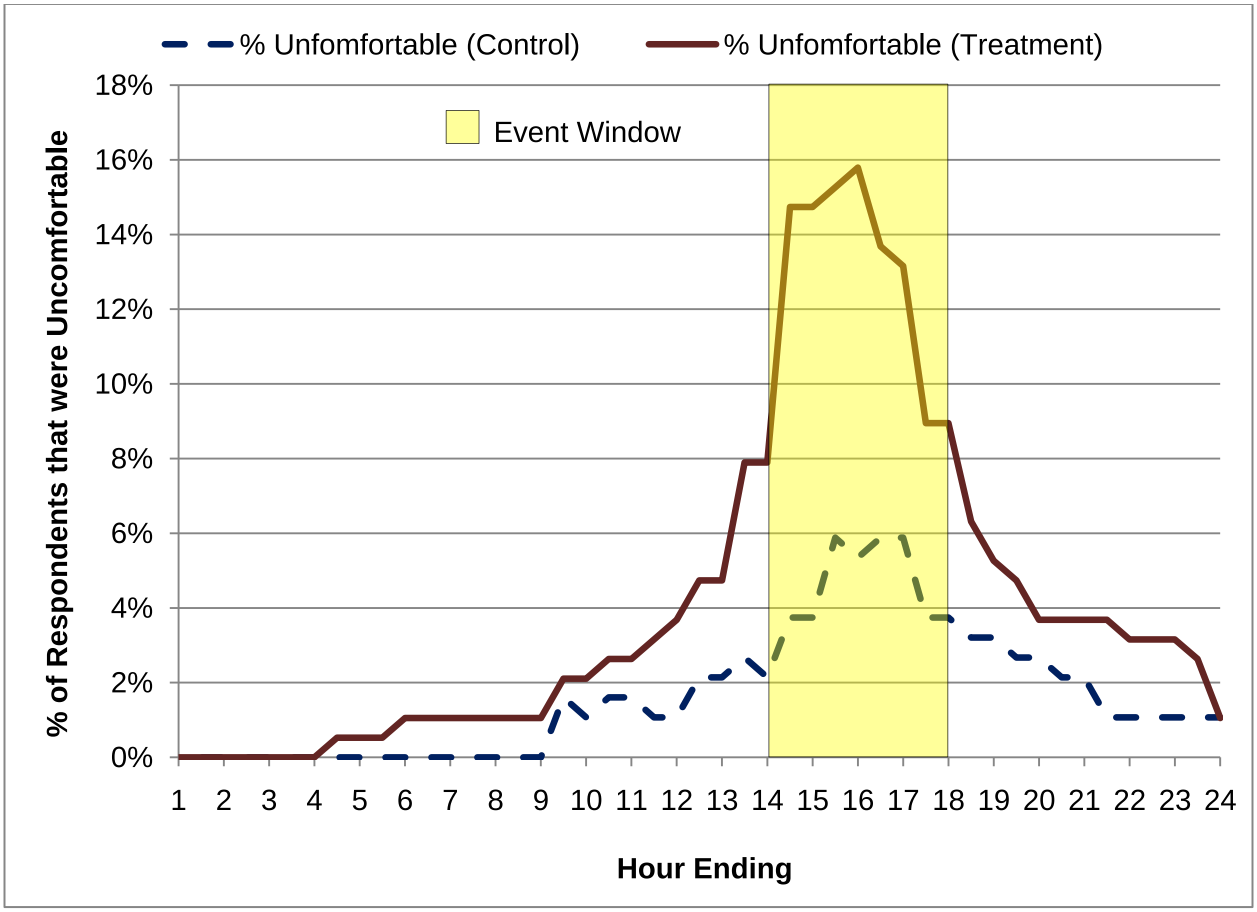
**Table 6-12:**
**Reasons Respondents Do Not Like SmartAC**
**(Counts)**

| Reasons for Liking | Control | Treatment | Total |
|---|---|---|---|
| Discomfort | 1 | 9 | 10 |
| Inconvenience | 0 | 1 | 1 |
| Do not like being controlled | 2 | 1 | 3 |
| Not seeing energy savings | 3 | 7 | 10 |
| Other (specify) | 11 | 5 | 16 |

