2002 SMART THERMOSTAT PROGRAM IMPACT EVALUATION

FINAL

Prepared for

San Diego Gas and Electric
San Diego, California

Prepared by

KEMA-XENERGY
Madison, Wisconsin

February 26, 2003

ma:project:wsdg0055:report:title

KEMA-XENERGY • 2001 W. Beltline Highway • Suite 200 • Madison, WI 53713 • (608) 277-9696

X EXECUTIVE SUMMARY

X.1 INTRODUCTION

X.1.1 Background

On March 27, 2001, the California Public Utility Commission (CPUC) issued Decision 01-03-073 ("D.01-03-073") mandating San Diego Gas and Electric (SDG&E) to implement a pilot program designed to test the viability of a new approach to residential load control and demand responsiveness through the use of Internet technology and thermostats to affect residential air conditioning use. To meet this mandate, SDG&E implemented the Smart Thermostat Program beginning in the spring of 2002. This report provides the findings from an impact evaluation of the first summer of this program.

X.1.2 Program Description

General Structure

The Smart Thermostat Program is designed to include approximately 5,000 residential customers representing an estimated 4 MW in peak demand reduction before 2002 year-end. Through the program, customers are provided the necessary technology installation and a small incentive for program participation. The equipment deployed allows SDG&E to remotely raise the cooling setpoints on participating customers' thermostats. Participating customers may over-ride the re-set, but forfeit a portion of their incentive each time they do so.

Conditions for Calling a Re-set Event

The program plan calls for the deployment of the Smart Thermostat system when the California Independent System Operator ("ISO") calls for a Stage 2 Emergency Notice ("Stage 2 Alert"). This alert is based on statewide conditions, and may occur at times when the weather in San Diego is mild.

During the time frame of this study, a single Stage 2 Alert was called. Thus, there was only one re-set event observed. That event occurred on a day with relatively mild weather in San Diego. The event was from 3:20 PM to 5:19 PM on July 10.

X.2 Findings

X.2.1 Estimated Impacts for the Observed Re-set Event

For the July 10 re-set period, the average savings per participating unit are estimated at 0.33 kW per unit. For the 2,259 units connected on the re-set day, this translates into an estimated total of 0.7 MW. If the targeted 5,000 units had all been in operation on that day, the estimate would be 1.6 MW. The estimated impacts are summarized in Table X-1, along with the standard errors and 90 percent confidence intervals for the estimates.

Table X-1
***Ex Post* Impact Estimates for the July 10, 2002, Re-set Event**

	Average Savings Per Unit in the Program (kW/unit)	Savings on July 10 for Installed Units as of that Date (MW)	Savings on July 10 if 5,000 Units Were in Place (MW)
Number of units		*2259*	*5000*
Estimate	0.33	0.74	1.63
Standard Error	0.13	0.30	0.67
90 percent confidence lower bound	0.10	0.24	0.52
90 percent confidence upper bound	0.55	1.24	2.74

On the day of the re-set event, only around 30 percent of the air conditioning units in the program contributed to savings. A crude ex post estimate derived by applying this 30 percent "contribution factor" to the ex ante estimate of 4 MW would yield 1.2 MW, well within the 90 percent error bounds of the *ex post* estimate in Table X-1.

X.2.2 What Fraction of Units Contribute to Savings

The fraction of participating units contributing to savings was found to be low in this analysis.

- Twenty-five percent of units were never used during weekday afternoons in the summer of 2002.
- Ten percent of units apparently were not successfully re-set by the system.
- Seven percent of units that were successfully re-set over-rode the re-set.
- On the day of the re-set event, only about 40 percent of the units in the program were in use.

The combined effect of the first three factors is that only about 60 percent of the participating units are "potential contributors" to impacts. These are units that are operated at least some times during the summer weekday afternoons, and do not have signal failures or over-rides. Further, on the day of the re-set event, only about half the units that were used at least on some weekday afternoons were in use. In total, then, average savings across all units in the program would be expected to be only about 30 percent of what would be expected for an operating unit that was successfully re-set without over-ride.

X.2.3 Projected Impacts for Future Events

Impacts projected for a future re-set of 3°F are indicated in Table X-2. The impact projected in the table for the conditions of the observed July 10 re-set event is somewhat lower than that obtained from the analysis of the particular re-set event. However, the projected impacts are well within the 90 percent confidence bounds of the impacts for the re-set day.

The projected impacts represent the average savings expected over the indicated conditions. Actual impacts on a particular day may be higher or lower, according to how much participants are using their air conditioners. The impact for the July 10 re-set event appears to have been somewhat higher than what might be expected on average for those temperature conditions. Additional re-set events will need to be observed to determine if the projections are more correct on average, or if the higher estimate for the single event observed so far indicates a general pattern.

Table X-2
Projected Impacts per Participating AC Unit by Outside Temperature
3°F Re-set

Average Daily Temperature	Impact per Thermostat (kW)
65	0.00
66	0.01
67	0.02
68	0.05
69	0.08
70	0.12
71	0.15
72	0.18
73	0.21
74	0.24
75	0.27
76	0.29
77	0.31
78	0.32
79	0.34
80	0.35
≥80	0.35

X.3 IMPLICATIONS OF THE FINDINGS

The summer of 2002 was the second coolest since 1980. Cooling degree-days at the Miramar station were 32 percent below the average for that period. In a more typical summer, more air conditioning use would be expected.

Nonetheless, the finding that only around 40 percent of units in the program were being used on the re-set day suggests that future performance of the program as a mechanism to respond to statewide emergencies is not reliable. Statewide emergency conditions do not necessarily coincide with hot weather in the San Diego area. This was the case for the single re-set event that occurred in this study period. As long as the emergency condition that triggers a re-set event is not tied to hot weather in San Diego, a high number of non-users is likely to be found during future re-sets.

The program has already been targeted to SDG&E's hotter climate region and higher-use customers. Thus, it does not appear likely that the impact levels can be improved substantially by redirecting the program. While it is possible that more restrictive targeting could still improve the average savings per unit, the necessary restrictions would reduce the eligible pool of participants so that even the current target might not be achieved.

1 INTRODUCTION

1.1 BACKGROUND

On March 27, 2001, the California Public Utility Commission (CPUC) issued Decision 01-03-073 ("D.01-03-073") mandating San Diego Gas and Electric (SDG&E) to implement a pilot program designed to test the viability of a new approach to residential load control and demand responsiveness through the use of Internet technology and thermostats to affect residential air conditioning use. The Energy Division recommended a budget of $3.9 million per program year. To meet this mandate, SDG&E implemented the Smart Thermostat Program beginning in the spring of 2002. This report provides the findings from an impact evaluation of the first summer of this program.

1.2 PROGRAM DESCRIPTION

1.2.1 General Structure

The Smart Thermostat Program is designed to include approximately 5,000 residential customers representing an estimated 4 MW in peak demand reduction before 2002 year-end. Through the program, customers are provided the necessary technology installation and a small incentive for program participation. The equipment deployed allows SDG&E control of the thermostat for emergency demand reduction, yet allows the customer the ability to over-ride the company signal remotely or directly at the thermostat.

The program's paging technology allows SDG&E to remotely raise the cooling setpoints on participating customers' thermostats. We refer to this action by SDG&E as a "re-set event." The effect of the higher setpoint is a reduction in the average demand of the air conditioners. This reduction is the desired demand impact.

1.2.2 Conditions for Calling a Re-set Event

The program plan calls for the deployment of the Smart Thermostat system when the California Independent System Operator ("ISO") calls for a Stage 2 Emergency Notice ("Stage 2 Alert"). A Stage 2 Alert is issued when an Operating Reserve of less than 5 percent exists or is forecast to occur within the next two (2) hours for the state. A Smart Thermostat Program re-set event is triggered by a Stage 2 Alert. This alert is based on statewide conditions, and may occur at times when the weather in San Diego is mild.

When a Smart Thermostat re-set event is initiated, SDG&E will increase the setting of the thermostat in participants' homes for a period of four (4) hours. The re-set may be extended or terminated as necessary. The maximum length of the re-set is six (6) hours per day. SDG&E has set a maximum of 20 re-sets per calendar year.

1.2.3 Incentives

The customer receives a state-of-the-art digital thermostat installed at no cost to the participant. In addition, the participant will receive up to $100 per year in incentives for the years 2002 through 2004. Participants could receive up to $20 in incentives if they were participating in the program during 2001. (Customers began signing up for the program in the fall of 2001, though the equipment was not fully installed until the spring of 2002.)

As noted, the participant may over-ride the increased setpoint of the re-set. However, each time the customer over-rides the re-set, the incentive will be reduced by $2. The incentive, less any reduction due to over-ride, will be paid each year.

1.2.4 Targeting

The targeting strategy for the program was prescribed by the CPUC in D.01-03-073, the decision mandating the program. The decision directed SDG&E to target the following three customer groups:

1. Residential customer whose average monthly electricity consumption is greater than average for their customer class, with the exact specified consumption level to be determined by SDG&E.
2. Residential customers residing in geographical areas in SDG&E's service territory known to have high electricity consumption due to climate.
3. Residential customers residing in known limited-to-moderate-income areas.

Medical baseline customers are not permitted to participate due to the potential air conditioner needs of these customers.

SDG&E met criteria 1 and 2 by selecting customers from California Energy Commission (CEC) Climate Zone 10 who had average monthly summer consumption of 700 kWh or greater. Data from MIRACLE XIII, SDG&E's residential appliance saturation survey, were used to estimate the average consumption for those residing in SDG&E's Transitional Climate Zone with central air conditioning. The average monthly summer kWh consumption for SDG&E's Transitional Climate Zone residents with central air conditioners is 700 kWh. The Transitional Climate Zone was used as a proxy for CEC Climate Zone 10, since the MIRACLE survey data were collected for the SDG&E climate zones (Maritime, Coastal, and Transitional zones). Initially, residents in CEC Climate Zone 10 with average monthly summer consumption of 700 kWh or greater were selected. In an effort to increase participation, an additional mailing was conducted during October 2002, with a follow-up mailing taking place approximately one month later. Targeted customers for this mailing included those in CEC Climate Zone 10 with average monthly summer consumption of at least 600 kWh.

Criteria 3 was met by selecting customers under SDG&E's low-income rate class, the DR-LI rate, in CEC Climate Zone 10, whose average monthly summer consumption was 700 kWh or greater.

1.3 IMPACT EVALUATION

SDG&E was required to evaluate this program effort, including both a process evaluation and a load impact evaluation component. The primary objectives of the process evaluation were to assess how efficiently and effectively SDG&E runs the program and to make suggestions for improvements. As part of that evaluation effort, survey data were collected from a sample of participants. These survey results shed some light on impact findings.

The load impact evaluation presented in this report provides estimates of the aggregate demand reduction and energy savings from re-set(s). Conditions during the summer of 2002 required SDG&E to implement only one re-set event. This event lasted approximately two hours on the afternoon of July 10, 2002. Estimates are provided here for savings during this single re-set event.

Estimates are provided also for projected savings in future events as a function of the degrees increase in thermostat setpoints and the ambient temperature for the day. Similar methods will be applied to data from the summers of 2003 and 2004 to estimate the specific savings in those years as well as to improve the projections for general conditions.

1.4 ORGANIZATION OF THE REPORT

Section 2 describes the impact analysis methods, including the data sources and the analytic approach. The findings from the analysis are presented in Section 3. Conclusions are summarized in Section 4. Tables of projected savings by temperature, time of day, and re-set amount are given in Appendix A.

2 METHODS

This section describes the various data used in the impact analysis as well as the methods by which demand impacts were estimated. Section 2.1 discusses the data and how it was collected. Section 2.2 discusses the analytical approach to processing the data to estimating the demand impacts.

2.1 DATA SOURCES

There were three types of data collected for this study. The data most necessary and difficult to collect was the energy consumption data from a sample of Smart Thermostat Program participants. A great effort was managed by SDG&E to gather that data. Weather data already being collected for other purposes were provided by SDG&E. Weather observations are necessary to model the dependency of air conditioning energy consumption on ambient temperature.

Silicon Energy, the implementation contractor responsible for the web-based control system, collected data on Smart Thermostat Program participants and on thermostat performance during re-set events. Those data were available directly from the Silicon Energy EEM Suite website.

2.1.1 Metered Data

Energy Consumption Data

Two streams of energy consumption data were collected at each study participant's premise:

1. whole-premise
2. air conditioning (AC).

These streams were monitored on separate meters installed by SDG&E. Both meters recorded energy consumption accumulated over 15-minute intervals. All observations were recorded at quarter-hour intervals. SDG&E provided the energy consumption data sets at the end of the metering period. In addition to these data, SDG&E provided a meter installation survey data set. The survey data included information on nominal cooling capacity, estimated age of AC condenser, and AC type. The survey data also contained information necessary to collate the energy consumption data with the re-set event data, discussed below.

As the name suggests, whole-premise data included all loads at the premise including the AC condenser. Whole-premise data are valuable to the impact assessment of an AC demand reduction program because other loads may be affected by changes in the AC load. For example, greater use of ceiling, floor, or desk fans may accompany decreased cooling by the AC. Refrigerators will run more as less cooling allows the interior temperature to climb, and water heaters may run less. There may be an increased tendency among occupants to lessen internal heat gains, such as cooking, clothes drying, and lighting. These uncertain variables can have marked effects on the impact of an AC demand reduction program. Theoretically, the total impact at a premise is best viewed from the perspective of whole-house consumption.

Unfortunately, the variation of non-AC electrical loads at a premise can make it difficult to discern the impacts of AC demand reduction from whole-premise data alone. The fundamental dependency of AC use on ambient temperature may become more difficult to capture. For this reason, AC data itself was also collected.

The AC energy consumption data collected were taken from the circuit of the AC condenser, that part of the AC system located outdoors that dumps heat from the premise to the ambient environment. The condenser's load includes those of the refrigerant compressor motor, the cooling fan motor, condenser controls, and case or emollient heaters if present. The heaters are found generally in older condensers and serve to vaporize any liquid refrigerant that might enter the compressor. It seems that many run near continuously, perhaps even throughout the heating season.

The condenser is the largest but not the only load in an AC system. The system typically includes the same interior air distribution fan used by a forced-air furnace. The fan demand is approximately 150 Watts per nominal ton of AC capacity, or on the order of an additional 10 percent of condenser demand. Common air conditioner load control programs of the past involve controlling only the condensers, with exterior control switches. This type of "cycling" control does not turn off the interior air distribution fan. By contrast, during re-set the Smart Thermostat is understood to turn off the interior air distribution fan just as it would under ordinary AC operation when the cooling setpoint is raised.

The interior air distribution fan is not on the same circuit as the condenser. In fact, it may be on a circuit with other, non-AC loads. To collect data from both the condenser and the interior distribution fan alone thus may become a time-consuming task of wiring sensors. For that reason, energy consumption data are collected from the condenser circuit alone and does not capture the impact of turning the interior fan off when the cooling setpoint is raised. This, then, is another reason to consider whole-premise data in a demand impact analysis.

Sample Design

The energy consumption data were collected from a random sample of 100 premises of program participants. Premises were limited to those with no more than two thermostats. The sample was divided randomly into two groups of approximately equal numbers of premises. The grouping was intended to allow one-half of the sample to serve as a comparison group for the other, for each re-set event. Thus, for each re-set, one group would be re-set while the other group continued to operate their AC as usual. With multiple re-set events, this would permit each group to be re-set in about half the events, and to act as the comparison group for the other group in the other half of the event.

