AUTOMATED DEMAND RESPONSE SYSTEM PILOT

Final Report
Volume 1

Introduction and Executive Summary

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Introduction

On October 29, 2004 the *Assigned Commissioner and Administrative Law Judge's Ruling Continuing Availability of Tariffs and Programs Under the Statewide Pricing Pilot* (SPP) (R.02-06-001) directed the joint utilities of Pacific Gas & Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E) filed tariffs to allow the critical peak pricing tariff options to be extended to December 31, 2006 and to continue the Advanced Demand Response System (ADRS) through December 31, 2005. The objectives of the program extension as defined by the ruling are:

1. Estimate the average ADRS residential customer's load response to the ongoing CPP-F, Ratio A tariff from July of 2004 to September of 2005.
2. Evaluate whether the level of load impacts of ADRS residential participants in response to CPP price signals has increased, decreased or stayed the same over time after controlling for weather and other independent factors, including a comparison of load impacts/response levels observed in summer of 2004 to levels observed in the summer of 2005.
3. Evaluate whether customer satisfaction levels (and perhaps willingness to pay for these systems) have increased or decreased over the course of the pilot.

Rocky Mountain Institute (RMI) was tasked to fulfill the ADRS research objectives 1 and 2 under subcontract to Invensys, lead contractor for the ADRS. The third objective, evaluate whether customer satisfaction levels have increased or decreased over the course of the pilot, has been tasked to Boice Dunham Group in a separate report.

The ADRS pilot participants were first recruited in 2004 from owner-occupied, single-family homes from the SPP climate zone 3 in zip codes neighborhoods served by appropriate television cable providers identified by Invensys. ADRS homes were recruited at random regardless of historical consumption, although homes were screened for eligibility with respect to presence of central air conditioning, within prescribed zip codes. Because ADRS technology is capable of controlling end uses in the home in addition to central air conditioning, homes were screened for availability of other loads (i.e., swimming pool pumps and spas), but not disqualified from participation in their absence.

The homes used for the 2005 analysis consisted of those households that remained on the ADRS pilot program after the summer of 2004. The ADRS program was offered to incoming residents of existing ADRS homes, in the event of rental or sale situations. However, no additional participant homes were recruited for the 2005 pilot extension.

Advanced automated technology for demand response

One of the defining characteristics of California's ADRS program is use of a residential-scale, automated demand response technology for a customer under a critical peak pricing tariff. ADRS participants had the GoodWatts system, an Invensys Climate Controls product, installed in their homes.

GoodWatts is an “always on”, two-way communicating, advanced home climate control system with web-based programming of user preferences for control of home appliances. Via the Internet, homeowners with GoodWatts can set climate control and pool or spa pump runtime preferences and view these settings at any time both locally and remotely. Participants can also view whole-house or end-use specific demand in real time and display trends in historical consumption.

The energy management technology includes the following components:

- Wireless RF communications network connecting all system components
- Two-way communicating whole-house meter capable of recording consumption data in 15-minute intervals
- Wireless Internet gateway and cable modem
- Programmable smart thermostats
- Load control and monitoring (LCM) device to manage selected loads (e.g., pool pump)
- Web-enabled user interface and data management software

GoodWatts allows users to view at all times the current electricity price on-line or via the thermostat. It has the further capability of allowing users to program desired thermostat and pool/spa responses to changes in electricity prices. For ADRS homes with pools and spas, supplemental LCMs were installed to garner additional demand reduction during utility triggered curtailment events.

In addition to technology, ADRS participants were placed on a time dependent electric rate schedule called CPP-F. The CPP-F electric rate is a time-of-use (ToU) tariff, which includes a critical peak pricing (CPP) element. Prices were higher between 2 p.m. and 7 p.m. (“peak period”) every weekday (“non-event” days), with critical peak prices imposed during the peak period on event days (“Super Peak” days). All other hours, weekends and holidays were on the base rate. ADRS customers were notified by phone the day ahead of a Super Peak event during which the CPP rate element would be imposed. On the day of the Super Peak event, customers were billed at a price that was three times higher than the normal on-peak price. In 2005, eleven Super Peak events were called. Four events were called in July, one in August, two in September, and five in October.

Organization of this report

This report presents the load savings results of ADRS participants for the 2005 and 2004 summer pilot periods. This report also compares the load savings results of ADRS participants achieved in 2005 with performance during the summer 2004 pilot period. Estimates of load impact at the household level of ADRS homes and recommendations for future program design are also presented, based on load impact results of the pilot.

The Executive Summary, which follows, highlights the main findings of the load impact evaluation for the ADRS pilot. The section presents sequentially the main findings of the 2005 load impact evaluation, the 2004 load impact evaluation, and the comparison of summer 2005 and 2004 pilot period load performance. The section also summarizes the principal conclusions drawn from the evaluation results for each part of the evaluation, and the main recommendations for future pilot design.

Results of the summer 2005 load impact evaluation are presented in detail in volume 2 of this report. Load reduction results are reported in terms of average consumption of ADRS homes relative to control homes during Super Peak periods on event days and peak periods on non-event days. First, RMI reports the summer 2005 results for the statewide average load impact for high consumption ADRS homes. We then present the utility-specific load impact results for high consumption ADRS customers for PG&E, SCE, and SDG&E, respectively. For each utility specific analysis, we discuss the results of load impact by temperature bin. Next, 2005 load impact results for low consumption ADRS homes are presented, for completeness. Peak period consumption behavior of high consumption ADRS homes with swimming pools, and therefore pool pump controls, is then discussed. Finally, we highlight the main load impact observations from the summer 2005 analysis in the conclusions section.

Following the 2005 load impact results are the restated load impact results of ADRS homes during the summer 2004 pilot period, also in volume 2 of this report. The restated results supersede RMI's reported results for the summer 2004 pilot period published in December 2004.[1] RMI restated the summer 2004 load impact results to facilitate comparison with summer 2005 results in fulfillment of the October 29, 2004 the Assigned Commissioner and Administrative Law Judge's Ruling (02-06-001).

The summer 2004 load reduction results are reported in terms of average consumption of ADRS homes relative to control homes during Super Peak periods on event days and peak periods on non-event days. Results are first reported for the statewide average load impact for high consumption ADRS homes. For the statewide results only, we compare the load reductions of ADRS homes against a population of residential customers who are on the CPP-F rate in climate zone 3, but who do not possess ADRS technology. Then, we present the utility-specific load impact results for high consumption ADRS customers, for load reductions on event and non-event days. The section concludes with a summary of the main load impact observations from the summer 2004 analysis.

Finally in volume 2 of this report, we present a comparison of summer 2005 load impact results to load impact results during summer 2004. First, we compared high consumption ADRS load performance in 2005 and 2004 statewide. These results are based on the statewide average loads during Super Peak periods on event days and peak periods on non-event days. Utility-specific load impact results for high consumption ADRS customers follow, for PG&E, SCE, and SDG&E, respectively. Next, load impact results for low consumption ADRS homes comparing summer 2005 and 2004 are reported. Finally, we highlight the main load impact observations from the comparison of summer 2005 with summer 2004 load impact results in the conclusions section.

In volume 3 of this report, we examine in more the detail the load reduction performance of individual high consumption ADRS homes. The goal of the household level analysis presented

[1] Rocky Mountain Institute (RMI), *ADRS Load Impact Final Report*. December 18, 2004.

in volume 3 is to study the distribution of load reductions among high consumption ADRS homes, and to try to identify specific physical characteristics (e.g. measured load or home location) and behavioral characteristics (e.g. customers not home during the day) that can be used to target homes to maximize program performance. The high consumption ADRS homes are segmented into high performers ("supersavers"), low performers ("program cruisers"), and improved performers based on estimated load reduction performance at 2 p.m. compared against their own loads during 1:45 p.m. on event and non-event days. Volume 3 ends with a number of recommendations for targeting strategies in future ADRS programs, as well as additional recommendations for operating and implementing ADRS programs in the future that should help increase program performance and cost effectiveness.

Executive Summary

This report summarizes the load impact results of residential customers equipped with the Automated Demand Response System (ADRS) through the summer of 2005. It highlights the major load impact results during the 2004 summer pilot period, which have been updated from our original report published in March 2005. The restatement of summer 2004 load impact results was to facilitate comparison with summer 2005 results in fulfillment of the October 29, 2004 the Assigned Commissioner and Administrative Law Judge's Ruling (02-06-001). This report then compares the load savings results of ADRS participants achieved in 2005 with performance during the summer 2004 pilot period. We then present the main conclusions based on the main findings from the load impact analysis, and recommend design options for future ADRS programs.

Summer 2005 load impact results

From July through September 2005, ADRS high consumption[2] customers successfully and consistently reduced load relative to control homes[3] by 1.4 kW or 7.1 kWh on average during the Super Peak period[4], across seven event days, called statewide. This translates to a 43% reduction relative to high consumption control homes statewide (Table 1). Ninety percent confidence intervals across the Super Peak period were ±0.17 kW for control homes and ±0.12 kW for ADRS homes[5].

On non-event weekdays statewide, ADRS high consumption customers reduced load relative to control homes by 0.7 kW or 3.7 kWh on average, during the peak period[6]. This translates to a 27% reduction relative to high consumption control homes statewide. Peak period 90% confidence intervals on non-event weekdays averaged ±0.053 kW for control homes and ±0.042 kW for ADRS homes[7].

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[2] Homes were designated as high consumption if average daily usage (ADU) during the summer season is greater than or equal to 24 kWh per day. Homes with an ADU of less than 24 kWh per day on average were designated as low consumption homes. At the beginning of the 2004 pilot period on July 1, 2004, there were 51 high consumption ADRS customers from PG&E, 72 high consumption ADRS customers in SCE, and 7 high consumption ADRS customers SDG&E.

[3] A control home is similar to the ADRS homes (single-family home with central air conditioning in climate zone 3) but are on a standard tiered rate and do not possess ADRS technology.

[4] Super peak period on event days occur from 2 p.m. to 7 p.m. on non-holiday weekdays between June 1st and September 30th.

[5] Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Ninety percent confidence intervals for control homes varied from ±0.155 kW to ±0.172 kW across the Super Peak period; ADRS confidence intervals varied from ±0.082 kW to ±0.142 kW.

[6] Peak period on non-event days occur from 2 p.m. to 7 p.m. on non-holiday weekdays.

[7] Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Non-event peak period 90% confidence intervals for control homes varied from ±0.049 kW to ±0.056 kW; 90% confidence intervals for ADRS high consumption homes varied from ±0.030 kW to ±0.049 kW.

Table 1
Peak period load reductions for high consumption ADRS homes by Utility
July – September 2005

	Event Days			**Non-Event Days**		
	Average reduction, kW	5-hour total, kWh	% Reduction	Average reduction, kW	5-hour total, kWh	% Reduction
PG&E	0.83	4.15	29%	0.47	2.36	18%
SCE	1.85	9.24	49%	0.89	4.47	30%
SDG&E	1.17	5.84	38%	0.69	3.46	27%
Statewide weighted average	1.42	7.10	43%	0.73	3.67	27%

Results also varied by utility (Table 1). ADRS high consumption customers in the PG&E service territory successfully reduced load by 0.83 kW or 4.15 kWh on average during Super Peak period on event days[8], while SCE and SDG&E achieved higher load reductions. On non-event days, PG&E's high consumption ADRS customers reduced peak period load by 0.5 kW or 2.4 kWh compared to control customers. This translates to an 18% reduction, on average during summer 2005.[9]

ADRS high consumption customers in the SCE service territory reduced Super Peak Period load by 1.9 kW or 9.2 kWh.[10] This translates to a 49% reduction on average relative to the control group. On non-event days, SCE's high consumption ADRS customers reduced peak period load by 0.9 kW or 4.5 kWh on average. This translates to a 30% reduction relative to the control group.[11]

For SDG&E, ADRS high consumption customers reduced load by 1.2 kW or 5.8 kWh during the Super Peak period on average across summer 2005. This translates to a 38% reduction relative to the control group.[12] On non-event days, ADRS high consumption customers reduced load by

[8]Ninety percent confidence intervals for the Super Peak period averaged ±0.26 kW for control homes and ±0.19 kW for ADRS homes. Super Peak period, 15-minute 90% confidence intervals for control load varied from ±0.25 kW to ±0.29 kW; 90% confidence intervals for ADRS homes across the Super Peak period varied from ±0.14 kW to ±0.22 kW.

[9]Ninety percent confidence intervals for the peak period averaged ±0.09 kW for control homes and ±0.07 kW for ADRS homes. Within the 15-minute data periods, peak period confidence intervals for control varied from ±0.082 kW to ±0.091 kW; ADRS homes confidence intervals varied from ±0.051 kW to ±0.074 kW.

[10]Ninety percent confidence intervals for the Super Peak period averaged ±0.25 kW for control homes and ±0.16 kW for ADRS homes. Within the 15-minute data periods, 90% confidence intervals for control homes varied from ±0.24 kW to ±0.26 kW; 90% confidence intervals for high consumption ADRS homes varied from ±0.11 kW to ±0.20 kW.

[11]Ninety percent confidence intervals for the non-event peak period averaged ±0.08 kW for control homes and ±0.06 kW for ADRS homes within the 15-minute data periods, 90% confidence intervals for control homes varied from ±0.074 kW to ±0.083 kW; 90% confidence intervals for ADRS homes varied from ±0.04 kW to ±0.07 kW.

[12]Ninety percent confidence intervals for the Super Peak period averaged ±0.35 kW for control homes and ±0.40 kW for ADRS homes. Ninety percent confidence intervals for control homes within the 15-minute data periods actually varied from ±0.30 kW to ±0.37 kW across the Super Peak period; ADRS home 90% confidence intervals varied from ±0.19 kW to ±0.57 kW

0.7 kW or 3.5 kWh during the peak period. This translates to a 27% reduction relative to its control group.[13] All of SDG&E results should be interpreted with caution, however, due to the small size of the high consumption sample (n=6). SDG&E results should be interpreted with caution, however, due to the small size of the SDG&E high consumption ADRS sample (n=6).

Load impact results by temperature bin were sustained and consistent for high consumption ADRS homes in the hottest temperature bins on both event and non-event days. For PG&E and SCE, the hottest temperatures experienced by ADRS homes ranged from 91°F to105°F. For SDG&E, the hottest temperatures experienced by ADRS homes ranged from 86°F-95°F, shown in Table 2 as the shaded cells. This result was expected due to the lack of need for air conditioning below 86 degrees. SCE demonstrated a wider diversity in percent load reductions between event and non-event days in all temperature bins. This probably can be explained by the higher saturation of controlled swimming pool loads (non-temperature sensitive) at the SCE high consumption ADRS homes.

Table 2
High consumption ADRS percent load reductions by temperature bin and by utility, July – September 2005

	PG&E		SCE		SDG&E	
Temp	Event (%)	Non-event (%)	Event (%)	Non-event (%)	Event (%)	Non-event (%)
<75	NA	-27	NA	45	-54	-12
76-85	NA	3	75	24	2	25
86-90	NA	8	71	26	46	47
91-95	29	25	56	28	48	39
96-100	23	25	50	26	NA	NA
101-105	29	19	41	27	NA	NA

ADRS technology has the ability to leverage residential end uses in addition to air conditioning consumption, such as pool pumping and water heating[14]. About one-third of the ADRS high consumption homes have swimming pools with circulation pumps that were also controlled using ADRS technology. Examination of average daily load profiles showed that high consumption ADRS customers with swimming pools consistently scheduled pool pump operation outside of the hours between 2 p.m. and 7 p.m. to reduce Super Peak and peak period consumption every day.

[13]On non-event weekdays, the peak period confidence intervals averaged ±0.11 kW for control homes and ±0.12 kW for ADRS homes. Within the 15-minute data intervals 90% confidence intervals for control homes varied from ±0.10 kW to ±0.12 kW across the peak period; 90% confidence intervals for ADRS homes varied from ±0.09 kW to ±0.17 kW.

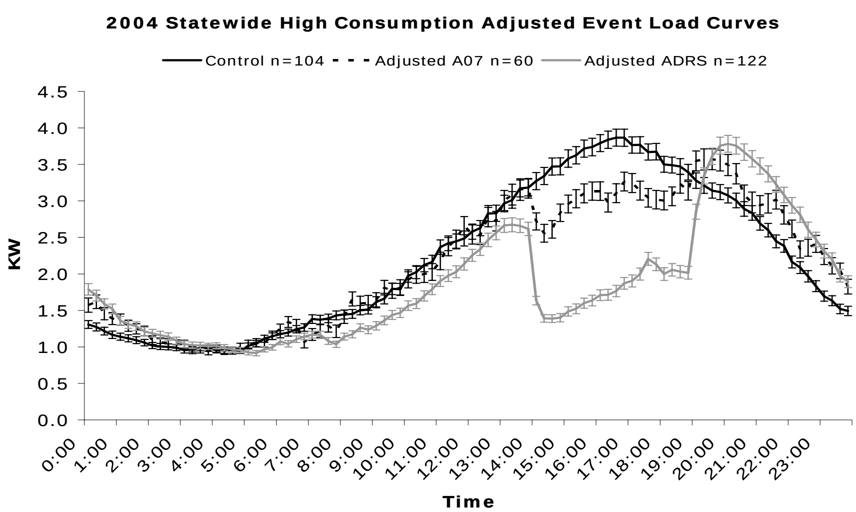
[14] However, water heating load control was not tested in this program.

On event days, pool pumps operation contributed 32% of total Super Peak reduction for an average high consumption ADRS home with a pool[15]. On non-event days, residents shifting pool pump operation contributed over 50% of total peak period reduction for an average home with a pool. Since approximately one out of every three ADRS participant owns a pool, this load reduction contributed about 10% of total Super Peak period reduction on event days. On non-event days, shifting pool pump schedules contributed about 27% of total peak period reduction on non-event days.

Summer 2004 load impact results

During the period July to September 2004, ADRS high consumption customers successfully and consistently reduced load relative to control homes by 1.84 kW or 9.21 kWh on average during the Super Peak period[16] across twelve event days, called statewide. This translates to a 51% reduction relative to high consumption control homes statewide (Figure 1 and Table 3). The control homes do not possess ADRS technology and are not subject to dynamic critical peak pricing (CPP) rates.

Figure 1. 2004 Statewide high consumption event day load curves



In contrast to the summer 2005 load impact analysis, the 2004 analysis compared the statewide load impact of ADRS customers to a second set of customers in addition to control homes. These are customers on dynamic critical peak pricing rates but without ADRS technology ("A07 homes"). ADRS high consumption participants successfully and consistently reduced load by an average of 1.24 kW or 6.22 kWh during Super Peak period on event days statewide relative to these A07 homes. This translates to a 41% reduction, statewide.

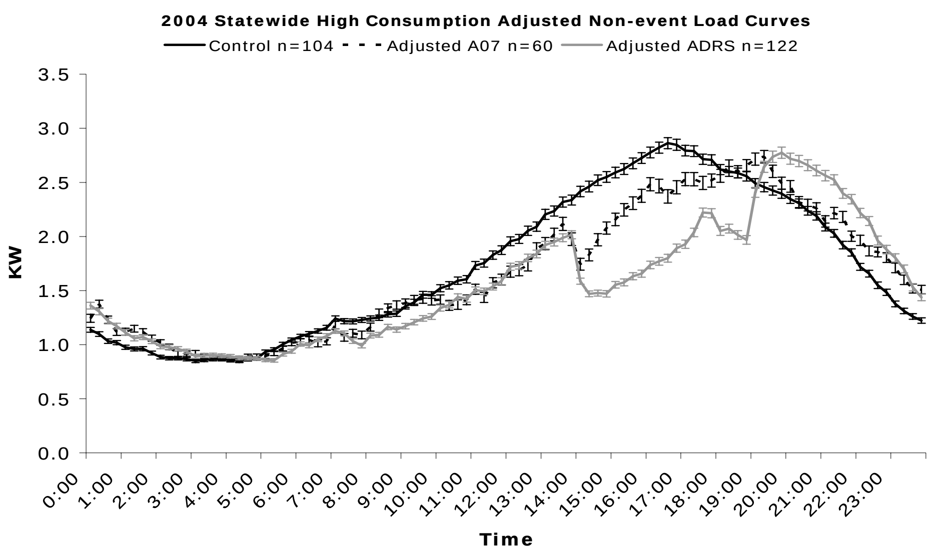
[15]Total reduction of Super Peak and peak period load by homes with pools is calculated algebraically rather than by direct measurement

[16]Super peak period on event days occur from 2 p.m. to 7 p.m. on non-holiday weekdays between June 1st and September 30th.

The A07 homes, reducing their load with only the Super Peak rate stimulus on event days but without the assistance of ADRS technology, averaged 0.60 kW reduction relative to control homes or 3.0 kWh during Super Peak period on event days, statewide. This translates to a 17% reduction for A07 high consumption customers relative to control customers on event days, statewide. Ninety percent confidence intervals of loads during the Super peak period averaged ±0.11 kW for control homes, ±0.07 kW for ADRS homes, and ±0.13 kW for A07 homes[17].

On non-event weekdays statewide, ADRS high consumption customers reduced load relative to control homes by 0.86 kW or 4.28 kWh on average, during the peak period[18]. This translates to a 32% reduction relative to high consumption control homes statewide (Figure 2 and Table 3). Compared to A07 homes statewide, ADRS high consumption customers reduced load by an average of 0.54 kW or 2.72 kWh during the peak period. This translates to a 23% reduction relative to A07 customers.

Figure 2. 2004 Statewide high consumption non-event day load curves



The A07 homes, reducing their load with only the peak rate stimulus on non-event days but without the assistance of ADRS technology, averaged 0.31 kW or 1.55 kWh compared to high consumption control customers. This translates to a 12% reduction for A07 high consumption customers relative to control customers on non-event days, statewide. Ninety percent confidence intervals during the non-event peak period averaged ±0.05 kW for control homes, ±0.03 kW for ADRS homes, and ±0.06 kW for A07 homes[19].

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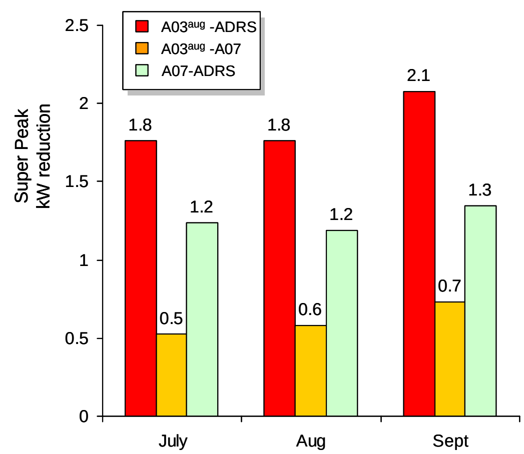
[17]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, of the essential companion document to this report, *Automated Demand Response System Pilot, 2005 Summer Load Impact Results and Comparison of 2005 with 2004 Summer Load Impact Results*. Super Peak 90% confidence intervals ranged from ±0.10 kW to ±0.12 kW for control homes, from ±0.05 kW to ±0.08 kW for ADRS homes, and from ±0.12 kW to ±0.13 kW for A07 homes.

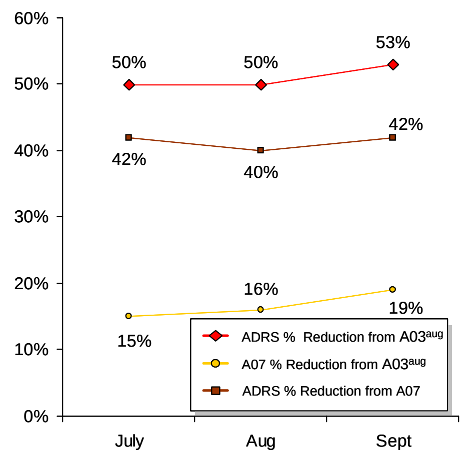
[18] Peak period on non-event days occur from 2 p.m. to 7 p.m. on non-holiday weekdays.

[19]Non-event peak period 90% confidence intervals ranged from ±0.0.4 kW to ±0.05 kW for control homes, from ±0.03 kW to ±0.04 kW for ADRS homes, and from ±0.055 kW to ±0.062 kW for A07 homes.

Statewide monthly performance of ADRS homes during 2004 varied little from the summer average (Figure 3). ADRS high consumption load reductions in July and August are equal to the summer average of 1.8 kW or 9 kWh during Super Peak periods on event days. This translates to a 50% savings in July and August. September was strongest performing month of the summer, with ADRS homes reducing load by more than 2 kW on average or 53% during Super Peak periods, compared to control homes.

Figure 3. Average monthly reduction in Super Peak load, high consumption homes





Statewide monthly load reductions of ADRS homes relative to A07 homes were also similar to the summer average (Figure 3). July, August and September savings were 1.2 kW, 1.2 kW, and 1.3 kW, respectively, with September the strongest performing month of the summer. This translates to 42%, 40%, and 42% reduction in July, August, and September, respectively, compared to A07 homes.

Finally, load reduction of high consumption A07 homes relative to control homes was 0.5 kW in July, 0.6 kW in August and 0.7 kW in September, after adjusting for selection bias. This translates to 15%, 16%, and 19% load reduction in July, August, and September, respectively.

Summer 2004 results also varied by utility (Table 4), and utility specific results were analyzed only for ADRS load reductions compared against control customers. ADRS high consumption customers in the PG&E service territory successfully reduced load by 1.29 kW or 6.44 kWh on average during Super Peak period on event days. This translates to a 39% reduction relative to the control group. On non-event days, PG&E's high consumption ADRS customers reduced peak period load by 0.55 kW or 2.74 kWh compared to control customers. This translates to a 22% reduction, on average during summer 2004.

ADRS high consumption customers in the SCE service territory reduced Super Peak Period load by 2.37 kW or 11.87 kWh. This translates to a 58% reduction on average relative to the control group. On non-event days, SCE's high consumption ADRS customers reduced peak period load by 1.12 kW or 5.6 kWh on average. This translates to a 38% reduction relative to the control group.

For SDG&E, ADRS high consumption customers reduced load by 1.2 kW or 6 kWh during the Super Peak period on average across summer 2004. This translates to a 41% reduction relative to the control group. On non-event days, ADRS high consumption customers reduced load by 0.37 kW or 1.87 kWh during the peak period. This translates to a 17% reduction relative to its control group. SDG&E results should be interpreted with caution, however, due to small size of the high consumption sample (n=7).

Table 3. Summary of 2004 statewide high consumption load impact results

		control – ADRS	A07 – ADRS	control – A07
Event days, Super Peak period	Average	1.84 kW	1.24 kW	0.60 kW
	5-hr total	9.21 kWh	6.22 kWh	3.00 kWh
	% Reduction	51%	41%	17%
Non-event days, peak period	Average	0.86 kW	0.54 kW	0.31 kW
	5-hr total	4.28 kWh	2.72 kWh	1.55 kWh
	% Reduction	32%	23%	12%

Table 4. Summary of 2004 high consumption ADRS load impact results by utility, control –ADRS homes only

		PG&E	SCE	SDG&E
Event days, Super Peak period	Average	1.29 kW	2.37 kW	1.20 kW
	5-hr total	6.44 kWh	11.87 kWh	6.0 kWh
	% Reduction	39%	58%	41%
Non-event days, peak period	Average	0.55 kW	1.12 kW	0.37 kW
	5-hr total	2.74 kWh	5.60 kWh	1.87 kWh
	% Reduction	22%	38%	17%

All results reported above were adjusted for selection bias in both ADRS and A07 customers. Also, the control group was augmented to improve the statistical quality of all results. Details of the control group augmentation, RMI's confirmation of A07 selection bias and investigation into ADRS selection bias are included in Appendix A of this report.

Table 5 summarizes the A07 load impact results based on CRA's and CEC's independent analyses of the SPP program for climate zone 3 customers in summer 2004. The table compares the CRA and CEC results against RMI's results for the A07 customer load reductions relative to a control group reported in RMI's December 2004 report and the restatement of the ADRS summer 2004 results in this report. Note that CEC and RMI used a straight difference of difference approach while CRA used a difference of differences approach based on regression models built from pre-treatment data, treatment data, and household surveys. Details of RMI's confirmation of A07 selection bias and investigation into ADRS selection bias are included in the appendix to this document.

Table 5 shows that RMI's reported results in this report for A07 load reductions on event days matches the results reported by the CEC and is similar to the results reported by CRA on a percentage basis. Both RMI and CEC arrived at an A07 percentage load reduction on event days of 17%, while CRA reported 13%. On non-event days, RMI's measured A07 load impact compared to control is 12%, reduced from results reported in December 2004. This result is significantly larger than results reported by CRA and CEC.

However, absolute energy savings in kWh are higher in the RMI evaluation compared to the CRA or CEC evaluation, on both event and non-event days. This is due to RMI's more focused control sample, emphasizing high consumption homes with central air conditioning. As such, RMI's control homes have higher average usage, and the comparable A07 home reductions were measured against this higher baseline usage. While the CRA and CEC control load on average peaked at 2.5 kWh during Super Peak and peak periods, RMI's control loads on average peaked around 3.5 kWh during those same periods.

Table 5. Comparison of CRA and CEC's control-A07 results for climate zone 3 SPP participants

Event Weekdays Peak Period Comparison (Climate Zone 3)			
	Zone 3 CPP Change (kW)	Savings (kWh)	% Reduction
CRA[1]	0.22	1.1*	13.37%
CEC[2]	0.30	1.5	16%
RMI March 2005[3]	0.94	4.7	28%
RMI March 2006[4]	0.60	3.0	17%
Non-event Weekday Peak Period Comparison (Climate Zone 3)			
	Zone 3 CPP Change (kW)	Savings (kWh)	% Reduction
CRA[1]	0.08	0.4*	5.59%
CEC[2]	0.11	0.6	8.5%
RMI March 2005[3]	0.37	1.8	15%
RMI March 2006[4]	0.31	1.6	12%

* RMI calculation
[1]Charles River Associates (CRA), *Statewide Pricing Pilot Summer 2003 Impact Analysis* Final Report October 11, 2004. p. 7
[2]Pat McAuliffe and Arthur Rosenfeld, *Response of Residential Customers to Critical Peak Pricing and Time-of-Use Rates During 2003 and 2004.* January 17, 2005. September 23, 2004. p. 4
[3]RMI 2005, Residential Automated Demand Response System (ADRS) Pilot Load Impact Final Report.
[3]RMI 2006, ADRS Load Impact Final Report, volume 2.

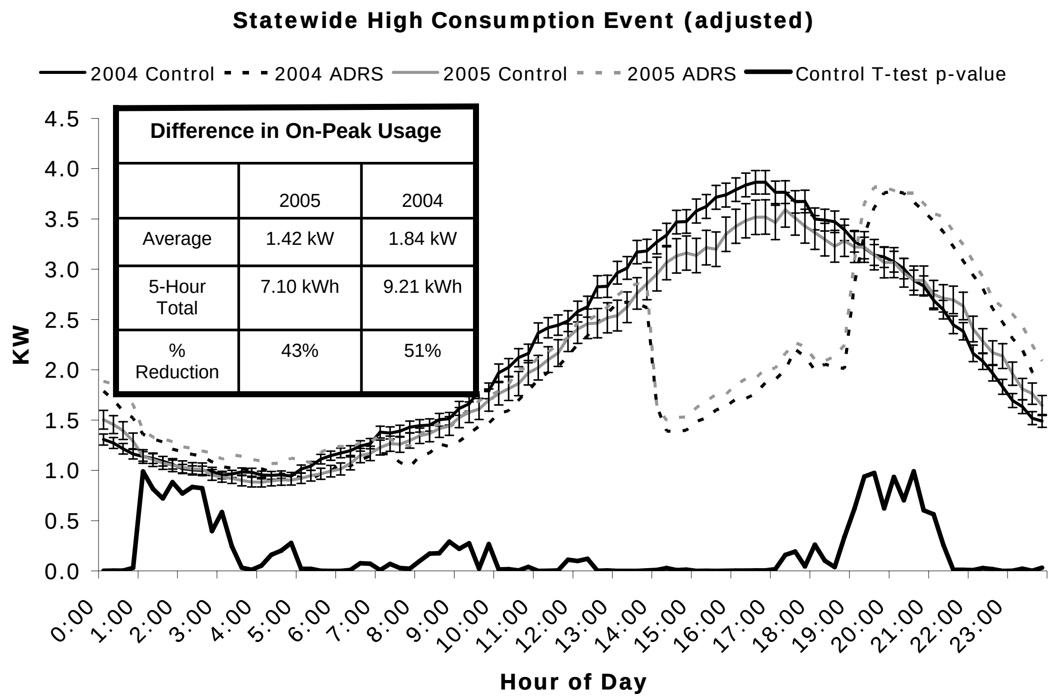
The residual differences in load impact results in Table 5 between CRA, the CEC, and RMI are due to the different control home samples and slight differences in the A07 homes evaluated in each study. The homes evaluated by CRA and CEC for the SPP program include both single and multifamily homes in climate zone 3, who may or may not have central air conditioning. The homes RMI evaluated for the ADRS pilot is the subset of the SPP control and participant homes, consisting only of single family homes with central air conditioning in climate zone 3.

Furthermore, RMI's results in Table 5 consist only of high consumption homes, whose average daily consumption is greater than 24 kWh, while results reported for CRA and CEC include both high and low consumption homes. As stated in the Introduction section of this report, RMI's restatement of ADRS summer 2004 results includes an augmented population of control homes in climate zone 3 that was not used for the SPP program evaluated by CRA and the CEC.

Comparison of summer 2005 with summer 2004 load impact results

Figure 4 and Figure 5 compare the 2005 and 2004 load reduction of high consumption ADRS customers against control homes on event and non-event days statewide. In summary, high consumption ADRS load reduction was greater in 2004 than 2005, by 25% on average on event days and by 15% on non-event days, statewide.

Figure 4: 2005 and 2004 statewide high consumption event day load curves



The smaller load reduction on event days in 2005 in general, is attributed mostly to lower control home loads in 2005. Average Super Peak Period control home consumption in 2005 decreased by 8% compared to 2004 (Figure 4), in spite of the fact that 2005 was a hotter summer on average[20]. The lower average control home load in 2005 on event days is counterintuitive, and we cannot explain this difference in behavior with available data[21]. Furthermore the control homes, by definition, cannot be interviewed. As such, we can only conjecture as to the reasons for this behavior.

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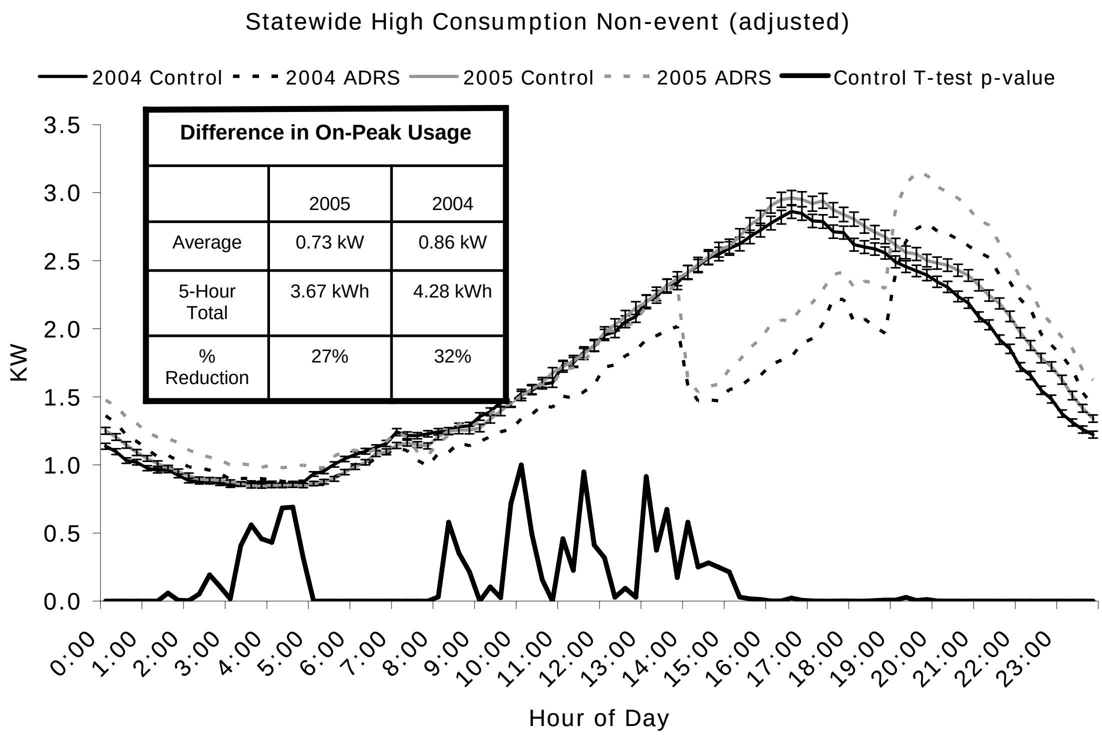
[20]Note that average peak temperatures were calculated based on data for specific zip codes where ADRS and control homes were located. Thus, the observation that 2005 was hotter than 2004 may not be true for all areas within each utility's service territory.

[21]Household level investigation into control home consumption revealed a significant number of outliers, where control homes exhibited almost no consumption throughout the entire day. These high consumption control homes were removed from the sample for the 2005 analysis. The number of control homes removed did not reduce the statistical significance of 2005 results. Details of control home household-level analysis and removal of outliers are included in Appendix A, Data development and Methodology.

High consumption ADRS loads, on the other hand, increased by 7% during Super Peak periods on average in 2005 (Figure 4), as expected during months with more cooling degree days. Note that the percent increase in ADRS Super Peak period load is calculated from a lower overall peak period consumption compared to higher control customer loads.

The smaller load reduction on non-event days in 2005 compared to 2004 is attributed mostly to higher average summer season temperatures in 2005. Figure 5 shows that both ADRS high consumption and control customers had higher peak period demand in 2005. While control load increased by 4% during the peak period in 2005, ADRS load increased by 12% during the peak period[22]. Note also that ADRS loads dropped further at 2 p.m. in 2005 than 2004, but recovered more quickly throughout the rest of the peak period, which is consistent with the observation that hotter summer weather causes the indoor temperatures to rise to the on-peak thermostat set-point faster. This results in modestly diminished ADRS savings, statewide.

Figure 5: 2005 and 2004 statewide high consumption non-event weekdays load curves



For both summers, note the dramatic increase in ADRS loads during the two hours immediately following the Super Peak and peak periods, from 7 p.m. to 9 p.m. At the end of the Super Peak period, the thermostats in ADRS homes automatically reset from their warmer Super Peak setting to their cooler off-peak setting. This resulted in a sudden jump in load at 7 p.m. as the air conditioners suddenly turned on to meet the new, cooler set point.

[22] Again, outliers in the control population have been removed from the 2005 analysis. However, a number of the remaining control homes still exhibited lower loads in 2005 than 2004, even though summer 2005 was hotter on average.

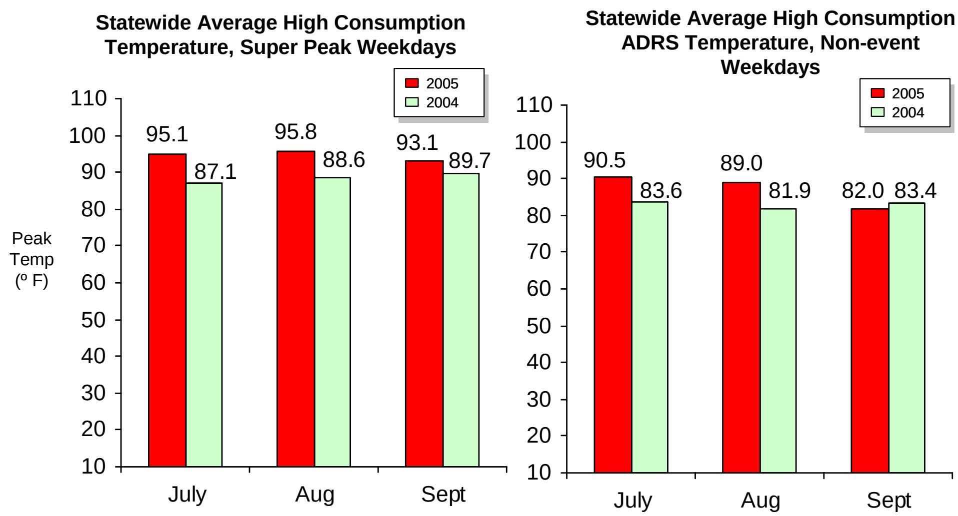
Results also varied by utility, with average load reductions equal to or higher in 2004 compared to 2005. For high consumption ADRS customers in PG&E territory, Super Peak period load reduction was 36% lower in 2005 than 2004. Super Peak period load reduction in 2005 was 0.8 kW, compared to 1.3 kW in 2004. On non-event weekdays, peak period reduction in 2005 was 15% lower than in 2004. Peak period load reduction in 2005 was 0.47 kW, or 18% of 2005 control load, compared to 0.55 kW, or 22% of control load in 2004.

In SCE service territory, high consumption ADRS customers reduced Super Peak load by 1.9 kW in 2005 and by 2.4 kW in 2004. Relative to control homes, ADRS homes reduced Super Peak load by 49% and 58%, respectively. On non-event days, high consumption ADRS customers reduced peak period load by 0.9 kW in 2005 and 1.1 kW in 2004, a 21% decrease in performance from 2004.

For high consumption ADRS customers in SDG&E territory, Super Peak period load reduction was virtually the same 2004 and 2005, at 1.20 kW and 1.17 kW, respectively. On a percentage basis, however, ADRS reductions were slightly lower in 2005 (38% compared to control) than 2004 (41% compared to control), as a result of lower control home consumption in spite of the hotter 2005 summer. On non-event days, SDG&E high consumption ADRS customers reduced load by 0.7 kW in 2005 and 0.4 kW in 2004, an 86% increase.

Figure 6 confirms that the ADRS homes during 2005 experienced hotter temperatures, on event and non-event days. On both event and non-event weekdays statewide, temperatures were nearly 8°F warmer in 2005 during both July and August. September temperatures were closer between the two summers, with 2005 event day temperatures exceeding 2004's by 3°F. Non-event day temperatures in September were essentially the same in 2004 and 2005.

Figure 6: 2005 and 2004 average peak period temperatures by month, statewide



Statewide, high consumption ADRS load reductions were relatively stable and consistent across event days. Figure 7 and Figure 8 show load reductions for each event day on a percentage basis. In 2005, load reductions varied modestly between 35% and 47% across seven event days called between July and September. Similarly in 2004, load reductions varied modestly between 47% and 56% across twelve event days called between July and September. Results also varied by utility.

Figure 7: Percent load reductions by event day statewide, high consumption ADRS homes in 2005

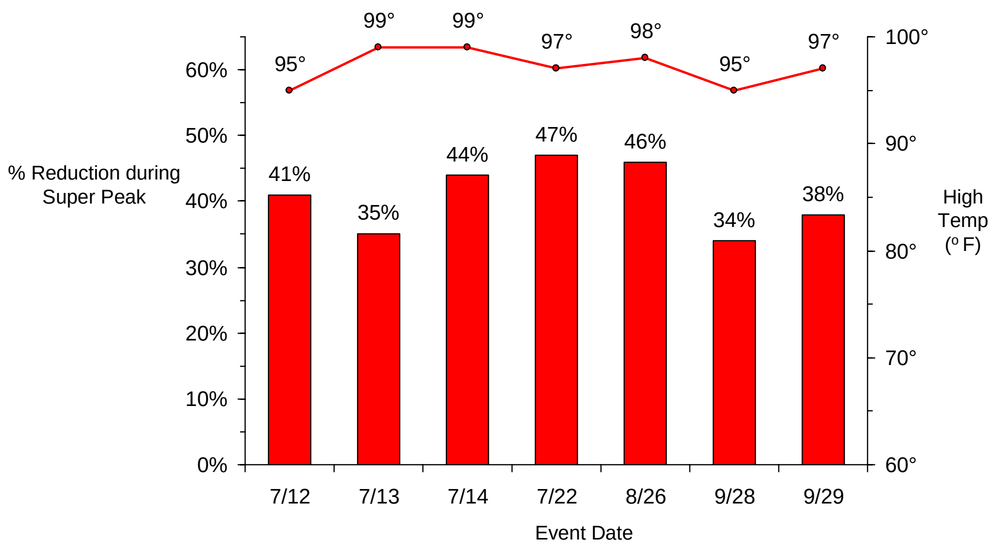
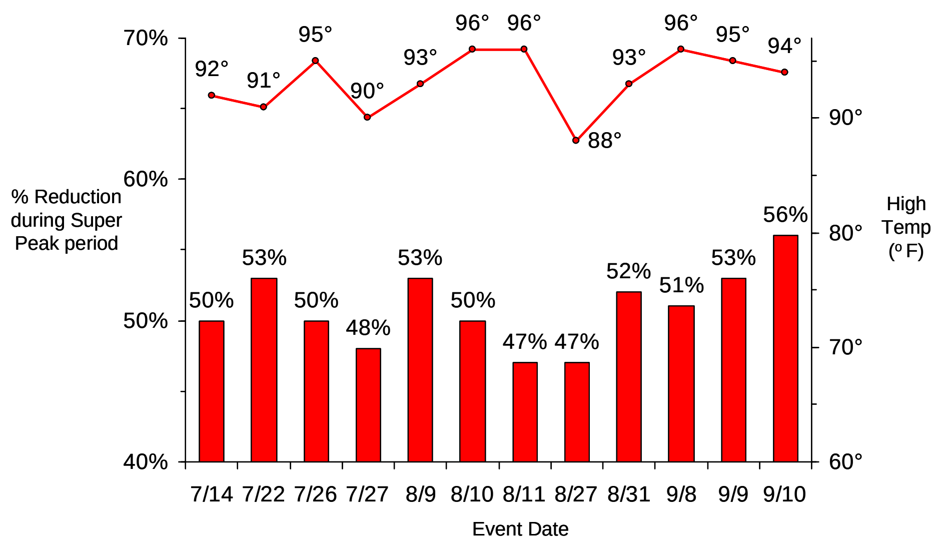


Figure 8: Percent load reductions by event day statewide, high consumption ADRS homes in 2004



Conclusions

Customers with ADRS technology and subject to CPP-F rates in climate zone 3 successfully achieved load reductions compared to control customers without ADRS technology on standard tiered rates, in both 2004 and 2005. The load reductions were substantial and stable across a range of days and temperatures for both years. Super Peak period load reductions on event days were consistently about twice the load reduced during peak periods on non-event days. Some of the load reduction was attributable to the dynamic pricing tariff[23]. However, technology appears to be an important driver in reducing load, especially Super Peak load, for high-consumption homes. Customers with technology in the ADRS pilot consistently reduced more than twice the load of residential customers in other demand response programs who do not have technology[24].

Load reduction performance for customers with ADRS technology and subject to CPP-F rates varied between utilities across the state. SCE high consumption ADRS customers consistently achieved close to 2 kW reductions on event days across a range of temperatures. PG&E and SDG&E high consumption ADRS customers achieved substantial, but lower reductions, close to 1 kW on event days on average.

Load reductions appeared to be stable for ADRS homes experiencing the hottest temperatures relative to other ADRS homes for a particular utility. For PG&E and SCE, load reductions were stable and consistent for homes experiencing maximum temperatures above 91°F on event and non-event days. For SDG&E, load reductions were stable and consistent for homes experiencing maximum temperatures above 86°F on event and non-event days.

Homes with ADRS technology produced a consistent and predictable load profile during Super Peak and peak periods. Reductions were at their maximum at the start of the period, then gradually decreased as homes warmed up and air conditioners pulsed on to maintain indoor temperatures at the higher set point. The hotter the outdoor temperature, typically the faster the load would rise throughout the peak period, on average. There was typically a dramatic recovery in load immediately following the Super Peak or peak periods, when thermostats in ADRS homes automatically reset from their warmer Super Peak or peak settings to their cooler off-peak setting.

Where present, pool pumps made a significant contribution to reduction of Super Peak and peak period load. Examination of average daily load profiles showed that high consumption ADRS customers with swimming pools consistently scheduled pool pump operation outside of the hours between 2 p.m. and 7 p.m. to reduce Super Peak and peak period consumption every day. On event days, pool pumps operation contributed 32% of total Super Peak reduction for an average high consumption ADRS home with a pool[25]. On non-event days, residents shifting pool pump operation contributed over 50% of total peak period reduction for an average home with a pool.

High consumption ADRS load reductions in 2004 were slightly greater than load reductions in 2005. In 2005, performance was strongest in July statewide and for PG&E and SCE high consumption ADRS homes. In 2004, performance was strongest in September statewide and for

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[23]Refer to statewide high consumption load impact results reported in the companion document to this report, *Automated Demand Response System Pilot, Restatement of 2004 Summer Load Impact Analysis.*

[24]Refer to statewide high consumption load impact results reported in the companion document to this report, *Automated Demand Response System Pilot, Restatement of 2004 Summer Load Impact Analysis.*

[25]Total reduction of Super Peak and peak period load by homes with pools is calculated algebraically rather than by direct measurement.

PG&E and SCE high consumption ADRS homes. For SDG&E high consumption ADRS homes, performance was strongest in September in both 2004 and 2005.

Comparing daily consumption patterns between 2005 and 2004 in energy terms, high consumption ADRS customers in PG&E and SCE service territory were more aggressively shifting load from Super Peak and peak periods to off-peak periods in 2005 compared to 2004[26]. High consumption ADRS homes in SDG&E service territory, on the other hand, appeared to have used technology to reduce overall energy consumption as opposed to shifting load on both event and non-event days, for both summer 2005 and summer 2004.

We can only hypothesize that in SDG&E, where average temperatures were typically 10^{o}F cooler that the statewide average, customers were better able to respond to peak pricing signals by reducing energy consumption overall. In PG&E and SCE service territories where temperatures tended to be higher than the statewide average, high consumption ADRS customers resorted to shifting load in order to save money while maintaining thermal comfort.

Recommendations for Future Program Design

Recommendations for improving the performance and therefore cost effectiveness of future ADRS programs involve how to target customers most likely to reduce substantial load and how to implement the program so as to induce the greatest amount of load reductions ($\geq$ 2 kW) per home. Details of our investigation into customer performance at the household level are presented in Volume 3 of this report, Future Program Design Recommendations.

Examination of ADRS customers at the household level for Super Peak and peak period load reductions confirmed that 51% of the ADRS high consumption homes produced the vast majority of savings (80%). This suggests that simply targeting high consumption homes during program recruiting is adequate to maximize customer program benefits, and could be an economical way of implementing the program.

However, we recommend that utilities raise the threshold between low and high consumption homes slightly from its current 24 kWh ADU to 32 kWh ADU, and to target homes with ADU 32 kWh or greater. Our analysis reveals that 90% of total Super Peak period load drop in summers 2004 and 2005 was achieved by ADRS homes with ADU greater than 32 kWh, which made up 80% of total high consumption ADRS population.

In addition to ADU > 32 kWh as a screen for potential ADRS participants, we recommend a number of additional physical and behavioral customer characteristics that utilities can use to target future ADRS customers to help maximize future program performance. The additional physical characteristics are:

[26] We derived this conclusion from the observation that in 2005, ADRS homes consumed about as much or slightly more energy than control homes as measured by average daily usage (kWh/day). Given the net load reductions during the Super Peak and peak periods, we concluded that ADRS homes must therefore be shifting load to the recovery and off-peak periods. In contrast, there was more substantial net energy reduction of ADRS homes in 2004, indicating greater energy conservation as opposed to simply load shifting.

- Customers located in geographical sub-regions within the service territory that experience hottest summer temperatures, preferably above 90^{o}F on average during the hours of 2 p.m. to 7 p.m.
- Customers possessing end uses in addition to air conditioning, such as swimming pool pumps and hot water heaters.
- Customers in regions that have similar home construction and demographics to ADRS pilot participants in SCE service territory: larger, newer (post 1985) homes that are more likely to have central air and developments with higher income households.
- Target customers located in areas with high total avoided costs[27].

The behavioral characteristics of ADRS customers we could most decisively identify as contributing to large load impact include the following:

- Customers who are away from home during the day.
- Households receptive to automation of appliance operation and control settings.
- Customers who are receptive to learning about new technology.

While these behavioral characteristics are more difficult to identify ahead of time, particularly the last two, we consider these household characteristics helpful for achieving high load reductions in future ADRS programs. These insights were developed by BDG, which is evaluating customer satisfaction levels with and willingness to pay for ADRS technology during the summer 2005 and summer 2004 pilot programs[28]. Rocky Mountain Institute has been coordinating our research efforts with BDG to develop a cohesive set of results and recommendations for future ADRS programs.

We do not claim that these behavioral elements are complete or exhaustive, but that it is a list of the chief behavioral characteristics than can be relatively easily (and therefore economically) screened for during targeted marketing and that would increase the chances of recruiting high performance participants. We also caution that these behavioral elements should be screened in conjunction with the physical characteristics described above, to avoid conflicting results.

For example, there is little program benefit to identifying a customer who's not usually home during the day but has average daily usage less than 32 kWh, indicating that the household does not have much load available to curtail. In this case, a utility would be recruiting based on behavioral characteristics that we recommended while ignoring the physical characteristics of high performing ADRS customers, thereby potentially reducing the effectiveness of the program.

Also, we propose some guidelines for program design and implementation of future ADRS programs to maximize load reductions and therefore program effectiveness. Utilities will likely achieve maximum program performance and benefits when they:

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[27] *i.e.*, avoided capacity, energy, transmission and distribution, and environmental costs

[28] Boice Dunhame Group. 2006. *Customer Satisfaction Report, ADRS pilot program,* and *Customer Super Peak Behavior Report, ADRS pilot program.*

- Call Super Peak event days when summer temperatures are highest (*minimum* of $90^{o}F$ in regions for ADRS customers). Else, reserve as a separate category for event days called when temperatures are merely warm or moderate, and call event days separately by utility.
- Shift start of peak period to 3 p.m.
- Shift end of peak period to 5:30 p.m. from 7 p.m.[29]
- Place ADRS customers on the CPP-V (day of) rate instead of CPP-F (day ahead) to maximize benefits, since the ADRS is automated.
- In limited situations, stagger calls to subsets of participants, rather than all participants at once, to even out the load reduction through the Super Peak period.
- Call consecutive event days only when absolutely necessary (avoid customer fatigue).
- Employ ADRS technology as a load response program for reliability purposes, due to the immediacy of dispatch.

Ultimately, our observation is that either automated technology or dynamic pricing can deliver significant demand response in large residential houses, but that the combination of both technology and dynamic pricing might not be necessary for the average home. The following rationale explains this observation.

In the summer 2005 pilot, ADRS load impact was evaluated against a control group without enabling technology or dynamic rates. The results show a substantial load drop during Super Peak Periods with larger homes. However, in the summer 2004 pilot, ADRS load impact was evaluated against a group of average homes that were on the CPP-F rate but did not possess ADRS technology ("A07" homes). Particularly for low-consumption homes, the 2004 load impact report revealed that the critical peak pricing rate captured the majority of load benefits, and the additional load reduction resulting from enabling technology was small to negligible[30].

Assuming that dynamic rates are adopted in California statewide, future ADRS load reduction performance would be comparable to statewide results reported compared against A07 customers in the 2004 ADRS load evaluation study[31]. Residential customers without enabling technology would already reduce some Super Peak and peak period loads as a result of the dynamic pricing tariff, and the incremental impact (and therefore cost effectiveness) of enabling technology would be reduced.

If dynamic pricing tariffs do not become the default tariffs, then the average residential customers generally would be similar to the control group studied in the pilot. In this case, the

[29]Practically, utilities will likely want to stagger the ending of Super Peak periods to control the magnitude of the recovery period. If all homes suddenly switch to off-peak mode at once, thermostats revert to their off-peak settings and cause a large increase in consumption during the two hours immediately following, and risk creating another system peak between 5:30 p.m. and 7 p.m.

[30]Rocky Mountain Institute. 2005. *Residential Automated Demand Response System (ADRS) Pilot Load Impact Final Report*. March 25. Downloadable from http://www.energy.ca.gov/demandresponse/documents/index.html

[31]Refer to statewide high consumption load impact results in this report, *Automated Demand Response System Pilot, Restatement of 2004 Summer Load Impact Analysis.*

ADRS program is more likely to be cost effective, and utilities could further optimize the program by targeting high consumption homes as described above.

Finally, we recommend that residential demand response programs for high consumption households should include automated technology regardless of whether dynamic pricing is in place. In this way, utilities would have the ultimate flexibility to induce reductions in air conditioning and other residential end use loads in response to system needs, or for reliability purpose. Automated technology and could also improve price responsiveness in the absence of tariffs, or for customers that opt out of default dynamic tariffs.

AUTOMATED DEMAND RESPONSE SYSTEM PILOT

Final Report
Volume 2

Load Impact Results

Summer 2005, Summer 2004
and
Comparison of Summer 2005 and Summer 2004 Results

Prepared by
Rocky Mountain Institute
Boulder, Colorado

31 March 2006

Table of Contents

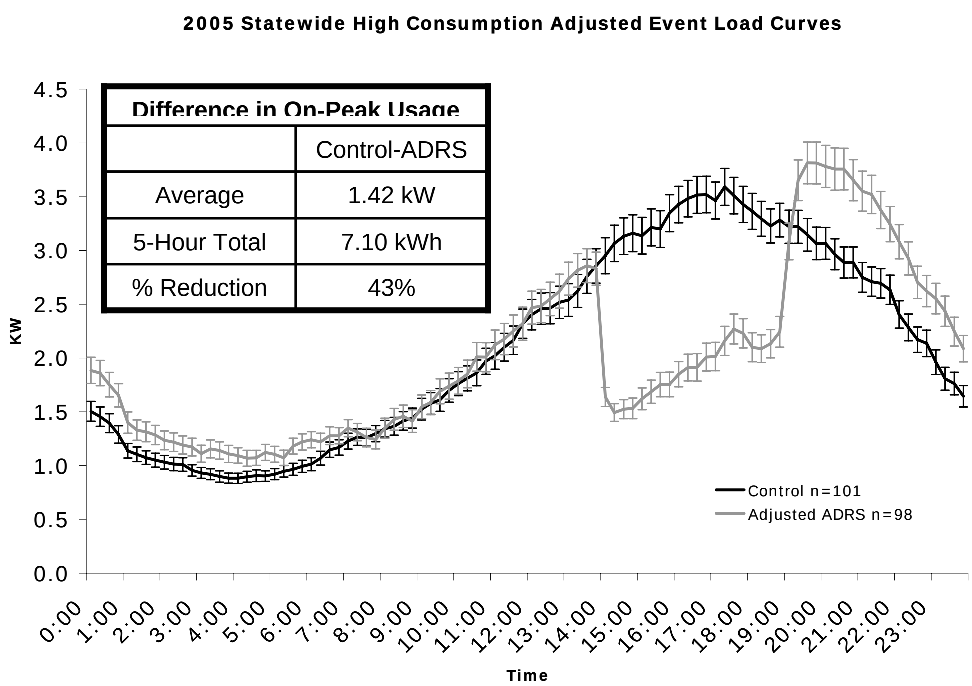
Chapter 1 Summer 2005 Load Impact Results

The following section presents in detail load reduction performance of ADRS homes with technology and subject to experimental CPP-F rates, compared to homes without technology and subscribed to standard tiered rates, from July through September 2005. Load reductions are first reported on a statewide basis for high consumption homes, followed by results for high consumption ADRS participants in each utility service territory of PG&E, SCE, and SDG&E, respectively. A summary of results for low consumption ADRS homes is then provided on a statewide basis, as well as for each utility individually. All load impact results have been adjusted for selection bias of ADRS homes. Details of RMI's investigation into selection bias are presented in Appendix C.

1.1   Statewide 2005 High Consumption ADRS Load Impact Results

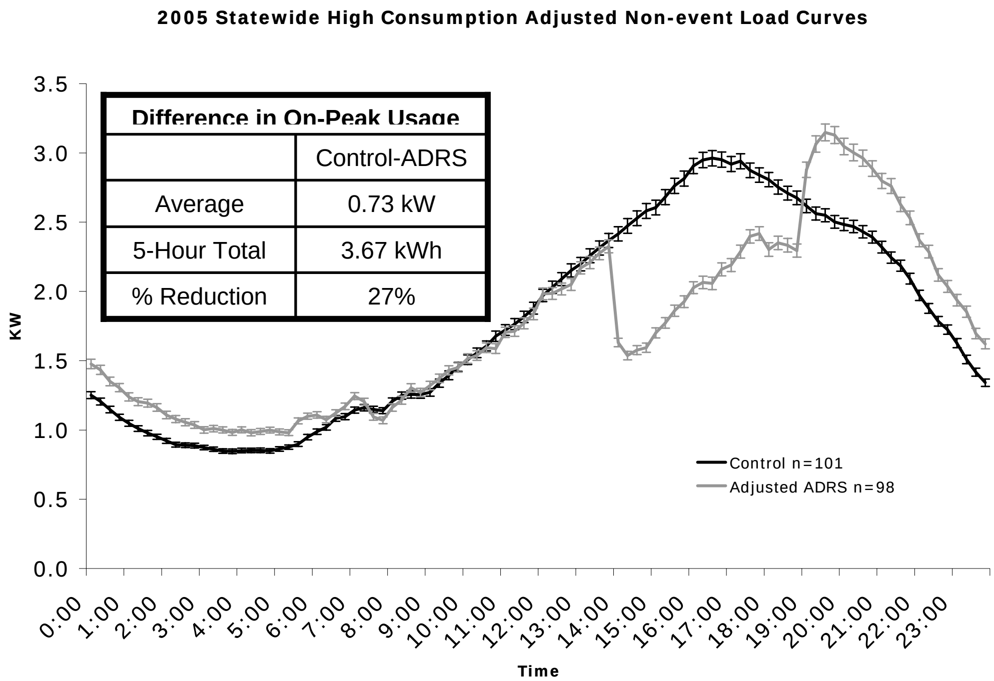
Figure 1 and Figure 2 chart the 2005 statewide high consumption home load curves for event days and non-event days respectively. On event days, high consumption ADRS customers reduced load by an average of 1.4 kW over the Super Peak period, corresponding to a 43% load reduction from control customers. Ninety percent confidence intervals across the Super Peak period were ±0.17 kW for control homes and ±0.12 kW for ADRS homes[1].

Figure 1: 2005 statewide high consumption event load curves



[1]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Ninety percent confidence intervals for control homes varied from ±0.155 kW to ±0.172 kW across the Super Peak period; ADRS confidence intervals varied from ±0.082 kW to ±0.142 kW.

Figure 2: 2005 statewide high consumption non-event load curves



On non-event days, ADRS homes reduced peak period load by an average of 0.73 kW, or 27% load reduction compared to control customers. Peak period 90% confidence intervals on non-event weekdays averaged ±0.053 kW for control homes and ±0.042 kW for ADRS homes[2]. Note the dramatic increase in consumption of ADRS homes during post-peak recovery periods on both event and non-event days, between 7 p.m. and 9 p.m. Control and ADRS loads matched closely through the morning period until the peak period for all days.

Refer to the section "Comparison of summer 2005 and summer 2004 ADRS load impact results" in this report for additional discussions of statewide ADRS high consumption load impact results.

1.2 PG&E high consumption summer 2005 load impact results

Figure 3 plots the load curves for PG&E high consumption homes on event days and Figure 4 plots the corresponding non-event days. During the Super Peak period, ADRS homes reduced load by an average of 0.83 kW, or 4.2 kWh on event days. This translates to a 29% reduction in consumption compared to control homes. Ninety percent confidence intervals for the Super Peak period averaged ±0.26 kW for control homes and ±0.19 kW for ADRS homes[3].

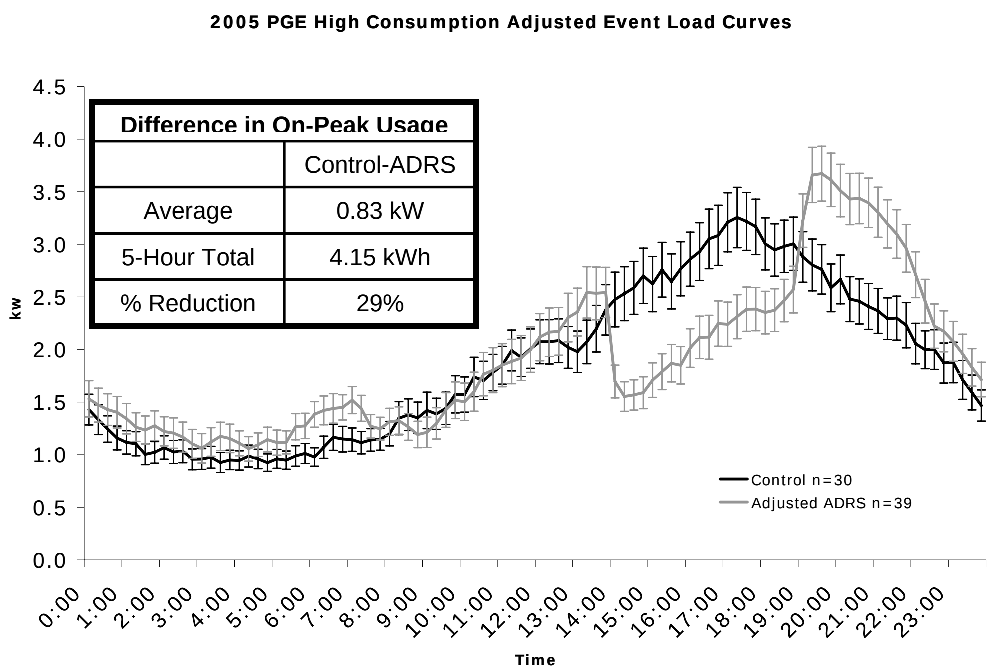
[2] Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Non-event peak period 90% confidence intervals for control homes varied from ±0.049 kW to ±0.056 kW 90% confidence intervals for ADRS high consumption homes varied from ±0.030 kW to ±0.049 kW

[3] Super Peak period 90% confidence intervals for control homes load varied from ±0.25 kW to ±0.29 kW; 90% confidence intervals for ADRS homes across the Super Peak period varied from ±0.14 kW to ±0.22 kW

On non-event days, peak period average reduction was slightly more than half of that on event days, at 0.47 kW. Ninety percent confidence intervals for the peak period averaged ±0.09 kW for control homes and ±0.07 kW for ADRS homes[4]. This translates to approximately 2.4 kWh energy savings during the peak period. As a percentage, ADRS homes reduced load by 18% of control load on non-event days.

Both event and non-event days showed a dramatic increase in ADRS consumption during a post-peak recovery period between 7 p.m. and 9 p.m. where ADRS homes consumed substantially more than control homes. At the end of the Super Peak or peak period, the thermostats in ADRS homes automatically reset from their warmer Super Peak setting to their cooler off-peak setting. This resulted in a sudden jump in load at 7 p.m. as air conditioners suddenly turned on to meet the new, cooler set point. Otherwise, ADRS and control loads were fairly similar for much of the off-peak period.

Figure 3: 2005 PG&E high consumption event day load curves



[4]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Non-event peak period confidence intervals for control varied from ±0.082 kW to ±0.091 kW; ADRS confidence intervals varied from ±0.051 kW to ±0.074 kW.