## 6.2 Non-residential Customers

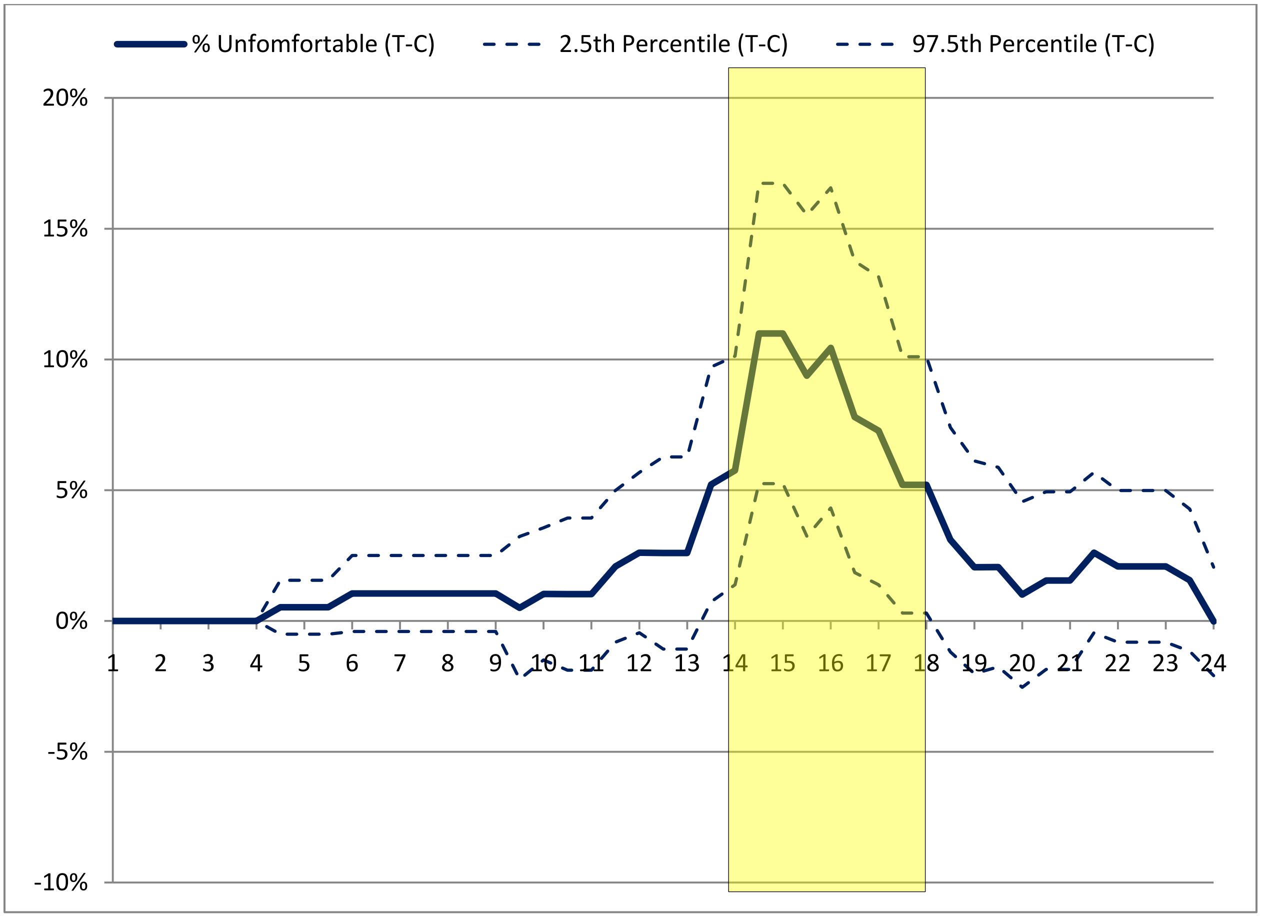
For non-residential customers, there is also an increase in discomfort for the treatment group during the event. In the treatment group, 19.5% of respondents were uncomfortable at some point during the event; while 7.5% of respondents in the control group were uncomfortable at some point during the event. Figure 6-3 shows the levels of reported discomfort in this sample for each half hour of the day. Both groups reported discomfort peaked near the middle of the event period.