During the summer of 2002, there was a single re-set event on July 10. One group from the sample, group A, was re-set during that event. The other, group B, was not re-set. For simplicity, group A is referred to simply as the re-set or re-set group. Group B is referred to simply as the comparison group.

Table 2-1 describes the sample in terms of numbers of premises, thermostats, and AC metered for each group. The table divides premises into categories by count of thermostats on the premise and numbers of AC metered. Each group had a two-thermostat premise where only one AC was metered. Otherwise, all AC were metered at all premises.

Table 2-1
Distribution of Premises, Thermostats, and Metered AC by Group in Sample

	Re-set Group			Comparison Group		
Premise Category	Premise Count	Thermostat Count	Count of Metered AC	Premise Count	Thermostat Count	Count of Metered AC
One AC, one metered	45	45	45	42	42	42
Two AC, one metered	1	2	1	1	2	1
Two AC, both metered	5	10	10	6	12	12
Total	51	57	56	49	56	55

The re-set and comparison groups differed by no greater than a count of one between premise, thermostat, and metered AC categories. The two groups likewise were very similar in terms of nominal cooling capacity. The re-set group had a combined capacity of 214.5 tons, while the comparison group had a combined capacity of 202.5 tons. Averages sizes were 3.8 and 3.7 tons per unit, respectively.

2.1.2 Weather Data

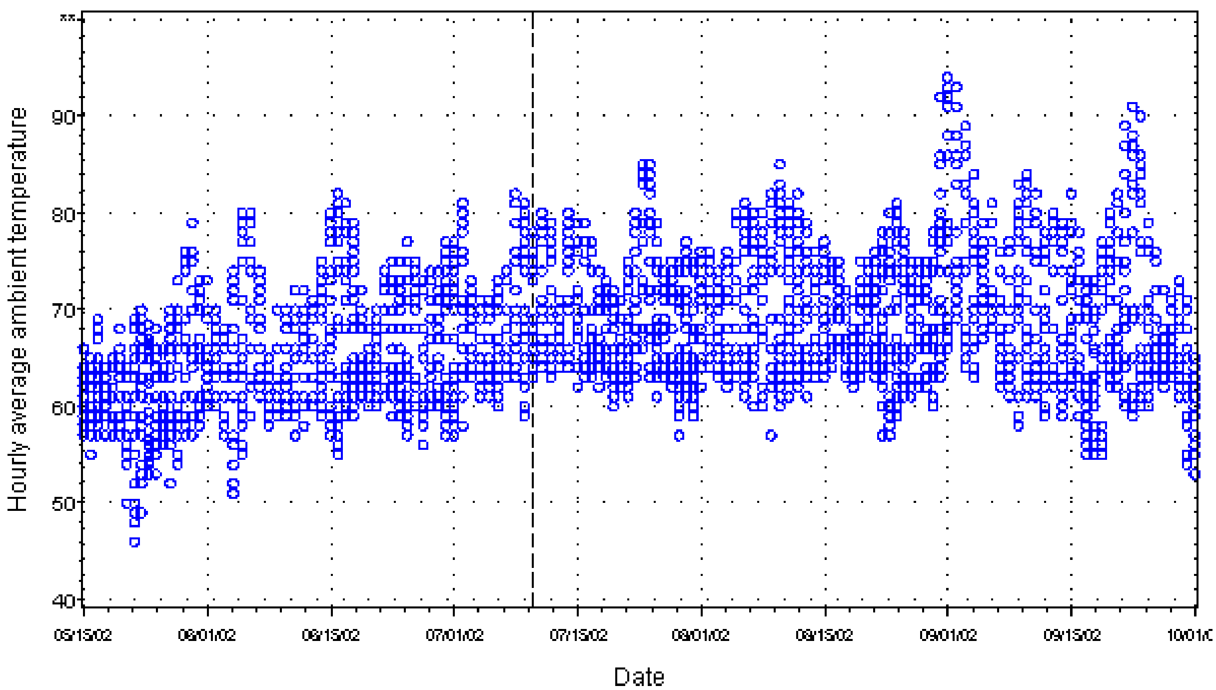
SDG&E provided observations of hour-ending average drybulb and dewpoint temperatures for the period from May through November 2002 from a weather station in Miramar, California. SDG&E believed these weather data to best represent the ambient conditions for the sample of program participants.

The weather data indicated a maximum drybulb temperature of 94°F at noon on September 1, 2002. It was a relatively cool summer. There were only 217 hours when the average drybulb temperature was 80°F or higher. Table 2-2 indicates the distribution of the temperatures above 80°F. Figure 2-1 charts the temperature variations across the summer, with a vertical reference line to indicate the re-set date of July 10.

Table 2-2
Count of Summer 2002 Hours At 80°F or Higher

Drybulb Temperature Range	Hours in Range
80–84°F	155
85–89°F	50
90–94°F	12
Total	217

Figure 2-1
Summer 2002 Ambient Temperature at Miramar, California (°F)



Vertical line indicates re-set event on July 10, 2002.

2.1.3 Event and Customer History Reports from Silicon Energy

The Silicon Energy EEM Suite website (rem.siliconenergy.com/siliconenergy/rem/asp/ event_summary_setup.asp) allowed ready access to and downloading of data on customer participation in the July 10 re-set event. These data included an observation for each thermostat that had been included in the re-set. Each observation identified the sample group to which the thermostat belonged, as well as customer name and account number information. Additional fields described the start time and planned duration of the re-set event, the amount in degrees Fahrenheit of the thermostatic cooling setback, and time stamps of thermostat acknowledgement of re-set and of over-ride as appropriate. It was these last two time stamps that identified "nonresponder" thermostats that did not appear to receive the re-set signal, and over-ride thermostats.

Customer history data were also available at the website. These data included customer name and contract number and a seven-digit number listed by the name "PIN" in the data. The PIN number in the customer history data was critical to collating metered consumption data with event participation data. The metered consumption data had a PIN number and a contract number, but the contract numbers did not match with either the customer history or event participation data. The history and participation data had to be collated by contract number first. It was then that the consumption and event participation data were then collated using PIN numbers.

2.2 METHODS

This section describes the methods by which the collected data were examined to estimate demand impacts. A combination of methods was used, in part because the single re-set event alone did not allow a robust analysis. It had been hoped that multiple re-set events would occur in 2002 to allow more comparisons of energy consumption between the alternating re-set and comparison groups. However, as described in Section 1, re-set events under the Smart Thermostat Program are triggered by an ISO Stage 2 Alert. During the summer of 2002, the ISO called one Stage 2 Alert, so that there was only one re-set event for which impacts could be observed.

The analysis has three main parts.

1. The fraction of units potentially contributing to savings is determined.
2. The impacts for the observed re-set period are calculated from analysis of the load data for potential contributors, then adjusted for the fraction not contributing.
3. The impacts for a range of conditions are projected based on the same load models used for the particular-day analysis, and adjusted for the same fraction of noncontributors.

These steps are described below.

2.3 POTENTIAL CONTRIBUTORS

Not all AC units in the program provide savings during a re-set event. This analysis determines the average savings per unit in two parts. First, the average savings per unit is determined for the subset of units classified as "potential contributors" to savings. Savings for the remaining units are zero. The overall average savings across all units is then calculated by multiplying the average savings for potential contributors by the fraction of units in this category. Thus, for example, if only one-quarter of the units in the program are estimated to be potential contributors to savings, the unit savings estimated for the potential contributors is reduced by one-quarter to get the savings per unit across all units in the program.

An alternative approach to accounting for units that do not contribute to savings would be simply to calculate savings directly over all units, both contributors and noncontributors, in the metered samples. With this more direct approach, however, the fraction of zero contributors in each metered group is random. This random variation in the proportion of zero contributors in each group adds to the variance of the estimated savings.

The two-part approach used here provides a more accurate estimate of the overall program savings. The accuracy is higher because the estimates of zero contributors are based on the largest available set of information, rather than on the metering sample only.

There are three reasons a unit might not provide demand savings during a re-set period:

1. The unit fails to receive the re-set signal.
2. The unit receives the re-set signal, but the customer over-rides the re-set.
3. The unit is not in use at the time the re-set signal was sent, therefore has no reduction to provide.

Data on the fraction of units that do not receive signals and the fraction that over-ride are available from the Silicon Energy website for the full participant population, for each re-set event. Whether or not an AC unit was in use on a particular day is determined only from the metering data.

2.3.1 Signal Failure Fraction

Signal receipt itself is not directly observed. What is known for all units in the program is whether they returned a signal to the system headend, acknowledging receipt of the re-set signal. We use the percent of units that do not send an acknowledgement as an upper bound on the percent that did not receive a signal. If the signal transmission in each direction is such that virtually any unit that successfully received a re-set signal would successfully return an acknowledgement, this percent of nonresponders is very close to the percent who didn't receive a signal, and is not an overstatement.

On the other hand, if signal failure randomly affects a fraction of units essentially symmetrically and independently in each direction, the fraction nonresponding overstates the fraction not receiving a signal. In this case, we can assume that half the nonresponders did not receive a signal, and half received a signal but the response signal failed. Thus, we treat one-half the observed fraction of nonresponders as a lower bound on the percent not receiving the re-set signal.

2.3.2 Over-ride Fraction

The number of switches over-ridden is recorded directly. However, only those switches that received a signal can over-ride. Thus, we consider the over-ride fraction as a fraction of those that received the signal.

2.3.3 Fraction Zero Use

Units that are never used during weekdays over the entire summer cannot contribute to savings from this program at any time. We determine the fraction of zero users based on analysis of the metered air conditioning data. This fraction is determined from the full metering sample, not just those in the re-set group on the particular day a re-set occurred. The full sample is the largest group for which we can estimate this population characteristic.

The “summer non-zero users” are those units that were used on a weekday at some time over the summer. Included in this group are some units that had zero use on the particular re-set day. We do not attempt to estimate a zero use fraction separately by re-set event. However, the effects of zero use by a subset of those who at least some of the time are non-zero users are included in the average impacts estimated for the non-zero use group.

2.3.4 Potential Contributors and Noncontributors

We estimate the fraction of units that are complete noncontributors to savings as:

$$p_{NC} = p_F + (1\text{-}p_F)(p_{OR} + p_z)$$

where

p_{NC} = fraction of units that are noncontributors

p_F = fraction of units that had signal failure

p_{OR} = fraction of units that over-rode, out of those that did not have signal failure

p_z = fraction of units with zero weekday AC usage all summer.

That is, all units with signal failure (p_F) are noncontributors. Of the remaining units (1-p_F), those that cannot contribute to savings are those that over-ride (p_{OR}) and those that were never used (p_z). These proportions are additive because they are essentially mutually exclusive. Whether a unit has zero use is assumed to be independent of whether or not the signal was received.

2.4 Impact Estimates on Re-set Day

This section describes the estimation of the average demand impacts for the single re-set event.

2.4.1 Overview

The impact estimates were developed in the following steps.

1. Fit a weather model to the interval load data, separately for each AC, in both groups.
2. For the re-set event
    a. For each AC in both Group A and Group B, use the AC's load data model (1) to estimate the load for that unit with no re-set
    b. For each quarter-hour of the re-set period, calculate the average over each group (A and B) of the difference between the observed load and the load model estimated load.
    c. Calculate the savings for each time interval of the re-set period as difference between the average re-set group difference from the model estimate and the average comparison group difference. This is the "difference of differences" estimate of savings.

These steps are described further below.

2.4.2 Load Model

To estimate the demand impact of a re-set event, it is necessary to estimate the demand to be expected without re-set. The first step in the analysis, therefore, was to fit a time-weather model to each premise's weekday energy consumption data. Weekends were not of concern since re-set is limited to weekdays.

There were a large number of premises in both the re-set and the comparison groups for which the model fit was moot. These were the premises that rarely, if ever, used their AC during weekdays between 10 AM and 10 PM. Their counts are provided in Section 3. These premises were set aside simply as having a load equal to zero during weekday afternoons. Their contribution to the program's aggregate demand impact likewise was zero.

After identifying premises with some weekday AC use, the model fit their hourly AC consumption to weather, specifically to hourly average ambient temperature. This was done after summing the 15-minute interval observations of AC consumption for a premise by each hour of each date. The modeling process then developed an estimated cooling base temperature for each premise. This cooling base temperature is the minimum ambient temperature at which AC use begins, and below which there tends to be no AC load.

The cooling base temperature was estimated by a grid search over the full possible range of combinations of heating and cooling base temperatures. Specifically, Eqn. 2-1 was fit separately for each premise to the AC consumption data for each of the 24 hours of a weekday. The optimal model of cooling and heating base temperatures then was chosen on the basis of the maximum R^2 of the fit.

$$L_{jdh} = \alpha_{jh} + \beta_{Hjh} H_d\left(\tau_{Hj}\right) + \beta_{Cjh}\, C_d\left(\tau_{Cj}\right) + \varepsilon_{jdh} \qquad \textbf{Eqn. 2-1}$$

where

L_{jdh}	=	sum of 15-minute interval AC consumption at hour *h* of day *d* for premise *j*;
$H_d(\tau_{Hj})$	=	heating degree-days at the heating base temperature τ_{Hj} for premise *j*, on day *d*, based on daily average temperature;
$C_d(\tau_{Cj})$	=	cooling degree-days at the cooling base temperature τ_{Cj} for premise *j*, on day *d*, based on daily average temperature;
ε_{jdh}	=	regression residual; and
α_{jh}, β_{Hjh}, β_{Cjh} τ_{Hj} τ_{cj}	=	coefficients determined by the regression.

The degree-day variables are calculated as

$$C_d(\tau_{Cj}) = \max((T_d - \tau_{Cj}),0)$$

$$H_d(\tau_{Hj}) = \max((\tau_{Hj} - T_d),0)$$

where T_d is the "daily average temperature," calculated as the mean of the daily minimum and maximum for day *d*. Because of thermal lags in the house, this form of daily average tends to be a better predictor of heating and cooling loads than the current hourly temperature, or than an average for particular hours of the day.

An alternative approach considered was to use lagged temperature variables in the cooling model. This approach can be effective. However, lag effects get confounded with time-of-day effects so that it may be difficult to obtain meaningful hourly coefficients if lag terms are also included. Using coefficients that do not vary by hour doesn't allow behavioral effects to be captured. The hourly coefficients β_{jh} account both for different behavior by time of day and also for the effects of thermal lags.

The model fit yielded 24 cooling load equations for each premise, one equation for each hour of a weekday. The independent variable for the model then was the daily average temperature. The heating and cooling base temperatures are additional coefficients estimated by the model fit. A single heating base temperature and a single cooling base temperature are estimated across all 24 hours.

Using estimates of the regression coefficients from this fitted equation, as indicated in Eqn. 2-2 by the overscript '^', and cooling and heating degree-days $H_d(\tau_{Hj})$ and $C_d(\tau_{Cj})$ for day *d* of the re-set event, the estimated load (without re-set) L_{jdh} , was calculated for each premise, day, and hour using Eqn. 2-2.

$$\hat{L}_{jdh} = \hat{\alpha}_{jh} + \hat{\beta}_{Hjh}\, H_d\left(\hat{\tau}_{Hj}\right) + \hat{\beta}_{Cjh}\, C_d\left(\hat{\tau}_{Cj}\right) \qquad \textbf{Eqn. 2-2}$$

2.4.3 Load Model Error Correction

Any load model will have some estimation error. The particular model used in this analysis is relatively simple, using just the time of day and the daily average temperature. Effects of humidity, sunshine, wind, and lagged temperature are not explicitly modeled.

