Summer Initiative
Expansion of the AB970
Small Commercial
Demand-Responsiveness
Pilot Program

IMPACT EVALUATION OF THE 2004
SCE Energy$mart Thermostat^SM Program
Summer Initiative Expansion

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Prepared for:

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Preface

The 2004 Summer Initiative Expansion of the AB970 SCE Energy$mart Thermostat^{SM} Program impact evaluation was performed on behalf of Southern California Edison Company, under the direction of Mark S. Martinez, manager of demand response program development. RLW would like to thank Mark for his contributions and commitment to the success of the evaluation. For further information on this report please contact Mark using the information provided below.

Dr. Roger Wright of RLW Analytics, Inc. directed the evaluation and Stacia Okura was acting project manager and analyst on this project.

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Background

This document is the final impact analysis report on the thermostats installed under the *2004 Summer Initiative Program Expansion* of Southern California Edison's SCE Energy$mart Thermostat℠ Program (E$T). The study was conducted by RLW Analytics, Inc. (RLW) on behalf of the Southern California Edison Company (SCE), administrator of the program.

The E$T pilot program was initiated by the CPUC in March 2001 under Assembly Bill 970[1] in order to test the viability of a new approach to small (under 200 kW) commercial/industrial customer demand-responsiveness in hot and rural areas. The initial program goals were to install at least 5,000 thermostats at small commercial businesses in SCE service territory, and to provide at least 4 MW in peak demand reduction by the end of 2002.

The SCE Energy$mart Thermostat℠ (E$T) program was the result of the AB970 pilot development by SCE and it was deployed in 2002. It provided small business customers in SCE service territory with two-way programmable communicating thermostats (PCTs) at no cost. SCE uses a software program to remotely curtail the HVAC load of the businesses by sending out a paging radio signal to the PCTs. The events are scheduled on a test basis, to coincide with a high system wide demand on a hot day.

When the curtailment is activated, the radio signal raises the cooling set point of the PCT by a specified number of degrees, called the temperature offset, thereby reducing the cooling load. The curtailment is designed to reduce the AC load without affecting customer comfort. The PCT sends a radio signal back to SCE indicating it has received the signal and has implemented the temperature offset and/or any local overrides of the curtailment by the participant.

SCE offered customers an annual incentive per PCT for participating in the program, payable at the end of the year. The participant was penalized a small fee each time they chose to override a curtailment by reducing the temperature back to the normal setpoint. Curtailments were scheduled for evaluation purposes during the summer months of May through October.

In July 2004, the CPUC approved SCE's request to expand the program by an additional 4,000 PCTs to help with potential resource challenges for the summer of 2004. It was anticipated that this Summer Initiative (SI) expansion would reduce peak demand by an additional 4 – 6 MW by the end of 2004, raising the total program demand reduction to around 13 -15 MW.

SCE conducted 12 curtailments during the summer of 2004, the maximum number agreed upon by the utility and its customers. The program was in effect from May 1st through October 31st, with the first event on July 15th.

Evaluation Objectives

The objectives of this 2004 Summer Initiative (SI) expansion impact evaluation were to assess the customer responsiveness to demand response curtailments, model the effects of event timing and daily temperature on the HVAC load reductions, and verify

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[1] Decision 01.03.073 dated March 27, 2001

the gross peak demand reduction of the SI expansion E$T program. These goals were addressed by leveraging program data collected by SCE during the summer of 2004 on the *existing* AB970 E$T PCTs and utilizing them to evaluate the Summer Initiative expansion thermostats, including:

- Information characterizing the date, time and temperature offset of each of 12 curtailments during 2004,
- Information about the number of installed SI expansion units (over 4,400 units installed as of May 2005) and overrides occurring in each curtailment,
- SI expansion program tracking data, describing the thermostats and controlled air conditioners including the rated cooling capacity in tonnage (size),
- Hourly PCT run time data from the *SI expansion* thermostats, collected from the SI expansion thermostats installed and receiving event signals in the summer of 2004,
- End use metering of *existing* E$T units: 5-minute interval load and run time data for 100 controlled air conditioners at a statistically representative sub-sample of 55 sites (drawn from existing E$T population),
- Hourly measurements of exterior temperature from representative SCE-area weather stations in each climate zone collected throughout the summer and fall of 2004.

Total Participation Assessment

By May of 2005, SCE had over 8,500 PCTs installed and responding to system events in the 2004 SCE E$T program. These devices were estimated to control roughly 34,000 tons of air conditioning capacity. The Summer Initiative PCTs were mainly installed *during* the summer of 2004. The installation effort began in July 2004, and by the end of 2004 there were over 4,000 PCTs installed.

With the understanding that not all of the units were installed and providing load control capacity for SCE during the summer of 2004 because the CPUC program approval came in July 2004, this report presents the results of the impact analysis that quantifies the *potential* demand response capability from the 4,000 additional PCTs installed by the end of 2004[2], and *not the actual* installed tonnage response from the program during the summer of 2004 since many of the thermostats were still being installed.

Impact Estimation from the End Use Meter Data

There were a total of twelve curtailment days during 2004, and the end use meter data collected from the sample of one hundred air conditioners in the program were sufficient to perform complete analyses on eight of these curtailment days. On five of the eight days, SCE called a 4-degree, 2-hour curtailment between 2 PM and 4 PM on a hot summer weekday. Two other curtailments were 4-degree, 2-hour events, one from 3 PM to 5 PM and an instantaneous event from 4:10 PM to 6:10 PM. On the final day, SCE called two back-to-back, 4-degree, 2-hour curtailments.

As an example, Figure ES-1 is included to show the weighted sample average impact of the curtailment that was called on September 7, 2004 from 2 PM to 4 PM. The graph shows a direct comparison of the averaged load/ton of the end use metered units on

[2] Controlling roughly 18,085 tons of AC capacity, derated 7% for signal communication losses.

September 7 (blue line) to the averaged load/ton for non-controlled comparison days (red line). The high on September 7 was 97.6 degrees, and the average high on the control days was 94.6 degrees. The peak load reduction was over 0.56 kW per rated AC tonnage.

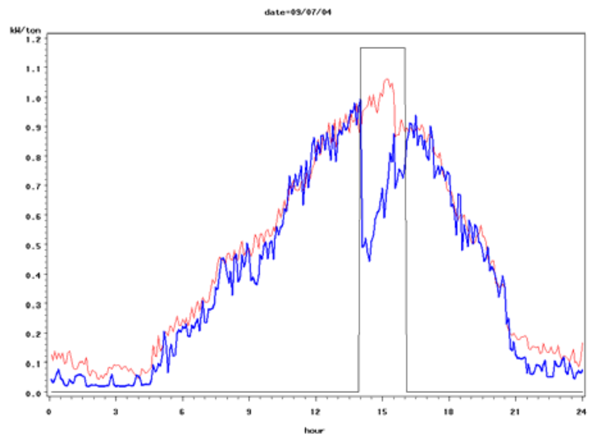

Figure ES-1: E$T kW/Ton Impact on September 7

By defining the effective curtailment duration to be the number of minutes during which the load reduction was at least half as large as the maximum initial load reduction, the average effective duration for the seven 2-hour, 4-degree curtailments was 76 minutes. The analysis of the data suggested little or no snapback following the curtailment period.

Averaging all eight curtailments, the maximum kW reduction in each curtailment was 0.51 kW per rated ton of the AC unit. The average kWh savings was 0.33 kWh per ton during the first hour of the curtailment and 0.22 kWh per ton during the second hour of the curtailment.

	Per Sample Ton	*Program Total*
Maximum kW Reduction	0.51	8,540
kWh Savings in Hour 1	0.33	5,554
kWh Savings in Hour 2	0.22	3,705

Figure ES-2: Estimated Program-Wide Impact from the End Use Metering

Overall Program Impact – Summer 2004

The impact estimates for this report are quantified on a kW and kWh per ton basis. This was done to value the connected capacity of the HVAC unit under curtailment since there is a positive correlation between the amount of load and the savings achieved when the load is curtailed.

Together, both the run time and the logger data analyses indicate that for a program population of over 4,000 PCTs installed as a result of the Summer Initiative, with a 4-degree positive adjustment in interior temperature, the following would have been achieved:

- First hour energy savings between 4.5 and 6 MWh
- Instantaneous demand reduction of 8.5 MW

1 Methodology

The research performed on the 4,000 new smart thermostats (PCTs) installed under the 2004 Summer Initiative closely followed the methods used to evaluate the existing thermostats in the program. The principle challenge with the Summer Initiative evaluation was that the timing of the program deployment precluded collecting data during the summer of 2004. The Summer Initiative thermostats were mainly installed *during* the summer of 2004 and the installed thermostats were subject to the 12 curtailment events called throughout the summer. However, there was inadequate time to design and install a new metering sample and collect load data at the customer sites to inform the impact evaluation.

RLW leveraged the end use metered data collected during the summer of 2004 on the existing AB970 E$T program participants to evaluate the Summer Initiative expansion participants. The participants in the Summer Initiative program should be similar to the existing small commercial participants in the E$T program for two reasons. First, the target populations of the two programs are the same, and second, the recruitment methods were similar for both programs. Therefore, the existing metered sample of E$T program participants should be representative of the Summer Initiative participants.

Any minor differences in the program populations were adjusted for by calculating new weights for the end use metered data using the Summer Initiative units as the population. The expansion population used in this analysis was all of the SI expansion units that were installed as of May 2005, the static population taken one year after the original installations began. The focus of this report is on the *potential* demand response capability of all of the units installed as part of this expansion, and *not* the actual demand response achieved during the summer of 2004 since the program population changed on a daily basis as a result of the ongoing installations.

RLW used the same approach to evaluating the Summer Initiative expansion impact as was used in the 2002-04 existing E$T program evaluations. This approach is described in detail below.

1.1 General Approach to the Evaluation

This section describes the general approach used to verify energy savings and peak demand reductions produced by the Summer Initiative expansion. The analysis will be described in much greater detail later in this report.

The impact evaluation was designed to address each of the key objectives and requirements of CPUC Decision 01.03.073 dated March 27, 2001. In particular, the impact evaluation addressed the following questions:

1. Technical potential - What is the technical potential demand reduction of the 2004 Summer Initiative expansion?
2. Reliability - How much is the technical potential degraded by technical failures such as failure to detect override signals and other communication problems?

The approach to the Summer Initiative (SI) expansion evaluation built on the experience gained in the 2002, 2003, and 2004 E$T impact evaluations. The 2004 SI expansion evaluation was based on the following data collected by SCE and its contractors during the summer and fall of 2004 on the *existing* AB970 E$T thermostats:

- Curtailment event summaries characterizing the date, time and temperature offset of each of 12 curtailments during 2004,

- Information about the number of installed units (over 4,000 units), verified units and overrides occurring in each curtailment, collected from the installed thermostats,
- Program tracking data, describing the thermostats and air conditioners, including the rated cooling capacity (size), in tons, recorded for the 4,000 air conditioners,
- Hourly thermostat run time data from the installed SI expansion thermostats, collected throughout the summer of 2004 on all of the curtailment days (number varied by curtailment since installation was concurrent with program operation),
- End Use meter (EUM) 5-minute interval load and run time data from 100 existing E$T controlled air conditioners at a statistically representative sub-sample of 55 sites drawn from the existing E$T population, collected during all of the curtailment events, and
- Hourly measurements of exterior temperature from representative SCE-area weather stations in each climate zone collected throughout the summer and fall of 2004.

1.2 Experimental Plan

Our general approach has been to use the 5-minute end use meter data from the existing E$T units, the thermostat run time data from the SI expansion units and the information about the size of the HVAC units collected for most of the SI expansion participants to estimate the potential program load reduction impact. Our goal has been to estimate the maximum *potential* kW load reduction, the effective duration of the load reduction, the *potential* kWh energy savings during each hour of the curtailment period, and the change in kWh energy savings during the first hour following the curtailment period.

1.3 Experimental Groups

SCE contracted with MeterSmart to install end use meters following a sampling plan developed by RLW. A total of 100 end use meters were installed throughout 2003 and 2004. The end use meters recorded 5-minute data measuring the kW load for the HVAC units with smart thermostats installed. The end use meters also recorded the operating run time of the HVAC system during each 5-minute interval which was used in the operating load model.

In the fall of 2002, RLW initially stratified the existing E$T sampling frame according to those sites with predominately single-stage units and those sites with predominately multistage units. To do this RLW classified each site to be in class 1 if the average size per unit was less than 7 tons rated capacity, and in class 2 if the average size per unit was at least 7 tons. Most of air conditioners at the sites in class 1 were single-stage units, whereas most of the air conditioners at the sites in class 2 were multistage units.

Model-based statistical sampling methods were used to develop the sample design for each class. RLW stratified each class by the number of tons of air conditioning capacity at the site. Five strata were constructed in each of the two classes. Figure 3 shows the resulting sample design. Across all ten strata, the sample design called for the collection of end use load data at a subset of 75 sites. A total of 105 end use meters were installed by the summer of 2003.

Class	Stratum	Number of Sites	Max Tons	Total Tons	Units per Site	Tons per Site	End Use Loads
1	1	509	4	1,596	1.0	3.1	10
1	2	372	5	1,722	1.1	4.6	10
1	3	283	9	1,852	1.8	6.5	10
1	4	184	15	2,055	2.6	11.2	10
1	5	97	114	2,472	5.7	25.5	10
Subtotal		1,445		9,697			50
2	6	21	8	161	1.0	7.7	5
2	7	18	13	172	1.0	9.6	5
2	8	12	18	184	1.8	15.3	5
2	9	9	24	208	2.3	23.1	5
2	10	6	60	232	4.0	38.7	5
Subtotal		66		957			25
Total		1,511		10,654			75

Figure 3: Recommended Sample Design

There are 100 end use meters that are currently providing valid data. The load data from these meters were used in this impact evaluation.

1.4 Methodology for the Statistical Analysis

The average 5-minute end use load of the 100 monitored existing E$T AC units together with the hourly measurements of exterior temperature were used to estimate the program load impact of curtailments called on eight different days during the summer and fall of 2004. To simplify the analysis, the average load of the 100 existing E$T units was converted to kW per rated ton in each 5-minute interval. The average loads per ton were calculated by first stratifying the units in the sample and program population by size in tons, then developing kW/ton for each stratified group. To account for any minor differences in the program populations, new weights were used throughout the analysis to extrapolate the existing E$T end use metered data to the Summer Initiative expansion population.

We also prepared hourly weather data from each of six weather stations that were representative of the six climate regions in the program. An average hourly temperature was calculated as a weighted average of the hourly temperatures in the six regions, weighted by the total rated cooling capacity in tons for the HVAC units in each region.

The differential impact of each of the ten curtailment events was developed by comparing the average 5-minute kW load per ton on each curtailment day to the load on one or more non-curtailment days that were selected to be similar to the curtailment day with respect to the hourly temperature.

The approach estimated the maximum kW load reduction per ton, and the effective duration of the load reduction - defined to be the number of minutes during the curtailment period in which the load reduction was greater than one-half of the maximum load reduction. We also estimated the kWh reduction during each hour of the curtailment period and the possible snapback - the change in kWh during the first hour following the curtailment period.

SCE and its subcontractors also used the thermostat communications software to collect hourly run time data for all of the installed SI expansion thermostats for the entire summer of 2004. These data are stored in the thermostats on a five day limited memory, and are downloaded via two-way paging upon request from the software, either manually or on a daily basis, to a secure FTP site. SCE and its contractors can then access the data.