**Figure 6-3:**
**Reported Discomfort Levels in the Non-residential Treatment and Control Groups**




Just as in the residential case, the difference in reported discomfort levels could be due to random variation, so we conducted a difference-in-means test on this group as well. Figure 6-4 shows the difference between the discomfort levels in each group for each half hour of the day, along with the 95% confidence interval boundaries. In this case, the confidence interval surrounding the difference in means does not include zero for the time during the event, and for the half hour before the event. The latter result may be due to respondents not accurately recalling the time during which they felt discomfort, or it could be due to underlying differences between the treatment and control groups. It is important to note though, that aside from the half hour immediately prior to the event and the times during the event, the difference in reported discomfort levels is not statistically significant at any other time during the event day. This provides confidence that the treatment and control groups are similar in their general tendency to report discomfort.

**Figure 6-4:**
**Difference in Means Between Treatment and Control Groups for Non-residential Respondents with Confidence Interval Bounds**



## Appendix A. Further Survey Results

Tables A-1 through A-8 show the distributions of various business characteristics across the treatment and control groups. Notice that in each case the distributions are similar suggesting that the difference in reported discomfort levels is not simply due to differences in customer characteristics between the two groups.

**Table A-1:**
**"What business sector does your firm belong to?"**
**(Answers are percentages)**

| Business Category | Control | Treatment | Total |
|---|---|---|---|
| Government/ Nonprofit | 5.2 | 2.2 | 3.7 |
| Retail/ Sales | 12.0 | 18.4 | 15.2 |
| Office/ Professional | 8.4 | 9.0 | 8.7 |
| Services | 28.5 | 18.4 | 23.4 |
| Food | 21.6 | 19.4 | 20.5 |
| Manufacturing/ Construction | 6.4 | 6.4 | 6.3 |
| Agriculture | 1.6 | 2.6 | 2.1 |
| Religious | 3.2 | 5.8 | 4.5 |
| Health/ Personal Care | 11.6 | 11.0 | 11.3 |
| Education | 1.0 | 4.2 | 2.6 |
| Other | 0.6 | 3.2 | 1.8 |
| **Total** | 100 | 100 | 100 |

**Table A-2:**
**"Do you lease or own your facility?"**
**(Answers are percentages)**

| Ownership | Control | Treatment | Total |
|---|---|---|---|
| Lease | 55.3 | 56.1 | 55.6 |
| Own | 38.9 | 39.3 | 39.1 |
| Other (specify) | 0.6 | 0.0 | 0.3 |
| Refused | 1.0 | 1.0 | 1.1 |
| Don't know | 4.2 | 3.6 | 3.9 |
| **Total** | 100 | 100 | 100 |

**Table A-3:**
**"How many locations does your company have in California?"**
**(Answers are percentages)**

| Locations | Control | Treatment | Total |
|---|---|---|---|
| 1 | 56.3 | 62.3 | 59.3 |
| 2 to 4 | 14.2 | 9.4 | 11.8 |
| 5 to 10 | 3.2 | 4.2 | 3.7 |
| 11 to 25 | 1.0 | 3.2 | 2.1 |
| Over 25 | 17.4 | 20.0 | 18.6 |
| Refused | 1.6 | 0.0 | 0.8 |
| Don't know | 6.4 | 1.0 | 3.7 |
| **Total** | 100 | 100 | 100 |