Because of some of these physical factors, a portion of the modeling error for a given day and hour will be similar across AC units. For instance, if the day is the third day of a heat wave, all homes might have higher usage than the load model would indicate based on that day's temperature alone. Likewise, if the day is very breezy, usage might tend to be lower than the temperature model would indicate. Further, even with a more sophisticated physical model there may be behavioral changes related to events in the news or holiday schedules that would be similar across homes.

The use of the comparison group provides a basis for correcting these systematic modeling errors. We take the average modeling error for the comparison group as an estimate of the likely average modeling error for the re-set group.

Thus, we calculate:

Re-set group average (unadjusted) model estimate for hour *h*

$$\hat{\bar{L}}_{rh} = \Sigma_{j \in R} \hat{L}_{jh}$$

Comparison group average model estimate for hour *h*

$$\hat{\bar{L}}_{ch} = \Sigma_{j \in C} \hat{L}_{jh}$$

Comparison group average model error for hour *h*

$$\bar{e}_{ch} = \Sigma_{j \in C} (L_{jh} - \hat{L}_{jh}).$$

Re-set group adjusted estimate of load if the re-set had not occurred

$$\hat{\hat{L}}_{rh} = \hat{\bar{L}}_{rh} + \bar{e}_{ch}.$$

(In these equations, the day subscript *d* is suppressed, since all the calculations are for the single re-set day.)

The group average savings or any hour h of the re-set period is then given as the difference between this adjusted estimate of load in the absence of re-set, and the observed load during the re-set period:

$$S_{rh} = \hat{\hat{L}}_{rh} - \bar{L}_{rh}$$

where $\bar{L}_{rh}$ is the average observed load for the re-set group at hour h. This equation can also be written as

$$S_{rh} = -\{(\bar{L}_{rh} - \hat{\bar{L}}_{rh}) - (\bar{L}_{ch} - \hat{\bar{L}}_{ch})\}.$$

That is, the comparison-group error is subtracted from the re-set group error. This is the "difference of differences" expression. That is, the savings is estimated by subtracting the comparison-group difference from modeled from the re-set group difference.

2.4.4 Savings Estimates by Time Interval

The load model is estimated on an hourly basis, and the savings equations above indicate estimates for each hour. However, the load data were available on a quarter-hour basis. kW savings for each quarter-hour interval were calculated analogously to the hourly equations indicated above. For the quarter-hourly estimates, the load in each time increment was estimated using the load model coefficients for the hour that included that increment.

Savings were also calculated for the average of the entire re-set period. Since this period's start and stop times did not coincide with exact quarter-hour increments in the data, the closest set of increments to the re-set period was used. For the overall re-set period savings, each AC unit's average observed load during the re-set period was calculated across all increments in the period. Each unit's estimated load was similarly averaged across all re-set period time increments. The difference of difference calculation was then applied to these re-set period averages to obtain the re-set period average kW savings.

2.4.5 Assessing Comparability of the Comparison Group

The savings estimation approach assumes that the modeling error for the comparison group is a good indicator of the likely modeling error for the re-set group if no re-set had occurred. Thus, an important step prior to applying this method was to assess whether the two groups were in fact similar.

Premises were selected at random for the metering sample, and were randomly assigned to Group A or B. Thus, there was no a priori reason the groups should have been different. However, random effects could result in observable differences at the outset that would suggest a need for some kind of adjustment.

A particular concern was that the sizes of the air conditioning units in the two samples might be different. In this case, the comparison group error might be a good indicator of the re-set group error, but a scaling factor might need to be applied to the comparison group error to adjust for the size difference. Our original plan was to calculate savings after normalizing the two groups' observed and estimated loads by dividing by their respective average air conditioner capacity, in tons.

As it turned out, the two groups had practically the same distribution of AC unit size, and this normalization was not necessary. We compared the two groups in terms of the mean, median, minimum, maximum, and standard deviation of tons, both for the full sample and for the smaller sample used in different stages of the analysis, described in Section 3. In terms of these distribution statistics, the two groups were very similar to one another, and were similar also across the different subsets used in the analysis.

An additional check was to plot the average re-set group model error against the average comparison-group model error, for warm weekday afternoons excluding the re-set day. This plot is presented in Section 3.

This comparison showed a strong relationship between the two groups' errors. The comparison also showed a similar standard deviation of error between the two groups, indicating no scale difference. A regression of re-set average error on comparison group average error had an intercept very close to zero, indicating no systematic shift between the two. These comparisons support the use of the comparison group without scale adjustment.

Even with very comparable groups, normalization by capacity could be considered as a variance reduction technique. Ratio estimation, such as calculating savings per ton rather than mean savings per unit, can often be effective in reducing the variance of impact estimates. However, for this method to be effective in variance reduction, it is necessary to have the normalization variable known for the entire population. In this study, capacity data were collected for the metering sample to allow for scaling between the re-set and comparison groups if necessary, but were not available for the general population of participating AC units. Thus, once it was determined that scale adjustment was not required between the two groups, no normalization by capacity was used in calculating the savings estimate.

2.4.6 Whole-premise Analysis

For the re-set event, the same analysis method was applied to the whole-premise data as the AC data. The same units identified as potential contributors by the end-use analysis were included in the whole-premise analysis.

The results of this analysis, presented in Section 3, indicated that the AC-only estimates were more reliable than the whole-premise estimates. Thus, despite the slight bias resulting from the exclusion of the fan load from the AC metering, we treat the AC results as the preferred estimates. For the projected savings, we used only the AC-only models.

2.5 PROJECTED IMPACT ESTIMATES FOR GENERAL CONDITIONS

This section describes the methods by which demand impacts were estimated under general conditions. A general condition is defined simply by a daily average temperature and an hour of the day. The methods for general conditions used the same load models as described above, but essentially applied a theoretical model of equivalent temperature differences to describe the effect of re-set.

2.5.1 Model AC Loads at Different Temperatures

The load models described above to estimate load *without* re-set were used here in that same way. The average daily temperature and hour of day were the independent variables determining the load at a premise. The same models then were used to describe the load *with* re-set. The modeling difference was simply the daily average temperature used.

Loads *with* re-set were estimated using the daily average temperature less the thermostat setback. This in effect lowers the average daily temperature and thereby decreases the cooling load. That is, the effect of setting the thermostat forward by δ degrees is essentially the same as the effect of dropping the ambient temperature by δ degrees. The magnitude of the thermostat setback, in degrees Fahrenheit, thus was a critical determinant of the load with re-set. The basis for the demand impact estimate for a premise was simply the load without re-set less the load with re-set.

2.5.2 Accounting for Noncontributors and Nonresponders

As for the impact on the actual re-set day, this method is applied to the set of AC units with "effective impacts"; that is, to those that had non-zero usage and were not nonresponders or over-rides. The effects zero usage, nonresponders, and over-rides were estimated by applying the same adjustment for these effects as for the analysis of the one actual re-set event.

2.5.3 Calibration Against a Single Re-set Event

The impact estimates developed for the day of the re-set event were compared to estimates using this more general approach and using the daily average temperature for July 10, 2002. Consideration was given to calibrating the projected savings to the findings for the observed re-set day. As described in Section 3, however, with the information currently available, it is not clear if the projections require any adjustment.

3 FINDINGS

This section describes the findings of the analysis of the metered consumption data and the re-set event data. We first describe the data screening used to determine which meters had usable data for the analysis. We then present the results of the analysis steps described in Section 2:

- Estimation of the Fraction Noncontributing
- Impacts for the Re-set Event
- Projected Impacts for General Conditions.

3.1 UNITS USED IN THE ANALYSIS

3.1.1 Identifying Meters with Good Data

Most of the 100 premises from which 15-minute interval energy consumption data were collected had acceptable whole-premise and AC observations. There were 10 exceptions. These were premises with missing or suspicious AC data.

There was a single premise that had no AC data available at all. A meter failure is believed to be the cause. This lack of data necessarily excluded the premise from the analysis.

There were eight premises with observations having AC energy consumption greater than whole-premise consumption. This should never be possible. Several of these premises were found later to have meter configuration problems. This questionable data excluded all eight premises from the analysis.

Another premise had non-zero values in over 99 percent of its AC consumption observations. This is not entirely unusual as there are many older AC that have small emollient or case heaters to prevent liquid refrigerant from ever entering the condenser's compressor. These heaters are generally less than 100 Watts. Thus, it is possible to see nearly continuous 15-minute interval observations of as much as 25 Watt-hours (Wh) for some AC. This premise, however, had nearly continuous observations between 70 and 90 Wh. This is a load between 280 and 350 Watts, which is too low for continuous operation of even a small capacity AC and too high for an emollient heater. This suspicious data excluded the premise from the analysis.

After excluding the 10 premises, there were 90 remaining with usable consumption data. The consumption data collection failure rate thus was 10 percent. This is somewhat high but not entirely unexpected in AC metering studies of this duration. The 90 premises whose consumption data were initially considered for use in the analysis had an average of 146 days with energy consumption data. The maximum and minimum numbers of days with data were 197 and 97, respectively.

Table 3-1 lists the counts of premises by an initial data classification of their consumption data and by group.

Table 3-1
AC Counts by Initial Data Class of Collected Energy Consumption Data

Initial Data Class	AC Count			Group Percentage	
	Re-set Group	Comparison Group	Sample Percent	Re-set Group	Comparison Group
Load not modeled due to suspect data	6	5	10%	11%	9%
Load not modeled due to weekday AC non-user	15	10	23%	27%	18%
Load modeled but nonresponder or over-ride during re-set	7	NA	6%	13%	NA
Load modeled and included in analysis as weekday AC user	28	40	61%	50%	73%
Total	56	55	100%	100%	100%

3.1.2 Units Included in Each Analysis Component

As described in Section 2, the AC units were classified as either "noncontributors" or "potential contributors." Noncontributors were those that either had zero usage on all summer weekdays, did not receive the re-set signal, or over-rode the signal. Potential contributors were those with successful signal receipt, no over-ride, and non-zero usage during summer weekdays. Load data analysis was used to determine the savings per unit for potential contributors. This unit savings was then adjusted by the estimated population percent of potential contributors to obtain the average savings over all units, including the noncontributors.

The load data modeling was restricted to units with non-zero summer weekday usage. The full set of AC meters with good data, after the screening described above, was used to determine the fraction of units with non-zero summer weekday usage. All units with good data and non-zero usage were used to determine the projected savings for general conditions. These units were used also for the load model analysis for the observed re-set event. However, for this analysis, the units in the re-set group that were nonresponders or over-riders were also excluded.

Table 3-2 indicates the number of units included at each stage of the analysis. A total of 111 AC units were metered, of which 100 provided usable data. However, only 75 of these had non-zero summer weekday use. Thus, the fraction of units with zero summer weekday use is estimated from this sample as 25 percent.

Table 3-2
Units in the Analysis

Category	Analysis Use	Group	Number of AC Units
All units		**A**	56
		B	55
		Total	111
Units with good data		**A**	50
		B	50
	Denominator of fraction non-zero summer use	**Total**	100
Units with good data and non-zero summer use		**A**	35
		B	40
	Potential savings load modeling Numerator of fraction non-zero summer use	**Total**	75
Potential Contributors:	*Re-Set Day Load Modeling*	**A**	28
Units with good data and non-zero summer use,	*Re-Set Day Load Modeling*	**B**	40
excluding non-responder and over-ride from re-set		**Total**	68

Load model results from all 75 units with non-zero summer weekday use were used in calculating the projected impacts for general conditions. For the impact analysis of the actual re-set event, the 8 units in this group that either did not respond to the re-set signal or over-rode the re-set were excluded from the re-set group load model analysis. For the comparison group. there was no opportunity for either signal nonresponse or over-ride, hence there were no such exclusions.

3.2 FRACTIONS POTENTIALLY CONTRIBUTING AND NOT CONTRIBUTING TO SAVINGS

The analysis levels indicated above as well as the impact adjustment for noncontributing units require estimates of the fractions of non-zero summer use, signal failure, and over-ride.

3.2.1 Identifying AC Non-users

AC non-users were identified by the absence of AC data, indicating more than minimal AC use during weekday afternoons. AC use was defined as a quarter-hourly consumption observation greater than 0.025 kWh to allow for the possibility of continuously case or emollient heaters running in the condenser. Minimal AC use then was defined as having less than one percent of quarter-hourly observations between 10 AM and 10 PM on weekdays between May 1 and October 1 showing AC use.

Since only one AC energy consumption meter was used at any one premise, two-thermostat premises considered non-users necessarily showed no AC use from either thermostat. If they showed AC use and two AC-metered, it could not be discerned whether one thermostat might have been a non-user.

It is recognized that metering errors could result in the appearance of no AC use at any hour. While this remains a possibility, it is to be expected during a relatively cool summer that many premises might not have any AC use at all.

3.2.2 Nonresponding Thermostats

Nonresponding thermostats are identified as nonresponders on the Silicon Energy EEM Suite website. The nonresponders were identified by event reports available from that website (sdgerem.siliconenergy.com/siliconenergy/rem/asp/ event_summary_setup.asp). Nonresponder thermostats had neither an acknowledgement time stamp nor an over-ride time stamp in the event report.

As discussed in Section 2, for some nonresponders the unit may in fact have raised the cooling setpoint successfully but failed to send an acknowledgement reply to the system headend. Thus, the percentage of thermostats reported as nonresponders could be viewed as an upper bound on the signal failure rate. On the other hand, there could also be cases where the signal was received but the re-set did not occur. Recognizing these potential sources of over- and under-statement, we treat the percent not responding to the re-set signal as the percent that were not re-set.

For the single observed re-set event, there were 232 nonresponders out of 2,259 thermostats in place in the program. Thus, an estimated 10.3 percent of units were not re-set due to signal failure.

3.2.3 Over-ride Thermostats

Over-ride thermostats also were identified by event reports available from the Silicon Energy EEM Suite website. Over-ride time stamps were available in those reports. They were believed to indicate the time of receipt of the over-ride acknowledgement message. Thus, there could be some delay between the time the occupant changed the setpoint and the reported over-ride time. The possible range of delay times is believed to exceed 15 minutes.

The over-ride stamp always indicates that the setpoint has been reduced after the re-set signal increased it. A thermostat that was set to a higher setpoint than that set by the re-set signal, or an AC unit that was turned off, would not be registered as over-riding. Thus, over-riding thermostats always reduce the total savings.

As indicated, during the single observed re-set event, there were 155 units over-riding out of the 2,027 that had a successful signal response, for an over-ride rate of 7.6 percent among the responding units.

3.2.4 Percent Not Contributing

Table 3-3 summarizes the nonresponder and over-ride findings during the July 10 re-set event. The population values are used in calculating the proportions not contributing to savings. The re-set group counts indicate the number of units excluded from the model of potential contributor savings for the re-set day. The comparison group received no re-set signals, hence had no nonresponse or over-ride to record. The Silicon Energy website report for that event provided the data. About 20 observations without account numbers were removed from that report as they were suspected to be thermostats not installed.

Table 3-3
Counts of Metered AC by Data Category and July 10 Event Status

	Program Population		Re-set Group	
Event Status	Thermostat Count	Percent	Thermostat Count	Percent
Nonresponder	232	10%	8	14%
Over-ride	155	7%	4	7%
Successful	1,872	83%	45	79%
Total	2,259	100%	57	100%

Table 3-3 shows that the nonresponder and over-ride percentages were similar for the re-set group to those for the program population as a whole. The nonresponder percentage in the re-set group, however, was higher than the program population's. The difference between the re-set sample and the population proportions of nonresponder thermostats are within the bounds that would be expected from random sampling: with a sample size of 57 and a population proportion of 0.9, the standard error of the sample proportion is 4 percent.