The 5-minute end use meter data from each of the 100 sample existing E$T AC units was used to develop two statistical regression models that estimated the operating kW load of each unit as a function of its size in tons and the exterior temperature. We developed one model for the small units (less than 7 tons) and another for the large units in order to capture the behavior of two-stage compressor operation in the large units. We used this model to convert the end use hourly run times into estimates of the hourly kWh consumption of each of these 100 units.

We then used the run time data collected from the SI expansion thermostats together with the SCE customer tracking information about the size of each of the SI expansion units to estimate the average hourly kWh consumption per ton of all participating SI expansion units on the days in which the run time data had been collected. Since the participants in the SI expansion are similar to the existing E$T participants, the operational load model from the existing E$T participants was considered appropriate to convert the SI expansion run time into hourly kWh.

We used these data to provide an independent estimate of the hourly kWh impact per ton among all program participants when run time was collected on the curtailment days. Finally, we extrapolated the results by multiplying the impact per ton by the estimated total potential curtailable tonnage of all SI expansion units installed as of May 2005.

2 Findings from the Tracking Data

In this section we will present the detailed results of the preliminary analysis primarily developed from the SCE 2004 Summer Initiative (SI) program expansion tracking data, along with other data sources, that were used to support the impact analysis.

2.1 Number and Size of Installed Units

The SCE program tracking system is an ACCESS based database system that provides customer and program-related data for each of the thermostats that have been installed in the program. At the time of receipt of the tracking data in May 2005, the SCE database provided records for 8,034 installed thermostats, which included AB970 participants, closed accounts, and other pilot program participants (not part of AB970). The ID of each unit includes an alphabetical designation (A – H) that identifies the regions and climate zones where the thermostats are installed, as shown in Figure 4.

Zone	Weather Zone	Name	Description
A	6	Coastal	Santa Barbara and Los Angeles coast.
B	8	OC	Orange County inland.
C	9	Central Valley	Burbank, Hollywood, and Pasadena area.
D	10	Inland Empire	San Bernardino and Riverside area.
F	14	Coachella Valley	Southern deserts.
G	15	Upper Desert	Southeast deserts.
H	16	Mountains	Mountains - Sierra Nevada.

Figure 4: E$T Climate Zones

The zones are mapped into the SCE customer tracking software, as well as the third-party communications and control software that operates the thermostats, enabling SCE to curtail the thermostats either as a complete group, or by zone. The Weather Zones are based on the California Energy Commission climate zones[3]. SCE Zones A, B, C, D and F are progressively "hotter" climate areas with increased AC usage. The Name indicates the general area in Southern California.

SCE Zones G and H are outlying rural areas with limited radio coverage and very small commercial populations, and Zone H has recently been cancelled, as it no longer has any customers. Zone E (not listed) is not a weather zone, but a special group that includes SCE test sites for engineering verification.

A map of all of the 16 California climate zones is presented below in Figure 5. Many of them are not in SCE's territory, and some are shared with other utilities. Although SCE territory includes climate zone 13 (Tulare County), customers here have not been included in the AB970 pilot program due to the lack of two-way paging coverage in this rural area. Other areas such as the high desert (climate zone 14) had limited coverage and the program was not extensively marketed there.

[3] http://www.energy.ca.gov/

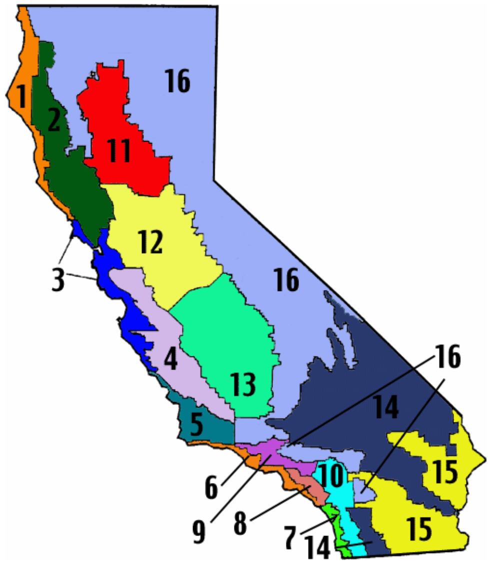

Figure 5: California Climate Zone Map

Knowing the rated AC tonnage of every air conditioner with a smart thermostat is important to the load impact analysis since many of the statistics from the program are estimated in terms of kWh or kW per ton. Tonnage information on the population enables a more accurate extrapolation of the sample findings.

SCE's installation plan required the contract thermostat installers to report the rated tonnage of each controlled air conditioning unit and to record other site and customer information. However, in many instances the installation contractor could not locate the tonnage on the nameplate or neglected to record the information. After identifying the missing tonnage data, RLW worked on a field inspection project during early 2005 to supplement the tonnage information that was in the database. The project was designed to collect tonnage at 100 of the Summer Initiative sites without tonnage recorded.

There were 2,309 sites in the SI expansion tracking data as of May 2005, and 581 of those sites had at least one unit with missing tonnage information. The 2,309 sites had a total of 4,415 stats for an average of 1.9 thermostats per site. The tracking database contains a total of 913 thermostats with missing tonnage information.

The tonnage collection project showed that the inspections and resulting addition of "lost tonnages" did not substantially increase or decrease the average tonnage of the population therefore the remaining missing tonnages should not have a substantial impact on the analysis. The tracking data had a *small* number of very high tonnages recorded by the installation contractor[4].

The second column of Figure 6 shows the count of units in the population of all units, with and without known rated capacity. The third and fourth columns of Figure 6 show the distribution of the tonnage in the population of units with known size.

[4] Tonnages greater than 15 were dropped from the tracking data. The businesses with these large tonnages were smaller businesses where 15 ton units were not likely to be found. They were more likely data entry errors.

Tons	Units	Known Tons	% of Units with Tons
1 to 1.9	22	28	1%
2 to 2.9	329	698	9%
3 to 3.9	1,101	3,408	31%
4 to 4.9	775	3,105	22%
5 to 5.9	1,094	5,470	31%
6 to 6.9	40	241	1%
7 to 7.9	25	181	1%
8 to 8.9	28	225	1%
9 to 9.9	8	76	0%
10 to 10.9	54	540	2%
>= 11	26	353	1%
Total w/ Tons	**3,502**	**14,325**	
Unknown Tons	**913**	**-**	
Total	**4,415**		
Average Tons	**4.1**		

Figure 6: Participant SI Population with Known Capacity

Figure 7 shows the distribution of the participating units and tonnages by climate zone. The majority of the units are from climate zones 8 and 9.

Size	Climate Zone	% of All Units	% of Units with Tons	% of Tons
Small	6	1%	1%	1%
	8	27%	34%	31%
	9	22%	27%	25%
	10	14%	17%	17%
	15	13%	17%	17%
Large	6	0%	0%	0%
	8	1%	1%	3%
	9	1%	1%	2%
	10	1%	1%	2%
	15	1%	1%	2%
Unknown	6	0%	-	-
	8	7%	-	-
	9	6%	-	-
	10	4%	-	-
	15	3%	-	-

Figure 7: Small vs. Large SI Units by Climate Zone

We noted earlier that the large units, i.e. rated at 7 tons or larger, were all multi-stage units. The presence of these units was of concern to the impact analysis because the thermostat run time data were not designed to describe the operation of multi-stage units. Fortunately, there are relatively fewer units greater than 7 tons distributed among the climate zones.

Figure 8 shows the number of installed SI expansion thermostats by month. The SI expansion was approved in July 2004, and the first installations were in August 2004. As mentioned previously, the end use metered data analysis was performed using the existing E$T sample as a proxy for a true SI expansion sample. Although all of the thermostats were not installed during the summer of 2004, a potential demand response capability impact was computed by expanding the end use impacts to the final population of SI expansion units.

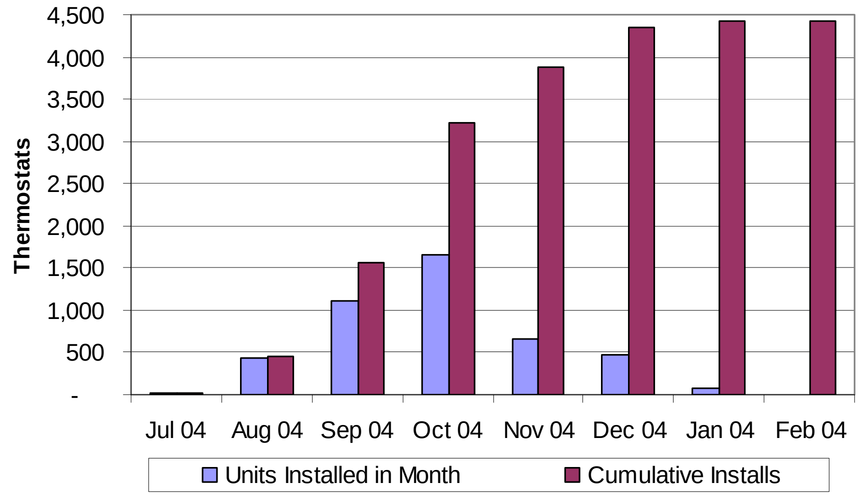

Figure 8: Summer Initiative Expansion Units Installed by Month

2.2 Signal Reception

The thermostat communications system sends out a radio page for controlling and communicating with the thermostats, and has the ability to track a "handshake" signal received from each of the thermostats after curtailment commands. The thermostat has a 2-way pager built into its system, and can verify that a command has been received. For a period of time after a command to curtail has been transmitted by the system, the thermostats send back a confirmation signal that they have "acknowledged" the command. Since there are over 9,000 E$T units in the SCE system, these acknowledgements are programmed in each thermostat to occur randomly over a 2 hour period after the command has been sent, to prevent the server incoming "mailbox" from being overloaded.

The communications software server also conducts a weekly communication test every Sunday, called a heartbeat test, with each thermostat. It tracks which thermostats respond to the test, and when the latest response to the test was received.

According to SCE, communication problems with thermostats can be broken down into two functional categories of non-responding devices:

1. Those that do not respond to a curtailment event (Non-Respondents), and
2. Those that do not send a weekly heartbeat response (Deadbeats).

SCE asserts that "Non-Respondents" may receive the curtailment requests, and act accordingly by reducing load, but their response for some reason is not registered by the server. Investigation into the non-respondents by SCE revealed that some devices do receive the curtailment signal and reduce load, but do not respond back, thereby indicating a false non-operational status. The two-way thermostat in effect becomes a one-way device, still operational in adjusting the setpoint, but not able to be "heard" by the paging system and confirmed[5].

True Deadbeats, on the other hand, fail to communicate on a weekly basis, do not respond to any signals and do not respond to curtailment events. True Deadbeats can arise from a defective radio, no radio reception, an unused or defective HVAC system, or the fact that the thermostat has been replaced. SCE defines a Deadbeat as a thermostat that has not responded to a heartbeat signal after 3 weeks. Deadbeats tend to grow in numbers before and after the summer ends, indicating that many customers turn off their air conditioners (and power to the thermostats).

Figure 9 presents the percentage of the average number of devices that failed to respond to the curtailment signal or were not heard by the paging system. This percentage includes the non-respondents during each curtailment event, and the deadbeats during that month.

Month	% of Devices
September	15%
October	21%

Figure 9: Non-Respondent and Deadbeat Thermostats

The review of the heartbeat tests from the paging server indicates that, on average, 5% to 7% of the installed units during the curtailments fall into the deadbeat category. In order to provide a conservative estimate of the total impact of the program, we have reduced our estimate of the total tonnage of all controlled units by 7%, i.e., from over 18,058 tons to 16,794 tons. Accordingly, subsequent analysis assumes that the total size of the controlled air conditioners is 16,794 tons.

2.3 Frequency of Customer Override

This section presents information on the number of thermostats that confirmed receipt of the curtailment notice, and the percentage of thermostats that were overridden by customers. The information is obtained from the thermostat control software database which tracks the aggregate number of active thermostats along with the percentage of those thermostats that responded to the event signal and overrode the curtailment. An override is defined as a manual operation of the thermostat by the customer during a curtailment event (such as raising or lowering the setpoint) which effectively ends the curtailment event.

All non-responsive thermostats are excluded from the analyses in this section. Figure 10 presents the number of confirmed SI expansion thermostats and the override rate by event. The highest override rate occurred on September 7th with 22% of the thermostats being overridden. The override rate is the number of units in the population that overrode the curtailment as a percentage of the units that confirmed the call. This statistic is taken from the event tracking data maintained by the thermostat communications server. The September events are the earliest events where participation from the SI expansion units are recorded in the participant summary report.

[5] The pager transmitter in the PCT is limited by FCC regulations to one Watt, and the signal can be masked by other radio frequency traffic in an attempt to reach the local paging receiver towers

Event	Date	Confirmed Thermostats	% Overrides
181	9/ 1/ 2004	226	21%
183	9/ 7/ 2004	299	22%
187	9/ 8/ 2004	313	7%
191	9/ 23/ 2004	661	20%
192	10/ 7/ 2004	1,226	21%
193	10/ 14/ 2004	1,543	NA

Figure 10: Participation Rates and Curtailments by Month and Degree Setback

2.4 Dates and Times of Curtailment

During the summer of 2004, SCE issued 12 curtailments. Curtailments were called at a variety of times and weather conditions. SCE attempted to call curtailments in the middle of a heat period, in order to simulate the same conditions that would cause an ISO event. SCE also tried to match the timing of the curtailments during the day to the ISO peak load.

The selection of the dates of curtailment during the summer of 2004 by SCE was based upon weather forecasts for Los Angeles and Ontario and the CAL ISO web site[6]. The SCE program manager considered the type of day and week, such as holiday weekends and warming trends, the peak temperature of the predicted peak day, pre-heating trends, day of the peak, and the potential for peak electricity demand. The manager also tried to include an assortment of business day types so that business operation trends could be assessed. The CAL ISO web site was used to establish the timing of the event by obtaining data on peak day usage for the system.

The E$T program tracking system provides detailed information about each curtailment event called in the summer of 2004. Figure 11 summarizes the curtailment events. The first column lists 13 events[7]. The table shows the ID assigned to the event by Carrier, the thermostat manufacturer, the date of the event, the start and end times, and the setback.

Due to problems with data retention with the thermostat communications tracking system, thermostat run time data were only partially available for the events in July. If the data are not collected from the thermostats within 5-7 days, the run time is written over due to a memory limitation in the thermostat. As a consequence, only the eight curtailment events that took place from August 9 onward (due to the completeness of all data) were used in all of the impact analyses for this report.

[6] *http://www.wunderground.com/US/CA/Ontario.html* and *http://www.caiso.com/EIS/weatherbank.html*

[7] The event on October 14th counts as one event for customer overrides, as it was a continuous reduction over 4 hours.

Event ID	Month	Date	Start time	End time
157	July	7/15/2004	2:00 PM	4:00 PM
160	July	7/22/2004	1:00 PM	6:00 PM
164	July	7/26/2004	3:00 PM	5:00 PM
166	July	7/27/2004	3:00 PM	5:00 PM
171	August	8/9/2004	3:00 PM	5:00 PM
174	August	8/10/2004	2:00 PM	4:00 PM
181	September	9/1/2004	2:00 PM	4:00 PM
183	September	9/7/2004	2:00 PM	4:00 PM
187	September	9/8/2004	4:10 PM	6:10 PM
191	September	9/23/2004	2:00 PM	4:00 PM
192	October	10/7/2004	2:00 PM	4:00 PM
193	October	10/14/2004	2:00 PM	4:00 PM
194	October	10/14/2004	4:00 PM	6:00 PM

Figure 11: Dates and Times of Curtailment

There were two events that occurred on 10/14, events 193 and 194. Event 193 was a 2-hour, 4-degree curtailment from 2 PM to 4 PM. At 4 PM the SCE Program Manager called another 4-degree setback for 2 hours. The manager wanted to understand what the load impact would be like if two curtailments were called continuously.