Figure 4: 2005 PG&E high consumption non-event load curves

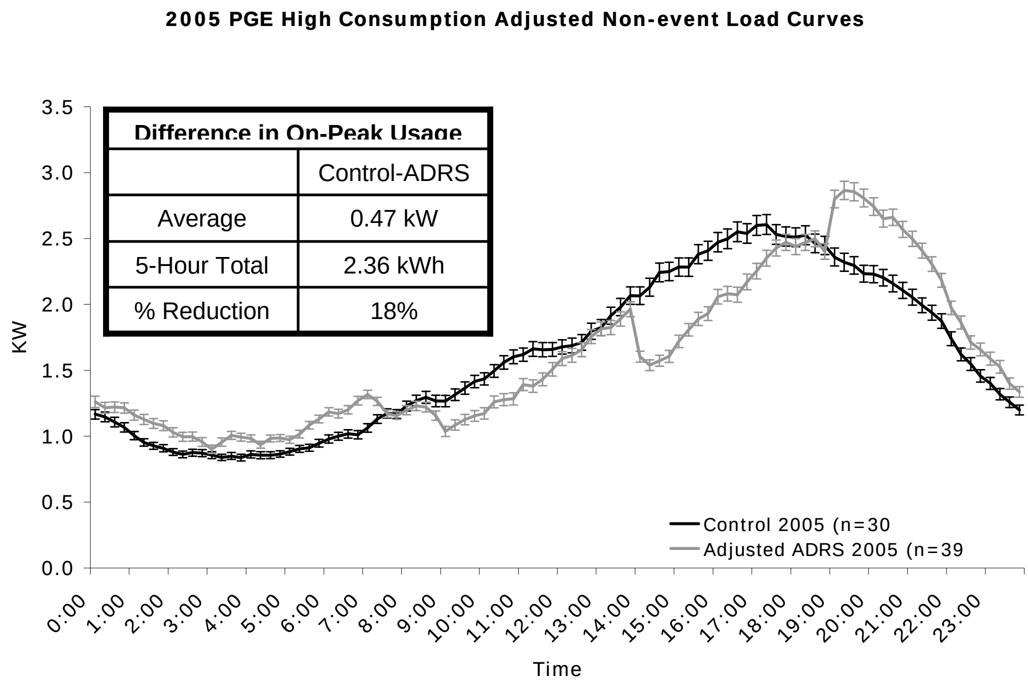
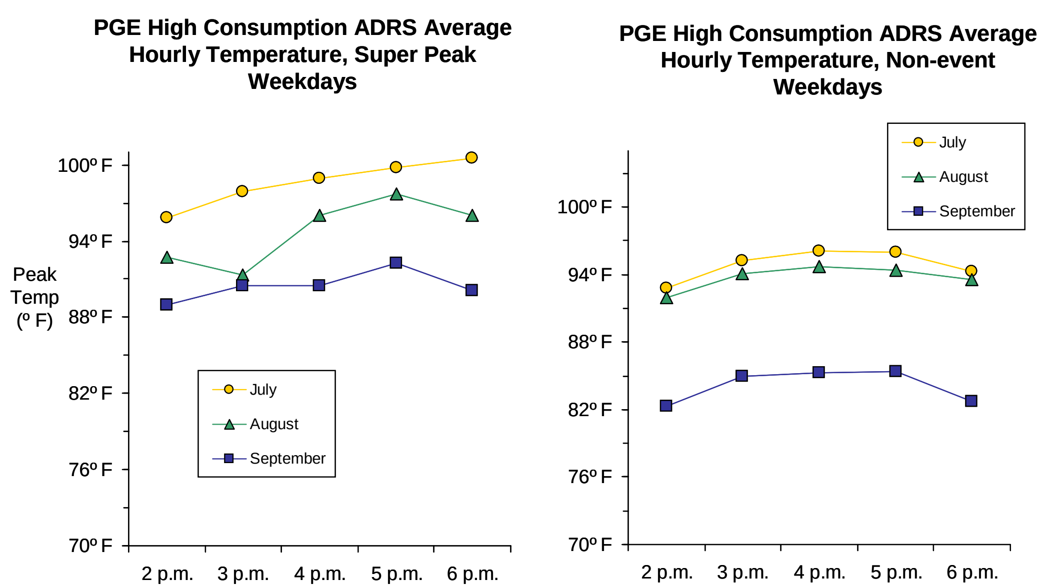


Figure 5 displays the average temperature in ADRS homes for each hour of the peak period on event and non-event days. Average hourly temperatures are reported by month from July through September 2005. On event days, July was the hottest month, with temperatures rising from 96^{o}F at 2 p.m. to just over 100^{o}F at 6 p.m. September event days were the coolest month, peaking at 92^{o}F and falling modestly to 89^o F during the last Super Peak hour at 6 p.m.

Figure 5: 2005 PG&E high consumption homes-- average hourly peak period temperatures at ADRS homes



Non-event days in PG&E territory portray a much wider range of peak period temperatures across months than event days. July and August were the warmest months, with peak period temperatures that were comparable to the event day temperatures, ranging from 91°F-96°F. September non-event days were 10°F cooler, ranging from 82°F-85°F.

Figure 6 illustrates the hourly trend of load savings across the Super Peak period for PG&E high consumption ADRS homes. During the first hour at 2 p.m., ADRS homes reduced load by almost 1 kW compared to control homes. By the second hour, the load savings declined to 0.89 kW. ADRS homes maintain this level of kW savings for the 3rd and 4th hour. However, ADRS savings as a percentage of control load steadily declined from the 1st through the 3rd Super Peak hours because control load also increased (refer to Figure 3). During the 4th hour, control loads began to decline as ADRS loads continued to increase. ADRS homes continued warming to the higher temperature set points induced by Super Peak signal initially sent at 2 p.m. Air conditioners in some homes cycled on periodically to maintain temperatures inside. By the 5th hour, savings declined to 0.54 kW, or 56% of first hour load reduction. This is due to controls' load declining while ADRS load was still increasing during the final Super Peak hour. On a percentage basis, high consumption ADRS homes reduced load compared to control homes by 38% during the first Super Peak hour, declining steadily to 18% reduction by the end of the Super Peak period at 7 p.m.

Figure 6: 2005 PG&E high consumption Super Peak period hourly load reductions

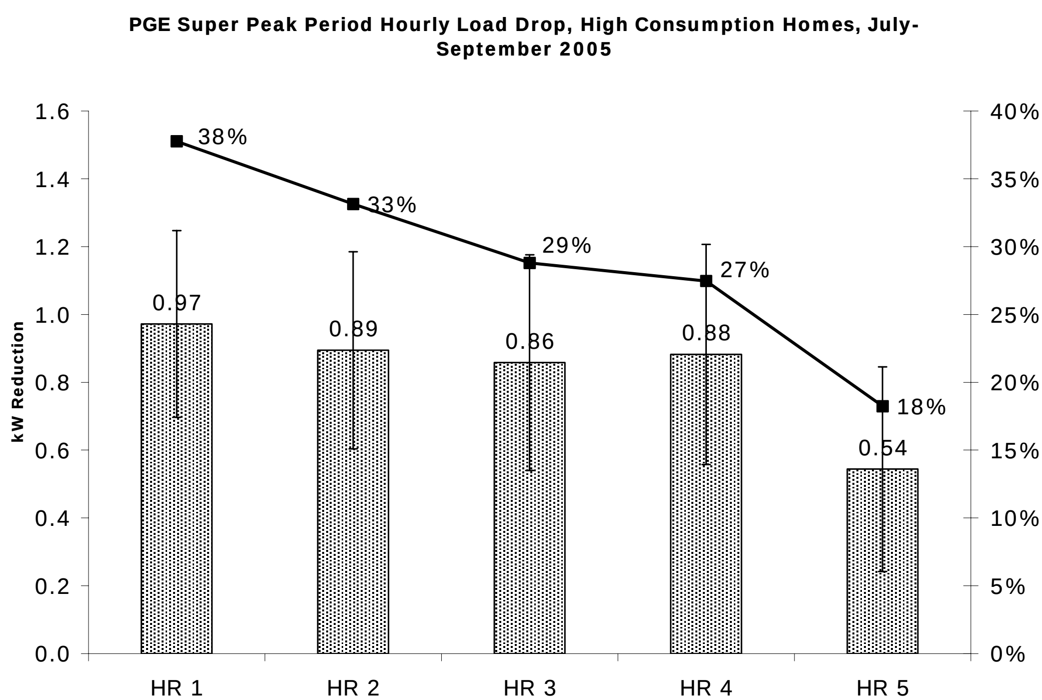


Figure 7 shows ADRS homes' on-peak savings compared to control homes on non-event weekdays. ADRS homes show a sizable savings of 0.72 kW during the first hour of the peak period. Savings declined to 0.56 kW, or 20% savings by the 3rd hour, and then declined more steeply to 0.12 kW (4%) during the last peak period hour. Referring to the load curves in Figure 4, the first 3 hours of the peak period show ADRS load ascended more rapidly than control load, resulting in gradually declining savings during this period. During the 4th peak period hour, control load peaked with ADRS load still increasing. This corresponds with the 0.20 kW reduction in savings between the 3rd and 4th hour. By the 5th hour, ADRS load flattened while control load declined, causing a 0.22 kW reduction in savings between the 4th and 5th hour. ADRS and control loads during this last hour were virtually the same, producing the modest 0.12 kW, or 4% savings.

Figure 7: 2005 PG&E non-event peak period hourly load reductions

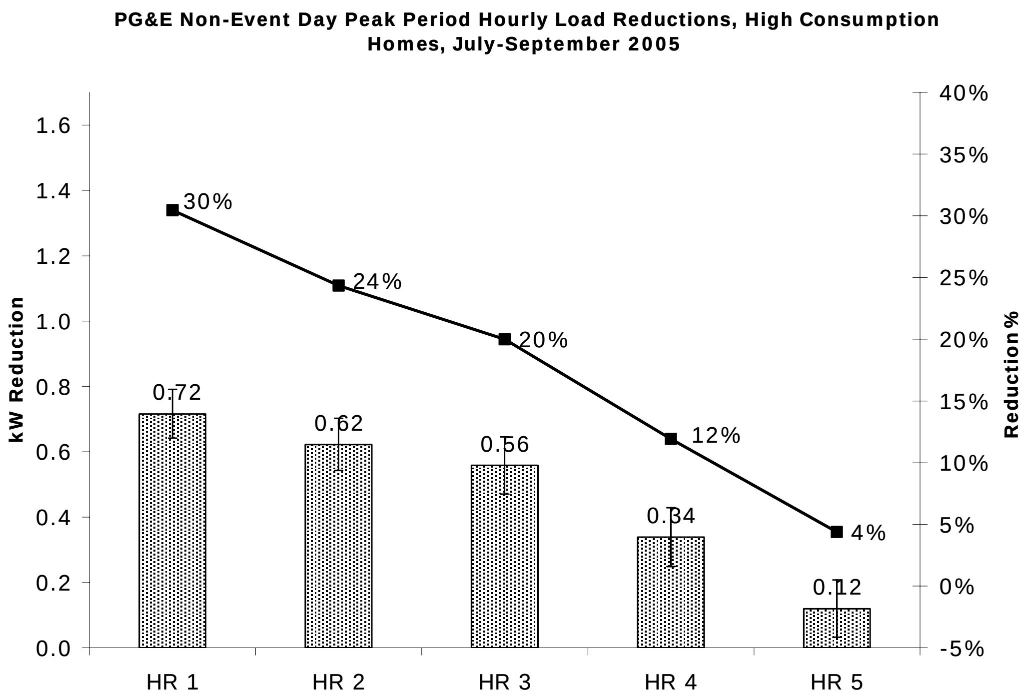


Figure 8 and Figure 9 plot ADRS Super Peak savings on event days by temperature bin, in kW and percent basis, respectively. ADRS homes are assigned into temperature bins based on the maximum temperature experienced each day, averaged across Super Peak days. Absolute savings averaged about 0.65 kW on event days when the temperatures were in the 90°F to 100°F range. Above 100°F, the savings nearly doubled to 1.07 kW. This trend indicates a positive correlation between temperature and kW savings.

On a percentage basis, however, Super Peak savings were consistent across temperature bins on event days. Percent savings ranged narrowly between 23% in the 96°F-100°F temperature bin to 29% for the 91°F-95°F, and 101°F-105°F temperature bins.

Figure 8: 2005 PG&E high consumption Super Peak period reductions by temperature bin: in kW

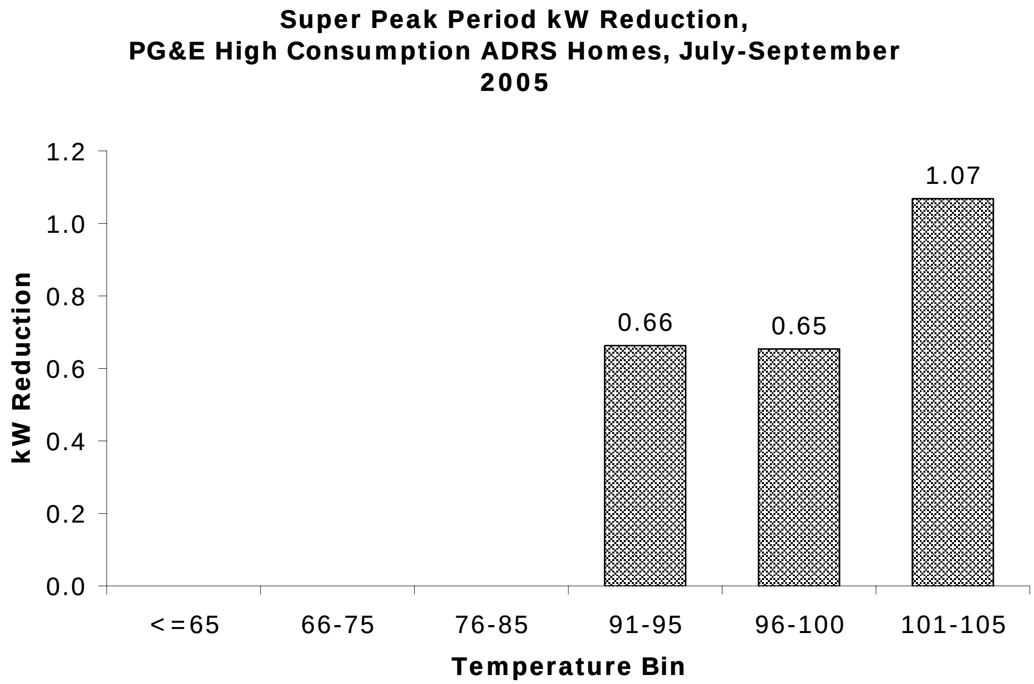
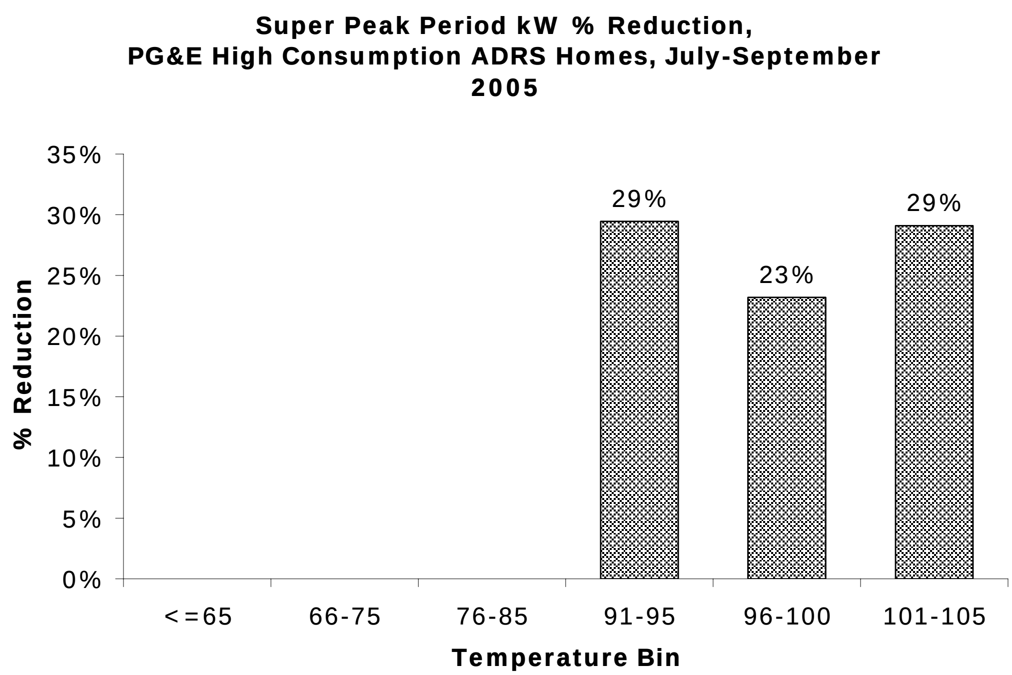


Figure 9: PG&E high consumption Super Peak period reductions by temperature bin: in percent



Peak period ADRS reductions by temperature bin on non-event days are shown in Figure 10 and Figure 11. ADRS homes reduced load relative to control only when the temperatures rose above 76^{o} F, which corresponds reasonably to the temperature that air conditioners would begin to have significant load in the average home. Above 76^{o}F, load savings increased with each hotter temperature bin, until temperatures exceeded 100^{o} F. On a kW load basis, ADRS load savings increased from near zero in the 76^{o}F temperature bin to a maximum savings of 0.86 kW in the 96^{o}F -100^{o}F temperature bin. Load reductions declined to 0.71 for the 101-105^{o}F bin, likely a result of increased ADRS cooling consumption to maintain comfort at these extreme temperatures.

On a percent basis, high consumption ADRS reductions were stable and consistent for warmest temperatures in the 91^{o}F-105^{o}F range. Load reductions in this range were stable at 25% compared to control homes in the 91^{o}F -100^{o}F bins, and declined modestly to 19% in the 101^{o}F-105^{o}F bin.

Figure 10: 2005 PG&E high consumption non-event day peak period reductions by temperature bin: in kW

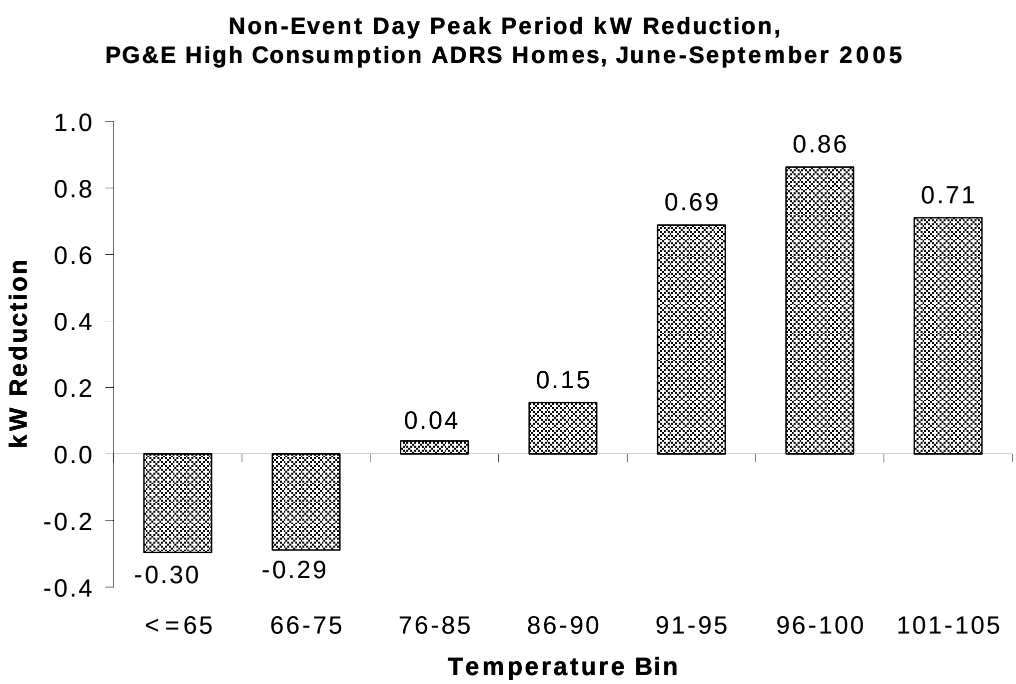
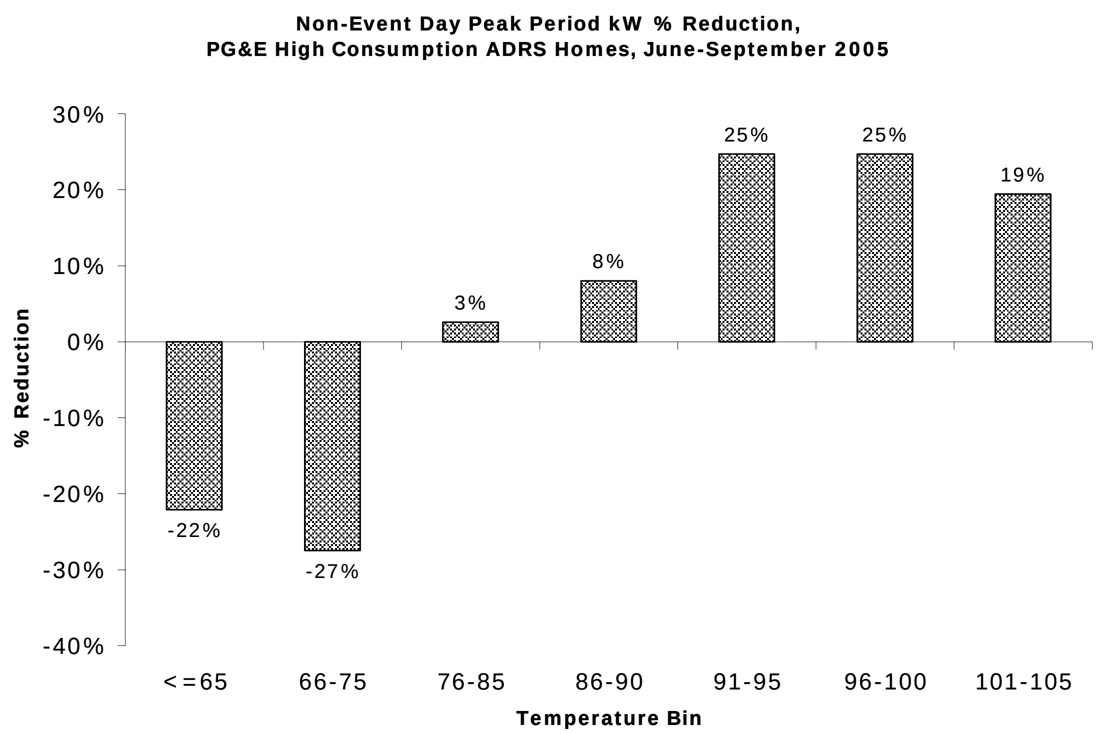


Figure 11:PG&E high consumption non-event peak period reductions by temperature bin: in percent



1.3 SCE high consumption summer 2005 load impact results

Average daily load curves for high consumption ADRS and control homes in SCE territory are plotted in Figure 12 and Figure 13 for event and non-event weekdays, respectively. On event days, ADRS homes reduced load by an average of 1.85 kW or 9.2 kWh during the Super Peak period. Ninety percent confidence intervals for the Super Peak period averaged ±0.25 kW for control homes and ±0.16 kW for ADRS homes[5]. On a percentage basis, ADRS homes reduced load relative to control homes by 49% on event days.

On non-event days, SCE's high consumption ADRS customers reduced peak period load by 0.89 kW or 4.5 kWh on average. Ninety percent confidence intervals for the non-event peak period averaged ±0.08 kW for control homes and ±0.06 kW for ADRS homes[6]. As a percentage, ADRS homes reduced load by 30% of control load on non-event days.

[5]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Super Peak period 90% confidence intervals for control homes varied from ±0.24 kW to ±0.26 kW; 90% confidence intervals for high consumption ADRS homes varied from ±0.11 kW to ±0.20 kW.

[6]Non-event peak period 90% confidence intervals for control varied from ±0.074 kW to ±0.083 kW; 90% confidence intervals for ADRS homes varied from ±0.04 kW to ±0.07 kW.

Both event and non-event days show a recovery period where ADRS homes consumed substantially more than control homes. Otherwise, ADRS and load curves on event days matched for much of the off-peak period. On non-event days, however, ADRS load was significantly higher than control load during most of the off-peak period.

Figure 12: 2005 SCE high consumption event day load curves

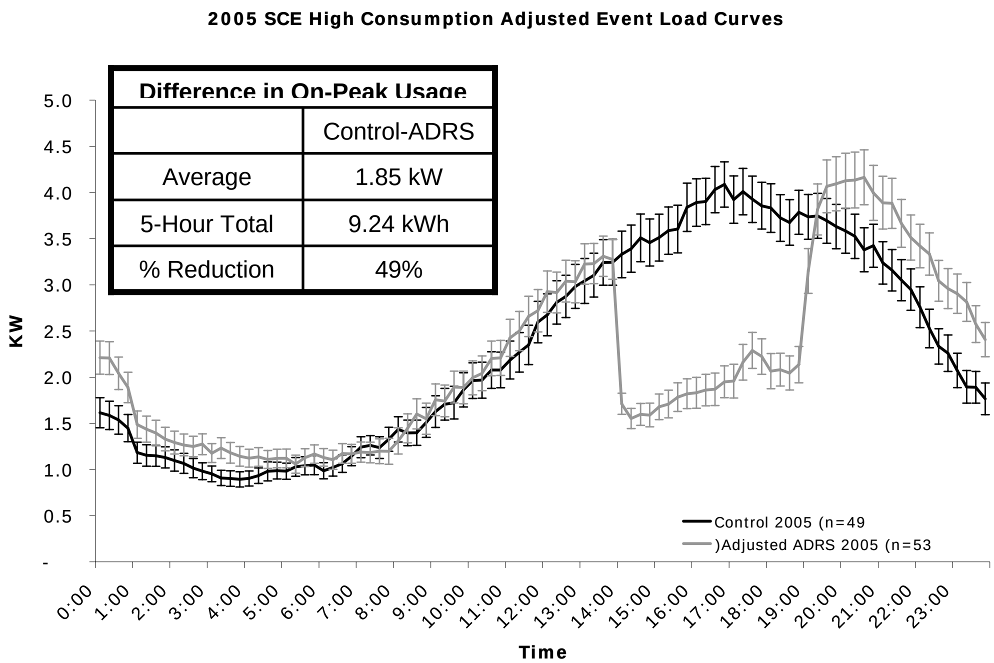


Figure 13: 2005 SCE high consumption non-event weekday load curves

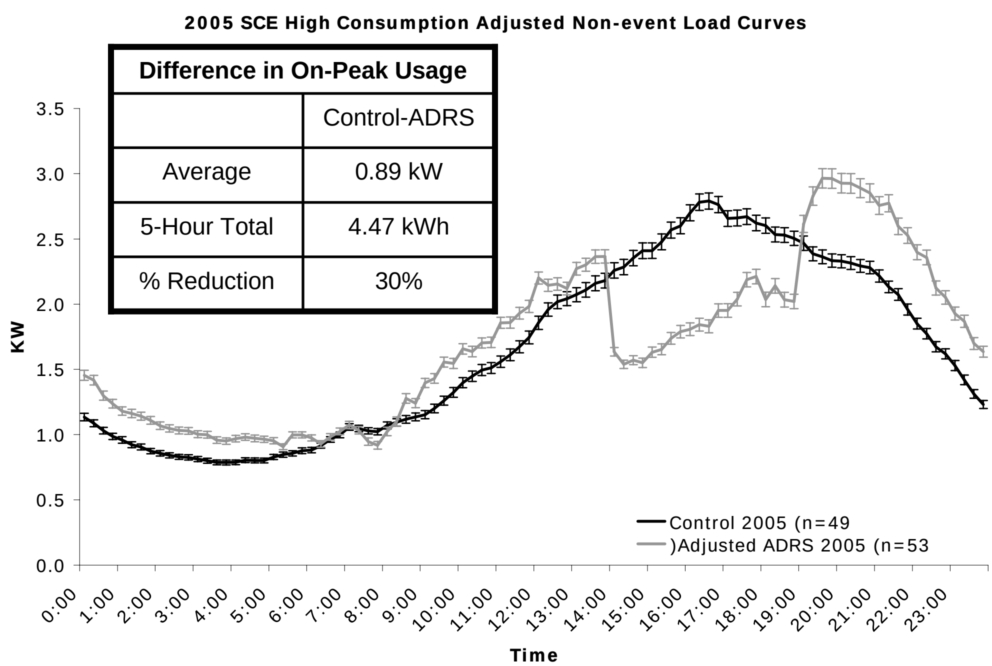
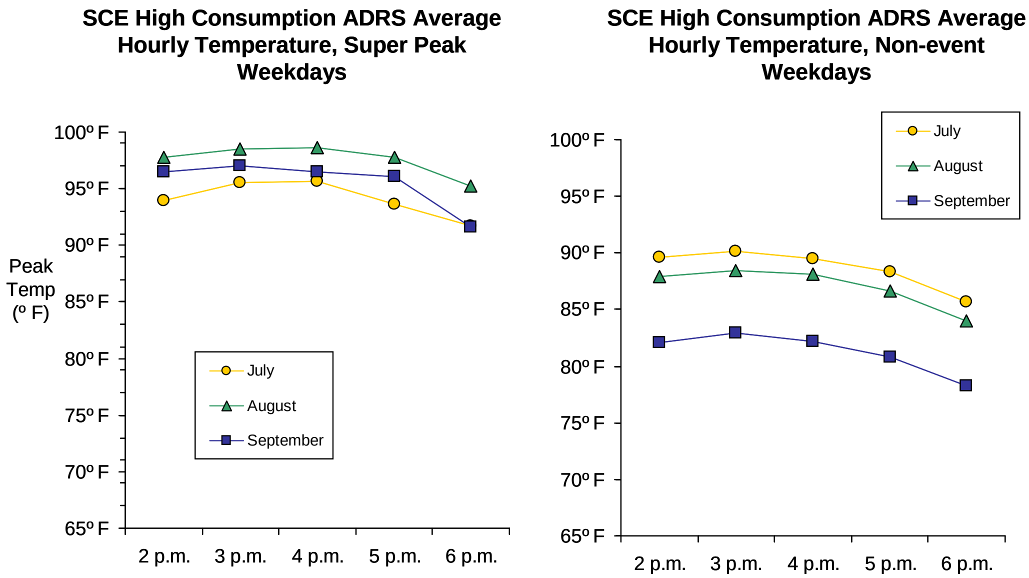


Figure 14 illustrates the average temperature at ADRS homes for each hour of the peak period on event and non-event days. August was the warmest month, with temperatures ranging between 95°F and 98°F, peaking at 4 p.m. September was the next warmest month, with temperatures peaking at 97°F at 3 p.m. and dropping steeply in the final Super Peak hours, which is indicative of autumn sunset during the last Super Peak hour.

Figure 14: 2005 SCE high consumption ADRS peak period hourly temperatures



Non-event weekday peak periods exhibited much more variability in hourly temperatures. July and August were the two warmest months, with peak hourly temperatures, topping out at 90°F and 88° F, respectively, before declining to 86°F and 84°F, respectively, at the end of the peak period. Peak period temperatures for all months peaked at 3 p.m. in SCE territory.

Hourly load reductions for Super Peak hours are shown in Figure 15**.** On a kW basis, high consumption ADRS savings compared to control rise from 1.81 kW during the 2 p.m. hour to a considerable peak savings of 2.1 kW during the 4 p.m. hour. Savings fell off modestly to 1.67 kW during the last Super Peak hour beginning at 6p.m. During the first three Super Peak hours, control load grew more rapidly than ADRS load (refer to Figure 12), resulting in the gradual increase in kW savings through the 4 p.m. hour. Around 5 p.m., control load peaked while ADRS load continued to climb, resulting in falling ADRS savings during the last two Super Peak hours.

On a percent basis, high consumption ADRS customer reductions were substantial and constant during the first three Super Peak hours with average load reduction of 53% compared to control homes load. During the last two Super Peak hours, percent load reductions declined modestly to 45%.

Figure 15: 2005 SCE high consumption Super Peak period hourly load reductions

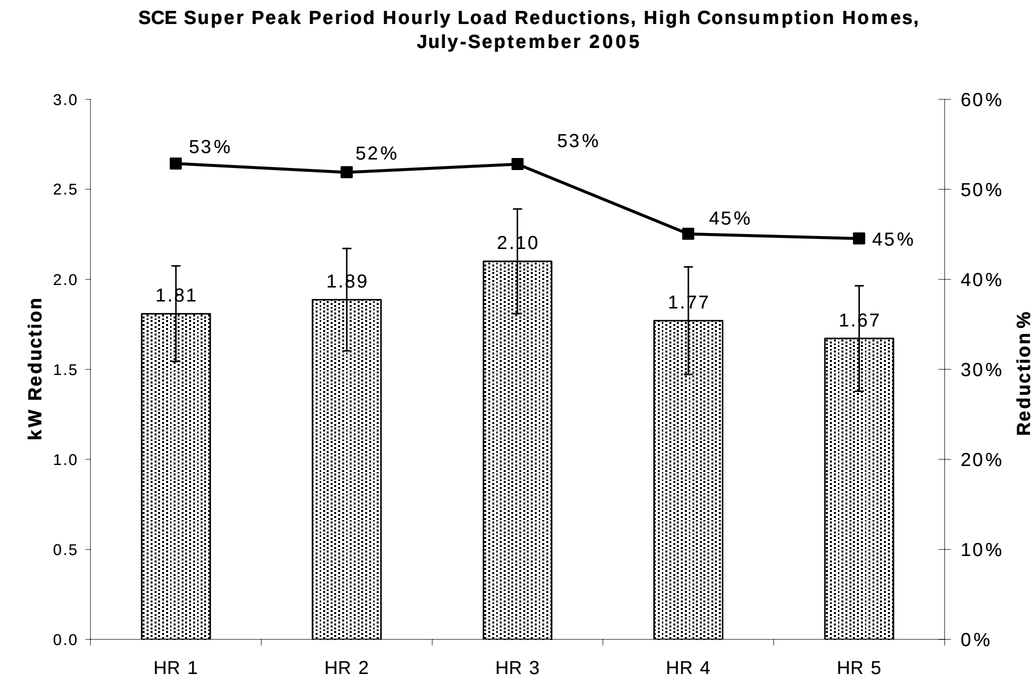


Figure 16: 2005 SCE high consumption non-event peak period hourly load reductions

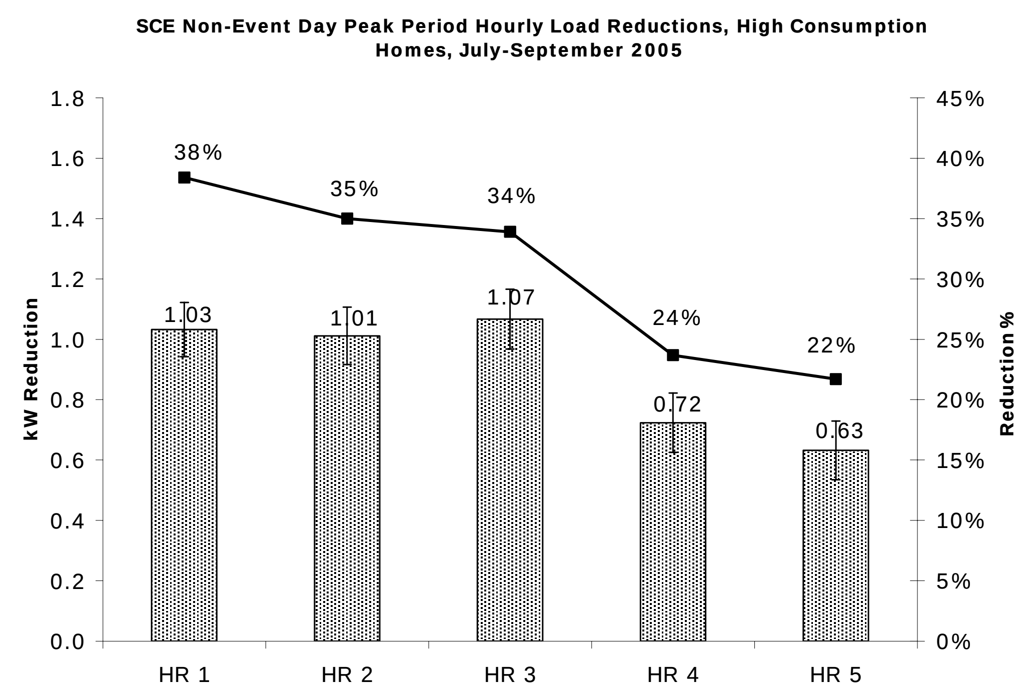


Figure 16 shows the on-peak hourly load savings of ADRS from control load for non-event weekdays. On a kW basis, savings display a mild positive trend during the first three hours of the peak period, starting at 1.03 kW savings and peaking at 1.07 kW savings during the third hour. Savings dropped markedly during the 4th and 5th hours to 0.72 and 0.63 kW, respectively. This decline in savings during the last two peak period hours corresponds to control load peaking while ADRS load was still increasing (refer to Figure 13). ADRS homes continued warming throughout the Super Peak period to the higher temperature set points induced by Super Peak signal initially sent at 2 p.m. Air conditioners in some homes cycled on periodically to maintain temperatures inside. On a percentage basis, hourly savings show a negative trend over the peak period. Maximum percent savings occurred during the 2 p.m. hour at 38%, and then declined to 22% by the last peak hour.

Super Peak period ADRS savings on event days declined with increasing temperature bins, which is illustrated in Figure 17 and Figure 18. The figures display ADRS load savings on event days according to temperature bin on a kW and percent basis, respectively. Savings ranged from 2.68 kW in the 76°F-85°F temperature bin to 1.69 kW in the 100°F-105°F temperature bin. On a percentage basis, savings declined from a high of 75% in the 76°F-85°F temperature bin to a still substantial 41% reduction in the 100°F-105°F bin.

Figure 17: SCE high consumption Super Peak period reductions by temperature bin: in kW

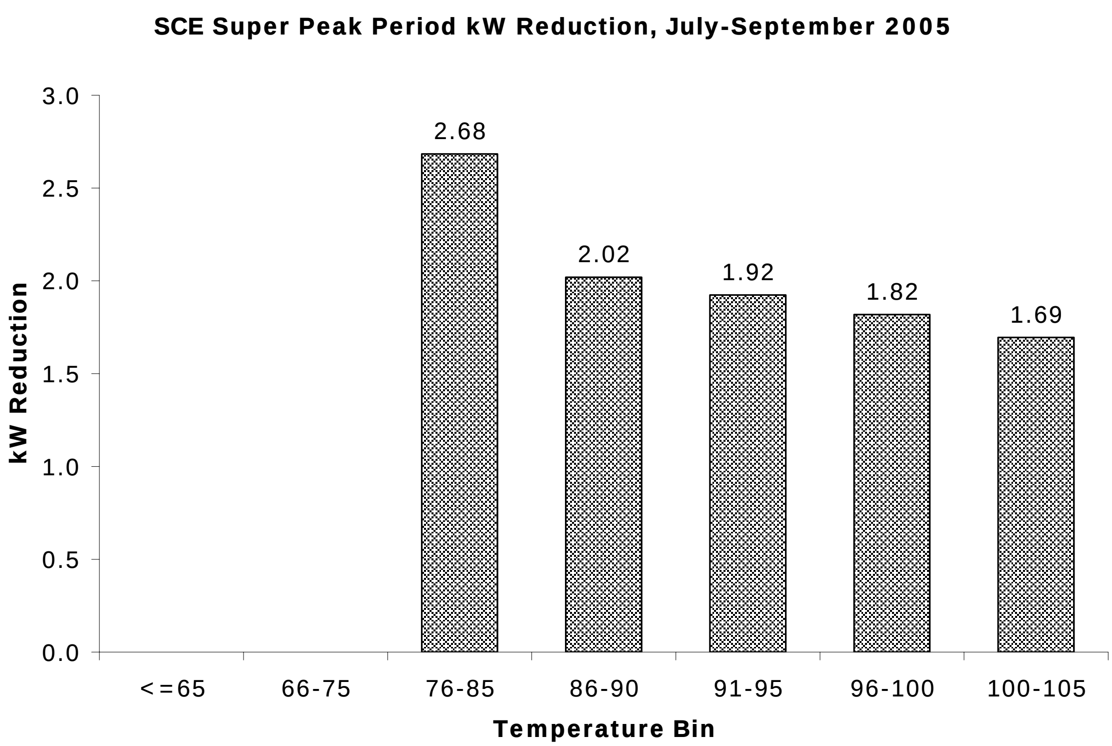
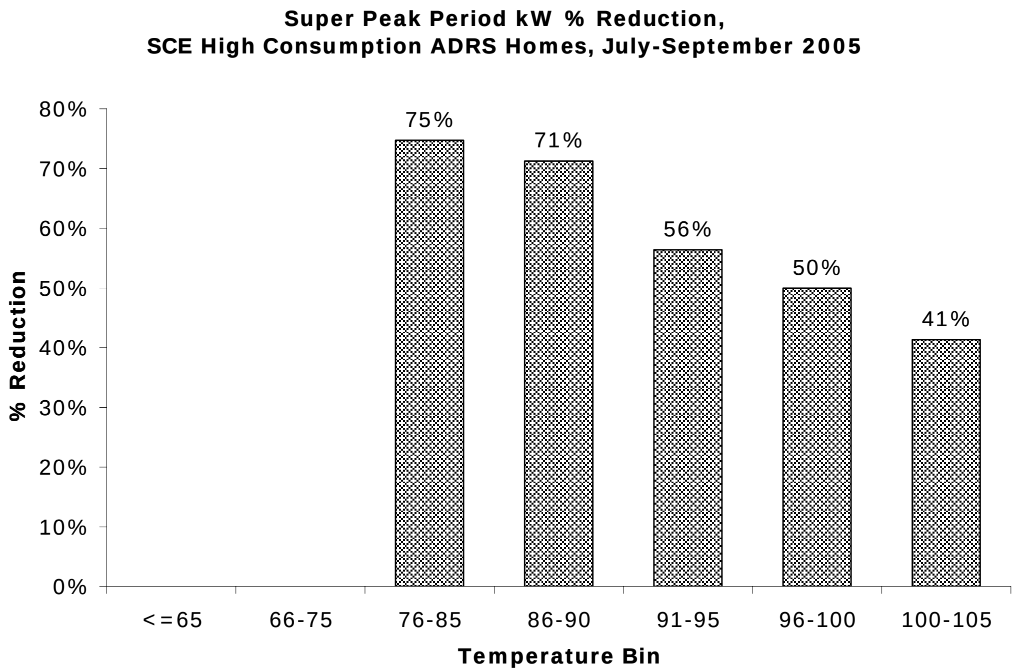


Figure 18: SCE high consumption Super Peak period reductions by temperature bin: in percent



Further investigation yields two insights that possibly explain this counterintuitive trend. First, the average peak temperature over all event days in SCE territory was 97^{o}F. Thus the temperature bins below 91^{o}F consisted of only a few customer-days. For example, the 76^{o}F-85^{o}F bin contained only three ADRS customer-days and thirteen control customer-days. The 86^{o}F-90^{o}F bin contained only six ADRS customer days and eleven control customer days. Hence, the large reductions in the 76^{o}F -85^{o}F and 86^{o}F-90^{o} F temperature bins should be interpreted with caution due to the small sample sizes in these bins.

Second, an examination of ADRS and control loads by temperature bin reveals that control loads increased only slightly in hotter temperature bins while ADRS loads show a larger positive response to increasing temperature. For example, in the 76^{o}F-85^{o}F temperature bin, control load during the peak period averaged 3.6 kW while ADRS averaged 0.94 kW. In the 101-105^{o} F bin, peak period control load averages at 4.1 kW while ADRS load averages at 2.4 kW. This suggests that control customers were already running their air-conditioners at near full loads at lower temperatures while ADRS customers used the technology to minimize consumption while maintaining comfort through the range of summer temperatures. In other words, ADRS customers could not save more on the hottest days than the amount they were already saving during the slightly cooler days. Because of these different sensitivities to temperature and differences in ability to control comfort settings between the ADRS and control groups, load savings dropped on both a percent and kW basis with increasing temperatures.

Non-event weekday load reductions by temperature bin are displayed in Figure 19 and Figure 20. On a kW basis, savings generally show a positive trend across increasing temperature bins with a minimum reduction of 0.45 kW in the 76^{o}F-85^{o}F bin, increasing to 1.15 kW reduction in temperatures exceeding 100°F. On a percent basis, savings were nearly flat across 76°F-105°F range, maintaining a robust 24%-28% savings from control load. This consistency in percent savings indicates that ADRS customers were able to use technology to maintain load reductions across a wide range of temperatures.

Figure 19: SCE high consumption non-event peak period reductions by temperature bin: in kW

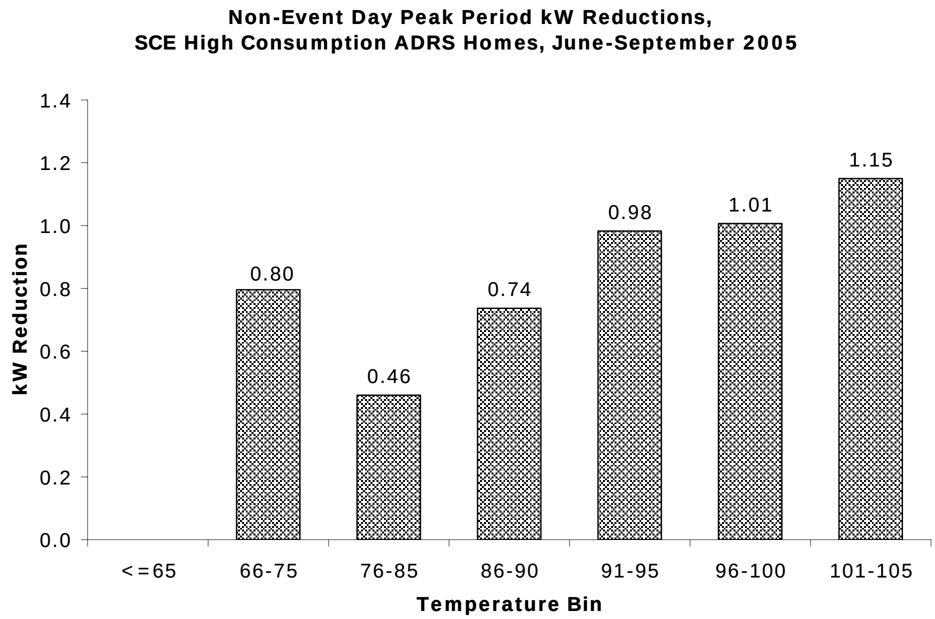
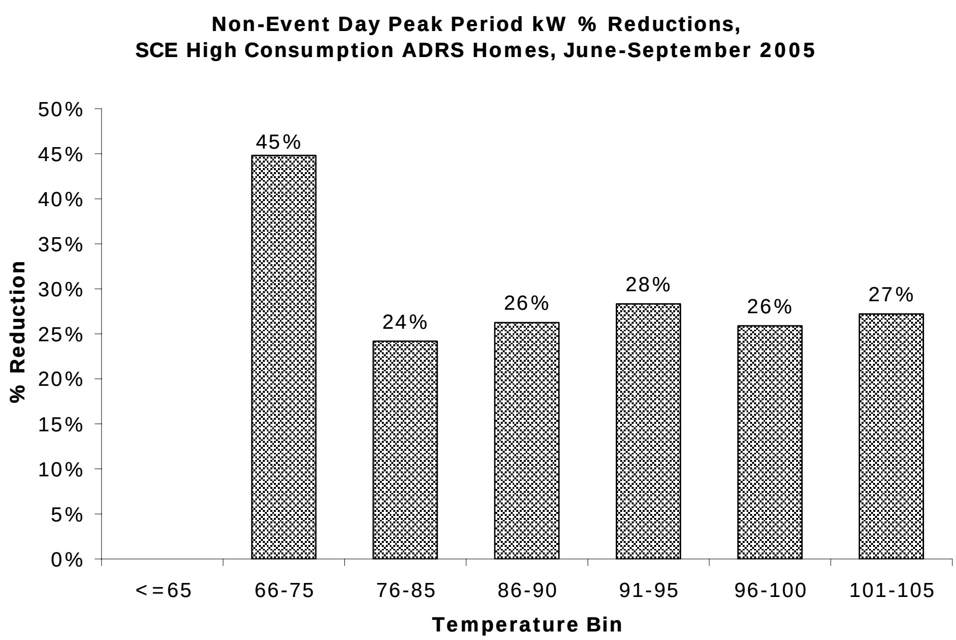


Figure 20: 2005 SCE high consumption non-event peak period reductions by temperature bin: in percent

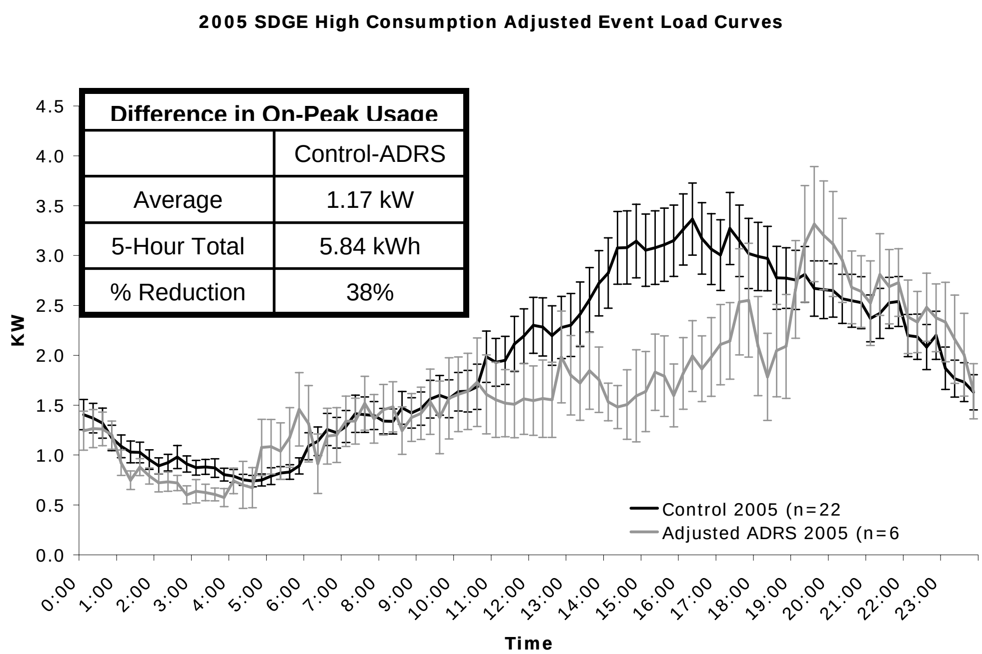


The percentage reduction in the 66°F-75°F temperature bin seems anomalous at first glance. However, the impressive performance is likely due to relatively large kW savings compared to a relatively small control load in that temperature bin. ADRS load savings are 0.80 kW in this temperature bin, which is consistent with kW savings in the warmer temperature bins from 86°F to 95°F. Control loads are very similar during the peak period between each bin, while ADRS loads increase more substantially in response to increased temperature.

1.4 SDG&E high consumption summer 2005 load impact results

Load curves for SDG&E's high consumption homes are displayed in Figure 21 and Figure 22 for event days and non-event days, respectively. Note that these results are not statistically significant because there are only six high consumption ADRS homes within San Diego territory. Notwithstanding small sample size, ADRS homes in San Diego show substantial peak period reductions, with peak period savings of 1.17 kW (38%) on event-days and 0.69 kW (27%) on non-event days. Ninety percent confidence intervals for the Super Peak period averaged ±0.35 kW for control homes and ±0.40 kW for ADRS homes[7]. On non-event weekdays, the peak period confidence intervals averaged ±0.11 kW for control homes and ±0.12 kW for ADRS homes[8].

Figure 21: 2005 SDG&E high consumption event day load curves



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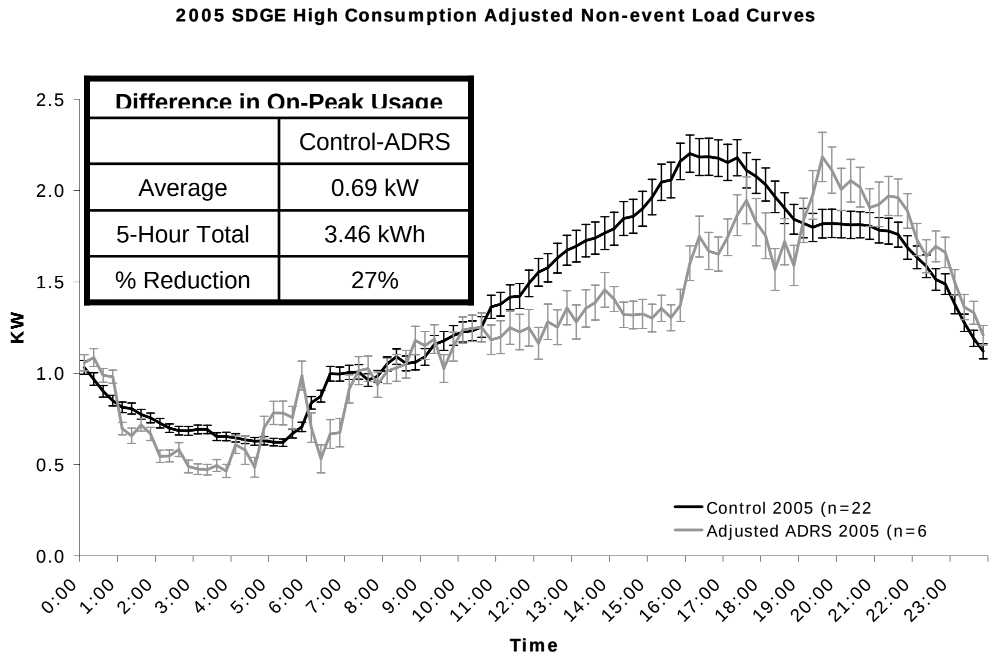
[7]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, Data Collection and Load Impact Analysis Methodology. Ninety percent confidence intervals for control homes actually varied from ±0.30 kW to ±0.37 kW across the Super Peak period; ADRS confidence intervals varied from ±0.19 kW to ±0.57 kW.

[8] Non-event peak period 90% confidence intervals for control homes varied from ±0.10 kW to ±0.12 kW; 90% confidence intervals for ADRS homes varied from ±0.09 kW to ±0.17 kW across the peak period..

Figure 22: 2005 SDG&E high consumption non-event load curves



Super Peak and peak period temperatures for SDG&E's ADRS homes were averaged for every hour in Figure 23. Temperatures in September and August event days were warmer than July. On event days, only the August temperatures exceeded 90°F, reaching a maximum average of 91°F at 2 p.m. September's event day temperatures were warm for the utility service territory, falling within the 80°F-90°F range. July's temperatures were the coolest of all event days, peaking at a relatively mild 83°F and falling into the upper 70's during the latter half of the Super Peak period. With the exception of September event days, hourly temperatures across all months peaked at 2 p.m. and cooled steadily (1.4°F per hour, on average) through the rest of the Super Peak period.

On non-event days, hourly peak period temperatures were mild across all months compared to event days. Again, August 2005 was the hottest summer month in SDG&E territory on average for non-event days, peaking at 78°F at 2 p.m. Average on-peak temperatures were within the 70°F- 80°F range for July through September. Non-event hourly peak period temperatures show the same trend as on event days— temperatures peaked at 2 p.m. and cooled steadily through the rest of the peak period.

Figure 23: 2005 SDG&E average hourly peak period temperatures

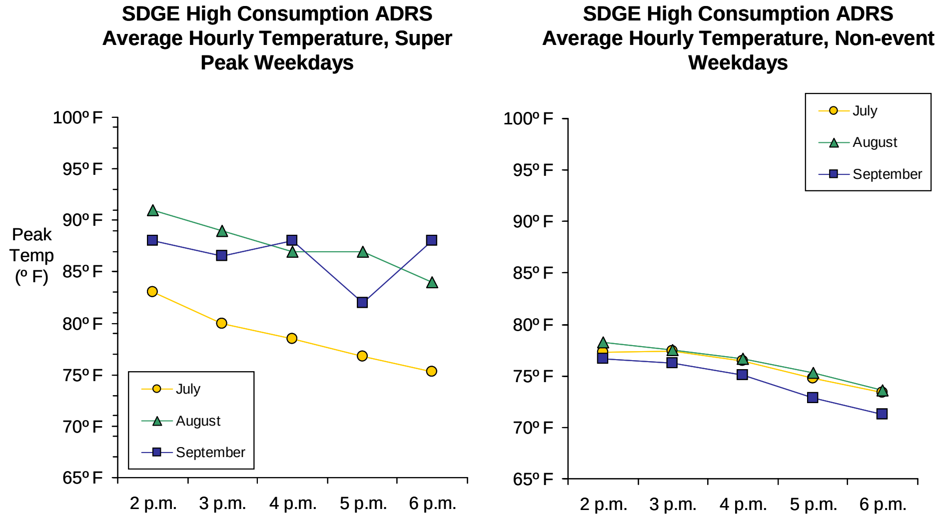
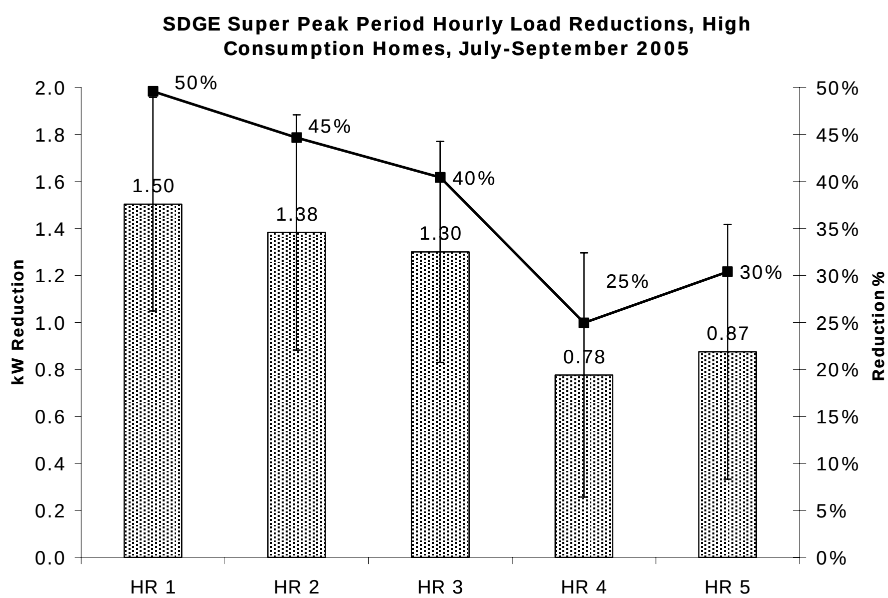


Figure 24 shows high consumption ADRS customer savings from control for every hour of the Super Peak period. Reductions at 2 p.m. were considerable at 1.5 kW, or 50% of SDG&E high consumption control load. Savings then dropped steadily for the rest of the Super Peak period, settling at a still substantial 0.87 kW, or 30% savings during the last Super Peak hour. The smallest hourly load reduction occurred during the fourth hour at 5 p.m., corresponding with an inexplicable spike in ADRS load during this time (Figure 21). Recall in the above discussion that temperatures reach their maximum at the beginning of the Super Peak period in SDG&E territory and cool throughout the Super Peak period. This curious behavior in consumption at 5 p.m. thus could be an artifact of the small sample size.

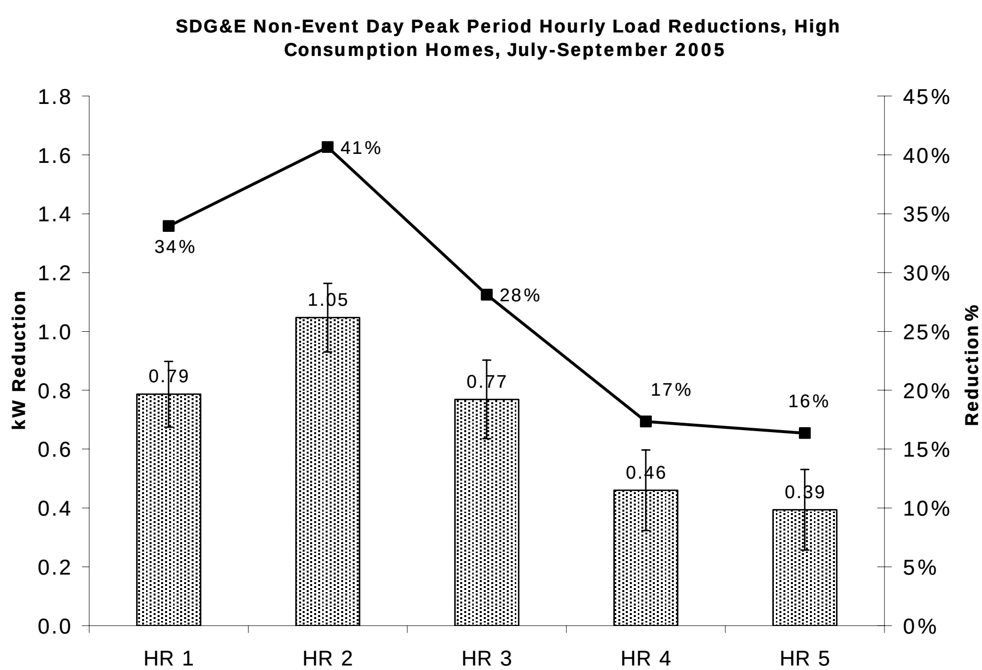
Figure 24: 2005 SDG&E high consumption Super Peak hourly reductions



The steady decline in savings over the Super Peak period generally corresponds with ADRS load increasing throughout the period while control load gradually decreased. Control load on event days appears to match well with hourly peak period temperatures shown in Figure 23. Control load gradually decreased along with the temperature. In contrast, ADRS load increased throughout the Super Peak period though temperatures were falling. In fact, it appears that ADRS homes were conserving *before* the peak period, as suggested by the divergence of ADRS and control load curves in the late morning in Figure 21. Cooling demand caught up with ADRS homes by afternoon during the Super Peak period, resulting in the diminishing savings during the peak period. Cooling demand (in spite of cooling temperatures in the range of 65°F to 70°F) was further implicated by the significant rise in ADRS load during the recovery period from 7 p.m. to 9 p.m.

Figure 25 plots the peak period hourly reductions for SDG&E high consumption ADRS homes on non-event weekdays. ADRS load reduction compared to control homes was greatest during the second peak period hour at 1.05 kW, or 41% then declined steadily throughout the rest of the peak period, settling to 0.39 kW or 16% savings during the final peak period hour. First hour reductions were 0.79 kW or 34% from control home loads. Reviewing these results against the non-event load curves in Figure 22, the control homes' average load rose substantially during the first two peak period hours from 2 p.m. to 4 p.m. while the ADRS customer load remained flat. This caused the increase in savings at the beginning of the peak period from 2 p.m. to 3 p.m. During the third hour, ADRS load increased sharply as control homes' average load peaked. The ADRS and control curves gradually converged during the last three peak period hours as outside temperatures fell and ADRS homes warmed up to the higher thermostat settings, resulting in the successively reduced, but substantial, savings.

Figure 25: 2005 SDG&E high consumption non-event peak period hourly reductions



High consumption ADRS load reductions temperature bin charts in Figure 26 and Figure 27 illustrate the positive effect that temperature has on the ADRS savings during the Super Peak period. Overall, high consumption ADRS homes in SDG&E territory achieved substantial savings on event days when temperatures exceeded 85^{o}F. ADRS homes experiencing maximum temperatures above 85^{o}F on event days on average gave an impressive performance, saving 1.44 kW from control in the 86^{o}F-90^{o} F bin and 1.82 kW in the 91^{o}F-95^{o}F temperature range. On a percentage basis, ADRS load savings in the hotter temperature bins were consistently around 46-48% of control homes.

The negative savings calculated for the 66^{o}F-76^{o}F bin on event days were a result of low peak period air conditioning demand. ADRS homes consumed more load than control homes at cooler temperatures in SDG&E territory. Total control and ADRS customer loads in this bin were both modest, averaging at 1 kW and 1.5 kW, respectively, during the peak period.

Figure 26: 2005 SDG&E high consumption Super Peak reductions by temperature bins: in kW

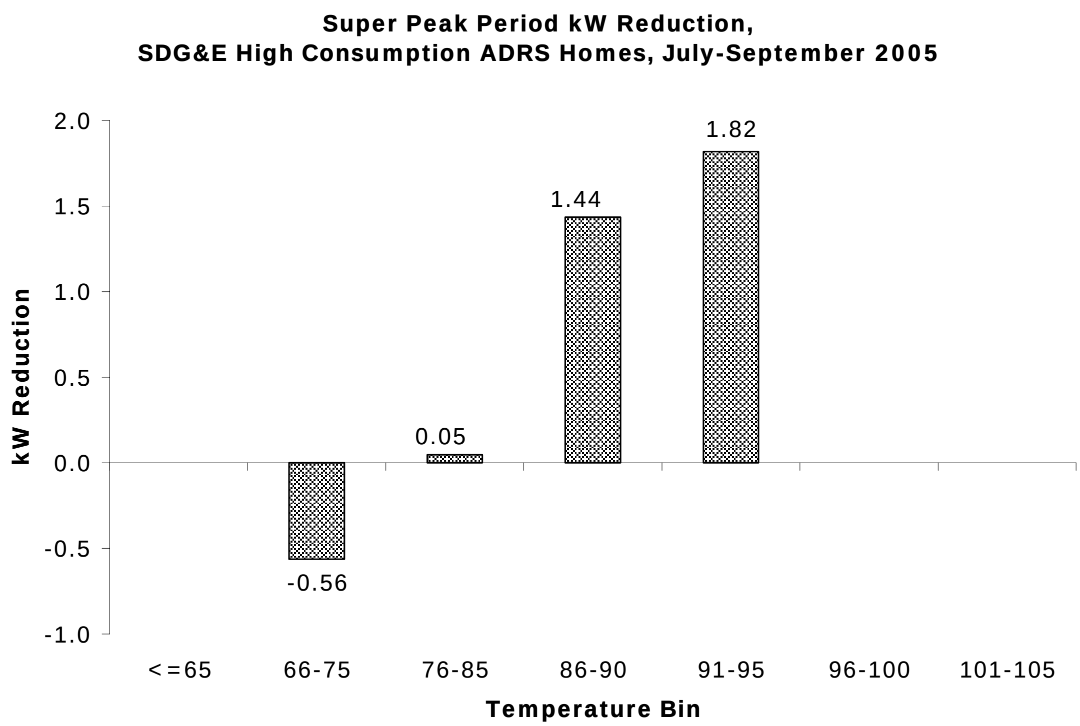


Figure 27: 2005 SDG&E high consumption Super Peak period reductions by temperature bin: in percent

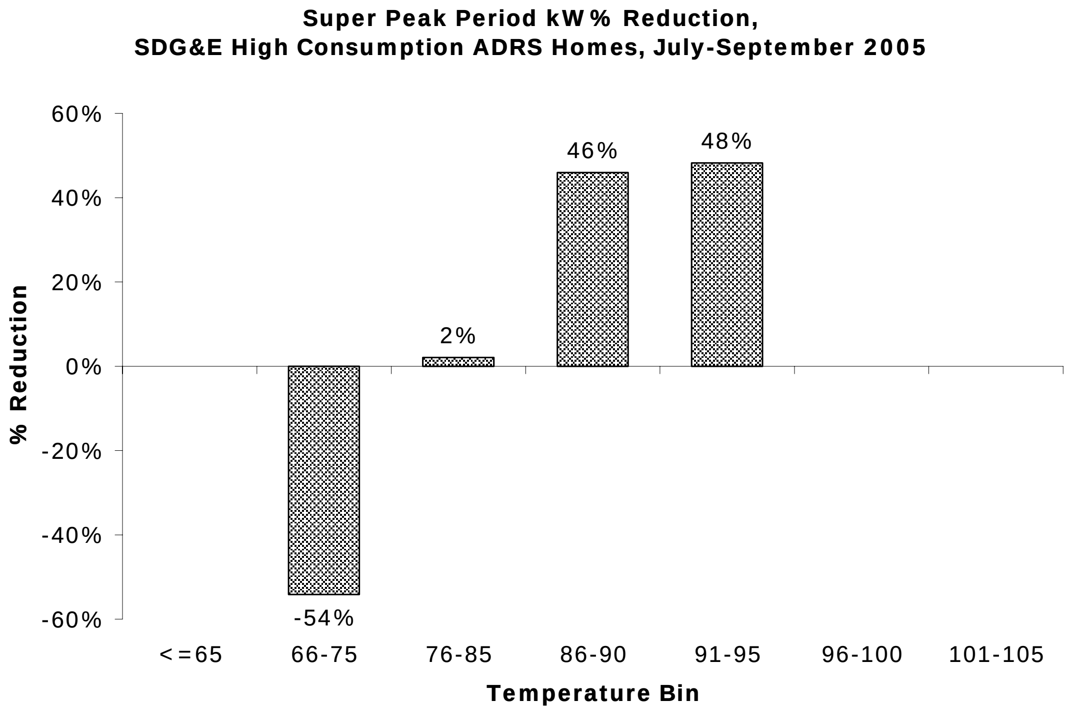


Figure 28 and Figure 29 reports high consumption ADRS peak period load reductions on non-event days by temperature bin in SDG&E territory. Since non-event days were mild on average, the volume of data is sparse in the temperature bins above 85°F. Notwithstanding, ADRS peak period savings show a positive response to increased temperature. ADRS customers generated substantial savings in temperature bins above 76°F, reducing load by an average of 0.66 kW during the peak period for customers experiencing maximum temperatures between 76°F and 85°F on non-event days. Reductions consistently exceeded 1.5 kW in the temperature bins above 85°F in SDG&E territory.