Table 3-4 summarizes the different types of noncontributors, and presents the overall estimate of the fraction not contributing. Nonresponders are 10.3 percent of the units. Over-riders are 7.6 percent, and zero users 25 percent of the remaining units. Combining these fractions as described in Section 2, the total fraction not contributing is 40 percent.

The remaining 60 percent are the potential contributors whose average savings per unit is determined in the load model analysis. Thus, if the average savings per unit among the potential contributors is equal to the ex ante estimate, the ex post savings estimate for the program as a whole would be only 60 percent of that.

Table 3-4
Estimate of Fractions Not Contributing and Potentially Contributing

Noncontributor Category	Basis	Numerator	Denominator		Percent
Nonresponder	Population	232	2259	pF	10.3%
Over-ride	Responding population	155	2027	pOR	7.6%
Zero summer use	Good meter sample	25	100	pz	25.0%
Total noncontributors	pF + (1-pF)(pOR + pz)			pNC	39.6%
Potential contributors	1-pNC				60.4%

3.3 Validation of Load Models and Comparison Group

3.3.1 Re-set and Comparison Group Characteristics

As described in Section 2, the size distribution of the comparison group was compared with that for the re-set group. The primary reason was to determine if there was a need to scale the savings by capacity and the appropriate magnitude of the scaling. The review also would reveal anomalous units.

Table 3-5 shows the distribution of AC unit capacity for each analysis group. The table shows that the re-set and comparison groups have essentially the same size distribution, in the initial sample selected and also in the reduced sets used for different parts of the analysis. Thus, there are no obvious anomalies in the selection of the units.

Table 3-5
Distribution of AC Unit Capacity (tons) by Analysis Category

			Capacity (tons)				
Category	**Group**	**Number of AC Units**	**Mean**	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
All units	**A**	56	3.8	4.0	2.0	6.0	0.9
	B	55	3.7	3.5	2.0	6.0	1.0
	Total	111	3.8	4.0	2.0	6.0	0.9
Units with good data	**A**	50	3.8	4.0	2.0	6.0	0.8
	B	50	3.6	3.5	2.0	6.0	1.0
Denominator of fraction non-zero summer use	**Total**	100	3.7	4.0	2.0	6.0	0.9
Units with good data and non-zero summer use	**A**	35	3.9	4.0	2.0	6.0	0.9
	B	40	3.7	3.5	2.0	6.0	1.1
Potential savings load modeling *Numerator of fraction non-zero summer use*	**Total**	75	3.7	4.0	2.0	6.0	1.0
Potential Contributors:							
Re-Set Day Load Modeling (re-set group)	**A**	28	3.9	4.0	2.5	6.0	0.9
Re-Set Day Load Modeling (comparison group)	**B**	40	3.7	3.5	2.0	6.0	1.1
	Total	68	3.8	4.0	2.0	6.0	1.0

3.3.2 Observed and Modeled Loads

Another type of method validation was examination of the quality of the load model fits for both the re-set and comparison groups. We considered both the AC end-use data and the whole-house data.

Table 3-6 summarizes key regression diagnostics for the end-use and whole-house model fits. The table indicates that the whole-house fits were generally better than the AC fits. The R^2 statistics were generally higher, and the t-statistics for the cooling slopes were also higher.

Table 3-6
Regression Diagnostics for End-use and Whole-house Load Model Fits

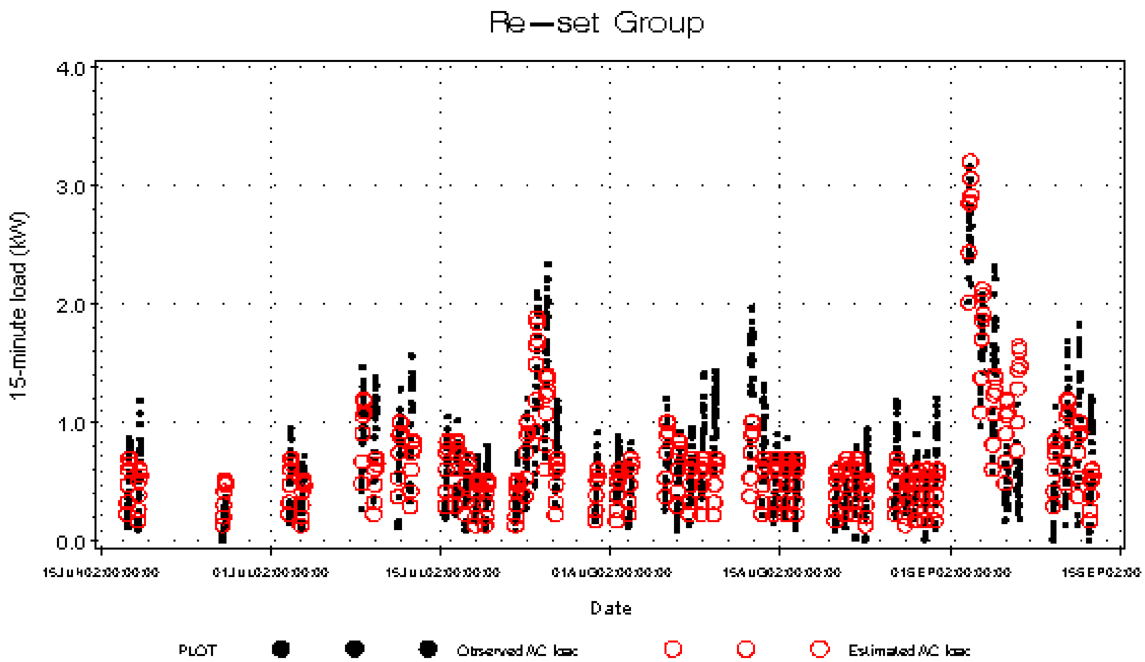
Regression Statistic	AC Data	Whole-House Data
Median R-squared	0.47	0.79
Median cooling slope t-statistics		
Hour 12	0.61	9.59
Hour 13	0.97	10.40
Hour 14	0.92	10.42
Hour 15	1.81	10.89
Hour 16	2.90	13.76
Hour 17	3.27	15.42
Hour 18	3.95	15.29

These comparisons are somewhat deceiving, because the data in the two models are different. Thus, despite the higher R^2 for the whole-house data, the end-use data generally exhibited smaller absolute modeling error. This higher absolute error was reflected in a much higher overall standard error of the final estimate when the whole-house data were used. For this reason, we focus on the AC model results.

For the AC model, Table 3-6 shows that the slope coefficients were reasonably well-estimated for the afternoon hours relevant to this analysis. Estimates for earlier hours are not as good, largely because air conditioning usage was generally low, and more intermittent.

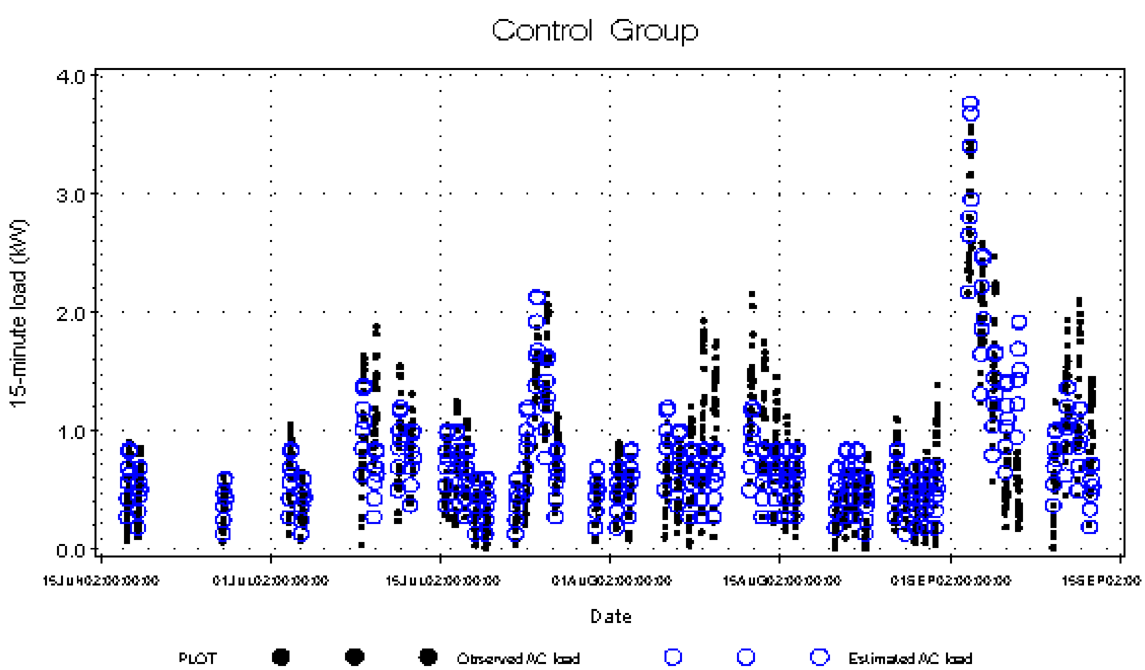
Figures 3-1 and 3-2 show observed and modeled AC loads for the re-set and comparison groups, respectively. The plotted data are limited to that from weekdays with an average temperature of 68°F or higher in summer 2002, time between the hours from 12 PM to 6 PM inclusive. The data shown are for the 28 re-set group and 40 comparison group units classed as "potential contributors." Each plot shows the estimated load tracking the actual load fairly well across the summer, for warm weekday afternoons. Comparison between the two plots also shows that the observed loads between the two groups also were similar, although there were some days with substantially different AC use.

Figure 3-1
Re-set Group Warm Weekday 15-minute Mean Observed (•) and Mean Estimated (◦) Loads vs Time



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

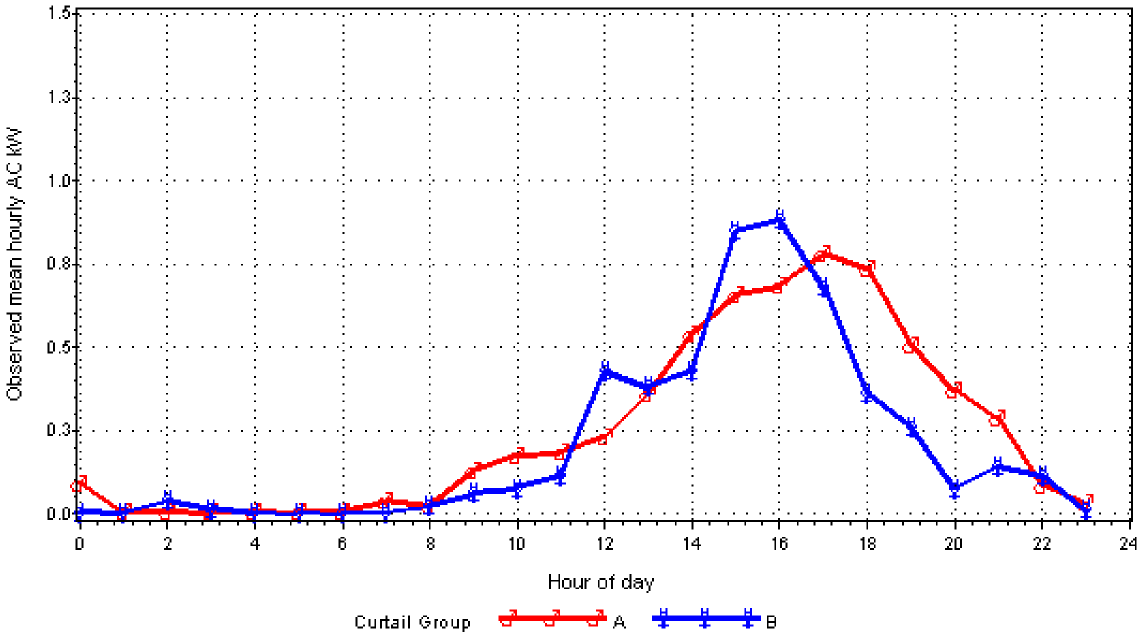
Figure 3-2
Comparison Group Warm Weekday 15-minute Mean Observed (•) and Mean Estimated (◦) Loads vs Time



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

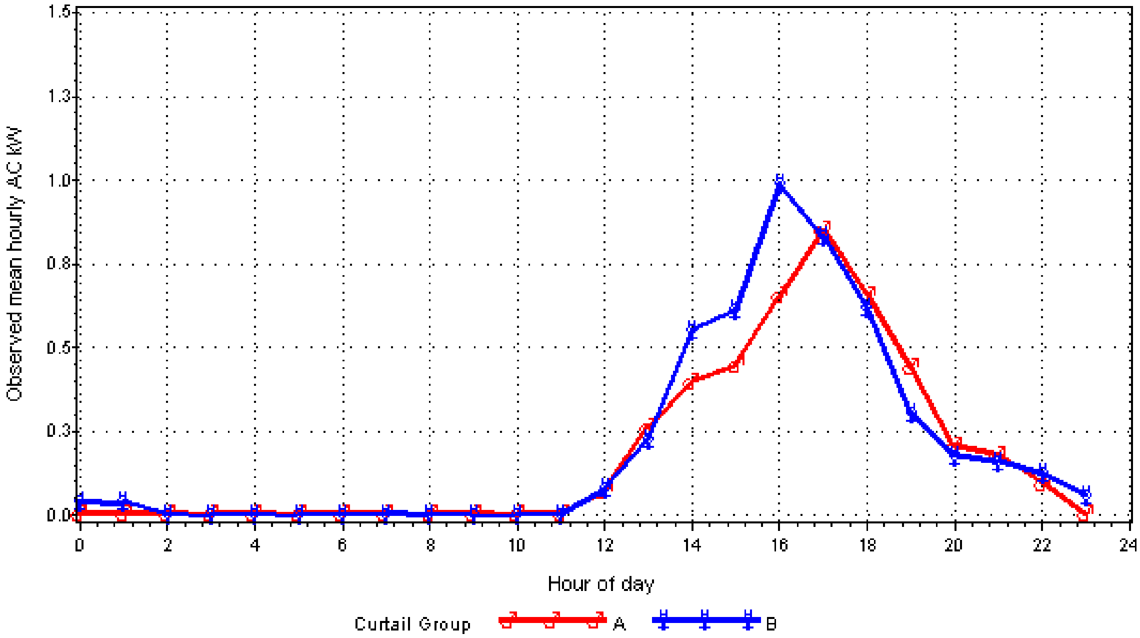
Figures 3-3a and 3-3b show hourly loads for the two groups for two days that had similar daily average temperature to that on the re-set day. Figure 3-3c shows a similar plot for the hottest day observed. While there are some differences between the two groups, the loads track one another fairly well on all these days.