2.5 Weather on Curtailment Days

We will start by examining the exterior temperature in the SCE service area during the summer of 2004. The weather data used in this project were obtained from MeterSmart who had access to weather data by zip code in the Southern California area. Figure 12 shows the entire list of weather stations that are associated with each of the climate zones.

Zone	Station	Tons
A	KLAX	68
A	KSLI	589
A	KTOA	63
B	KCNO	178
B	KCQT	405
B	KFUL	425
B	KHHR	156
B	KLGB	499
B	KSLI	249
B	KSNA	1,581
C	KEMT	2,998
C	KFUL	327
C	KNTD	959
C	KONT	107
C	KPOC	950
C	KVNY	568
D	KCNO	1,830
D	KFUL	534
D	KNFG	546
D	KONT	1,680
D	KRAL	1,597
D	KRIV	1,668
F	KPMD	68
F	KRIV	197
F	KWJF	587
G	KPSP	1,466
H	KRAL	13
H	KRIV	113

Figure 12: Weather Stations

The total tonnage of the participating units in each of the weather zones was used to calculate a weighted average of the temperature across the program in each hour.

Figure 13 shows the daily high temperatures for each weekday. The curtailment days of special interest to us are highlighted in bold.

We will use this type of information to select baseline days that are comparable to the curtailment days to be analyzed.

Date	Day of Week	High
8/2/2004	Mon	87.1
8/3/2004	Tue	88.5
8/4/2004	Wed	87.3
8/5/2004	Thurs	88.0
8/6/2004	Fri	90.9
8/9/2004	**Mon**	**98.1**
8/10/2004	**Tue**	**98.2**
8/11/2004	Wed	94.5
8/12/2004	Thurs	89.4
8/13/2004	Fri	87.5
8/16/2004	Mon	89.1
8/17/2004	Tue	89.7
8/18/2004	Wed	89.1
8/19/2004	Thurs	88.2
8/20/2004	Fri	86.7
8/23/2004	Mon	84.0
8/24/2004	Tue	84.3
8/25/2004	Wed	87.2
8/26/2004	Thurs	86.5
8/27/2004	Fri	89.1
8/30/2004	Mon	93.4
8/31/2004	Tue	96.8
9/1/2004	**Wed**	**97.1**
9/2/2004	Thurs	95.2
9/3/2004	Fri	84.2
9/6/2004	Mon	95.4
9/7/2004	**Tue**	**97.6**

Date	Day of Week	High
9/8/2004	**Wed**	**93.3**
9/9/2004	Thurs	91.8
9/10/2004	Fri	93.7
9/13/2004	Mon	87.1
9/14/2004	Tue	84.4
9/15/2004	Wed	85.4
9/16/2004	Thurs	87.4
9/17/2004	Fri	87.5
9/20/2004	Mon	77.5
9/21/2004	Tue	87.5
9/22/2004	Wed	90.6
9/23/2004	**Thurs**	**90.8**
9/24/2004	Fri	92.6
9/27/2004	Mon	87.9
9/28/2004	Tue	81.3
9/29/2004	Wed	76.4
9/30/2004	Thurs	73.9
10/1/2004	Fri	79.6
10/4/2004	Mon	82.8
10/5/2004	Tue	85.7
10/6/2004	Wed	88.1
10/7/2004	**Thurs**	**88.5**
10/8/2004	Fri	92.5
10/11/2004	Mon	82.0
10/12/2004	Tue	86.1
10/13/2004	Wed	84.4
10/14/2004	**Thurs**	**89.9**

Figure 13: Daily Weather Statistics

2.6 Comparison of Summer Initiative Population to Existing AB970 E$T Population

Figure 14 displays the proportion of units in the final SI expansion and the existing E$T populations. The distributions are very similar between the two populations, with the majority of the units in the three to six ton range.

Tons	***% of SI E$T Units with Tons***	***% of Existing E$T Units with Tons***
1 to 1.9	0.6%	0.5%
2 to 2.9	9%	12%
3 to 3.9	31%	25%
4 to 4.9	22%	24%
5 to 5.9	31%	32%
6 to 6.9	1.1%	0.9%
7 to 7.9	0.7%	1.8%
8 to 8.9	0.8%	1.5%
9 to 9.9	0%	0%
10 to 10.9	1.5%	1.3%
>= 11	0.7%	1.0%

Figure 14: Comparison of SI and Existing E$T Populations with Known Tons

Figure 15 maps each zip code that has the original E$T units installed. The size of the circle indicates the number of installed units in each zip code, with the larger circles indicating larger quantities of installed thermostats. Figure 16 shows a similar distribution of the Summer Initiative expansion units installed by each zip code that has the SI units installed. As expected, the two figures are remarkably similar since both program populations were drawn from the same group of SCE small commercial businesses. Since the existing E$T end use metered units were drawn from the existing E$T population using a statistically representative sampling plan, they are likely to be similar to the sample units that would have been metered using a sampling plan on the SI expansion units. The weather data from these two populations are also very similar.

Therefore the end use metered data will be expanded to the SI expansion population for the end use meter analysis. The temperature-load relationship established from the end use metered units will also be applied to the SI expansion units used in the runtime analysis to produce estimates of the hourly kWh energy consumption of each installed SI expansion unit.

Figure 15: Existing E$T Unit Locations

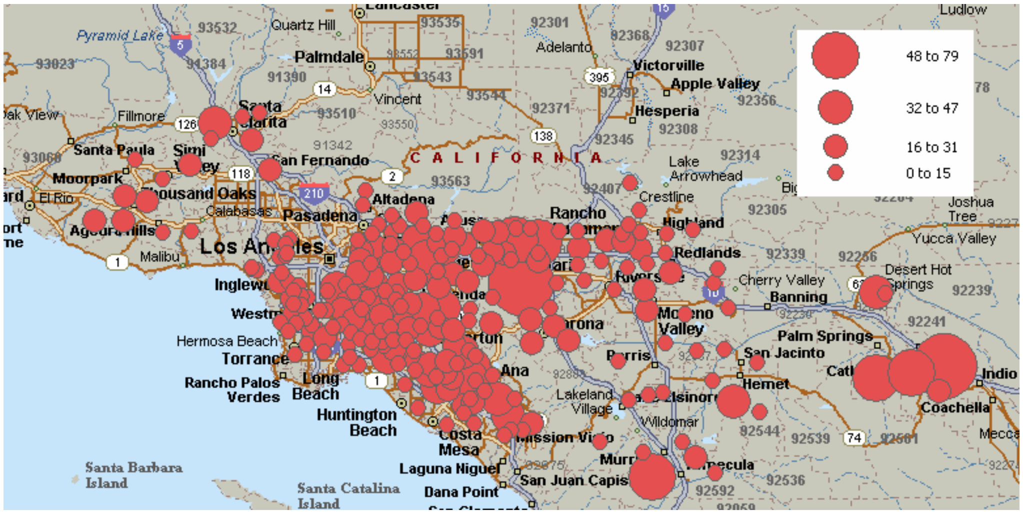

Figure 16: Summer Initiative Expansion Unit Locations

However, the early installations of the SI expansion units were not representative of the final SI expansion population since the installation contractors used a geographically targeted installation plan for the early installations. Figure 17 shows the SI expansion units installed through mid-September. It is apparent that the locations of the early installations are not representative of the final SI expansion population when comparing Figure 17 to the final SI expansion population shown in Figure 16. The early installs were targeted in the Coachella Valley, and had less units installed in the Los Angeles Basin and the Inland Empire. Since these areas have very different weather conditions, the run time data collected from the early installed SI expansion units are not representative of the program population.

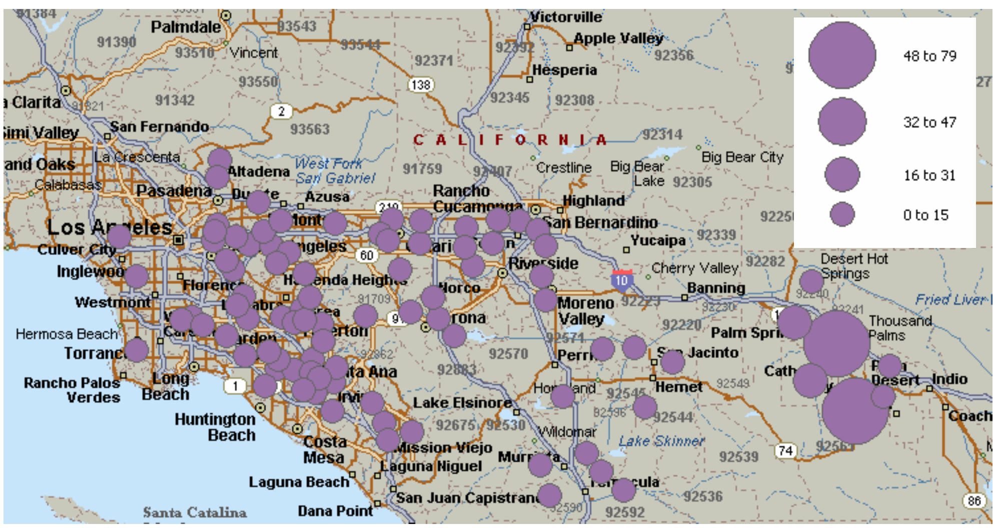

Figure 17: Summer Initiative Expansion Unit Locations – Early Installs

This difference in the timing of deployment affects the run time data analysis only, and not the end use metered data analysis. The end use metered data analysis simply uses the metered sample as a proxy sample that is expanded to the SI expansion population. In the run time data analysis, the actual data collected from the SI expansion installed sample is used. Since the SI expansion thermostats were being installed throughout the summer of 2004, there were limited data from the events called during 2004. The available data came from the early installs, which were geographically grouped, and were subject to different weather conditions than the population.

Therefore the results from this analysis should be used as a preliminary estimate of the impacts from the SI expansion program. It is very likely that as more thermostats were installed and began to respond to the signals (the locations of which were more representative of the population), the impacts stabilized and became more similar to the impacts seen in the End Use Meter data analysis.

3 Analysis of the End Use Meter Data

The end use meter data provide 5-minute kWh measurements of the 100 existing E$T units that were selected for end use metering. These data were used to estimate the average kW and kWh impact per rated ton on each of eight curtailment days. These 100 units were expanded to the Summer Initiative expansion population by tonnage to ensure that the existing E$T sample appropriately represents the SI population.

3.1 Method of Analysis

In this section we will summarize our methodology for using the existing E$T end use meter data to estimate impacts. Our analysis followed these steps:

1. Use interactive data visualization software to review the 5-minute load data of each unit,
2. Develop case weights for each HVAC unit with end use meter data to represent the size distribution of all units installed in the program,
3. Using the case weights, calculate the average 5-minute load per rated ton of all one hundred HVAC units to provide a single analysis variable,
4. Use the temperature data to identify one or more days that are comparable to each curtailment day,
5. Use the 5-minute load data for the average HVAC unit to calculate the baseline load per rated ton for the curtailment day, and
6. Calculate the kW load reduction per rated ton as the difference between the actual load per rated ton and the baseline load per rated ton.

The average load per rated ton was obtained by post-stratifying the sample units as shown in Figure 19. Each unit was given a case weight equal to the population size divided by the sample size in the corresponding stratum. Then the case weights were used to calculate the average load, measured as kW per rated ton, of the sample units in each 5-minute interval.

Once the savings were calculated, the estimated savings per rated ton was multiplied by the estimated total tons of cooling capacity of all participating units to estimate the total kW and kWh savings of all participating units.

3.2 End Use Metered Sites

The end use metered data involved one hundred thermostats that controlled HVAC units in the existing E$T program. MeterSmart collected 5-minute end use meter data for each unit from the beginning of August through October 2004. The data typically include the kWh usage of each HVAC unit and the run time of the unit, both measured and recorded continuously every five minutes. The data were transferred to RLW after being screened and verified as correct. RLW leveraged the end use metered data collected during the summer of 2004 on the existing AB970 E$T program participants to evaluate the Summer Initiative expansion participants.

Logger	Tons	Pin	Weight	Logger	Tons	Pin	Weight
A0101_1	4	1296644	58.56	D0300_2	8	1457288	6.57
A0330_1	4	1342046	58.56	D0300_3	8	1457998	6.57
A0330_2	4	1342681	58.56	D0403_1	8	1342218	6.57
B0142_1	8	1295719	6.57	B3335_1	12.5	1295639	11.10
B0243_1	4	1342462	58.56	D0403_2	15	1457046	11.10
B0243_2	3	1327320	58.09	D0403_4	8	1341902	6.57
B0243_3	3	1342099	58.09	D0471_1	3	6262097	58.09
B0243_4	5	1327791	55.54	D0471_2	3	6044145	58.09
B0633_1	10	1342183	6.57	D0812_1	5	1457372	55.54
B0950_1	4	1342594	58.56	D0812_2	5	1457364	55.54
B1085_1	4	1457120	58.56	D1013_1	3	1079790	58.09
B2036_1	5	1457116	55.54	D1013_2	4	1079840	58.56
B2298_1	3	1485938	58.09	D1013_3	5	1079791	55.54
B2333_1	4	1487072	58.56	D1013_4	3	1079800	58.09
B2333_2	4	1486714	58.56	D1317_1	2	1296539	58.09
B2521_1	10	1839227	6.57	D1379_1	3.5	1342627	58.56
B2956_1	5	1839157	55.54	D1379_2	4	1457616	58.56
B2970_1	4	1839166	58.56	D1573_1	8	1296589	6.57
D0403_3	15	1341875	11.10	D1648_1	5	6261966	55.54
C0258_1	5	1508523	55.54	D1831_1	2	1296186	58.09
C0258_2	3	1327216	58.09	D1831_2	2	1296445	58.09
C0444_1	10	1835022	6.57	D1831_3	2	1296446	58.09
C0444_2	5	1341112	55.54	D1831_4	2	1817945	58.09
C0676_1	4	1295725	58.56	D2018_1	5	1295960	55.54
C0676_2	4	1296285	58.56	D2099_1	7	1485265	6.57
C0705_1	3	1456987	58.09	D2099_2	7	1485592	6.57
C0705_2	3	1457037	58.09	D2200_1	5	1486939	55.54
C0842_1	8	1457644	6.57	D2428_1	2	1485257	58.09
C1042_1	5	1296372	55.54	D2428_2	6	1485587	25.18
C1042_2	5	1296183	55.54	D2428_3	6	1485588	25.18
C1936_1	5	1090857	55.54	D3034_1	8	6043985	6.57
C1936_2	5	1511751	55.54	D3034_2	8	6262134	6.57
C1936_3	5	1079958	55.54	D3034_3	3	6262097	58.09
C2373_1	7	1296266	6.57	D3034_4	8	6262083	6.57
C2373_2	7	1296227	6.57	D3618_1	4	6043939	58.56
C2373_3	3	1296271	58.09	D3714_1	5	1486712	55.54
C2814_1	4	1486701	58.56	D3714_2	5	1487049	55.54
C2814_2	4	1486699	58.56	D3714_3	4	1485926	58.56
C2977_1	5	1532901	55.54	D6010_1	8	1327654	6.57
C2977_2	3	1486820	58.09	F0379_1	2	1296407	58.09
C2977_3	3	1456943	58.09	F0379_2	3	1296410	58.09
C2977_4	5	1486513	55.54	F0379_3	4	1342824	58.56
C3029_1	5	1295568	55.54	F1633_1	3	1327337	58.09
C3029_2	5	1487053	55.54	F2389_1	4	6262060	58.56
C3029_3	5	1295666	55.54	G0007_1	5	1457373	55.54
C3029_4	5	1295670	55.54	G0336_1	10	1342520	6.57
C3225_1	2	1839595	58.09	G3999_1	8	1487065	6.57
D0075_1	3	1090505	58.09	G3999_2	8	1486674	6.57
D0129_1	3	1817919	58.09	G3999_3	4	6043189	58.56
D0300_1	8	1457181	6.57	G4130_1	3	6044137	58.09

Figure 18: HVAC Units in the End Use Metered Sample

There were one hundred units included in our analysis. The data provide a spot measurement of the kW load of each unit every five minutes from August through October. There are small units, less than 7-tons cooling capacity, and large units, 7-tons or greater, in the program. The smaller units sometimes have an independent fan load that is usually less than 1 kW and is not controlled by the thermostat. The large units are of concern to us for the analysis because they are often multi-stage units and the thermostat run time data were not designed to accurately describe the operation of these units.