On a percentage basis, ADRS performance in the temperatures above 76°F varied more widely, but was still sizable. In the mild 76°F-85°F range, ADRS homes reduced load by 25% of control load on non-event days. Percent reductions in the hotter temperature bins were larger: 47% for the 86°F-90°F bin and 39% for the 91°F-95°F.

The negative savings calculated for the 66°F-76°F bin on non-event days are a result of low peak period air conditioning demand. ADRS homes consumed more load than control homes at these cooler temperatures in SDG&E territory. Total control and ADRS customer loads in this bin were both modest, averaging at 1.4 kW and 1.6 kW, respectively, during the peak period.

Figure 28: SDG&E high consumption non-event peak period reductions by temperature bin: in kW

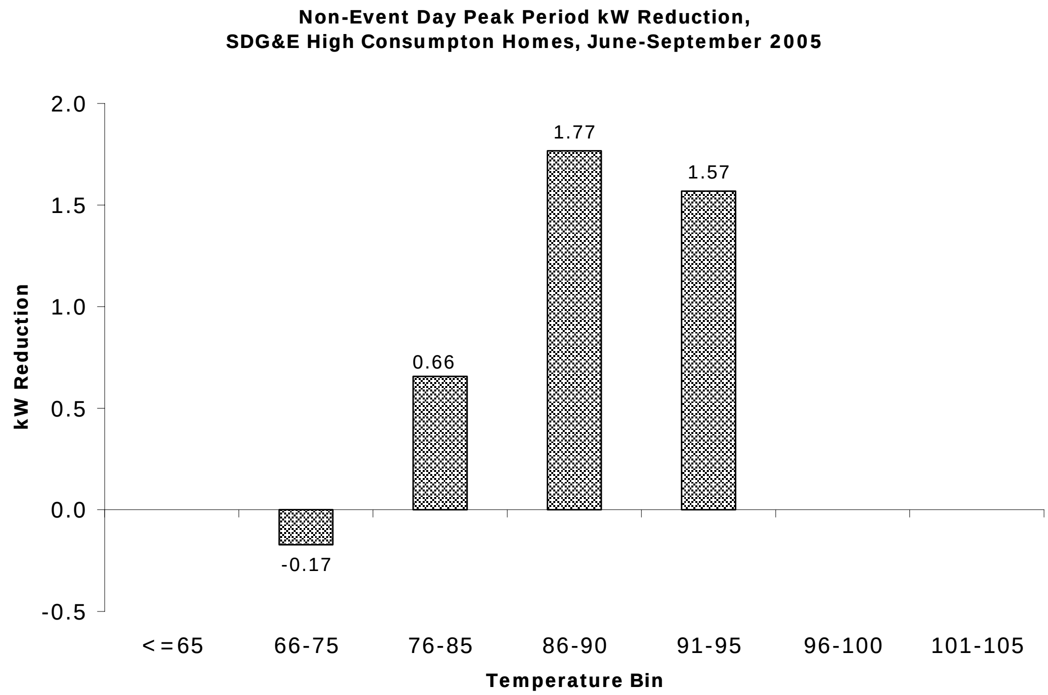
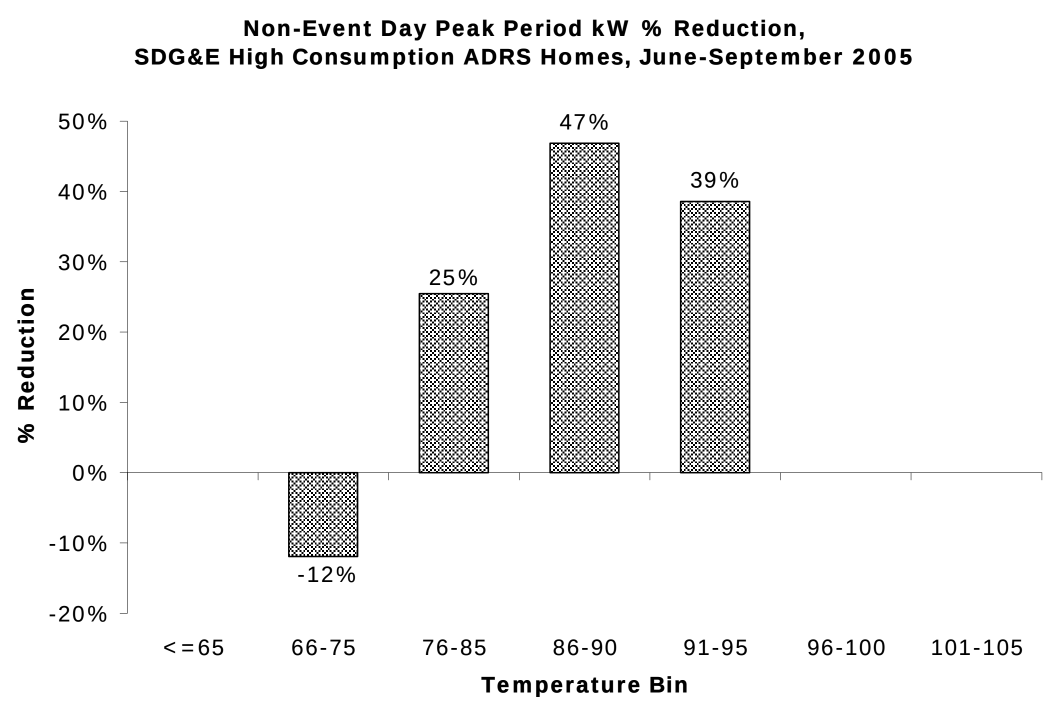


Figure 29: SDG&E high consumption non-event peak period reductions by temperature bin: in percent



1.5 2005 load impact results, low consumption homes

Load impact results for low consumption homes during summer 2005 are reported here for completeness, but it should be noted that the numbers are not statistically meaningful, due to small sample size of both the control and ADRS homes. Results corresponding to low consumption homes 2005 load impact results reported in this section are provided for reference in Appendix D to this report, Low Consumption ADRS 2005 and 2004 Load Impact Results Charts.

Table 1: Population of Low Consumption ADRS and control homes by utility

	PG&E		SCE		SDG&E	
	ADRS	control	ADRS	control	ADRS	control
Low Consumption	24	2	4	14	15	3

Statistical significance of load reductions of low consumption ADRS homes compared to control homes were limited by the group with the least number of homes. Table 1 shows the number of homes in the low consumption data set for each utility and group. For PG&E, the maximum resolution was constrained by only two homes in the control sample. For SCE, the constraint was the only four homes in the ADRS sample. For SDG&E, the constraint was the three homes in the control sample. Statewide results for low consumption homes were not statistically significant at the 90% confidence level given that total population of control homes statewide was only nineteen. A sample size of 36 homes is needed in each of the ADRS and control home samples for results to be significant with 90% confidence level and accuracy of $\pm$ 0.55 kW[9].

Another effect of small sample size is that confidence intervals at the 90% level selected by RMI around average control and ADRS loads are so wide that consumption differences between the two populations were essentially zero in most cases. This is true for the 2005 load impact results with the exception of PG&E peak period reductions. The loads driving the "large" peak period reduction of PG&E low consumption ADRS homes were only two control homes, as noted above.

Statewide, low consumption ADRS homes from July through September reduced load relative to homes by 0.25 kW or 1.25 kWh across the Super Peak period on event days. On a percentage basis, ADRS homes reduced load by 14% relative to low consumption control homes. On non-event days, low consumption ADRS homes consumed *more* load than control homes, by 0.25 kW or 1.23 kWh on average across the peak period. This translates to -20% reduction relative to control homes.

On a utility specific basis, PG&E low consumption ADRS homes showed peak period consumption excess of control homes on both event and non-event days. ADRS homes consumed on average 0.21 kW (12%) *more* than control homes during the Super Peak period and 0.64 kW (52%) more load during peak period.

[9] For a more detailed discussion of minimum sample sizes in designing an experiment, refer to Appendix A of this report, Data Collection and Load Impact Analysis Methodology.

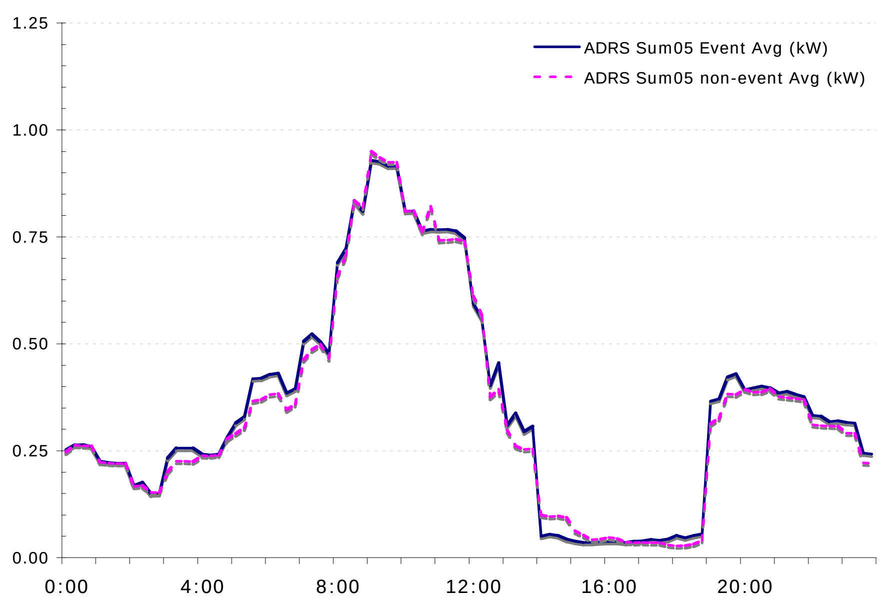
Low consumption ADRS homes in SCE territory reduced load relative control homes on both event and non-event days. On event days, the four SCE low consumption ADRS homes reduced Super Peak load by 0.56 kW, or 30% compared to control homes. On non-event days, ADRS homes reduced peak period load by 0.17 kW, or 14%, from control homes in SCE territory.

For SDG&E low consumption homes, SDG&E ADRS homes reduced Super Peak load by 0.16 kW (13%) during summer 2005 and peak period load by -0.13 kW (-14%), meaning that low consumption homes consumed *more* load than control homes on non-event days. The ADRS and control loads were statistically the same over most hours on event days, however, signifying zero net Super Peak load reductions.

1.6 Contribution of pool pumps to 2005 high consumption ADRS total load impact

Load data recorded by utility interval meters in ADRS and control homes measure whole-house data and cannot segregate consumption by end use. However, ADRS homes are equipped with an additional interval meter as part of the technology package from Invensys Climate Controls. Figure 30 plots average daily pool consumption during summer 2005 on event and non-event days. Reported load is average of all pools and reflects load diversity in scheduling. Load diversity refers to the percentage of customer loads that are not available or not operating at any point in time.

Figure 30: Average high consumption ADRS pool pump load, July-September 2005



The average daily load curve shows that high consumption ADRS customers with swimming pools consistently scheduled pool pump operation outside of the hours between 2 p.m. and 7 p.m. to reduce Super Peak and peak period consumption every day.

Load reductions compared to control customers resulting from shifting pool pump usage cannot be measured directly, as utility meters for control customers measure whole house consumption only. However, ADRS pools load reduction can be estimated based on consumption data of residential customers with identical technology installed in a similar pilot program in operated by Nevada Power Corporation. Since there is no financial incentive for pool owners to shift load away from peak in Nevada Power's residential load management program, operation of pools is presumed to provide an appropriate load shape for comparison purposes[10]. Only the estimated reductions are reported in Table 2 because Nevada Power customer load data are confidential.

Results in Table 2 reveal that residents shifting pool pump operation contribute 32% of the 9.2 kWh total Super Peak reduction for an average home with a pool. Since approximately one out of every three ADRS participant owns a pool, this load reduction contributed about 10% of total Super Peak period reduction on event days. On non-event days, residents shifting pool pump operation contributed over 50% of the 6.1 kWh total peak period reduction for an average home with a pool. This load reduction contributed about 27% of total peak period reduction on non-event days.

Table 2. Average Super Peak and peak load reduction, 2005

	Event day kWh				Non-event day kWh			
ADRS Segment	Pool*	Other**	Total	% Pool Contribution	Pool*	Other**	Total	% Pool Contribution
No Pool (65)	--	6.3	6.3	0%	--	2.9	2.9	0%
With Pool (33)	2.9	6.3	9.2	32%	3.2	2.9	6.1	53%
Wtd. Avg. (98)	1.0	6.3	7.3	13%	1.1	2.9	4.0	27%

*RMI estimate based on ADRS pool pump loads compared against Nevada Power Corporation residential customers using identical technology.
**Reduction of other loads calculated algebraically from total average load reduction and average pool load reduction rather than direct measurement

1.7 Summary of ADRS 2005 load impact results

Customers with ADRS technology and subject to CPP-F rates in climate zone 3 successfully achieved load reductions compared to control customers without ADRS technology on standard tiered rates in 2005. The load reductions are substantial and stable across a range of days and temperatures. Technology appears to be an important driver in reducing load, especially Super Peak load, for high-consumption homes.

Load reductions appeared to be stable for ADRS homes experiencing hottest temperatures relative to other ADRS homes for a particular utility. For PG&E and SCE, load reductions were stable and consistent for homes experiencing maximum temperatures above 91°F on event and non-event days. For SDG&E, load reductions were stable and consistent for homes experiencing maximum temperatures above 86°F on event and non-event days.

[10] The aggregate load profile from Nevada Power customers was scaled down to reflect the smaller operational load of pools participating in ADRS (from 1.8 kW in Nevada to 1.6 kW among ADRS participants)

Load reduction performance for customers with ADRS technology and subject to CPP-F rates varied between utilities across the state. SCE high consumption ADRS customers achieved close to 2 kW reductions on event days across a range of temperatures. PG&E and SDG&E high consumption ADRS customers achieved substantial, but lower reductions, close to 1 kW on event days on average.

Homes with ADRS technology produced a consistent and predictable load profile during Super Peak and peak periods. Reductions were at their maximum at the start of the period, then gradually increased as homes warmed up and air conditioners pulsed on to maintain indoor temperatures at the higher set point. The hotter the outdoor temperature became, typically the faster the load rose throughout the peak period, on average. There was typically a dramatic recovery in load immediately following the Super Peak or peak periods, when thermostats in ADRS homes automatically reset from their warmer Super Peak or peak settings to their cooler off-peak setting.

Where present, pool pumps made a significant contribution to reduction of Super Peak and peak period load. Examination of average daily load profiles showed that high consumption ADRS customers with swimming pools consistently scheduled pool pump operation outside of the hours between 2 p.m. and 7 p.m. to reduce Super Peak and peak period consumption every day. On event days, pool pumps operation contributed 32% of total Super Peak reduction for an average high consumption ADRS home with a pool[11]. On non-event days, residents shifting pool pump operation contributed over 50% of total peak period reduction for an average home with a pool.

[11]Total reduction of Super Peak and peak period load by homes with pools is calculated algebraically rather than by direct measurement.

Chapter 2 Summer 2004 load impact results

This section consists of a restatement of the 2004 Automated Demand Response System (ADRS) pilot load impact results. These results supersede Rocky Mountain Institute's (RMI) reported results for the summer 2004 pilot period published in December 2004[12].

The need for restatement of summer 2004 ADRS load impact results is two-fold. First, one of the ADRS pilot extension objectives was to compare load response levels observed in summer of 2005 to levels observed in the summer of 2004. The 2005 pilot program focused on studying results by utility, rather than statewide as was the convention in the original 2004 load impact analysis. The 2005 ADRS pilot focused furthermore on the performance of high consumption homes by utility: those homes with historical summer average daily usage of 24 kWh and greater. While the ADRS pilot sample was adequate, additional high consumption homes needed to be added to the control sample in order to make the utility-specific evaluation more statistically robust. The additional high consumption control homes were incorporated into the ADRS control sample and 2004 load impacts were re-evaluated in order to facilitate comparison of load impact results between the two pilot years[13].

Second, one major item of discussion from the 2004 ADRS pilot was the possibility of selection bias in the ADRS homes relative to the average California residential population at large. This ensued from discussions around California's pricing-only Statewide Pricing Pilot (SPP), a pilot program closely related to the ADRS pilot. Like ADRS, the SPP was a statewide demand response pilot program sponsored by the California Energy Commission to study the ability and extent of critical peak pricing to change energy consumption behavior during specific times of day.

In the SPP load impact evaluation, significant bias was discovered in the climate zone 3 SPP residential participants (A07) and subsequently corrected. The SPP Evaluation Subcommittee and the California Energy Commission (CEC) stated their concerns for the existence of selection bias in the A07 and ADRS homes, respectively, and suggested the need for adjustments to load impact results in light of possible bias in the samples[14]. While selection bias in A07 homes was identified and corrected by the SPP evaluation team led by Charles River Associates in 2005, RMI had not investigated the existence of possible selection bias for ADRS homes.

Thus, during the pilot extension in 2005, RMI conducted a selection bias evaluation for the ADRS customers. The investigation concluded that ADRS selection bias existed, albeit small in magnitude, particularly during peak periods. Adjustments were thus applied to all load impact results for the summer 2005 ADRS pilot extension. In order to fulfill the 2005 ADRS pilot extension objective of comparing load response levels observed in summer of 2004 to levels

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[12]Rocky Mountain Institute (RMI), *ADRS Load Impact Final Report*. December 18, 2004.

[13] In total, utilities provided a total of 68 additional control homes, with 30 from SCE, 19 from PG&E, and 19 from SDG&E. The additional high consumption control homes brought the total high consumption control sample count to 52 for SCE, 30 for PG&E, and 22 for SDG&E.

[14]McAuliffe, Pat and Arthur Rosenfeld, California Energy Commission (CEC), Response of Residential Customers to Critical Peak Pricing and Time-of-Use Rates During 2003 and 2004. January 17, 2005.

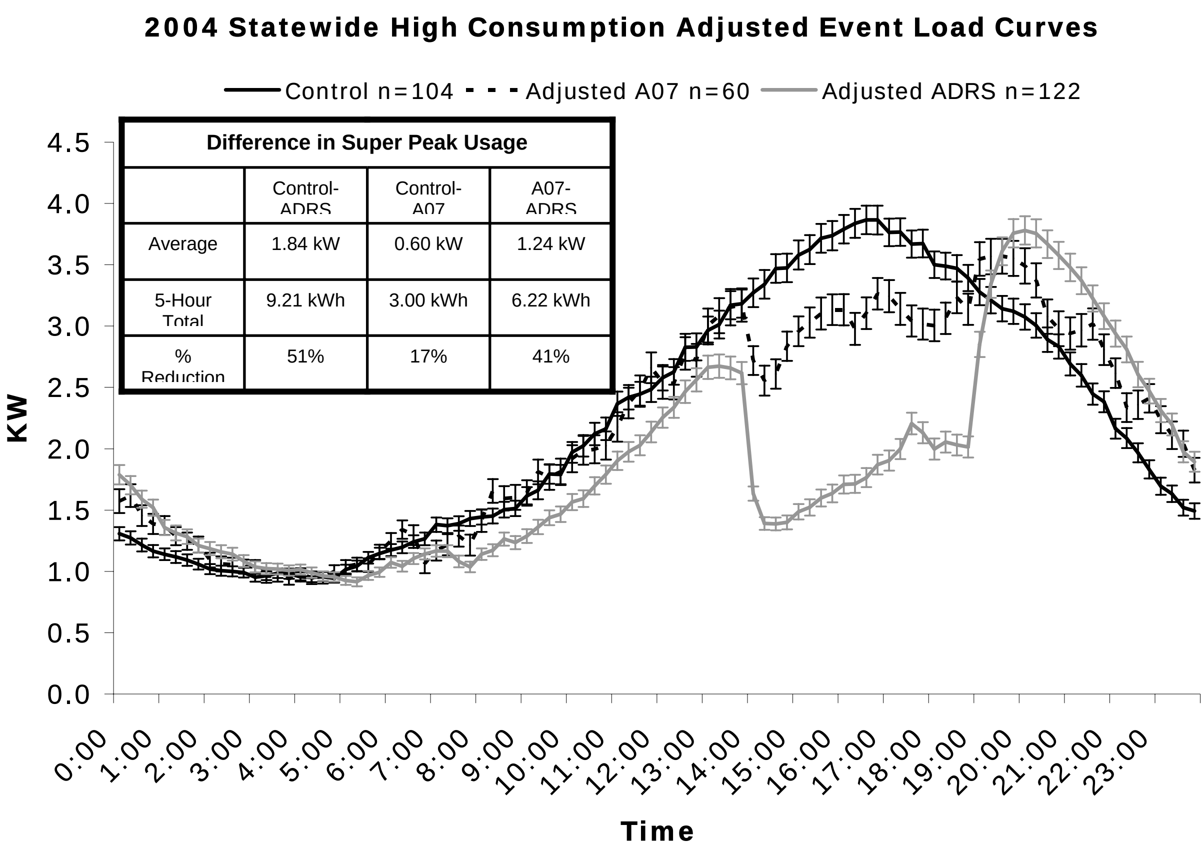
observed in the summer of 2005, RMI also needed to adjust load impact results reported for the 2004 ADRS pilot and restate the results to include the selection bias adjustment.

The restated 2004 ADRS load impact results are thus enumerated in this section, with selection bias adjustments to the ADRS and A07 customers. Details of RMI's confirmation of A07 selection bias and investigation into ADRS selection bias are included for reference in Appendix C to this report.

2.1 Statewide high consumption summer 2004 load impact analysis results

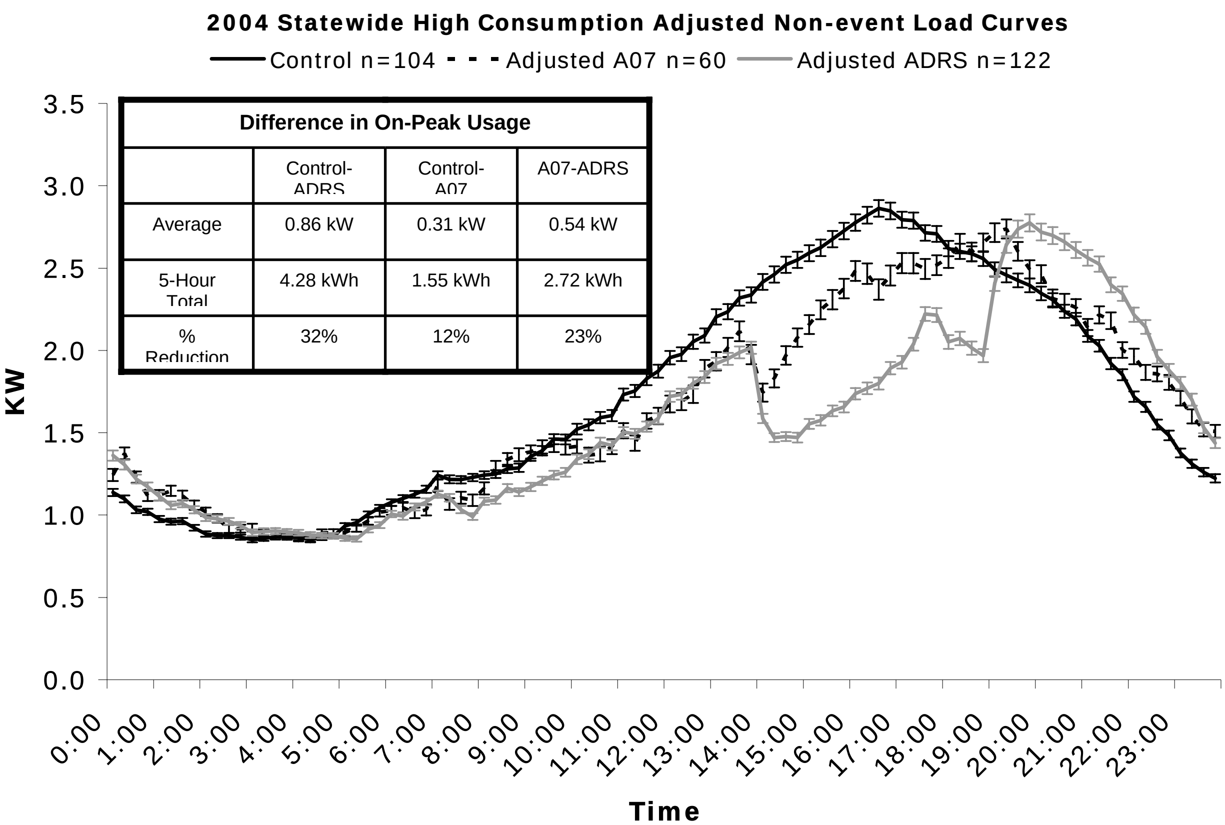
During the period July to September 2004, ADRS high consumption customers successfully and consistently reduced load relative to control homes by 1.84 kW or 9.22 kWh on average during the Super Peak period across twelve event days, called statewide (Figure 31). This translates to a 51% reduction relative to high consumption control homes statewide. The control homes do not possess ADRS technology and are not subject to dynamic critical peak pricing (CPP) rates.

Figure 31: Statewide high consumption event day load curves



Compared to customers on dynamic critical peak pricing rates but without ADRS technology (A07 homes), ADRS high consumption participants successfully and consistently reduced load by an average of 1.24 kW or 6.22 kWh during Super Peak period on event days statewide. This translates to a 41% reduction relative to A07 high consumption homes, statewide. The A07 homes, reducing their load with only the Super Peak rate stimulus on event days but without the assistance of ADRS technology, averaged 0.60 kW reduction relative to control homes or 3.0 kWh during Super Peak period on event days, statewide. This translates to a 17% reduction for A07 high consumption customers relative to control customers on event days, statewide. Ninety percent confidence intervals of loads during the Super peak period averaged ±0.11 kW for control homes, ±0.07 kW for ADRS homes, and ±0.13 kW for A07 homes[15].

Figure 32: Statewide high consumption non-event day load curves



On non-event days statewide, ADRS high consumption customers reduced load relative to control homes by 0.86 kW or 4.28 kWh on average, during the peak period. This translates to a 32% reduction relative to high consumption control homes statewide (Figure 32). Compared to A07 homes statewide, ADRS high consumption customers reduced load by an average of 0.54 kW or 2.72 kWh during the peak period. This translates to a 23% reduction relative to A07 customers. The A07 homes, reducing their load with only the peak rate stimulus on non-event days but without the assistance of ADRS technology, averaged 0.31 kW or 1.55 kWh compared to high consumption control customers. This translates to a 12% reduction for A07 high

[15] Confidence intervals were calculated for each 15-minute interval as described in Appendix A, of the essential companion document to this report, *Automated Demand Response System Pilot, 2005 Summer Load Impact Results and Comparison of 2005 with 2004 Summer Load Impact Results*. Super Peak 90% confidence intervals ranged from ±0.10 kW to ±0.12 kW for control homes, from ±0.05 kW to ±0.08 kW for ADRS homes, and from ±0.12 kW to ±0.13 kW for A07 homes.

consumption customers relative to control customers on non-event days, statewide. Ninety percent confidence intervals during the non-event peak period averaged ±0.05 kW for control homes, ±0.03 kW for ADRS homes, and ±0.06 kW for A07 homes[16].

2.1.1 Comparison of adjusted and unadjusted statewide 2004 load impact results

The load impact results presented above and in the rest of this report include corrections for selection bias in both ADRS and A07 homes along with an augmented control group. RMI conducted a selection bias evaluation for the ADRS customers found small but statistically significant pre-existing differences in the amount of electricity consumption between ADRS customers and the control group, particularly during peak periods. Details of RMI's confirmation of A07 selection bias and investigation into ADRS selection bias are included in the appendix to this document.

Interestingly, the direction of ADRS bias differed between utilities. For PG&E and SDG&E, ADRS customers generally consumed less on-peak energy than control homes. ADRS loads for the two utilities were thus adjusted upward to reflect this bias, reducing the apparent savings. For ADRS customers in SCE's service territory, consumption was generally greater than control homes. ADRS loads for SCE were thus adjusted downward to reflect this bias.

The bias adjustment used to report statewide ADRS load reduction results was calculated in the form of a weighted average of the individual bias adjustments used for each utility. Because the bias adjustments for each utility were different in magnitude and direction, the net adjustment to ADRS customers used in reporting the statewide average results in this report was relatively small, about 0.1 kW.

In contrast, the bias adjustment applied to A07 homes was more substantial, on the order of 0.6 kW during the Super Peak period for event days and 0.15 kW during the peak period for non-event days. RMI calculated the bias adjustment using pretreatment load data from June 2003 for both A07 homes and the augmented control group. A statewide bias adjustment was calculated using combined load data from the utilities, rather than from the weighted average of bias adjustments calculated from each utility in the case of ADRS bias adjustments. No utility-specific adjustments were calculated for the A07 homes, as the quantity of pretreatment data available for each utility was sparse for A07 homes. Details of the selection bias investigation and adjustment calculation for A07 and control homes are included in the appendix to this report.

The effect of adding the additional control homes was to increase control load statewide for all days during summer 2004. On non-event days, the augmented control load increased by 9.6% compared to the original (A03) control group load (Table 3). On event days, the augmented control load increased by 13% compared to the original A03 control group load. While the load difference between augmented and A03-only control customers on event days are slightly higher

[16] Non-event peak period 90% confidence intervals ranged from ±0.0.4 kW to ±0.05 kW for control homes, from ±0.03 kW to ±0.04 kW for ADRS homes, and from ±0.055 kW to ±0.062 kW for A07 homes.

than for non-event days, the overall difference in load across all summer days between augmented and original A03 control group was determined to be statistically insignificant[17].

Table 3. Comparison of 2004 ADRS high consumption load impact before and after correcting for selection bias, kW

	Unadjusted (Dec 2004 report)	**Unadjusted w/ augmented control group**	**Adjusted w/ augmented control group (This report)**	**% difference**
Super Peak period, event days				
Control - ADRS	1.7	1.9	1.8	-5%
Control - A07	0.9	1.2	0.6	-50%
A07 - ADRS	0.8	0.7	1.2	+71%
Peak period, non-event days				
Control - ADRS	0.87	0.95	0.86	-10%
Control - A07	0.37	0.46	0.31	-33%
A07 - ADRS	0.50	0.49	0.54	+10%

The effect of applying the adjustments was that the high consumption ADRS load reduction relative to (augmented) control group statewide decreased slightly by 5% during the Super Peak period, down from 1.93 kW or 9.65 kWh prior to the adjustment (Table 3). Similarly on non-event days, high consumption ADRS load reduction decreased 10% during peak periods, down from 0.95 kW or 4.75 kWh prior to applying the adjustment.

Relative to A07 customers, ADRS high consumption customers statewide load reductions were 0.7 kW and 3.5 kWh prior to applying the adjustment, during Super Peak periods. With the adjustment, load reductions on event days improved 71%. On non-event days, ADRS load reduction relative to A07 customers improved 10% from the unadjusted performance of 0.49 kW and 2.45 kWh during peak periods.

As a result of applying the adjustment, A07 customer load savings relative to the control group declined 50% to 0.6 kW or 3.0 kWh, down from 1.2 kW or 6.0 kWh during Super Peak period in 2004. Similarly on non-event days, A07 high consumption load reductions declined 33% relative to control group, down from 0.46 kW or 2.3 kWh prior to applying the adjustment.

2.1.2 Reconciliation of RMI reported A07 load reductions with results reported by CRA and the CEC

Table 4 summarizes the A07 load impact results based on CRA's and CEC's independent analyses of the SPP program for climate zone 3 customers in summer 2004. The table compares the CRA and CEC results against RMI's results for the A07 customer load reductions relative to a control group reported in RMI's December 2004 report and the restatement of the ADRS summer 2004 results in this report. Note that CEC and RMI used a straight difference of

[17] The two-sided test of significance for the difference in the augmented and A03 groups across all summer days in 2004 produced a p-value of 0.63 indicating a probability of 63% (high) that the difference is due to random chance.

difference approach while CRA used a difference of differences approach based on regression models built from pre-treatment data, treatment data, and household surveys. Details of RMI's confirmation of A07 selection bias and investigation into ADRS selection bias are included in the appendix to this document.

Table 4. Comparison of CRA and CEC's control-A07 results for climate zone 3 SPP participants

Event Weekdays Peak Period Comparison (Climate Zone 3)			
	Zone 3 CPP Change (kW)	Savings (kWh)	% Reduction
CRA[1]	0.22	1.1*	13.37%
CEC[2]	0.30	1.5	16%
RMI Dec 2004[3]	0.94	4.7	28%
RMI Mar 2005[4]	0.60	3.0	17%
Non-event Weekday Peak Period Comparison (Climate Zone 3)			
	Zone 3 CPP Change (kW)	Savings (kWh)	% Reduction
CRA[1]	0.08	0.4*	5.59%
CEC[2]	0.11	0.6	8.5%
RMI Dec 2004[3]	0.37	1.8	15%
RMI Mar 2005[4]	0.31	1.6	12%

* RMI calculation
[1]Charles River Associates (CRA), *Statewide Pricing Pilot Summer 2003 Impact Analysis* Final Report October 11, 2004. p. 7
[2]Pat McAuliffe and Arthur Rosenfeld, *Response of Residential Customers to Critical Peak Pricing and Time-of-Use Rates During 2003 and 2004.* January 17, 2005. September 23, 2004. p. 4
[3]RMI, 2004 ADRS Load Impact Final Report
[3]RMI, ADRS 2005 Summer Load Impact Final Report

Table 4 shows that RMI's reported results in this report for A07 load reductions on event days matches the results reported by the CEC and is similar to the results reported by CRA on a percentage basis. Both RMI and CEC arrived at an A07 percentage load reduction on event days of 16%, while CRA reported 13%. On non-event days, RMI's measured A07 load impact compared to control is 12%, reduced from results reported in December 2004. This result is significantly larger than results reported by CRA and CEC.

The residual differences in load impact results in Table 4 between CRA, the CEC, and RMI are due to the different control home samples and slight differences in the A07 homes evaluated in each study. The homes evaluated by CRA and CEC for the SPP program include both single and multifamily homes in climate zone 3, who may or may not have central air conditioning. The homes RMI evaluated for the ADRS pilot is the subset of the SPP control and participant homes, consisting only of single family homes with central air conditioning in climate zone 3.

Furthermore RMI's results in Table 4 consist only of high consumption homes, whose average daily consumption is greater than 24 kWh, while results reported for CRA and CEC include both high and low consumption homes. As stated in the Introduction section of this report, RMI's restatement of ADRS summer 2004 results includes an augmented population of control homes in climate zone 3 that was not used for the SPP program evaluated by CRA and the CEC.

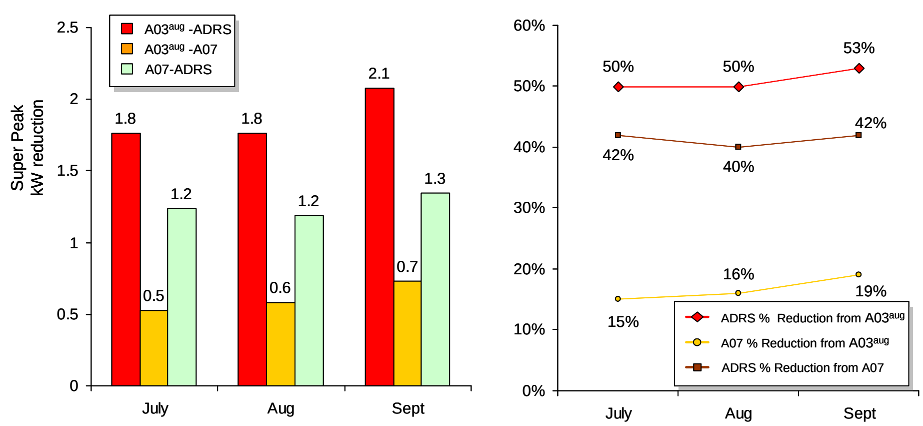
2.1.3 Statewide Monthly performance

Statewide monthly performance of ADRS homes varied little from the summer average (Figure 33). ADRS high consumption load reductions in July and August are equal to the summer average of 1.8 kW or 9 kWh during Super Peak periods on event days. This translates to a 50% savings in July and August. September was strongest performing month of the summer, with ADRS homes reducing load by more than 2 kW on average or 53% during Super Peak periods, compared to control homes.

Statewide monthly load reductions of ADRS homes relative to A07 homes were also similar to the summer average. July, August and September savings were 1.2 kW, 1.2 kW, and 1.3 kW, respectively, with September the strongest performing month of the summer. This translates to 42%, 40%, and 42% reduction in July, August, and September, respectively, compared to A07 homes.

Finally, load reduction of high consumption A07 homes relative to control homes was 0.5 kW in July, 0.6 kW in August and 0.8 kW in September, after adjusting for selection bias. This translates to 15%, 16%, and 19% load reduction in July, August, and September, respectively.

Figure 33: Average reduction in Super Peak load, high consumption homes statewide



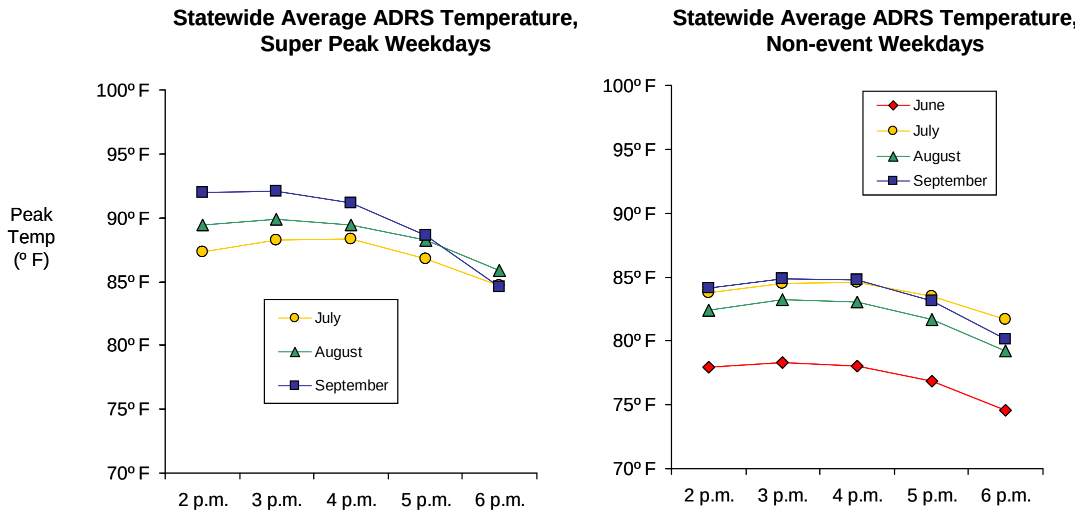
2.1.4 2004 Statewide temperatures

Statewide, temperatures during Super Peak period on event days were hotter than corresponding periods on non-event days[18] (Figure 34). September was the warmest month, with event day temperatures reaching to 92^{o}F on average across the three utility service territories statewide. Event days called in July experienced the coolest temperatures statewide, with temperatures reaching to 88^{o}F by 4 p.m. Super Peak period hourly temperature variations exhibited similar

[18] A total of 15 event days were called during summer 2004. In general, event days were called on the basis of weekly weather forecasts, when temperatures are expected to reach summer season highs. On these hottest of summer days, air conditioning loads are high and stress on the electric power system is relieved when customers curtail their energy consumption, as in the case of ADRS pilot participants.

patterns between months, with temperatures reaching a maximum at 4 p.m. and dropping by 5 degrees by 6 p.m. Statewide, ADRS homes in September experienced the greatest variation in temperature across the Super Peak period, cooling down to 84°F by 6 p.m. from a high of 92°F at 3 p.m.

Figure 34: 2004 Statewide high consumption ADRS temperatures



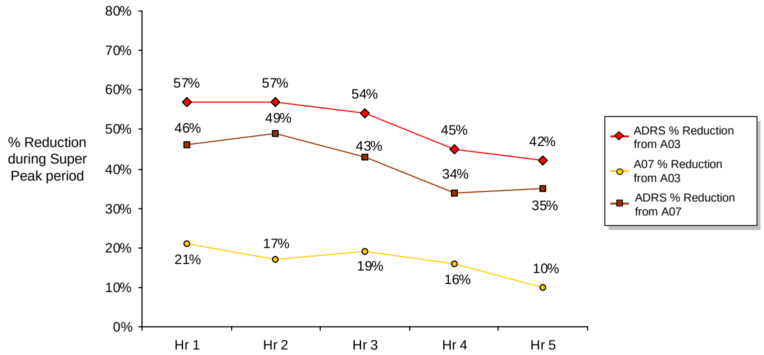
On non-event days, September was again the warmest month overall. Temperatures across the three utility service territories reached an average high of 85°F at 3 p.m. July was also relatively warm month for non-event days, with temperatures reaching 84.5°F by 3 p.m. Hourly temperatures on non-event days follow a similar pattern as for event days, with temperatures peaking at 3 p.m. or 4 p.m. and cooling off substantially by 6 p.m.

2.1.5 Statewide Super Peak period hourly load reductions, high consumption homes

On event days, high consumption ADRS homes reduced the most load during the first three hours of the Super Peak period. Averaged across the summer, ADRS load reductions from 2 p.m. to 4 p.m. was 57%, 57%, and 54%, respectively, compared to control homes (Figure 35). Load reductions during the last two hours of the Super Peak period on event days were lower but still substantial, and ADRS homes statewide achieved average reductions of 45% and 42% relative to control homes at 5 p.m and 6 p.m., respectively.

Compared to A07 customers on dynamic critical peak pricing rates but without ADRS technology, high consumption ADRS customers reduced load consistently between 43% and 46% during the first three hours of Super Peak period, on average. Like the ADRS load reduction relative to control group, savings decline during the last two hours of the Super Peak period. Thus at 5 p.m., ADRS reduced load by 34% compared to A07 customers and at 6 p.m., ADRS customers reduced load by 35%. The slight rebound in ADRS savings at 6 p.m. is a consequence of the A07 behavior during that hour resulting in just 10% load reduction relative to control. It is likely that A07 customers ramped up their use of air conditioning at the last hour of the peak period at 6 p.m. due to the hot weather, thereby reducing their load savings relative to control homes.

Figure 35: ADRS vs. control: statewide percent reduction in Super Peak period load



On event days, high consumption A07 customers reduced load relative to control consistently by 21%, 17%, and 19% during the first three hours of the Super Peak period. A07 load reductions decline steadily during the fourth and fifth hours (5 p.m. and 6 p.m.), to 16% and 10%, respectively. During the last hour, A07 load reductions relative to control customers decline dramatically to 10%, half the reduction of the first hour at 2 p.m. It is likely that A07 customers ramped up their use of air conditioning at the last hour of the Super Peak period at 6 p.m. due to the hot weather, thereby reducing their load savings relative to control homes.

2.1.6 Super Peak reductions by event day, statewide high consumption homes

Figure 36 and Figure 37 plot the Super Peak period performance of high consumption ADRS homes relative to control homes on each event day in the summer of 2004. Figure 36 reports the ADRS savings in kW and Figure 37 reports the savings as a percentage reduction of the control load. In both figures, a secondary axis plots the average peak temperature for ADRS homes on that event day.

Figure 36: Statewide average reduction in ADRS Super Peak period load relative to control homes

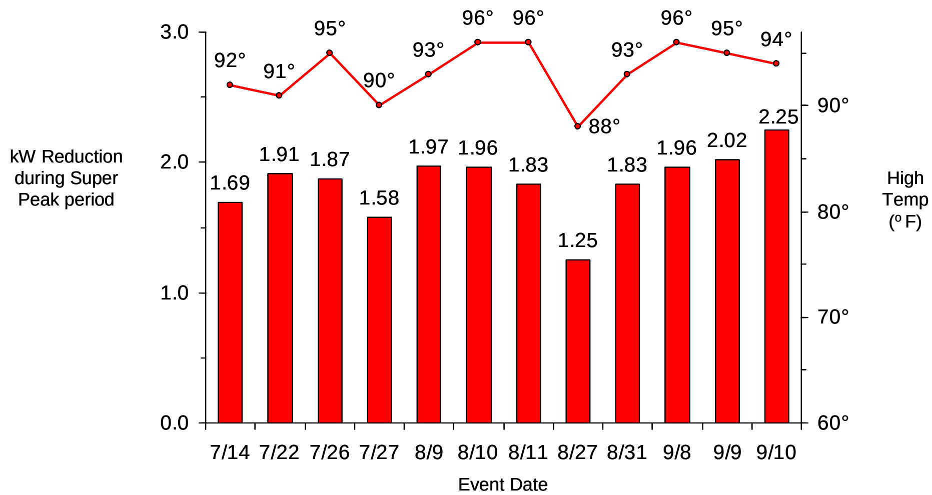
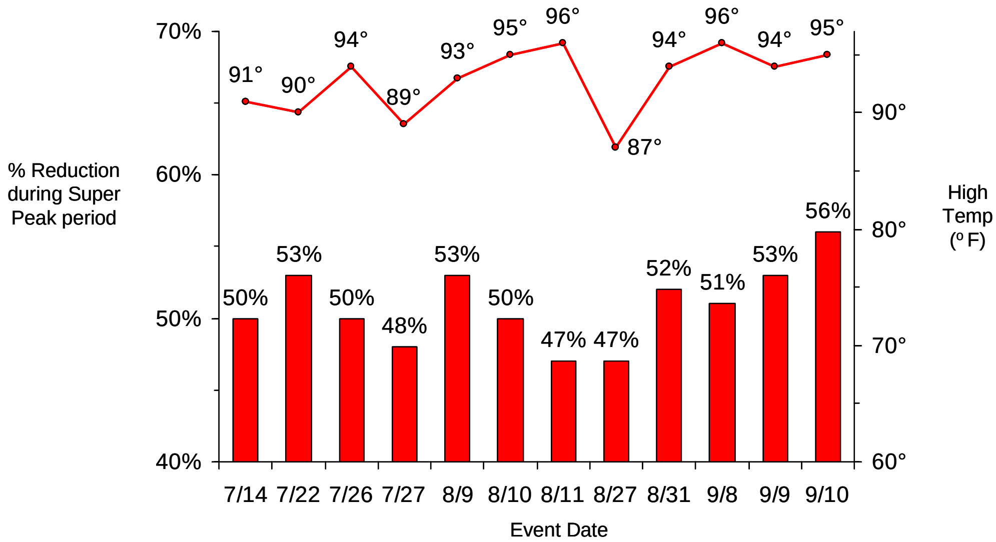


Figure 37: Statewide percent reduction in ADRS Super Peak period load relative to control homes



Statewide, high consumption ADRS homes reduced load by 1.6 kW to 2.25 kW on eleven of twelve Super Peak days called during 2004. Reductions were particularly strong in September, the hottest summer month in 2004, where ADRS load reductions exceeded 2 kW on two of three event days that month. This performance is particularly impressive given that September Super Peak events were consecutive days. High consumption ADRS load reductions fell below 1.6 kW during the Super Peak period on one event day, August 27^{th}. Super Peak reduction was 1.25 kW on August 27^{th}, which also the coolest event day of the year.

On a percentage basis, high consumption ADRS homes reduced load by 50% to 56% on nine of twelve Super Peak days called during 2004, compared to control homes. Two of three event days where load reductions fell below 50% was August 27^{th}, the coolest event day of the year, and July 27^{th}, when average peak temperatures were also below 90°F statewide. Savings on August 11^{th} event day were 47% even though temperatures averaged 96°F statewide. August 11^{th} was the third consecutive event day of steadily increasing temperatures, and control customer loads were also higher as well, resulting in the lower percentage reduction result. On that day, absolute ADRS load reduction relative to control homes was 1.83 kW, a strong statewide performance in spite of the hot weather.

Figure 38 and Figure 39 plot the Super Peak period performance of high consumption ADRS homes relative to A07 homes on each event day in the summer of 2004. Figure 39 reports the ADRS savings in kW and Figure 39 reports the savings as a percentage reduction of the control load. In both figures, a secondary axis plots the average peak temperature for ADRS homes on that event day.

Figure 38: Average statewide reduction in ADRS Super Peak period load relative to A07 homes

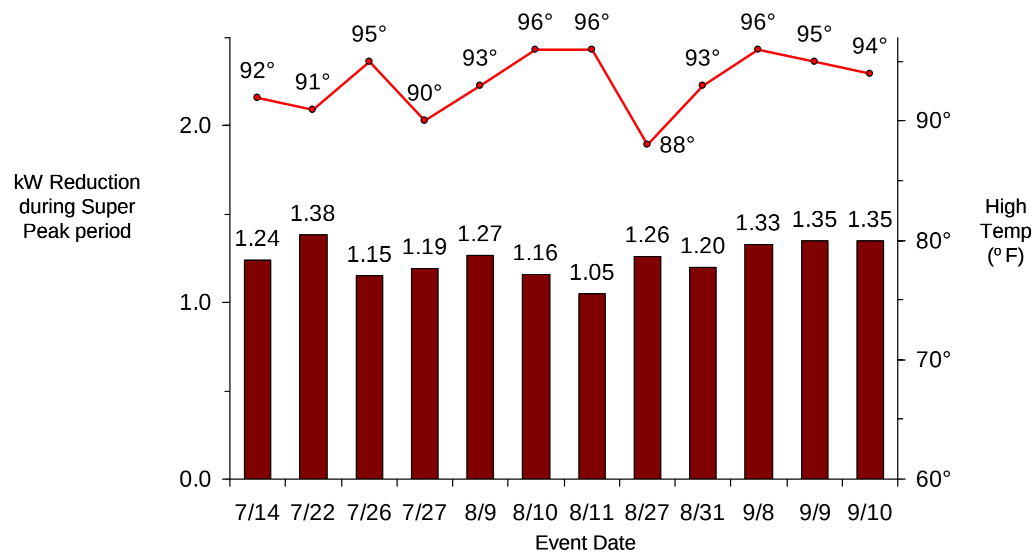
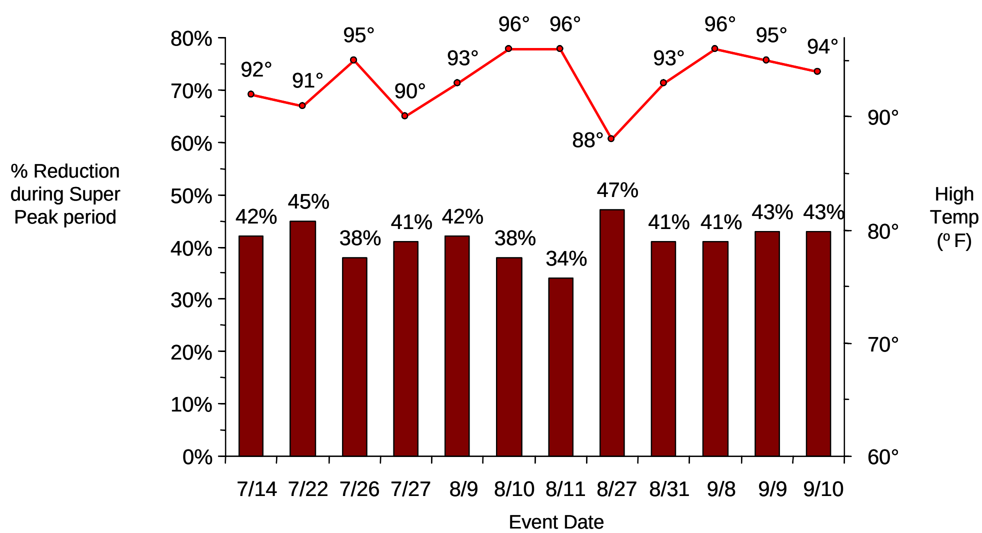
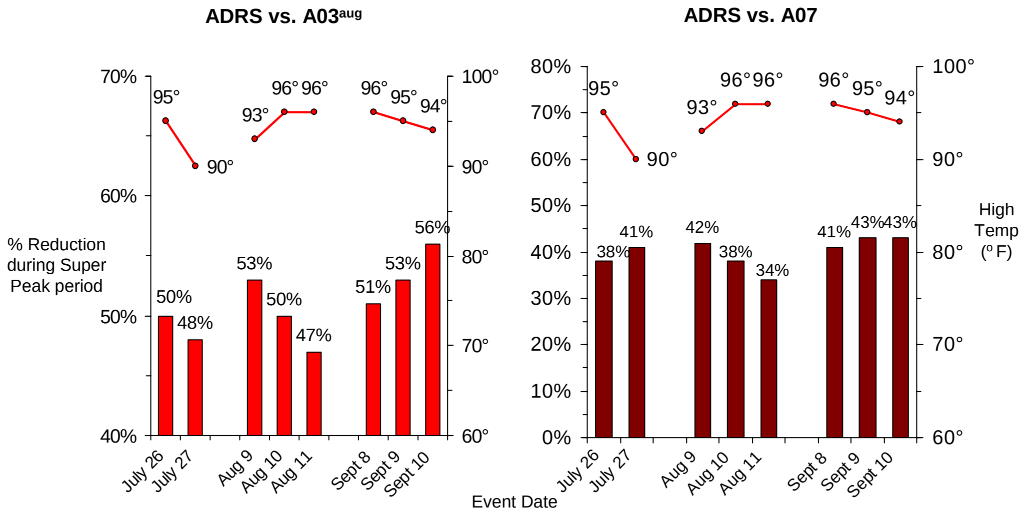


Figure 39: Statewide percent reduction in ADRS Super Peak period load relative to A07 homes



Statewide, high consumption ADRS homes reduced load by 1.1 kW to 1.4 kW relative to A07 homes on eleven of twelve Super Peak days called during 2004. On a percentage basis, ADRS homes reduced load by 41% to 47% relative to A07 homes on nine out of eleven event days. On three event days, ADRS homes reduced load on a percentage basis by 38%, 38%, and 34%, respectively, on July 26, August 10 and August 11. All of the three days are part of consecutive event days, where temperatures increased throughout each consecutive day. While absolute load reductions on those days are very reasonable, it is possible that percentage reductions are lower because the A07 loads increased as a result of warmer weather.

Figure 40 Consecutive event day performance statewide, high consumption ADRS homes compared to control (left) and high consumption ADRS homes compared to A07 homes (right)

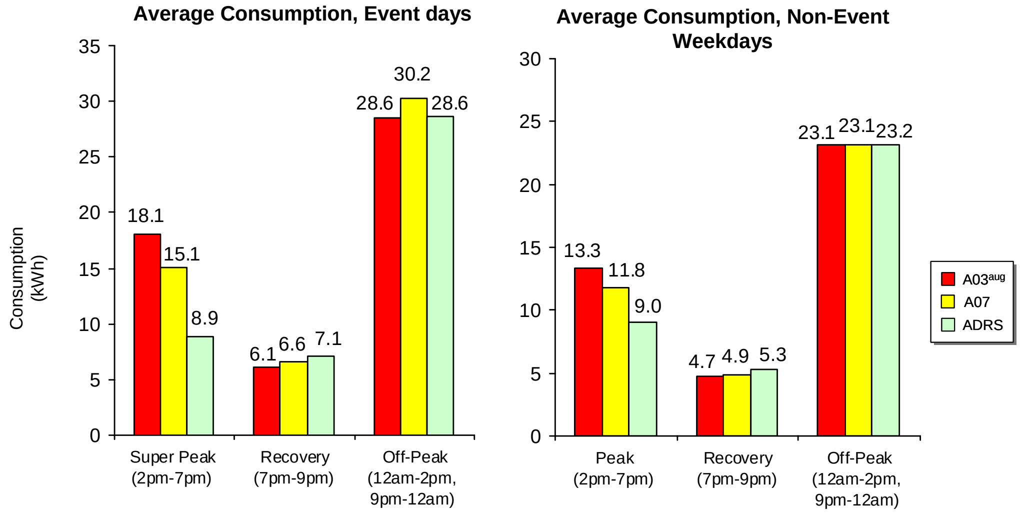


Super Peak period performance on consecutive event days varied both for ADRS load reductions compared to control homes and for ADRS load reductions compared to A07 homes (Figure 40). Compared to control homes, ADRS reductions declined on some consecutive event days (July 26th and 27th, August 9-11) while savings increased throughout other consecutive event days (September 8-10). Compared to A07 homes ADRS reductions also declined on some consecutive event days (August 9-11) but increased throughout other consecutive event days (July 26-27, September 8-10). The variations in performance however corresponded well with temperature variations across consecutive event days in each month.

Figure 41 shows the average energy consumption for ADRS and control homes during peak, recovery, and off-peak periods on event and non-event days. On event days, ADRS homes consumed 50% less energy than control customers and 41% less energy than A07 customers during Super Peak periods, on average, statewide. ADRS homes consumed 0.5 kWh or 8% more load than control and A07 customers during the recovery period on event days.

This reversal of consumption patterns during the recovery period corresponds to the post-peak period rebound, which is exhibited in the increase in ADRS load at 7 p.m. evident in Figure 31 and Figure 32. At the end of the Super Peak period, the thermostats in ADRS homes are automatically reset from their warmer Super Peak setting to their cooler off-peak setting. This results in a sudden jump in load at 7 p.m. as air conditioners suddenly turn on to meet the cooler set point. ADRS homes consume just as much energy as control homes during the off-peak period, reflecting the similarity in off-peak loads.

Figure 41: Statewide average Consumption: event and non-event weekdays



ADRS consumption compared to control and A07 customers on non-event days exhibit similar patterns. ADRS homes' peak period consumption is substantially less than control and A07 customers, while ADRS consumption during the recovery period is slightly more than control and A07 customers. Control homes consume just as much energy as ADRS homes during off-peak periods, indicating similarity in loads during this period. A07 customers tend to consume marginally more energy than both control homes and ADRS homes during off-peak periods, on event days (1.6 kWh more) and just as much energy non-event days, indicating similarity in loads during this period.

Figure 42: Average daily consumption statewide: event (left) and non-event weekdays (right)

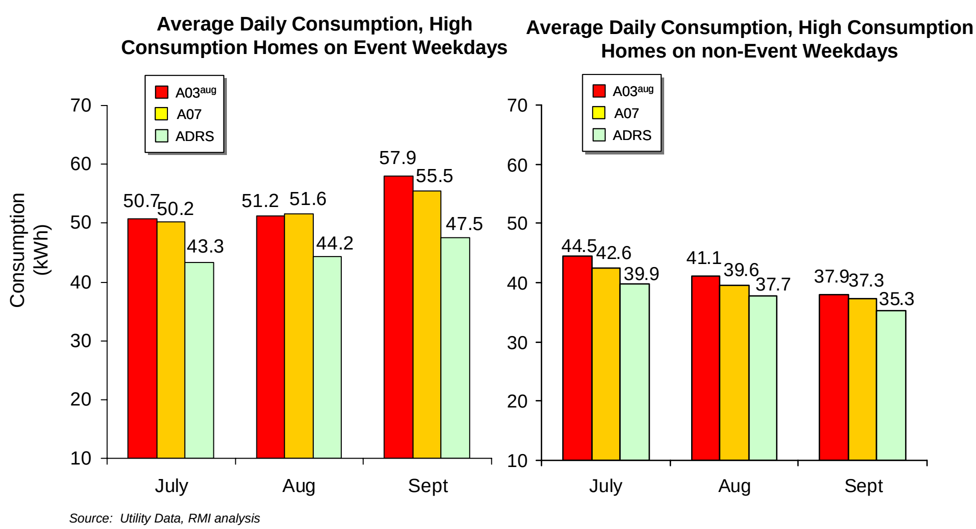


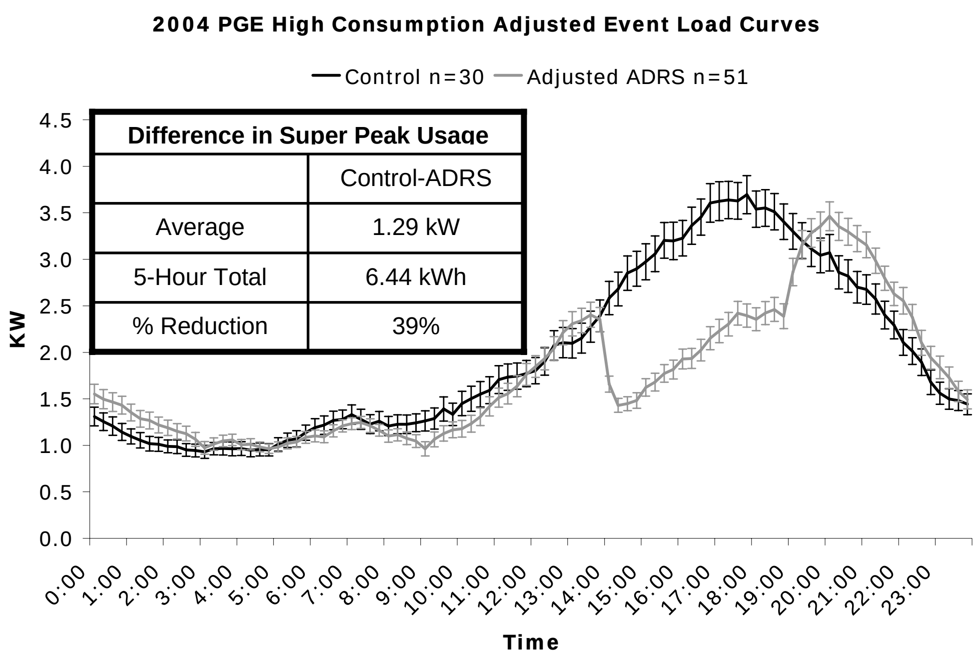
Figure 42 charts the average daily consumption by month for ADRS and control homes. Event days are shown on the left while non-event days are shown on the right. On event days, ADRS homes consistently consume 14% to 18% less energy than control and A07 homes, from July through September. From Figure 41 we observe that most of the difference in consumption comes from ADRS load reduction during the Super Peak period.

On non-event days, ADRS homes also consistently consume less than control and A07 homes. In July, ADRS homes consume an average of 10% less energy than control customers and 6% less energy than A07 customers. High consumption ADRS consumed 7% less energy than control customers and 5% less energy than A07 customers in September, the warmest month of the summer.

2.2 PG&E high consumption summer 2004 load impact analysis results

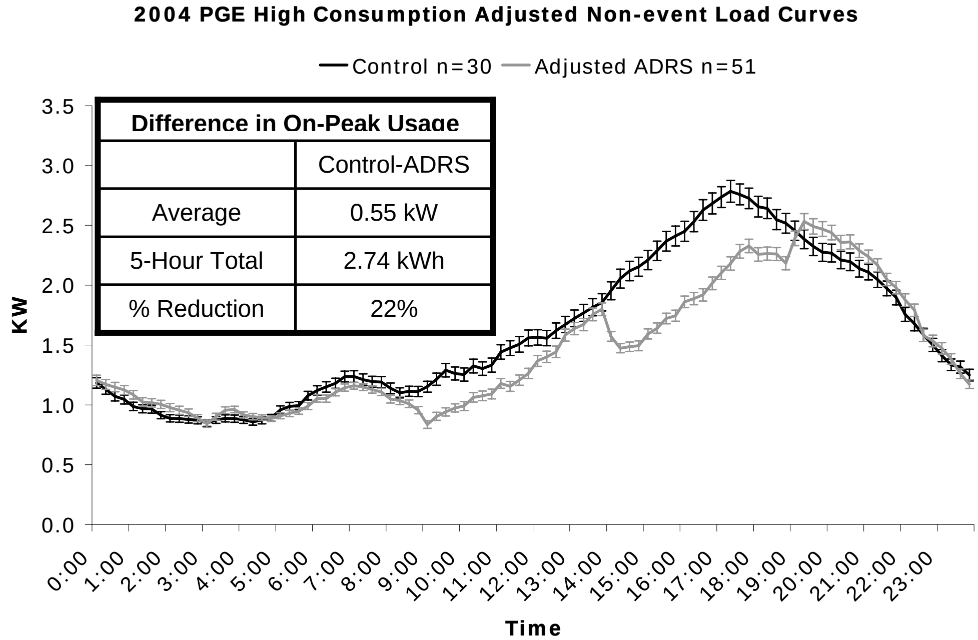
The average event day load curves for PG&E high consumption ADRS and control homes are represented in Figure 43. ADRS homes reduced Super Peak period consumption by an average of 6.4 kWh on event days during the summer of 2004. This equates to an average 1.3 kW load reduction compared to control homes. Overall Super Peak period consumption in ADRS homes was 39% lower than control customers' consumption. Ninety percent confidence intervals during the Super Peak period averaged ±0.20 kW for control homes and ±0.11 kW for ADRS homes[19].

Figure 43: PG&E high consumption event day load curves



[19]Confidence intervals were calculated for each 15-minute interval as described in Appendix A, of the essential companion document to this report, *Automated Demand Response System Pilot, 2005 Summer Load Impact Results and Comparison of 2005 with 2004 Summer Load Impact Results*. Super Peak period 90% confidence intervals ranged from ±0.18 kW to ±0.21 kW for control homes, and from ±0.08 kW to ±0.13 kW for ADRS homes.