Figure 3-3a
Re-set and Comparison Group Loads on a Day with Similar Temperature to the Re-set Day
Example 1



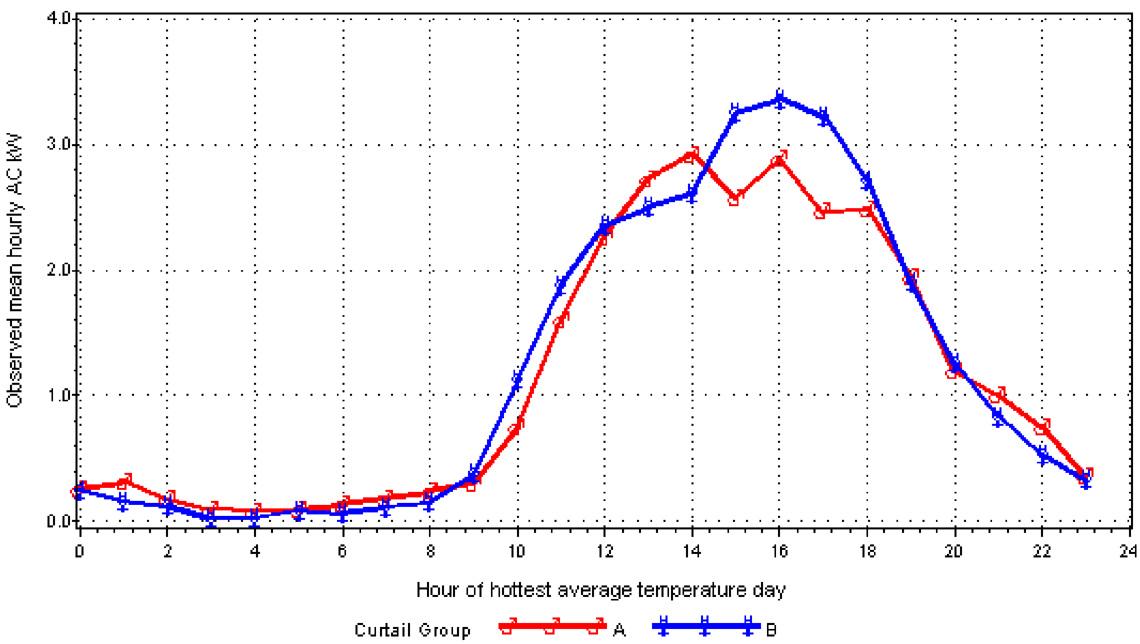
Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

Figure 3-3b
Re-set and Comparison Group Loads on a Day with Similar Temperature to the Re-set Day
Example 2



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

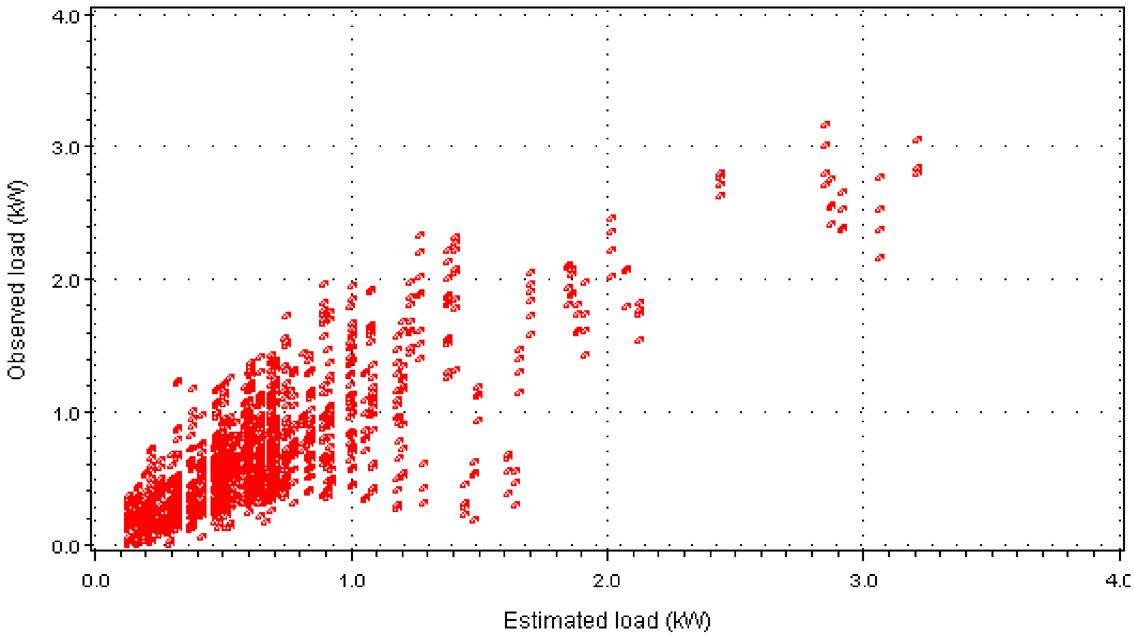
Figure 3-3c
Re-set and Comparison Group Loads on Hottest Day of the Study Period



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

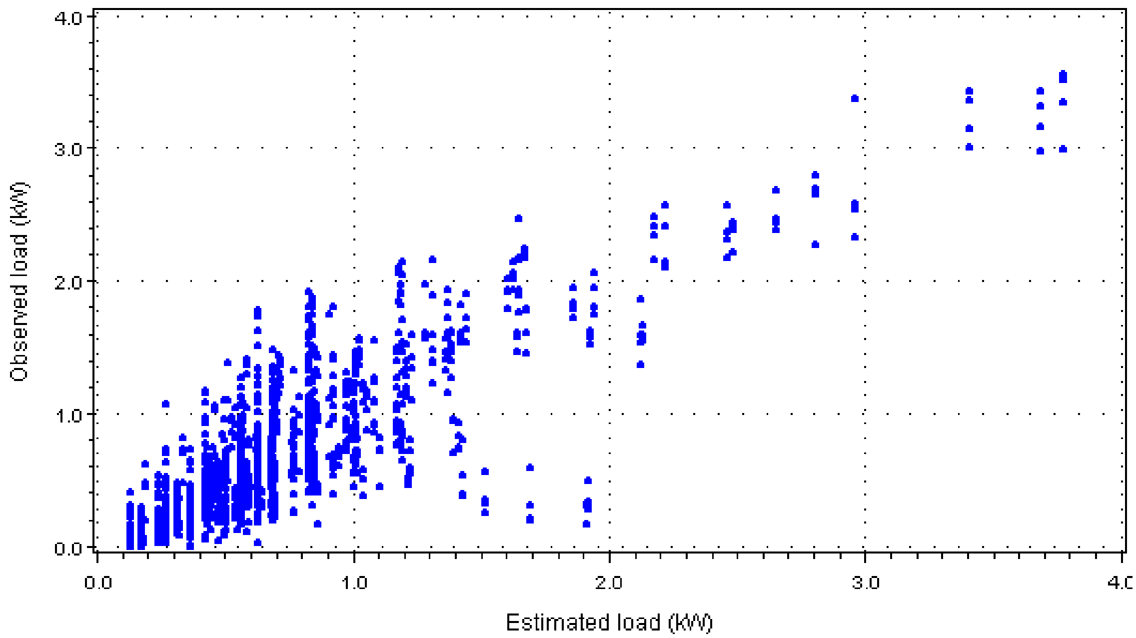
The same data as shown in Figures 3-1 and 3-2 are plotted in Figures 3-4 and 3-5. These charts show observed versus modeled hourly mean loads. Both charts show a fairly uniform linear relationship along a 1:1 ratio of observed to estimated load. This is a good indicator of model fit. Still there is a fair amount of estimation error given that each point is an average error over 28 and 40 AC units.

Figure 3-4
Re-set Group Warm Weekday Observed vs Modeled 15-minute Mean Loads



Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

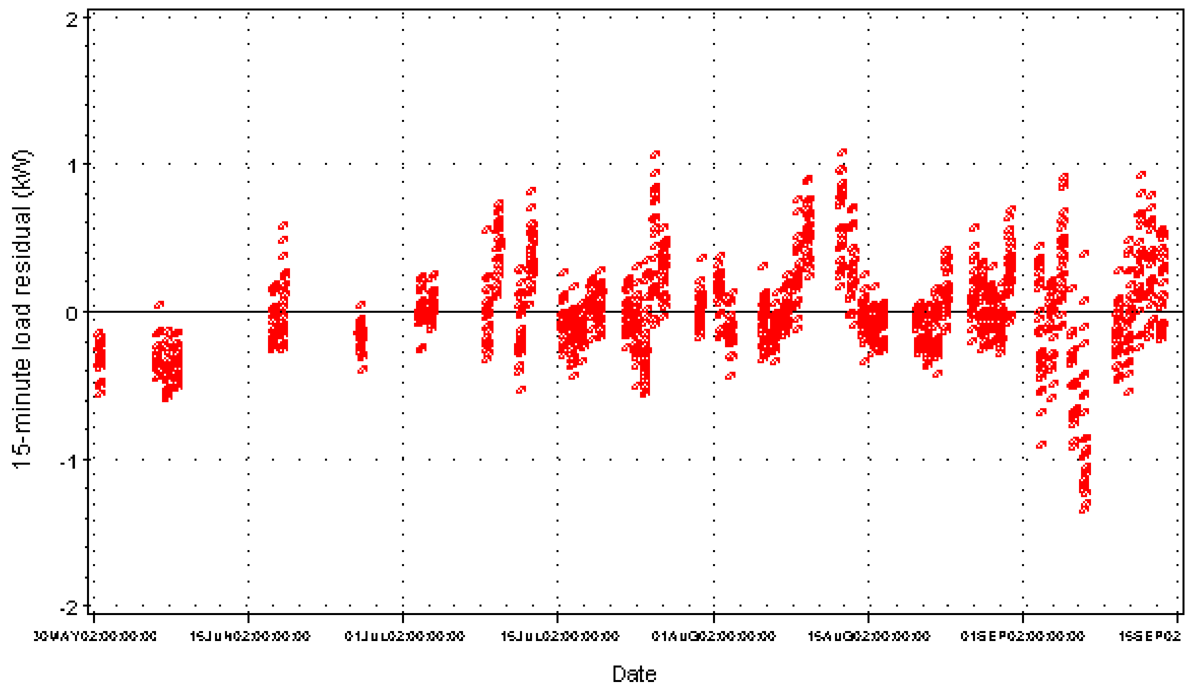
Figure 3-5
Comparison Group Warm Weekday Observed vs Modeled 15-minute Mean Loads



Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

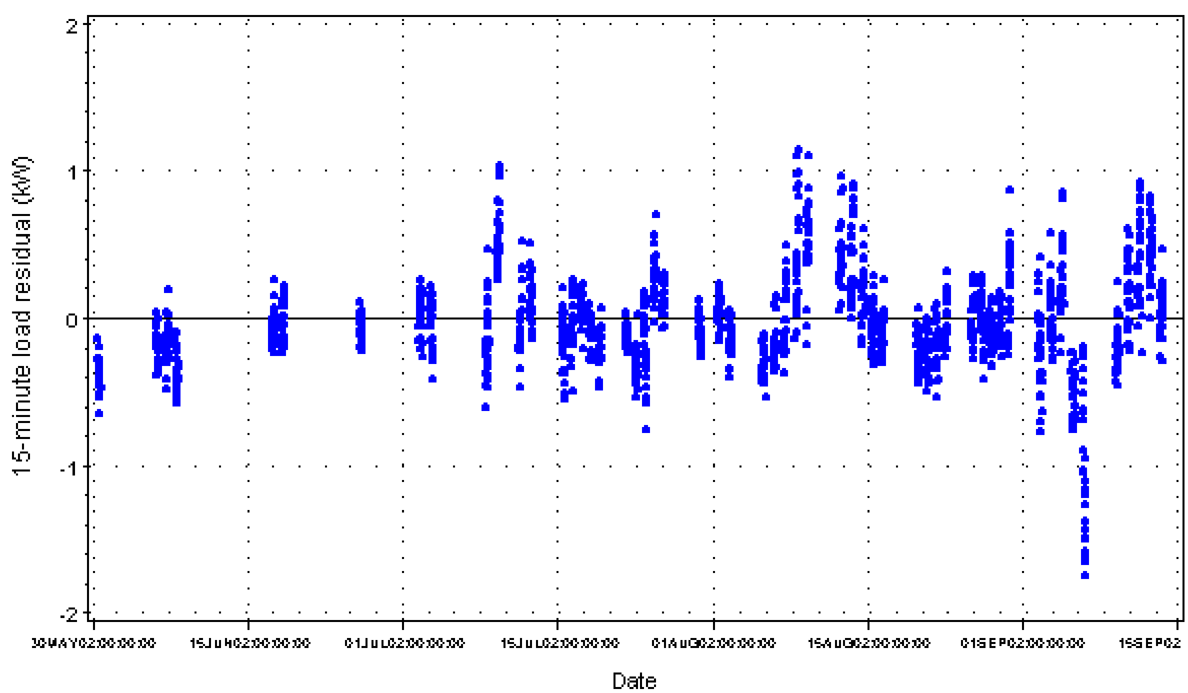
Figures 3-6 and 3-7 show the residuals, or errors, of the model estimates of hourly mean load from June 15 to September 15 for the re-set and comparison groups, respectively. The larger magnitude errors are concentrated among a few hours and not scattered across all hours. The patterns of errors over time are very similar between the re-set and comparison groups. This relationship is consistent with the conjecture that particular weather conditions for those days with larger errors create systematic modeling errors across premises. The similarity of the error pattern also shows that errors of the comparison group can be a good indicator of the error of the re-set group error for a given day and hour.

Figure 3-6
Re-set Group Warm Weekday 15-minute Mean Load Residual vs. Time



Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

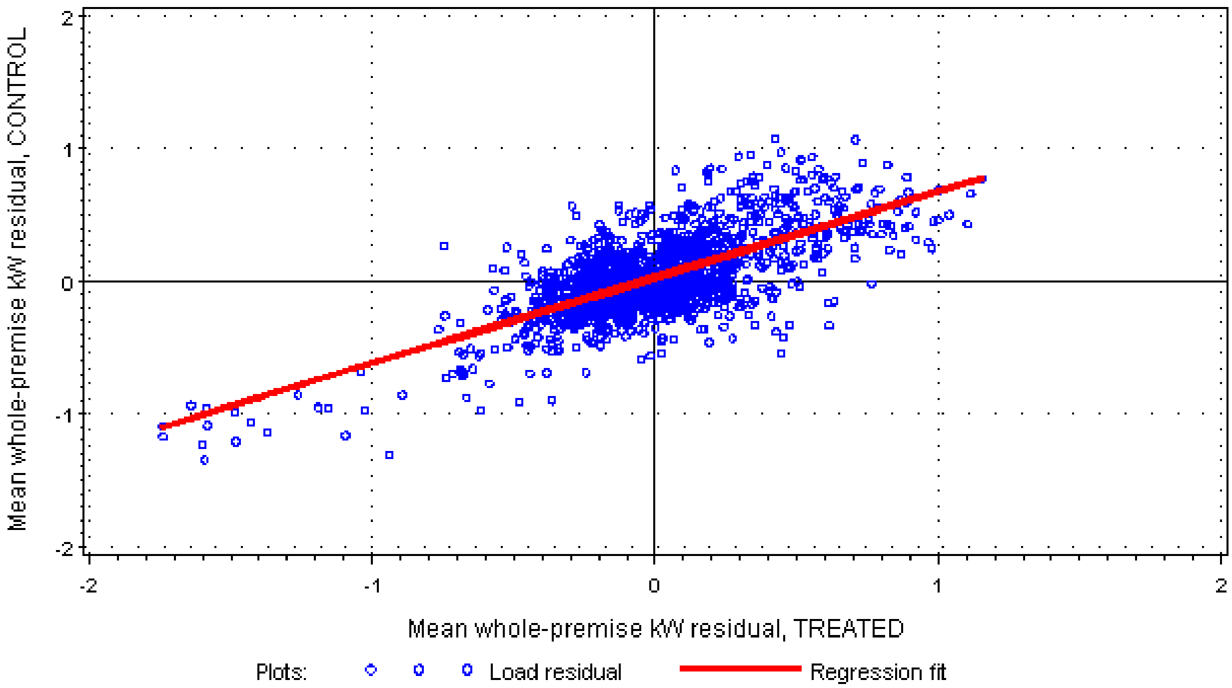
Figure 3-7
Comparison Group Warm Weekday 15-minute Mean Load Residual vs. Time



Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

The difference of difference method requires not just that the two groups be similar in actual load, but also that the modeling error for the comparison group be a good indicator of the modeling error for the other. Figure 3-8 shows a plot of the comparison group's hourly mean residuals against the re-set group's. Also shown is the regression line, which gave an R^2 of 0.59.