Fortunately, after review of the end use data, it appears that the temperature-offset curtailment strategy appears to affect large, multistage units in essentially the same way as small one-stage units, ensuring a correlation of tonnage to load reduction.

3.3 Case Weights

The small commercial sites included in the end use metering sample were initially designed to be a representative sample of the existing E$T program participants. We developed case weights to ensure our analysis of the existing E$T end use metered sample units located at these sites reflected the size distribution of all air conditioners installed in the SI expansion E$T program. We developed the six ex-post strata shown in Figure 19. The column named 'Weight' shows the case weight used to calculate the average load per rated ton of the sample units.

Class	*Stratum*	*Max Size*	*Total Tons*	*Population*	*Sample*	*Weight*
Small	1	3	3,788	1,400	27	58.09
Small	2	4	4,029	1,082	21	58.56
Small	3	5	4,217	908	25	55.54
Small	4	6.5	4,287	847	2	25.18
Subtotal				4,237	75	
Large	1	10	832	99	22	6.57
Large	2	15	905	79	3	11.10
Subtotal				178	25	
Total			18,058	4,415	100	

Figure 19: Post Stratification of the HVAC Units with End Use Meter Data

3.4 Load of HVAC Units with End Use Meter Data

We now utilize the average load of the sample units with end use meter data to assess the impact of the eight curtailment days from August 9 onward. We will analyze the curtailment days in chronological order.

Event 171 - August 9, 2004

The August 9 curtailment was a 4-degree setback from 2 to 4 PM. The first step in the analysis of this event was to choose a comparison day to provide a baseline for calculating the true load impact of the curtailment. Instead of selecting one comparison day we decided to use an average of 3 comparison days (8/11, 8/31, 9/2). We first directly compared the average load of the sample units on the curtailment day to the average load on the three averaged comparison days. The temperatures were slightly different between the three comparison days and the curtailment day, therefore we chose to adjust the averaged baseline load to better reflect the load of a true baseline day by multiplying the baseline load by a fixed factor. We calculated the adjustment factor as the ratio between the average load during the two hours corresponding to the curtailment on the three baseline days, divided by the average load during the two hours prior to the actual curtailment on August 9.

After applying this true-up adjustment, we produced the graph shown in Figure 20. The blue line is the actual load on August 9 and the red line is the average load of the three baseline days. The area between the red and blue lines shows the estimated impact of the curtailment. In the first hour of the curtailment the load relief is the greatest, after which the load relief becomes smaller, a result of some of the HVAC units beginning to operate again.

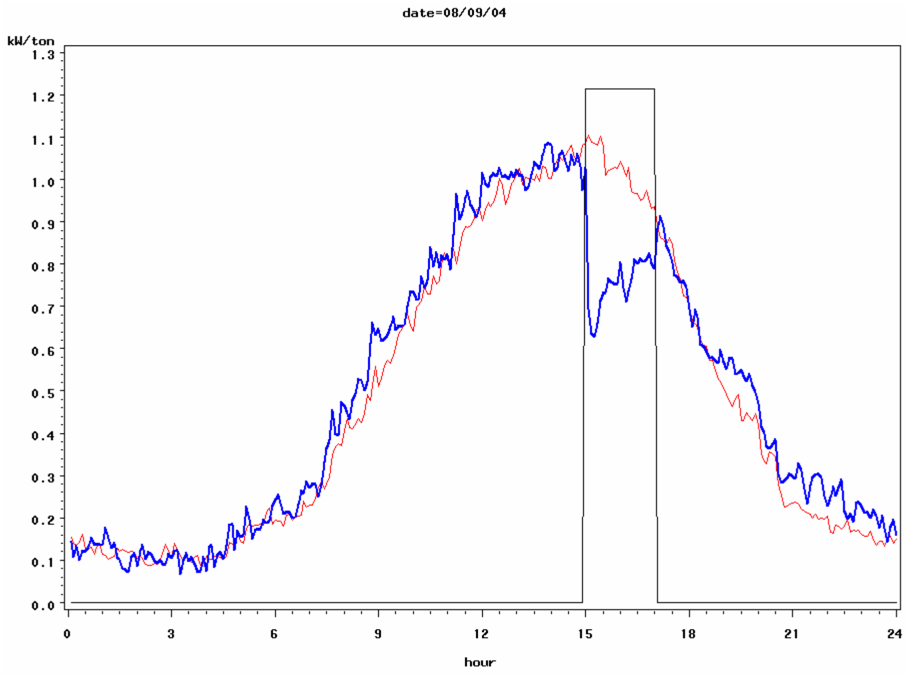

Figure 20: Estimating the Impact on August 9

Figure 21 summarizes the characteristics of the event. The summary shows the date and time of the curtailment and the temperature offset. The table also shows the high temperature on the day of curtailment, taken from Figure 13. The remaining statistics in Figure 21 reflect our analysis of the average load of the sample units with end use meter data. During the two-hour curtailment, the average load per unit dropped by a maximum of 0.46 kW per ton. The minimum reduction was 0.12 kW per ton during the period, indicating that the full savings did not persist through the full period. The energy savings during the entire curtailment period was estimated to be 0.53 kWh per ton.

We also calculated the kWh savings during each hour of the curtailment, as well as during the first hour following the curtailment period. During the first hour of the curtailment the savings were 0.34 kWh per ton. From the first hour to the second hour of the curtailment period, the energy savings fell from 0.34 kWh to 0.19 kWh per ton. This is consistent with the estimated effective duration of the curtailment. In the hour following the curtailment period, there was little change in energy consumption. This suggests that there was little or no snapback. The summary characteristics shown in Figure 21 are consistent with the graphical description of the results shown in Figure 20.

Curtailment Date	8/9/2004
Start Time	3:00 PM
End Time	5:00 PM
Offset	4
Curtailment Day High	98.1
Baseline Days	8/11/04, 8/31/04, 9/2/04
Baseline Days Average High	92.1
Maximum Reduction	0.46
Minimum Reduction	0.12
Energy Savings	0.53
Minutes Duration	75
kWh Savings in Hour 1	0.34
kWh Savings in Hour 2	0.19
Hour Following	0.001

Figure 21: Summary Report for August 9

We will follow a similar approach for each of the remaining curtailment days of interest. Our commentary will be brief since the format of the results will be similar. After developing the results for each of the eight curtailment days, we will provide an analysis of the results and findings across all eight days.

Event 174 - August 10, 2004

As shown in Figure 22, the August 10 curtailment was a 4-degree setback from 2 to 4 PM. The chosen baseline days for August 10 were August 11, August 31, and September 2. Figure 22 shows the results graphically, and Figure 23 provides the summary report.

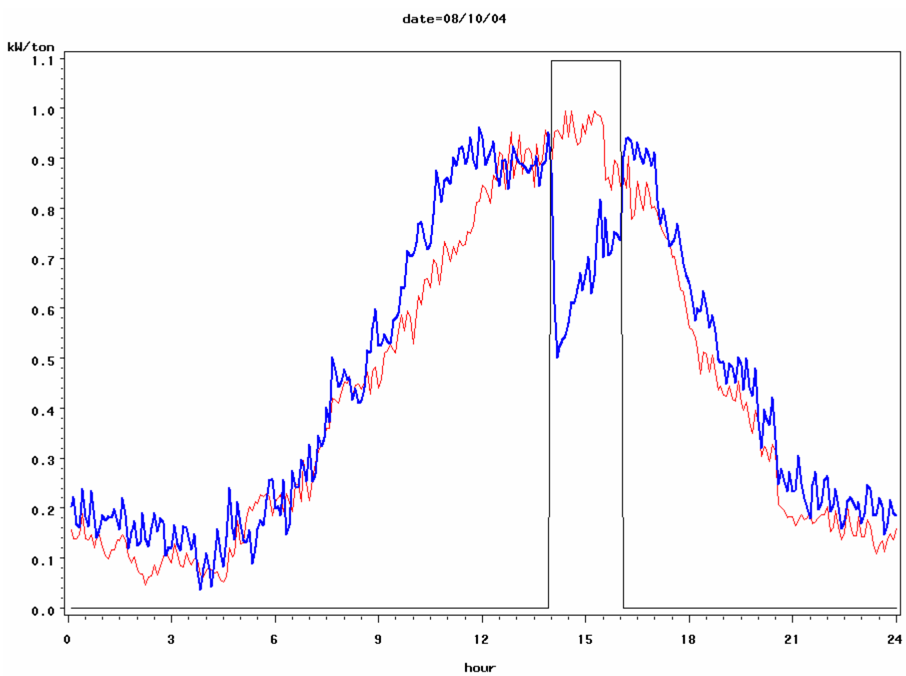

Figure 22: Estimating the Impact on August 10

Curtailment Date	8/10/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4
Curtailment Day High	98.2
Baseline Days	8/31/04, 8/11/04, 9/2/04
Baseline Days Average High	92.1
Maximum Reduction	0.46
Minimum Reduction	0.08
Energy Savings	0.56
Minutes Duration	80
kWh Savings in Hour 1	0.36
kWh Savings in Hour 2	0.20
Hour Following	-0.09

Figure 23: Summary Report for August 10

Event 181 - September 1, 2004

The September 1 curtailment was a 4-degree setback from 2 to 4 PM. As baseline days for September 1, we chose August 30, August 31, and September 2. The average high temperature on these days fell in a range from 90.1 to 94.4 degrees. Figure 24 shows the results graphically, and Figure 25 provides the summary report.

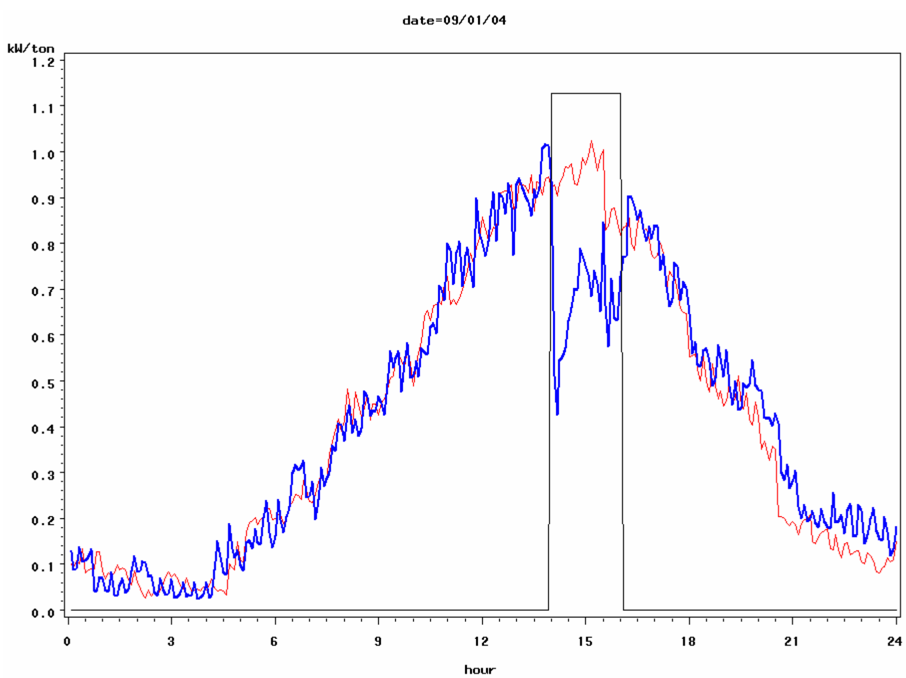

Figure 24: Estimating the Impact on September 1

Curtailment Date	9/1/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4
Curtailment Day High	97.1
Baseline Days	8/30/04, 8/31/04, 9/2/2004
Baseline Days Average High	91.9
Maximum Reduction	0.48
Minimum Reduction	0.09
Energy Savings	0.54
Minutes Duration	70
kWh Savings in Hour 1	0.31
kWh Savings in Hour 2	0.23
Hour Following	-0.02

Figure 25: Summary Report for September 1

Event 183 - September 7, 2004

The September 7 curtailment was a 4-degree setback from 2 to 4 PM. As shown in Figure 13, it was a hot 94 degrees that day. August 31, September 2, and September 9 were selected as comparison days because of their respective similar high temperatures.

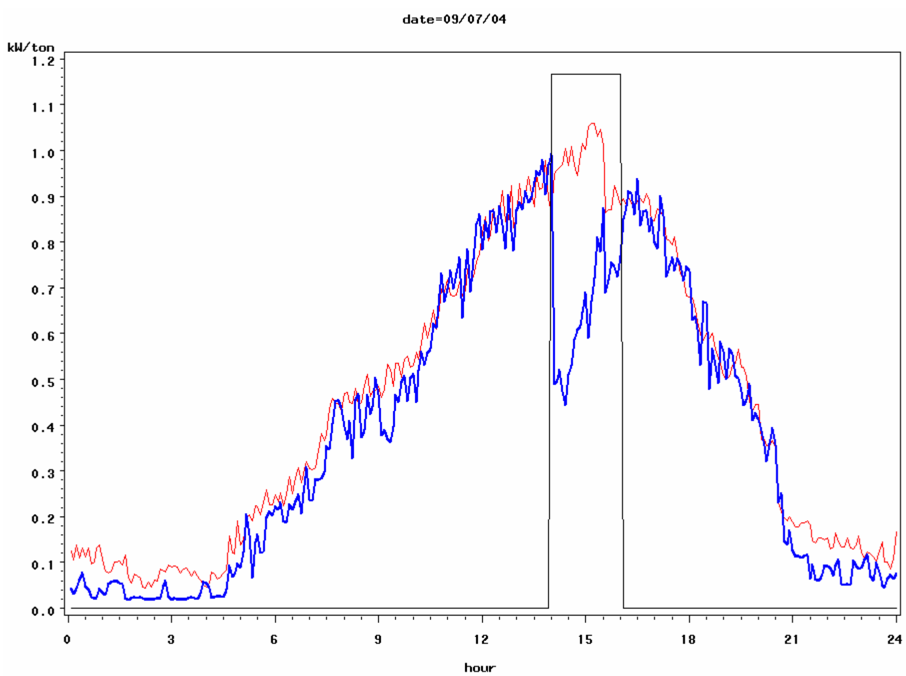

Figure 26: Estimating the Impact on September 7

Curtailment Date	9/7/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4
Curtailment Day High	97.6
Baseline Days	8/31/04, 9/2/04, 9/9/04
Baseline Days Average High	92.4
Maximum Reduction	0.56
Minimum Reduction	0.11
Energy Savings	0.66
Minutes Duration	75
kWh Savings in Hour 1	0.43
kWh Savings in Hour 2	0.23
Hour Following	0.02

Figure 27: Summary Report for September 7

Event 187 - September 8, 2004

The September 8 curtailment was a 4-degree setback from 4:10 to 6:10 PM. The September 8 event occurred on a day with a high of 93.3 degrees. The days with comparable temperatures used as baseline for this day were August 31, September 2, and September 9, which had an average high of 94.6. The results are shown in Figure 28 and summarized in Figure 29. The maximum reduction on September 8 was 0.48 kW per ton. The estimated effective duration was 55 minutes.