Figure 44: PG&E high consumption non-event day load curves



On non-event days, ADRS homes reduced Super Peak period consumption by an average of 2.74 kWh, corresponding to a 0.55 kW and 22% average reduction in load compared to control homes (Figure 44). Ninety percent confidence intervals during the peak period averaged ±0.08 kW for control homes and ±0.04 kW for ADRS homes[20].

Figure 45: Average reduction in Super Peak period load, PG&E high consumption homes on event days

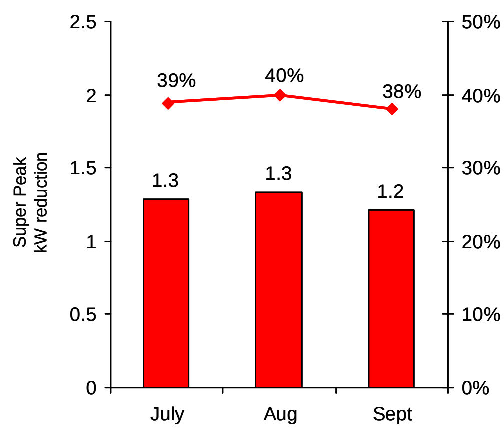
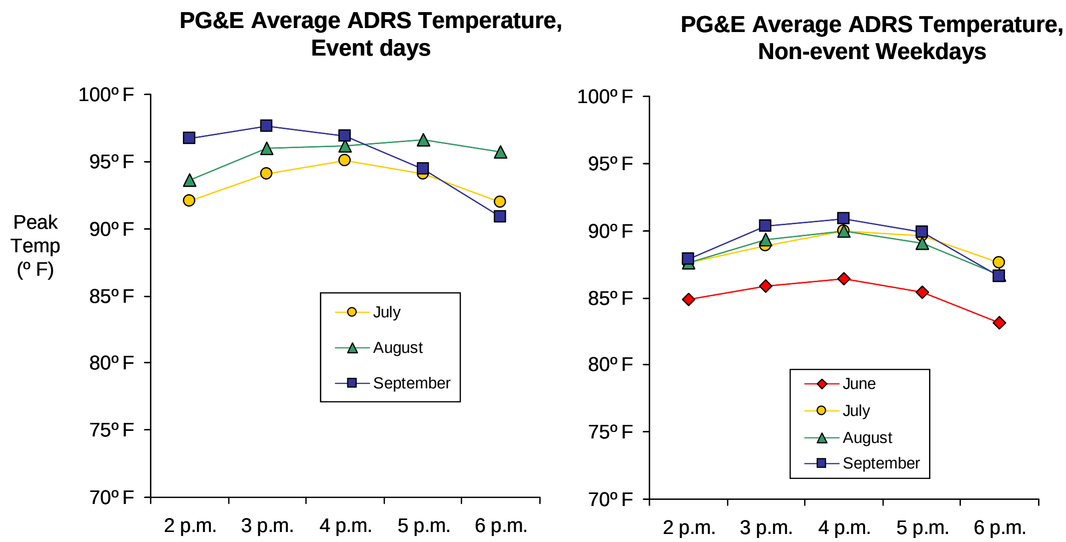


Figure 45 shows ADRS's event day peak period reduction in consumption from control for each summer month. Monthly load reductions for high consumption ADRS homes in PG&E territory

[20] Non-event peak period fifteen-minute 90% confidence intervals ranged from ±0.08 kW to ±0.09 kW for control homes, and from ±0.04 kW to ±0.06 kW for ADRS homes.

varied little from the summer average. Load reductions in July and August are equal to the summer average of 1.3 kW or 6.5 kWh during Super Peak periods on event days. This translates to a 39% and 40% savings in July and August. September reductions were slightly lower, with ADRS homes reducing load by 1.2 kW on average or 38% during Super Peak periods, compared to control homes.

Figure 46: PG&E Average ADRS temperature, event days (left) and non-event weekdays (right)



Hourly average temperatures for PG&E high consumption ADRS homes are illustrated in Figure 46. The left chart displays the Super Peak period temperature averages for each summer month and the right chart displays the average non-event weekday peak period temperature.

Event day average temperatures in PG&E territory are universally higher than non-event day averages. September event days had the hottest peak temperatures, with Super Peak hourly temperatures averaging between 91°F and 98°F. Note the steep drop in temperature for September from 2 p.m. to 6 p.m. Event days called in August averaged between 94°F and 97°F across the Super Peak hours. Unlike September and July, hourly peak temperatures in August remained relatively consistent across the Super Peak period. July event days were also relatively warm, averaging between 92°F and 95°F during Super Peak hours. Super Peak period temperatures in July peaked at 4 p.m. and cooled off by 6 p.m.

For non-event days, June was the coolest month for ADRS customers in PG&E territory, with an average peak afternoon temperature of 86°F. September exhibited the hottest peak period temperatures, reaching a maximum of 91°F at 4 p.m. July and August peak period temperatures were only slightly cooler than September with temperatures peaking at 90°F at 4 p.m.

Figure 47: Average ADRS percent reduction in Super Peak period load for all event weekdays, PG&E high consumption homes

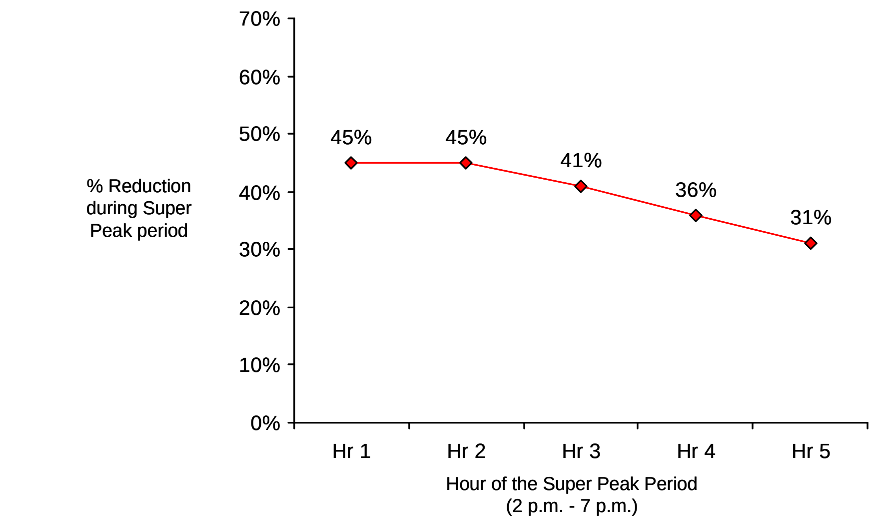


Figure 47 shows the hourly percentage savings of ADRS homes from control homes during the Super Peak period. The percentage reduction at 2 p.m. is 45% relative to control customers, but steadily decreases to 31% at 6 p.m. Referring to the load curves in Figure 43, ADRS load drops at the start of the Super Peak period then increases at the same rate as control load until about 4 p.m., when control load peaks, corresponding to outside temperatures. As control load begins to fall after 4 p.m. as outside temperatures also begin to cool, ADRS load continues to climb, as homes heat up to higher thermostat set points and begin to cycle back on. This results in progressively smaller ADRS savings over the latter hours of the Super Peak period. This behavior in the two groups explains the decline in ADRS load reductions relative to control homes across the Super Peak period.

Figure 48: Average ADRS reduction in Super Peak period load relative to control homes, PG&E high consumption homes

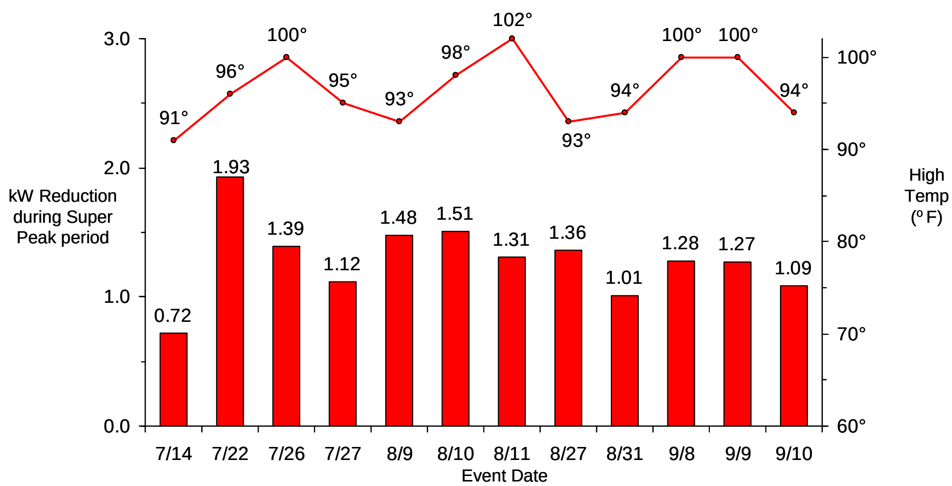


Figure 49: Average ADRS percent reduction in Super Peak period load relative to control homes, PG&E high consumption homes

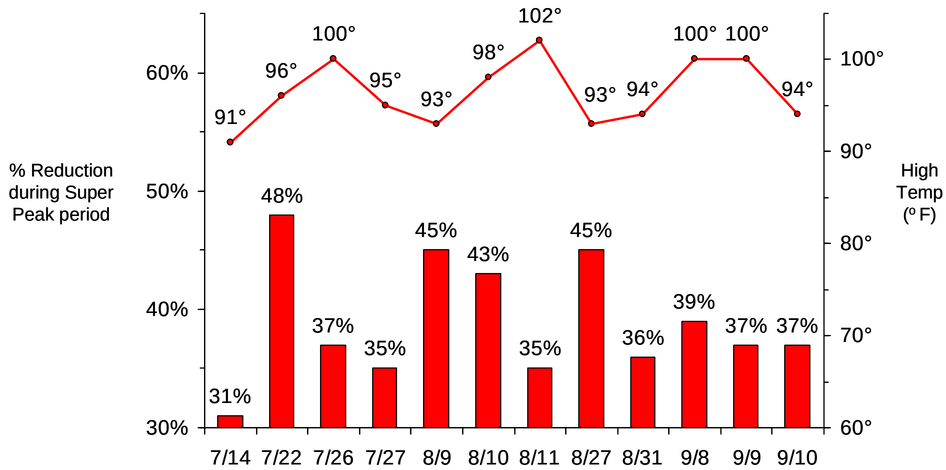


Figure 48 and Figure 49 plot the Super Peak period performance of high consumption ADRS homes in PG&E territory relative to control homes on each event day in the summer of 2004. Figure 48 represents the ADRS savings in kW and Figure 49 represents the savings as a percentage of the control Super Peak period consumption. Both figures plot the average ADRS peak temperature for each event day on a secondary axis.

On a kW basis, the smallest savings occur on the first event day, July 14th, which corresponds as the coolest of all event days at 91° F. The largest savings of 1.93 kW occur on July 22nd, the warmest of the non-consecutive event days of the summer. For the rest of summer 2004 events, the savings fall within a range of 1.1 kW savings and 1.5 kW with the temperature ranging between 93° F and 100° F.

On a percentage basis, PG&E high consumption ADRS load reductions varied across the event days. On most event day, ADRS savings ranged from 35% to 39% in load reduction relative to control homes. Although ADRS homes achieved 45% to 48% reduction on four event days in July and August, these four days were not the hottest days in the summer. The hottest event day in PG&E service territory occurred on August 11th, with peak temperatures reaching 102°F. August 11th was also the third day of consecutive event days in August. On that day, absolute ADRS load reduction relative to control homes was 1.31 kW, a very strong performance in light of the extremely hot weather.

ADRS savings over consecutive event days are displayed in Figure 50. Average maximum daily temperatures are also plotted on the secondary axis. Generally, consecutive event days all produce a small decrease in savings for high consumption ADRS homes in PG&E service territory.

With respect to temperature, there does not appear to be any consistent pattern with regards to consecutive event days. All three consecutive event day periods indicate a similar small decrease in savings in spite of increasing temperature over some days (August 9th through 11th) and decreasing temperature on others (July 26th-27th and September 8th through 10th).

Figure 50: Average ADRS percent reduction in Super Peak period load relative to control homes ("A03aug") on consecutive event days, PG&E high consumption homes

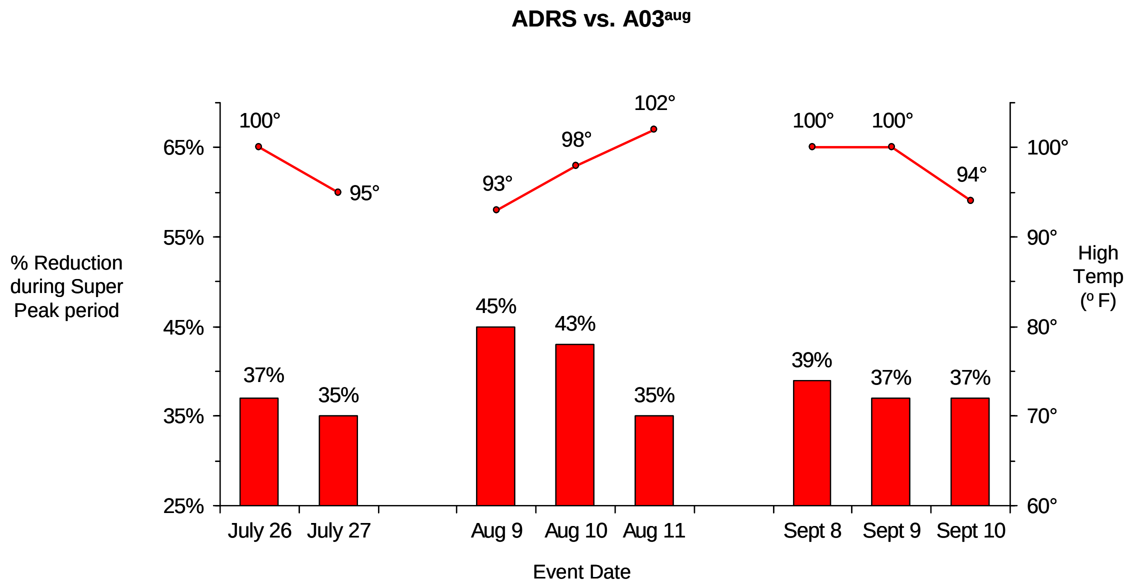


Figure 51: Average consumption, PG&E high consumption ADRS and control homes ("A03aug"), event (left) and non-event (right) weekdays

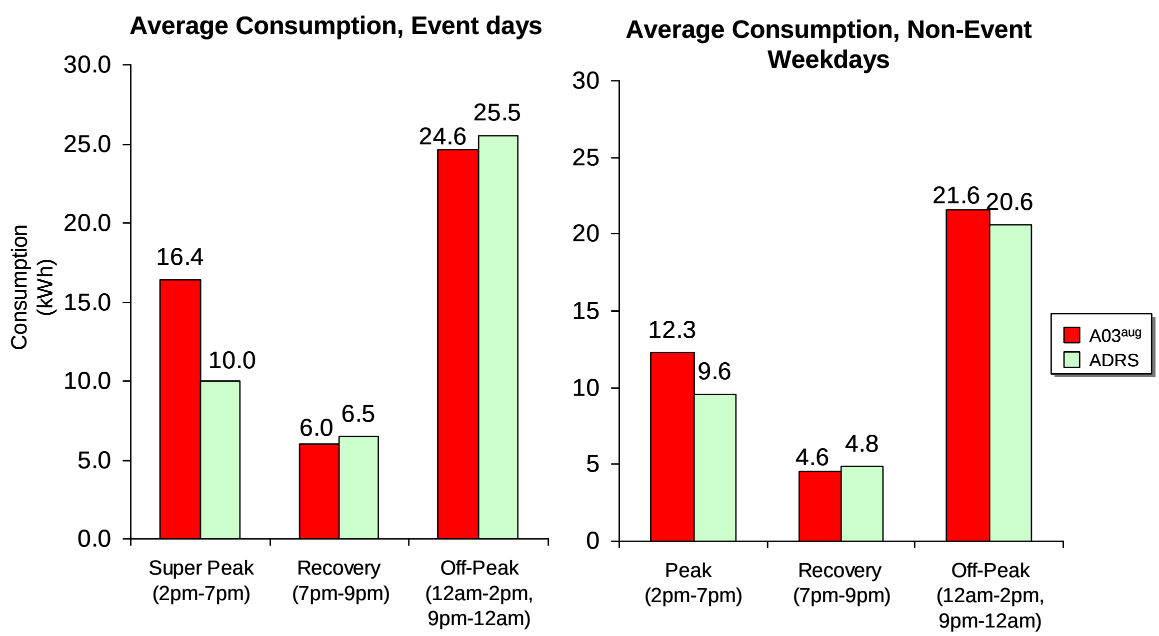
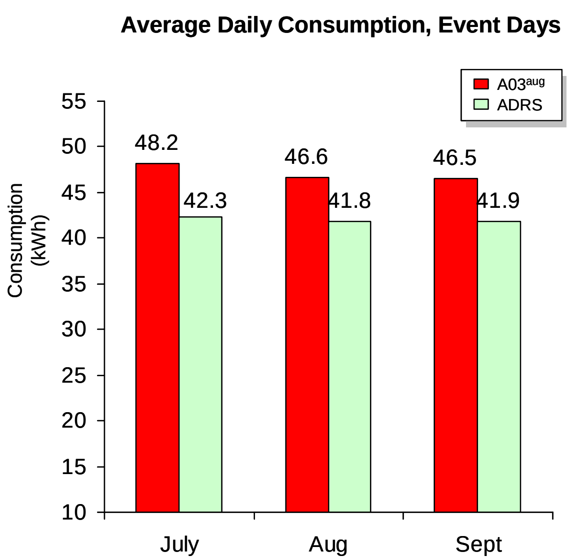


Figure 51 shows the average energy consumption for ADRS and control homes during peak, recovery, and off-peak periods on event and non-event days. On event days, ADRS homes consume 6.4 kWh less energy than control customers during the Super Peak periods. ADRS homes consume marginally more load (0.5 kWh or 8% of peak period savings) during the recovery period. This reversal of consumption patterns during the recovery period corresponds to the post-peak period rebound in consumption in the ADRS homes, which is exhibited in the increase in ADRS load at 7 p.m. At the end of the Super Peak period, the thermostats in ADRS homes are automatically reset from their warmer Super Peak setting to their cooler off-peak setting. This results in a sudden jump in load at 7 p.m. as all the air conditioners suddenly turn on to meet the new, cooler set point. ADRS homes consume marginally more energy than control homes (1 kWh) during the off-peak period, reflecting the similarity in off-peak loads.

Non-event weekday consumption for PG&E high consumption homes exhibit a similar pattern. ADRS homes' peak period consumption is substantially less than control homes (by 22%), while ADRS recovery consumption is slightly more than control homes'. Control homes consume marginally more than ADRS homes during off-peak periods (1 kWh), indicating similarity in loads during this period.

Figure 52:Average daily consumption, PG&E high consumption ADRS and control homes on event (left) and non-event (right) weekdays



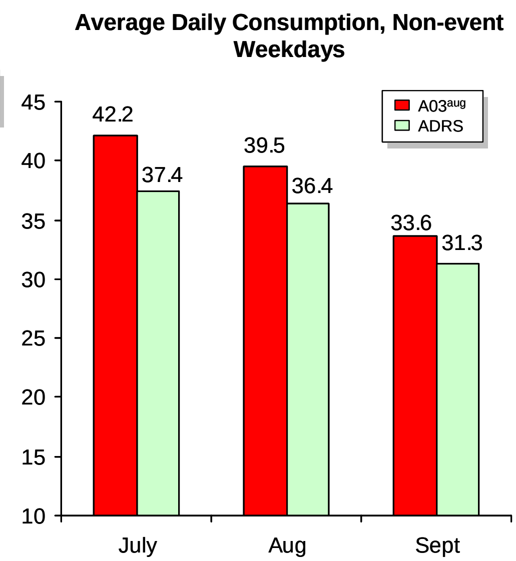


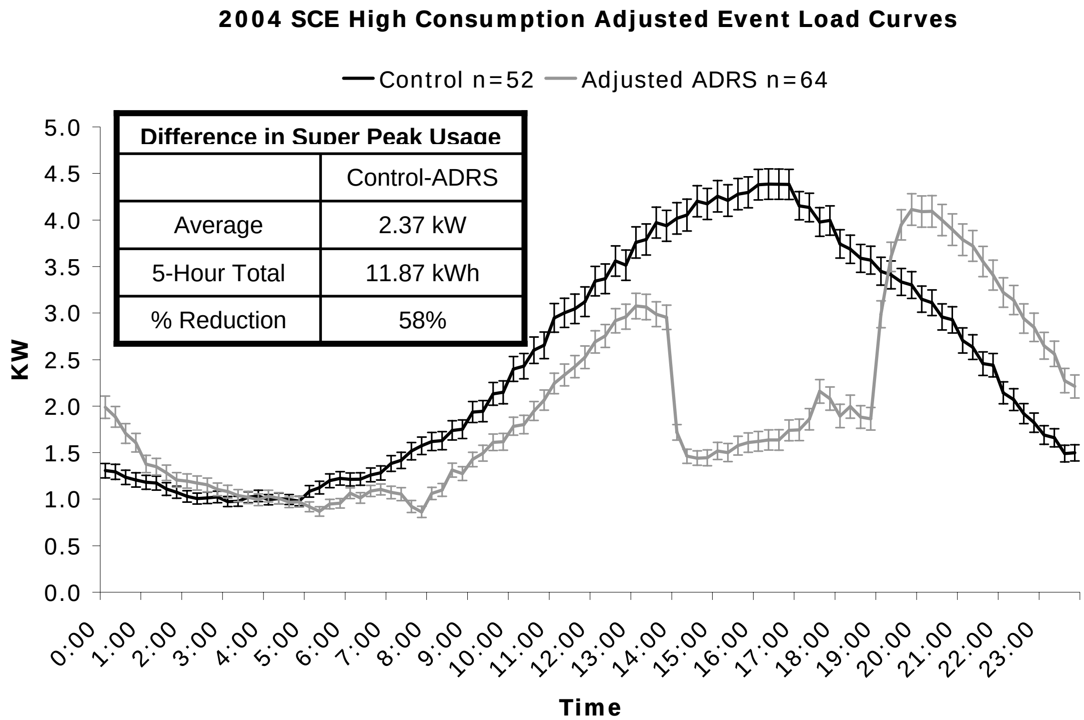
Figure 52 plots the average daily consumption by month for ADRS and control homes. Event days are shown on the left while non-event days are shown on the right. On event days, control homes consistently consume about 5-6 kWh more than ADRS homes. This difference in average daily consumption comes mainly from the ~6 kWh consumption difference between control and ADRS during the Super Peak period shown in Figure 51. The kWh difference in average daily usage on event days between ADRS and control customers varies little across summer months.

On non-event days, ADRS homes again consistently consume less than control homes. In July, ADRS homes consume an average of 4.8 kWh less than control homes, which declines to a difference of 2.3 kWh in September. Thus, the average difference in average daily consumption between ADRS and control homes is about 3 kWh.

2.3 SCE high consumption summer 2004 load impact analysis results

In Figure 53, SCE high consumption ADRS and control load curves are plotted, averaged across event days. ADRS homes in SCE territory reduce Super Peak consumption by an average of 11.87 kWh over the Super Peak period compared to control homes. This represents an average 2.37 kW or 58% reduction on event days. Ninety percent confidence intervals during the Super Peak period averaged ±0.16 kW for control homes and ±0.11 kW for ADRS homes[21].

Figure 53: 2004 SCE high consumption event day load curves



On non-event days, ADRS homes reduced load by an average of 1.12 kW compared to control customers (Figure 54). This corresponds to 38% savings, on average. Ninety percent confidence intervals during the peak period averaged ±0.07 kW for control homes and ±0.05 kW for ADRS homes[22].

[21] Super peak period fifteen-minute 90% confidence intervals ranged from ±0.15 kW to ±0.17 kW for control homes, and from ±0.08 kW to ±0.13 kW for ADRS homes.

[22] Non-event peak period fifteen-minute 90% confidence intervals ranged from ±0.06 kW to ±0.07 kW for control homes, and from ±0.04 kW to ±0.07 kW for ADRS homes.

Figure 54: SCE high consumption non-event day load curves

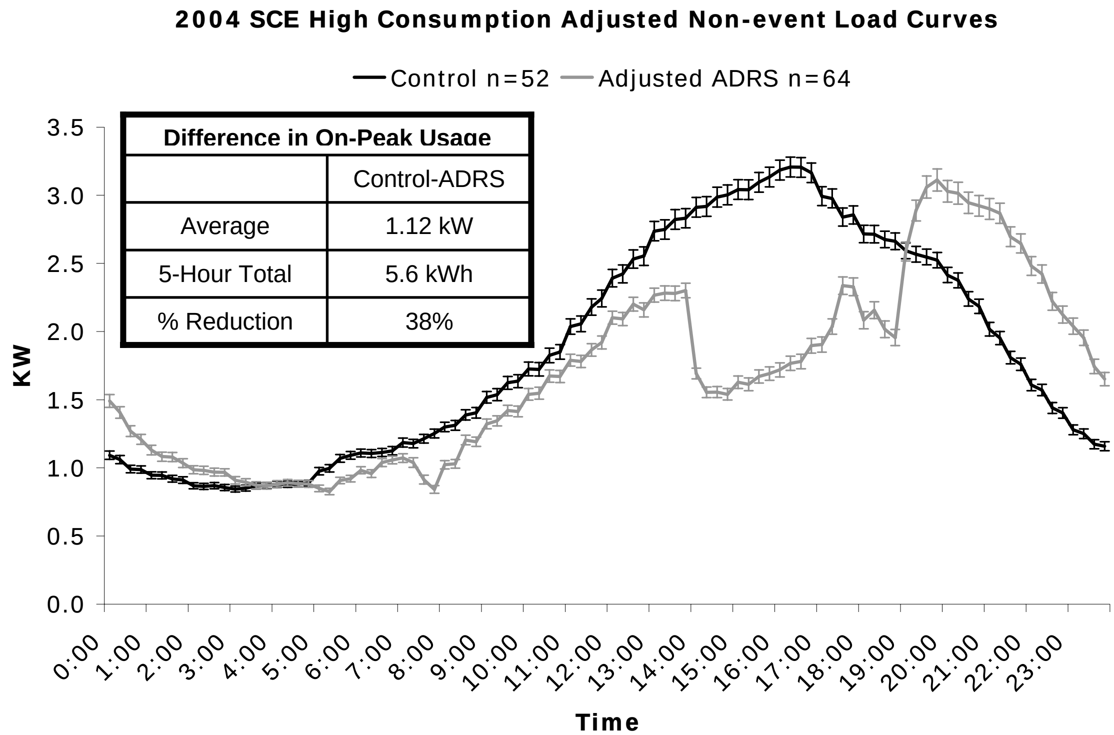
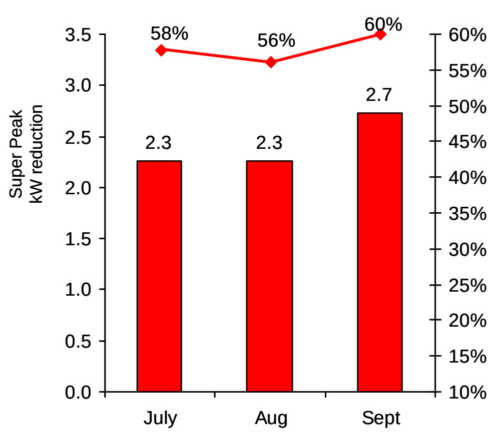
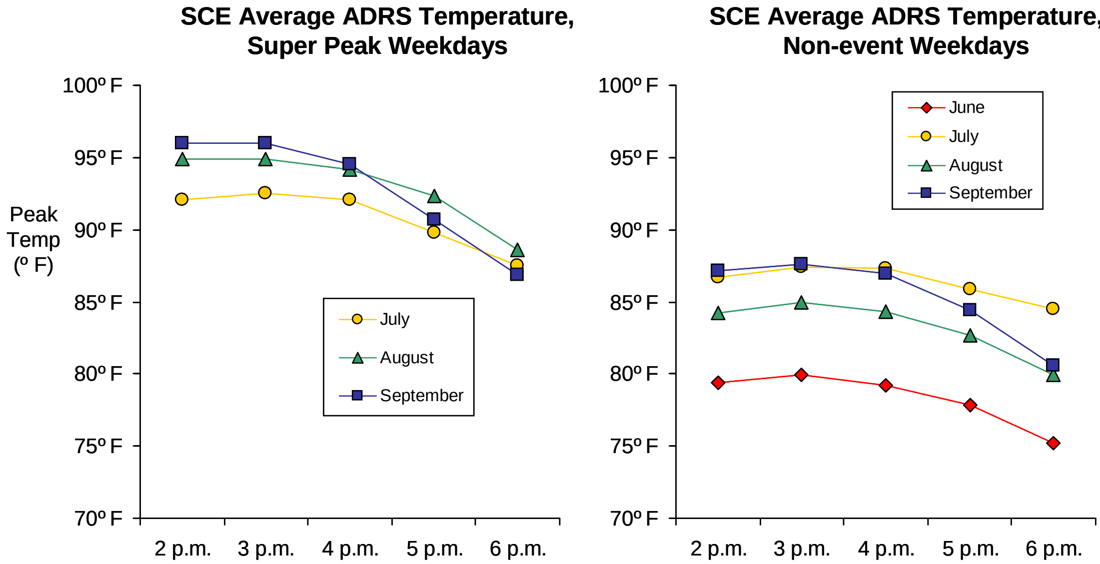


Figure 55:Average ADRS reduction in Super Peak period load, SCE high consumption homes on event days



Super Peak period savings for SCE high consumption ADRS homes are also consistent across the summer months (Figure 55). ADRS load reduction relative to control customers during July and August are the same (2.3 kW) and have roughly the same percentage savings (58% and 56% for July and August, respectively). SCE ADRS homes performance in September was the strongest, with Super Peak period savings of 2.7 kW or 60% relative to control homes.

Figure 56: Average SCE ADRS temperatures, non-event and event weekdays



Hourly temperatures for SCE ADRS homes during Super Peak periods (left chart in Figure 56) were generally hotter than peak period temperatures on non-event days. Super Peak period temperatures never dropped below 87^{o}F while on non-event days, temperatures never exceeded 87^{o}F, on average. Super Peak temperatures on event days followed a similar pattern across July, August, and September. Temperatures peaked at 3 p.m. and fell off substantially by 6 p.m. Super Peak period temperatures during September were both the hottest and the coolest that ADRS homes in SCE territory experienced, peaking at 96^{o}F at 3 p.m. and falling to 86.9^{o}F at 6 p.m., a ten-degree difference. July was the coolest month across Super Peak hours, varying from 92.5^{o}F at 3 p.m. to 87.5^{o}F at 6 p.m.

Non-event day peak period temperatures showed more variability between months than event days. June was the coolest month on average for peak period temperatures. June's average hourly temperature peaked at 80^{o}F and declined to 75^{o}F. August was the next coolest month for non-event peak period temperatures, varying from 85^{o}F to 80^{o}F. September and July featured some of the highest average peak period temperatures for non-event days. These ranged from 87.4^{o}F to 84.5^{o}F for July. September had similar peak temperatures to July's, but declined more steeply after 4 p.m. September's temperatures peaked at 87.6^{o}F and cooled to 80.6^{o}F by 6 p.m.

Figure 57: Average percent reduction in ADRS Super Peak period load for all summer events, SCE high consumption homes

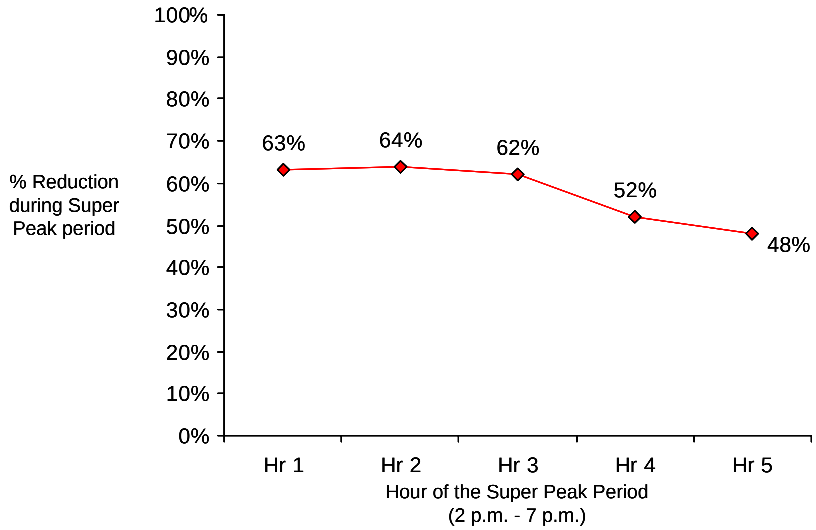


Figure 57 charts the average percent reduction of ADRS load relative to control customers for each hour during Super Peak periods. Savings were substantial and consistent during the first three hours of the Super Peak period, varying between 64% and 62% from 2 p.m. to 4 p.m. and declined slightly to 48% by the last hour. Lower savings during the last two hours of the Super Peak period can be explained by an examination of the event day load curves in Figure 53. Control load peaks at 5 p.m. while ADRS load rises steadily throughout the peak period after a large initial drop at 2 p.m. Thus, with control load declining and ADRS load still increasing after 5 p.m., ADRS savings relative to control customers decline.

Figure 58:Average ADRS reduction in Super Peak period load relative to control homes, SCE high consumption homes

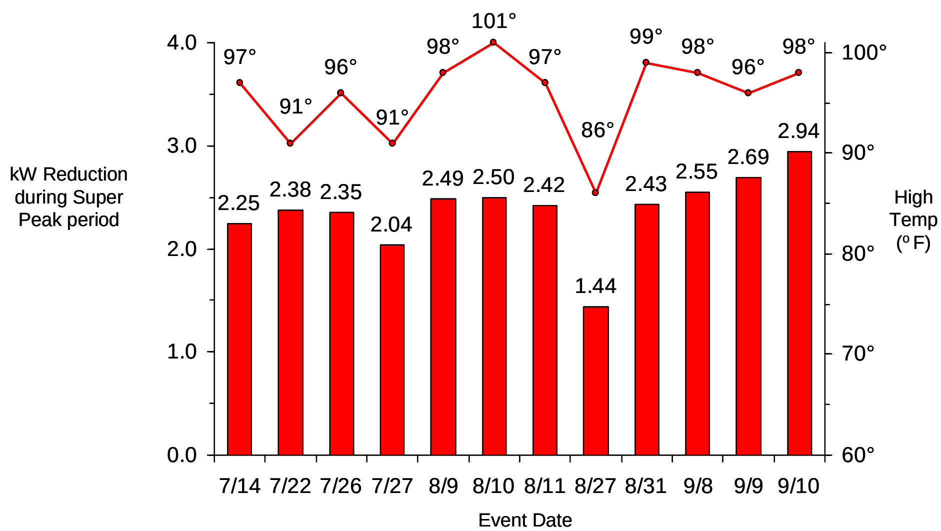


Figure 59: Average ADRS percent reduction in Super Peak period load relative to control homes, SCE high consumption homes

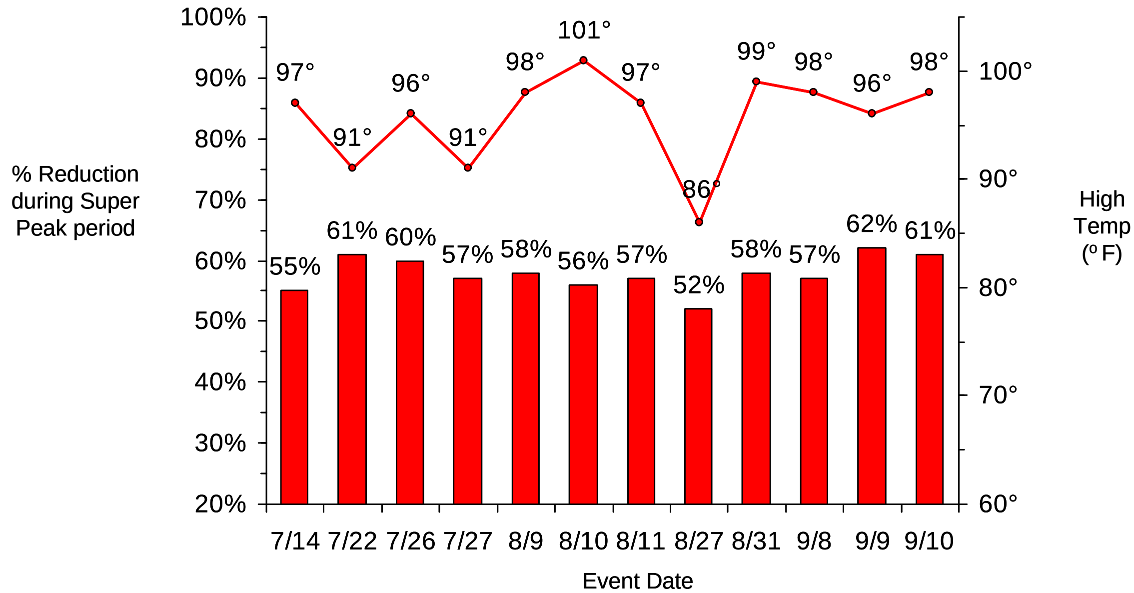


Figure 58 and Figure 59 graph Super Peak period performance of ADRS homes relative to control for each event day in 2004. Figure 58 shows the savings in terms of actual load drop and Figure 59 shows ADRS load reductions as a percentage of control customers' consumption. Average ADRS homes' peak temperature is plotted on the secondary axis for each in both figures.

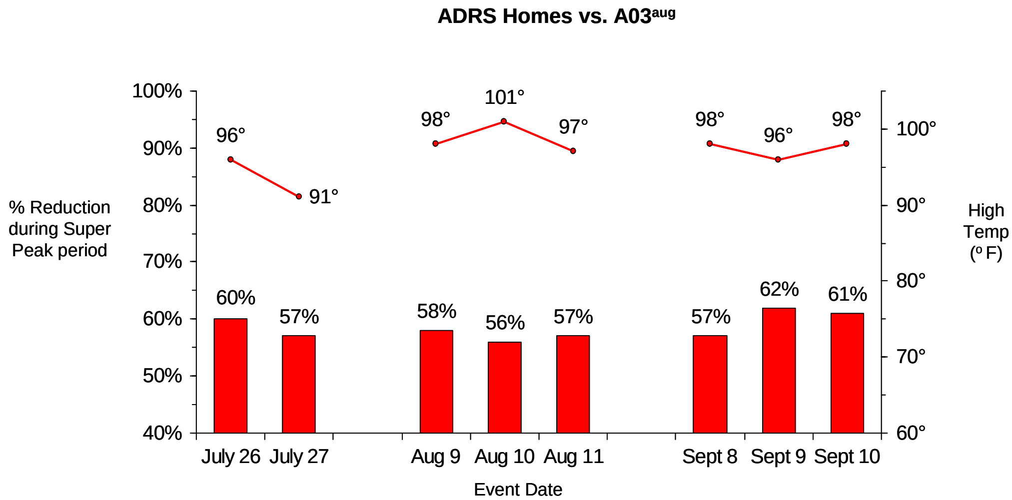
SCE ADRS high consumption customers consistently reduced load by more than 2 kW on almost all event days during summer 2004. One exception is Super Peak period savings on August 27th at 1.44 kW, which was also the coolest event day, with an average peak period temperature of 86°F in SCE territory. The highest savings of 2.94 kW occurred on September 10th. The high reduction is particularly remarkable in light of the fact that September 10th was the last event day of the summer, and the third consecutive event day. The hottest average peak temperature of 101° occurred on August 10th, which had a savings of 2.5 kW. The remaining event day savings fall within a range of 2.0 to 2.7 kW.

On a percent basis, SCE high consumption homes consistently reduced load by 55% to 62% on average during Super Peak periods. The lowest percent reduction occurred on August 27th at 52%. The highest percent reduction happened on September 9th at 62%, which is different than September 10th, the day with the highest absolute savings.

Figure 60 segregates percent performance of consecutive event days from the percent savings of ADRS homes on all event days. SCE high consumption ADRS customers maintained savings relative to control homes on consecutive event days. With the exception of July 26th and 27th, consecutive event day savings were the same or higher than the first day. The 58% savings on August 9th declined slightly to 56% on August 10th, and then rebounded slightly to 57% on

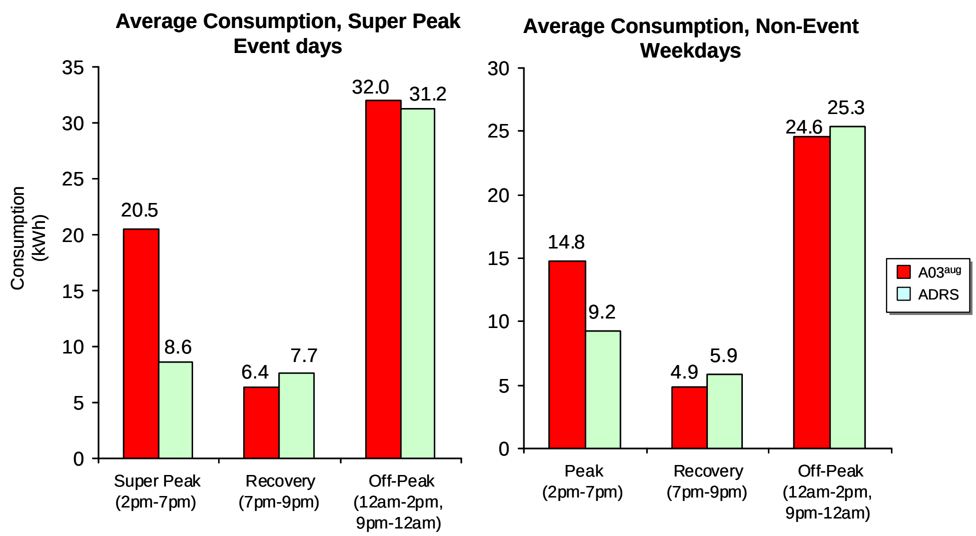
August 11th. The September consecutive days show a trend of increasing savings on consecutive days. September 8th's 57% savings increased to 62% on September 9th, which then declined slightly to 61% on September 10th. With the exception of July, there appears to be good correlation between average peak temperature and percent savings on consecutive event days. On hotter event days, control loads increase, causing ADRS load reductions as a percentage of control load to decrease.

Figure 60: Average ADRS percent reduction in Super Peak period load relative to control homes on consecutive event days, SCE high consumption homes



Average consumption of ADRS and control homes during peak, recovery, and off-peak hours is shown in Figure 61. Event days are illustrated in the left chart and non-event days are illustrated in the right chart.

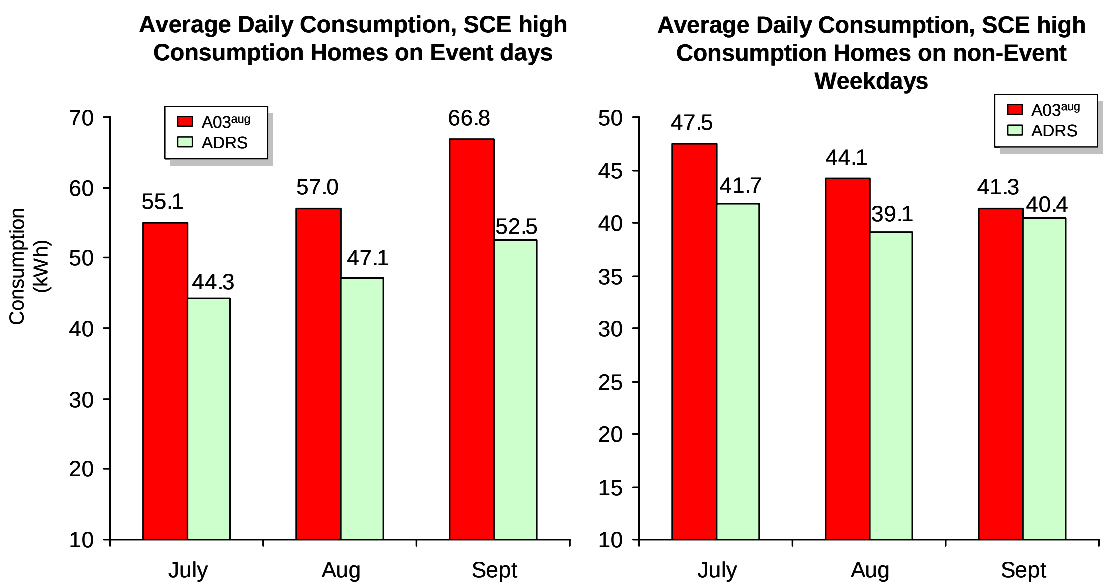
Figure 61:Average consumption, SCE high consumption ADRS and control homes on event (left) and non-event days (right)



Consumption difference during Super Peak period between control and ADRS customers is most striking. ADRS homes in SCE territory consume 12 kWh less or 42% as much energy as control homes during the Super Peak period. During the recovery period for event days, ADRS customers in SCE territory consume marginally more energy than control homes, by 1.3 kWh or 11% of peak period energy savings. This is likely explained by the automatic downward adjustment of ADRS thermostats to off-peak settings after the Super Peak period. Once the thermostats are reset at 7 p.m. to pre-Super Peak level, air conditioners in most ADRS homes turn on to meet the lower setpoint, resulting in a spike in load. Off-peak consumption for ADRS homes on event days is lower than control homes by 0.8 kWh, indicating similarity in loads during this period.

On non-event days, ADRS and control homes' relative energy consumption during peak, recovery, and off-peak periods are similar to that of corresponding periods on event days. ADRS homes consume substantially less load (38% less) than control homes during the peak period while control homes consume marginally less load during the recovery period.. ADRS consumption during the recovery period is 5.9 kWh, exceeding control consumption by 1 kWh. This reversal in consumption patterns for ADRS homes during the recovery period has the same explanation as for event days. Off-peak consumption on non-event days has ADRS consuming 25.3 kWh on average, marginally exceeding control's 24.6 kWh consumption, again indicating similarity in loads during this period.

Figure 62: Average daily consumption, SCE high consumption ADRS and control homes on event (left) and non-event (right) weekdays



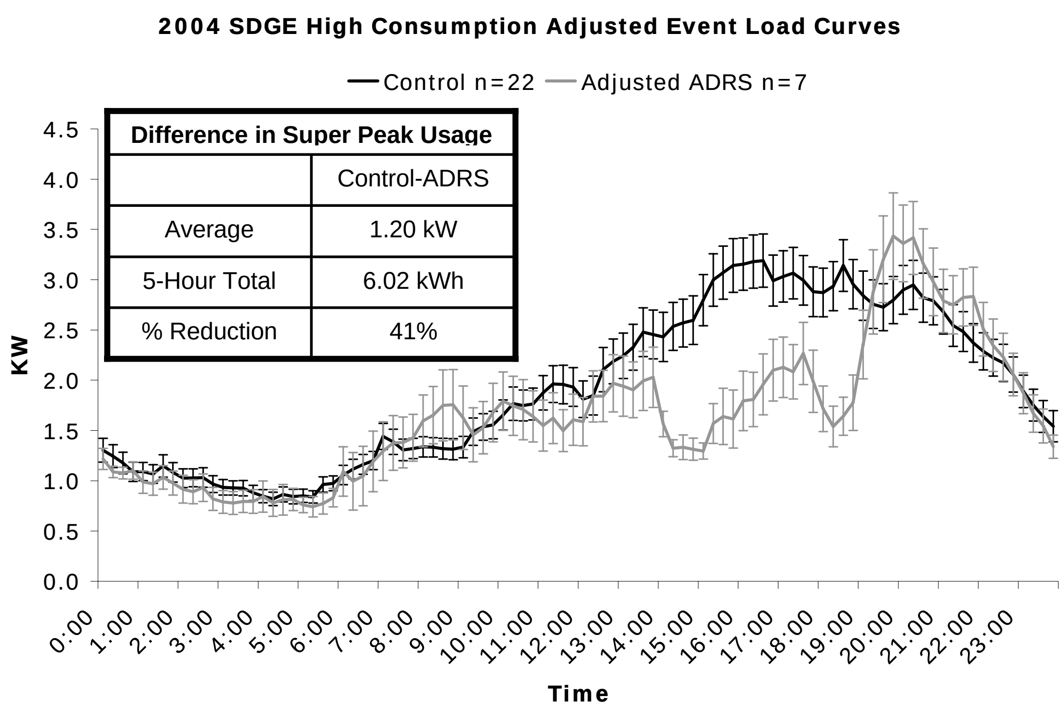
Average daily consumption for ADRS and control homes are plotted in Figure 62 by month for event days (left) and non-event days (right). For event days, ADRS high consumption homes in SCE territory consume less energy overall compared to control homes. The bulk of this reduction in average daily ADRS consumption on event days is from the Super Peak period, shown in Figure 61. July and August event days show ADRS homes consuming 10.7 and 9.9 kWh less energy than control homes, respectively. In September, the difference climbs to 14.3 kWh.

For non-event days, average ADRS daily consumption is also lower than control customers, though less dramatically than on event days. During July and August non-event days, ADRS daily consumption is lower than control customers' by 5.8 kWh and 5 kWh, respectively. In September, this difference falls to 0.9 kWh, indicating similarity in non-event day loads during this month.

2.4 SDG&E high consumption summer 2004 load impact analysis results

The average event day load curves for SDG&E high consumption ADRS and control homes are shown in Figure 63. ADRS homes reduced Super Peak period consumption by an average of 6.0 kWh on event days during the summer of 2004. This represents a 1.2 kW load drop, or 41% savings. Ninety percent confidence intervals during the Super Peak period averaged ±0.25 kW for control homes and ±0.23 kW for ADRS homes[23].

Figure 63: SDGE high consumption event day load curves



On non-event days, ADRS homes reduced Super Peak period consumption by an average of 1.87 kWh over the entire peak period (Figure 64). This corresponds with 0.37 kW, or 17% average reduction in load compared to control homes. Ninety percent confidence intervals during the peak period averaged ±0.11 kW for control homes and ±0.13 kW for ADRS homes[24].

[23] Super peak period 90% confidence intervals ranged from ±0.24 kW to ±0.27 kW for control homes, and from ±0.08 kW to ±0.31 kW for ADRS homes.

[24] Non-event peak period 90% confidence intervals ranged from ±0.10 kW to ±0.11 kW for control homes, and from ±0.10 kW to ±0.16 kW for ADRS homes.

Figure 64: SDG&E high consumption non-event day load curves

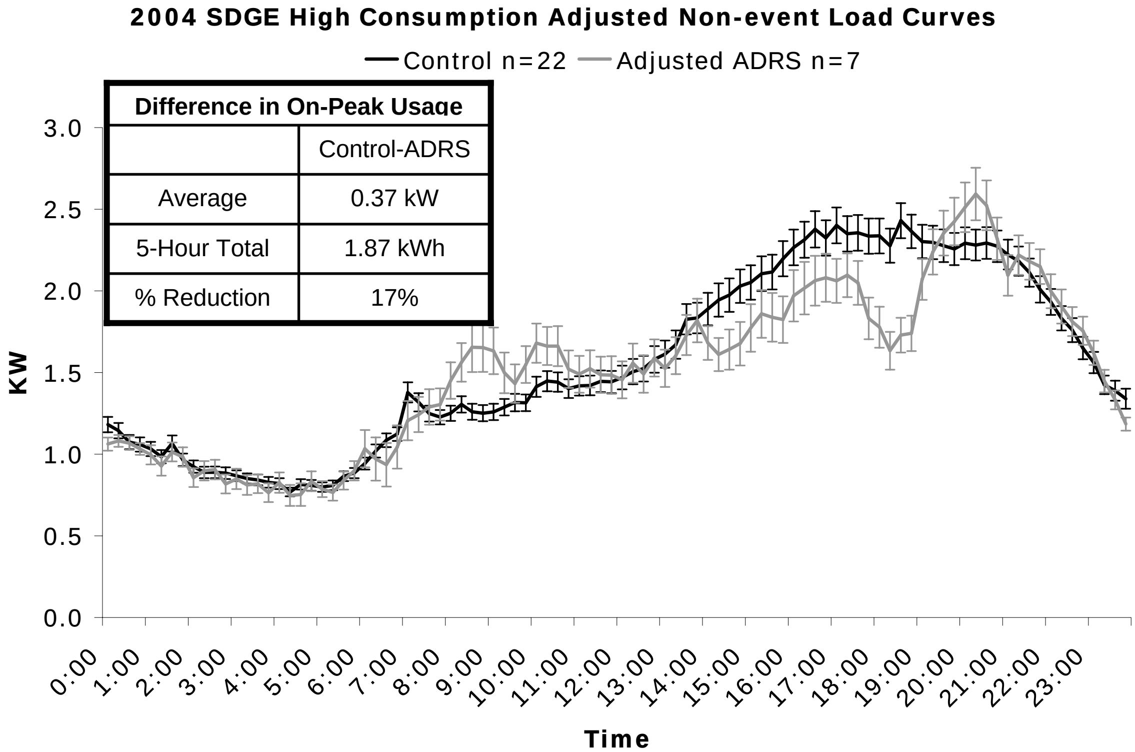


Figure 65: Average reduction in Super Peak period load, SDG&E high consumption homes

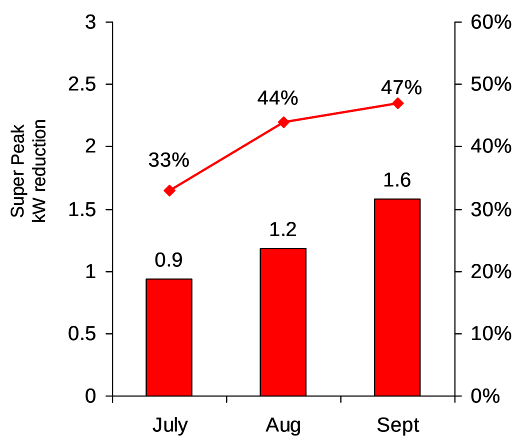
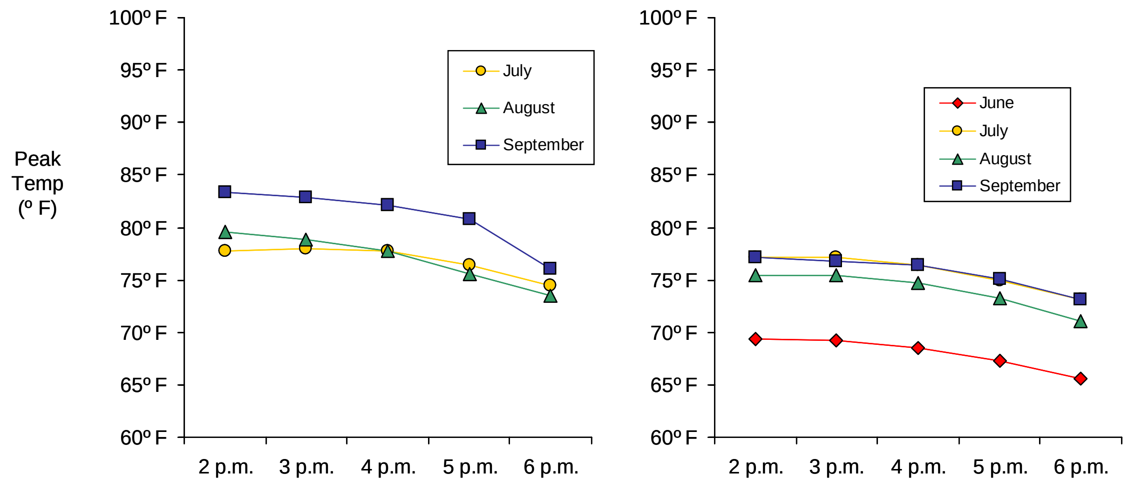


Figure 65 displays ADRS's event day peak period load reduction relative to control homes for each summer month. SDG&E ADRS savings steadily increased throughout the summer. In July, ADRS's Super Peak reduction was 0.9 kW, or 33%, and increased to 1.2 kW, or 44%, in August. ADRS load reduction in September was greatest of all, with 1.6 kW, or 47%, reduction relative to control homes.

Figure 66 charts the event and non-event day average hourly peak temperatures during the Super Peak and peak periods in SDG&E territory, respectively. The left chart displays the Super Peak period temperature averages for each summer month and the right chart displays the average peak period temperature for non-event days.

Figure 66: Average ADRS temperature, event (left) and non-event weekdays (right), SDG&E ADRS homes

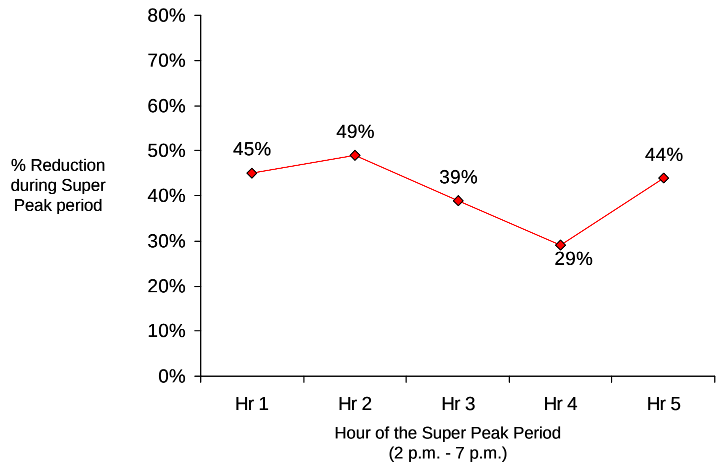


Event day temperatures in SDG&E territory were generally cool, with average peak temperatures reaching only into the low 80°F. Super Peak period temperatures generally peak at 3 p.m. and decline into the late afternoon. September event days were the hottest, averaging 83.3°F at 2 p.m. then declining to 76°F at 6 p.m. July was the coolest month, with temperatures on Super Peak days, peaking at 78°F at 3 p.m.

On non-event days, June had the lowest average afternoon temperature averages of the summer. Temperatures in July and September were warmest, and peak period temperatures were nearly identical. At 2 p.m., temperatures peaked at a mild 77°F and then declined to 73.1°F at 6 p.m. June non-event day temperatures were cool, averaging from 69.4°F to 64.6°F during the afternoon peak period.

Hourly percentage savings of ADRS homes during the Super Peak period are graphed in Figure 67. SDG&E high consumption ADRS load reductions were significant, ranging between 29% and 49% throughout the Super Peak period. There is no discernible pattern to SDG&E hourly Super Peak savings, and could be attributed to small sample size of SDG&E high consumption ADRS homes (n=7). This somewhat sporadic savings profile is also reflected in the erratic Super Peak period load profiles in Figure 63. The control load peaks at 4 p.m. then declines for the remainder of the Super Peak period. ADRS load continues to rise from 4 p.m. to 6 p.m. resulting in the decline in percent savings during the 3rd and 4th hours. At 6 p.m., ADRS load suddenly drops, resulting in a rebound in savings relative to control homes during the 5th Super Peak hour.

Figure 67:Average percent reduction in Super Peak period load, SDG&E high consumption ADRS homes



Event day Super Peak reductions for SDG&E high consumption ADRS homes are plotted in Figure 68 and Figure 69. Figure 68 represents the ADRS savings in kW and Figure 69 represents the savings as a percentage of the control load. Average maximum Super Peak day temperatures are plotted along a secondary axis above each bar chart.

Figure 68: Average reduction in Super Peak period ADRS load relative to control, SDG&E high consumption homes

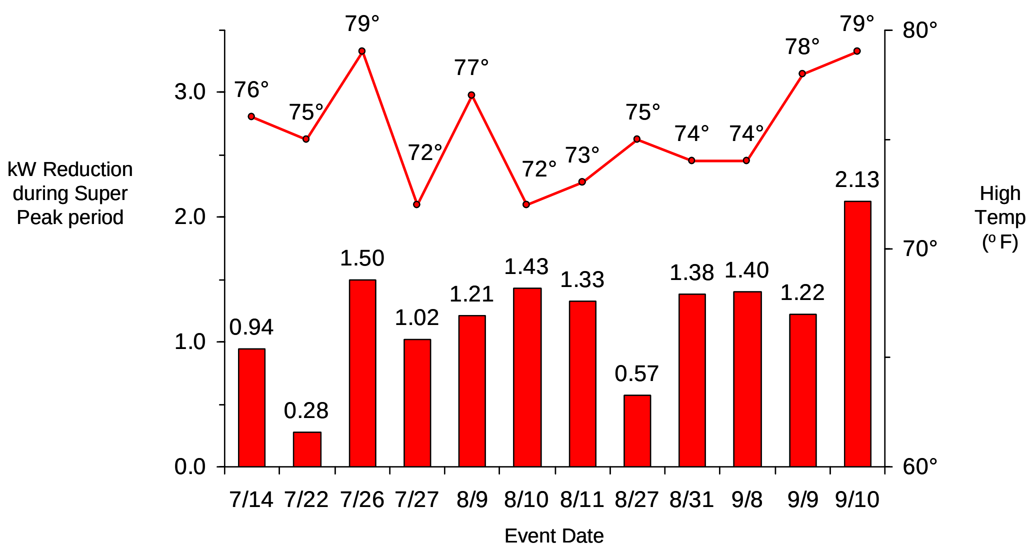
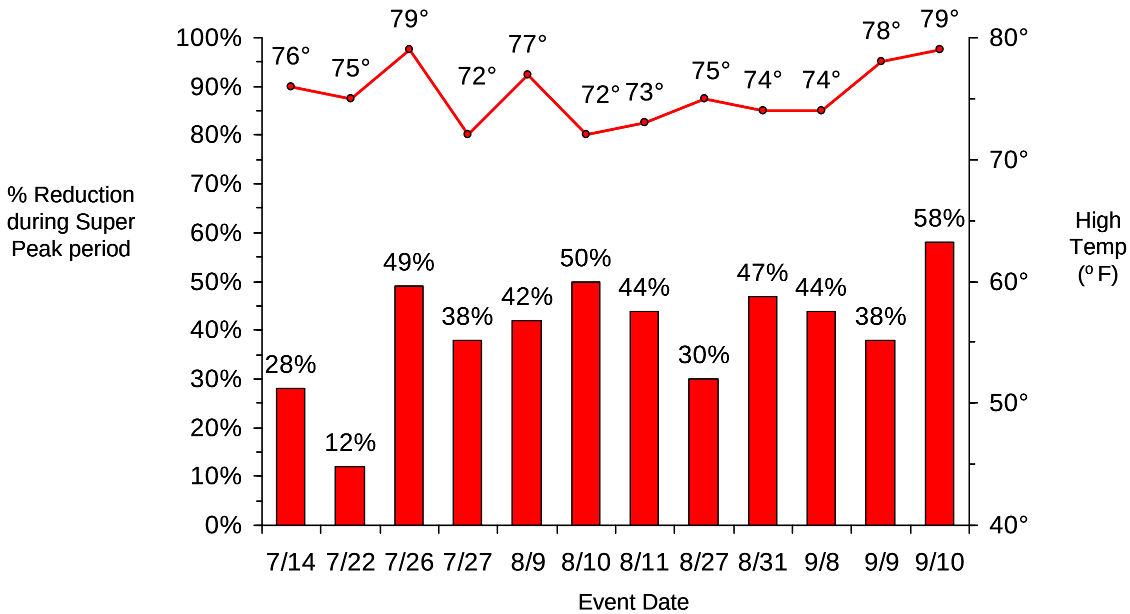


Figure 69: Average percent reduction in Super Peak period ADRS load relative to control, SDG&E high consumption homes



ADRS load reductions were inconsistent between event days on both absolute and percent bases. This was likely due to mild temperatures experienced in SDG&E territory on event days. On most event days, ADRS in SDG&E territory reduced loads relative to control by 1 kW to 1.5 kW. The smallest load reduction was on July 22nd at 0.28 kW, or 12% of control load. The maximum savings of 2.13 kW, or 58%, occurred on the last event day of the summer, September 10th, which also had the highest average peak temperature of all the event days at 79° F.

As a percentage, Super Peak period savings varied from 28% to 50%. Temperature variations do not appear to provide any insight into the variability of savings. For example, some of the largest event day savings, such as those of August 10th, 11th, and 31st, occurred in some of the mildest temperatures.

ADRS savings over consecutive event days are plotted in Figure 70. Average maximum daily temperatures are also plotted on the secondary axis. There is no consistent pattern to consecutive event day load reductions in SDG&E territory. Temperature variations do not provide any additional insight into the variability of savings on consecutive event days.

July 26th and 27th exhibit decreased savings on the second day. ADRS homes first increase then decrease load reductions on August 10th, and 11th compared to August 9th, as temperatures drop from 77°F to 72°F and 73°F on the second and third consecutive event days. In contrast to August event days, consecutive September days show the opposite pattern. September 8th savings of 44% drop to 38% on September 9th as the temperature increases from 74°F to 78°F. Then ADRS load reduction jumps to 58% on September 10th while average peak temperatures increase by only 1°F.

Figure 70: SDGE high consumption ADRS vs. A03aug

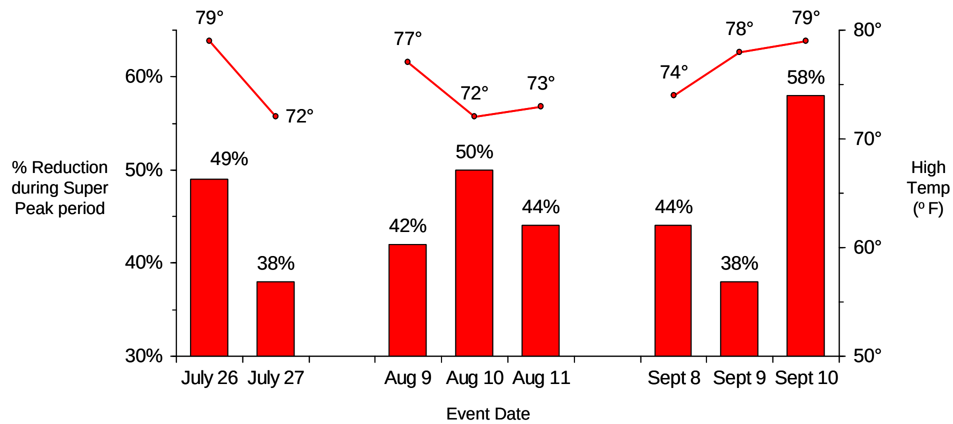
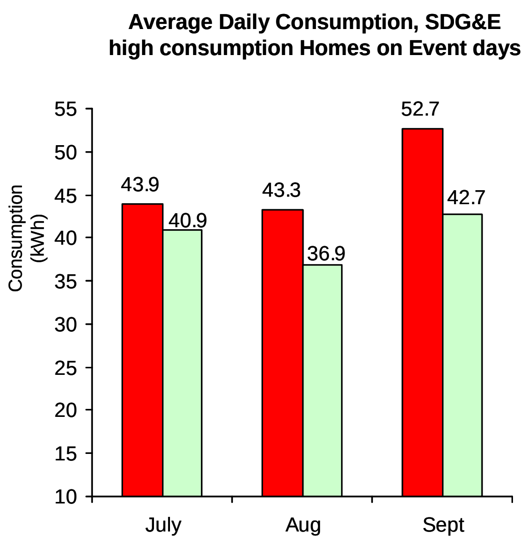
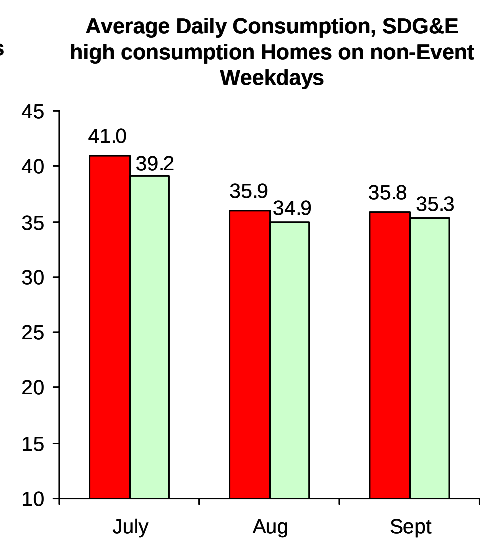


Figure 71 shows the average energy consumption for ADRS and control homes during peak, recovery, and off-peak periods on event and non-event days. On event days, ADRS homes consume 6 kWh less energy than control customers during Super Peak periods. ADRS homes consume marginally more load (0.6 kWh) during the recovery period. This reversal of consumption during the recovery period corresponds to the post-peak period rebound in consumption in the ADRS homes, which is exhibited in the spike in ADRS load at 7 p.m. This rebound is likely due to the latent air-conditioning demand in ADRS homes on event days. At the end of the Super Peak period, the thermostats in ADRS homes are suddenly reset from their warmer Super Peak setting to their cooler off-peak setting. This results in a sudden jump in load at 7 p.m. as all the air conditioners suddenly turn on to meet the new cooler setpoint. Control homes consume marginally more energy than ADRS homes (0.8 kWh) during the off-peak period, reflecting the similarity in off-peak loads.