Figure 3-8
Comparison Group versus Re-Set Group 15-minute Mean Load Residuals and Regression

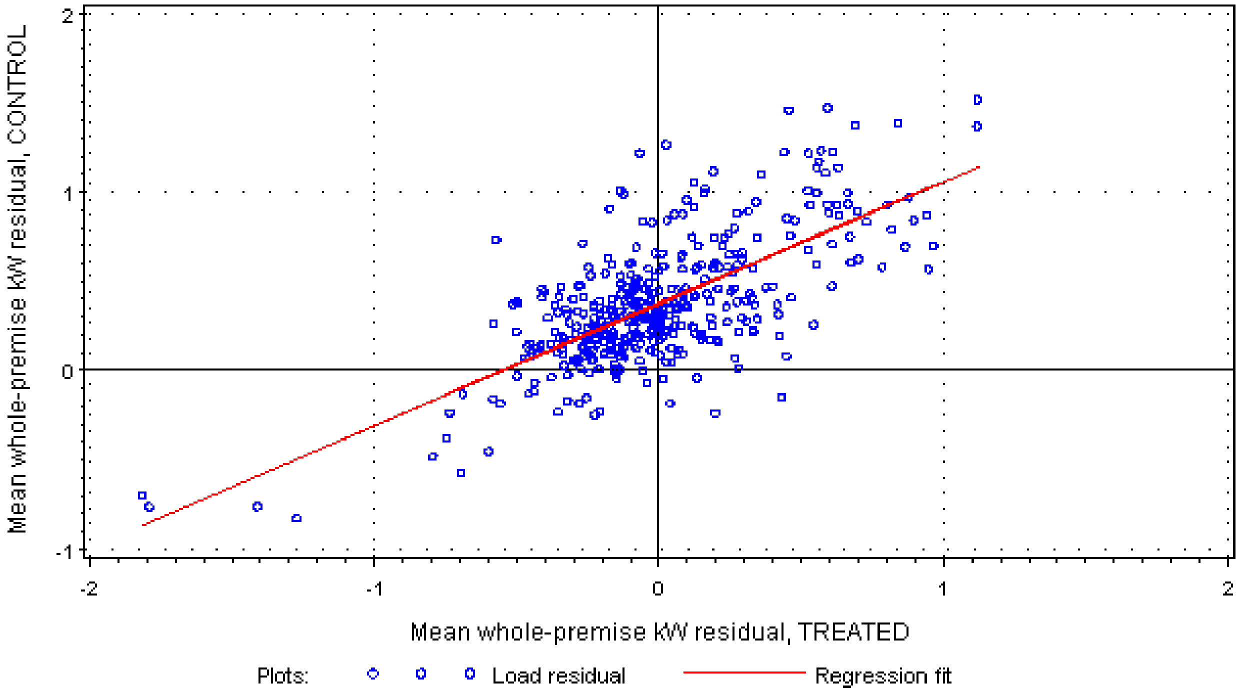


Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

The figure shows a strong relationship between comparison group and re-set group modeling error, with the regression line passing very close to the center point (0,0). The plot also indicates that the scale of the errors is similar, so that no scaling adjustment is required when using the comparison group to estimate the re-set group error. Thus, the difference of difference method appears to be well-founded for the end-use AC data.

A similar plot for the whole-house data, in Figure 3-9, gives a somewhat different relationship. While the scale of variation is similar for the two groups, the regression line does not pass through the origin. Rather, the average errors appear to be offset. This figure indicates that, for the type of days for which the model is needed in the analysis, the comparison-group error is not as good an indicator of the re-set group error as is true for the end-use data.

Figure 3-9
Comparison Group Versus Re-Set Group Modeling Error
Whole-House Data



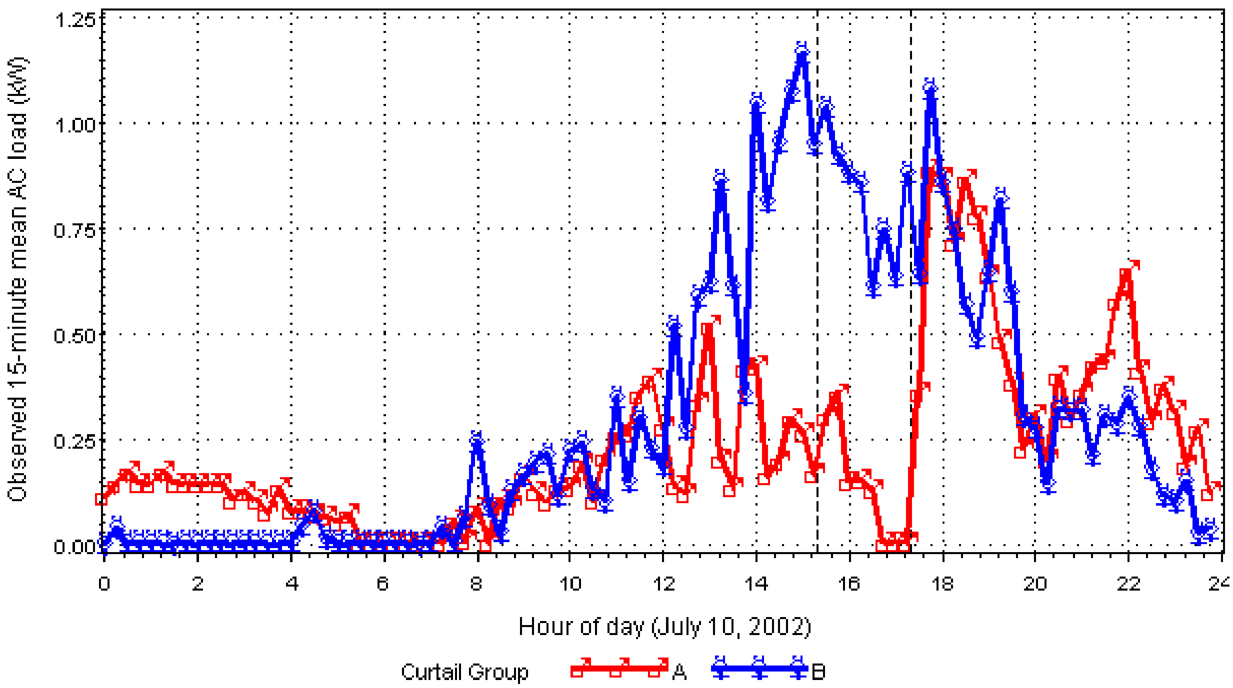
Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

3.4 Estimated Impacts of the Re-set Event

3.4.1 Modeled and Observed Load on the Re-set Day for Potential Contributors

The re-set period was from 3:20 PM to 5:19 PM on July 10. Figure 3-10 shows the average hourly loads observed on that day. These data reflect only the “potential contributor” premises. These were weekday AC users and were neither nonresponders nor over-riders during the re-set.

Figure 3-10
Observed 15-min Average AC Loads on Re-set Day vs. Time



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

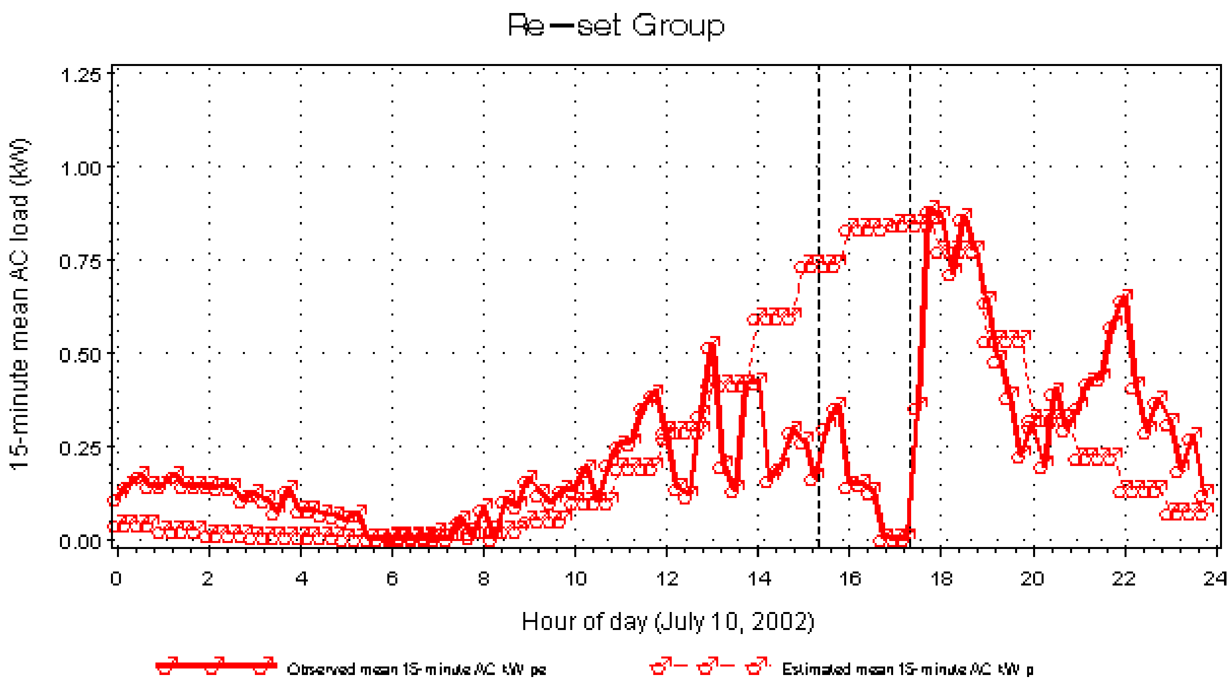
The red plot of the re-set group's average hourly load begins to diverge dramatically from the blue plot of the comparison group's just before noon. The divergence becomes wider up until about the reported start time of the event. The plots become closer at that point primarily because the load of the comparison group begins to diminish. The re-set group finally assumes a load like that of the comparison group only after the reported stop time of the event.

The divergence of the two group's loads in the hours prior to the re-set period at first may seem anomalous considering the general similarity seen in Figures 3-3a through 3-3c. However, the absolute level of the load in Figure 3-10 is modest compared to the peak loads seen in Figures 3-1 through 3-5 above. Thus, the difference between the two groups reflects a fair amount of random variation.

As it turns out, on the re-set day, only 13 re-set group AC units and 23 comparison group units in the good data sample had non-zero use. This situation contributes to greater variability of the two averages. The low fraction of users on the re-set day also indicates the difficulty of obtaining reliable peak load reductions in this region on statewide emergency days. Together with those who never used their air conditioners, the non-users within the "potential contributor" group mean that only about 40 percent of the units in the program were in use on the re-set day.

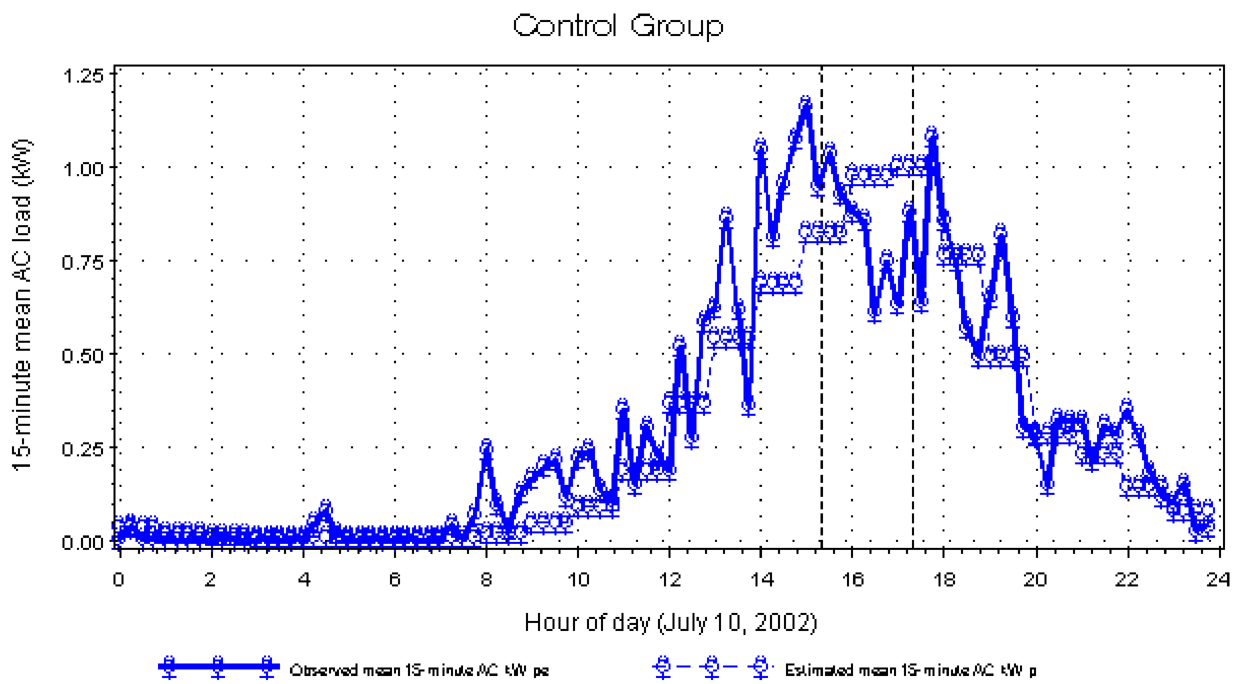
Figure 3-11 shows the modeled and observed quarter-hourly AC loads for the re-set group on the re-set day. Figure 3-12 shows a similar comparison for the comparison group. These two figures are the basis of the estimated savings for potential contributors. The difference between the modeled and observed load for the re-set group provides the unadjusted savings estimate. Subtracting the difference between modeled and observed for the comparison group gives the comparison-adjusted savings estimate, or difference of difference estimate, for each quarter-hour interval. Averaging across the quarter-hour intervals that approximately span the re-set period gives the average demand savings per contributing unit across the re-set period.

Figure 3-11
Observed (—) and Estimated (--) AC Loads on Re-set Day vs Time



Points plotted are average values over 28 re-set group and 40 comparison group “potentially contributing” AC units.

Figure 3-12
Observed (—) and Estimated (--) AC Loads on Re-set Day vs Time



Points plotted are average values over 28 re-set group and 40 comparison group "potentially contributing" AC units.

3.4.2 Savings Estimates

Table 3-7 displays the components of the savings estimates and corresponding standard errors for the re-set period, using the end-use AC data and using the whole-house data. The savings shown are the average across the eight quarter-hour intervals that approximately span the re-set period.

Using the end-use data, the re-set group averaged 0.64 kW below the model estimate. If no comparison group were available, this would be the estimate of the unit savings among potential contributors. The comparison group, however, averaged 0.11 kW below the model estimate. Thus, the estimated savings is the difference of these differences, or 0.54 kW per unit.