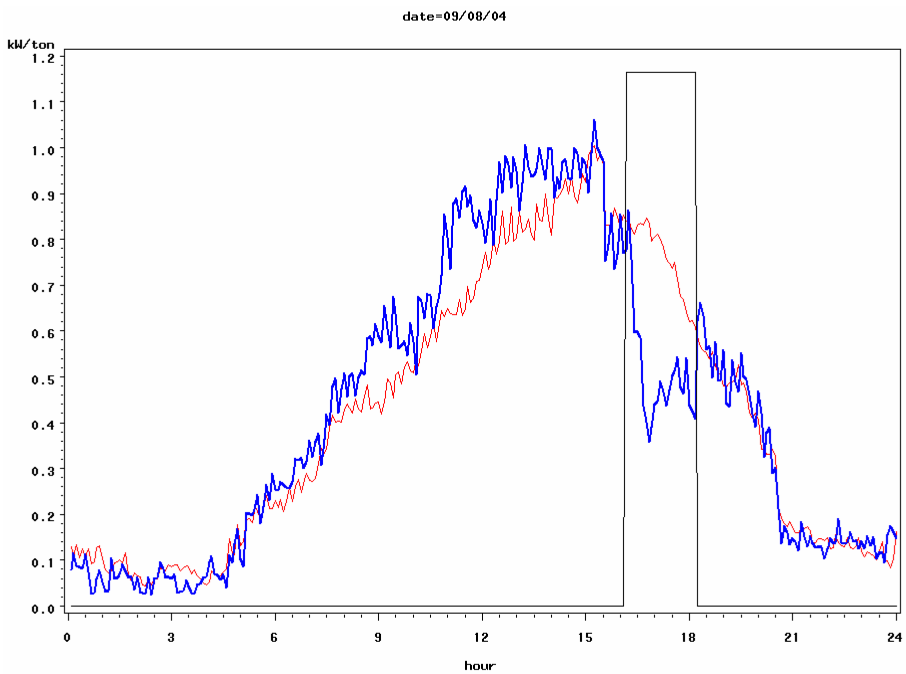

Figure 28: Estimating the Impact on Sept 8

Curtailment Date	9/8/2004
Start Time	4:10 PM
End Time	6:10 PM
Offset	4
Curtailment Day High	93.3
Baseline Days	8/31/04, 9/2/04, 9/9/04
Baseline Days Average High	92.4
Maximum Reduction	0.48
Minimum Reduction	-0.02
Energy Savings	0.51
Minutes Duration	55
kWh Savings in Hour 1	0.29
kWh Savings in Hour 2	0.22
Hour Following	-0.02

Figure 29: Summary Report for Sept 8

Event 191 - September 23, 2004

The September 23 curtailment was a 4-degree setback from 2 to 4 PM. The baseline for this curtailment was based on the load for the days of September 21, September 22, and September 27. As shown in Figure 13, on September 23, a Thursday, the maximum temperature was 90.8 degrees. The baseline days were chosen because of their similar average high temperature of 88.6.

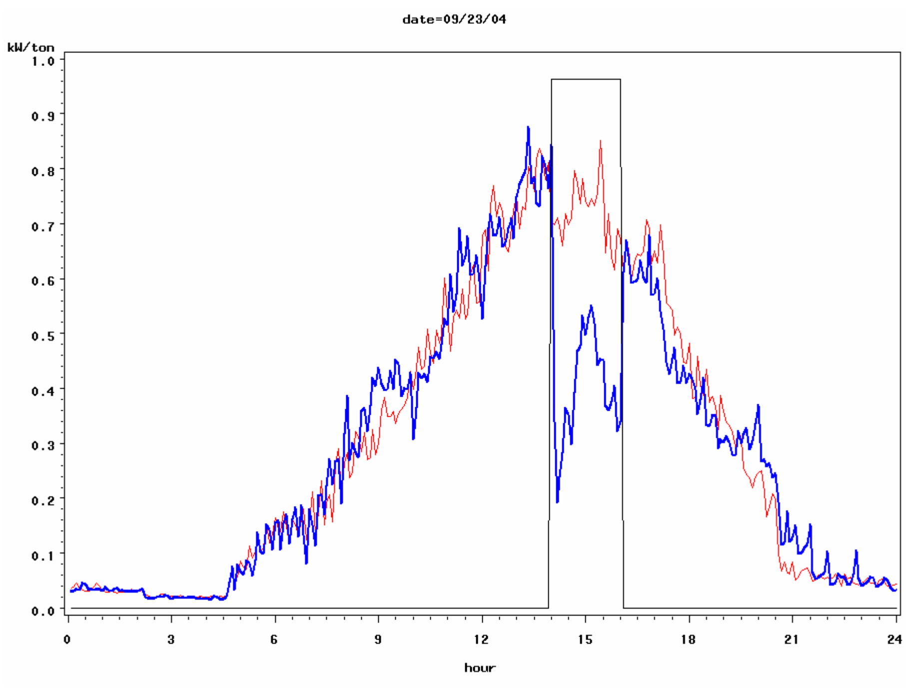

Figure 30: Impact of Curtailment on Average Load for September 23

Curtailment Date	9/23/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4
Curtailment Day High	90.8
Baseline Days	9/21/04, 9/22/04, 9/27/04
Baseline Days Average High	87.5
Maximum Reduction	0.52
Minimum Reduction	0.19
Energy Savings	0.64
Minutes Duration	85
kWh Savings in Hour 1	0.36
kWh Savings in Hour 2	0.29
Hour Following	0.03

Figure 31: Summary Report for Sep 23

Event 192 - October 7, 2004

The October 7 curtailment was a 4-degree setback from 2 to 4 PM. The baseline for the October 7 curtailment was based on the load for the days of September 27, October 6, and October 12. These days were chosen because their average high temperature was 87.3 degrees, which is similar to the high temperature on October 7.

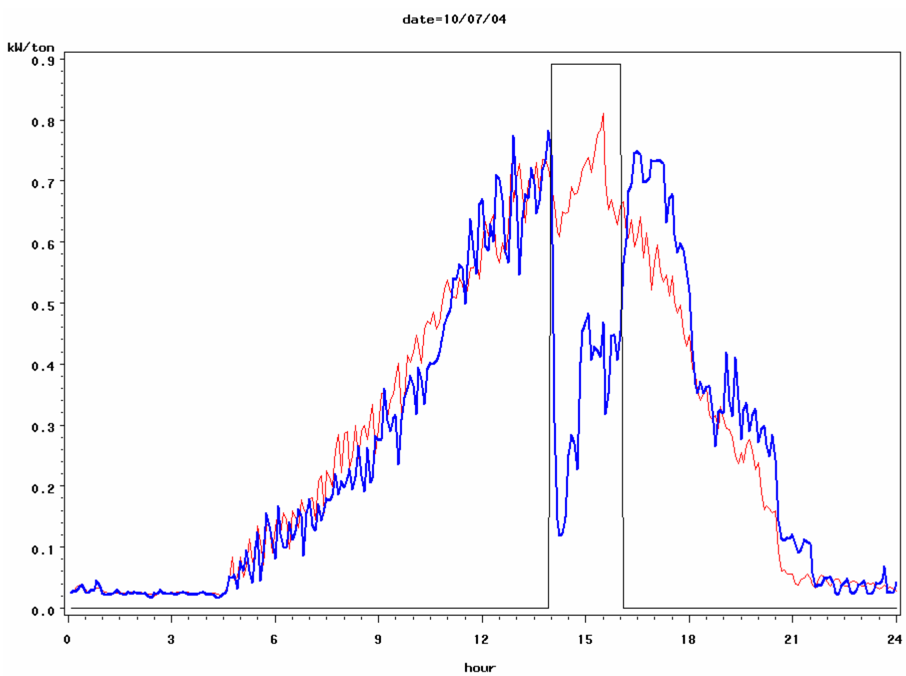

Figure 32: Impact of Curtailment on Average Load for Oct 7 Event

Curtailment Date	10/7/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4
Curtailment Day High	88.5
Baseline Days	9/27/04, 10/6/04, 10/12/04
Baseline Days Average High	84.9
Maximum Reduction	0.53
Minimum Reduction	0.20
Energy Savings	0.69
Minutes Duration	90
kWh Savings in Hour 1	0.40
kWh Savings in Hour 2	0.29
Hour Following	-0.09

Figure 33: Summary Report for Oct 7

Event 193 - October 14, 2004

There were two separate curtailment events called on October 14. The first was a 4-degree setback from 2 to 4 PM and the second was a 4-degree setback from 4 to 6 PM. The baseline for the October 14 curtailment was based on the averaged load on September 21, September 22, and October 12. These days were chosen because they were weekdays with an average high temperature of 88.1 degrees.

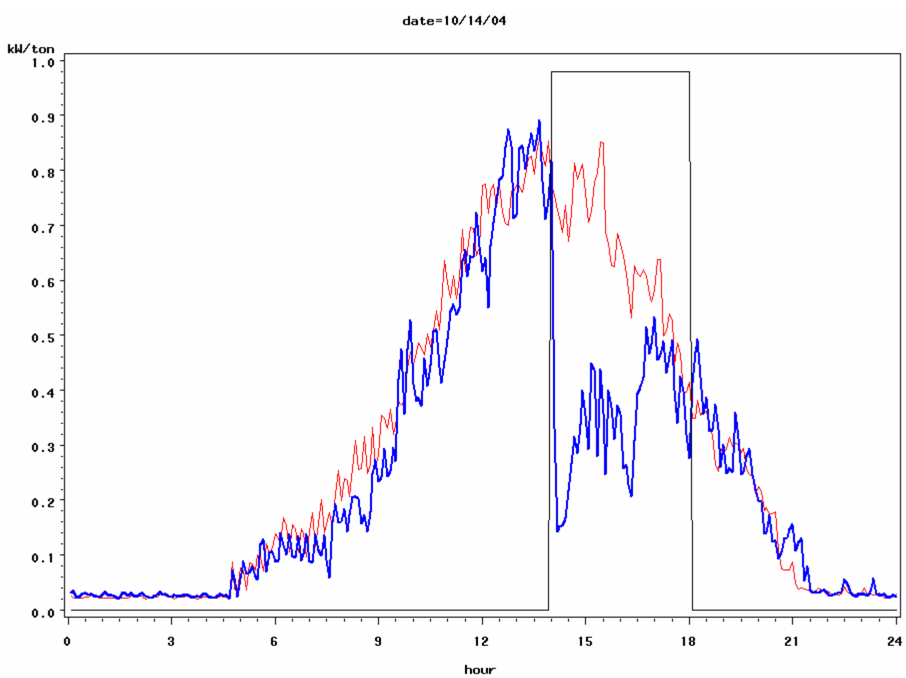

Figure 34: Impact of Curtailment on Average Load for Oct 14 Event

Curtailment Date	10/14/2004
Start Time	2:00 PM
End Time	6:00 PM
Offset	4
Curtailment Day High	89.9
Baseline Days	9/21/04, 9/22/04, 10/12/04
Baseline Days Average High	87.6
Maximum Reduction	0.59
Minimum Reduction	0.00
Energy Savings	1.16
Minutes Duration	130
kWh Savings in Hour 1	0.49
kWh Savings in Hour 2	0.36
kWh Savings in Hour 3	0.22
kWh Savings in Hour 4	0.08
Hour Following	-0.05

Figure 35: Summary Report for Oct 14

3.5 Summary of All Eight Curtailment Days with End Use Meter Data and Program Impact Estimate

Figure 36 provides the information from the summary reports for each of these eight curtailment events. Although these events differed in some respects, we believe they can be analyzed as a group.

We will start by noting the average characteristics of the eight curtailments shown in Figure 36. Based on a simple numerical average, the 'typical' event can be described as follows:

- The maximum reduction was 0.51 kW per ton,
- The savings in the first hour was 0.33 kWh per ton,
- The savings in the second hour was 0.22 kWh per ton,
- The effective duration was 76 minutes, measured as the 'half-life' of the savings,
- There was little or no snapback following the curtailment period.

Based on these results from the end use meter data sample, we can estimate the total program-wide impact of a 4-degree curtailment. In Figure 19 we estimated that the 4,415 participating units have a total size of 18,058 tons. As discussed previously, after discounting for **7% non-responsive thermostats** (deadbeats), we estimated that the total controlled tonnage was 16,794 tons. Using this information together with the preceding results, we can estimate the total program impact as shown in Figure 37.

Curtailment Date	8/9/2004	8/10/2004	9/1/2004	9/7/2004	9/8/2004	9/23/2004	10/7/2004	10/14/2004
Start Time	3:00 PM	2:00 PM	2:00 PM	2:00 PM	4:10 PM	2:00 PM	2:00 PM	2:00 PM
End Time	5:00 PM	4:00 PM	4:00 PM	4:00 PM	6:10 PM	4:00 PM	4:00 PM	6:00 PM
Offset	4	4	4	4	4	4	4	4
Curtailment Day High	98.1	98.2	97.1	97.6	93.3	90.8	88.5	89.9
Baseline Days	8/11/04, 8/31/04, 9/2/04	8/31/04, 8/11/04, 9/2/04	8/30/04, 8/31/04, 9/2/2004	8/31/04, 9/2/04, 9/9/04	8/31/04, 9/2/04, 9/9/04	9/21/04, 9/22/04, 9/27/04	9/27/04, 10/6/04, 10/12/04	9/21/04, 9/22/04, 10/12/04
Baseline Days Average High	92.1	92.1	91.9	92.4	92.4	87.5	84.9	87.6
Maximum Reduction	0.46	0.46	0.48	0.56	0.48	0.52	0.53	0.59
Minimum Reduction	0.12	0.08	0.09	0.11	-0.02	0.19	0.20	0.00
Energy Savings	0.53	0.56	0.54	0.66	0.51	0.64	0.69	1.16
Minutes Duration	75	80	70	75	55	85	90	130
kWh Savings in Hour 1	0.34	0.36	0.31	0.43	0.29	0.36	0.40	0.49
kWh Savings in Hour 2	0.19	0.20	0.23	0.23	0.22	0.29	0.29	0.36
kWh Savings in Hour 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.22
kWh Savings in Hour 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08
Hour Following	0.001	-0.09	-0.02	0.02	-0.02	0.03	-0.09	-0.05

Figure 36: Summary of 4-Degree Curtailments

From this analysis which developed a kW per ton estimate of the demand reduction for the SI expansion, we can now extrapolate to the SI expansion population. We estimate that among all 4,415 participating units, a 4-degree, two-hour curtailment will yield on average a maximum initial kW reduction of approximately 8.5 MW, first hour energy savings of about 5.6 MWh, and second hour energy savings of about 3.7 MWh.