Figure 71:Average consumption, SDG&E high consumption homes, event (left) and non-event (right) days





Non-event days consumption for PG&E high consumption homes exhibit a similar pattern. ADRS homes' peak period consumption is slightly less than control homes', while ADRS recovery consumption is slightly more than control homes'. Control homes consume marginally more than ADRS homes during off-peak periods (0.5 kWh), evincing similarity in loads during this period.

Figure 72:Average daily consumption, SDG&E high consumption homes on event (left) and non-event (right) weekdays

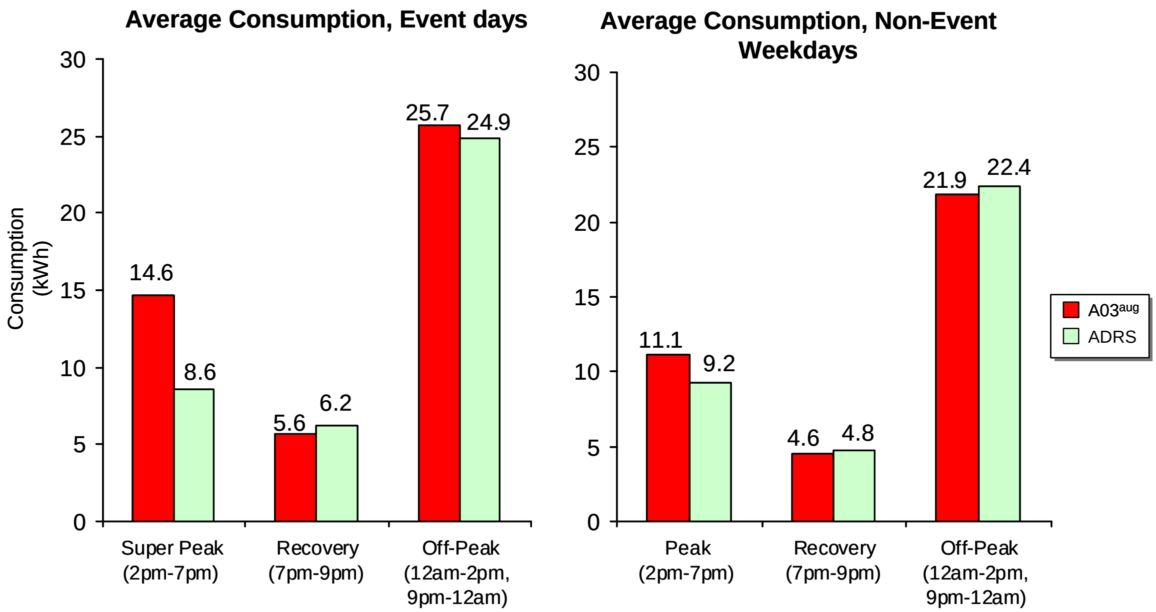


Figure 72 charts the average daily consumption by month for ADRS and control homes in the SDG&E territory. Event days are shown on the left and non-event days are shown on the right. On event days, the ADRS consumption relative to control homes decrease throughout the summer. In July, ADRS homes consume 3 kWh less than control homes. For August event days, this difference increases to 6.4 kWh. In September, high consumption ADRS homes consume 10 kWh less than control homes. From Figure 71, we observe that most of the difference in consumption comes from ADRS load reduction during the Super Peak period.

On non-event days, ADRS homes also consistently consume less energy than control homes, with the opposite monthly trend as the event days. In July, there is a 1.8 kWh difference in consumption. This diminishes to a 1 kWh difference in August and then to a 0.5 kWh difference in September.

2.5 Summary of ADRS 2004 load impact results

Following adjustments for selection bias of ADRS customers and addition of high consumption control homes, load impact results are stable and improved. Customers with ADRS technology and subject to CPP-F rates in climate zone 3 successfully achieved load reductions compared to control customers without ADRS technology on standard tiered rates in 2004. The load reductions are substantial and stable across a range of days and temperatures.

Compared to A07 homes statewide, which reduced their load with only the Super Peak rate stimulus on event days but without the assistance of ADRS technology, ADRS customers also achieved load reductions successfully across a range of days and temperatures. Following adjustments for selection bias of ADRS customers and adjusting for selection bias of A07 customers, RMI's reported results for A07 load reductions on event days matches the results reported by the CEC in 2004 and is similar to the results reported by CRA in 2004 on a percentage basis.

Load reduction performance for customers with ADRS technology and subject to CPP-F rates varied between utilities across the state, when compared to control customers. SCE high consumption ADRS customers achieved more than 2 kW reductions on event days across a range of temperatures. PG&E and SDG&E high consumption ADRS customers achieved substantial, but lower reductions, just over 1 kW on event days on average.

Homes with ADRS technology produced a consistent and predictable load profile during Super Peak and peak periods. Reductions were at their maximum at the start of the period, then gradually increased as homes warmed up and air conditioners pulsed on to maintain indoor temperatures at the higher set point. There was typically a dramatic recovery in load immediately following the Super Peak or peak periods, when thermostats in ADRS homes automatically reset from their warmer Super Peak or peak settings to their cooler off-peak setting.

In 2004, high consumption ADRS homes achieved some reduction in daily energy consumption in addition to shifting load from peak to off-peak periods. Most of the reduction in daily energy consumption was from load shifting during the Super Peak and peak periods, rather than additional energy reductions during the off-peak periods. This was true for ADRS customers from all three utility service territories.

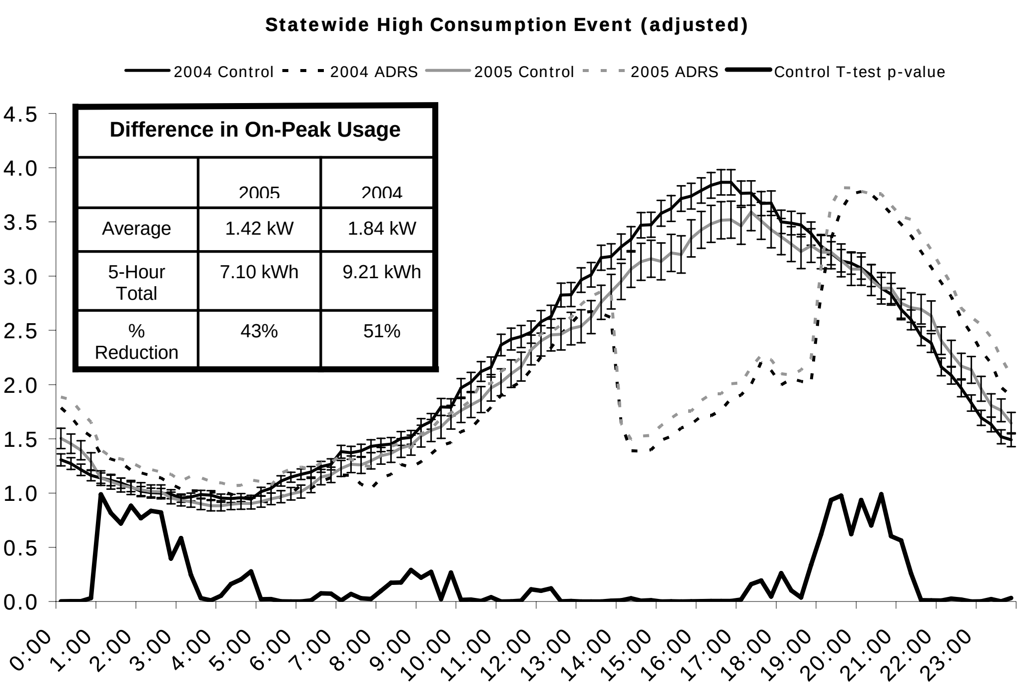
Chapter 3 Comparison of summer 2005 and summer 2004 ADRS load impact results

The following section compares the load reduction performance of customers participating in the ADRS pilot during the summer of 2005 to load reduction performance during the summer of 2004. ADRS participants are households with technology and subject to experimental CPP-F rate compared to homes without technology and subscribed to standard tiered rates. Load reductions are first reported on a statewide basis for high consumption homes, followed by results for high consumption ADRS participants in each utility service territory of PG&E, SCE, and SDG&E, respectively. A summary of results for low consumption ADRS homes is then provided on a statewide basis, then for each utility individually. All load impact results have been adjusted for selection bias of ADRS homes. Details of RMI's investigation into selection bias are presented in Appendix C.

3.1   Comparison of 2005 and 2004 high consumption ADRS load impact, statewide

Statewide high consumption average daily load curves are shown in Figure 73 and Figure 74 for both summer 2004 and summer 2005 event and non-event weekdays. Also drawn are ninety percent confidence intervals for each 15-minute period of control load as well as the t-test p-values evaluating the statistical similarity of control loads between years.

Figure 73: Statewide high consumption event load curves: 2004 and 2005

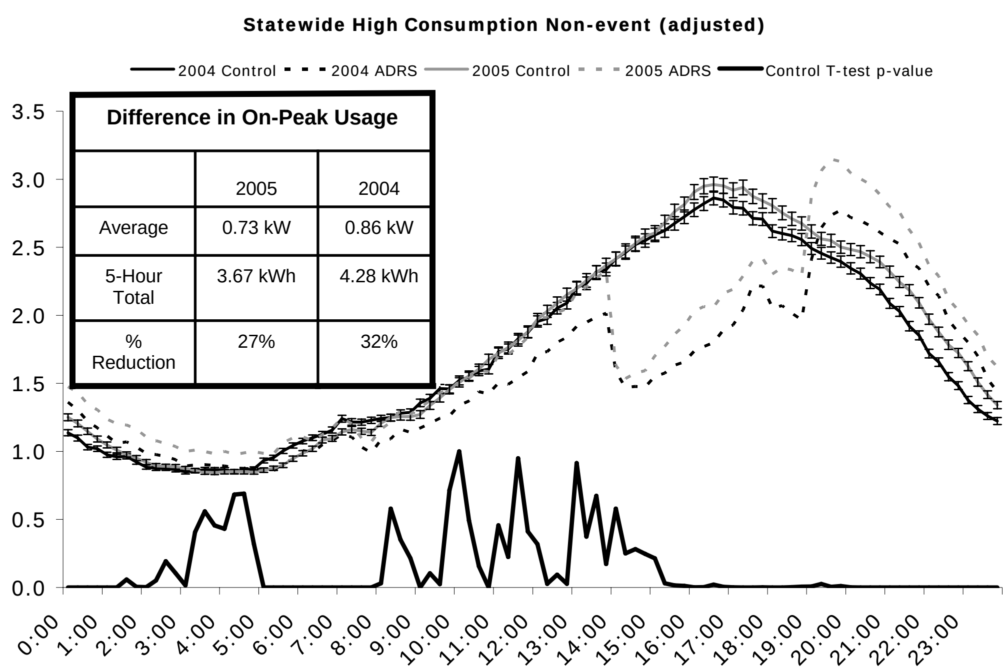


On event days, ADRS homes in 2005 show a 1.37 kW, or 42% reduction in Super Peak load compared to control. This result was less than in 2004, when ADRS load reductions were 1.81 kW, or 51% compared to control. Total energy reduction across the Super Peak period was 6.8 kWh in 2005 and 9.3 kWh in 2004. Nonetheless, ADRS load reductions during both years were substantial. The smaller load reduction in 2005 appears to be mostly a result of lower control load during the Super Peak period rather than the slight increase in ADRS load.

Examining the results in more detail, ADRS loads in 2005 and 2004 match closely, with ADRS load higher by 8% in 2005 than in 2004 load over the whole day, and 7% higher during the Super Peak period specifically. This makes sense, as average event day temperatures were slightly higher in 2005 (refer to Figure 75), so it is reasonable that 2005 loads were slightly higher.

Control loads in 2005 compared to 2004 show the opposite behavior. Event day control load in 2005 matches 2004 load closely through much of the morning off-peak period. During the Super Peak period, control load in 2005 was significantly less than load in 2004 by approximately 8%. The near zero p-values in Figure 73 from late morning through the Super Peak period mean that there is a near zero probability (low) that differences in control loads between the two years are due to random chance (see Appendix B for a review of statistical tools used in this report). This result is counterintuitive given that summer 2005 was hotter than summer 2004, on average. The 2005 control load, furthermore, represents the averages *after* the removal of anomalous control homes from the dataset[25]. We cannot explain this behavior of high consumption control homes with the available load data.

Figure 74: Statewide high consumption non-event load curves: 2004 and 2005



[25]Refer to Appendix A of this report, Data Collection and Load Impact Analysis Methodology for details of high consumption control homes data verification and removal of outliers in the 2005 load impact analysis.

On non-event days, ADRS load reductions compared to control averaged 0.73 kW or 3.7 kWh in 2005, compared to 0.86 kW or 4.3 kWh across the peak period in 2004 (Figure 74). On a percentage basis, high consumption ADRS homes reduced load by 27% in 2004 and 32% in 2005, respectively.

Non-event weekday control customers' load in 2005 compared to 2004 displayed a different pattern than event-day loads for the two years. Control customers' loads on non-event days were similar in 2005 and 2004 for much of the morning off-peak period through the first two hours of the peak period. After 4 p.m., however, 2005 control load exceeded 2004 control load for the remainder of the peak period. This is as expected due to higher average non-event weekday temperatures in 2005 (see Figure 75).

ADRS loads in 2005 also surpassed 2004 ADRS loads, especially during the peak and following recovery periods. However, note that the 2 p.m. ADRS load dropped further in 2005 than 2004, but recovered more quickly during the rest of the peak period, resulting in modestly reduced savings overall. This observation is consistent with the explanation that hotter summer weather causes the indoor temperatures to rise to the on-peak thermostat set point faster.

Figure 75 confirms that 2005 was a hotter year during the summer season. The figure displays the average peak temperatures by month over all the high consumption homes. With the exception of September non-event weekdays, 2005 featured higher average peak temperatures than 2004. Event day temperatures in 2005 were hot, ranging from 93°F to 96 °F on average during Super Peak period over the summer months. Corresponding event day peak temperatures in 2004 varied in the 87°F to 90°F range, about eight degrees lower than 2005 temperatures. Non-event day temperatures were not much cooler than event day temperatures in 2005, averaging at 91°F and 89°F, respectively, in July and August. Corresponding 2004 temperatures in July and August were much cooler on non-event days, averaging between 82°F and 84°F, about ten degrees lower than in 2005. September temperatures in 2005 averaged just one degree higher than in 2004, indicating similarity in climate between the two years during that month.

Figure 75: 2004 and 2005 average peak temperatures by month

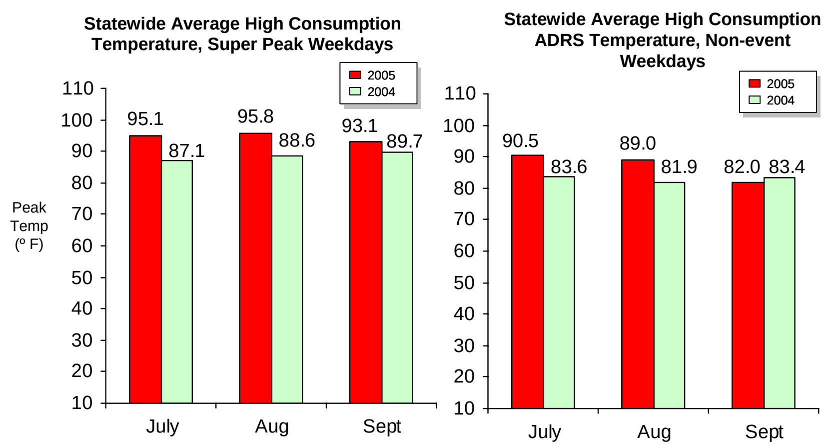


Figure 76 compares the 2004 and 2005 percent load reductions during Super Peak hours for high consumption homes statewide. Overall, Figure 76 demonstrates the constancy of strong ADRS performance over consecutive years. High consumption ADRS load reductions in 2005 and 2004 were at their maximum during the first Super Peak hours, and declined modestly on a percentage basis until the end of the Super Peak period. In 2005, hourly ADRS reductions compared to control homes declined from 50% to 35% over the peak period. Hourly Super Peak period reductions in 2004 were slightly higher, from 57% at 2 p.m. to 42% by 6 p.m. Thus, percent load reductions in 2004 were consistently 7-10% more than 2005. Recall that high consumption control loads were curiously higher in 2004 than 2005 in spite of the fact that 2004 was a cooler summer. Otherwise, both years feature about a 15% decline in load reduction performance over the five hour Super Peak period.

Figure 76: 2004 and 2005 statewide high consumption Super Peak hourly percent load reductions

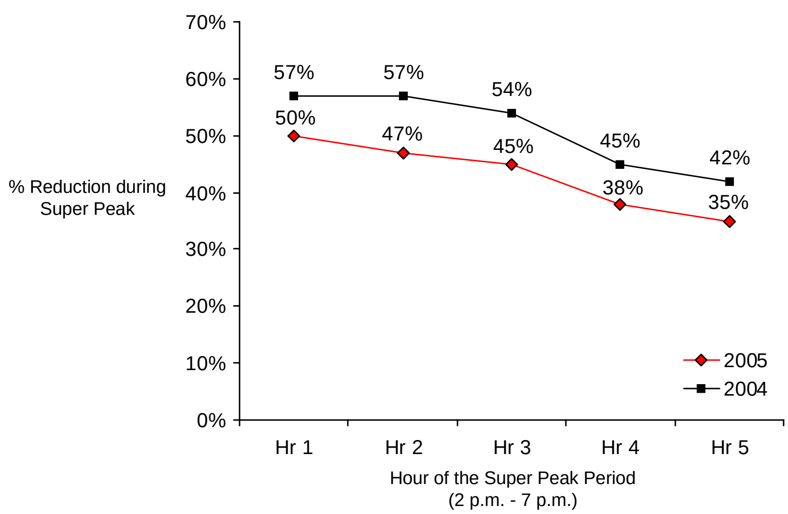


Figure 77 and Figure 78 plot the Super Peak period load reductions of high consumption ADRS homes statewide for 2005 and 2004, respectively. 2005 ADRS Super Peak reductions were consistently less than on 2004 event days, indicating the consistency of lower peak period control load over all 2005 events.

On a monthly basis for event days, only July can be used for intra-year comparison. Event days in July 2005 exhibited smaller ADRS load reductions compared to July 2004 events on average. There were five events called in August 2004 while only one event was called in August 2005. With only one data point for August 2005 event days, we cannot be certain event day performance was typical of Super Peak period ADRS load reduction for that month. September events in 2005 come at the end of the month, after the beginning of autumn. This likely accounts for their markedly reduced savings compared to the September 2004 events, which were called early in the month, just after Labor Day.

Figure 77: 2005 statewide high consumption Super Peak period load reductions by event day: in kW

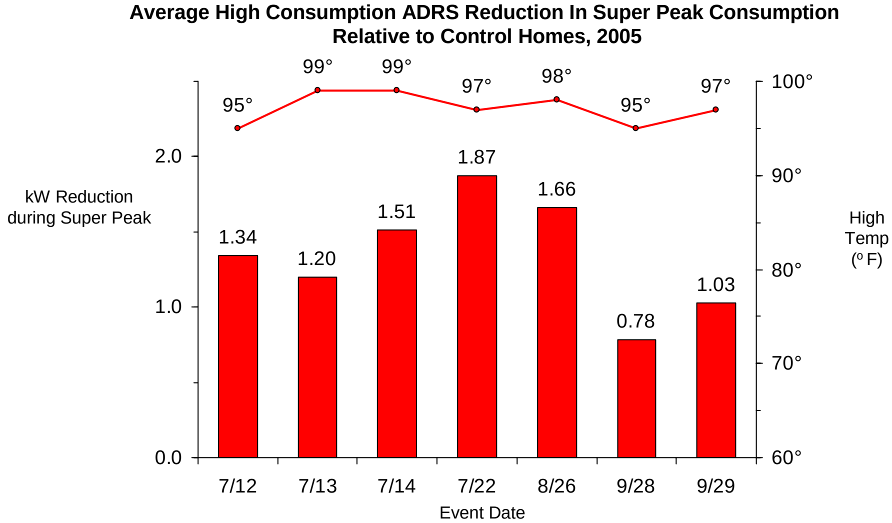
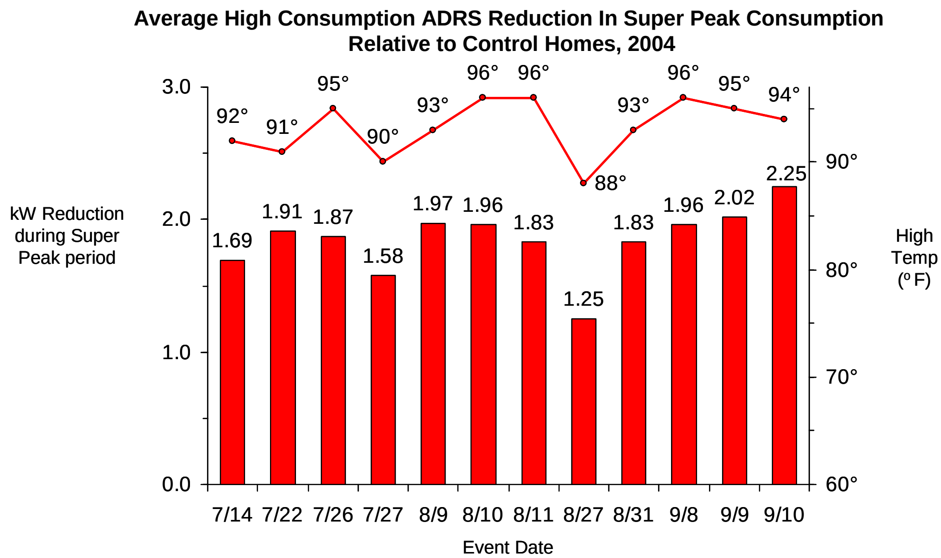


Figure 78: 2004 statewide high consumption Super Peak load reductions by event day: in kW



Event day load reductions on a percentage basis are graphed in Figure 79 and Figure 80 for 2005 and 2004 respectively. Again, only July is relevant for direct intra-year comparison. In general however, percent load reductions in 2005 were lower than in 2004. 2005 percent load reductions range from 34%-47% from July through September, while 2004 reductions vary from 47%-56%.

Figure 79: 2005 statewide high consumption Super Peak percent load reductions by event day

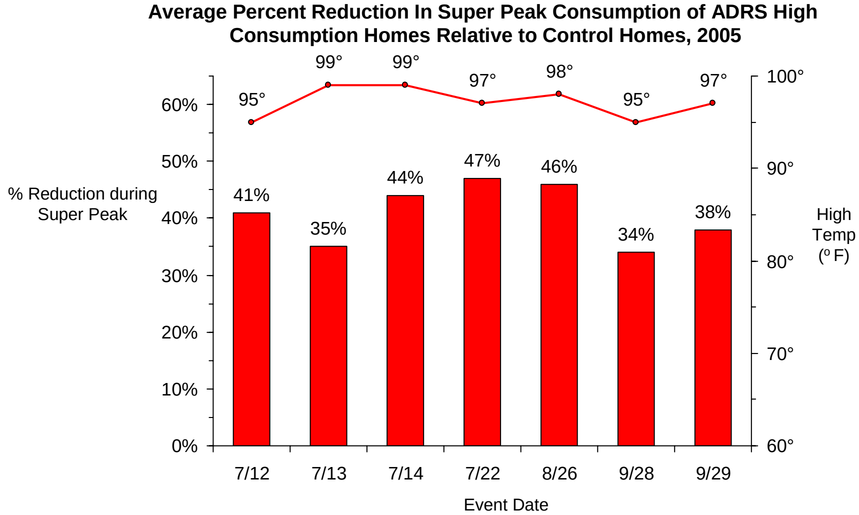


Figure 80: 2004 statewide high consumption Super Peak load percent reductions by event day

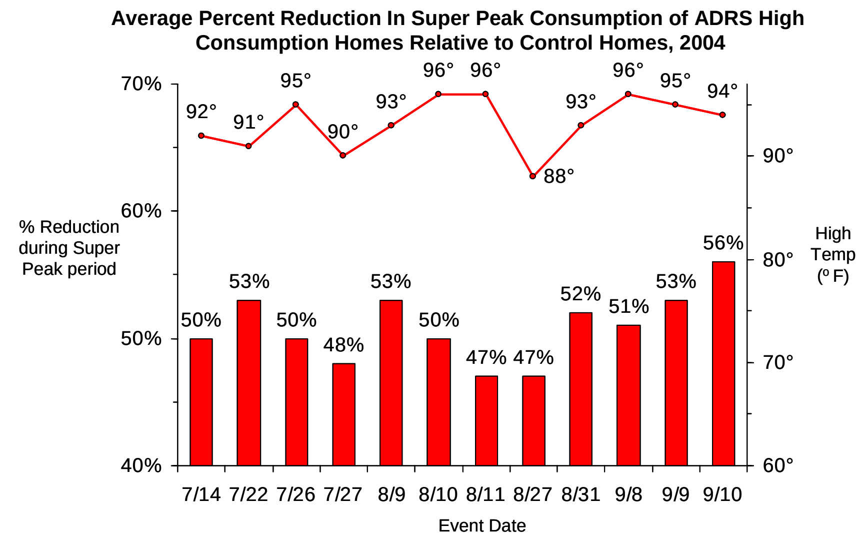


Figure 81 reports both statewide percent load reductions and corresponding average Super Peak temperatures over consecutive event days for 2005 (left) and 2004 (right). High consumption ADRS load reductions were consistent across consecutive event days, with reductions varying narrowly between 34% and 44% in 2005 and between 47% and 56% in 2004. The 2005 percent load reductions generally show higher variability over consecutive days compared to 2004. Consecutive events in July for both years show a second day drop in performance. Consecutive events in September for both years show a second day increase in performance. No consistent pattern is observed between changes in temperature and percent reductions over consecutive event days -- either within or between years.

Figure 81: statewide high consumption 2004 and 2005 consecutive event day Super Peak period load reductions: in percent

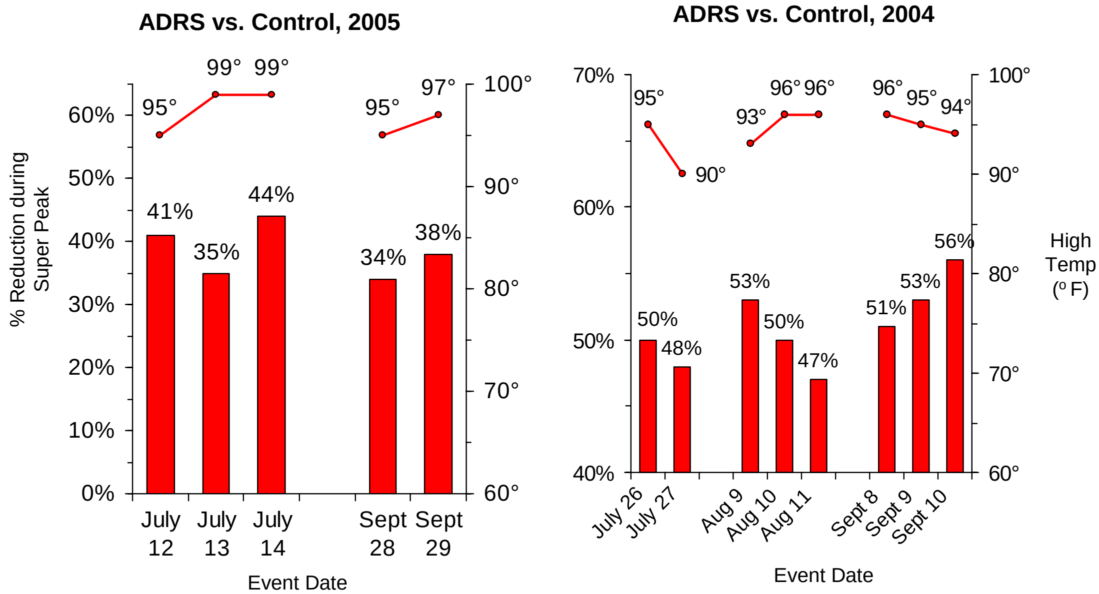


Figure 82 and Figure 83 segment average daily consumption of ADRS and control customer loads into peak, recovery, and off-peak periods for 2005 and 2004. In both figures, event day averages are shown on the left and non-event weekdays are shown on the right. Because of load reductions during Super Peak periods, ADRS high consumption homes consumed less energy than control homes during the period in both 2004 and 2005. In 2005, ADRS homes reduced energy consumption by 7 kWh compared to control homes. In 2004, ADRS customers consumed 9.2 kWh less energy relative to control customer during Super Peak periods.

Figure 82: 2005 statewide high consumption homes, usage by period

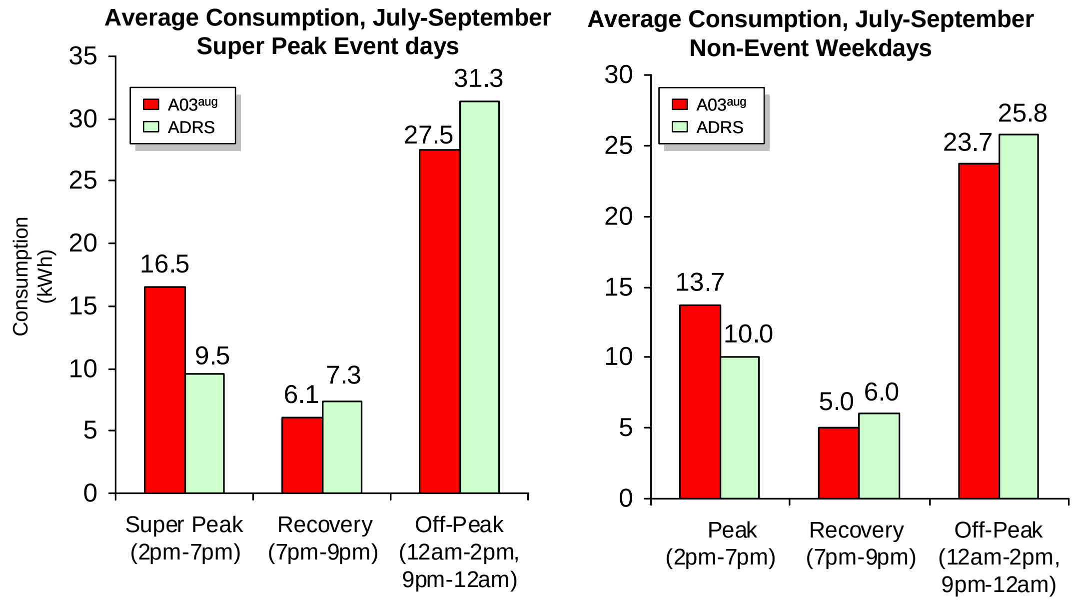
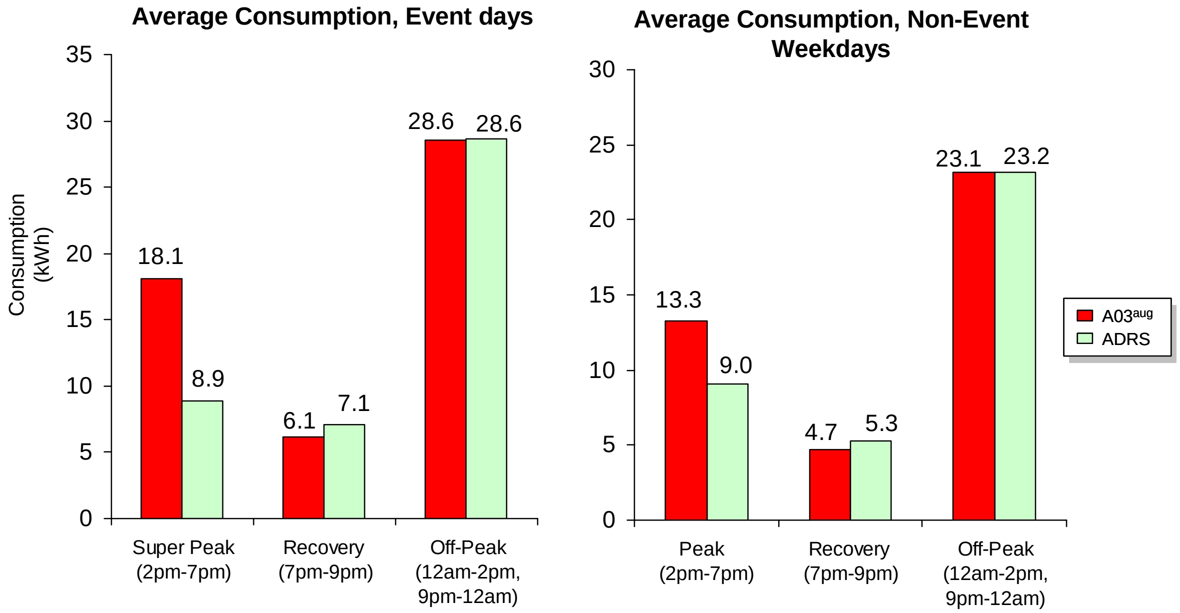


Figure 83: 2004 statewide high consumption homes, usage by period



During the recovery period from 7 p.m. to 9 p.m. on event days, ADRS customer consumption rebounded to exceed control consumption by 1.2 kWh in 2005 and by 1.0 kWh in 2004 as ADRS thermostats were reset to off-peak period set points. ADRS homes also consumed more than control homes in the off-peak periods on event days in 2005, by 3.7 kWh. Off-peak period consumption on event days between ADRS and control customers was the same in 2004. The load-shifting away from the Super Peak in ADRS homes is apparent in the relatively higher ADRS consumption in recovery and off-peak periods in 2005 and 2004.

Non-event day consumption patterns in 2005 and 2004 show the same trends as event days, though differences between ADRS and control customers were more modest in 2005. ADRS homes reduced peak period consumption by 3.7 kWh in 2005. These energy reductions compared to control customers were nearly cancelled out by the greater ADRS consumption during the recovery period and off-peak hours, when ADRS homes consumed 1.0 kWh more and 2.1 kWh more than control homes in 2005 and 2004, respectively. Hence, the non-event day peak period reductions represent load shifting to off-peak periods rather than overall reduction in energy consumption over the whole day.

Non-event weekday consumption reflects this same pattern in 2004. ADRS homes achieved peak period savings of 4.3 kWh with a recovery rebound of only 0.6 kWh relative to control. Off-peak consumption was nearly equivalent between ADRS and control homes in 2004. Hence, both load shifting and energy conservation were present during 2004 non-event weekdays as well.

Figure 84 charts the 2005 average daily energy consumption for high consumption ADRS and control homes on event (left) and non-event weekdays (right), statewide. Figure 85 plots the average daily consumption for ADRS and control groups on event and non-event days in 2004. Comparing across years, ADRS homes exhibited conservation behavior on event days in both years. On non-event days, however, ADRS homes exhibited conservation in 2004, but virtually no conservation in 2005.ADRS homes consistently consumed less average daily energy than control homes over all summer months on both event and non-event days in both 2004 and 2005.

Figure 84: 2005 statewide high consumption homes, average daily usage by month

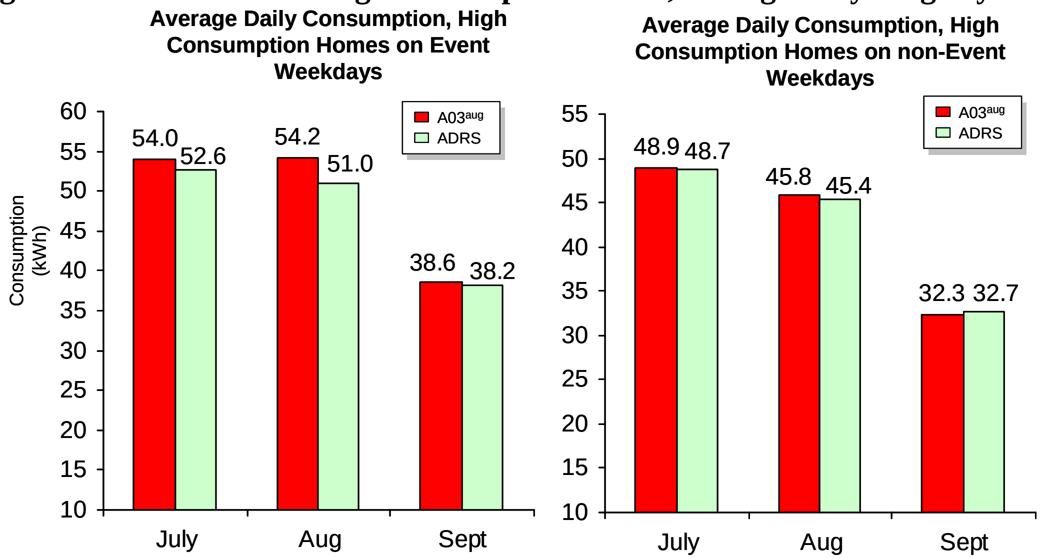
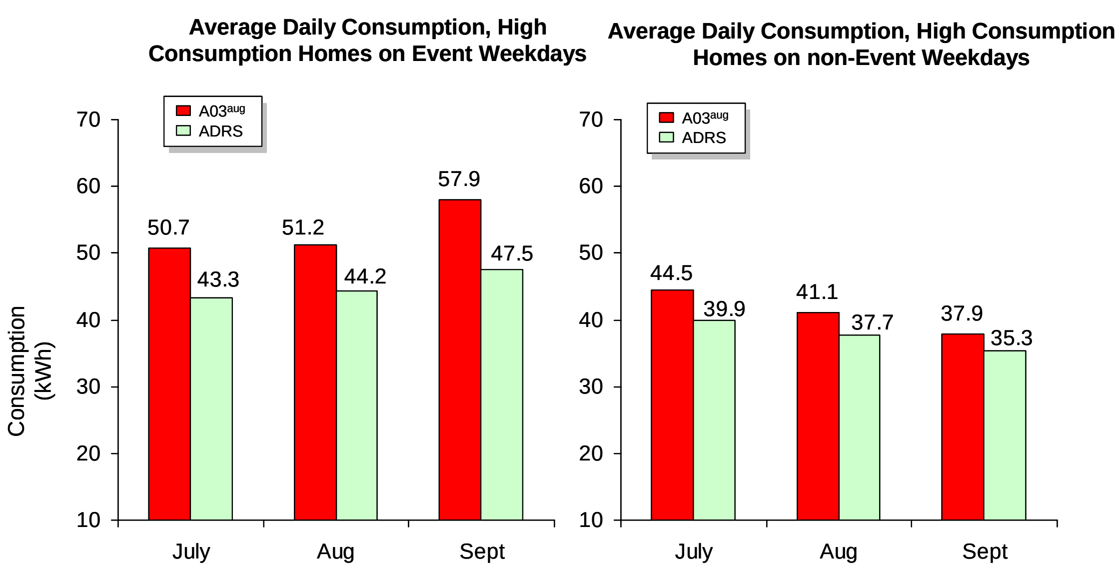


Figure 85: 2004 statewide high consumption homes, average daily usage by month



Comparing between years, average daily energy consumption of both ADRS and control customers were considerably greater in 2005 than in 2004 on both event and non-event days, with the exception of September. Event days and non-event weekdays in September 2005 featured substantially reduced overall consumption compared to other months. In contrast, September event and non-event days in 2004 featured similar ADRS and control consumption compared to other months. This corroborates the notion that the September event days in 2005, which were called at the end of the month, reflect a transition to autumn climate and different consumption behavior.

On event days in 2005, ADRS homes consumed 2.5 kWh and 3.2 kWh less than control homes in July and August, respectively. On September event days in 2005, the difference in ADRS and control customer energy consumption was only 0.4 kWh, demonstrating only a small conservation effect. On event days in 2004, ADRS customers generated greater energy savings than in 2005, between 7-10 kWh less than control customers' consumption from July through September. From Figure 82 and Figure 83, we see that most of this reduction in ADRS consumption on event days comes from the Super Peak period.

On non-event days in 2005, average daily energy consumption in ADRS and control groups was virtually the same from July through September, indicating that ADRS customers used the technology mostly to shift load to off-peak hours without any net conservation effect. This may also be due in part to lower control customer loads in 2005. On non-event days in 2004, on the other hand, ADRS customers consistently consumed marginally less energy than control customers across all summer months.

3.2 Comparison of 2005 and 2004 high consumption ADRS load impact, PG&E

Figure 86 superimposes high consumption control and ADRS customer loads in PG&E service territory for both 2004 and 2005 summers. Ninety percent confidence intervals are drawn around control loads for each 15-minute period. The black line along the bottom of the chart displays the t-test p-value for each 15-minute period, which evaluates the probability that control home load differences between 2004 and 2005 were due to random chance.

ADRS loads correspond closely with each other between summer 2005 and summer 2004, especially during the Super Peak period. ADRS load during the Super Peak Period in 2005 was negligibly higher than in 2004, by only 0.3 kWh or 3%. However, average control customer load in 2005 was significantly less than in 2004 during the Super Peak period and subsequent recovery period, as indicated by the near zero p-values. Super Peak period control customer load in 2004 was 12% or 0.4 kW on average lower than in 2005. During the morning and late evening off-peak periods, both ADRS and control homes had similar loads in both years.

Due mostly to the downward shift in 2005 control load during the Super Peak period, ADRS load reduction relative to control homes was less in 2005 than in 2004. ADRS homes in 2005 reduced Super Peak period load by an average of 0.83 kW or 4.2 kWh, compared to 1.29 kW or 6.4 kWh in 2004. On a percent basis, 2005 ADRS homes saved 29% of 2005 control load, compared to 39% in 2004. Notwithstanding changes in control customer load between years, high consumption ADRS homes in PG&E territory achieved consistent and significant Super Peak load reductions on event days.

Figure 86: PG&E high consumption 2004 and 2005 event day load curves

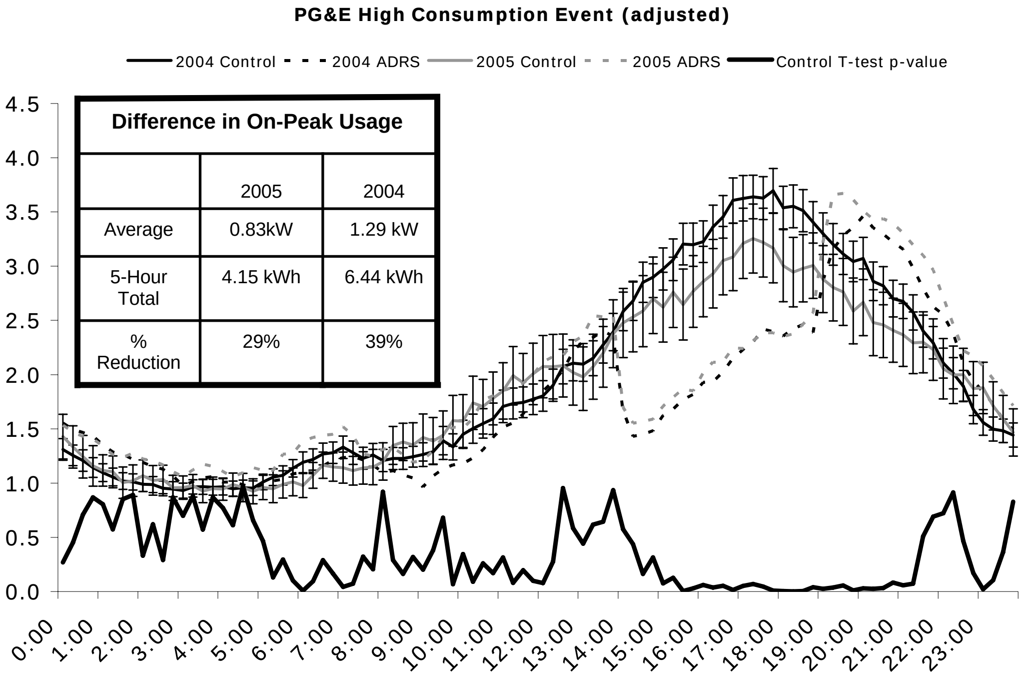


Figure 87 charts the average daily load curves for high consumption ADRS and control on non-event weekdays for both 2004 and 2005 summers in PG&E territory. Ninety percent confidence intervals were calculated and plotted around average load curves for control homes for each 15-minute period. The black line along the bottom of the chart displays the t-test p-value for each 15-minute period, which evaluates the probability that control home load differences between 2004 and 2005 were due to random chance.

Comparing peak period load reduction performance between years, high consumption ADRS homes reduced slightly less load compared to control during summer 2005 than in summer 2004, on non-event days. PG&E high consumption ADRS homes in 2005 reduced peak period load by an average 0.47 kW (18%) in 2005, compared to a 0.55 kW (22%) reduction in 2004. We deduce that the decrease in ADRS peak period load reduction in 2005 is because ADRS loads during the peak period increased in 2005 more than control home loads increased. The increase in both ADRS and control loads in 2005 is reasonable due to the hotter temperatures in the 2005 summer relative to the 2004 summer.

From the average daily load curves for ADRS and control homes shown in Figure 87, we observe that ADRS high consumption loads in 2005 were consistently higher than in 2004. The magnitudes of the ADRS load differences, however, varied by time of day. During off-peak periods, the difference in ADRS load between years was generally negligible. However the differences between years during peak and recovery period loads were more substantial, at 0.3 kW and 0.6 kW, respectively.

Similarly, control loads match each other fairly closely for the majority of off-peak hours between years. During the morning off-peak hours and early peak period, however, control load in 2005 is significantly greater than in 2004 on non-event weekdays. The average difference in control loads between years is 0.23 kW, or 16% greater than 2004 control load, from 9 a.m. to 1:45 p.m., and 0.19 kW, or 8%, greater during the peak period.

Figure 87: PG&E high consumption 2004 and 2005 non-event load curves

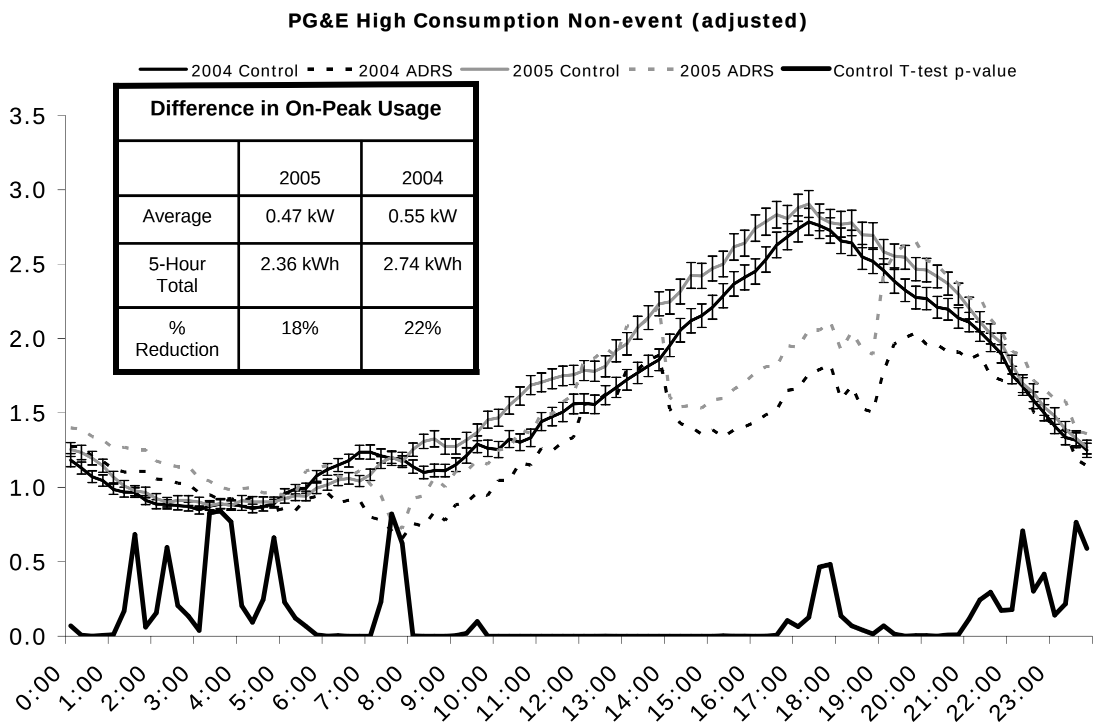
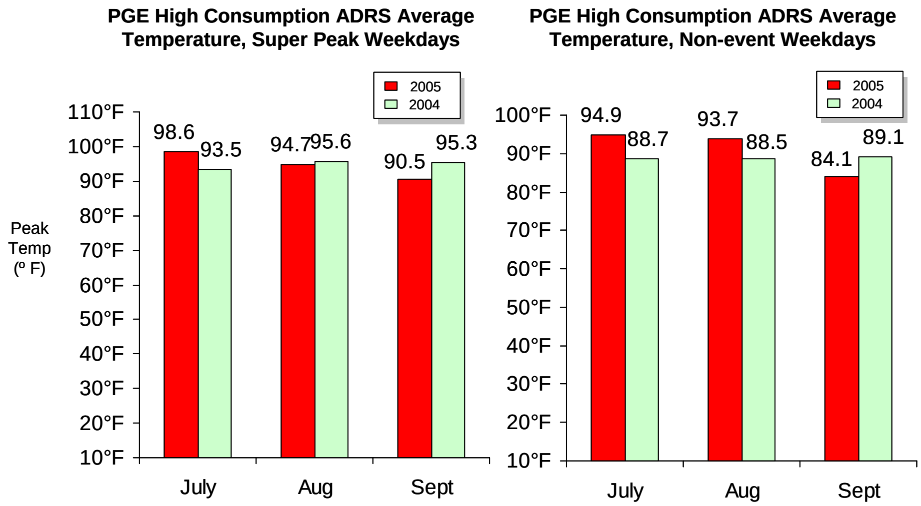


Figure 88 compares the average peak temperatures on event and non-event weekdays for 2004 and 2005. In PG&E service territory, September 2005 was a cooler month on both event and non-event days compared to 2004, while both July and August were hotter on average in 2005 than in 2004. On the other hand, while average temperatures were higher in 2005 for July on event days, they were same in August between the two years.

Specifically on event days, Super Peak period temperatures were high during all three summer months in both years. Average monthly event temperatures in 2005 declined from 98.6°F in July to 94.7°F in August and even further to 90.5°F in September. Corresponding 2004 monthly temperatures were less variable, maintaining averages between 93.5°F and 95.3°F from July through September. On event days, July temperatures were hotter in 2005 than in 2004. In August and September, however, event day temperatures were warmer in 2004.

Figure 88: Average Super Peak and peak period temperatures for 2004 and 2005 by month, PG&E



July and August 2005 non-event weekday average temperatures were almost as hot as the corresponding event days, averaging 94.9°F and 93.7°F, respectively. In September 2005, non-event weekday averages cooled by about 10°F relative to July and August, to 84.1°F. Non-event day peak period temperatures in July and August 2004 were cooler than corresponding months in 2005, but more consistent, varying between 88.7°F and 88.5°F between the two months. September non-event days in 2004 were 5°F higher than in September 2005.

Comparing against statewide average temperatures summarized in Figure 75, PG&E monthly temperatures were hotter than the statewide average in 2004, on both event and non-event days. In 2005, however, PG&E average temperatures were hotter than statewide average temperatures on non-event days, but experienced similar and also cooler temperatures than the statewide average on event days, in August and September, respectively. This suggests that the event days called statewide in August and September were not the hottest days experienced by PG&E customers in 2005, with possible adverse results on ADRS load reduction performance.

Figure 89 compares the percentage load reductions during each hour of the Super Peak period between 2004 and 2005 of high consumption ADRS customers compared to control customers in PG&E service territory. Percentage reductions are consistently less in 2005 than in 2004. As noted before, this is mostly due to a lower relative 2005 control load during the peak period, resulting in lower savings in 2005. Nevertheless, Super Peak performance in high consumption ADRS homes in PG&E territory is reliable over consecutive years. Both years show the same downward trend in load reduction over the duration of the Super Peak period. In 2005, ADRS load reductions fell more substantially between the first and last hours of the Super Peak period than in 2004. In 2005, ADRS load reductions dropped 20% between the first and last hours of the Super Peak period compared to a 14% drop in 2004. This is again due to a curiously lower control customer load in 2005 compared to 2004.

Figure 89: PG&E high consumption 2004 and 2005 Super Peak hourly load reductions: in percent

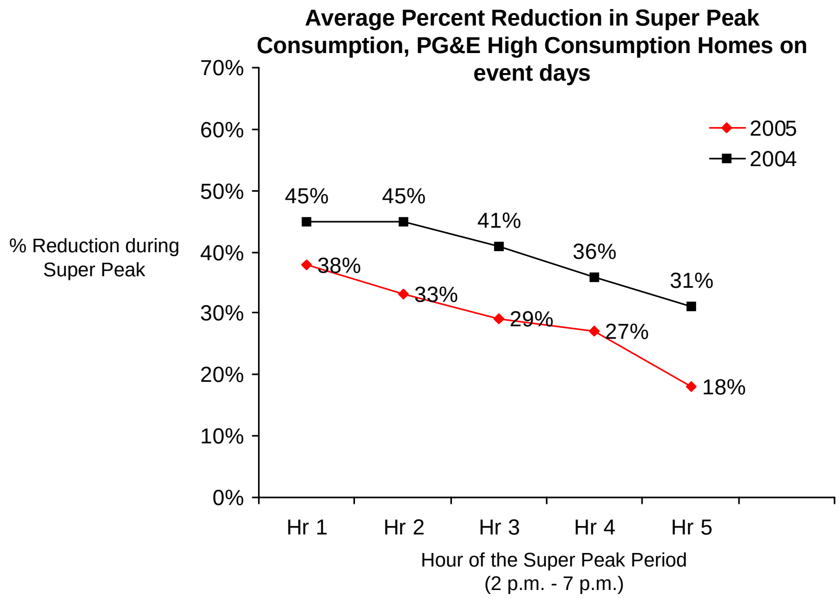


Figure 90: PG&E high consumption ADRS homes, 2005 event day Super Peak period kW reductions

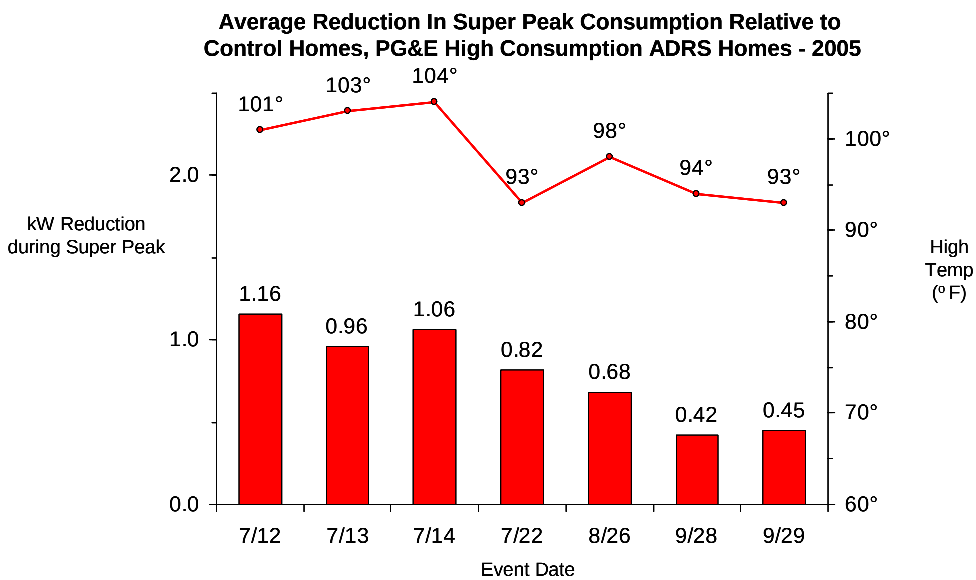


Figure 90 summarizes the 2005 ADRS load reductions for each event day along with the corresponding average peak temperatures for each event day in PG&E service territory. Super Peak period load reductions steadily declined over the course of the summer in 2005. The maximum savings of 1.16 kW occurred on the first event and the weakest performance of 0.42 kW reduction happened on the penultimate event day in September. The downward trend in performance also appears to correspond with the downward trend in average peak temperature. September 2005 event days are also suspect given they were called late in the month when the season was transitioning into autumn and likely changes in ADRS customer consumption behavior.

Figure 91 shows the ADRS load reductions for each event day in 2004 along with the corresponding average peak temperatures for each event day. Super Peak reductions were greater in 2004 than in 2005, compared to control home loads. The July 14 and July 22 event days elicited both the maximum and minimum performance of ADRS homes for summer 2004, at 1.93 kW and 0.72 kW reduction from control homes, respectively. The remaining event days in 2004 exhibited a smaller range of ADRS load reductions, between 1 kW and 1.5 kW.

Figure 91: PG&E high consumption ADRS homes 2004 event day Super Peak period kW reductions

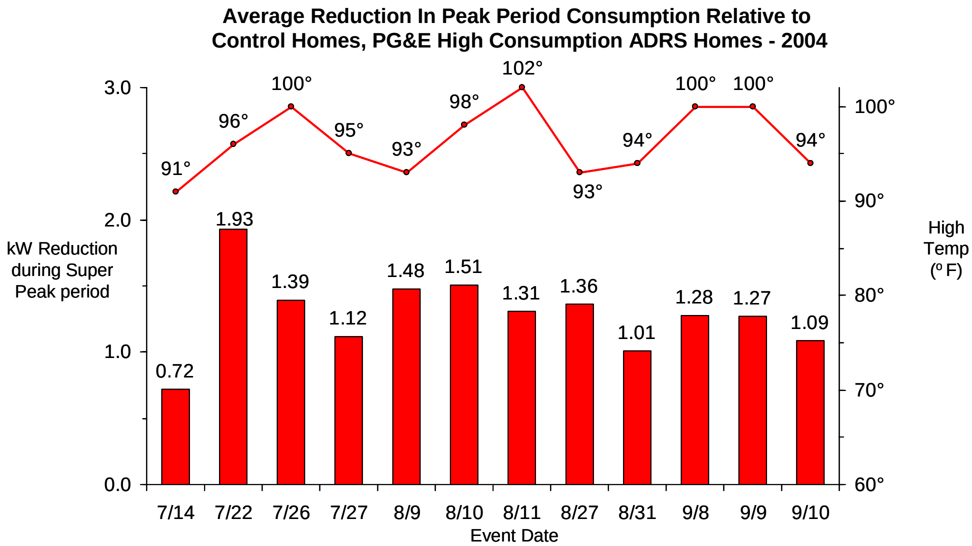


Figure 92 and Figure 93 calculate the 2005 and 2004 ADRS high consumption Super Peak period load reductions on each event day as a percentage of average control home load in PG&E service territory. Average peak temperature on each event day is also plotted, on a secondary axis. Percent load reductions are fairly consistent over all event days in 2005 and 2004. ADRS load reductions in 2005 as a percent of control home loads fell within an 11% range: between 22% and 33%. With the exception of July 14 event day in 2004, Super Peak period load reductions fell within a 13% range: between 35% and 48%.

To examine the relationship between average peak temperature and kW load reduction, we performed a correlation analysis using combined data for both 2004 and 2005 in Figure 90 through Figure 93. The resulting coefficient of correlation was 0.30, indicating a low correlation between temperature and ADRS load reduction.

Since the correlation between average peak temperature and ADRS Super Peak period load reduction was low, we decided to test the correlation between average ADRS load at 1:45 p.m. for each event day and the corresponding average Super Peak load reduction. After combining both 2004 and 2005 event day data, we calculated a coefficient of correlation of 0.36. Thus, for PG&E high consumption ADRS homes, there was also a low correlation between 1:45 p.m. load and average Super Peak load reductions.

Figure 92: PG&E high consumption ADRS homes 2005 event day Super Peak period percent reductions

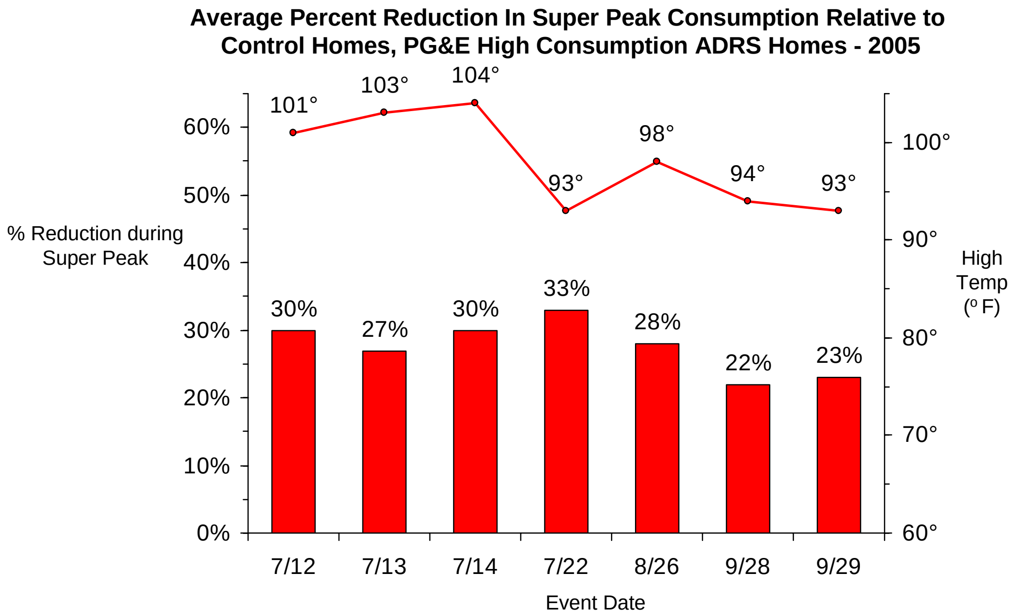


Figure 93: PG&E high consumption ADRS homes 2004 event day Super Peak period percent reductions

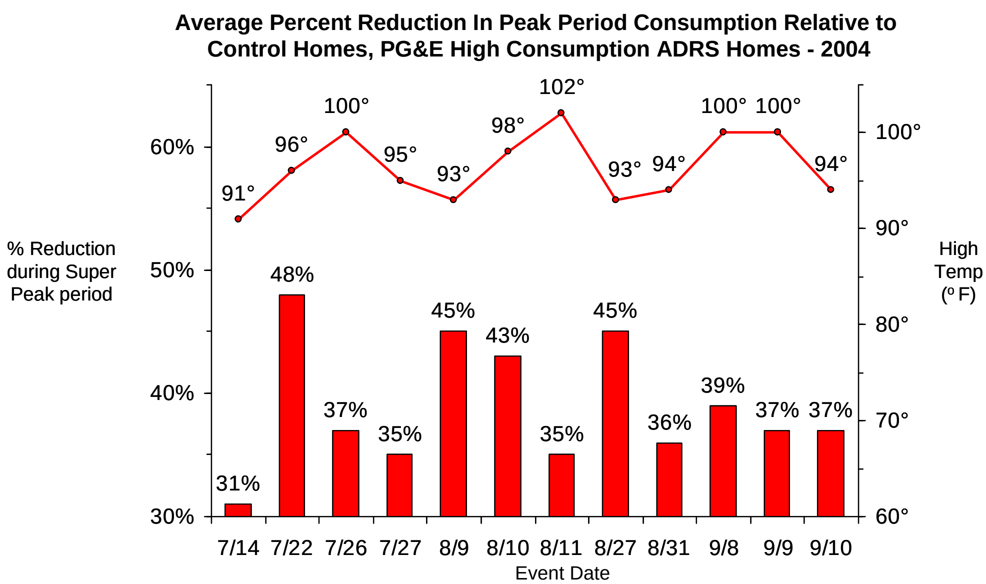


Figure 94 shows ADRS percent reductions compared to control homes over consecutive event days. 2005 event days are on the left and 2004 event days are on the right. In 2005, high consumption ADRS homes in PG&E service territory had consistent percent reductions across consecutive event days throughout the summer. For example in 2005, the three consecutive July event day load reductions varied by only 3% and September event day load reductions varied by only 1%. Event days in 2004 varied slightly more over consecutive days, especially on the August events. Load reductions shrunk 10% from August 9th to August 11th in 2004. Looking across both years, there does not seem to be any consistent relationship between temperature and consecutive day percent reduction.

Figure 94: PG&E high consumption 2004 and 2005 consecutive event days: Super Peak period percent reductions

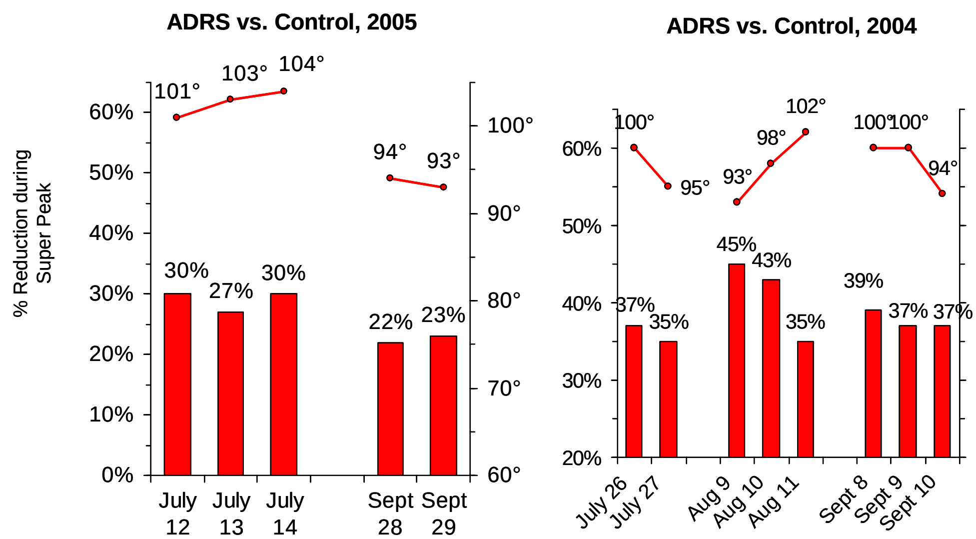


Figure 95 and Figure 96 plot the 2005 and 2004 event and non-event average consumption by peak, off-peak and recovery periods for ADRS and control groups. Comparing daily consumption patterns between years, the primary observable trend in these charts is the reduction of net energy conservation in ADRS homes and the increasing effect of shifting load into off-peak periods, from 2004 to 2005. On both event and non-event days for both years, ADRS high consumption homes consumed less energy than control homes during the peak period, and more energy than control homes in the recovery and off-peak periods. These differences in consumption are more pronounced on event days compared to non-event days, and more pronounced in 2004 compared to 2005. This indicates that ADRS homes were mostly engaged in shifting load from peak periods to off-peak periods in 2005, compared to 2004.