The standard error of this difference is 0.15. Thus, while modest, the estimate is reasonably well-determined, and is statistically significantly different from zero at 90 percent confidence.

The whole-premise data, on the other hand, give a difference of difference estimate near zero, and a standard error roughly 7 times the estimate. The whole-premise data thus are not able to provide a meaningful savings estimate.

Table 3-7
Savings Estimation and Standard Errors Using End-use and Whole-premise Data
Average Demand Savings Over the Re-set Period

			End-use AC Data	Whole-premise Data
Re-set group modeled minus observed				
	Number of units		28	28
	Average	(kW)	0.64	0.31
	Standard Deviation	(kW)	0.53	1.40
	Standard Error	(kW)	0.10	0.26
Comparison group modeled minus observed				
	Number of units		40	40
	Average	(kW)	0.11	0.35
	Standard Deviation	(kW)	0.68	0.74
	Standard Error	(kW)	0.11	0.12
Difference of Difference				
	Savings per potential contributor unit	(kW)	0.54	-0.04
	Standard Error	(kW)	0.15	0.29
Non-contributor-adjusted savings per unit				
	Fraction of units that are potential contributors		60%	60%
	Savings per unit, all units	(kW)	0.33	-0.02
	Standard Error of savings per unit, all units	(kW)	0.13	0.26

These estimates are the savings per potential contributor. As indicated in Table 3-4 above, only about 60 percent of units in the program are potential contributors. Adjusting for this proportion, the estimated savings per unit across all units in the program is 0.33 kW, with a standard error of 0.13 kW, based on the end-use AC metering data.

Table 3-8 shows the estimated savings, standard error, and 90 percent confidence intervals for each quarter-hour increment as well as for the entire re-set period. These savings are the average across all units in the program, and include the adjustment for noncontributors. Results are shown on a per-unit basis, and also total for the program. The program totals are shown on two bases. First is the total for the thermostats installed in the program on the re-set date. Second is the total assuming a total of 5,000 units enrolled.

Table 3-8
Re-set Day Impacts and Standard Errors
for All Units in the Program

	Increment Ending								Re-Set Period
	3:30	3:45	4:00	4:15	4:30	4:45	5:00	5:15	
Average savings per unit in program									
Estimate	0.52	0.32	0.19	0.36	0.20	0.30	0.28	0.44	0.33
Standard Error	0.12	0.17	0.18	0.17	0.18	0.17	0.16	0.17	0.13
90 percent confidence lower bound	0.33	0.04	-0.11	0.08	-0.10	0.02	0.03	0.17	0.10
90 percent confidence upper bound	0.71	0.60	0.49	0.63	0.50	0.58	0.54	0.71	0.55
Total Savings on Re-set Day									
Population size =	*2,259*								
Estimate	1174	724	423	805	451	669	642	997	736
Standard Error	265	386	411	382	413	385	353	374	304
90 percent confidence lower bound	738	89	-252	177	-229	36	60	382	235
90 percent confidence upper bound	1610	1358	1099	1434	1131	1302	1223	1611	1236
Total Savings assuming full enrollment									
Population size =	*5,000*								
Estimate	2,599	1,602	937	1,783	997	1,481	1,420	2,206	1,628
Standard Error	587	854	909	846	915	852	782	827	673
90 percent confidence lower bound	1,633	197	(559)	391	(508)	79	134	846	521
90 percent confidence upper bound	3,565	3,006	2,432	3,175	2,502	2,882	2,707	3,566	2,735

The table shows that the estimates are significantly different from zero at the 90 percent confidence level only for most of the individual time increments. Across the whole re-set period, there are statistically significant savings. However, at full enrollment the savings are estimated to be only around 1.6 MW, compared with the ex ante estimate of 4 MW. Part of the shortfall comes from the nearly 40 percent of units estimated to be noncontributors. Another part comes from the fact that even among the "potential contributors," who received the re-set signal, did not over-ride, and use their air conditioners at least some time during the summer, only about half used their air conditioners on the day of the re-set itself.

3.5 Projected Impacts By Temperature And Re-set Amount

Projected impacts at various outside temperatures and re-set amounts were estimated from the same load models developed in the analysis of the specific re-set event, as described in Section 2. For each unit with good data and non-zero summer use, the unit's load model was used to calculate the load for each hour of the day at a given daily average temperature. The same model was used also to calculate the hourly loads assuming an increase in the thermostat setpoint. This increase is represented in the model as an increase in the unit's cooling reference temperature. The difference in the model's estimate of load with and without the set-point change is the estimated savings at that outside temperature and re-set amount, for each hour.

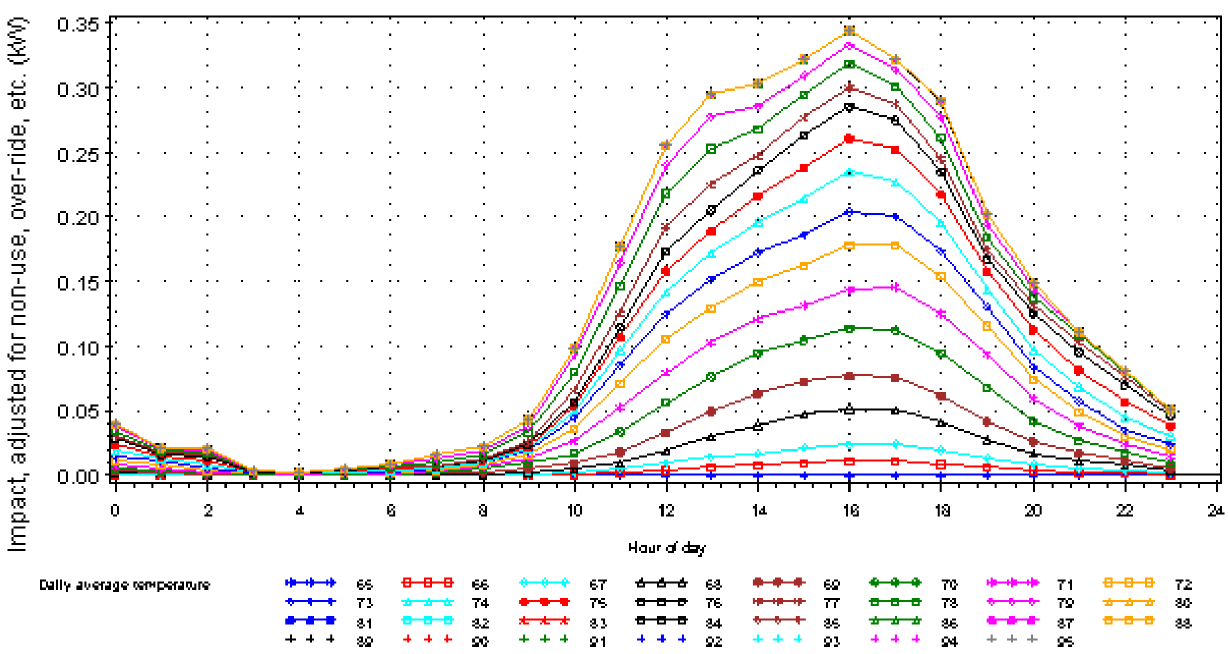
These savings estimates were averaged across all units in the sample for which the model could be estimated. For this projection analysis, the assignment of units to re-set or comparison group was not relevant.

These savings estimates apply to the universe of potential contributors. Multiplying by the estimated proportion of potential contributors gives the projected average savings per unit across all units in the program.

The results are plotted by time of day in Figure 3-13, for a 3°F re-set, and various daily average outside temperatures. Savings are low at low outside temperatures, where air conditioning use is low, and higher at higher outside temperatures. Savings are also low in the early morning and overnight. Savings per unit are greater at higher outside temperatures because a larger fraction of AC units are on. At lower temperatures, many of the units have zero estimated load and zero savings.

For outside temperatures above 80°F, there is no additional increase in the projected savings. This leveling off occurs once the outside temperature exceeds the point where all the units are projected to be on based on the individual load model fits. The load models assume a linear relationship between load and outside temperature above each unit's reference temperature. Thus, a 3°F shift in reference temperature has the same affect on load for all outside temperatures above this reference point.

Figure 3-13
Projected Impacts by Hour, Average per AC Unit
(For 3°F Re-set)



The impacts at 4 PM are listed in Table 3-9. As noted, these estimates are the average across all units in the program, and have been adjusted for noncontributors (non-users, nonresponders, and over-rides). While the fractions of non-users and over-rides might be different at higher temperatures, the fractions assumed were the same as were observed on the one re-set day in this study period.

Table 3-9
Projected Demand Impact per Unit
at Hour Ending 4 PM for 3°F Re-set

Average Daily Temperature	Impact per Thermostat (kW)
65	0.00
66	0.01
67	0.02
68	0.05
69	0.08
70	0.12
71	0.15
72	0.18
73	0.21
74	0.24
75	0.27
76	0.29
77	0.31
78	0.32
79	0.34
80	0.35
≥80	0.35

The results of this approach were in rough alignment with the demand impact observed in the metered data for the July 10 re-set event. The daily average temperature for that date was 71°F. The 4 PM demand impact for impact contributors expected at such a condition would be 0.15 kW based on the values of Table 3-9. This is about half the impact of around 0.27 kW shown in Table 3-8 for the July 10 event, but well within the 90 percent confidence bounds.

The projected impacts represent the average savings expected over the indicated conditions. Actual impacts on a particular day may be higher or lower, according to how much participants are using their air conditioners. Thus, one interpretation of the difference between the projected impacts and the estimated July 10 impact is that this particular day had higher impacts than what would be typical for those temperature conditions. Another interpretation is that the projection estimate is more accurate, and the July 10 specific estimate reflects random noise in the sample on that day. Additional re-set events would need to be observed to determine if the projections are more correct on average, or if the higher estimates developed for the single event observed so far indicate a general pattern.

Projected savings for other re-set amounts are tabulated by outside temperature and time of day in Appendix A. These tables will be used to estimate savings from re-set events next summer, if these estimates are needed before results based on the metering data from those events are available.

4 CONCLUSIONS

Impact findings from this study are tentative for two reasons:

1. The summer in which the study was conducted was somewhat cool, so that impacts in a hotter summer could not be observed.
2. Only a single re-set period was observed, at a fairly mild temperature.

Nonetheless, there are some useful observations that can be made from the analysis.

4.1 WHAT FRACTION CONTRIBUTE TO SAVINGS

1. About 90 percent of the thermostats in the program appeared to operate correctly during the re-set event.
2. At least for the single re-set in mild weather, only a small fraction of thermostats, 7 percent, had the re-set over-ridden. This finding of limited over-ride is consistent with the survey findings that very few customers were accurately aware that a re-set event had taken place.
3. Twenty-five percent of participating AC units were not used at all during the summer of this study. While some of these units might be used during severe hot weather, they contribute no savings in the milder weather.
4. On the day of the re-set event, only about half the units in the study that were used at least on some weekday afternoons were in use.

The combined effect of the first three factors is that only about 60 percent of the participating units are "potential contributors" to impacts. With the addition of the fourth factor, average savings across all units in the program would be expected to be only about one-third of what would be expected for an operating unit that was successfully re-set without over-ride.

In more severe weather, the fraction over-riding might be higher, while the fraction not using the AC might be lower. The net effect is difficult to gage without observing behavior in the warmer conditions, but the overall fraction not contributing to impacts may be similar. Clearly, the fraction not using the AC is the biggest single factor.

4.2 SAVINGS FOR THE RE-SET DAY

Over the re-set period, the average savings per participating unit on the re-set day are estimated at 0.33 kW per unit, with a 90 percent confidence interval from 0.10 to 0.55 kW. For the 2,259 units connected on the re-set day, this translates into an estimated total of 0.7 MW (with a 90 percent confidence interval from 0.2 to 1.2 MW). If the targeted 5,000 units had all been in operation on that day, the estimate would be 1.6 MW (90 percent confidence interval 0.5 to 2.7 MW).

A crude ex post estimate derived by applying the 30 percent "contribution factor" from Section 4.1 to the ex ante estimate of 4 MW would produce a similar result.

4.3 Projected Savings from Future Re-set Events

Savings for other re-set conditions were estimated from the load models only, without adjustment for observed re-set or comparison-group loads during re-set. These results give lower estimated impacts compared to those found during the single re-set event. Nevertheless, they indicate the potential magnitude of savings under different temperature conditions and re-set strategies.

At all ambient temperatures, the peak impacts are estimated for the hour ending 4 PM. At 80°F or higher daily average ambient temperature, a 3°F re-set is estimated to yield 0.35 kW savings per thermostat. The savings is about one-quarter that amount for the hours ending 10 PM and 10 AM, and is small between those hours.

Projected savings are lower at daily average temperatures below 80°F, and fall to zero at 65°F or below At 80°F or higher, a change of 1°F in the re-set amount changes the 4 PM impacts per unit at by about 0.12 kW.

All of these estimates will be revisited in the impact evaluation for the summer of 2003. However, at this time there is no plan to collect additional survey data to develop a better understanding of customer behavior during actual or anticipated re-set events. If there is sufficient hot weather and a sufficient number of re-set events next summer, such a survey may be warranted. Understanding customer behavior in these situations will establish a better understanding of the performance of this program and the impacts that can be expected from it.

4.4 Future Program Performance

The summer of 2002 was the second coolest since 1980. Cooling degree-days at the Miramar station were 32 percent below the average for that period. In a more typical summer, more air conditioning use might be expected.

Nonetheless, the finding that only around 40 percent of units in the program were being used on the re-set day suggests that future performance of the program as a mechanism to respond to statewide emergencies is not reliable. Statewide emergency conditions do not necessarily coincide with hot weather in the San Diego area. This was the case for the single re-set event that occurred in this study period. As long as the emergency condition that triggers a re-set event is not tied to hot weather in San Diego, a high number of non-users is likely to be found during future re-sets.

The program has already been targeted to SDG&E's hotter climate region and higher-use customers. Thus, it does not appear likely that the impact levels can be improved substantially. More restrictive targeting might improve the average savings per unit, but would reduce the eligible pool of participants so that even the current target might not be achieved.