	Per Sample Ton	***Program Total***
Maximum kW Reduction	0.51	8,540
kWh Savings in Hour 1	0.33	5,554
kWh Savings in Hour 2	0.22	3,705

Figure 37: Estimated Program-Wide Impact from the End Use Metering Results

3.6 Precision

Figure 38 again shows the estimates of the kWh savings for each curtailment event measured in kWh per ton of controlled air conditioning that were presented in Figure 36. The last row of Figure 38 shows the average results across the curtailments. Considering all eight curtailments taken together, the savings were 0.331 kWh per ton in the first hour and 0.221 kWh per ton in the second hour, for a total savings of 0.551 kWh per ton in the first two hours of the curtailment. The average value of the maximum impact across the eight curtailments was 0.55 kW per ton. In calculating the average duration, we have excluded the one 4-hour curtailment (event 193). Among the seven 2-hour curtailments the average duration was 76 minutes. In the hour following the curtailment, the average snapback was 0.026 kWh per ton.

		Savings in Hour				Total	Maximum	Minutes	Hour
Date	Event	1	2	3	4	Savings	Impact	Duration	Folowing
8/9/04	171	0.381	0.222	na	na	0.602	0.46	75	-0.001
8/10/04	174	0.370	0.156	na	na	0.525	0.46	80	-0.091
9/1/04	181	0.417	0.290	na	na	0.708	0.48	70	-0.037
9/7/04	183	0.419	0.227	na	na	0.646	0.56	75	-0.051
9/8/04	187	0.249	0.249	na	na	0.498	0.48	55	0.031
9/23/04	191	0.425	0.315	na	na	0.740	0.52	85	0.077
10/7/04	192	0.340	0.195	na	na	0.535	0.53	90	-0.130
10/14/04	193	0.420	0.299	0.225	0.135	1.079	0.59	130	-0.061
Average, all Events		0.331	0.221	na	na	0.551	0.51	76	-0.026

Figure 38: Measures of Impact from End Use Metering

Figure 39 shows the relative precision of the kWh savings reported in Figure 38, calculated at the 90% level of confidence. For example, the first-hour savings of all eight curtailments taken together had a relative precision of ± 21% at the 90% level of confidence. So the 90% confidence interval for the first-hour savings of all eight curtailments taken together can be calculated as 0.331 ± (0.21)(0.331), or 0.331 ± 0.07 kWh per ton. Similarly, the 90% confidence interval for the total savings over the two hours of the curtailment period is 0.551 ± 0.119 kWh per ton.

		Relative Precision in Hour				Total
Date	Event	1	2	3	4	Savings
8/9/2004	171	0.28	0.36	0.00	0.00	0.29
8/10/2004	174	0.31	0.64	0.00	0.00	0.36
9/1/2004	181	0.26	0.33	0.00	0.00	0.26
9/7/2004	183	0.29	0.48	0.00	0.00	0.33
9/8/2004	187	0.31	0.37	0.00	0.00	0.30
9/23/2004	191	0.25	0.37	0.00	0.00	0.27
10/7/2004	192	0.33	0.48	0.00	0.00	0.35
10/14/2004	193	0.34	0.34	0.34	na	0.32
Average, all Events		0.21	0.27	0.34	na	0.22

Figure 39: Relative Precision of Savings from End Use Metering

Figure 40 shows the error ratios associated with the kWh savings. The error ratios are a measure of site to site variability for stratified ratio estimation, and can be used to help plan the sample sizes for future studies. Considering the average savings of all events, the error ratio was found to be 1.2 for the first-hour savings, and 1.5 for the second-hour savings. The increase in the error ratio from the first hour to the second hour suggests greater variability in the savings in the second hour compared to the first hour, reflecting site to site differences in the persistence of the savings. The error ratio was 1.2 for the total savings in the two hours of the curtailment.

The error ratios for the average of all events are always smaller than the error ratios for the individual events. This reflects the reduction in site to site variation in the average savings of each site across several events compared to the site to site variation in the savings of the individual events. However, the reduction in the error ratio from averaging eight events is less than would be the case if the savings were statistically independent from event to event within a given site. Thus the variability is more strongly affected by the number of sites in the sample than by the number of curtailments per sample site.

		Error Ratio in Hour				Total
Date	Event	1	2	3	4	Savings
8/9/2004	171	1.4	1.8	0.0	0.0	1.4
8/10/2004	174	1.5	3.2	0.0	0.0	1.8
9/1/2004	181	1.2	1.6	0.0	0.0	1.2
9/7/2004	183	1.4	2.3	0.0	0.0	1.6
9/8/2004	187	1.5	1.8	0.0	0.0	1.5
9/23/2004	191	1.1	1.5	0.0	0.0	1.2
10/7/2004	192	1.6	2.2	0.0	0.0	1.7
10/14/2004	193	1.5	1.4	1.4	na	1.4
Average, all Events		1.2	1.5	0.0	na	1.2

Figure 40: Error Ratio of Savings from End Use Metering

4 Analysis of the Thermostat Run time Data

A key element of our analysis strategy is the hourly HVAC run time data that can be retrieved from each of the thermostats via the communications software. The thermostat manufacturer has described the run time data collected by these thermostats as follows:

- What it does:
  - Each hour, the thermostat monitors and records the HVAC equipment run time for each hour in minutes, average room temperature, and thermostat temperature set points.
  - The thermostat can store the hourly data for 7 days, then it starts to write over its own records.
  - The run time data can be transmitted via two way pager on request to a server maintained by another contractor, which then stores the data and can later retrieve it for analysis upon request.

There is also a means to collect a real time "Snapshot" of the run time available from the thermostat on an as-requested basis during a curtailment. Figure 41 illustrates a "snapshot" of the run time data that is collected during a curtailment. The figure shows that just prior to the curtailment, the set point was 72° F, but this was raised to 76° F for four hours. The current temperature shows the average temperature at the thermostat during each hour during the curtailment. At the Start of the curtailment, the temperature was 72 degrees. By Hour 3 this had risen to 76 degrees.

	Start	Hour 1	Hour 2	Hour 3	Hour 4	End
Current Temp	72	74	75	76	76	76
Cool Setpoint	72	76	76	76	76	72
Mode	Cool	Cool	Cool	Cool	Cool	Cool
Fan	Auto	Auto	Auto	Auto	Auto	Auto
Hold	Off	Off	Off	Off	Off	Off
Run Time	-	0	0	17	45	-
Number of Starts	-	0	0	1	2	-

Figure 41: Sample Snapshot Data

The run time shows that in this example the air conditioner was idle during the first two hours and ran only 17 minutes during the third hour. In the third hour the AC was started once. We can infer from this that the effective duration of the curtailment was at least 2 hours and probably about 2 hours and 43 minutes. In the fourth hour, the AC had two starts and a total run time of 45 minutes. By this time we can infer that the AC was cycling normally at the higher set point. So these data provide a rather complete picture of the curtailment event for this particular air conditioner.

If the run time data are coupled with estimates of the operating kW of each HVAC unit, these data can be used to estimate the hourly kWh energy consumption of each installed unit. These data can also be used to estimate the hourly energy savings during each curtailment.

4.1 Available data

During 2004, SCE attempted to collect hourly thermostat run time data from all installed SI expansion thermostats throughout the program on as many days as possible from August through October. The data are available on a flat file format, and the fields are: Account Number, PIN, Local Time Stamp, Run Time, Starts, and Temperature, where the PIN identifies each unique thermostat.

Over that period, SCE managed to collect hourly thermostat run time data from almost 1,093 thermostats, including data on the 8 previously analyzed curtailment days. The great advantage of the run time data is that it is available from such a large number of thermostats, almost as a census. Moreover, the run time data can be collected at relatively low cost because the thermostats themselves generate these data, and no additional equipment is required.

The disadvantage of this approach for determining load impacts with the run time data is that the thermostats do not provide kW itself, only the number of minutes of HVAC unit operation in each hour. The run time data have to be converted using information about the kW load of the units when they are operating. Moreover, the hourly data do not provide the fine resolution of the 5-minute end use meter data. In particular, the hourly run time data are not very useful in assessing the impact of a curtailment that begins on a half-hour, such as a curtailment from 2:30 to 4:30.

In the 2002 impact evaluation study, the run time data from the thermostats were compared to run times calculated from 5-minute end use metered data. These results showed that the average thermostat run time data is quite accurate within 99% as a means of estimating program load impacts. This type of validation of the thermostat run time data will not be repeated in this report.

Data from the existing E$T end use metered units will be used to produce estimates of the kW load of the units when they are operating. These estimates will then be applied to the sample of SI expansion units with run time to estimate the hourly kWh energy consumption of each installed SI expansion unit.

A comparison of the existing E$T units to the SI expansion units was presented earlier in the report that showed that the two final populations were very similar. Since the existing E$T end use metered units were drawn from the existing E$T population using a statistically representative sampling plan, they are likely to be similar to the sample units that would have been metered using a sampling plan on the SI expansion units. Therefore, the temperature-load relationship established from the end use metered units will be applied to the SI expansion units used in the runtime analysis.

As mentioned in section 2.6, we have reason to believe that the early installations of the SI expansion units were not representative of the final SI expansion population since the installation contractors used a geographically targeted installation plan for the early installations. This affects the run time data analysis, and not the end use metered data analysis because in the run time data analysis, the actual data collected from the SI expansion installed sample is used. Since the SI expansion thermostats were being installed throughout the summer of 2004, there were limited data from the events called during 2004. The available data came from the early installs, which were geographically grouped, and were subject to different weather conditions than the population. The results from this analysis should be used as a preliminary estimate of the impacts from the SI expansion program. It is very likely that as more thermostats were installed and began to respond to the signals (the locations of which were more representative of the population), the impacts stabilized and became more similar to the impacts seen in the end use meter data analysis.

4.2 Estimating the Operating Load

In this section we address the following problem – how to best estimate the average hourly kW loads of each HVAC unit from the run time reported by the thermostat. The operating load of each unit is the key to converting the thermostat run time data into an estimate of the kW load of each unit. The operating load of an air conditioner is defined to be its kW demand when the compressor is operating. In the 2002 E$T study, we demonstrated that the operating load is related to the cooling capacity (tons) of the unit, as might be expected, but the operating load is *also* related to the exterior temperature. We have used regression analysis to determine the effect of both factors: cooling capacity and temperature.

In particular, we have analyzed the 5-minute existing E$T end use metered data as follows:

1. For each of the one hundred existing E$T units with end use data, identify and select all 5-minute intervals in which the unit was operating throughout the interval, i.e. the recorded operating time was equal to 5 minutes, and calculate the operating kW load per ton of the unit during each interval. To ensure that the analysis was representative of hours in which a curtailment was most likely, the analysis was restricted to the 5-minutes intervals during the 2 pm through 5 pm hours of each day.
2. For each unit and each selected interval, identify the outside temperature during the associated hour in the climate zone in which the unit was located.
3. Prepare and review scatter plots for each of the end use metered units relating the operating load per ton to the temperature. Exclude the unit from further analysis if there were very few intervals with meaningful data. Also, identify filters for each unit to exclude spurious measures such as any operating loads associated with fan-only operation.
4. Use the resulting operating load per ton and temperature data to estimate a simple linear regression model for each unit relating the operating load per ton to the temperature.
5. Save and plot the studentized[8] residuals from each of the preceding regression models, and drop intervals in which the studentized residual is greater than three in absolute value.

[8] The result of standardizing the residual with an independent estimate of $sigma^2$.

See: http://www.csc.fi/cschelp/sovellukset/stat/sas/sasdoc/sashtml/insight/chap39/sect54.htm

6. Re-estimate the simple linear regression models for each unit relating the operating load per ton to the temperature after dropping the intervals identified in the preceding step.
7. Calculate the average value of the intercept and slope for the small and large units.

From this analysis, we arrived at the following two simple predictive equations:

Small Units: kW per Ton = 0.6006 + 0.0085 * Temp : if tons < 7, and

Large Units: kW per Ton = 0.5353 + 0.0066 * Temp : if tons >= 7

Where 'Temp' is the exterior temperature in the climate zone, measured in degrees Fahrenheit.

Figure 42 and Figure 43 summarizes the results of this analysis. The table shows our estimate of the operating load of an HVAC unit versus the exterior temperature. The operating load is measured in kW per tons. The exterior temperature is measured in degrees Fahrenheit. As an example, a two-ton unit would be expected to have an operating load of about 2.82 kW on a 90-degree afternoon.

Figure 43 shows that throughout the temperature range, larger units tend to be more efficient in terms of kW/ton than small units. Large units are also just slightly less temperature sensitive since their operating load increases about 0.006 kW per degree per ton whereas the operating load of small units increases slightly more, about 0.008 kW per degree per ton.

Exterior Temperature	***Operating Load***	
	Small (< 7 Tons)	***Large (>= 7 Tons)***
70	1.20	1.00
75	1.24	1.03
80	1.28	1.07
85	1.33	1.10
90	1.37	1.13
95	1.41	1.17
100	1.45	1.20

Figure 42: Operating Load per Ton for various Exterior Temperatures

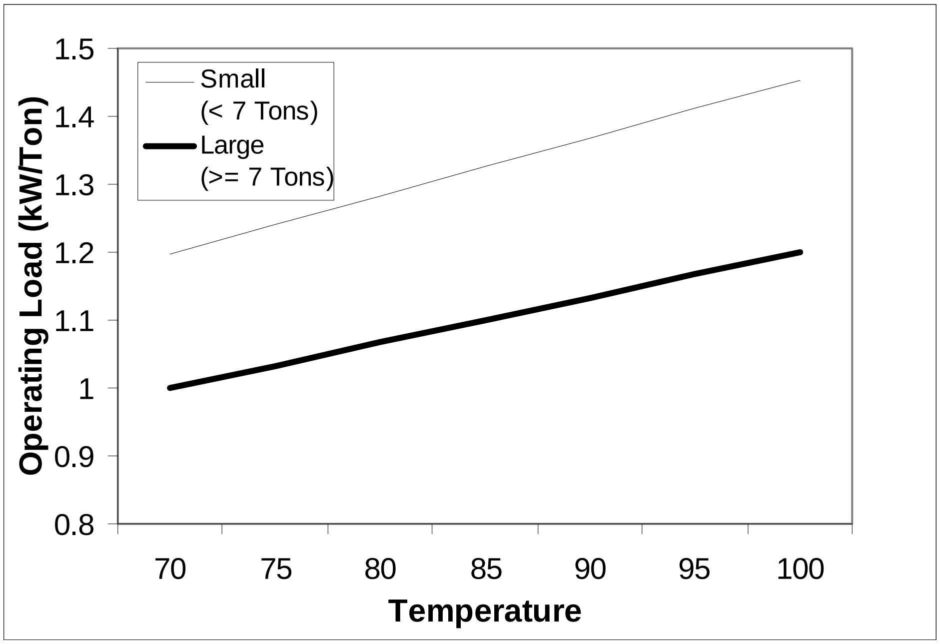

Figure 43: Operating Load per Ton vs. Exterior Temperature

4.3 Estimating Hourly kWh Consumption from Thermostat Run time Data

The next step was to use the operating load models described in the preceding section to estimate the hourly kWh consumption of each SI expansion unit with thermostat run time data. In previous E$T studies we have restricted the run time analysis to units with run time data for more than 30 days. However, since the SI expansion units were being installed throughout the summer of 2004, there were very few units with over 30 days of run time data. Therefore, we dropped this restriction from the analysis and ran the run time analysis on all of the available run time data.