Figure 95: 2005 PG&E high consumption homes energy usage by period on event and non-event days

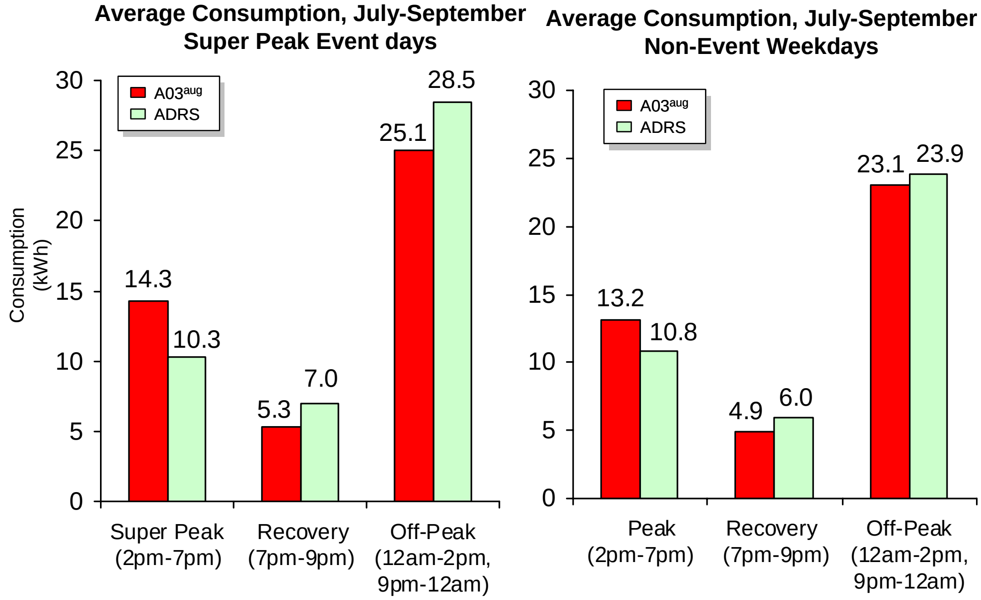
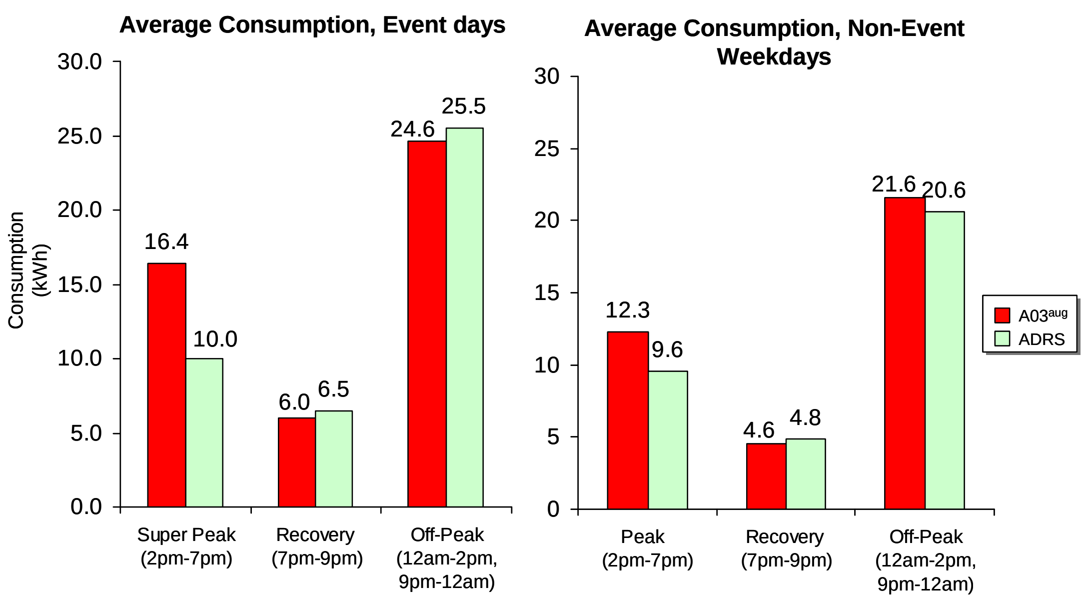


Figure 96: 2004 PG&E high consumption homes energy usage by period on event and non-event days



On event days, ADRS homes greatly reduced energy consumption relative to control during the Super Peak period by 4 kWh in 2005 and by 6.4 kWh in 2004. ADRS consumption increased marginally relative to control homes during the recovery and off-peak periods, by 1.7 kWh and 3.4 kWh, respectively, in 2005 and by 0.5 kWh and 0.9 kWh, respectively, in 2004.

On non-event days, ADRS homes showed a smaller peak period reduction relative to control compared to event days for both years. Peak period ADRS load reductions were 2.4 kWh and 2.7 kWh in 2005 and 2004, respectively. ADRS consumption during the recovery period was 1.1 kWh higher than control homes consumption in 2005 and was virtually the same in 2004. Finally on non-event days, ADRS homes consumed about as much energy in 2005 and by 1 kWh less than control homes in 2004 during the off-peak period.

Figure 97 and Figure 98 compare ADRS and control's average daily usage by month for event and non-event weekdays in 2005 and in 2004. Comparing average daily usage between 2004 and 2005, the trend is an increase in overall ADRS consumption in 2005, suggesting a movement away from conservation towards shifting load into off-peak periods.

Figure 97: 2005 PG&E high consumption homes average daily usage by month

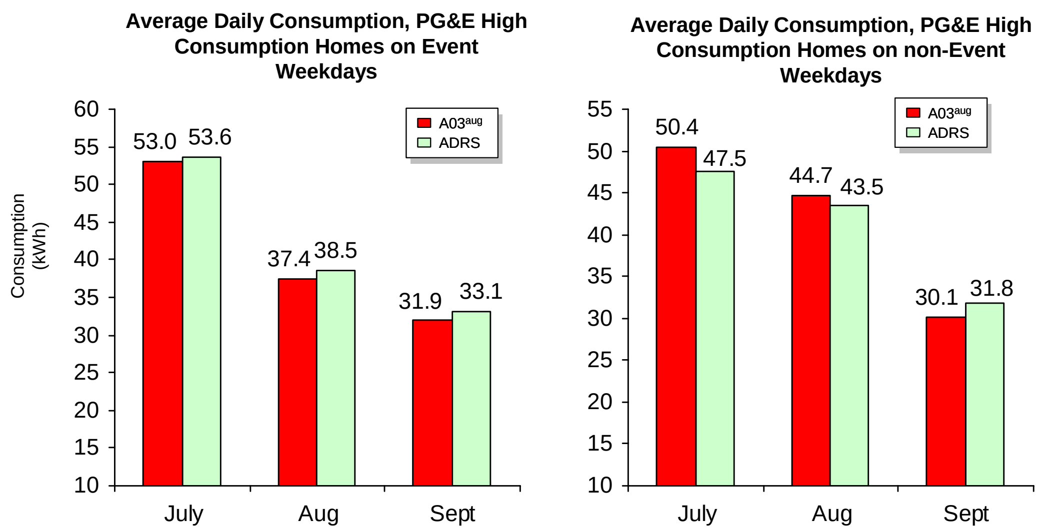
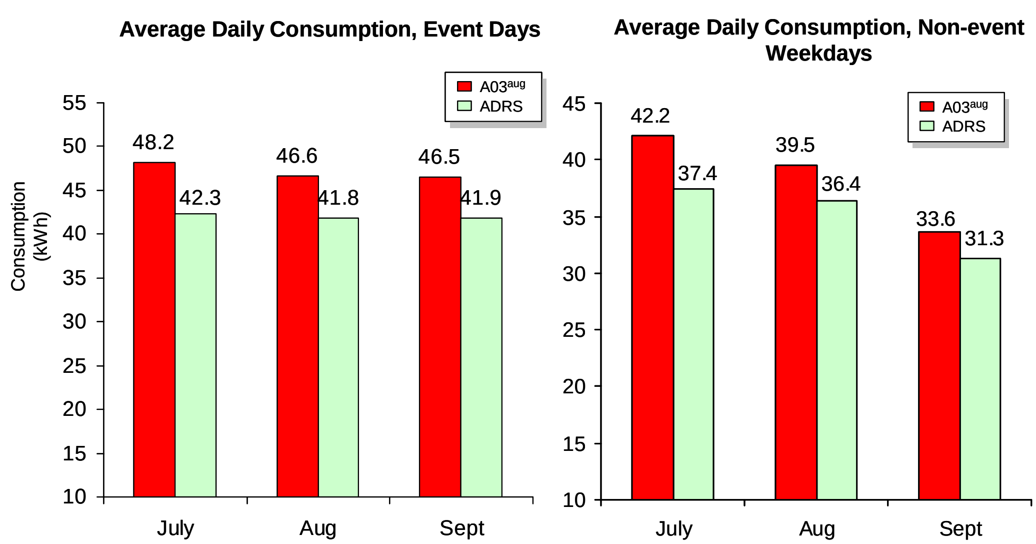


Figure 98: 2004 PG&E high consumption homes average daily usage by month



On event days in 2005, ADRS overall consumption was greater than control's for all summer months. This discrepancy is small, however, ranging from a 0.6 to 1.2 kWh difference in consumption. The relative parity in consumption supports the notion that the ADRS technology has a load-shifting benefit with no conservation benefit on 2005 event days. In contrast, high consumption ADRS homes in PG&E territory consumed significantly less energy than control homes on all summer days in 2004. On event days in 2004, ADRS homes consumed 5.6 to 5.9 kWh less energy than control homes from July through September.

On non-event days in July and August 2005, ADRS homes consumed less energy than control by 2.9 kWh and 1.2 kWh, respectively, while in September, ADRS homes consumed 1 kWh more energy than control homes. On non-event days in 2004, ADRS homes reduced more energy overall compared to 2005, by 2.3 to 5.8 kWh between July and September. Thus, for the majority of the summer, overall consumption patterns indicate both load shifting and conservation at work in ADRS homes on non-event days in 2005. In contrast, ADRS homes used technology to achieve a modest amount of energy conservation in 2004.

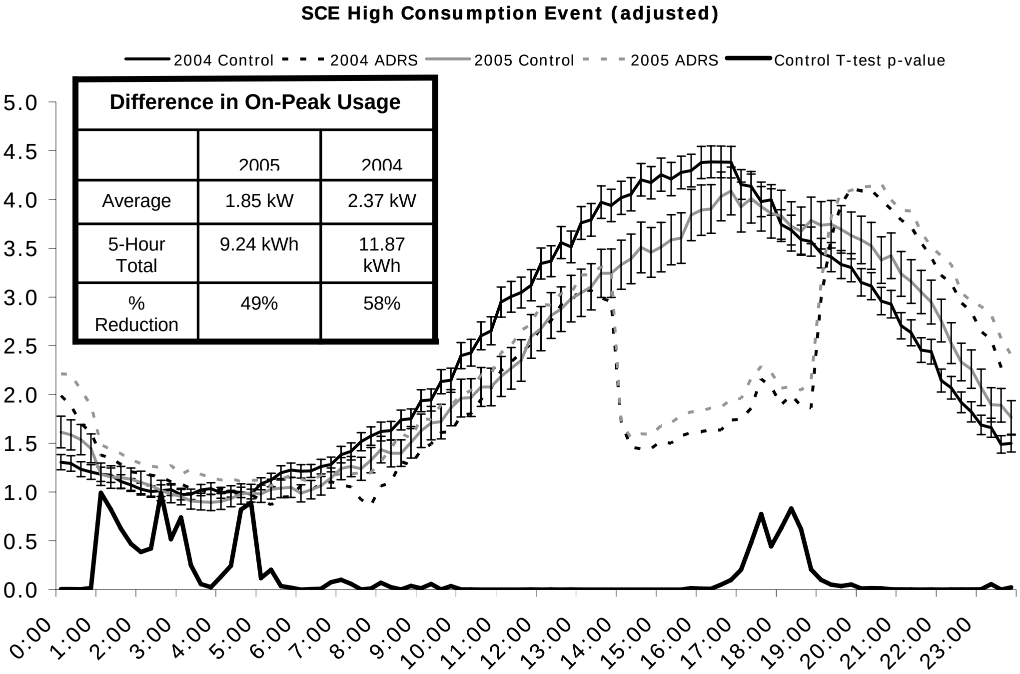
Event days in September 2005 featured substantially reduced overall consumption compared to other months. In contrast, September event days in 2004 featured similar ADRS and control consumption compared to other months. In PG&E service territory, non-event days in September were also substantially lower than the other months, for both 2005 and 2004. This corroborates the notion that the September event days in 2005, which were called at the end of the month, reflect a transition to autumn climate and different consumption behavior. This possibly explains the diminished reductions in both load and energy consumption observed in the above graphs in PG&E service territory.

3.3 Comparison of 2005 with 2004 high consumption ADRS load Impact, SCE

Figure 99 charts the 2004 and 2005 average event day load curves for ADRS and control groups. Figure 100 plots the 2004 and 2005 load curves for ADRS and control groups for non-event weekdays. Control customer load curves in both figures have ninety percent confidence intervals calculated for each 15-minute period as well as a statistical t-test p-value evaluating the similarity in control loads between years.

On event days in 2005, high consumption homes in SCE territory reduced load by 1.9 kW or 9.2 kWh during the Super Peak period. Super Peak period reductions were slightly higher in 2004, at 2.4 kW or 11.9 kWh on event days. On a percentage basis, ADRS customers reduced load by almost 50% relative to control homes in 2005 and by almost 60% in 2004. The downward shift in 2005 control load results in the small reduction in savings in 2005 compared to 2004. In contrast, ADRS loads were nearly the same between years. For ADRS homes, average Super Peak period load in 2005 was slightly higher on event days than in 2004, by 0.17 kW on average.

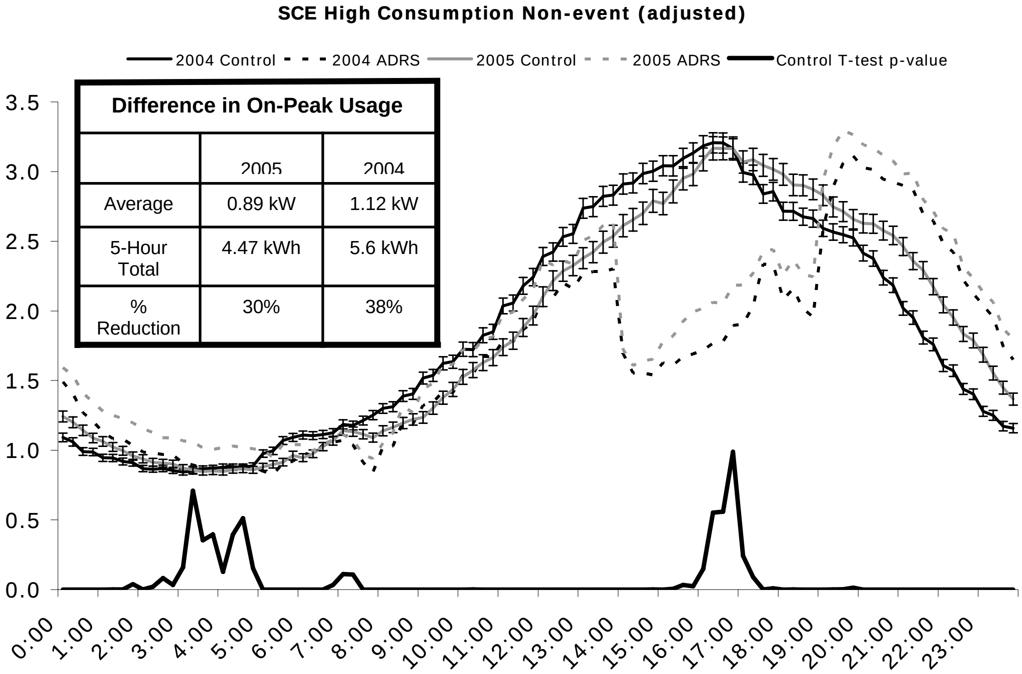
Figure 99: 2004 and 2005 SCE high consumption load curves



In addition to consuming less electricity in 2005 compared to 2004, high consumption control homes in SCE territory appear to shift load away from Super Peak period on event days. From Figure 99, we observe that control home load in 2005 rebounded noticeably between 7 p.m. and 9 p.m. in a manner that is very similar to ADRS load following the Super Peak period on event days. It appears from this observation that control homes on SCE territory might have become aware of announcements of event days and attempted to conserve energy on those days. Control homes loads during off-peak period between 12 a.m. and 7 a.m. were statistically similar, as indicated by the high t-test p-values. After 7 a.m., however, average control home loads between 2004 and 2005 began to diverge, with 2005 control homes consuming less than in 2004 through the rest of the morning and the majority of the Super Peak period.

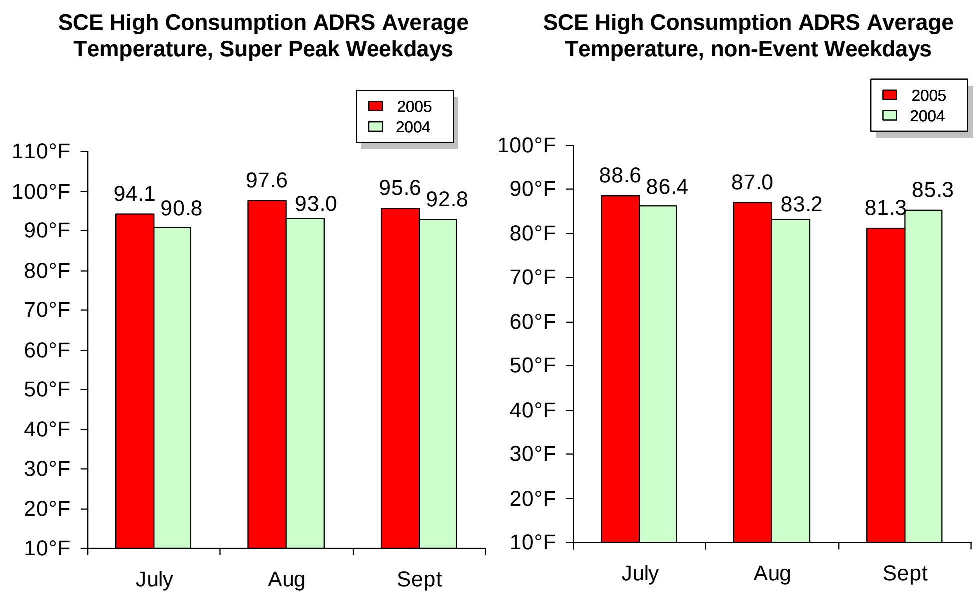
Differences in 2004 and 2005 non-event day control and ADRS average daily loads show similar trends described for event days (Figure 100). For ADRS homes, average load in 2005 was slightly higher on event days than in 2004, by approximately 0.2 kW during the peak period. Otherwise, ADRS loads have very similar profiles between years. Non-event day loads for control homes between 2005 and 2004 match up more closely than for event days. Control loads for the early morning off-peak period are similar but diverge around 7 a.m. As with event day loads, control homes consume less load in 2005 than in 2004 until the latter half of the peak period. Then, 2005 load exceeds 2004 load for the remainder of the day. There does not appear to be load shifting behavior in the high consumption control homes population on non-event days in 2005. However, the lower control homes consumption in 2005 at least during the first half of the peak period, despite hotter weather, suggests some degree of energy conserving behavior that was not observed in the control population in 2004.

Figure 100: 2004 and 2005 SCE high consumption load curves



According to the average peak temperatures in SCE territory shown in Figure 101 for 2004 and 2005 event and non-event days, 2005 was a hotter summer. Event days in 2005 averaged between 94.1^{o}F to 97.6^{o}F over 2005 summer months. The corresponding 2004 monthly averages ranged from 90.8^{o}F to 93^{o}F. Therefore, for event days, 2005 was 2.8^{o}F to 5.6^{o}F hotter than 2004 in SCE service territory.

Figure 101: 2005 and 2004 SCE high consumption average peak temperatures by month



Non-event days were consistently cooler (but still quite warm) on average than event days for both 2004 and 2005. Non-event average peak temperatures ranged from 81^{o}F to 89^{o}F, with July 2005 averaging the hottest out of any month in both years. The average August 2005 temperature of 87^{o}F exceeded the average temperature in August 2004 by 3.8^{o}F. On non-event days in September, the pattern is reversed, as 2005 was 5^{o}F cooler than the corresponding temperature in September 2004.

Comparing the average monthly temperatures in SCE territory to the statewide averages in Figure 75, temperatures were cooler than the statewide averages on both event and non-event days in 2005 with the exception of August. In 2004, average temperatures in SCE territory were slightly warmer than the statewide average on both event and non-event days.

Figure 102: 2004 and 2005 SCE high consumption Super Peak hourly percent reductions

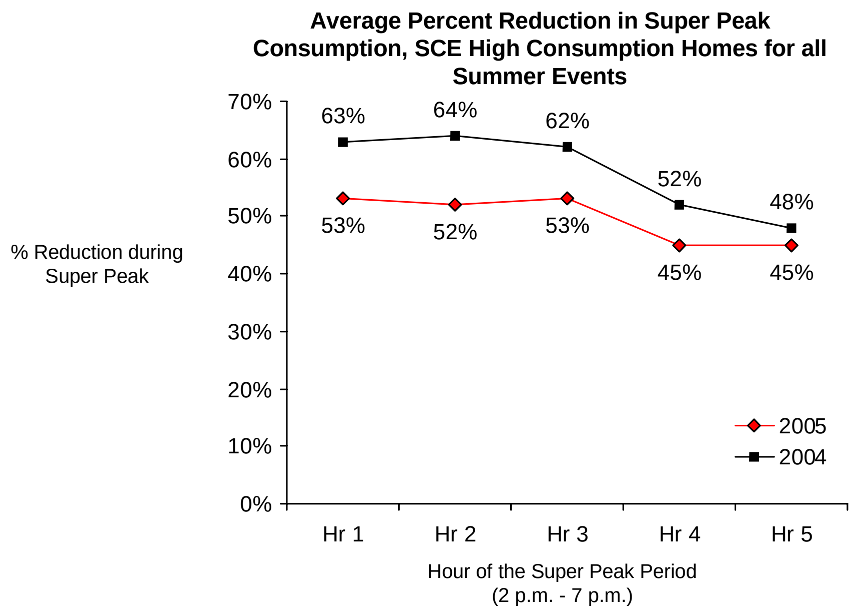
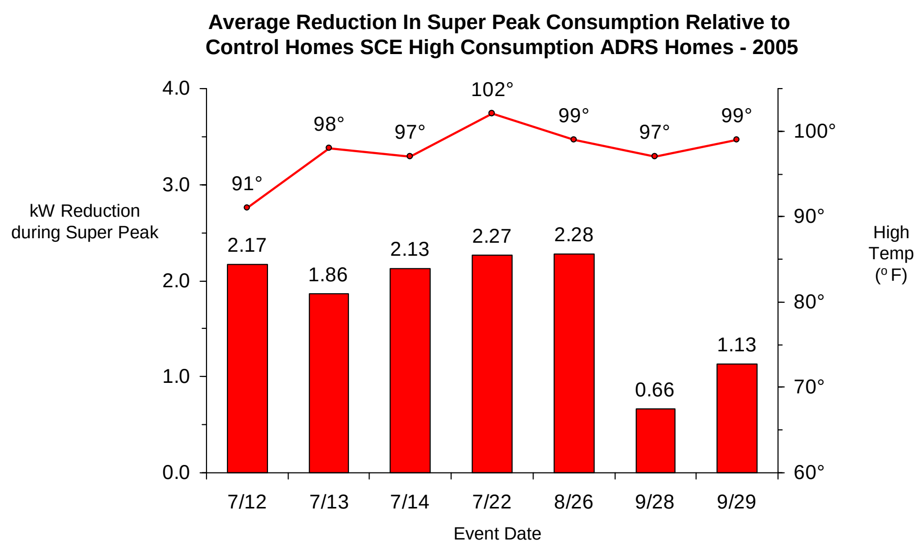


Figure 102 compares the 2005 and 2004 ADRS load reductions during each hour of the Super Peak period in SCE territory. Overall, hourly percent reductions are lower in 2005 than in 2004. Each year shows a similar downward trend of otherwise large percent reductions over the duration of the Super Peak period. Hourly percent reductions in 2004 show a slightly steeper decline than 2005 percent reductions, beginning at 4 p.m. On the other hand, ADRS load reductions compared to control customers are stable and sustained during the first three hours of the Super Peak period in both 2005 and 2004. ADRS load reductions in 2004 drop 15% over the Super Peak period compared to an 8% drop in 2005.

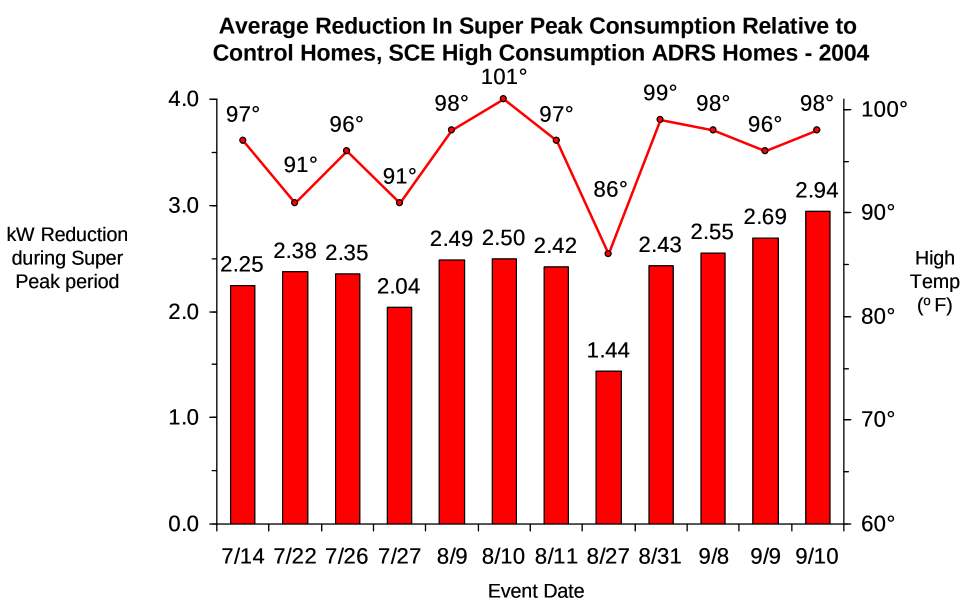
Figure 103 displays the 2005 ADRS load reductions for each event day along with the average Super Peak temperature on that day. ADRS load reductions compared to control group were very strong in July and August 2005, ranging from 1.86 kW to 2.28 kW. September event days in 2005 had markedly lower load reductions of 0.66 and 1.13 kW. This may be due in part to the timing of the event days at the end of September with associated changes in ADRS consumption behavior in anticipation of autumn. The dramatically lower Super Peak reductions in September contributed to lower average summer 2005 load impact of SCE's high consumption ADRS homes.

Figure 103: 2005 SCE high consumption event day Super Peak period load reductions: in kW



Load reductions for 2004 event days were even stronger than 2005 event day load reductions, shown in Figure 104. With the exception of a cool August 27th event, reductions in 2004 ranged from 2.0 kW to nearly 3 kW on average over the Super Peak period. Unlike summer 2005, September load reductions for SCE ADRS customers were the greatest compared to July and August, with average reductions between 2.6 kW and 2.9 kW.

Figure 104: 2004 SCE high consumption event day Super Peak period load reductions: in kW



The 2005 and event day load reductions as a percentage, drawn in Figure 105 and Figure 106, indicate a slight downward trend. With the exception of September 2005 event days, percent reductions were substantial, ranging from 47% to 59%. Super Peak load reductions in September 2005 were still admirable, at almost 30% and 37% compared to control homes. Maximum percent reduction occurred on the first event day and the lowest percent reductions happened on the last two event days in 2005. The percentage reductions for 2004 indicated more consistent savings than the 2004 load reductions represented in Figure 104. Reductions fell consistently within a 10% range between 52% and 62%. These percent reductions were also consistent across a variety of temperatures.

Figure 105: 2005 SCE high consumption event day Super Peak period percent load reductions

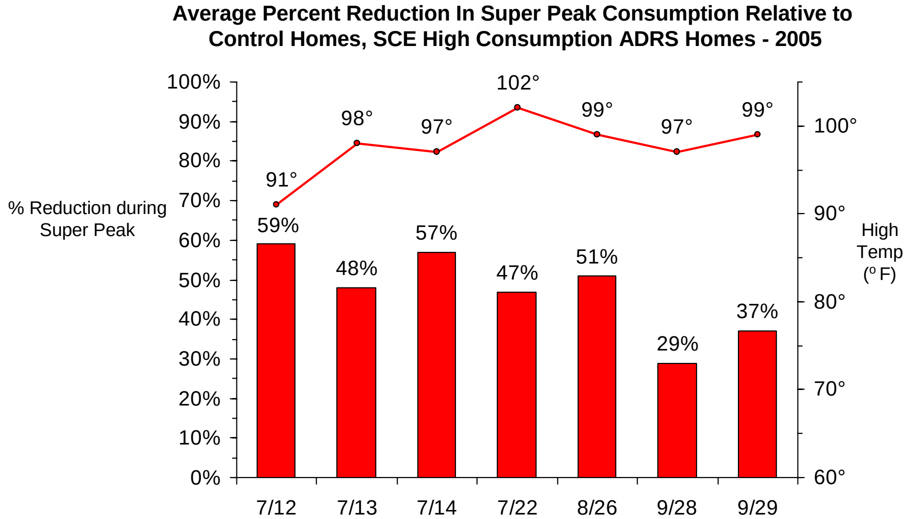
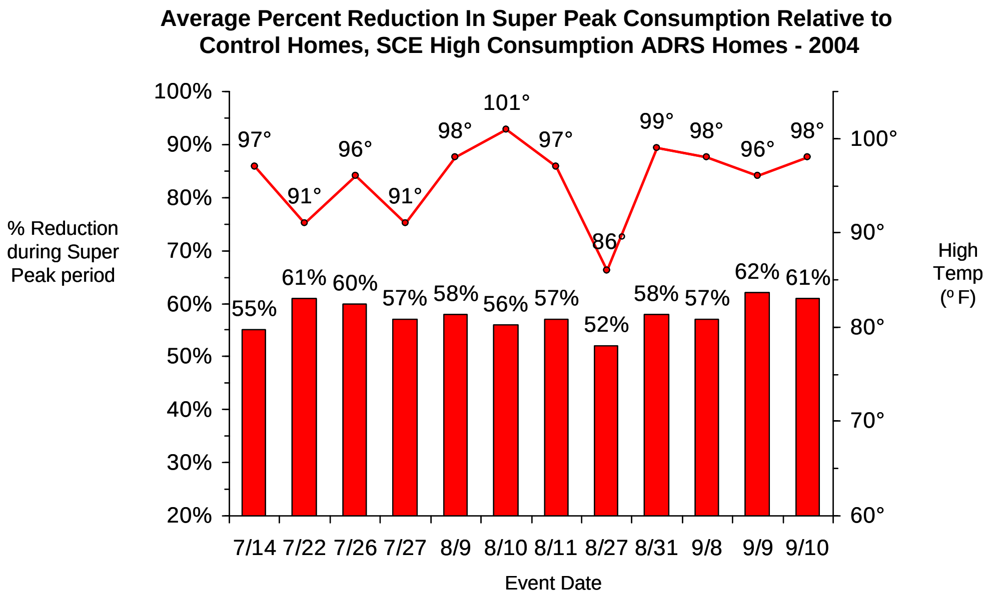


Figure 106: 2004 SCE high consumption event day Super Peak period percent load reductions



To examine the relationship between average peak temperature and kW load reduction, we combined the data in Figure 103 and Figure 104 and performed a correlation analysis. The resulting coefficient of correlation of 0.22 indicated a low correlation between these two factors.

Since the correlation between average peak temperature and ADRS Super Peak period load reduction was low, we decided to test the correlation between average ADRS load at 1:45 p.m. for each event day and the corresponding average Super Peak load reduction. After combining both 2004 and 2005 event day data, we calculated a coefficient of correlation of 0.49. Thus, for SCE high consumption ADRS homes, there was a moderate correlation between 1:45 p.m. load and average Super Peak load reductions.

Figure 107 juxtaposes percent load reductions over consecutive event days for 2004 (right) and 2005 (left). High consumption ADRS Super Peak period load reductions compared to control homes in SCE territory were consistent across consecutive event days, though 2005 displayed wider variability over consecutive days than in 2004. Consecutive event days in July 2005 varied by 11% while the maximum variability in 2004 consecutive event days was only 5%. July 2005 reductions were comparable with 2004 July reductions. However, September reductions in 2005 were roughly half September 2004 reductions. Temperature appeared to correspond well with percent reduction on consecutive days in either year.

Figure 107: 2004 and 2005 SCE high consumption Super Peak period percent load reduction on consecutive event days

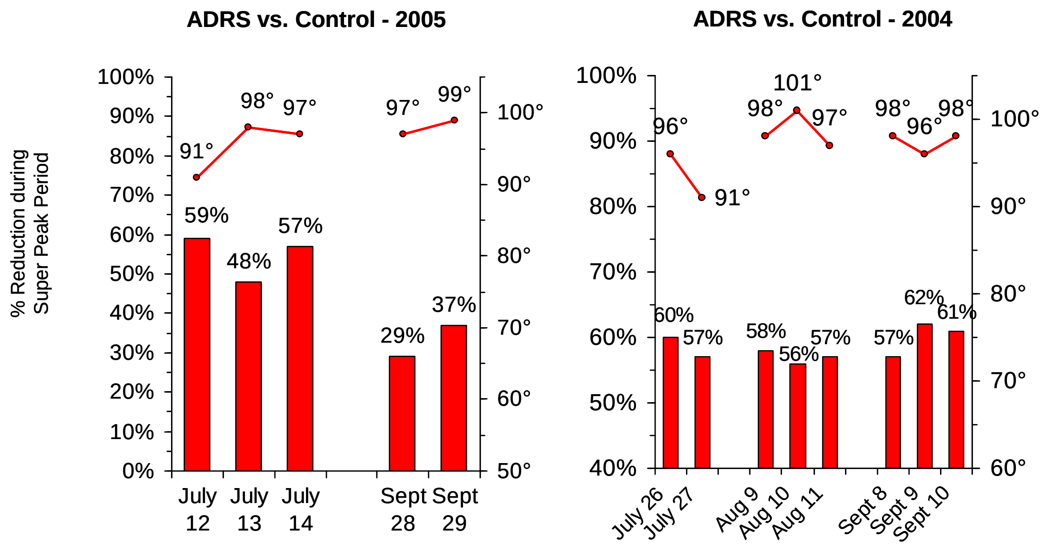


Figure 108 and Figure 109 chart average energy consumption by peak, off-peak and recovery periods for ADRS and control groups in 2005 and 2004 in SCE territory. The recovery and off-peak energy consumption of ADRS homes in excess of control homes energy consumption indicates that ADRS homes were mostly engaged in significant load shifting from peak to off-peak periods for both summer 2005 and summer 2004. During summer 2005, there was further reduction in net energy conservation of ADRS customers towards load shifting to off-peak periods compared to summer 2004.

On both event and non-event days in both 2005 and 2004, ADRS customers consumed less energy than control customers during the Super Peak and peak periods, and more energy in the recovery and off-peak periods. ADRS energy reduction relative to control customers was lower during the Super Peak period in 2005 than in 2004, by 9 kWh and 12 kWh, respectively.

ADRS and control customer consumption during the recovery period was similar on event days in 2005 and 2004, where both groups consumed between 6.4 and 7.9 kWh during the period. On non-event days, ADRS and control customers' consumption during the recovery period was also similar, at almost 5 kWh and 6.3 kWh during this period. On the other hand, ADRS customers consistently consumed 1 kWh more than control customers on both event and non-event days, and for both 2005 and 2004 pilot years. An exception is recovery period energy consumption averaged across event days in 2005, when the difference in consumption between ADRS and control customers was a marginal 0.7 kWh.

ADRS and control customer consumption during the off-peak period were similar on event days in 2005 and 2004, where both groups consumed between 30 kWh and 34 kWh during the period. On non-event days, ADRS and control customers consumption during the recovery period were also similar, between 24 kWh and 27 kWh during this period. However, differences between ADRS and control customer consumption during the off-peak period were greater in 2005 than in 2004, supporting our view that ADRS homes were engaged in more significant load shifting in summer 2005 than in summer 2004.

Figure 108: 2005 SCE high consumption homes energy usage by period on event and non-event days

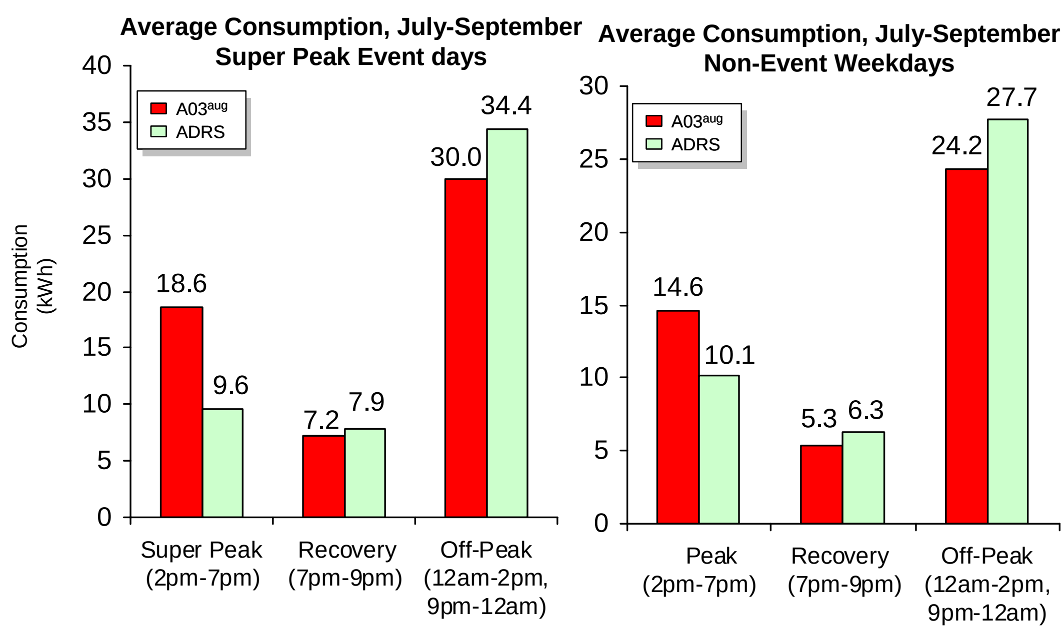


Figure 109: 2004 SCE high consumption homes energy usage by period on event and non-event days

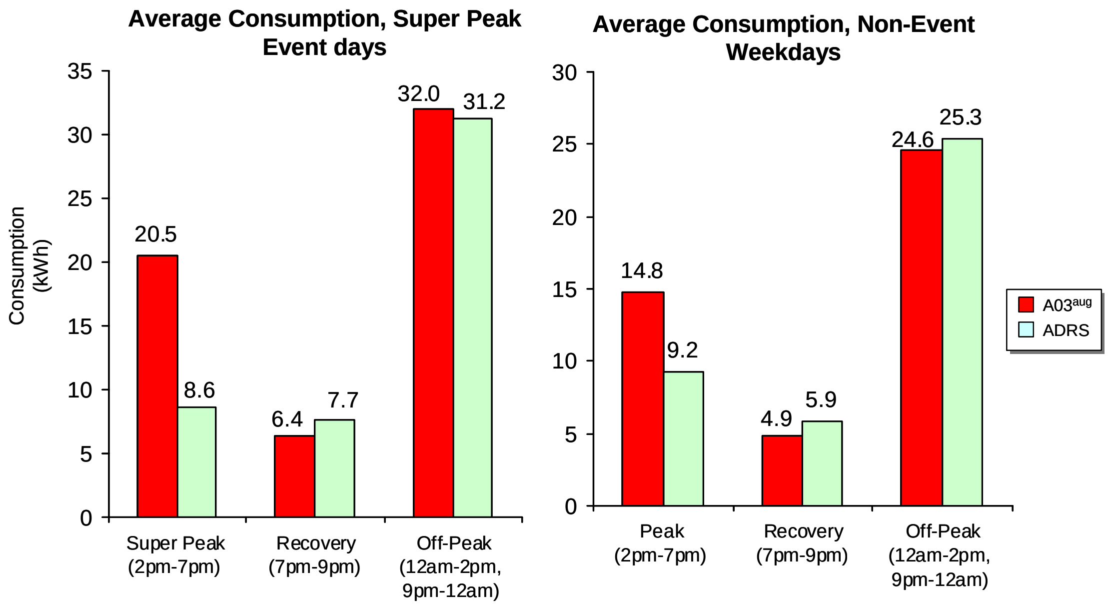


Figure 110 and Figure 111 compare average daily usage of high consumption ADRS and control customers in SCE territory by month for event and non-event weekdays in 2005. In 2004, ADRS high consumption customers consistently consumed less energy than control customers throughout the summer months, on both event and non-event days. Note that most of this reduction in average daily usage results from load reductions during Super Peak and peak periods. Thus, ADRS technology proves to be conserving a modest amount of energy on all days in 2004. On the other hand, ADRS high consumption customers consistently consumed as much or more energy on a daily basis compared to control customers in 2005, with the exception of event days in July and August. These observations support our view that ADRS customers moved away from conservation towards more aggressively shifting load from peak period to off-peak periods in 2005.

For event days in 2005, ADRS overall consumption was less than control's for July and August. This discrepancy in July and August event day consumption was significant, ranging from 4.1 kWh to 5.9 kWh. ADRS event day energy consumption was 1.2 kWh greater than control homes in September, signifying ADRS load shifting behavior from Super Peak to off-peak hours. Average daily usage on non-event days in 2005 show that ADRS homes consumed about the same amount of energy daily as control homes. Thus in 2005, ADRS homes on non-event days seem to be exclusively shifting load from peak period to off-peak hours.

On all summer days in 2004, ADRS homes consumed 9.9 kWh to 14.3 kWh less energy than control homes. On non-event days, ADRS customers achieved more modest savings from control consumption between 0.9 kWh to 5.8 kWh lower average daily usage.

Figure 110: 2005 SCE high consumption homes: average daily usage on event and non-event weekdays by month

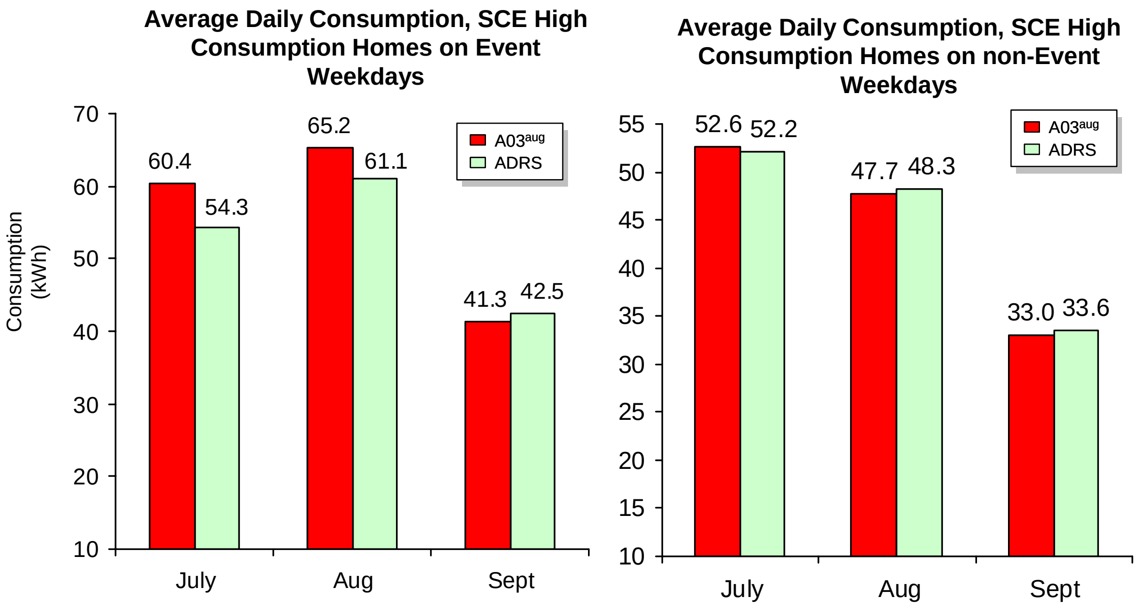
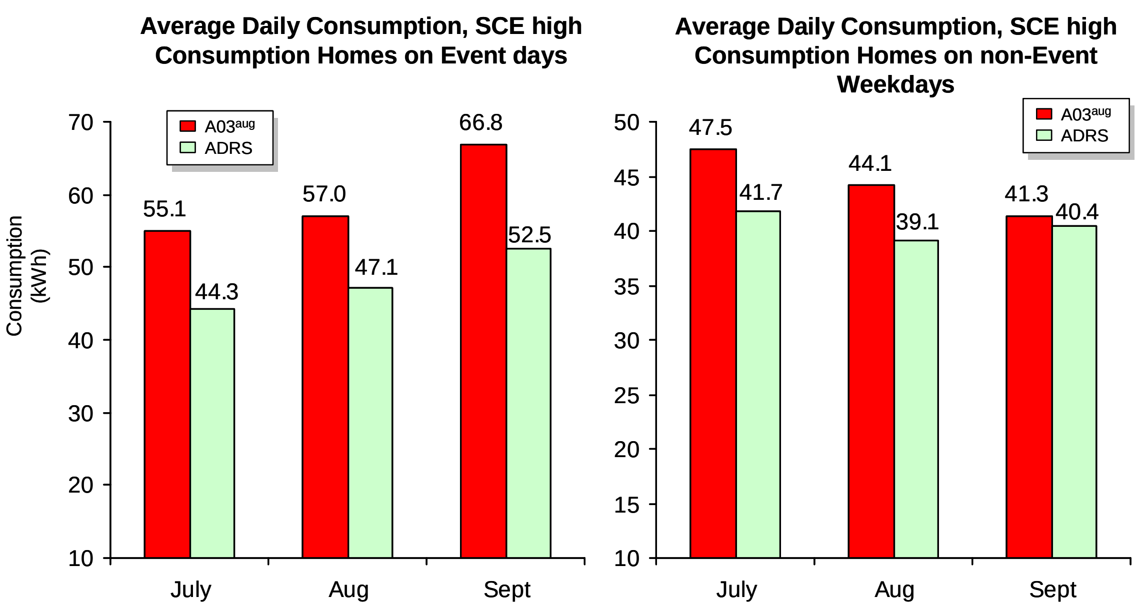


Figure 111: 2004 SCE high consumption homes: average daily usage on event and non-event weekdays by month



Event days and non-event weekdays in September 2005 featured substantially reduced overall consumption compared to other months in SCE service territory. In contrast, September event and non-event days in 2004 featured similar ADRS and control consumption compared to other months. This corroborates the notion that the September event days in 2005, which were called at the end of the month, reflect a transition to autumn climate and different consumption behavior. This possibly explains the diminished reductions in both load and energy consumption in September observed in the above graphs in SCE service territory.

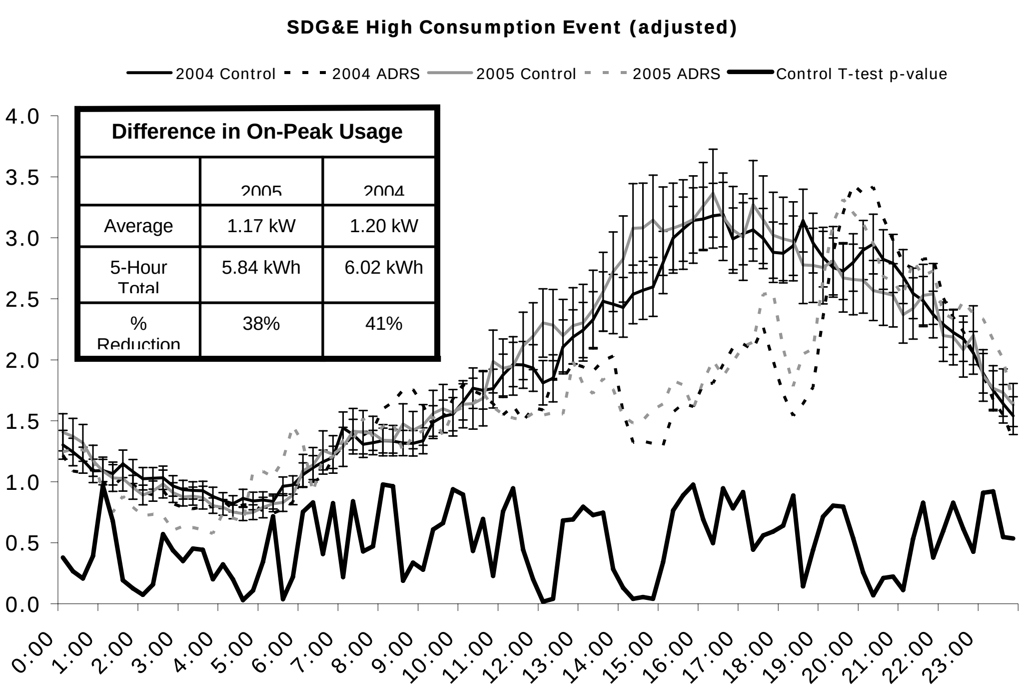
3.4 Comparison of 2005 and 2004 high consumption ADRS load impact, SDG&E

The SDG&E event day load curves for 2004 and 2005 are plotted in Figure 112. Ninety percent confidence intervals were drawn above and below the control curves for each 15-minute period and the t-test p-value evaluating similarity in control loads is plotted beneath the curves. It should be noted that there are only six existing high consumption ADRS homes in SDG&E territory. This small sample size does not usually yield statistically significant or meaningful results.

Super Peak period savings exhibited virtually no change between years. In both years, ADRS homes reduced load by 1.20 kW in 2004 and 1.17 kW in 2005 compared to control homes. As a percentage, however, these reductions translated to 38% and 41% for 2005 and 2004, respectively.

ADRS loads during Super Peak period in 2005 surpassed 2004 ADRS load from 5 p.m. to 7 p.m. Overall, 2005 ADRS Super Peak load was higher by 10% compared to 2004. Control loads, on the other hand, were statistically the same for a majority of the day, as indicated by the near unity t-test p-values, suggesting a high probability that differences in control home loads between to two years are due to random chance. The 2005 average control homes loads are slightly higher than average control homes loads in 2004, by 5% during the Super Peak period.

Figure 112: SDG&E high consumption 2004 and 2005 event day load curves



Difference in On-Peak Usage		
	2005	2004
Average	1.17 kW	1.20 kW
5-Hour Total	5.84 kWh	6.02 kWh
% Reduction	38%	41%

Figure 113 plots the summer 2004 and 2005 average daily load curves for ADRS and control homes for non-event weekdays. Control homes load curves have ninety percent confidence intervals plotted above and below the average value for each 15-minute period. T-test p-values measuring the similarity of control loads between years are also plotted at the bottom of the figure.

High consumption ADRS homes in SDG&E service territory achieved greater peak period load reductions in 2005 compared to 2004. ADRS homes reduced peak period load by an average of 0.7 kW on non-event weekdays in 2005, compared to 0.4 kW in 2004. As a percentage, ADRS Super Peak period load reduction in 2005 was 27% compared to 17% in 2004. The increase in ADRS load reduction in 2005 was due to the increase in 2005 control home load relative to 2004 during the peak period.

ADRS load curves plotted for 2005 and 2004 in Figure 113 match each other closely. ADRS load consumption differences during the peak period were negligible at 0.1% between 2004 and 2005. Control loads match between years for a majority of off-peak hours. Around 10 a.m., 2005 control load diverges above 2004 load until the end of the peak period. Over the peak period, control load in 2005 was 14% higher than control load in 2004.

Figure 113: SDG&E high consumption 2004 and 2005 non-event load curves

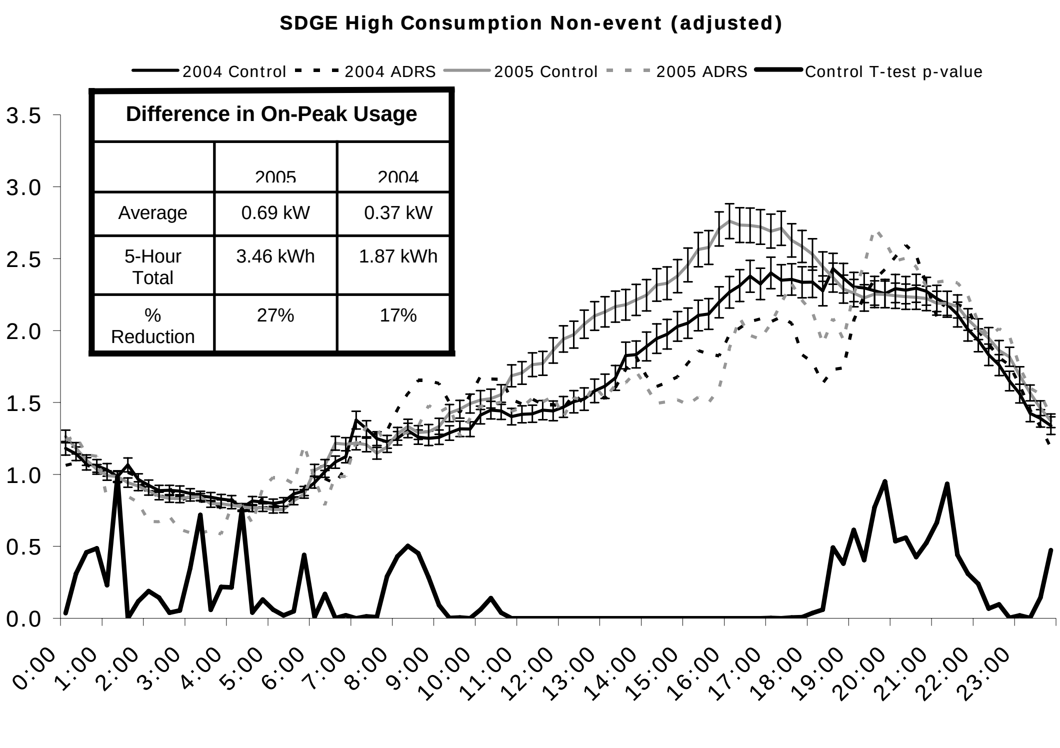
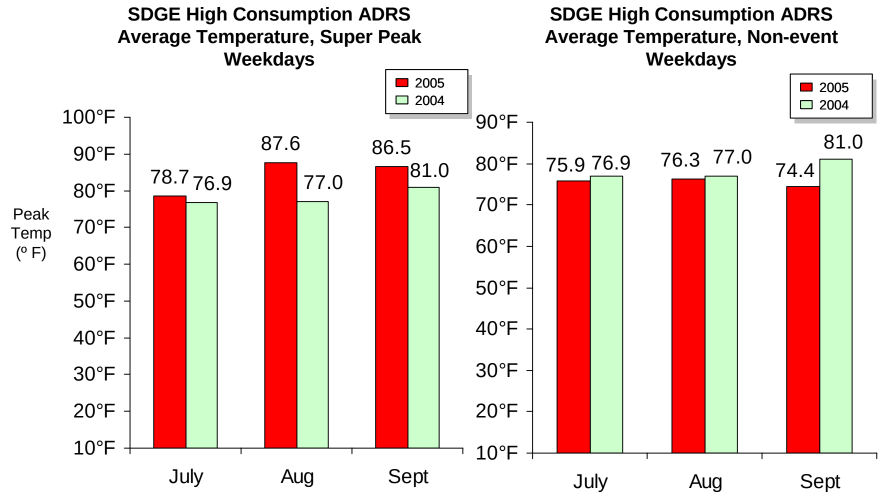


Figure 114 illustrates the average Super Peak and peak period temperatures on event and non-event days, respectively, for high consumption control and ADRS homes in SDG&E service territory. Event day temperatures were hotter in 2005 than in 2004 for all summer months. Average temperatures in SDG&E territory became warmer as the summer progressed in both 2005 and 2004.

Figure 114: SDG&E 2004 and 2005 average peak temperatures for event and non-event weekdays



On non-event days, average temperatures between summer 2005 and summer 2004 were reversed: 2004 was slightly hotter than 2005 during July and August and considerably hotter in September. Monthly average temperatures on non-event days in 2005 also appeared to get warmer as the summer progressed, while average temperatures remained fairly consistent across the summer months in 2004. Temperatures in SDG&E territory were consistently cooler than the statewide average temperatures on event and non-event days, by at least 10^oF in both 2005 and 2004.

Figure 115: SDG&E 2004 and 2005 Super Peak period percent load reductions

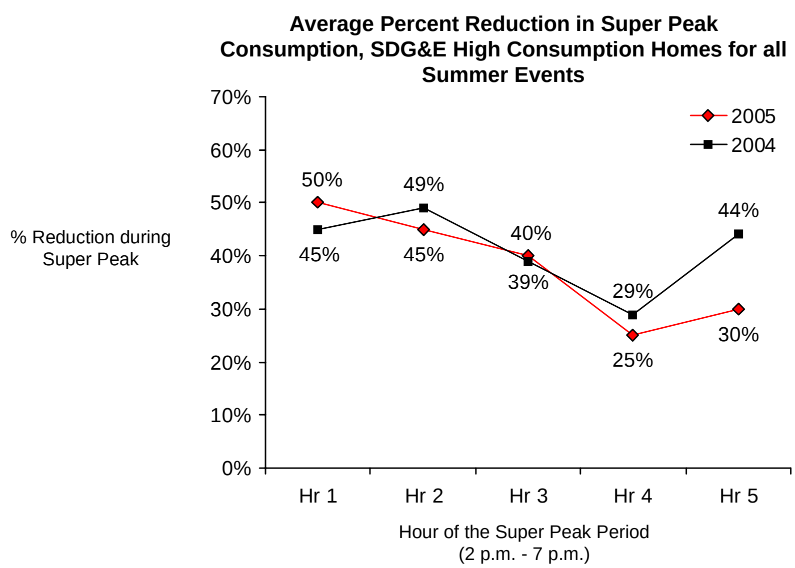


Figure 115 graphs the average hourly percent load reductions during the Super Peak period for high consumption ADRS customers during summer 2004 and summer 2005. Both years show the same downward trend for the first four Super Peak hours with recovery in performance during the fifth hour. For the first four hours, hourly percent reductions in 2005 are quite similar compared to 2004, with differences of only 5% on average. Overall, SDG&E ADRS customers achieved consistently strong load reductions during both 2004 and 2005.

Figure 116 displays the high consumption ADRS Super Peak period load reductions on each event day during summer 2005 and plots the average peak temperature on a secondary axis. Figure 117 presents the same information for summer 2004. Event days in 2005 showed a wide range of load reductions, varying from 0.5 kW to 1.74 kW. There was also a noticeable increase in savings with the steady increase in temperature. High consumption ADRS load reductions in 2004 show a similar variability as in 2005, with a nearly 2 kW spread between event days. The 2004 load reductions showed the same variability in spite of much more consistent and mild average peak temperatures.

Combining both years of event day temperature and kW load reduction data from Figure 116 and Figure 117, we performed a correlation analysis to evaluate the relationship between the two sets of data. The resulting coefficient was calculated as 0.30, indicating low correlation between temperature and kW savings. In a subsequent analysis, we examined the correlation between average ADRS load at 1:45 p.m. for all event days and the corresponding average Super Peak period ADRS load reductions. This resulting coefficient of correlation was 0.65, indicating a moderately strong relationship for SDG&E high consumption homes.

Figure 116: 2005 SDG&E high consumption event day Super Peak period kW reductions

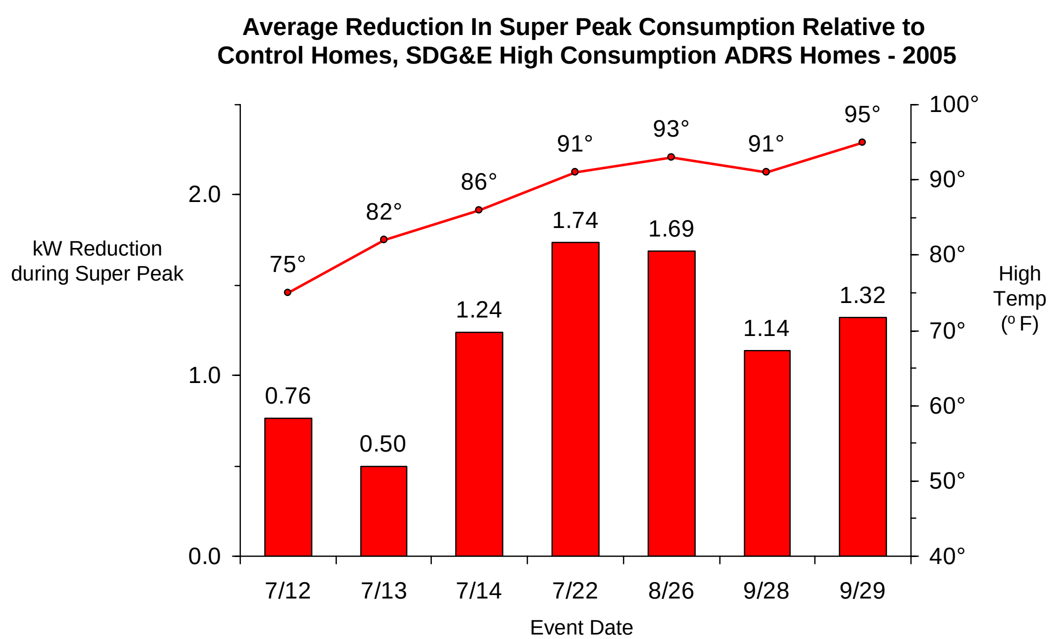


Figure 117: 2004 SDG&E high consumption event day Super Peak period kW reductions

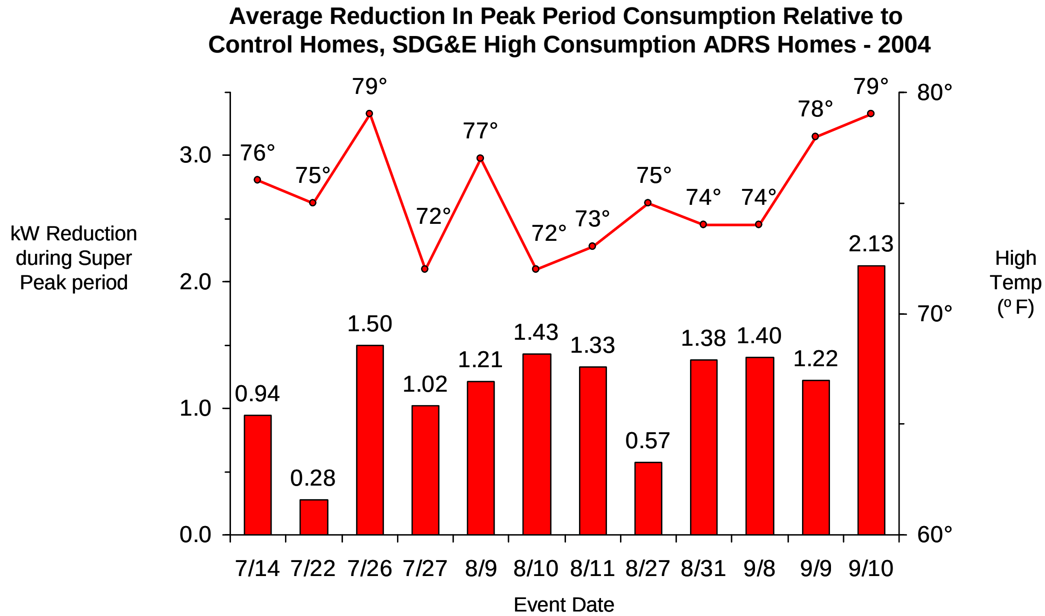


Figure 118 and Figure 119 summarize the Super Peak period load reductions as a percentage of control customer load in 2005 and 2004, respectively. Corresponding event day temperatures are plotted along a secondary axis in both figures. High consumption ADRS Super Peak period load reductions were consistent across event days in both years. Performance was strong from mid-July through September, when the average peak temperatures were above 85° F, percent reductions fall within 40% and 45%. Percent load reductions in 2004 were often substantial, but also show great variability compared to 2005. Savings in 2004 ranged from 12% to 58% between July and September.