**Table A-4:**
**"What is the approximate TOTAL square footage of your facility at this location?"**
**(Answers are percentages)**

| Square Footage | Control | Treatment | Total |
|---|---|---|---|
| Less than 1,500 sq ft | 21.6 | 15.2 | 18.4 |
| 1,500 – 4,999 sq ft | 31.7 | 31.5 | 31.5 |
| 5,000 – 9,999 sq ft | 7.4 | 12.0 | 9.7 |
| 10,000 – 24,999 sq ft | 7.8 | 7.8 | 7.9 |
| Over 25,000 sq ft | 6.8 | 5.8 | 6.3 |
| Refused | 1.0 | 0.0 | 0.5 |
| Don't know | 23.6 | 27.7 | 25.7 |
| **Total** | 100 | 100 | 100 |

### Table A-5:
### "What is the approximate AIR-CONDITIONED square footage of your facility at this location?"
### (Answers are percentages)

| Square Footage | Control | Treatment | Total |
|---|---|---|---|
| Less than 1,500 sq ft | 27.5 | 20.0 | 23.6 |
| 1,500 – 4,999 sq ft | 32.1 | 36.7 | 34.4 |
| 5,000 – 9,999 sq ft | 7.4 | 6.4 | 6.8 |
| 10,000 – 24,999 sq ft | 5.8 | 7.8 | 6.8 |
| Over 25,000 sq ft | 2.2 | 2.6 | 2.4 |
| Refused | 1.0 | 0.0 | 0.5 |
| Don't know | 24.2 | 26.7 | 25.5 |
| **Total** | 100 | 100 | 100 |

### Table A-6:
### "About how many employees do you have at this location?"
### (Answers are percentages)

| Employees | Control | Treatment | Total |
|---|---|---|---|
| 1 to 5 | 44.7 | 37.7 | 41.2 |
| 6 to 10 | 15.2 | 12.6 | 13.9 |
| 11 to 20 | 16.2 | 16.8 | 16.5 |
| Over 20 | 21.0 | 28.7 | 24.9 |
| Refused | 1.6 | 2.6 | 2.1 |
| Don't know | 1.0 | 1.6 | 1.3 |
| **Total** | 100 | 100 | 100 |

### Table A-7:
### "Do you have anyone devoted full-time as a building engineer or facility manager?"
### (Answers are percentages)

| Response | Control | Treatment | Total |
|---|---|---|---|
| Yes | 18.4 | 23.0 | 20.7 |
| No | 75.8 | 73.3 | 74.5 |

**Table A-8:**
**"Approximately what percentage of your facility's annual operating cost is associated with the electricity bill?"**
**(Answers are percentages)**

| Response | Control | Treatment | Total |
|---|---|---|---|
| 0 - 9% | 20.5 | 21.5 | 21.0 |
| 10 - 19% | 10.5 | 13.6 | 12.1 |
| 20 - 29% / 25% | 5.3 | 4.7 | 5.0 |
| 30 - 39% | 1.1 | 1.6 | 1.3 |
| 40 - 49% | 0.5 | 0.5 | 0.5 |
| 50 - 59% | 0.5 | 2.1 | 1.3 |
| 60 - 69% | 0.5 | 0.0 | 0.3 |
| 70 - 79% / 75% | 0.0 | 2.1 | 1.1 |
| 80 - 89% | 0.5 | 0.5 | 0.5 |
| 90 - 100% | 0.5 | 0.0 | 0.3 |
| Refused | 1.1 | 1.1 | 1.1 |
| Don't know | 59.0 | 52.4 | 55.6 |

Finally, the survey asked about satisfaction with PG&E and satisfaction with SmartAC. Before they were asked about discomfort, customers were asked, "Considering all aspects of the electricity service you receive from PG&E, are you…?" with four possible answers. These answers are shown in Table A-9. The levels of dis-satisfaction in the non-residential samples are notably higher than in the residential samples. In both the treatment and control groups, the fractions of customers saying they are somewhat or very dissatisfied are about 16%, as compared to less than 9% in the residential samples.