Throughout the summer, there was available thermostat run time data for 1,506 thermostats, and 1,093 of these controlled air conditioners had known cooling capacities. The available data on each curtailment day varied greatly as can be seen in the table below. There are very few SI expansion units with available run time data in August 2004, therefore the two curtailments in August will be excluded from the run time data analysis. As the summer of 2004 progressed, more units were installed at SI expansion sites as can be seen by the increasing sample sizes below.

Date	Sample
8/9/2004	49
8/10/2004	63
9/1/2004	142
9/7/2004	174
9/8/2004	263
9/23/2004	426
10/7/2004	195
10/14/2004	366

Figure 44: Available Run Time Data by Curtailment Event

We calculated the kWh consumption of each of these 1,093 units by hour using the following steps:

1. Identify the size of the unit in tons,
2. Identify the temperature of the hour in degrees Fahrenheit in the region that the unit is located,
3. Use either the small or large operating load model to calculate the operating load of the unit,
4. Multiply the operating load by the run time in the hour, measured as a fraction between 0 and 1.

Then we post-stratified the 1,093 units as if they were a sample, using the strata definitions given in Figure 19, and calculated case weights. Finally, we used the case weights to calculate the average hourly kWh per ton of all of the 1,093 units taken together.

4.4 Estimating Load Impacts using the Run time Data

In preceding sections we have estimated the total potential impact of the program by examining eight curtailments that were called during the summer of 2004 using the 5-minute load data for one hundred end use metered units in the existing E$T program. In order to extrapolate these results to the population of the SI expansion participating units, we assumed that this sample of units were representative of the population of SI expansion HVAC units in the program. This assumption is reasonable since the units that were end use metered were selected following a statistical sampling plan from a population that is very similar to the existing E$T population.

In this section we will report on our analysis of the SI expansion run time data available for the summer of 2004. We hope that these results will reinforce the estimates of impact that we developed from the end use metered data.

Our work will follow the same general approach used to analyze the end use metered data. However, because these data are hourly, the results will not have the 5-minute time resolution of the end use metered results. For this reason we will not attempt to estimate the maximum impact of the curtailment, or the duration. Instead, we will focus on the impact in each hour during the curtailment event. Moreover, given the hourly resolution, we will not attempt to use these data to estimate the impact of a curtailment event starting on a half-hour.

Our work has followed these steps:

1. Merge the run time data with the tracking data characterizing the size of the controlled HVAC units and with the weather data giving the exterior temperature.
2. Describe the set of units included in the analysis.
3. Use the equation for the operating load that we have developed to convert the run time data for each of these units to estimated hourly kWh consumption and calculate the average hourly kWh consumption per unit of all units.
4. Estimate the hourly impact (kWh per unit) of each of the eight curtailments.
5. Compare the results to our prior analysis from the end use metering data.

Figure 45 shows the results of step 2. The table shows that there were a total of 3,998 units included in this analysis and that these units had an average size of 4.15 tons per unit. The smaller units comprise 95% of all units and 88% of the total tons.

Recall from Figure 6 that there were a total of 3,502 participating units with recorded tons in the tracking database and that these units have an average size of 4.1 tons per unit. Among these units, the smaller units comprise 96% of all units and 91% of the total tons. The average size of these units is practically identical to the entire population.

The units included in the present analysis represent 31% of all installed units with recorded size. However, because run time data are not collected for each of the units for each curtailment day, the actual percentage of all installed units included in the August through October curtailment run time analyses varies from 4% to 12%. This percentage would be much higher if all the thermostats had been installed during the summer of 2004. As seen in Figure 8, the October results are likely to be more reliable than the September results since a larger quantity of thermostats were installed and responding to the curtailments called in October.

Size in Tons	Number	Percent	Total Tons	Percent	Tons per Unit
6 or Smaller	1,045	96%	4,051	90%	3.88
7 or Larger	48	4%	475	10%	9.89
Total	1,093	100%	4,526	100%	4.14

Figure 45: Summary Statistics for the Units Included in the Run Time Analysis

We now present the results for the curtailment days with minimally adequate run time data.

Event 181 - September 1, 2004

The curtailment on September 1 was a 4-degree offset from 3 PM to 5 PM. August 30, August 31, and September 2 were chosen as the baseline for September 1 because of their comparable daily high temperatures.

Figure 46 displays the results of our new analysis using all available run time data for installed units. Figure 46 is based on the hourly run time data of 142 units. Note that these series of graphs will differ significantly from the graphs generated from end use metered data, due to the “smoothing” effect and slower transitions of hourly run time data as opposed to the more detailed presentation of 5-minute metered data.

Figure 47 summarizes the results of the new analysis. This table is similar to those developed from the 5-minute end use metering data, but some of the statistics have been deleted since the current results are based on hourly load.

The table also shows the number of units included in the run time analysis of the event, in total and as a proportion of all confirmed units in the program group. The remaining characteristics reported in Figure 47 are equivalent to their use in the summary reports that have been presented using the end use metering data.

The first hour savings for the September 1, 2004 event are 0.14 kWh per ton, with second hour savings of 0.01 kWh per ton. This drop in savings in the second hour is expected, because some of the HVAC units are being curtailed and also begin to reach the new set point in the second hour.

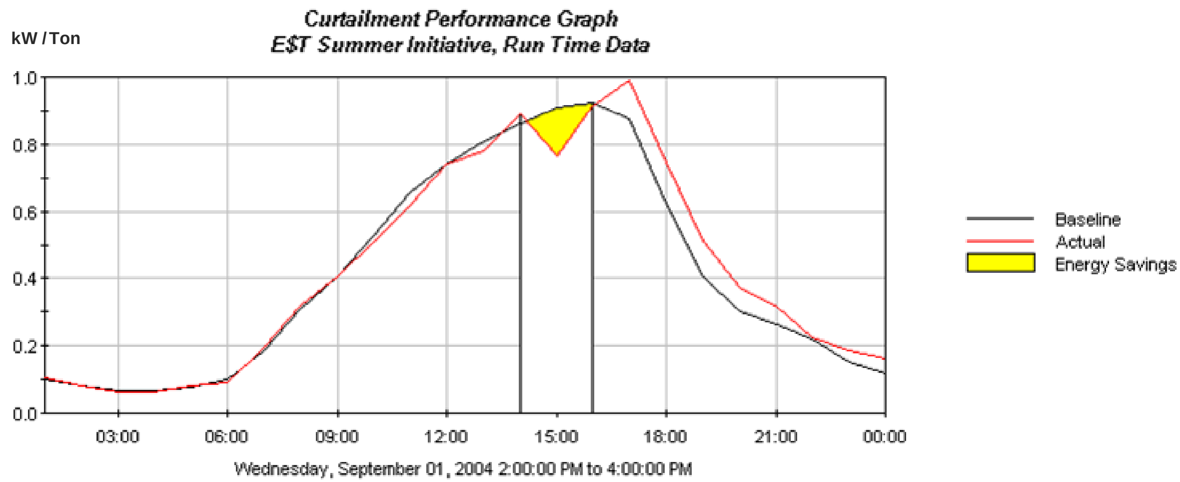

Figure 46: Estimating the Impact on September 1 using the Run time Data

Curtailment Date	9/1/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	2 Degrees
Curtailment Day High	97.1
Units in the Analysis	142
Baseline Day(s)	8/30/04, 8/31/04, 9/2/2004
Baseline Day High	95.2
Trueup Adjustment	95.2%
kWh Savings in Hour 1	0.14
kWh Savings in Hour 2	0.01
Hour Following	-0.11

Figure 47: Summary Report for September 1 from the Run Time Analysis

Event 183 - September 7, 2004

The curtailment that occurred on September 7 was a 4-degree offset from 2 to 4 PM. The days chosen as the baseline for this day were August 31, September 2, and September 9 due to their similar daily high temperatures.

Figure 48 displays the results of our analysis using all available run time data for installed units.

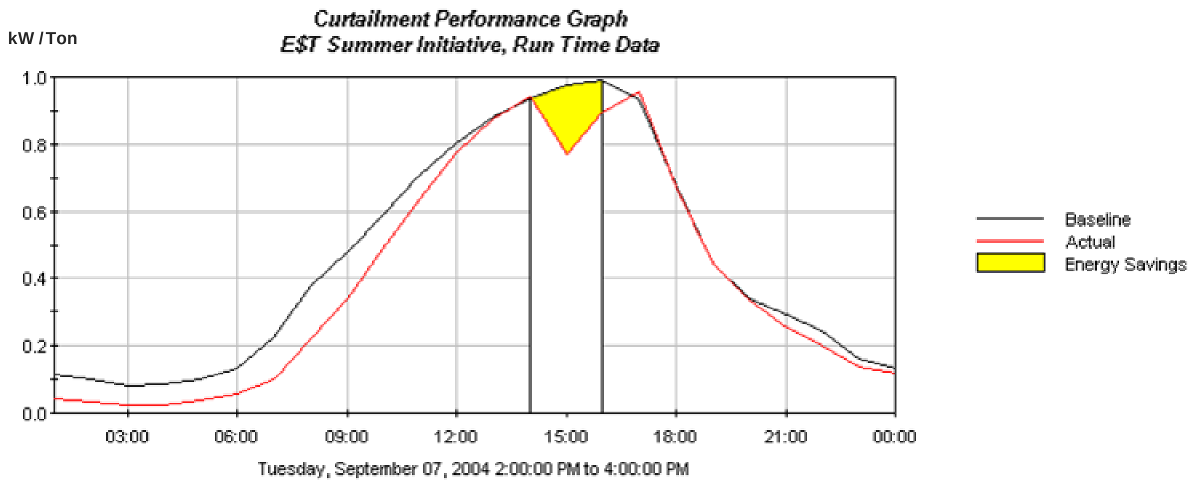

Figure 48: Estimating the Impact on September 7 using the Run time Data

Figure 49 summarizes the results of the run time analysis. The first hour savings were 0.20 kWh per ton and the second hour savings were 0.10 kWh savings per ton.

Curtailment Date	9/7/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4 Degrees
Curtailment Day High	97.6
Units in the Analysis	174
Baseline Day(s)	8/31/04, 9/2/04, 9/9/04
Baseline Day High	94.6
Trueup Adjustment	102.1%
kWh Savings in Hour 1	0.20
kWh Savings in Hour 2	0.10
Hour Following	-0.03

Figure 49: Summary Report for September 7 from the Run Time Analysis

Event 187 - September 8, 2004

The curtailment that took place on September 8 was a 4-degree instantaneous offset from 4:10 to 6:10 PM. August 31, September 2, and September 9 were chosen as the baseline days for September 8 due to their similar daily high temperatures

Figure 50 displays the results of our analysis using all available run time data for installed units.

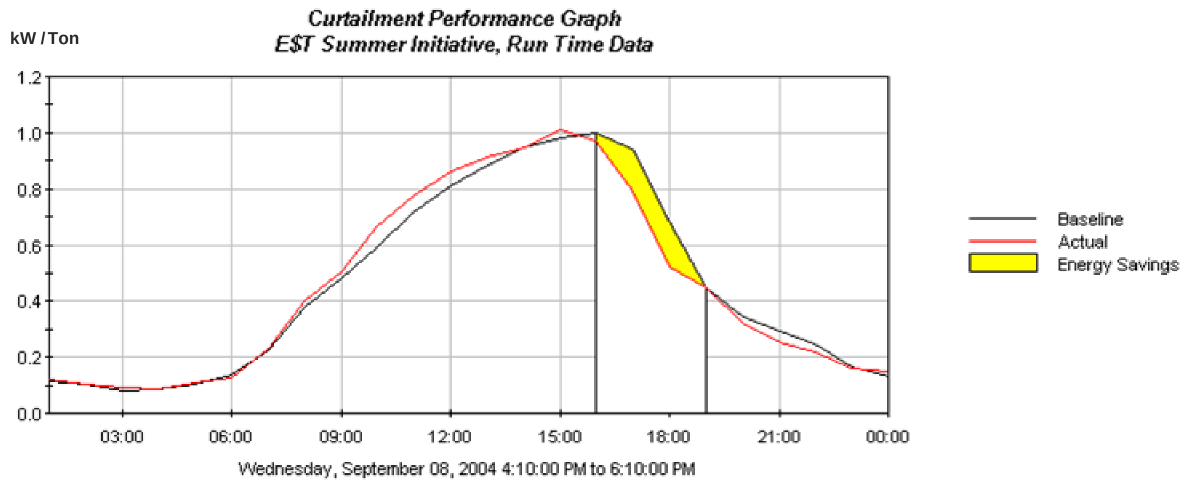

Figure 50: Estimating the Impact on September 8 using the Run time Data

Figure 51 summarizes the results of the run time analysis. The first hour savings were 0.12 kWh per ton and the second hour savings were 0.16 kWh savings per ton. The second hour of curtailment showed increased savings over the first hour because of the time chosen to curtail the thermostats, at 4pm. The first hour showed a much less dramatic drop than usual because the curtailment began at a time when cooling equipment usage is expected to lower naturally. The second hour showed continued savings because the later curtailment occurred at a time when exterior temperatures were dropping, which slowed the increase in internal temperature, thus preventing units from running for a longer period. Coincidentally, this later curtailment also led to a lower override rate.

Curtailment Date	9/8/2004
Start Time	4:10 PM
End Time	6:10 PM
Offset	4 Degrees
Curtailment Day High	93.3
Units in the Analysis	263
Baseline Day(s)	8/31/04, 9/2/04, 9/9/04
Baseline Day High	94.6
Trueup Adjustment	102.8%
kWh Savings in Hour 1	0.12
kWh Savings in Hour 2	0.16
Hour Following	0.00

Figure 51: Summary Report for September 8 from the Run Time Analysis

Event 191 - September 23, 2004

The September 23 curtailment was a 4-degree offset that occurred from 2 to 4 PM. September 21, September 22, and September 27 had comparable daily high temperatures, and were therefore used as the baseline for September 23.

Figure 52 displays the results of our analysis using all available run time data for installed units.

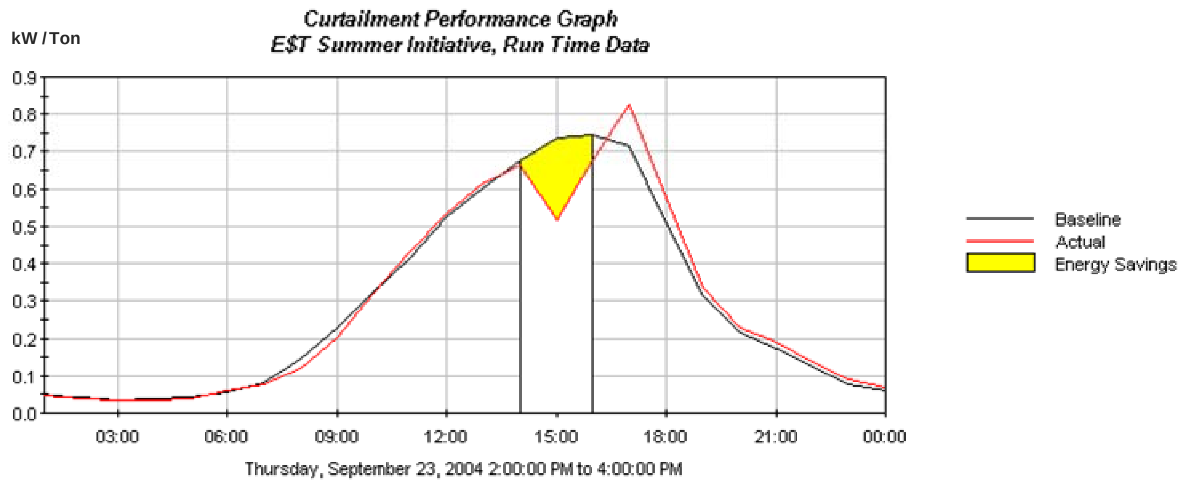

Figure 52: Estimating the Impact on September 23 using the Run time Data

Figure 53 summarizes the results of the new analysis. The first hour savings were 0.22 kWh per ton and the second hour savings were 0.07 kWh savings per ton.