Figure 118: 2005 SDG&E high consumption event day Super Peak period % reductions

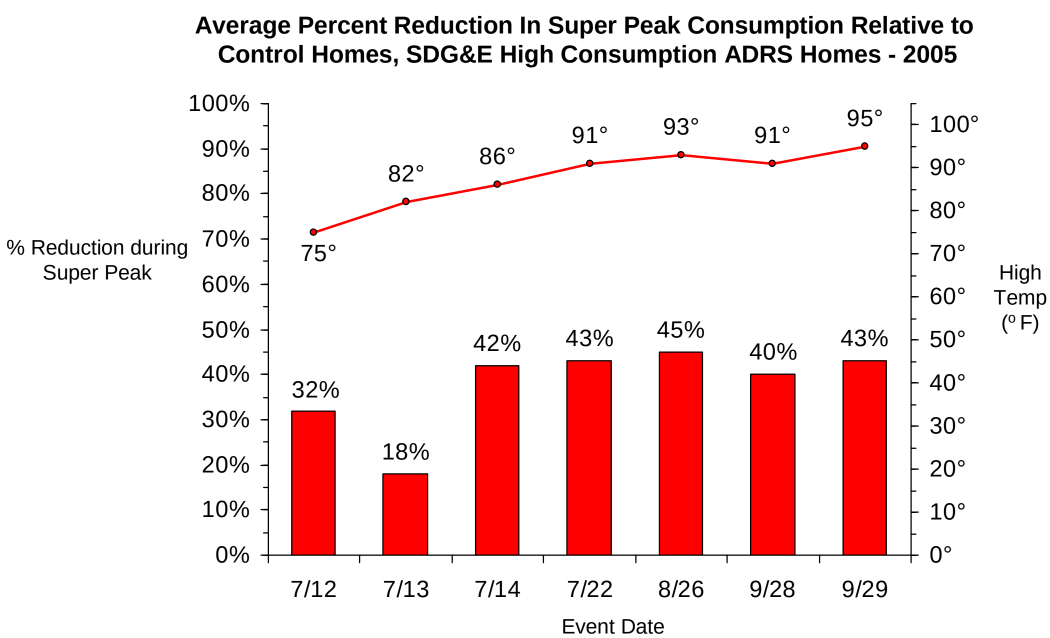


Figure 119: 2004 SDG&E high consumption event day Super Peak period percent reductions

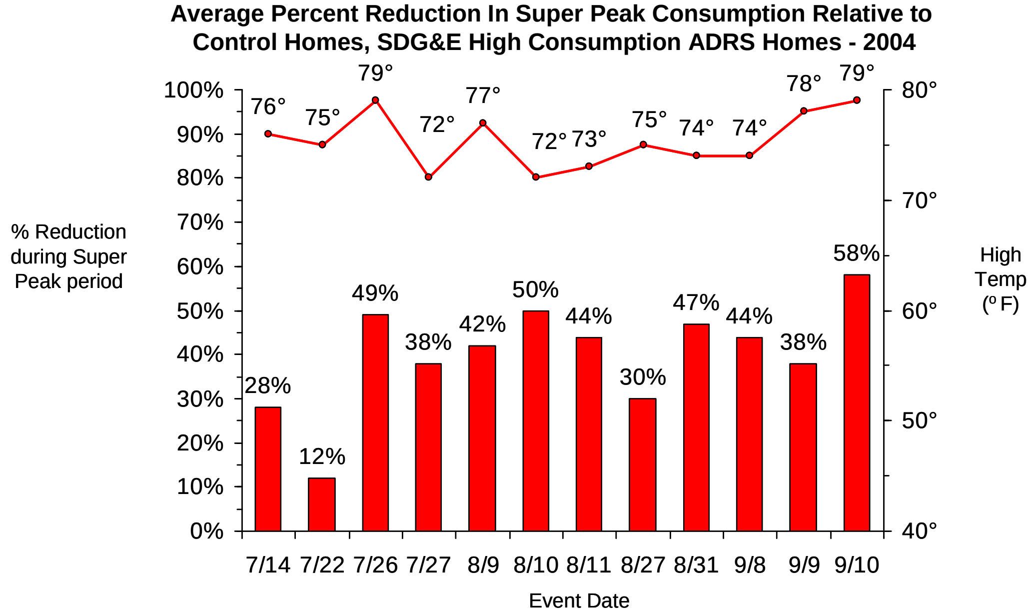
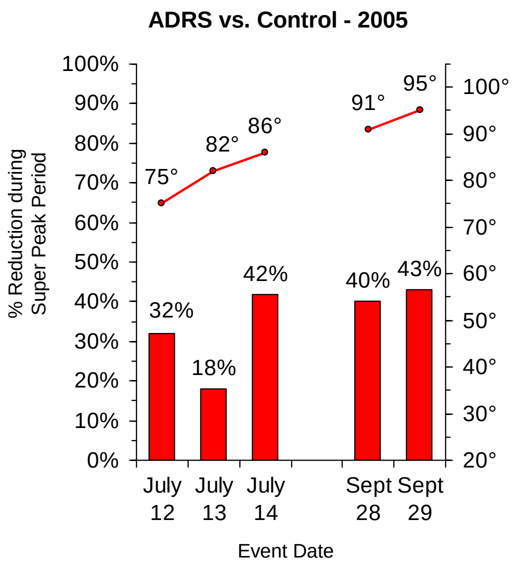


Figure 120 juxtaposes percent load reductions over consecutive event days for 2004 (right) and 2005 (left). Consecutive event days in 2004 and 2005 in SDG&E territory showed similar percent reductions and variability between ADRS load reductions compared to control, with the exception of the July 13, 2005 event day. Looking across both years, there does not appear to be any particular trend in consecutive day percent reductions, nor a particularly strong relationship with average peak temperature on corresponding event days.

Figure 120: SDG&E high consumption 2004 and 2005 consecutive event day Super Peak period percent reductions



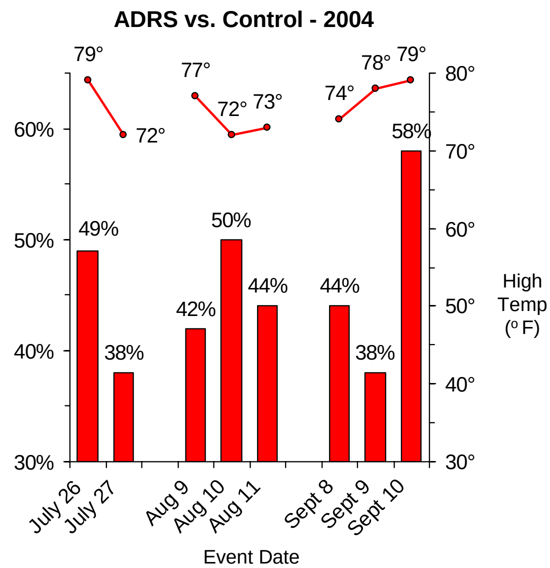


Figure 121 and Figure 122 chart the average energy usage by Super Peak, peak, recovery, and off-peak periods for ADRS and control groups during summer 2005 and 2004. The results should be interpreted with caution given that SDG&E has only six high consumption ADRS homes, indications are that these ADRS homes were primarily engaged in energy conservation as opposed to load shifting on event and non-event days. With the exception of the off-peak period in 2004, ADRS homes consumed less energy than control homes on event and non-event days. During the off-peak period, the difference between ADRS and control home consumption was 0.5 kWh, indicating similarity in usage. ADRS consumed marginally more energy than control homes during the recovery period during both summer 2005 and 2004.

Figure 121: 2005 SDG&E high consumption event and non-event usage by period

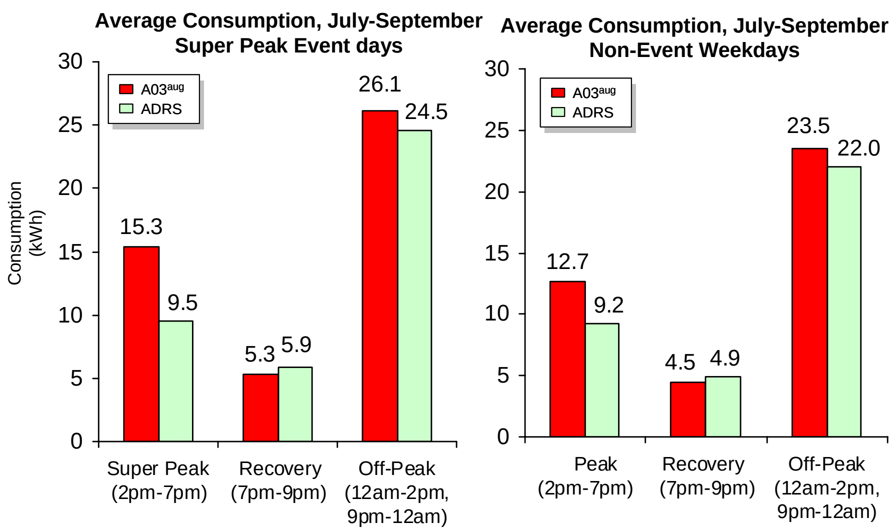


Figure 122: 2004 SDG&E high consumption event and non-event usage by period

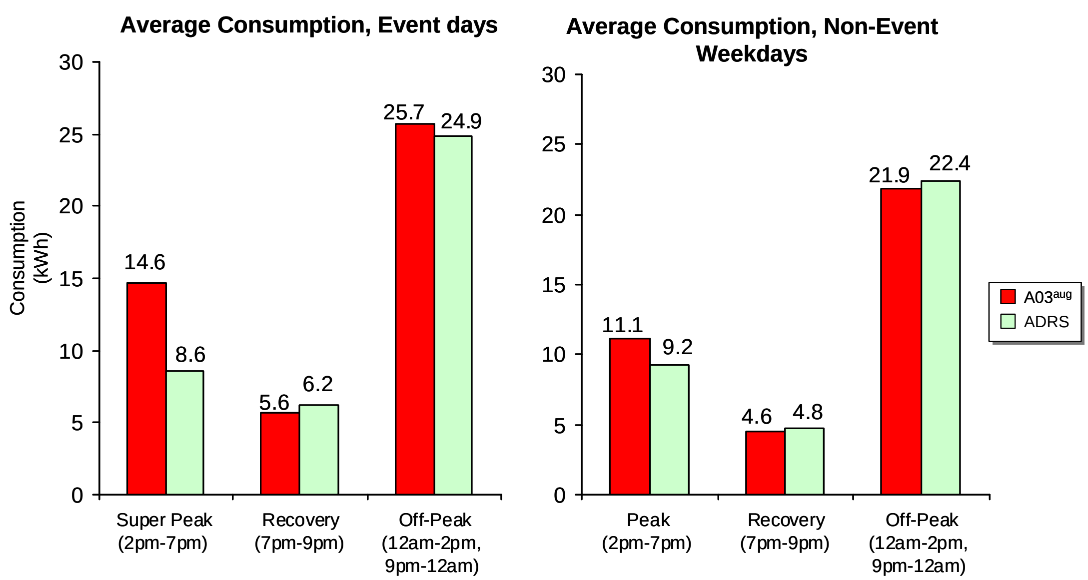


Figure 123 and Figure 124 compare the average daily usage for high consumption ADRS and control homes on event and non-event days during summer 2005 and 2004, respectively. With the exception of non-event days in September 2005, ADRS homes consumed less energy than control homes for all months on both event and non-event days, for both 2004 and 2005. This observation is supported by Figure 121 and Figure 122, where ADRS homes consumed less energy than control homes during Super Peak and peak periods in both 2005 and 2004. These results suggest that high consumption ADRS homes in SDG&E territory were using technology primarily to conserve energy as opposed to load shifting on event and non-event days.

Figure 123: 2005 SDG&E high consumption average daily usage on event and non-event weekdays by month

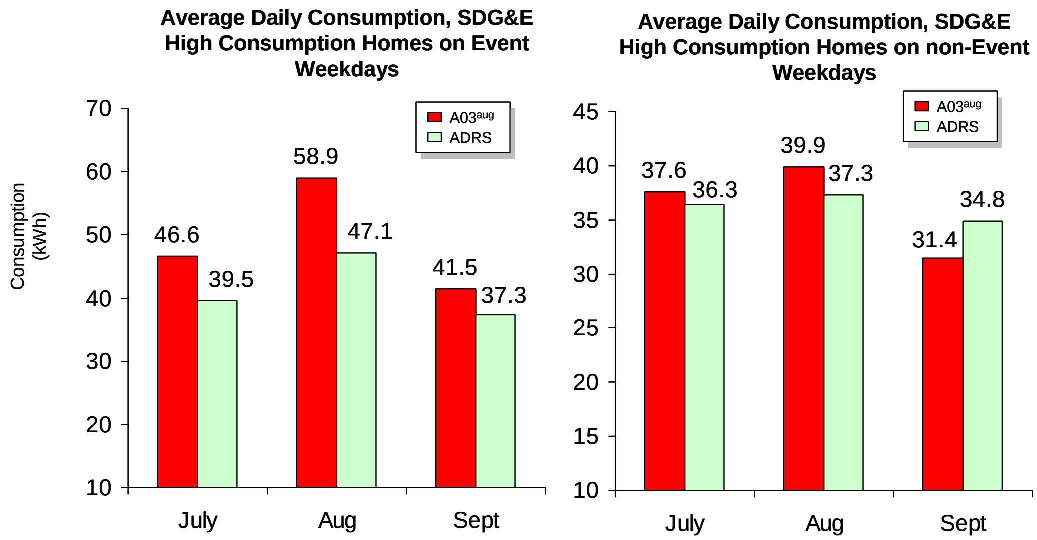
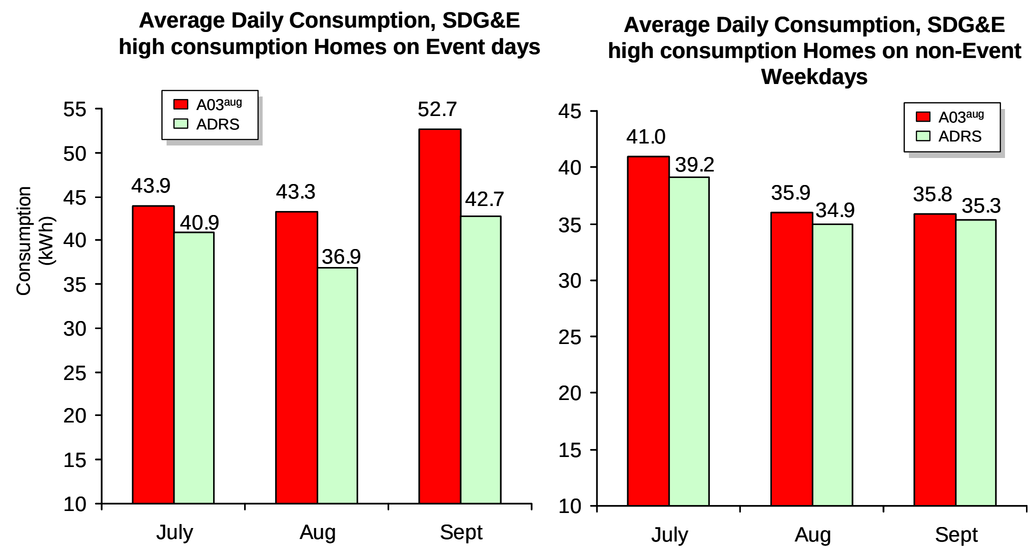


Figure 124: 2004 SDG&E high consumption average daily usage on event and non-event weekdays by month



On event days in 2005 and 2004, differences between ADRS and control homes consumption were similar from July through September, ranging from 4.2 kWh to 11.8 kWh in 2005 and from 3 kWh to 10 kWh in 2004. On non-event weekdays in 2005, absolute consumption as well as differences in ADRS and control consumption were more moderate compared to event days. These differences varied from 1.3 to 3.4 kWh between July and September. Non-event weekday consumption differences between control and ADRS homes in 2004 were also more moderate than event day consumption. Differences were small, varying from 1 kWh to 1.8 kWh across 2004 summer months.

3.5 Comparison of 2005 and 2004 load impact results, low consumption homes

Load impact results for low consumption homes during summer 2005 compared to summer 2004 are reported here for completeness but it should be noted that the numbers are not meaningful due to small sample size of both the control and ADRS homes in both years. Figures and tables corresponding to comparison of 2005 to 2004 load impact results for low consumption homes reported in this section are provided for reference in Appendix D to this report, Low Consumption ADRS 2005 and 2004 Load Impact Results Charts.

Statewide, low consumption ADRS homes reduced less load during Super Peak period in 2005 compared to summer 2004. In 2004, the Super Peak period reductions were 0.54 kW, or 28%, double the reductions in 2005. On non-event days, low consumption ADRS homes also reduced less load in 2005 compared to 2004. ADRS homes reduced peak period load by 0.02 kW (1%) in 2004, which declines to -0.25 kW (-20%) in 2005. The 90% confidence interval around the average peak period load reduction, however, indicates that reductions were essentially zero in 2004.

On a utility-specific basis, low consumption ADRS homes in PG&E service territory reduced more Super Peak period load during 2004 than in 2005. In 2004 ADRS homes reduced Super Peak period load by 0.74 kW or 30% while in 2005, ADRS homes consumed more load than control homes. On non-event days, low consumption ADRS homes consumed more load than control homes both in 2005 and in 2004. Taking into consideration the 90% confidence interval around the average peak period load reductions, however, PG&E low consumption ADRS customers’ reductions were essentially zero on event days in 2005 and on non-event days in 2004.

Low consumption ADRS homes in SCE service territory reduced less load in 2005 than in 2004 during the Super Peak period. In 2004, ADRS homes reduced load by 1.0 kW or 49%, while in 2005 ADRS homes reduced load by 0.6 kW or 30% compared to low consumption control homes. On non-event days, ADRS homes again reduced more load in 2004 than in 2005, by 0.4 kW or 28% in 2004 compared to 0.2 kW or 14% in 2005 across the peak period.

In SDG&E service territory, low consumption ADRS homes reduced Super Peak period load by 0.2 kW or 14% in 2005. This was greater than Super Peak period reductions in 2004, when ADRS homes consumed slightly more load than low consumption control homes on average. On non-event days, ADRS homes consumed more load than control homes in both 2005 and 2004. Taking into consideration the 90% confidence interval around the average peak period load reductions, however, SDG&E low consumption ADRS customers reductions essentially produced zero on event days in 2005 and in 2004.

3.6 Summary of comparison of summer 2005 and summer 2004 ADRS results

Customers with ADRS technology and subject to CPP-F rates in climate zone 3 successfully achieve load reductions compared to control customers without ADRS technology on standard tiered rates in both 2005 and 2004. The load reductions were substantial and stable across a range of days and temperatures. Technology appears to be an important driver in reducing load, especially Super Peak load, for high-consumption homes.

High consumption ADRS load reductions in 2004 were slightly greater than load reductions in 2005. In 2005, performance was strongest in July statewide and for PG&E and SCE high consumption ADRS homes. In 2004, performance was strongest in September statewide and for PG&E and SCE high consumption ADRS homes. For SDG&E high consumption ADRS homes, performance was strongest in September in both 2004 and 2005.

Part of the reason why 2005 ADRS load reductions were lower than in 2004 was due to curiously lower control home load on event days in 2005 in spite of the fact that 2005 was a hotter summer on average. Furthermore, high consumption control homes in SCE service territory in particular seemed to display load shifting behavior in the manner of ADRS homes. Superimposing 2005 high consumption control home load curve with control home load curve in 2004, we observed that SCE control homes in 2005 consumed less load during Super Peak period, followed by a noticeable increase in load between the hours of 7 p.m. and 9 p.m. that was similar to the recovery in load of ADRS homes on event days. It is unclear whether and how control homes in SCE territory were aware of event day announcements. However, given that summer 2005 was hotter than in 2004, and given that energy issues were prominent in the news in 2005 with record high oil prices, perhaps control customers combined various energy marketing messages and attempted to actively reduce consumption in the home.

Comparing daily consumption patterns between years in energy terms, high consumption ADRS customers in PG&E and SCE service territory shifted load more aggressively from Super Peak and peak periods to off-peak periods in 2005 compared to 2004, with subsequent reductions in net energy conservation. High consumption ADRS homes in SDG&E service territory, on the other hand, appeared to have used technology to reduce overall energy consumption as opposed to shifting load on both event and non-event days, for both summer 2005 and summer 2004. It may be that in SDG&E, where average temperatures were typically 10^{o}F cooler that the statewide average, customers were better able to respond to peak pricing signals by reducing energy consumption overall. In PG&E and SCE service territory where temperatures tended to be higher than the statewide average, high consumption ADRS customers resorted to shifting load in order to save money while maintaining thermal comfort.

Peak temperatures experienced by ADRS customers within each utility territory did not always coincide with days when statewide Super Peak events were called. SDG&E, for example, typically experienced lower temperatures than the statewide average temperature on any given event day that was called. Although ADRS homes in PG&E and SCE territories in climate zone

3 are on average hotter than SDG&E, ADRS homes in the two territories alternated between hotter and cooler temperatures than the statewide average when event days were called[26].

[26] Additional analysis showing differences in average daily temperatures by utility for summer 2005 is included in the body of this report and in Appendix A, Data Development and Analysis Methodology.

AUTOMATED DEMAND RESPONSE SYSTEM PILOT

Final Report
Volume 3

Future Program Recommendations

Prepared by
Rocky Mountain Institute
Boulder, Colorado

31 March 2006

Table of Contents

In this volume of the report, we explore the Super Peak and peak period load reductions at the individual household level, to test the hypothesis that a minority of high performance households contributes to the majority of load reductions. From this finding and from the load impact results presented in volume 2 of this report, we describe our recommendations for future program design. The recommendations include targeting strategies that utilities can use to recruit in to the program likely high performing customers. We identify and present physical and behavioral characteristics that can help utilities screen and target customers during the recruiting process. Additionally, we make some recommendations for how utilities can implement ADRS programs in the future to enhance program performance.

Introduction

One of the primary conclusions from the 2004 and 2005 Automated Demand Response System (ADRS) pilot program is that CPP-F customers in the Statewide Pricing Pilot (SPP) with ADRS technology in climate zone 3 successfully achieved additional load reductions during the Super Peak Period, compared to both CPP-F customers without ADRS technology and control customers on standard tiered rates. The load reductions were substantial and stable across a range of days and temperatures, with the technology appearing to be an important driver in reducing energy usage, especially during the Super Peak Period.

In particular, "high consumption" CPP-F customers with ADRS technology in the pilot consistently produced more than twice the load reduction of "low consumption" CPP-F customers with ADRS technology, compared to their respective control groups. Furthermore, high consumption ADRS customers reduced more than twice the load of residential customers in other demand response programs who do not have technology[1]. High consumption ADRS customers are defined as customers with average daily usage (ADU) during the summer season greater than or equal to 24 kWh per day. Homes with an ADU of less than 24 kWh per day on average were designated as low consumption homes.

Since the cost-effectiveness of a demand response program is a function of the magnitude of the peak demand reduction achieved per home and the number of homes participating in the program, these conclusions from the ADRS pilot suggest a strategy of targeting residential demand response enabling technology to higher-usage customers. This leads to the question of whether there are other characteristics of high consumption customers that would help utilities better identify them as high-performance customers in terms of potential to deliver relatively large peak demand reductions. For this information to be most useful in programs design, it should be obtainable during the program recruiting process. If so, it could be used to screen in customers that would benefit the most from an ADRS-like program.

This report examines in more detail the load reduction performance of specific high consumption customers in the ADRS pilot. Using these results, we attempt to identify characteristics of high performing ADRS customers for purposes of screening and targeting in future ADRS programs.

[1]Ibid.

This report also makes recommendations for the implementation and operation of future ADRS programs to maximize load reduction benefits.

ADRS high consumption ADRS homes segmentation

In the ADRS pilot, high consumption homes are defined as those customers with summer average daily usage (ADU) greater than 24 kWh. In our opinion, this is still a rather low threshold. The range of ADU for high consumption ADRS homes in the pilot was actually between 24 kWh to 150 kWh, a 750% difference. As will be evident in the analysis discussed herein, the population of high consumption homes is diverse, resulting in different potentials and ability to reduce on-peak loads using technology.

To segment the high consumption ADRS homes in more detail, RMI studied the relative performance of high consumption ADRS customers against each other. The objective of this analysis was to determine the types of homes that comprise the bulk of the Super Peak and peak period load reductions. We wanted to test the hypothesis that the largest ADRS homes contributed most to Super Peak and peak period reductions on event and non-event days, respectively.

Determining the portion of homes that contributed the most to Super Peak and peak period reductions requires a measurement of ADRS load impact at an individual household level. This is problematic, because control homes cannot be matched with ADRS homes on a one to one basis. In all of the load impact analyses we've conducted in this report, RMI compared the <u>average load</u> of all control homes with that of ADRS homes for each time interval, by consumption stratum. Comparing an individual ADRS home with the average load of all control homes at a given time interval is not informative either, as we would be comparing an average control load that includes both large and small homes to one ADRS home that may have large or smaller loads than the average control load.

Given the data available, we decided to determine household level performance according to each home's immediate load drop at 2 p.m. compared to the period immediately prior, at 1:45 p.m. Furthermore, the 2 p.m. load drop would be scaled to the ratio of adjusted statewide average load reduction to the average 2 p.m. load drop. We judged this to be the best compromise to determining individual household performance, given the inability to compare against a control group at the individual household level. This "pre-curtailment" approach has been studied as an approach for automated demand response baseline calculations for individual customer accounts[2].

Thus for each ADRS customer, we began with the calculation of immediate load drop relative to 1:45 p.m. to 2:00 p.m. load on event and non-event days, for each month from July 2004 through September 2005. The ADRS homes and their load impact results were then segregated by high and low consumption strata. RMI calculated the average initial load drop between 2:00 p.m. and 2:15 p.m. and between 2:15 p.m. and 2:30 p.m. for each ADRS customer during every weekday

[2] "Development of Uniform Protocols for Demand Response "Peak Savings" Calculations: A Review of Existing Methods and Recommendations for Uniform Protocols" Miriam L. Goldberg, CEC Staff Workshop, August 15, 2002

from June 2004 through September 2005. The two time intervals were chosen because the first half hour of the 2:00 p.m. to 7 p.m. period generally produces the largest load drop on event and non-event days. The larger of the two values, percent load drop during the first fifteen minutes and percent load drop during the second fifteen minutes of the peak period, was used as the representative performance value for each ADRS participant.

An average 2 p.m. load drop was then calculated for all homes combined, according to high and low consumption strata. Next, we calculated the ratio of the adjusted statewide average load reduction, which is based on the results of our 2004 and 2005 load impact evaluation, to the average 2 p.m. load drop of all ADRS homes. A separate ratio was calculated for each month from July 2004 through September 2005 for event and non-event days. This ratio was then multiplied by the immediate load drop at 2 p.m. for each individual household by consumption stratum. Once the adjusted immediate load drop at 2 p.m. for each household was calculated, RMI calculated the percentage of homes in each stratum whose load drop equaled or exceeded a given level on average.

Estimates of load impact at the individual household level[3] revealed that 14% of high consumption ADRS customers who remained on the program from July 2004 through September 2005 were "supersavers" (Table 1). These homes consistently reduced their load at 2 p.m., the start of the Super Peak and peak periods, by 30% or greater, compared to their load immediately prior at 1:45 p.m. Supersavers contributed 19% of Super Peak reduction and 20% non-Super Peak reduction across the summer months from 2004 to 2005, in terms of instantaneous load shed at 2 p.m.

Table 1: Summary of house level performance based on 2 p.m. load drop July 2004-September 2005

	High consumption stratum	Low consumption stratum
Supersavers		
No. of Homes	14	2
% of Homes	15%	13%
Improved Performers		
No. of Homes	5	0
% of Homes	5%	0%
Program Cruisers		
No. of Homes	11	5
% of Homes	12%	16%
Not categorized		
No. of Homes	62	23
% of Homes	67%	24%
Opt outs/Incomplete data		
No. of Homes	36	15
% of Homes	N/A	N/A

[3]Description of analysis methodology for household level analysis is included in Appendix A to this report, Household Level Analysis Methodology.

While Supersavers consistently reduced 2 p.m. load every event day during both years of the pilot program, another one-third (35%) of high consumption ADRS homes reduced their 2 p.m. load by 30% or greater on a majority of event days from July 2004 through September 2005. An additional 15% of high consumption ADRS homes reduced their 2 p.m. load by 20% or greater on most Super Peak days from July 2004 through September 2005. While we did not segment these two groups of customers into specific categories with names, they were also good to high performing customers.

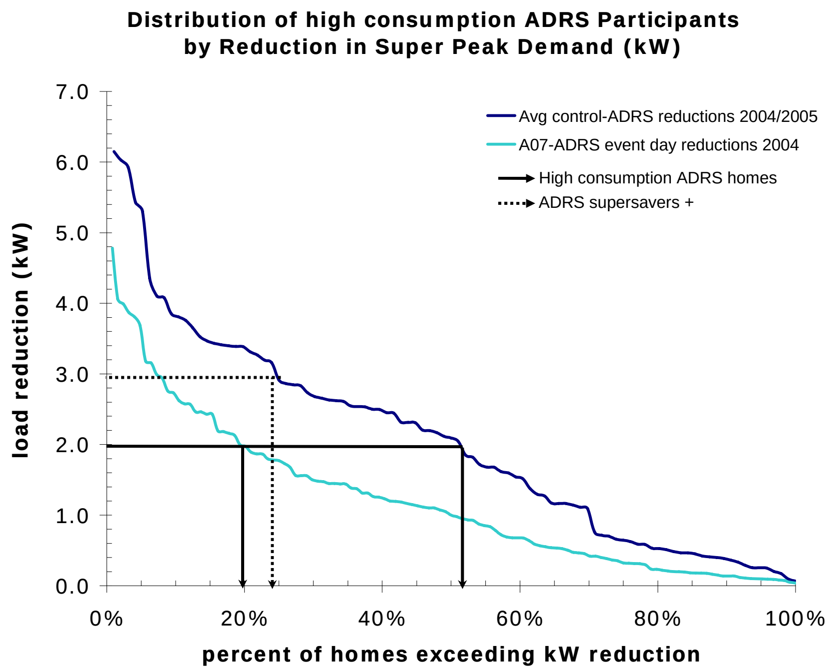
Twelve percent of all ADRS homes were "program cruisers". These customers consistently reduced their 2 p.m. load on event and non-event days by less than 20%, and did not appear to experiment very much with the technology.

Approximately 5% of high consumption ADRS homes gradually improved their 2 p.m. percent load drop performance from July 2004 to September 2005, which we categorized as "improved performers". These homes initially reduced Super Peak and peak period load by 20% or less during 2004 but increased their load reductions to 30% or more by the end of 2005. Finally, about 2% of homes saw their performance decline from July 2004 through September 2005 on both event and non-event days.

Load drop distribution among high consumption ADRS homes

Figure 1 plots the estimated, individual-household level Super Peak period reductions relative to control homes on standard, tiered rates without ADRS technology, averaged across July 2004 and September 2005. Also plotted are estimated individual ADRS household Super Peak reductions relative to SPP A07 customers (customers who are on the CPP-F rate but do not have ADRS technology) from July through September 2004.

Figure 1: Distribution of high consumption ADRS load reduction on event days, July 2004-September 2005



Also indicated in Figure 1 is the percentage of high consumption ADRS homes reducing 2 kW or more load compared to control and A07 customers on event days, as well as the percentage of homes represented by supersavers. Thus on event days, over half or 51% of all high consumption ADRS homes statewide reduce Super Peak period load by 2 kW or more, compared to control homes. Furthermore, these same ADRS homes made up 80% of the total load shed during Super Peak periods. However, just 19% of high consumption ADRS homes statewide reduce load by 2 kW or more compared to A07 customers. These same homes made up 46% of the total load shed during Super Peak periods.

Supersavers reduced load compared to control homes by an average of 3.0 kW during Super Peak periods. Compared to A07 customers, supersavers reduced load by 2.3 kW during Super Peak periods. As reported above, supersavers represent 15% of the high consumption ADRS population and contribute about 20% of total load reduction on event and non-event days. Note in Figure 1, however, that the percent of homes reducing Super Peak load by 3.0 kW or more is 24%, slightly greater than the population of supersaver homes. This is because there are other large, high consumption homes reducing significant load but this load is not 30% or more of their off-peak load at 1:45 p.m. This implies that the relationship between available load and load reduction is not as strong as one would hope, as further revealed by Figure 2 and Figure 3 below.

The results for non-event days are similar, with the exception that we used a lower load reduction threshold of 1.0 kW (graph not shown). Almost 40% of all high consumption ADRS homes statewide reduced peak period load by 1.0 kW or more, compared to control homes. Furthermore, these same homes made up 66% of the total load shed during peak periods.

However, just 15% of high consumption ADRS homes statewide reduce load by 1.0 kW or more compared to A07 customers. These same homes made up 43% of the total load shed during peak periods. Supersavers reduced peak period load by an average of 1.5 kW, compared to control homes. Compared to A07 customers, supersavers reduced load by 1.2 kW during Super Peak periods.

Figure 2 and Figure 3 look at this issue from a slightly different perspective, in terms of size of high consumption ADRS homes (as measured by summer average daily usage) and amount of load drop during event and non-event days, respectively. We make two observations from the figures. First, that the population of high consumption ADRS homes is quite diverse, as the range of ADU varies 750% between 24 kWh to 150 kWh. Second, it is not consistently true that the highest energy consuming homes will reduce the most loads, particularly on non-event days. The figures show that the relationship between Super Peak or peak period load drop and energy consumption is rather weak, with r-squared (r^2) values close to zero[4].

While these results support our hypothesis that even within the high consumption ADRS sample, a subset of homes contributed to the majority of Super Peak and peak period load reductions compared to control homes, they are not particularly compelling because the "subset" consists of the majority of high consumption homes. <u>This suggests that targeting high consumption homes during program recruiting is adequate, and is an economical way of implementing the program.</u> Monthly consumption data on customers are readily available and easily accessible, so that utilities can screen for this parameter if so desired during program recruiting.

[4]A strong relationship would have r-squared values close to 1.0.

Figure 2. Correlation study of event day, Super Peak period load drop and 2003 summer average daily usage, high consumption ADRS homes

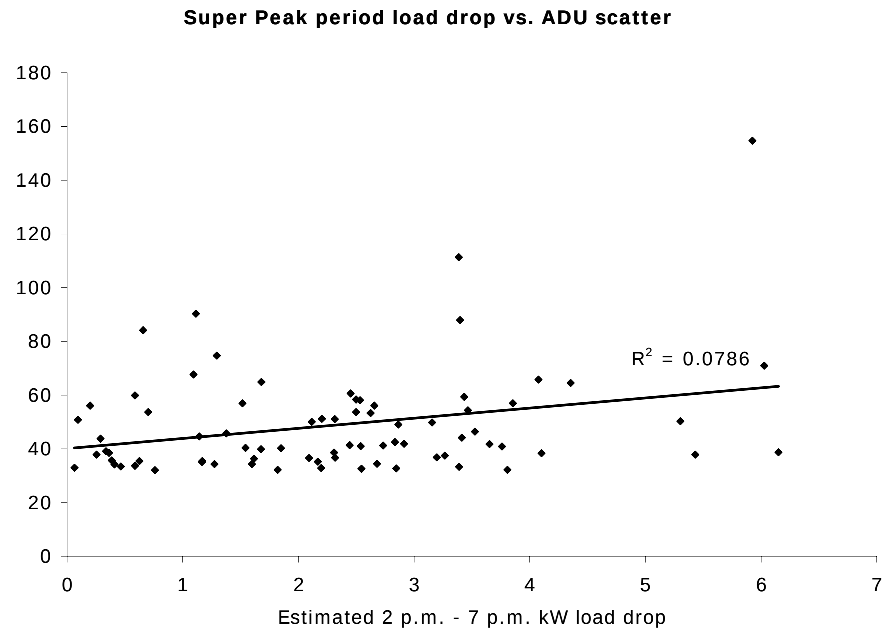
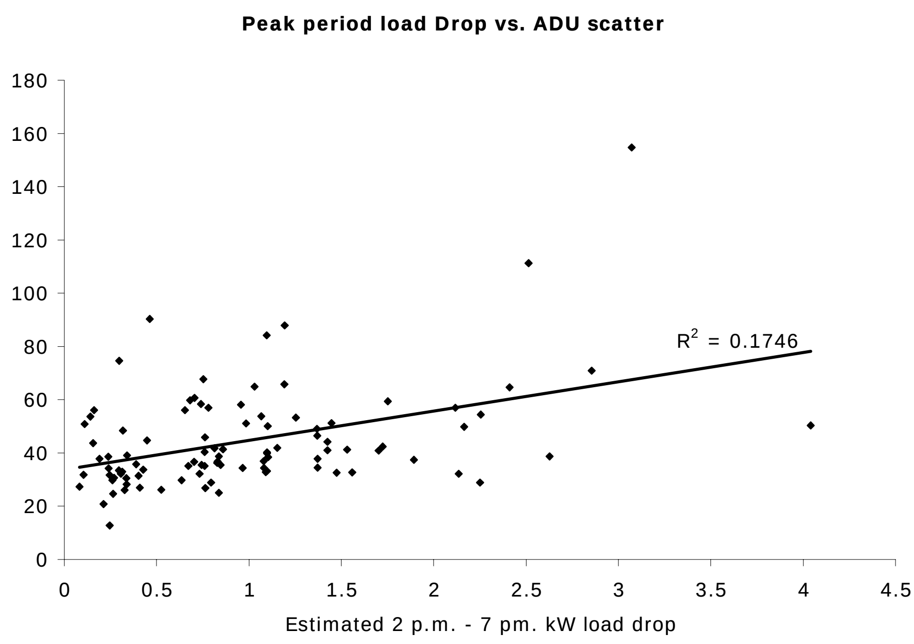


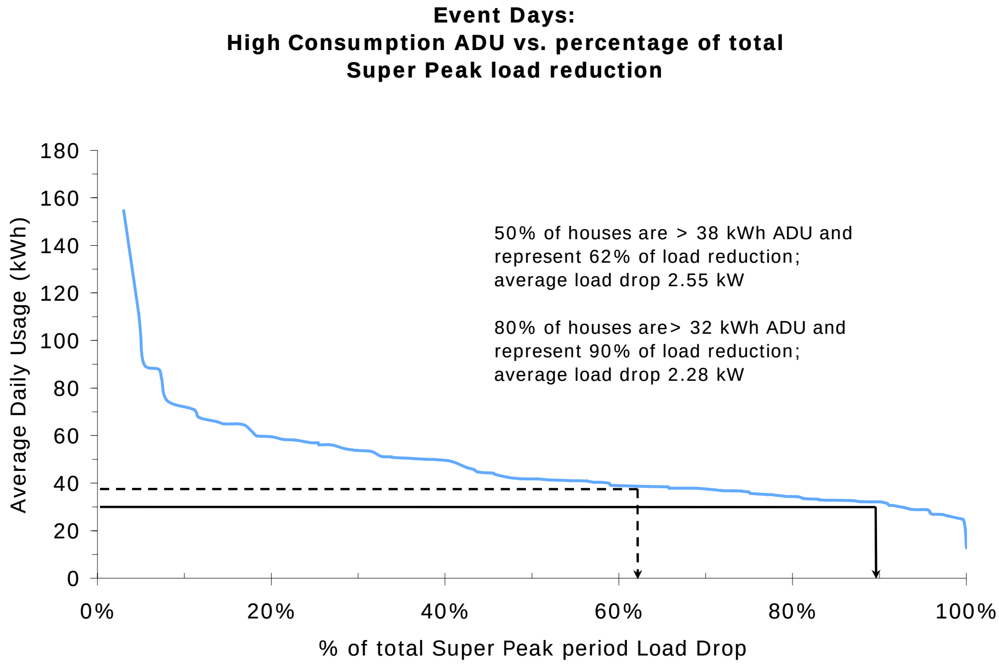
Figure 3. Correlation study of non-event day, peak period load drop and 2003 summer average daily usage, high consumption ADRS homes



<u>We recommend, however, that the threshold between low and high consumption homes is raised slightly from its current 24 kWh ADU to 32 kWh ADU.</u> As illustrated in Figure 4, 90% of total Super Peak period load drop in summers 2004 and 2005 was achieved by ADRS homes with ADU greater than 32 kWh, which made up 80% of total high consumption population. These

homes have ADU greater than 32 kWh, and achieved an average (unadjusted, household-level estimate) load drop of 2.3 kW from 2004 to 2005. An ADU study for non-event days produced identical results, with homes achieving an average (unadjusted, household-level estimate) load drop of 1.1 kW across the peak period.

Figure 4. Distribution of high consumption ADRS homes on event days by summer 2003 average daily usage, July 2004-September 2005



The fact that there are a number of particularly high consuming households (> 50 kWh ADU) in Figure 2 and Figure 3 that reduce load by 1.5 kW or less on event and non-event days suggests that there is a behavioral element to participation. Predicting behavior based on observable data, however, is harder and therefore, more difficult to use as a targeting strategy. However, if utilities can cost effectively identify and target these homes when implementing ADRS programs in the future, they can potentially capture most of the potential benefits of the program while reducing their costs of running the program. The key, then, is determining how these high performing homes can be identified.

Targeting high performance homes to maximize program benefits

Given that high performing, high consumption ADRS homes were identified in the summer 2004 and summer 2005 pilot program, we next attempted to outline some physical and behavioral characteristics for use in screening for potentially high performing customers in future ADRS programs. We also looked into elements of pilot implementation that could be improved in the future to further increase program effectiveness. The following section specifies guidelines for maximizing load reduction performance of homes using ADRS technology.

Screening for desired household physical characteristics during recruitment

High consumption homes tend to have higher demands on the hottest summer days. The ADRS pilot defined high consumption homes as customers with summer ADU greater than 24 kWh. As discussed in the above section, however, 90% of total Super Peak period load drop in summers 2004 and 2005 was achieved by 80% of high consumption ADRS homes. These homes have ADU greater than 32 kWh, and achieved an average (unadjusted, household-level estimate) load drop of 2.28 kW from 2004 to 2005. We thus recommend that utilities raise the high consumption threshold to 32 kWh in future ADRS programs. Locating customers with ADU greater than 32 kWh is relatively straightforward, as monthly consumption data on customers are readily available and easily accessible, so that utilities can screen for this parameter if so desired during program recruiting.

Evaluation results showed that load reductions were stable and consistent for high consumption ADRS homes experiencing peak temperatures greater than 90^{o}F. The exception was ADRS participants in SDG&E territory, where temperatures rarely exceed 95^{o}F during the summer. However, SDG&E homes also exhibited stable load reductions during event days greater than 85^{o}F. This leads to the hypothesis that what is considered "hot" is relative, and suggests that homeowners use ADRS technology to help them maintain comfort while minimizing energy expenditures. Furthermore, ADRS customers in this pilot were located in climate zone 3 only, in the California inland areas. RMI recommends that climate zone 4 customers located in desert climates be included in future programs in addition to climate zone 3 homes that were recruited for the pilot.

Pilot evaluation results showed that where present, pool pumps made a significant contribution to reduction of Super Peak and peak period load. The 2005 load impact evaluation revealed that residents shifting pool pump operation contribute 32% of the total Super Peak reduction for an average home with a pool. On non-event days, residents shifting pool pump operation contributed over 50% of the total peak period reduction for an average home with a pool.

Additional in-home interviews and focus groups conducted by Boice Dunham Group (BDG) as part of the ADRS pilot further uncovered that many homeowners with pools abstained from use of pool pumps completely in anticipation of Super Peak days[5]. Other homeowners reschedule pool pumps well outside the Super Peak hours, for example beginning at noon rather than at 2 p.m. These load shifting strategies were thus not clearly captured by measurement of load drop only during the peak period between 2 p.m. and 7 p.m. Nevertheless, these homeowners with pools contribute to overall peak period reductions.

As such, ADRS programs should target communities with a high incidence of pool ownership to maximize opportunities for significant load shifting during Super Peak and peak periods. Utilities implementing ADRS programs in the future should try to employ technology with additional end use control capability for other large customer loads such as pool pump operation in addition to air conditioning. The ADRS technology has the ability to schedule the use of

[5]Boice Dunhame Group. 2006. *Customer Satisfaction Report, ADRS pilot program,* and *Customer Super Peak Behavior Report, ADRS pilot program.*

electric water heating as well, though this capability was not employed for this pilot. We surmise control of electric water heating could also increase the effectiveness of future ADRS programs in the manner that pools did in the pilot.

Another primary conclusion from the summer 2005 and 2004 ADRS pilot load impact evaluation is that load reduction performance for ADRS customers varied between utilities across the state. SCE high consumption ADRS customers achieved on average about 2 kW reductions on event days across a range of temperatures[6]. PG&E and SDG&E high consumption ADRS customers achieved substantial, but lower reductions, close to 1 kW on event days on average.

While both PG&E and SCE ADRS homes in the pilot program experienced similar temperatures on event and non-event days, the different performance between the two utilities suggests that additional factors other than temperature contribute to load reduction performance. On one hand, we cannot compare the results of one utility relative to another because each utility operated the pilot within their service territories independently of each other. As such, there were too many variables to consider in the process of explaining why one utility achieved higher reductions. On the other hand, we wish to suggest some factors based on qualitative evidence that appear to contribute to significant load reduction performance among ADRS participants. We feel that these factors warrant further study for future ADRS program design.

One of the factors that appear to provide a strong link to better program performance is targeting specific geographic regions. ADRS homes in SCE territory were selected from zip codes[7] where homes tended to be larger than ADRS homes from zip codes targeted in PG&E and SDG&E territory, on average. About 40% of SCE customers owned homes with floor areas larger than 2,000 sq.ft., compared to about 30% and 20% for ADRS customers in PG&E and SDG&E service territories, respectively (Table 2). These homes also tended to have larger air conditioning units, on average 4 tons cooling capacity per unit. Furthermore, the majority of ADRS participants in SCE territory had household incomes greater than $100,000 per year.

Table 2
Some Summary Characteristics of ADRS Homes*

	SCE	**PG&E**	**SDG&E**
Average air conditioner size (tons)**	4.25	3.25	3.3
% of homes > 1,500 sq. ft	80%	68%	64%
% of homes > 2,000 sq. ft.	42%	29%	23%
Avg. # of bedrooms	3.8	3.3	3.3
Household income > $100,000-yr	59%	10%	41%

*Source for all data with exception of average a/c size from Utility Home Energy Survey for ADRS pilot and Statewide Pricing Pilot programs.
**Source for a/c sizing data from ADRS Installer Survey conducted April-May 2004 based on respondents

[6] This result is consistent with RMI's evaluation of ADRS technology in another pilot program conducted by Nevada Power Corp during summers of 2003 and 2004.
[7] The ADRS technology utilized cable TV for broadband connectivity, and cable providers for the GoodWatts system were identified by zip code

Given the number of residential customers that PG&E and SDG&E serve and the geographical diversity of the two utility service territories, we are confident that there are subsets of customers within PG&E and SDG&E service territories located in zip codes with similar household size and income profiles that SCE recruited into the ADRS pilot. <u>It is highly plausible then, that utilities that target larger customers in zip codes with relatively newer and higher income residential developments will have a better chance of achieving 2 kW load reduction performance. These customers will likely have larger homes (>2,000 ft^2), and thus likely to have air conditioning units along with other end uses such as swimming pool pumps.</u>

Another factor that can contribute to maximizing overall program benefits of load reduction of homes using ADRS technology is <u>if the homes are located in zip codes with relatively high avoided capacity and energy costs.</u> In general, a demand response program such as ADRS will be worthwhile to implement if avoided generation capacity and energy costs, avoided distribution capacity costs, and avoided environmental costs accrued to utilities and society are greater than the costs to implement and operate the program[8].

In California, the California Public Utilities Commission (CPUC) adopted a methodology in October 2004 for calculating area-specific total avoided cost values based on the specific hour of a typical year and by planning areas and climate zones within the state[9]. Transmission and/or distribution capacity and line losses, the marginal cost of ancillary services, and the price effect of demand reduction on energy consumers are also accounted for in the total avoided costs. The utilities can consult this methodology and the corresponding cost model to identify high avoided cost areas within their service territory in order to concentrate recruiting of ADRS participants there[10]. The load impact evaluation has shown that ADRS customers can successfully relieve statewide and utility-specific system Super Peak period loads when called upon to do so. At an even smaller scale, ADRS has the potential to help utilities relieve peaks at the local distribution level and defer distribution capacity on a planning area basis.

Screening for desired household behavioral characteristics during recruitment

As suggested by BDG, high consumption <u>customers who are customarily away from home during the day</u> are good enrollment targets as they can more readily reduce significant load between 2 p.m. and 7 p.m. on both event and non-event days. The remote programmable feature of ADRS technology is highly appropriate in this case, as homeowners can program their desired preferences to respond automatically to price signals.

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[8]Benefits from the customer perspective includes utility bills savings resulting from lower consumption during peak hours.

[9]California Public Utilities Commission. 2004. R. 04-04-025. Order Instituting Rulemaking to Promote Consistency in Methodology and Input Assumptions in Commission Applications of Short-run and Long-run Avoided Costs, Including Pricing for Qualifying Facilities.

[10] The avoided cost valuation model designed by Energy and Environmental Economics, Inc. (E3) for the CPUC was originally for energy efficiency programs specifically. Currently, there is a module that allows users to allocate energy reductions to specific hours of the year and to locate hours when avoided costs are greatest by planning area. This gives it some flexibility for evaluating avoided cost benefits of demand response programs. There are plans for updating the avoided cost valuation model to more accurately calculate value for demand response programs such as ADRS specifically, but no new versions of the valuation model have been issued to date.

While this behavioral characteristic is relatively easy to screen for, it also makes for difficult (and potentially uneconomic) recruiting given that these homeowners are hard to reach during the day, and hard to schedule appointments with during the week to handle equipment installations or customer service calls. This is not an absolute screen, furthermore, as other pilot participants have expressed appreciation of ADRS technology's sophisticated capability to flexibly control energy consumption to help minimize energy bills even when customers are regularly at home.

During various interviews with existing ADRS participants, BDG discovered a group of customers who enjoy the "set and forget" capability that the ADRS technology allows them. These customers feel that the automation makes it easy and relatively effortless for them to participate in the program. These customers may experiment with the technology's features and settings, but will restore the technology programming during Super Peak days to maximize performance. This is a <u>set of high consumption customers who are receptive to automation</u>, and are not limited to technophiles who tend to be early adopters of new technology. Unlike the customers who are regularly away from home, this set of customers is harder to identify prior to their participation. However, this is a characteristic which we have identified as helpful for achieving high load reductions in future ADRS programs.

A third chief behavioral characteristic that BDG identified as useful for targeted marketing is the set of <u>high consumption customers who are receptive to learning about ADRS technology</u>. This tends to be the group of customers who read program materials carefully, who attend informational workshops, and who will invest the time and attention to learn about the ADRS program. Like the customers who enjoy automation, this set of customers are difficult to target, but possess a characteristic we have identified as useful for achieving high load reductions in future ADRS programs.

We do not claim that the behavioral elements just discussed are complete or exhaustive. However, we feel that they are the chief behavioral characteristics that can be relatively easily (and therefore economically) screened for during targeted marketing and that would increase the chances of recruiting high performance participants.

We also caution that these behavioral elements should be screened in conjunction with the physical characteristics described above, to avoid conflicting results. For example, there is little program benefit to identifying a customer who's not usually home during the day but has average daily usage less than 32 kWh, indicating that the household does not have much load available to curtail. In this case, a utility would be recruiting based on behavioral characteristics that we recommended while ignoring the physical characteristics of many high performing ADRS customers, thereby potentially reducing the effectiveness of the program.

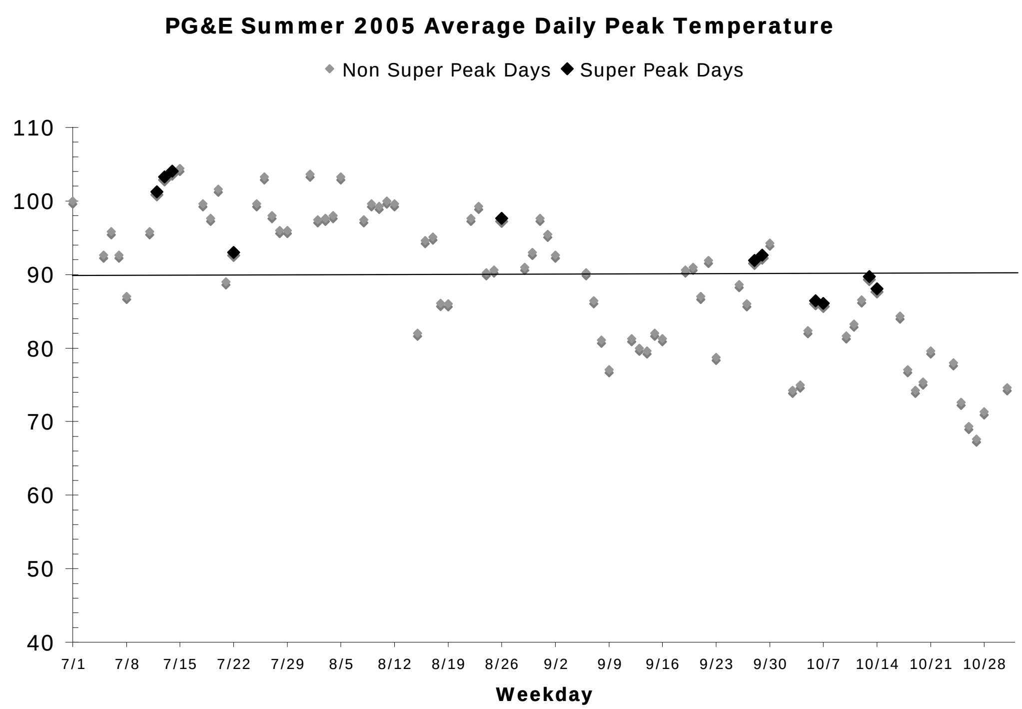
Other Recommendations for Program Implementation

The remainder of this section discusses recommendations for implementation and operating ADRS programs to maximize program benefits. First, RMI's evaluation results showed that load reductions were stable and consistent for high consumption ADRS homes experiencing peak temperatures greater than 90°F, as mentioned above. This suggests that utilities should call event days when temperatures are predicted to be highest for the summer.

As Figure 5 illustrates using PG&E service territory as an example, a Super Peak event day was not always the hottest day in the ADRS pilot. The black dots in Figure 5 are the peak temperatures recorded for ADRS homes in PG&E's territory on event days called statewide, and the gray dots are the remaining non-event days between July and October 2005. ADRS homes in PG&E's service territory experienced about 32 days in the early summer that were hotter than average peak temperatures on six Super Peak event days called statewide. Only one event day in August was called, though there were many hot days that were higher than 95°F.

Four event days were called statewide in October 2005, when average peak temperatures in PG&E territory regularly fell below 90°F. According to BDG's in-home interviews and focus group sessions, ADRS customers from all utility service territories did not understand why late September and October events during 2005 were necessary when summer was essentially over and temperatures had become mild.

Figure 5. PG&E Summer 2005 Average Daily Peak Temperature



While we agree that there will be occasions when event days need to be called for other reasons such as unexpected plant shutdowns, we recommend that utilities create a separate category for event days when outside temperatures are less than 90°F. We recommend that utilities call these exceptional event days as "emergency" days, for example, rather than "Super Peak" events that customers associate with high summer temperatures.

Given that the ADRS technology has the capability of reporting outside temperatures of ADRS participants by zip code, utilities have the ability to check this data point against weather forecasts and tailor notification of Super Peak events by zip code. For ADRS homes located in zip codes that will experience temperatures on Super Peak days lower than 90°F, utilities may recast the notification as emergency events, or refrain from triggering Super Peak for those homes altogether. In this way, customers receive more consistent messages on the calling of events and may more likely perceive that the program is simple, straightforward, and effective.

Figure 5 also supports the conclusion that peak temperatures experienced by ADRS customers within each utility territory do not always coincide with days when statewide Super Peak events are called. Calling event days statewide for a pilot program that is operated on a statewide basis makes sense in terms of system requirements and allows for easier program evaluation. However, it may not be the best approach for maximizing program performance. Because of temperature differences by utility, and because utility system electrical peaks do not always coincide, RMI recommends that event days should be called by each utility separately.

Results from the load impact evaluation revealed that homes with ADRS technology produce a consistent and predictable load profile during Super Peak and peak periods. Load reductions are at their maximum at the start of the period, then gradually increase as homes warm up and air conditioners pulse on to maintain indoor temperatures at the higher setpoint. For some homes, such as those observed in SCE territory, load reductions are sustained over the first two or three hours of the peak period but decline noticeably during the fourth and fifth hours[11].

As a second implementation recommendation, then, ADRS load reductions should be called closer to actual utility system peaks. Currently, Super Peak and peak periods are defined as 2 p.m. to 7 p.m. on weekdays excluding holidays from July through September. However, utility system loads in California tend to peak around 4 p.m. on weekdays during the summer, which also corresponds to the hottest hour of the summer day[12]. <u>Thus, utilities may want to consider starting Super Peak and peak periods shortly prior, at 3 p.m.</u>

<u>As a second alternative, we recommend that utilities end the peak period earlier than 7 p.m.</u> While shifting the start of the peak period on event and non-event days one or two hours later in the afternoon benefits utility operators, ending the peak period earlier may further increase customer satisfaction with the program. According to BDG interviews, customers felt that extending the peak period to 7 p.m. was inconvenient for them because most customers were home during that time and wanted to be comfortable while they make dinner or else relax at home.

As a third alternative, <u>we recommend putting ADRS customers on the CPP-V rate, as oppose to the CPP-F rate used for this pilot</u>. The difference between the rates is that Super Peak price

[11]This behavior is potentially problematic if the recovery period coincides with the local distribution system peak, and utilities should take note. The sharp increase in load following the end of the designated peak period would not, however, affect the utility system-wide peak given that utilities schedule ADRS homes to reduce load during these system peaks, such that the recovery period occurs after the system-wide peak occurs.

[12]Rufo, Michael and Fred Coito. 2002. *California's Secret Energy Surplus: The Potential for Energy Efficiency*. Final Report. Prepared for the Energy Foundation and the Hewlett Foundation. Figure A-8, page A-6.

signals can be sent during any hour of the peak period under the CPP-V rate, and duration of the Super Peak period varies between the hour the price signal is sent and 7 p.m. Under the CPP-F used for the ADRS pilot, the Super Peak period is fixed, always beginning at 2 p.m. and always ending at 7 p.m. We conclude that the CPP-V rate should be a better fit for homes with ADRS technology, given the transient nature of load reductions observed in this pilot[13].

Finally, we recommend that utility managers may sometimes be able to call on homes with ADRS technology to reduce load alternately at different times throughout the Super Peak period to help sustain load reductions through a five hour period, as opposed to "dispatching" all ADRS homes at the same time at 2 p.m. For example, utilities may try sending the Super Peak price signal at 2 p.m. to half of the ADRS homes and another Super Peak price signal at 4 p.m. to the remaining half. Utilities may also consider dividing the Super Peak period customer participation into thirds. Additionally, customers could alternate between being the first group to be dispatched on alternate event days, such that the same homes are not always dispatched to 7 p.m. over the course of a summer.

This last alternative is not likely to be effective as the standard method of calling Super Peak events, however. While this strategy would smooth out the average kW reduction over a longer (5 hour) peak period, it also reduces the total load available for curtailment (since utilities are only calling ½ of customers at a time, for example). The reduced load performance per household thus reduces program cost effectiveness. Furthermore, the jump in load during the recovery period for the group called first may coincide with when the utility is still trying to get other customers to curtail, and risks negating the overall savings. Utilities can mitigate this effect by further staggering the homes for the end of the peak period to control the magnitude of the recovery. Because of these issues with recovery period load, we recommend this as a strategy only some times.

In addition to the timing and length of peak and Super Peak events that are called only on the warmest days or else during emergencies, we recommend that future ADRS program limit the number of consecutive event days to those absolutely necessary, to minimize opt outs or program churn. We understand that multiple, consecutive event days were called in 2004 and 2005 to test the efficacy of ADRS technology. However, customer responses based on BDG research have indicated that calling too many consecutive event days have caused them to consider opting out of the program.

Furthermore, our observation is that either automated technology or dynamic pricing can deliver significant demand response in large residential houses, but that the combination of both technology and dynamic pricing might not be necessary for the average home. The following rationale explains this observation.

In the summer 2005 pilot, ADRS load impact was evaluated against a control group without enabling technology or dynamic rates. The results show a substantial load drop during Super Peak Periods with larger homes. However, in the summer 2004 pilot, ADRS load impact was

[13] The reason why the CPP-V rate was not used for the ADRS pilot was because only two utilities had filed the rate application with the CPUC when the pilot began in 2004. PG&E still does not have a CPP-V tariff at time of this writing.

evaluated against a group of average homes that were on the CPP-F rate but did not possess ADRS technology ("A07" homes). Particularly for low-consumption homes, the 2004 load impact report revealed that the critical peak pricing rate captured the majority of load benefits, and the additional load reduction resulting from enabling technology was small to negligible[14].

Assuming that dynamic rates are adopted in California statewide, future ADRS load reduction performance would be comparable to statewide results reported compared against A07 customers in the 2004 ADRS load evaluation study[15]. Residential customers without enabling technology would already reduce some Super Peak and peak period loads as a result of the dynamic pricing tariff, and the incremental impact (and therefore cost effectiveness) of enabling technology would be reduced.

If dynamic pricing tariffs do not become the default tariffs, then the average residential customers generally would be similar to the control group studied in the pilot. In this case, the ADRS program is more likely to be cost effective, and utilities could further optimize the program by targeting high consumption homes as described above.

Finally, <u>we recommend that residential demand response programs for high consumption households should include automated technology regardless of whether dynamic pricing is in place</u>. In this way, utilities would have the ultimate flexibility to induce reductions in air conditioning and other residential end use loads in response to system needs, or for reliability purpose. Automated technology and could also improve price responsiveness in the absence of tariffs, or for customers that opt out of default dynamic tariffs, using either messaging or pricing signals.

Summary

The results of the 2004-2005 ADRS pilot evaluation concluded that high consumption (>24 kWh ADU) customers with ADRS technology and subject to CPP-F rates in climate zone 3 successfully achieved load reductions compared to control customers without ADRS technology on standard tiered rates, and compared to customers in climate zone 3 subject to CPP-F rates only, without ADRS technology. This report examines in further detail the distribution of load reduction performance among high consumption customers, explores and recommends strategies for maximizing program cost effectiveness by targeting only those customers that can reduce the most load ($\geq$ 2 kW) when implementing ADRS programs in the future.

Examination of ADRS customers at the household level for Super Peak and peak period load reductions confirmed that 51% of the ADRS high consumption homes produced the vast majority of savings (80%). This suggests that simply targeting high consumption homes during program recruiting is adequate to enhance customer program benefits, and is an economical way of implementing the program.

[14]Rocky Mountain Institute. 2005. *Residential Automated Demand Response System (ADRS) Pilot Load Impact Final Report*. March 25. Downloadable from http://www.energy.ca.gov/demandresponse/documents/index.html
[15]Refer to statewide high consumption load impact results in this report, *Automated Demand Response System Pilot, Restatement of 2004 Summer Load Impact Analysis.*

However, we recommend that utilities raise the threshold between low and high consumption homes slightly from its current 24 kWh ADU to 32 kWh ADU, and to target homes with ADU 32 kWh or greater. Our analysis reveals that 90% of total Super Peak period load drop in summers 2004 and 2005 was achieved by ADRS homes with ADU greater than 32 kWh, which made up 80% of total high consumption ADRS population.

In addition to ADU > 32 kWh as a screen for potential ADRS participants, we recommend a number of additional physical and behavioral characteristics that utilities can use to target future ADRS customers to help maximize future program performance. The additional physical characteristics are:

- Customers located in geographical sub-regions within the service territory that experience hottest summer temperatures, preferably above 90°F on average during the hours of 2 p.m. to 7 p.m.
- Customers possessing end uses in addition to air conditioning, such as swimming pool pumps and hot water heaters.
- Customers in regions that have similar home construction and demographics to ADRS pilot participants in SCE service territory: larger, newer (post 1985) homes that are more likely to have central air and developments with higher income households >$100,000 per year.
- Customers located in areas with high total avoided costs[16].

The behavioral characteristics of ADRS customers we could most decisively identify as contributing to large load impact include the following:

- Customers who are away from home during the day.
- Households receptive to automation of appliance operation and control settings.
- Customers who are receptive to learning about new technology.

While these behavioral characteristics are more difficult to identify ahead of time, particularly the last two, we consider these household characteristics helpful for achieving high load reductions in future ADRS programs. These observations were developed by BDG, which is evaluating customer satisfaction levels with and willingness to pay for ADRS technology during the summer 2005 and summer 2004 pilot programs[17]. Rocky Mountain Institute has been coordinating our research efforts with BDG to develop a cohesive set of results and recommendations for future ADRS programs.

Also, we propose some guidelines for program design and implementation of future ADRS programs to maximize load reductions and therefore program effectiveness. Utilities will likely achieve maximum program performance and benefits when they:

- Call Super Peak event days when summer temperatures are highest (*minimum* of 90°F in regions for ADRS customers). Else, reserve a separate category for event days

[16] *i.e.*, avoided capacity, energy, transmission and distribution, and environmental costs

[17] Boice Dunhame Group. 2006. *Customer Satisfaction Report, ADRS pilot program,* and *Customer Super Peak Behavior Report, ADRS pilot program.*

called when temperatures are merely warm or moderate, and call event days separately by utility.

- Shift start of peak period to 3 p.m.
- Shift end of peak period to 5:30 p.m. from 7 p.m.
- Place ADRS customers on the CPP-V (day of) rate instead of CPP-F (day ahead) to maximize flexibility, since the ADRS is automated.
- In limited situations, stagger calls to subsets of participants rather than all participants at once to even out the load reduction through the Super Peak period.
- Call consecutive event days only when absolutely necessary (avoid customer fatigue).

Furthermore, our observation is that either automated technology or dynamic pricing can deliver significant demand response in large residential houses, but that the combination of both technology and dynamic pricing might not be necessary for the average home.

Finally, we recommend that residential demand response programs for high consumption households should include automated technology regardless of whether dynamic pricing is in place. In this way, utilities would have the ultimate flexibility to induce reductions in air conditioning and other residential end use loads in response to system needs, or for reliability purpose. Automated technology and could also improve price responsiveness in the absence of tariffs or for customers that opt out of default dynamic tariffs.

AUTOMATED DEMAND RESPONSE SYSTEM PILOT

Final Report

Appendices

Rocky Mountain Institute

Table of Contents

Appendix A
Data Collection and Load Impact Analysis Methodology

This section summarizes the sample design, data development and load impact estimation methodology that underlies the load impact results evaluated for the 2004 and 2005 ADRS pilot.

Sample Design

This section characterizes the ADRS pilot participant population and the control population used in the load impact analysis. For the 2005 load impact analysis, one control population was used (identified as A03) while for the 2004 load impact analysis, two control populations were used (A03 plus and additional control group, identified as A07). Characterization of the 2004 control group A07 is included here given that load impact results from 2005 are compared against load impact results from 2004.

All participant and control homes in the ADRS pilot shared three key characteristics: homes were single family, detached units with central air conditioning located in climate zone 3. ADRS participants and control homes were each stratified into two sub-samples according to average daily consumption or usage (ADU). Homes are designated as high consumption if ADU is greater than or equal to 24 kWh per day. Homes with an ADU of less than 24 kWh per day on average were designated as low consumption homes.

ADRS Participants

A total of 175 homes were initially recruited into the ADRS pilot program in 2004, consisting of 75 homes from PG&E, 76 homes from SCE, and 24 homes from SDG&E. The pilot participants were recruited from owner-occupied, single-family homes from climate zone 3 in neighborhoods served by appropriate cable providers and in zip codes identified by the participating utilities. ADRS homes were recruited at random in 2004 regardless of historical consumption, although homes were screened for eligibility with respect to the presence of central air conditioning and within prescribed zip codes. Because ADRS technology is capable of controlling end uses in the home in addition to central air conditioning, homes were screened for availability of other loads (i.e., swimming pool pumps and spas), but not disqualified from participation in their absence.

ADRS homes were stratified into two sub-samples according to average daily consumption or usage (ADU). For ADRS, stratification was based on monthly billing data from June-September 2003 (summer season), divided by the number of days per month to arrive at an average daily usage. Table 1 breaks down the population of ADRS participants by consumption stratum and by utility at the start of the pilot program in 2004.

Table 1
Count and Distribution of ADRS Homes as of July 1, 2004

	PG&E	SCE	SDG&E
High Stratum	51	71	7
Low Stratum	24	5	17
Total	**75**	**76**	**24**

The ADRS homes used for the 2005 pilot load impact analysis consisted of the same households that remained in the pilot program after the summer of 2004. ADRS participants were notified that the pilot would be extended for an additional year and were promised a $125 incentive payment to be paid out in early November 2005 if they stayed with the program through December 31, 2005. The ADRS program was offered to incoming residents of existing ADRS homes, in the event that a current resident rented or sold their home. However, no additional homes were recruited for the 2005 pilot extension.