**Table A-9:**
**Satisfaction Levels with PG&E Electric Service**
**(Answers are Percentages)**

| Satisfaction Level | Control Group | Treatment Group | Total |
|---|---|---|---|
| Very satisfied | 40.0 | 41.9 | 40.9 |
| Somewhat satisfied | 44.2 | 38.2 | 41.2 |
| Somewhat dissatisfied | 11.6 | 10.5 | 11.0 |
| Very dissatisfied | 3.7 | 6.3 | 5.0 |

If customers stated they were somewhat or very dissatisfied, they were asked what they dislike. These responses are shown in Table A-10. Note that customers were allowed to list more than one reason, and the table includes all answers. Because few customers indicated dissatisfaction, Table A-10 has few responses. Raw counts are shown rather than percentages. Of the 12 "other" responses, 4 mention

SmartMeter complaints and 5 mention technical problems with their air-conditioning or thermostat that the customer attributes to the SmartAC program.

**Table A-10:**
**Reasons for Dissatisfaction**
**(Counts)**

| | Treatment | Control | Total |
|---|---|---|---|
| Too costly | 6 | 8 | 14 |
| Poor response to service requests | 0 | 6 | 6 |
| Billing issues | 3 | 4 | 7 |
| Other (Specify) | 3 | 9 | 12 |
| Refused | 0 | 1 | 1 |

Following the discomfort questions, non-residential customers were asked about their satisfaction with SmartAC. These questions were asked after the discomfort questions to avoid biasing the discomfort responses.

Responses to the question, "In general, how satisfied are you with your experience in the SmartAC program?" are shown in Table A-11. As in the satisfaction levels with PG&E electricity service, satisfaction levels in the non-residential sample are noticeably lower than in the residential sample. The levels of customers who are somewhat or very dissatisfied with SmartAC are greater than 30% in each group, as compared to about 7% in the residential samples.

**Table A-11:**
**Satisfaction Levels with SmartAC Program**
**(Answers are Percentages)**

| Satisfaction Level | Control Group | Treatment Group | Total |
|---|---|---|---|
| Very satisfied | 32.6 | 36.7 | 34.7 |
| Somewhat satisfied | 30.5 | 27.8 | 29.1 |
| Somewhat dissatisfied | 30.0 | 23.0 | 26.5 |
| Very dissatisfied | 3.2 | 7.3 | 5.3 |

If customers stated they were somewhat or very satisfied, they were asked what they like. These responses are shown in Table A-12. Note that customers were allowed to list more than one reason and the table includes all answers. For this reason, raw counts are shown rather than percentages. The 30 "other" responses did not show a pattern towards any particular type of response.

**Table A-12:**
**Reasons Respondents Like SmartAC**
**(Counts)**

| Reasons for Liking | Control | Treatment | Total |
|---|---|---|---|
| Getting a $25 rebate/incentive from PG&E | 1 | 5 | 6 |
| Getting a new/better/programmable thermostat | 35 | 33 | 68 |
| Helping PG&E avoid power shortages/outages | 7 | 17 | 24 |
| Helping fight global warming/climate change | 0 | 1 | 1 |
| Helping the environment | 4 | 4 | 8 |
| Saving my energy | 15 | 25 | 40 |
| Saving money on my electric bill | 19 | 26 | 45 |
| It is easy / Takes cares of itself | 16 | 18 | 34 |
| Never or seldom causes discomfort or inconvenience | 29 | 25 | 54 |
| Other (specify) | 19 | 11 | 30 |
| Don't know | 18 | 20 | 38 |

If customers stated that they were somewhat or very dissatisfied, they were asked what they disliked. These responses are shown in Table A-13. Note that customers were allowed to list more than one reason and the table includes all answers. Raw counts are shown rather than percentages. Of the 19 "other" responses, 7 mentioned customer complaints or other heat-related issues, 3 mentioned higher bills and 6 mentioned technical problems with their AC or thermostat—either due to something breaking or due to the program being too complicated. The other three are unique issues in the survey.

**Table A-13:**
**Reasons Respondents Do Not Like SmartAC**
**(Counts)**

| Reasons for Liking | Control | Treatment | Total |
|---|---|---|---|
| Discomfort | 8 | 14 | 22 |
| Inconvenience | 7 | 5 | 12 |
| Do not like being controlled | 0 | 5 | 5 |
| Not seeing energy savings | 1 | 7 | 8 |
| Other (specify) | 7 | 12 | 19 |