Table A-1
Projected Savings per AC Unit (kW)
Re-set = 1°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.01	0.01	0.01	0.01	0.01
68	0.01	0.02	0.02	0.03	0.03	0.03	0.02
69	0.02	0.03	0.03	0.04	0.04	0.04	0.03
70	0.03	0.04	0.04	0.05	0.05	0.05	0.04
71	0.03	0.04	0.05	0.05	0.06	0.06	0.05
72	0.04	0.05	0.06	0.07	0.07	0.07	0.06
73	0.05	0.06	0.06	0.07	0.08	0.07	0.06
74	0.05	0.06	0.07	0.08	0.09	0.09	0.08
75	0.06	0.07	0.08	0.09	0.10	0.10	0.08
76	0.06	0.08	0.09	0.09	0.10	0.10	0.08
77	0.07	0.08	0.08	0.10	0.11	0.10	0.09
78	0.09	0.10	0.10	0.11	0.12	0.11	0.10
79	0.09	0.10	0.10	0.11	0.12	0.11	0.10
80	0.09	0.10	0.10	0.11	0.12	0.11	0.10
81	0.09	0.10	0.10	0.11	0.12	0.11	0.10
82	0.09	0.10	0.10	0.11	0.12	0.11	0.10
83	0.09	0.10	0.10	0.11	0.12	0.11	0.10
84	0.09	0.10	0.10	0.11	0.12	0.11	0.10
85	0.09	0.10	0.10	0.11	0.12	0.11	0.10
86	0.09	0.10	0.10	0.11	0.12	0.11	0.10
87	0.09	0.10	0.10	0.11	0.12	0.11	0.10
88	0.09	0.10	0.10	0.11	0.12	0.11	0.10
89	0.09	0.10	0.10	0.11	0.12	0.11	0.10
90	0.09	0.10	0.10	0.11	0.12	0.11	0.10
91	0.09	0.10	0.10	0.11	0.12	0.11	0.10
92	0.09	0.10	0.10	0.11	0.12	0.11	0.10
93	0.09	0.10	0.10	0.11	0.12	0.11	0.10
94	0.09	0.10	0.10	0.11	0.12	0.11	0.10
95	0.09	0.10	0.10	0.11	0.12	0.11	0.10

Table A-2
Projected Savings per AC Unit (kW)
Re-set = 2°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.02	0.03	0.04	0.04	0.04	0.03
69	0.03	0.04	0.05	0.06	0.07	0.06	0.05
70	0.05	0.06	0.07	0.08	0.09	0.09	0.07
71	0.06	0.08	0.09	0.10	0.11	0.11	0.10
72	0.08	0.10	0.11	0.12	0.13	0.13	0.11
73	0.09	0.11	0.13	0.14	0.15	0.14	0.12
74	0.10	0.12	0.14	0.15	0.17	0.16	0.14
75	0.11	0.13	0.16	0.17	0.19	0.18	0.16
76	0.13	0.15	0.17	0.19	0.20	0.19	0.16
77	0.14	0.16	0.17	0.19	0.21	0.20	0.17
78	0.16	0.18	0.19	0.21	0.22	0.21	0.18
79	0.17	0.20	0.21	0.22	0.23	0.22	0.20
80	0.17	0.20	0.21	0.22	0.23	0.22	0.20
81	0.17	0.20	0.21	0.22	0.23	0.22	0.20
82	0.17	0.20	0.21	0.22	0.23	0.22	0.20
83	0.17	0.20	0.21	0.22	0.23	0.22	0.20
84	0.17	0.20	0.21	0.22	0.23	0.22	0.20
85	0.17	0.20	0.21	0.22	0.23	0.22	0.20
86	0.17	0.20	0.21	0.22	0.23	0.22	0.20
87	0.17	0.20	0.21	0.22	0.23	0.22	0.20
88	0.17	0.20	0.21	0.22	0.23	0.22	0.20
89	0.17	0.20	0.21	0.22	0.23	0.22	0.20
90	0.17	0.20	0.21	0.22	0.23	0.22	0.20
91	0.17	0.20	0.21	0.22	0.23	0.22	0.20
92	0.17	0.20	0.21	0.22	0.23	0.22	0.20
93	0.17	0.20	0.21	0.22	0.23	0.22	0.20
94	0.17	0.20	0.21	0.22	0.23	0.22	0.20
95	0.17	0.20	0.21	0.22	0.23	0.22	0.20

Table A-3
Projected Savings per AC Unit (kW)
Re-set = 3°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.03	0.05	0.06	0.07	0.08	0.08	0.06
70	0.06	0.08	0.10	0.11	0.12	0.11	0.10
71	0.08	0.10	0.12	0.13	0.15	0.15	0.13
72	0.11	0.13	0.15	0.17	0.18	0.18	0.16
73	0.13	0.15	0.18	0.19	0.21	0.20	0.18
74	0.14	0.17	0.20	0.22	0.24	0.23	0.20
75	0.16	0.19	0.22	0.24	0.27	0.26	0.22
76	0.18	0.21	0.24	0.27	0.29	0.28	0.24
77	0.20	0.23	0.25	0.28	0.31	0.29	0.25
78	0.22	0.26	0.27	0.30	0.32	0.31	0.27
79	0.24	0.28	0.29	0.32	0.34	0.32	0.28
80	0.26	0.30	0.31	0.33	0.35	0.33	0.30
81	0.26	0.30	0.31	0.33	0.35	0.33	0.30
82	0.26	0.30	0.31	0.33	0.35	0.33	0.30
83	0.26	0.30	0.31	0.33	0.35	0.33	0.30
84	0.26	0.30	0.31	0.33	0.35	0.33	0.30
85	0.26	0.30	0.31	0.33	0.35	0.33	0.30
86	0.26	0.30	0.31	0.33	0.35	0.33	0.30
87	0.26	0.30	0.31	0.33	0.35	0.33	0.30
88	0.26	0.30	0.31	0.33	0.35	0.33	0.30
89	0.26	0.30	0.31	0.33	0.35	0.33	0.30
90	0.26	0.30	0.31	0.33	0.35	0.33	0.30
91	0.26	0.30	0.31	0.33	0.35	0.33	0.30
92	0.26	0.30	0.31	0.33	0.35	0.33	0.30
93	0.26	0.30	0.31	0.33	0.35	0.33	0.30
94	0.26	0.30	0.31	0.33	0.35	0.33	0.30
95	0.26	0.30	0.31	0.33	0.35	0.33	0.30

Table A-4
Projected Savings per AC Unit (kW)
Re-set = 4°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.04	0.06	0.07	0.08	0.09	0.09	0.07
70	0.06	0.09	0.11	0.12	0.13	0.13	0.11
71	0.09	0.12	0.15	0.16	0.17	0.18	0.15
72	0.13	0.16	0.19	0.20	0.22	0.22	0.19
73	0.16	0.19	0.22	0.23	0.26	0.26	0.22
74	0.18	0.22	0.25	0.27	0.30	0.29	0.25
75	0.21	0.25	0.28	0.31	0.34	0.33	0.28
76	0.23	0.27	0.31	0.34	0.37	0.35	0.30
77	0.25	0.29	0.33	0.36	0.40	0.38	0.32
78	0.28	0.33	0.36	0.39	0.42	0.40	0.35
79	0.31	0.36	0.38	0.41	0.44	0.42	0.36
80	0.33	0.38	0.39	0.43	0.46	0.43	0.38
81	0.35	0.40	0.41	0.44	0.47	0.44	0.39
82	0.35	0.40	0.41	0.44	0.47	0.44	0.39
83	0.35	0.40	0.41	0.44	0.47	0.44	0.39
84	0.35	0.40	0.41	0.44	0.47	0.44	0.39
85	0.35	0.40	0.41	0.44	0.47	0.44	0.39
86	0.35	0.40	0.41	0.44	0.47	0.44	0.39
87	0.35	0.40	0.41	0.44	0.47	0.44	0.39
88	0.35	0.40	0.41	0.44	0.47	0.44	0.39
89	0.35	0.40	0.41	0.44	0.47	0.44	0.39
90	0.35	0.40	0.41	0.44	0.47	0.44	0.39
91	0.35	0.40	0.41	0.44	0.47	0.44	0.39
92	0.35	0.40	0.41	0.44	0.47	0.44	0.39
93	0.35	0.40	0.41	0.44	0.47	0.44	0.39
94	0.35	0.40	0.41	0.44	0.47	0.44	0.39
95	0.35	0.40	0.41	0.44	0.47	0.44	0.39

Table A-5
Projected Savings per AC Unit (kW)
Re-set = 5°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.04	0.06	0.07	0.08	0.09	0.09	0.07
70	0.07	0.09	0.11	0.13	0.14	0.14	0.12
71	0.10	0.13	0.16	0.17	0.19	0.19	0.16
72	0.14	0.17	0.21	0.23	0.25	0.24	0.21
73	0.17	0.22	0.25	0.27	0.30	0.29	0.25
74	0.21	0.25	0.29	0.32	0.35	0.34	0.30
75	0.24	0.29	0.33	0.36	0.40	0.39	0.33
76	0.27	0.32	0.37	0.40	0.44	0.42	0.36
77	0.30	0.35	0.39	0.43	0.47	0.45	0.39
78	0.33	0.39	0.43	0.47	0.51	0.49	0.42
79	0.37	0.43	0.46	0.50	0.54	0.51	0.45
80	0.40	0.46	0.48	0.52	0.56	0.53	0.46
81	0.42	0.48	0.50	0.54	0.57	0.54	0.48
82	0.43	0.50	0.51	0.55	0.58	0.55	0.49
83	0.43	0.50	0.52	0.55	0.58	0.55	0.49
84	0.43	0.50	0.52	0.55	0.58	0.55	0.49
85	0.43	0.50	0.52	0.55	0.58	0.55	0.49
86	0.43	0.50	0.52	0.55	0.58	0.55	0.49
87	0.43	0.50	0.52	0.55	0.58	0.55	0.49
88	0.43	0.50	0.52	0.55	0.58	0.55	0.49
89	0.43	0.50	0.52	0.55	0.58	0.55	0.49
90	0.43	0.50	0.52	0.55	0.58	0.55	0.49
91	0.43	0.50	0.52	0.55	0.58	0.55	0.49
92	0.43	0.50	0.52	0.55	0.58	0.55	0.49
93	0.43	0.50	0.52	0.55	0.58	0.55	0.49
94	0.43	0.50	0.52	0.55	0.58	0.55	0.49
95	0.43	0.50	0.52	0.55	0.58	0.55	0.49

Table A-6
Projected Savings per AC Unit (kW)
Re-set = 6°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.04	0.06	0.07	0.08	0.09	0.09	0.07
70	0.07	0.09	0.11	0.13	0.14	0.14	0.12
71	0.10	0.13	0.16	0.18	0.20	0.20	0.17
72	0.14	0.18	0.22	0.24	0.26	0.26	0.22
73	0.18	0.23	0.27	0.30	0.32	0.32	0.27
74	0.23	0.28	0.32	0.35	0.39	0.38	0.33
75	0.27	0.32	0.37	0.41	0.45	0.44	0.38
76	0.30	0.36	0.42	0.46	0.50	0.48	0.42
77	0.34	0.40	0.45	0.50	0.55	0.52	0.45
78	0.38	0.45	0.49	0.54	0.59	0.56	0.49
79	0.42	0.49	0.53	0.58	0.63	0.60	0.52
80	0.46	0.53	0.56	0.61	0.66	0.62	0.54
81	0.48	0.56	0.58	0.63	0.67	0.63	0.56
82	0.51	0.58	0.60	0.64	0.69	0.65	0.58
83	0.52	0.60	0.62	0.66	0.70	0.66	0.59
84	0.52	0.60	0.62	0.66	0.70	0.66	0.59
85	0.52	0.60	0.62	0.66	0.70	0.66	0.59
86	0.52	0.60	0.62	0.66	0.70	0.66	0.59
87	0.52	0.60	0.62	0.66	0.70	0.66	0.59
88	0.52	0.60	0.62	0.66	0.70	0.66	0.59
89	0.52	0.60	0.62	0.66	0.70	0.66	0.59
90	0.52	0.60	0.62	0.66	0.70	0.66	0.59
91	0.52	0.60	0.62	0.66	0.70	0.66	0.59
92	0.52	0.60	0.62	0.66	0.70	0.66	0.59
93	0.52	0.60	0.62	0.66	0.70	0.66	0.59
94	0.52	0.60	0.62	0.66	0.70	0.66	0.59
95	0.52	0.60	0.62	0.66	0.70	0.66	0.59

Table A-7
Projected Savings per AC Unit (kW)
Re-set = 7°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.04	0.06	0.07	0.08	0.09	0.09	0.07
70	0.07	0.09	0.11	0.13	0.14	0.14	0.12
71	0.10	0.13	0.16	0.18	0.20	0.20	0.17
72	0.14	0.19	0.22	0.25	0.27	0.27	0.23
73	0.19	0.24	0.28	0.31	0.34	0.33	0.28
74	0.24	0.30	0.35	0.38	0.41	0.41	0.35
75	0.29	0.35	0.41	0.44	0.48	0.48	0.41
76	0.33	0.40	0.46	0.50	0.55	0.54	0.46
77	0.37	0.45	0.50	0.55	0.60	0.59	0.50
78	0.43	0.50	0.55	0.61	0.66	0.63	0.55
79	0.47	0.55	0.60	0.65	0.71	0.67	0.59
80	0.51	0.59	0.63	0.69	0.75	0.71	0.62
81	0.54	0.63	0.66	0.72	0.77	0.73	0.64
82	0.57	0.66	0.68	0.74	0.79	0.74	0.66
83	0.59	0.68	0.70	0.75	0.81	0.76	0.68
84	0.61	0.70	0.72	0.77	0.82	0.76	0.69
85	0.61	0.70	0.72	0.77	0.82	0.76	0.69
86	0.61	0.70	0.72	0.77	0.82	0.76	0.69
87	0.61	0.70	0.72	0.77	0.82	0.76	0.69
88	0.61	0.70	0.72	0.77	0.82	0.77	0.69
89	0.61	0.70	0.72	0.77	0.82	0.77	0.69
90	0.61	0.70	0.72	0.77	0.82	0.77	0.69
91	0.61	0.70	0.72	0.77	0.82	0.77	0.69
92	0.61	0.70	0.72	0.77	0.82	0.77	0.69
93	0.61	0.70	0.72	0.77	0.82	0.77	0.69
94	0.61	0.70	0.72	0.77	0.82	0.77	0.69
95	0.61	0.70	0.72	0.77	0.82	0.77	0.69

Table A-8
Projected Savings per AC Unit (kW)
Re-set = 8°F

Daily Average Temperature (°F)	Hour Ending						
	12	13	14	15	16	17	18
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.01	0.01	0.01	0.01	0.01	0.01
67	0.01	0.01	0.02	0.02	0.02	0.02	0.02
68	0.02	0.03	0.04	0.05	0.05	0.05	0.04
69	0.04	0.06	0.07	0.08	0.09	0.09	0.07
70	0.07	0.09	0.11	0.13	0.14	0.14	0.12
71	0.10	0.13	0.16	0.18	0.20	0.20	0.17
72	0.14	0.19	0.22	0.25	0.27	0.27	0.23
73	0.19	0.25	0.29	0.32	0.35	0.34	0.29
74	0.24	0.30	0.35	0.39	0.43	0.42	0.36
75	0.30	0.37	0.43	0.47	0.51	0.50	0.43
76	0.35	0.43	0.49	0.54	0.59	0.57	0.49
77	0.40	0.48	0.54	0.60	0.65	0.64	0.55
78	0.46	0.55	0.60	0.66	0.72	0.69	0.60
79	0.51	0.61	0.66	0.72	0.78	0.74	0.65
80	0.56	0.65	0.70	0.76	0.82	0.78	0.68
81	0.59	0.69	0.74	0.80	0.86	0.82	0.72
82	0.63	0.73	0.77	0.83	0.89	0.84	0.74
83	0.66	0.76	0.79	0.85	0.91	0.85	0.76
84	0.68	0.78	0.81	0.86	0.92	0.87	0.77
85	0.69	0.80	0.82	0.88	0.94	0.87	0.79
86	0.69	0.80	0.82	0.88	0.94	0.87	0.79
87	0.69	0.80	0.82	0.88	0.94	0.87	0.79
88	0.69	0.80	0.82	0.88	0.94	0.87	0.79
89	0.69	0.80	0.83	0.88	0.94	0.87	0.79
90	0.69	0.80	0.83	0.88	0.94	0.87	0.79
91	0.69	0.80	0.83	0.88	0.94	0.87	0.79
92	0.69	0.80	0.83	0.88	0.94	0.87	0.79
93	0.69	0.80	0.83	0.88	0.94	0.87	0.79
94	0.69	0.80	0.83	0.88	0.94	0.87	0.79
95	0.69	0.80	0.83	0.88	0.94	0.87	0.79