Curtailment Date	9/23/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4 Degrees
Curtailment Day High	90.8
Units in the Analysis	426
Baseline Day(s)	9/21/04, 9/22/04, 9/27/04
Baseline Day High	88.6
Trueup Adjustment	104.2%
kWh Savings in Hour 1	0.22
kWh Savings in Hour 2	0.07
Hour Following	-0.11

Figure 53: Summary Report for September 23 from the Run Time Analysis

Event 192 - October 7, 2004

The curtailment on October 7 was a 4-degree offset that occurred from 2 to 4 PM. In our analysis of this event, we selected September 27, October 6, and October 12 as the comparison days.

Figure 54 displays the results of our new analysis using all available run time data for installed units. This graph can be compared to Figure 32. While the two graphs are generally very similar, two differences should be noted:

- The baseline load in Figure 54 has a maximum of about 0.7 kW per ton, whereas the baseline load in Figure 32 has a maximum of about 0.8 kW per ton, and
- Figure 54 is based on the hourly run time data of 195 units, whereas Figure 32 is based on 5-minute end use metered data from 100 units.

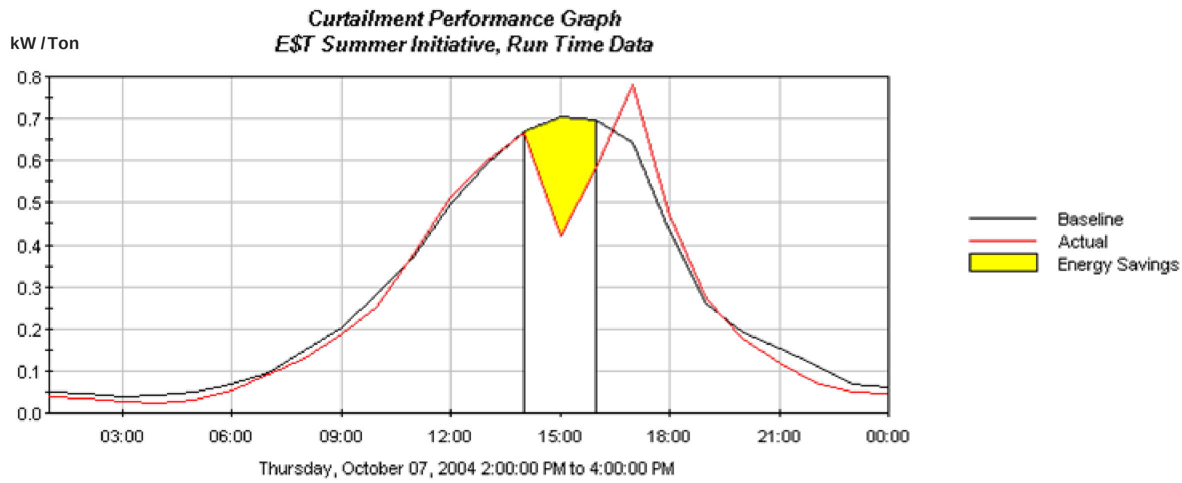

Figure 54: Estimating the Impact on October 7 using the Run time Data

Figure 55 summarizes the results of the new analysis. Figure 55 can be compared to Figure 33. Figure 55 shows that the run time analysis is based on 195 units. By contrast, Figure 33 is based on the weighted results from the 100 units in the end use meter data. The savings in the first and second hour of the curtailment reported in Figure 55 are about 75% of the kWh savings reported in Figure 33.

Curtailment Date	10/7/2004
Start Time	2:00 PM
End Time	4:00 PM
Offset	4 Degrees
Curtailment Day High	88.5
Units in the Analysis	195
Baseline Day(s)	9/27/04, 10/6/04, 10/12/04
Baseline Day High	87.3
Trueup Adjustment	97.3%
kWh Savings in Hour 1	0.28
kWh Savings in Hour 2	0.11
Hour Following	-0.14

Figure 55: Summary Report for October 7 from the Run Time Analysis

Event 193 - October 14, 2004

On October 14 there were two separate 4-degree offsets that occurred back to back. The first curtailment was from 2 to 4PM, and the second curtailment was from 4 to 6 PM. We chose September 21, September 22, and October 12 as the baseline days for our analysis of the run time data and the end use metered data. Figure 56 describes our results. Figure 57 provides the summary report.

The savings shown in Figure 57 differ from the average savings reported in Figure 35. In the end use metered data analysis, the first, second, third, and fourth hours savings were 0.49, 0.36, 0.22, and 0.08 kWh per ton respectively, while in the run time data analysis the savings were 0.29, 0.13, 0.17, and 0.11 respectively. In the end use metered analysis the savings dropped each hour, whereas in the run time data analysis the savings dropped, then increased, then dropped again. Also, the magnitude of savings differed between the two.

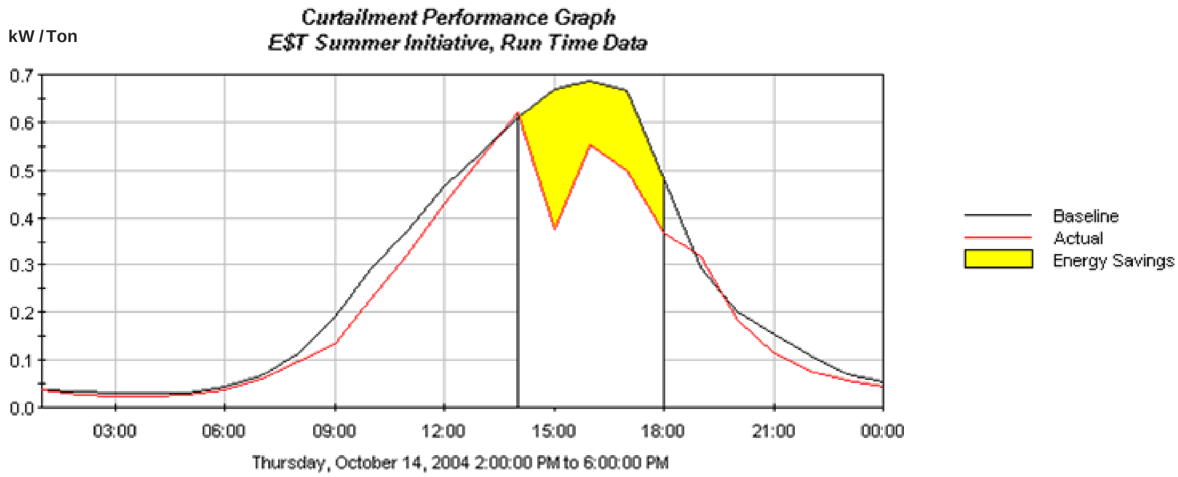

Figure 56: Estimating the Impact on October 14 using the Run time Data

Curtailment Date	10/14/2004
Start Time	2:00 PM
End Time	6:00 PM
Offset	4 Degrees
Curtailment Day High	89.9
Sample Units in the Analysis	366
Baseline Day(s)	9/21/04, 9/22/04, 10/12/04
Baseline Day High	88.1
Trueup Adjustment	98.0%
kWh Savings in Hour 1	0.29
kWh Savings in Hour 2	0.13
kWh Savings in Hour 3	0.17
kWh Savings in Hour 4	0.11
Hour Following	-0.02

Figure 57: Summary Report for October 14 from the Run Time Analysis

4.5 Comparison of the End Use Metering and Run Time Results

Figure 58 compares the results of the end use metering and run time analysis for the eight curtailment days with 4-degree offsets that were included in both analyses. These data are taken directly from Section 4.4, and Section 3.4 the end use metered data analysis results. The table shows that the two methods of analysis yielded more similar estimates of savings per ton in the first and second hours of these two curtailment events as more SI expansion units were installed and included in the analysis, namely in the two October events. This is due to the fact that as more units were included in the analysis, the results became more stable across the sample sites. The results from the early September events are much lower than the results from the End Use Metering analysis and should be used as preliminary impact estimates.

The table restates the results in kWh savings per ton.

Curtailment Date	9/1/2004		9/7/2004		9/8/2004		9/23/2004		10/7/2004		10/14/2004	
Method	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers
kWh Savings per Ton in Hour 1	0.14	0.31	0.20	0.43	0.12	0.29	0.22	0.36	0.28	0.40	0.29	0.49
kWh Savings per Ton in Hour 2	0.01	0.23	0.10	0.23	0.16	0.22	0.07	0.29	0.11	0.29	0.13	0.36
Hour Following	-0.11	-0.02	-0.03	0.02	0.00	-0.02	-0.11	0.03	-0.14	-0.09	-0.02	-0.05
Units in Run Time Analysis	142	-	174	-	263	-	426	-	195	-	366	-

Figure 58: Summary of Savings per Ton for 4-Degree Curtailments

Figure 59 summarizes the characteristics of all units installed in the program. We can estimate the total impact of the program by multiplying the per ton impact shown in Figure 58 by the total discounted tons of the installed units, 16,794. Figure 60 shows the results.

Installed Units	4,415
Tons per Unit	4.1
Total Tons	18,058
Discounted Tons (less 7%)	16,794

Figure 59: Summary of Units Installed in Program

The new results shown in Figure 60 are lower than the total program impacts developed earlier in our analysis of the end use metering data. If the run time data analysis had been performed on all 4,415 of the installed SI expansion units, it is likely that the impact estimates would have been more similar to the end use metered results. As mentioned previously, the installations were scheduled geographically therefore there is a bias in the locations (and weather) of the units that received the early installations in the program.

Curtailment Date	9/1/2004		9/7/2004		9/8/2004		9/23/2004		10/7/2004		10/14/2004	
Method	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers	RTD	Loggers
MWh Savings in Hour 1	2.4	5.3	3.4	7.2	2.0	4.9	3.7	6.0	4.7	6.8	4.9	8.2
MWh Savings in Hour 2	0.2	3.8	1.7	3.8	2.7	3.7	1.2	4.8	1.8	4.9	2.2	6.1
Hour Following	-1.8	-0.3	-0.5	0.3	0.0	-0.3	-1.8	0.6	-2.4	-1.6	-0.3	-0.8
Units in Run Time Analysis	142	-	174	-	263	-	426	-	195	-	366	-

Figure 60: Estimated Total Impact of Program-Wide 4-Degree Curtailment

We have summarized the information from the run time analysis summary reports for six of the 4-degree curtailment events. These six events differed in many respects, with the most importance difference being the number of units included in the run time data analysis. We first present the summary results from the six curtailments, then we present the summary results from the two October events only.

September through October Event Summary

We will start by noting the average characteristics of the six 4-degree curtailments shown in Figure 61. Based on a simple numerical average, the 4-degree event can be described as follows:

- The savings in the first hour was 0.21 kWh per ton,
- The savings in the second hour was 0.10 kWh per ton,
- There was little or no snapback following the curtailment period.

Date	kWh Savings per Ton in Hour 1	kWh Savings per Ton in Hour 2	Hour Following	Units in Run Time Analysis
9/1/2004	0.14	0.01	-0.11	142
9/7/2004	0.20	0.10	-0.03	174
9/8/2004	0.12	0.16	0.00	263
9/23/2004	0.22	0.07	0.00	426
10/7/2004	0.28	0.11	0.00	195
10/14/2004	0.29	0.13	-0.11	366
Average	**0.21**	**0.10**	**-0.04**	-

Figure 61: Average kWh Savings using Run Time Data from September and October

Based on these results we can estimate the total program-wide impact of a 4-degree curtailment. Recall that we estimated that the 4,700 participating units have a total size of 19,701 tons. That number was reduced by 7% due to the existence of deadbeats, resulting in a program total of 18,322 tons. Using this information together with the preceding results, we can estimate the average total program impact using the run time data as shown below. We estimate total savings of 6.0 MWh in hour 1 and 3.2 MWh savings in hour 2.

	Run Time Data	
	Per Sample Ton	Program Total
kWh Savings in Hour 1	0.21	3,499
kWh Savings in Hour 2	0.10	1,623

Figure 62: Estimated Program-Wide Impact Using Run time Results from September and October Events

Figure 63 summarizes the data presented in Figure 62 and Figure 37. We find that the average kWh savings in hour 1 are different for the two data sources, differing by 0.12 kWh per ton. We find that the average kWh savings in hour 2 are different for the two data sources by 0.12 kWh per ton.

	Run Time Data		End Use Meter Data	
	Per Sample Ton	Program Total	Per Sample Ton	Program Total
kWh Savings in Hour 1	0.21	3,499	0.33	5,554
kWh Savings in Hour 2	0.10	1,623	0.22	3,705

Figure 63: Comparison of Impact from September and October Run Time Events and End Use Meter Data

From this run time data analysis using the September and October run time events, we estimate that among all 4,415 participating units, a 4-degree, two-hour curtailment will yield first hour energy savings of about 3.5 MWh, and second hour energy savings of about 1.6 MWh.

October Event Summary

The average characteristics of the two October 4-degree curtailments are shown in Figure 63. Based on a simple numerical average, the 4-degree events can be described as follows:

- The savings in the first hour was 0.29 kWh per ton,
- The savings in the second hour was 0.12 kWh per ton.

The kWh per ton estimates using the October events only are 0.08 kWh higher than the September and October average for the first hour energy savings and 0.02 kWh higher for the second hour energy savings. The October only estimates are likely to be more representative of the program as a whole since more thermostats were installed by October and the run time sample was likely to be more representative.

	September and October		October Only	
Run Time Data	**Per Sample Ton**	**Program Total**	**Per Sample Ton**	**Program Total**
kWh Savings in Hour 1	0.21	3,499	0.29	4,786
kWh Savings in Hour 2	0.10	1,623	0.12	2,015

Figure 64: Average kWh Savings using Run Time Data – October Only

Figure 65 compares the average September and October run time impacts to the average October run time impacts and the end use metered data impacts. The October only run time impacts are much closer to the end use meter data impacts, differing by only 0.04 kWh per ton for the first hour energy savings. The average kWh savings in hour 2 are again closer for October run time impacts relative to the end use metered impacts, differing by 0.10 kWh per ton.

	Run Time Data				End Use Meter Data	
	September and October		October Only			
	Per Sample Ton	**Program Total**	**Per Sample Ton**	**Program Total**	**Per Sample Ton**	**Program Total**
kWh Savings in Hour 1	0.21	3,499	0.29	4,786	0.33	5,554
kWh Savings in Hour 2	0.10	1,623	0.12	2,015	0.22	3,705

Figure 65: Comparison of Impact from September/October and October only Run Time Events to End Use Meter Data

From this run time data analysis using the October only run time events, we estimate that among all 4,415 participating units, a 4-degree, two-hour curtailment will yield first hour energy savings of about 4.8 MWh, and second hour energy savings of about 2.0 MWh.