However, by the start of the second year of the pilot in June 2005, a number of participants opted out of the program, resulting in the following population sizes by utility (Table 2):

Table 2
Count and Distribution of ADRS Homes as of July 1, 2005

	PG&E	SCE	SDG&E	Total
High Stratum	40	53	6	99
Low Stratum	19	4	9	32
Total	**59**	**57**	**15**	**131**

Control sample design

Control homes all with identification numbers beginning with A03 are a subset of the control homes used in California's statewide pricing pilot (SPP), a pricing-only peak load reduction pilot program that ran concurrently with the ADRS program in 2004. The A03 control homes selected into the ADRS pilot resembled ADRS participants in three key parameters: single-family homes in climate zone 3 with central air conditioning. Consumption stratification of A03 homes was assigned as part of the SPP program using the same convention as for ADRS, in which homes are designated as high consumption if their ADU was greater than or equal to 24 kWh per day, and designated as low consumption otherwise. Table 3 counts the number of A03 control homes extracted from the SPP climate zone 3 population sample at the start of the ADRS pilot period in 2004.

Table 3: Count of A03 Control Homes as of July 1, 2004

	PG&E	SCE	SDG&E	Total
High Stratum	12	22	3	37
Low Stratum	3	14	3	12
Total	**15**	**28**	**6**	**49**

In addition to A03 control homes, a subset of SPP participants on the CPP-F dynamic pricing tariff were used for comparison against ADRS homes in the 2004 load impact analysis. These homes had identification numbers beginning with "A07". Because they were on the CPP-F rate but did not possess ADRS technology, comparison of ADRS load impact relative to this group served as a rough proxy for the incremental impact of ADRS technology.

The A07 homes resembled ADRS participants in three key parameters: single-family homes in climate zone 3 with central air conditioning. Consumption stratification of A07 homes was assigned as part of the SPP program using the same convention as for ADRS, in which homes are designated as high consumption if their ADU was greater than or equal to 24 kWh per day, and designated as low consumption otherwise. Table 4 counts the number of A03 control homes extracted from the SPP climate zone 3 sample at the start of the ADRS pilot period in 2004.

Table 4: Count of A07 Control Homes as of July 1, 2004

	PG&E	SCE	SDG&E	Total
High Stratum	20	38	5	53
Low Stratum	9	16	2	27
Total	**29**	**54**	**7**	**90**

)<u>Augmentation of A03 control population</u>

Load impact evaluation in 2005 shifted emphasis from statewide reporting of results to reporting results by utility. In addition, the focus of the evaluation shifted to the high consumption homes, given their higher performance during the 2004 pilot period relative to the rest of the pilot participants. Examination of the control sample (A03) revealed that the number of high consumption control homes was too small to make statistically significant inferences about load impact for each utility separately. RMI thus moved to secure additional high consumption control homes for the 2005 ADRS pilot period. Because one of the objectives of the 2005 ADRS pilot includes a comparison of 2005 load impact results with those of 2004, we ultimately re-evaluated the 2004 load impact results of high consumption ADRS homes against the augmented population of high consumption control homes.

The following paragraphs describe our methodology for determining the number of additional high consumption homes needed to achieve statistically significant load impact results. Ordinarily in a statistical experiment, the sample size would be set based on the underlying desired precision and expected standard deviation. The statistical formula for sample size is:

$$Z^2 / H^2 * (\sigma)^2 = N, \text{ where}$$

Z = z-value of standard normal distribution curve corresponding to desired level of confidence
H = desired level of precision
σ = standard deviation of the sample, and
N = sample size

From the prior pilot data, the average standard deviation in average kW consumption for A03 homes is 2.06 kW in the high consumption stratum and 1.45 kW in the low consumption stratum. If the precision is to be +/- 0.55 kW, and we want to target a 90% confidence interval (corresponding to a z-value of 1.65), then the sample size should be:

$$(1.65)^2 / (0.55)^2 * (2)^2 = 36 \quad \text{High consumption homes}$$

Under these circumstances, a 40-home sample would be effective to account for unforeseen circumstances such as homeowners moving or dropped/missing meter data for a given sample at a given time. Note that this low standard deviation is achieved within population strata. By contrast, an entirely random sample of ADRS residential customers from across all housing types would likely result in a higher standard deviation and would not accurately represent the appropriate target consumer of GoodWatts.

At the end of the pilot period in 2004, there were 36 total control homes in the high consumption stratum from all three utilities combines. A total of 40 high consumption control homes from each utility would bring the total control population to 120. However, having a comparable proportion in the number of control homes to ADRS homes by utility is also desirable to facilitate ease of statewide reporting of 2005 results in comparison to 2004 in fulfillment one of the 2005 pilot objectives. Thus, the final recommendation was to augment the control population mostly for PG&E and SCE, with fewer additions for SDG&E to keep the proportional weightings similar.

A total of 40 high consumption control homes from PG&E and SCE, and 10 control homes from SDG&E would bring the total control population to 90, which is then comparable in magnitude to the ADRS population. This means addition of 29 control homes from PG&E, 18 control homes from SCE, and 7 control homes from SDG&E for a total A03 distribution of 40-40-10 (a proportion of 44%-44%-11%, or roughly the ADRS home distribution).

Data collection

The three utilities provided 15-minute interval load data for ADRS and control homes for the period June 1 through October 31, 2005 (June 1 through September 30 in 2004). Because ADRS homes have an additional interval meter as part of the ADRS technology (GoodWatts) package, this second source of load data was also available, and downloadable in real time via the Internet. The ADRS meters serve as a backup to utility meter data as part of the pilot project design in the event that any of the utility meter data were unavailable at the time of the load impact analysis. In the 2004 ADRS load impact analysis, GoodWatts meter data were used in place of SCE data for September[1]. In 2005, no GoodWatts meter data were used, since all data were successfully collected by utilities for all months over the summer period (June-October).

Customer and ADRS pilot load data received from utilities typically contained several customer-days[2] with blank readings or zero readings. RMI screened the data and removed customer days that contained zero readings or blank readings. Typically the customer days with zero or blank reading constituted a very small percentage (less than 1 percent) of the overall data set. In addition, other adjustments were made. SCE and PG&E data were transmitted as kW loads for each 15-minute period. On the other hand, SDG&E data were transmitted as kWh consumption for each 15-minute period. To facilitate analysis, SDG&E data were converted to kW units by multiplying data values by four.

[1]Verification of interval load data recorded by Invensys meters compared to Utility meters was performed in 2004. Results of the verification showing that data difference between the two meters was less than 1 percent is reported in Rocky Mountain Institute's 2004 Load Impact Evaluation Report.
[2] Customer-day is defined as the data set for one customer for one day.

It should be noted that a complete data set for PG&E's low consumption control homes was not available. Data for these homes include only June 1st through September 13th. As a result, any event day results reported for PG&E's low consumption homes reflect only the five event-days in the June through August period.

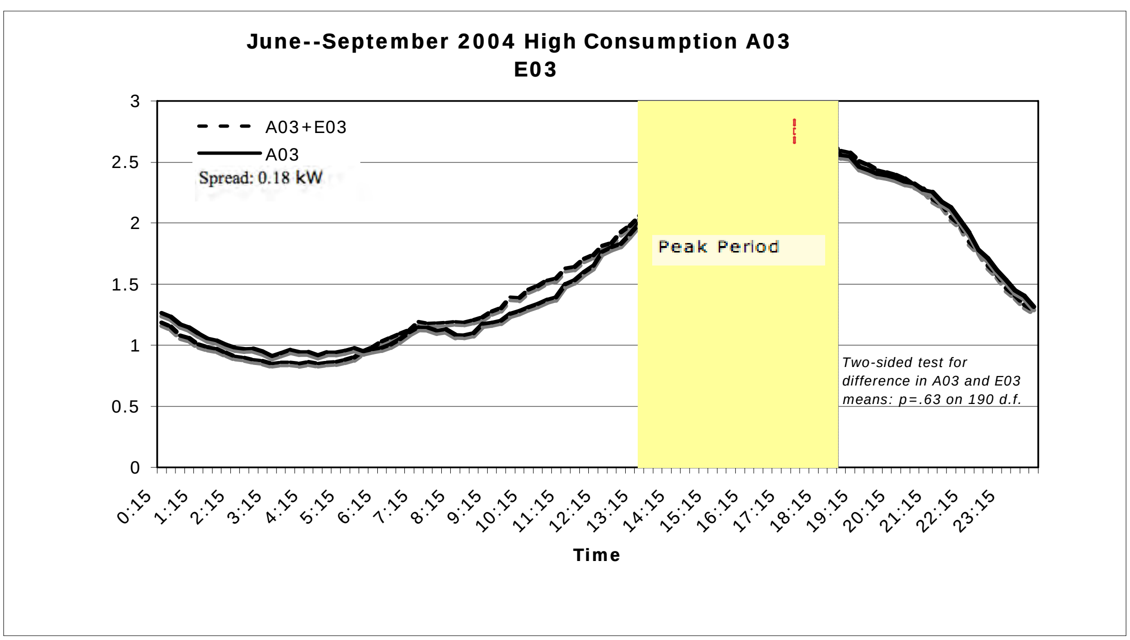
Zip codes and temperature data

Hourly temperature data were collected for June 1- October 31, 2005. Different methods were used for collecting temperature data on control and ADRS homes. For control homes, Invensys provided hourly temperature data through their weather subscription service by weather station, based on home zip code information provided by utilities. For ADRS homes, temperature data were also based on Invensys' weather subscription service by zip code but were downloaded directly from Invensys' GoodWatts website. The temperature data were the same for all ADRS homes for a given zip code. Zip code information for ADRS homes was extracted from the pilot program database administered by Invensys.

Verification of augmentation control homes' load data

In total, the utilities provided 68 augmentation homes: 30 from SCE, 20 from PG&E, and 19 from SDG&E. The additional high consumption control homes thus brought the total high consumption control sample count to 52 for SCE, 32 for PG&E, and 21 for SDG&E. These homes were assigned identification numbers all beginning with the designation "E03" to distinguish them from the original control population. This section presents the results of our verification of E03 load data against the original A03 control sample load data.

Figure 1
Confirmation of E03 Augmentation Control Load Data with A03 Control Data



Supplemental high-consumption E03 homes were compared against the A03 homes in order to determine whether the augmented control group was an appropriate representation of the A03 population. Following detailed investigation, the E03 augmentation sample was accepted and integrated into the A03 sample to form the control sample for use in the 2005 ADRS load impact analysis (see Figure 1). The two-sided test of significance for the difference in average summer loads between the additional and A03 control groups, across all days in 2004, produced a p-value of 0.63. This value indicates a probability of 63% (high) that the differences are due to random chance. For all results presented in this report, "augmented control homes" refers to the control sample that includes the E03 and A03 high consumption homes.

Load impact analysis

To construct average daily loads, RMI averaged the utility interval load data within each 15-minute period across a 24-hour day. Average daily kW loads were calculated for event and non-event days by utility, and by consumption stratum. The averaged daily loads were used to construct event day and non-event day load curves by utility and by consumption stratum. Separate load curves were constructed for ADRS customers, A07 and control customers (A03).

The load curves for the A07 and ADRS customers were then adjusted for selection bias (see discussion in **Error! Reference source not found.**) by adding the appropriate differences adjustments. The difference adjustments, either positive or negative if loads are lower or greater than the control group, respectively, were added to the load curves within each 15-minute data interval. As with the load curves, adjustments were calculated for event and non-event days for each utility, by consumption stratum. For example, the PG&E high consumption ADRS event day load curve was adjusted by adding the PG&E high consumption adjustment. Statewide difference adjustments were calculated from a weighted average of utility-specific difference adjustments. For A07 customers, difference adjustments were made on a statewide basis only, and load impact results are only reported on a statewide basis (see **Error! Reference source not found.**). The quantity of data available for a utility-specific adjustment for A07 consumption was too small and would not have yielded statistically significant results.

ADRS load savings, compared to the control group (A03), were calculated for each 15-minute period by subtracting the adjusted average ADRS load from the corresponding average control home load, for each 15-minute data interval (e.g. PG&E high consumption event day adjusted ADRS loads were subtracted from PG&E high consumption event day control loads). This method is consistent with the "difference of differences" method used by Charles River Associates and California Energy Commission for the larger Statewide Pricing Pilot program. ADRS load reductions were calculated for event and non-event days, by utility and by consumption stratum. The same method was used for calculating ADRS load reductions relative to A07 homes, and for calculating A07 reductions relative to control homes.

Ninety percent confidence intervals were then calculated for average load curves for each 15-minute interval. This range is plotted above and below the mean for a given 15-minute period. Thus we are ninety percent confident that the actual average load of homes in the general population (single family, with central air conditioning, in climate zone 3) are within the range of average load calculated for the sample. By calculating confidence intervals for both ADRS and control homes we also hoped to show that mean differences in load consumption were statistically significant. This was indicated if the confidence intervals above and below the two load curves do not overlap across the peak period.

The ninety percent confidence interval is defined as:

$$\bar{x} \pm 1.645\left(\frac{\sigma}{\sqrt{n}}\right), \text{ where}$$

x bar is the mean for the 15-minute period, σ is the standard deviation of the sample, and n is the sample size. The ±1.645 is the number of standard deviations from a normally distributed mean that contain 90 percent of the sample.

Calculation of peak period reductions

Using the average load reductions calculated for each 15-minute interval on event and non-event days, RMI then calculated Super Peak and peak period reductions for each utility by consumption stratum. Average load drop (kW) across the Super Peak and peak periods was calculated by averaging the load savings curve from 2 p.m. to 7 p.m. on event and non-event days, respectively. The total energy savings (kWh) across Super Peak and peak periods was calculated by summing the 15-minute interval load savings from 2 p.m. to 7 p.m. and then dividing by four[3]. Percentage load reduction during the peak period was calculated by dividing the average load reduction and energy savings during the peak period by the average control load during the peak period.

For the hourly Super Peak and peak period load reductions, the load reduction was averaged for each hour separately from 2 p.m. to 7 p.m. on event and non-event days, respectively. For example, the load savings for each 15-minute period between 2 p.m. and 3 p.m. were averaged to represent the load savings for the 2 o'clock hour. Hourly percent load savings were then calculated by dividing the average hourly load savings by the average hourly control load.

Ninety percent confidence intervals were then calculated for the savings during each hour of the peak period. This was done by first averaging the 90 percent confidence intervals on the control and adjusted ADRS load curves for each hour of the Super Peak period. These errors were then combined to yield a 90 percent confidence interval for the savings (difference between control and ADRS homes) during each hour using standard error propagation techniques.[4]

Exclusion of October data from 2005 load impact analysis

Load impact analysis for the 2005 ADRS pilot was based on performance from July to September only. Although four Super Peak events were called in October 2005, they were excluded from the average load impact calculations for the following four reasons, discussed below.

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[3] Because load data were reported in 15-minute intervals, the energy use in any given interval $kWh_1 = kW_1 * (^1/_4 \text{ hr})$. Thus, the energy savings during the peak period is then $(kWh_1 + \ldots + kWh_{20})$ or $(kW_1 + \ldots + kW_{20}) * (^1/_4 \text{ hr})$.

[4] $Error_{combined} = \sqrt{Error_{control}^2 + Error_{ADRS}^2}$

First, October events called in the ADRS pilot program are not representative of actual system emergencies during the summer. Typical system emergency events in California occur during the months from July through September, when customer loads reach their annual peak, and when capacity reserve margins are at their lowest as a result.

Second, October events called in the ADRS pilot program are not representative of regional summer temperatures that trigger high demands and actual system emergencies. Figure 2 through Figure 4 show that ADRS homes experienced many days throughout the summers that were hotter than Super Peak days called in 2005. The figures plot the average of maximum temperatures experienced by ADRS homes each day throughout the summer. Black points highlight days when Super Peak events were called statewide.

In PG&E service territory for example, the hottest days were concentrated early in the summer, in July, and declined noticeably by the end of August 2005 (Figure 2). Furthermore, ADRS homes in PG&E's service territory experienced about 32 days in the early summer that were hotter than average peak temperatures on six Super Peak event days called statewide. ADRS homes in SCE service territory experienced very hot days consistently throughout the summer, but there was noticeable decline in temperatures beginning mid-October, after all event days had been called (Figure 3). For ADRS homes in SDG&E territory, it is clear from Figure 4 that temperatures were distinctly different from other regions in the state, with mild temperatures rarely reaching above 90^{o}F. RMI questions the necessity of central air conditioning in homes in climates as mild as those experienced by ADRS homes in SDG&E territory in well-insulated and well-designed homes that are Title24 compliant.

Figure 2
PG&E Summer 2005 Average Daily Peak Temperature

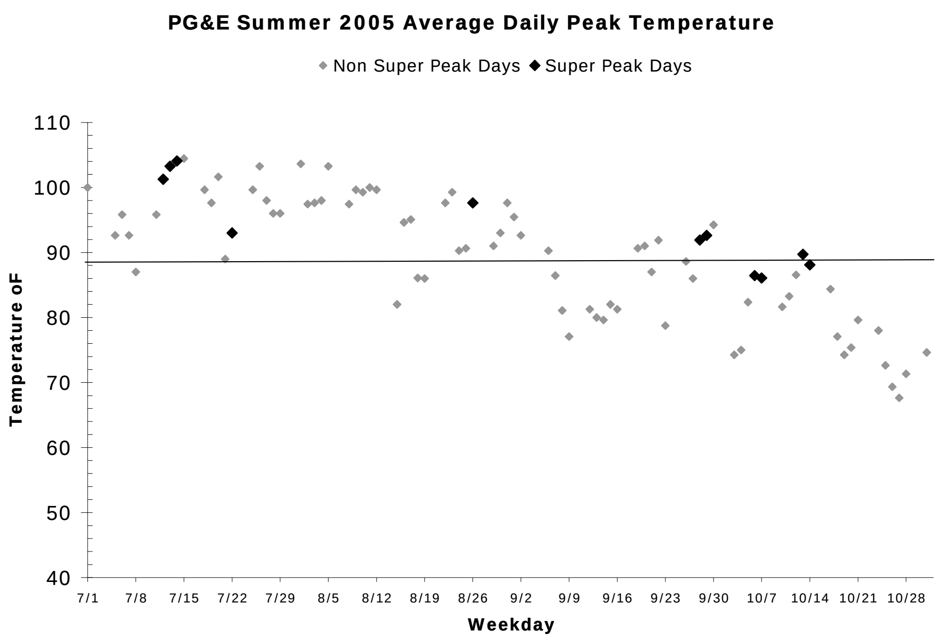


Figure 3
SCE Summer 2005 Average Daily Peak Temperature

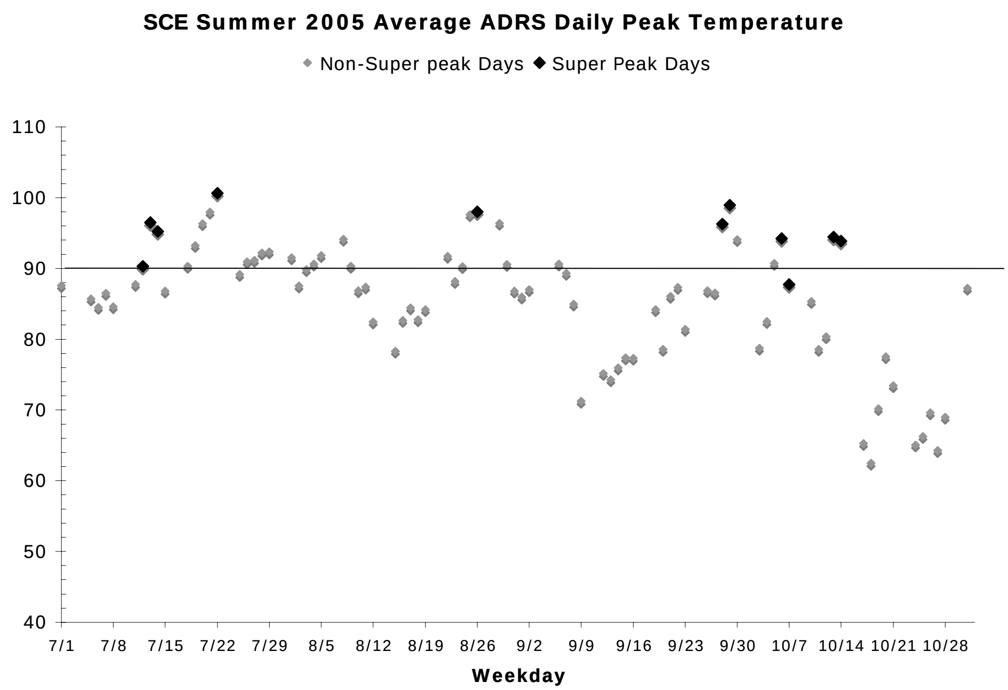
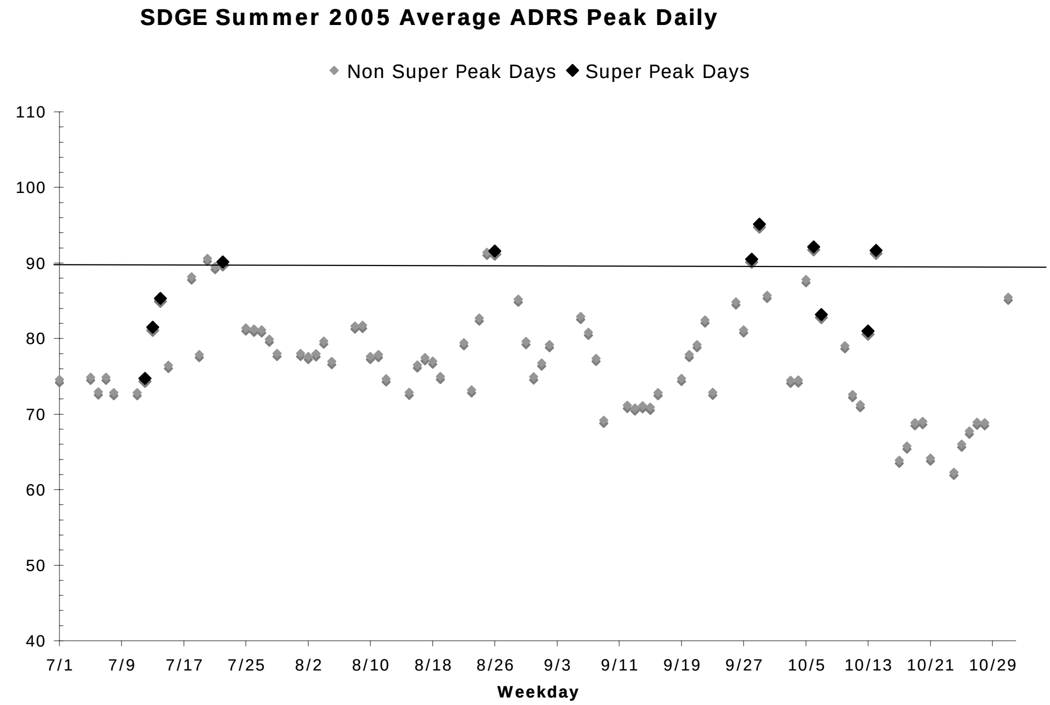


Figure 4
Summer 2005 Average Daily Peak Temperature



Third, October events called in the ADRS pilot program are not representative of insolation values during the interior summer months, July through September. Solar gain is a primary driver of air conditioning load, in addition to temperature. Not only are days noticeably shorter in October, the October sun tends to be much lower in the sky, with associated reductions in solar heat gain inside buildings. Table 5 shows the total solar radiation (beam, diffuse, weather effects) on a horizontal surface such as building rooftops for the summer months in Fresno, CA. Notice that September and October radiation measurements decline to 76 and 60 percent of solar radiation in July, respectively, with associated affects on indoor heat gain and cooling demands.

Table 5
Average Daily Incident Solar Radiation Horizontal Surface (e.g. Roof) for Fresno

	June	**July**	**August**	**September**	**October**
Solar radiation: Btu/ft^2	2507	2439	2215	1861	1425

Source: Weathermaker v1.01, National Renewable Energy Laboratory, US DOE. 1999.

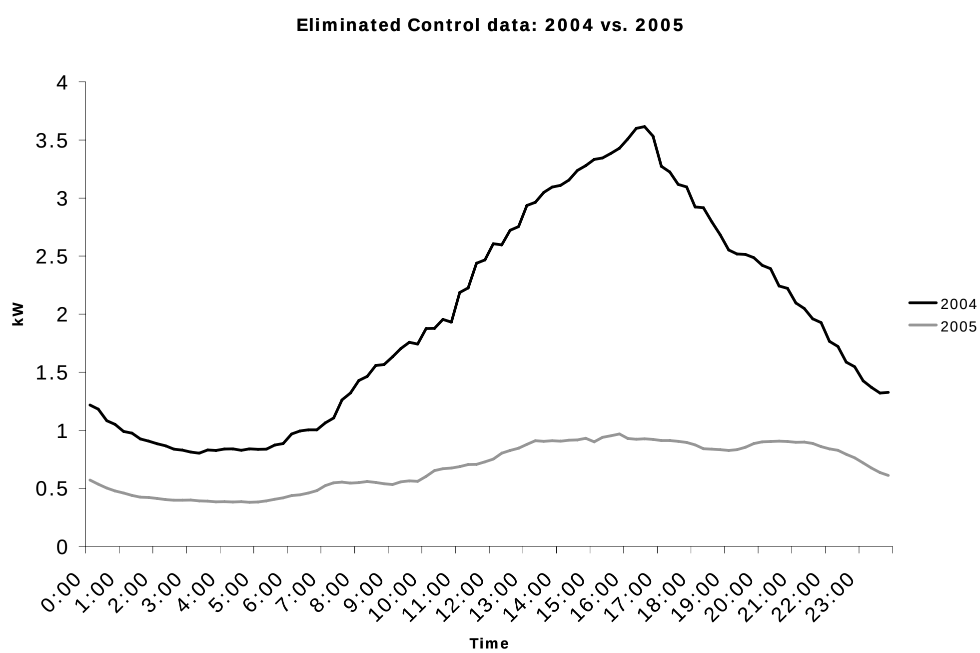
Fourth, October events called in the ADRS pilot program may not be representative of occupancy patterns during the interior summer months. The school year in California starts in September, which potentially drives down total consumption, as children and parents spend more time away from home during the day. Given that October generally tends to be cooler than other times during the summer, ADRS homeowners may change the programming on thermostat settings in anticipation of cooler weather, and use less electricity during the few warmer days that occur in October.

Elimination of outliers in augmented control sample for 2005 analysis

Comparisons of 2004 and 2005 ADRS load reductions revealed that load reductions were lower in 2005 than 2004, but not because ADRS customers consumed significantly more load. Rather, control home loads in 2005 were significantly lower than in 2004. This was in spite of the fact that 2005 was a hotter summer, on average. ADRS loads increased only slightly in 2005, which is consistent with a hotter summer, while control loads decreased, especially during the Super Peak and peak periods.

Delving into the issue in more detail, we examined both 2004 and 2005 control loads for each high consumption control customer in the entire control population. Fifteen-minute interval load data for each high consumption control home were averaged across the entire summer from July through September. Average daily load curves were constructed from the data values and the two years were plotted against each other. We found that generally most control homes' loads were consistent between 2004 and 2005, with some notable exceptions. Nine control homes in SCE and five control homes in SDG&E territories featured normal load profiles in 2004 and nearly flat load profiles in 2005, with consumption in 2005 near zero. Figure 5 shows the 2004 and 2005 average loads for these SCE and SDG&E outlier control houses. Off-peak loads in 2005 were 0.5 kW less than 2004 loads on average and peak period loads differed by as much as 2.7 kW. These 2005 loads seemed to be outliers that were skewing the average control load downward in 2005.

Figure 5: Eliminated control data: 2004 vs. 2005



We adjusted the control homes' data by removing the outlier homes from the summer 2005 control dataset. We did not make the same eliminations for the 2004 data because the control homes in question exhibited normal control home behavior during the 2004 summer. After the elimination of the outlying control home data from the summer 2005 dataset, the 2005 control loads more closely matched 2004 control loads, as seen in the 2004-2005 combined control-ADRS load curves in this report. SCE control loads for 2004 still exceed those for 2005 on event days even after removal of the outlier control homes, but were more similar on non-event days. For SDG&E, 2004 and 2005 control loads were virtually the same on event days after removing the outlying data. On non-event days, 2005 SDG&E loads were greater than 2004 control loads. No outlier control homes were removed from PG&E service territory.

Temperature bin analysis for 2005 pilot

As part of the ADRS load impact evaluation for 2005, RMI was also requested to report ADRS load reductions by temperature bin. This section summarizes the methods we employed for the temperature bin analysis.

First, we grouped temperature data associated with ADRS and control homes into eight temperature bins. Temperatures greater than 85°F were divided into five-degree increments to capture greater detail on hotter days. Temperatures less than 85°F were more coarsely divided into ten-degree increments for evaluating cooler days. These bins are: greater than 105°F, 101-105°F, 96-100°F, 91-95°F, 86-90°F, 76-85°F, 66-75°F, and less than 65°F.

ADRS and control homes within each utility were assigned to one of eight temperature bins. The temperature bin assignment was based on the *maximum* temperature recorded for a zip code associated with an ADRS or control customer on a particular day. We chose this convention on the assumption that the peak temperature experienced drives consumption behavior for ADRS and control customers.

Average kW load reduction was then calculated by temperature bin. Temperature bin results were reported separately for Super Peak and peak periods on event and non-event days, respectively. Consistent with all load impact analyses in this pilot program, all ADRS loads included a selection bias adjustment on event and non-event days, by utility and by consumption stratum (see selection bias discussion in **Error! Reference source not found.**). Instead of applying the adjustment for each 15-minute interval, however, we calculated an average adjustment for the Super Peak and peak period from 2 p.m. to 7 p.m. This selection bias adjustment was then applied to the peak period ADRS load reductions relative to the control sample.

A percentage savings was also calculated for each temperature bin for each consumption stratum, for both event and non-event days. We divided the respective kW savings for each temperature bin by the average control home load in each temperature bin to determine the percentage savings.

Household level analysis

To assess the relative performance of ADRS customers at the household level, RMI calculated the average initial load drop between 2:00 p.m. and 2:15 p.m. and between 2:15 p.m. and 2:30 p.m. for each ADRS customer during every weekday from June 2004 through September 2005. The two time intervals were chosen because the first half hour of the 2:00 p.m. to 7 p.m. peak period generally produces the largest load drop every day. The load drop was calculated as a percent reduction from the period immediately prior, from 1:45p.m. to 2:00 p.m. The larger of the two values, percent load drop during the first fifteen minutes and percent load drop during the second fifteen minutes of the peak period, was used as the representative performance value for each ADRS participant.

The performance values calculated for each day for each ADRS customer were then assigned one of three numeric scores. A “3” score (high performance) was assigned if the average initial load drop was greater than thirty percent. A “2” score (medium performance) was assigned if the average load drop was between twenty and thirty percent. Finally, a “1” score (low performance) was assigned if the initial load drop was less than twenty percent. The daily scores were then segregated by event and non-event days. Finally, average event and non-event day scores were calculated by month. Thus, each ADRS customer had two average performance scores for each month: an average Super Peak Period performance score for event days and an average non-event day peak period performance score.

The monthly performance scores for all event days each month were then averaged again into an overall score for each ADRS customer for the period of June 2004 through September 2005. An overall score averaging all the non-event day score by month was also calculated for each customer for this period.

ADRS participants were then sorted according to the overall scores. ADRS participants were first ordered by event day overall performance score. The list was then ordered by non-event day overall performance score. For example, if two ADRS participants both have an overall event day performance score of 3, but one participant has a non-event day overall performance score of 3 while the second has a score of 2.5, they are ordered so that the customer with a 3 score for both event and non-event days is placed higher on the list.

ADRS customers with average performance scores of 2.8 or greater for event days and 2.0 or greater for non-event day peak period initial load drop were selected as *super savers*. Customers with average Super Peak Period initial load drop performance score of 1.4 or less were selected as *program cruisers*. Customers who showed increasing performance from month to month in the average Super Peak Period initial load drop were designated as *improved performers.* Customers with 2 or more months with missing data were excluded from the selection process.

Estimating per household kW load impact

Measurement of ADRS load impact at an individual household level is problematic, because control homes cannot be matched with ADRS homes on a one to one basis. In all of the load impact analyses we’ve conducted in this report, RMI compared the <u>average load</u> of all control homes with that of ADRS homes for each time interval, by consumption stratum. Comparing an individual ADRS home with the average load of all control homes at a given time interval is not informative either, as we would be comparing an average control load that includes both large and small homes to one ADRS home that may have large or smaller loads than the average control load.

Given the data available, we decided to determine household level performance according to each home’s immediate load drop at 2 p.m. compared to the period immediately prior, at 1:45 p.m. Furthermore, the 2 p.m. load drop would be scaled to the ratio of adjusted statewide average load reduction to the average 2 p.m. load drop. We judged this to be the best compromise to determining individual household performance, given the inability to compare against a control group at the individual household level. This “pre-curtailment” approach has been studied as an approach for automated demand response baseline calculations for individual customer accounts[5].

Thus for each ADRS customer, we began with the calculation of immediate load drop relative to 1:45 p.m. to 2:00 p.m. load on event and non-event days as described above, for each month from July 2004 through September 2005. The ADRS homes and their load impact results were segregated by high and low consumption strata.

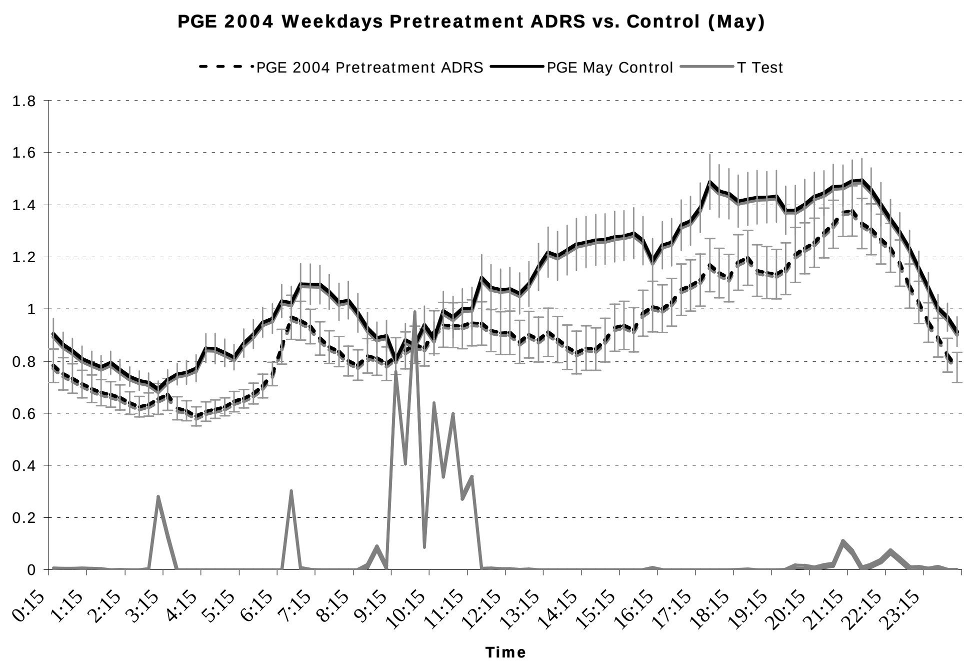
To scale the 2 p.m. load drop to the ratio of adjusted statewide average load drop, the average 2 p.m. load drop was then calculated for all homes combined, according to high and low consumption strata. Next, we calculated the ratio of the adjusted statewide average load reduction, which is based on the results of our 2004 and 2005 load impact evaluation, to the average 2 p.m. load drop of all ADRS homes. A separate ratio was calculated for each month from July 2004 through September 2005 for event and non-event days. This ratio was then multiplied by the immediate load drop at 2 p.m. for each individual household by consumption stratum. Once the adjusted immediate load drop at 2 p.m. for each household was calculated, RMI calculated the percentage of homes in each stratum whose load drop equaled or exceeded a given level on average.

[5] “Development of Uniform Protocols for Demand Response “Peak Savings” Calculations: A Review of Existing Methods and Recommendations for Uniform Protocols” Miriam L. Goldberg, CEC Staff Workshop, August 15, 2002

Appendix B
Statistical Tools

Figure 1 shows an example of a load curve from the pretreatment period, which RMI defined as the days in June 2004 prior to installation of technology in ADRS homes. The dashed line represents the average load by 15-minute time series for all the ADRS data in the pretreatment period. The solid black line represents the average load in the control group by fifteen-minute time series of all the days there are Pretreatment ADRS data. In a non-biased sample, one would expect to see the ADRS consumption curve closely matching that of the control (since it was assumed the ADRS group was biased). The issue is then how close would ADRS and control consumption have to be in order to consider them essentially the same. The statistical tools described below were used in the analyses to resolve this issue as well as many others in the qualifying and quantifying of bias in the ADRS sample.

Figure 1
PG&E Pretreatment



Confidence Intervals

Note the bars indicating the "confidence interval" around each data point on each line in Figure 1. Each point is an average of the data in our sample, but there were only a limited number of participants in the program.

This sample average is a proxy for a "population" average for whatever the sample represents. The confidence interval is a range around each average where the actual "population" average likely is (how "likely" is set by a predetermined interval). In the case of Figure 1, the 80% confidence interval is drawn around each data point, which translates into saying that there is an eighty percent chance that the actual population average for that time period is in this range.

Confidence intervals are also useful in giving some indication of how much variation or "noise" is in the data. Consider a city with an average temperature of 76°F. The average of 76°F could mean that day to day, the actual temperature hovers around 76°F, or it could mean that the temperature varies from 105°F to 55°F. For the sake of the analysis, data with a lot of noise are more difficult to draw conclusions from, so information was included on the variability of the data in all of our analyses.

Student's t-Test

Another statistical test to assess whether differences between two samples are significant is called the t-test. The t-test is based on a family of distributions closely related to the normal distribution of probabilities that are influenced by sample size. While the Normal distribution is a good measure of distribution around statistics of interest (e.g. averages of load consumption) for large populations, t-distributions are typically used for sample sizes of less than 120 units. t-values along a t-distribution correspond to a range of probabilities (a.k.a. p-values) that a measured statistic (e.g. average load consumption) are *the same.* Thus, p-values resulting from the t-test range from zero to one. A p-value close to one indicates that two samples, such as the ADRS and control homes, have the same average loads for a particular fifteen-minute time interval. A p-value close to zero, then, means that average loads between ADRS and control homes are *different*. Note that throughout the day in Figure 1 the t-test is close to zero, indicating that the ADRS and control average load profiles are "significantly" different for most of the day.

The term "significant" refers to a result that is meaningful compared to one that is not. For instance, in all the analyses, a "significant difference" is defined as when the p-value for the t-test result is less than 0.05. This would mean that there is a five percent probability that two averages are the same. At or above 0.05, the averages are considered to be the same. Below 0.05, the averages are considered to be different.

Correlation

The correlation coefficient in statistics is a way to quantify the strength of a relationship between two independent variables. This coefficient falls between negative one and one: negative one indicates that the variables show a very strong *negative* correlation (as X increases, Y decreases) and one shows a strong *positive* correlation (as X increases, Y increases). A coefficient of zero indicates that there is no correlation at all. Another way to present this coefficient is in the form of R^2, which is simply the coefficient squared (so that it always falls between zero and one). This statistical tool was used to investigate how various variables affected the differences between ADRS and control groups.

Appendix C
Selection Bias Analysis

A07 Selection Bias and Load Impact Adjustment

In a January 16, 2004 draft program report**,** Charles River Associates (CRA) performed an initial investigation into the presence of selection bias between Statewide Pilot Program (SPP) participants on the critical peak pricing rate (CPP-F) and the control group in all three utility service territories across all climate zones. Subsequent to CRA's investigation, the California Energy Commission (CEC) conducted an independent evaluation of SPP load impact performance using a slightly different methodology for identifying and applying a selection bias adjustment. This section presents the two methodologies used in measuring the selection bias of SPP participants, and discusses RMI's rationale for choosing a selection bias adjustment approach that more resembles CEC's methodology than CRA's.

In 2003, PG&E, SCE, and SDG&E began recruiting residential and small commercial customers for the pricing-only Statewide Pilot Program. Eligible customers were invited to opt-in to the program. The three utilities sent out marketing materials, which included a pitch targeting working households not at home during the day. The pitch claimed that homeowners who did not already consume energy during the specific daytime hours when the program's experimental rate would be high would save money by participating in the program (see Figure 6). In essence, the program actively invited potential participants to join who would save money without any change in behavior. The program thus targeted potential free riders, and the SPP participants were found to have a bias towards lower peak period and overall consumption.

During the 2004 Pilot Program analysis, CRA, CEC, and RMI used different approaches in determining the use reductions due to the SPP and ADRS programs. CRA used a difference of differences approach based on regression models built from pre-treatment data, treatment data, and household surveys while CEC used a difference of differences calculated from the actual data. RMI made no adjustment for self-selection bias in the analysis of the A07 group in its December 2004 report[6] but is now restating the 2004 A07 results using the difference of differences method from actual data. The A07 homes used in the ADRS summer 2004 load impact evaluation are the subset of SPP participants in climate zone 3.

CRA examined the differences between the mean electric energy consumption for peak and off-peak usage in the pretreatment period[7]. A t-test was used to determine if the difference between the means was statistically significant. The differences in mean values during the peak hours in the pretreatment period were significant for climate zones 2, 3, and 4, indicating selection bias.

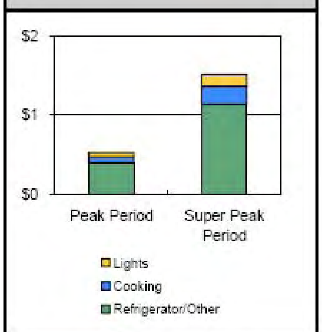
[6]Rocky Mountain Institute (RMI), *ADRS Load Impact Final Report*, December 28, 2004.
[7]CRA defined the pretreatment period as before a customer was put on the CPP-F rate. This definition problematic in that it is not clear the customers waited to be put on the rate to change their behavior. It is possible that treatment customers changed their behavior after receiving informational packets prior to be put on the rate.

Figure 6. Example welcome package material for SPP participants[8]

Example 3. No Air Conditioning: Customers At Work

CHART 9

Routine Electricity Cost



Weekday Electricity Use Habits

Patty and John both work away from home and usually return to their apartment between 6:30 p.m. and 7:30 p.m. They live on the coast and do not have air conditioning. Because of their work schedule, they use their dishwasher after 7 p.m. and do laundry on the weekends.

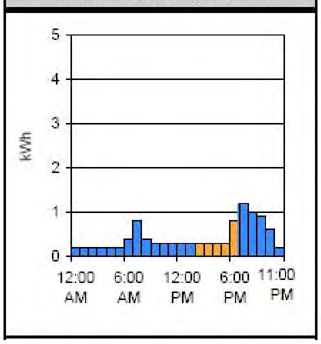
Patty and John use less electricity during the Peak period, Monday through Friday, 2 p.m. to 7 p.m., than the average customer. Since most of their electricity will be charged at the new, lower Off-Peak rate, their bill is likely to go down without shifting or reducing their electricity use.

> **Chart 9: Electricity use between 2 p.m. to 7 p.m. on Super Peak Days is about three times more expensive than on other weekdays. However, since Patty and John are not home in the afternoon, their Super Peak costs are under a dollar more than on other weekday afternoons.**

On most days, the cost of their electricity use is between about $1 and $2. Because they are not home during most of the Peak period and don't have air conditioning, Patty and John's cost on a Super Peak Day is about $2. As shown in Chart 9, they do not have many options to shift or reduce their use during a Super Peak period because most of their electricity use is for appliances that are always on, like their refrigerator.

CHART 10

Hot Summer Day
Routine Electricity Use = $2



Cost Saving Ideas: Shift & Save

However, even Patty and John can lower their monthly bills. In areas where lights are usually on in the evening, compact fluorescent lamps will pay for themselves with electricity cost savings in about a year. This is an investment that will be easy to take with them if Patty and John move in the future.

Chart 10 shows Patty and John's hourly electricity use on a Super Peak Day, assuming that they take no action to shift or reduce their use. Shifting what they can control after 6 p.m. will save them under $0.20 that day.

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8 SHIFT & SAVE PRICING PLAN

[8]Charles River Associates (CRA), *Statewide Pricing Pilot Summer 2003 Impact Analysis, Appendices*. August 29, 2004. Appendix 4, page 29.

CRA's regression model and difference of differences approach

In order to correct for the apparent bias, CRA performed a "difference of differences" analysis to subtract the pretreatment difference between the participant and control groups from the difference observed after the program went into effect. However, they did not simply compare the measured differences during the pretreatment period to those measured after the SPP began in order to arrive at a measure of actual load reduction, minus selection bias. Instead, they performed a regression analysis. CRA stated that simple comparisons of means can be misleading because they ignore the influence of various other variables that may also affect energy usage, such as weather, appliance holdings, socio-demographic factors, income, and attitudes about the environment and the utility. Thus, they employed a multivariate linear regression model to control for the difference in weather between pre- and post-treatment periods and for other variables between the control and treatment groups and the population at large.

Steps Taken to Arrive at the Final Measure of Bias through the Regression Model[9]

1. Separate regression models were estimated for peak usage, off-peak usage, and daily usage for each participant by rate treatment and climate zone in the *pretreatment period*. All data from each customer were used to create a model with the following characteristics:
   - Model Form: $\text{kWh} = \text{constant} + \text{coefficient}_1 * \text{variable}_1 + \text{coefficient}_2 * \text{variable}_2 + \ldots$
   - There were 22 variable terms in total, some of which included interactions between the variables.
   - Several variables were binary terms, indicating that they could take only two values. This was represented with a 1 or a 0.
2. The models were then used to predict kWh, the dependent variable, for all participant and control populations in the pretreatment period. The average values for each variable were calculated within each target population and were multiplied by the regression coefficients solved for in step 1 to predict kWh. SPP Pilot period weather, measured by cooling degree hours, was also used.
3. The kWh difference between control and participant customers was calculated, providing a pretreatment difference in consumption for the two groups.
4. Steps 1 through 3 were then repeated for SPP *pilot period* data and an estimated difference in consumption between control and treatment populations was calculated.
5. The "difference of differences" was then calculated in order to attain an <u>unbiased estimate of the treatment impact after adjusting for differences between the groups</u>.

A summary of the procedure is displayed as follows:

- Δ_1 = Participant Predicted kWh – Control Predicted kWh (in the pretreatment period)
- Δ_2 = Participant Predicted kWh – Control Predicted kWh (in the treatment period)
- $\Delta = \Delta_2 - \Delta_1$

[9] All variables in the regression model are displayed on p.67 of the CRA January Draft Report.

*For super peak day analysis, CRA used the data from their 12 high system load days in May and June in the pretreatment peak regression model.

CEC's difference of differences approach

The CEC used the differences of differences approach using actual data. This entails taking the difference in consumption between treatment and control groups during peak and off-peak periods in the pretreatment period and subtracting that from the difference in consumption between the treatment and control groups during the peak and off-peak periods in the treatment period. This accounts for possible selection bias in the treatment group. In contrast to CRA, the CEC defined the pretreatment period as the month of June 2003. Though an uncomplicated approach, this definition is problematic in that it assumes that all customers began modifying their behavior after June. In reality, many customers were not aware of when exactly they were placed on the experimental CPP rate, and could have begun modifying their behavior as soon as they agreed to join the program.

Both CRA and CEC defined a proxy for super peak days as the 12 maximum system load days in the months of May and June. For climate zone 3 participants, the differences in peak period energy use were significantly greater on these hotter days than the cooler ones. For example, participant (A07) peak period use was 20 percent less than control customer use. Total daily energy use was 13 percent less for participant customers than for control customers in climate zone 3 on these hot days. No significant difference in daily energy use was observed in climate zone 3 on the cooler pretreatment days (CRA January 2004 Draft Report, p. 53).

Table 6. Comparison of CRA and CEC's summer 2003 SPP results for climate zone 3 participants

CPP Days Peak Period Comparison (Climate Zone 3)

	Zone 3 CPP Change (kWh/h)	Savings (kWh)	% Reduction
CRA[†]	0.22	1.1*	13.37%
CEC[††]	0.30	1.5	16%

Non-event Weekday Peak Period Comparison (Climate Zone 3)

	Zone 3 CPP Change (kWh/h)	Savings (kWh)	% Reduction
CRA[†]	0.08	0.4*	5.59%
CEC[††]	0.11	0.6	8.5%

CPP Days Peak Period Comparison (Statewide)

	Zone 3 CPP Change (kWh/h)	Savings (kWh)	% Reduction
CRA[1]	0.15	0.75*	12.50%
CEC[††]	n.a.	n.a.	12%

* Value calculated by author
†: Charles River Associates (CRA), *Statewide Pricing Pilot Summer 2003 Impact Analysis* Final Report October 11, 2004. p. 7
††: Pat McAuliffe and Arthur Rosenfeld, *Response of Residential Customers to Critical Peak Pricing and Time-of-Use Rates During 2003 and 2004*. January 17, 2005. September 23, 2004. p. 4

Table 6 summarizes the results of the CPP programs based on CRA's and CEC's independent analyses. Note that the CEC and CRA are evaluating the success of the CPP-F program for June through October of 2003, while the RMI control-A07 comparison looks at performance from June through September of 2004.

Using a difference of differences approach, the CEC calculated a statewide reduction due to the CPP-F rate of 12%. Using a multivariate regression based model CRA calculated a 12.5% reduction in energy use due to the CPP-F rate. The 0.5% difference between the two approaches is negligible, especially when uncertainties in the CRA modeling process demand values are reported to no more than 2 significant figures.

RMI's difference of differences approach

Our restating of the 2004 ADRS load impact results in volume 2 of this report includes a selection bias adjustment for A07 homes that is similar to the CEC's difference of differences approach. The additional benefit of using multivariate regression based models approach that CRA adopted is not great in this case (see Table 6). The regression model approach is strong because it tries to control for weather differences between pre- and post-treatment periods. This is necessary because the temperature in the pretreatment months was generally lower than in the summer when critical peak days would be called. Thus, cooling degree hours and the binary central air conditioning variable appear to be a useful control in arriving at a true measure of bias. They allow for treatment period weather conditions to be used when analyzing pretreatment data and they control for whether or not a customer has central air conditioning to respond to the weather.

However, the additional variables regarding household characteristics have questionable basis in the CRA model. These variables were introduced to try to control for differences between homes in the sample and the population at large. However, in CRA's final report, published in October 2004, an analysis of summer average daily use from 2002 from the three investor-owned utilities indicated that there was no bias in the treatment and control samples compared with the population as a whole. These results question the need to include additional household characteristic variables that were aimed at correcting for differences between the control and treatment groups and the population at large.

There is also no evidence of any substantial model selection analysis that quantitatively justifies the model choice. There is no presentation of any statistics that compare model explanatory power to a loss of precision with the addition of new terms. The only justification for the large regression model is that all "observable" factors need to be accounted for[10]. However, some variables in the selected model may have no influence or may be redundant and/or unnecessary. There is no evidence of any quantitative comparison that would support the decision to use the selected model over an alternative with fewer terms. In addition, there is no attempt to state that model selection statistics are unnecessary through some type of qualitative justification of why every term is relevant to the research question at hand.

Figure 7 shows the selection bias adjustments that we applied to the statewide A07 loads. These differences were calculated based on the control and A07 groups' loads during June 2003, which the CEC designated as the pre-treatment period. May 2003 data were excluded from pretreatment

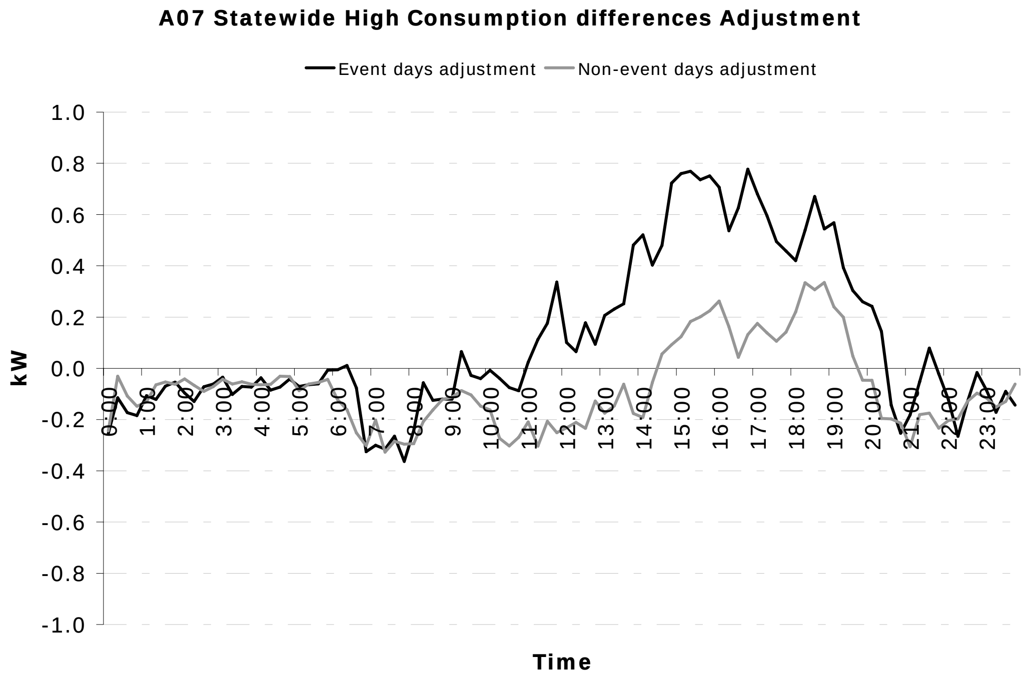
[10] Charles River Associates (CRA), *Statewide Pricing Pilot Summer 2003 Impact Analysis, Draft Report*. January 16, 2004. p. 66

analysis due to its scarcity. For the same reason, bias adjustment for A07 was not evaluated on a utility-by-utility basis from June 2003 data due to scarcity.

From the pre-treatment data furthermore, we extracted seven of the hottest days during the pre-treatment period to simulate event days during the pilot period. These were also the same days used by the CEC in its original selection bias adjustment for A07[11].

The rest of the June 2003 data were used to simulate the non-event days during the pilot period. We calculated hourly loads averaged over all houses for the control and A07 groups in the CPP and non-CPP subsets and then calculated the difference between these averaged loads (Control-A07).

Figure 7. Selection bias adjustment applied to A07 load impact results for the 2004 ADRS pilot



The plot of the differences adjustments is as expected. Statewide, the A07 group consumed less load than the control group during the peak period (2pm-7pm) on both hot and cool days. As such, the differences adjustment was used to shift the A07 loads higher to match the control customer consumption during these hours. The differences during off-peak hours are very small—less than 0.05 kW. The peak period differences are much greater on the simulated event days than the simulated non-event days. On simulated event days, control-A07 differences averaged 0.61 kW across the peak period. On simulated non-event days, control-A07 differences averaged 0.14 kW across the peak period.

[11] June 2, 16,17, 25, 26, 27, 30

ADRS Selection Bias and Load Impact Adjustment

In 2004, RMI's load impact analysis method was a straightforward engineering approach where actual meter data for ADRS participants were compared against two sample populations on Super Peak and non-Super Peak days. The first sample consisted of single-family homes with central air-conditioning in climate zone 3 with on standard tiered electricity rates. This group is named the "A03" control group. In addition, a second sample was used that was a subset of the single-family homes with central air-conditioning in climate zone 3 on an experimental, dynamic critical peak pricing rate (CPP-F). These customers were also participants in California's Statewide Pricing Pilot program (SPP), and are named the "A07" homes. The simple differences approach in analyzing ADRS load impact against the two sample populations ignored any pre-existing differences between the three groups.

The ADRS pilot was structured such that homeowners opted into the program in the manner of a typical utility demand-side management program. It is possible that participants who self-selected into the ADRS pilot possessed non-random characteristics that differ from the general population at large. Based on these discussions during the summer 2004, RMI was tasked to assess the presence of bias in the ADRS home selection and adjusted the load data accordingly.

Methodology overview

In an ideal experiment, relevant data are collected on a population prior to the instigation of the experimental treatment—in this case, ADRS participation. The "pretreatment" data are thus used to confirm that a population is truly random and representative of the general population at large, or to measure any differences between a selected population and the population at large. In the case of ADRS, ideal pretreatment data entails the installation of interval meters on a population of homes *one year* before the actual initiation of the pilot program, such that fifteen-minute interval data would have been collected the summer period before pilot activities began.

In reality, interval meters were installed on homes after participants opted to participate in the program. This not only limits the quantity of data available that can be considered pretreatment but also reduces the certainty that the data truly reflects "pretreatment" behavior. In light of the scarcity of true pretreatment data RMI employed additional data sets used as pretreatment proxies in the assessment of potential bias in the ADRS participant population. Each dataset has inherent weaknesses because it is technically just a proxy for true pretreatment data. However, the use of several data sources to create a composite picture of ADRS consumption behavior compared to control creates a more complete picture of potential bias than any of the methods alone.

Ultimately, one qualitative and three quantitative analyses were conducted using the following data sets:

1. ADRS program recruiting and welcome materials,
2. Interval meter data during ADRS "pretreatment" weekdays prior to ADRS (GoodWatts) technology installation,
3. Interval meter data during 2004 summer weekends, and
4. Monthly kWh billing meter data from summer 2003

First, recruitment and welcome materials for the ADRS pilot program were reviewed to determine whether marketing messages were framed such that they would encourage homeowners already consciously conserving loads to volunteer for the program. While the SPP program explicitly invited homeowners already conserving energy to join, the ADRS pilot marketing messages focused on the use of technology to enable energy and cost savings and did not try to attract customers based on lifestyle or ethos. Furthermore, the utilities specifically wanted to downplay the potential savings aspect of the program since they wanted to ensure that customers did not expect savings, but rather, would realize savings only if they changed their behavior during peak and super peak periods. Because customer recruitment targeting was limited to physical household parameters such as single-family homes with central air conditioning, RMI's initial hypothesis is that customers who were recruited into the ADRS program were not much different in their consumption behavior on average from the general population at large.

Second, ADRS pretreatment data were evaluated to detect differences, if any, with control homes before the ADRS program. The pretreatment period was defined as non-holiday weekdays prior to installation date of ADRS technology. This parameter was selected because installers were required to enter participant homes in order to install the technology. Interval meters were installed outside the home, without the need to contact customers for scheduling. RMI thus hypothesized that ADRS participants believed they were placed on the critical peak pricing rate (also CPP-F) at the time of technology installation and thus began to change behavior at that time[12].

A major weakness in the pretreatment data is that they were collected *after* residents volunteered to participate in the pilot. It is also debatable whether or not "treatment" technically began when residents received marketing and recruiting. Some customers reported to Invensys Climate Controls that they believed that they were placed on the CPP-F at the time of the interval meter installation, which in most cases, occurred prior to the installation of the GoodWatts technology. Thus, these customers might have begun modifying behavior even before GoodWatts technology installation. Using the meter install date as the cutoff for pretreatment data, however, resulted in only a few day's of data from only a few homes. This would have eliminated the ability to use "pretreatment" data at all.

For lack of a more robust source of pretreatment data, the pre-Goodwatts installation data were considered for this analysis. Another weakness in using pre-GoodWatts technology installation as a proxy for pretreatment data is that the technology installation dates were only available for two utilities, PG&E and SCE. Thus, bias selection analysis could only be conducted for PG&E and SCE, but not for SDG&E ADRS customers.

Third, June – September 2004 weekend and holiday data for both ADRS participants and augmented control customers were consolidated and compared. The fundamental weakness of weekends and holidays data were that weekend consumption behavior was fundamentally different from weekday consumption behavior given differences in occupancy patterns. For this reason peak and Super Peak pricing did not occur during weekends and these data served as an imperfect approximation of behavior during peak and Super Peak hours. Furthermore, participants were in the program during summer 2004 weekends and had likely already modified their behaviors. However, the quantity of

[12]In reality, ADRS participants were put on the CPP-F rate on the billing date following technology installation, but most participants did not know when that was.

data available for this period was greater than that during the pretreatment period, providing a more statistically robust picture of off-peak behavior. Weekends were analyzed because participants were subject to a relatively low, non-dynamic off-peak rate that facilitates more “normal” behavior, with less influence of the ADRS program or peak/Super Peak electric rates.

Finally, monthly billing data for January – December 2003 were compared, for the ADRS and augmented control customers. The weakness of monthly consumption data was the inability to interpret behavior at finer than monthly time scales, as compared to intraday behavior provided by interval data. This data set represented an additional benchmark against which participant and control customer behavior could be compared.

Given that each of the three quantitative proxies for pretreatment data have their weaknesses, conclusions about bias *cannot* be made based on interpretation of each data source by itself. Rather, the determination of ADRS bias must rely on the simultaneous evaluation of all data sets together, based on the composite results produced.

Overview

A qualitative review of recruiting and welcome package materials confirmed there were no marketing messages specifically targeting homes that were already conserving energy. Monthly billing, pre-ADRS technology data (pretreatment) and summer 2004 weekends analyses produced consistent patterns in the orientation of ADRS customers’ consumption relative to the augmented control sample. While the 2003 monthly billing analysis revealed that these consumption differences were not statistically insignificant, more detailed information available through pre-ADRS technology installation and 2004 summer weekend interval load data revealed significant differences in ADRS-control consumption, particularly during the peak period hours of 2 p.m. to 7 p.m. Consumption differences outside of peak hours were mixed, with the majority of differences statistically insignificant.

The orientations, furthermore, differed by utility. For PG&E and SDG&E, ADRS customers consistently had **lower** load than their associated customers in the control sample. On the other hand, SCE ADRS customers consistently had **higher** load than their associated control sample customers.

The pretreatment dataset was highly problematic, primarily because it was extremely thin. SDG&E customers could not be evaluated, as ADRS technology installation dates were not available. The number of PG&E and SCE pretreatment homes by utility declined significantly beyond May 15, 2004. Homes in which ADRS technology was installed before other customers had more pretreatment data recorded than other homes. Other homes in which ADRS technology was installed later in May did not have load data available earlier in the month for analysis. This uneven weighting of homes in the pretreatment sample during May 2004 introduced significant noise in the pretreatment data analysis.

In an attempt to extract a meaningful dataset from the pretreatment dataset, we analyzed them from a variety of perspectives: by temperature, by geography, by utility, and finally by consumption stratum. Neither temperature nor geography yielded consistent results that could be explained by the available data. However, segmenting the pretreatment data by utility and by consumption stratum provided load curves resembling those of load curves during the ADRS pilot period. The signals that emerged from the pretreatment data, albeit weak, showed statistically significant differences between ADRS and control between 2 p.m. and 7 p.m.

Segmentation of weekends load data yielded consistent results with the pretreatment. Furthermore the ADRS vs. control differences measured using the two datasets were statistically similar. Combining both summer 2004 pretreatment data and weekends data into an average bias adjustment is not correct, as such a combination actually introduces more error than using one or the other data sources alone. The question then is which data set should ultimately be chosen for use in the bias adjustment. Given that the data set for summer 2004 weekends was larger and therefore more robust, it was selected for use in quantifying the difference adjustments for all load impact analyses.

ADRS program recruitment and welcome materials review

The first assessment of ADRS selection bias was a review of the recruitment materials sent to all potential ADRS homeowners and the welcome materials sent to those who later enrolled in the program. RMI received one non-utility specific version of these materials and assumed that homeowners received identical or nearly identical versions. We searched the materials for passages that attracted participants based on lifestyle or ethos.

Both the recruitment letter (Figure 8) and welcome package were found to have consistent marketing messages. The ADRS program was marketed as a technological and cost-neutral way to reduce electricity use without the imposition of conservation on the homeowner. Specifically, the program was an opportunity for the homeowner to “test the latest in home energy management technology” and allowed the homeowner to “take advantage of a new electric rate” and potentially “save money depending on when [they] use [their] appliances.” There did not appear to be any direct marketing pitch to potential “free riders” – homeowners that already actively conserved electricity or whose behavior or occupancy patterns resulted in low on-peak usage.

In the recruiting materials, there is an appeal for "By reducing your electricity use during the 2 p.m. - 7 p.m. period on super peak days, you can avoid these higher prices, and also help reduce the demand on the energy system," and "The new rate also includes higher prices on 12 "Super Peak Days" when electricity demand is highest, and when saving energy can help avoid rotating outages." The "help reduce demand on the energy system" is an appeal to consumers who are conscious of broader problems on the grid. However, given the California electricity crisis, this would be just about everyone in the state. It is not a direct marketing pitch to potential “free riders” –homeowners that already actively conserved electricity[13].

[13]This observation is also consistent with results of Boice Duham Group’s market research conducted for the summer 2004 pilot, that most ADRS participants were not conservers prior to GoodWatts.

Figure 8
ADRS Recruitment Letter

March 1, 2004

Mr. A. Customer
1256 Caliente Lane
San Diego, CA 10011

Dear Mr. Customer,

Managing your home's energy use and saving on energy costs is important to everyone. Within a few days, you'll receive our invitation to participate in a new Pacific Gas & Electric program. You can also sign up early by responding to this letter. Our GoodWatts program, endorsed by the California Public Utilities Commission, gives you an opportunity to test the latest in home energy management technology.

Along with the equipment, you'll also have the opportunity to take advantage of a new electric rate that changes during the day, and allows you to save money depending on when you use your appliances.

By participating in our GoodWatts program you'll receive a new Internet-programmable thermostat for your central air conditioning, and Internet energy management tools, both at no charge. With these tools, you'll be able to manage your home's energy use from anywhere you can access the Internet. You can track your energy use hour-by-hour, and reset your air conditioner or swimming pool pump to maximize your savings.

Your invitation will include a complete description of the GoodWatts program, an application and a postage paid return envelope. This program is free and will be available to a limited number of customers with central air conditioning.

If you join and later decide the program isn't right for you, you can opt-out at ***any time***.

If you'd like more information about this program, please call 877-811-8700, or go to www.goodwatts.com. You can see how the technology works and get more information on your savings potential. You'll also be able to find out more about the electric rate that is part of this program.

Thank you for your consideration and for helping to shape the future of energy technology in California.

Sincerely,

Tim Vahlstrom
Principal Project Manager, Energy Program Services

P.S. By participating in this program, you'll receive appreciation payments of up to $100.

Some homeowners might have been attracted to the program because they saw the Goodwatts technology as a way to augment their energy conservation efforts. Other homeowners with above average energy use might have seen it as a way to save money while maintaining their consumption habits. The marketing materials did not implicitly attract homeowners with any specific consumption pattern. Thus, no conclusions could be drawn about how marketing and recruitment tactics induced bias on the ADRS sample.

Pre-ADRS technology installation analysis (pretreatment)

PG&E, SCE, and SDG&E provided fifteen-minute interval data for May 2004 for both ADRS and (augmented) control homes. A list of the dates on which ADRS technology was installed in participant homes was also requested and provided by Invensys. PG&E and SCE ADRS homes had these dates recorded but SDG&E dates were missing, so no pretreatment analysis could be performed for SDG&E ADRS homes.

For PG&E and SCE, ADRS customers were included in the calculation of daily average loads *until* the technology was installed. After the technology install date, ADRS homes were considered *actively* participating in the program and removed from the pretreatment set. Load curves shown in Figure 9 and Figure 10 for PG&E and SCE respectively were created by averaging all weekdays in the pretreatment period for the ADRS and control homes by utility. P-values for each time interval using two-tailed t-test are also plotted below both curves. Statistical tools used in ADRS bias analysis are described in APPENDIX B.

Figure 9
Comparison of ADRS vs. Control (Augmented) Consumption During Pretreatment Period, PG&E

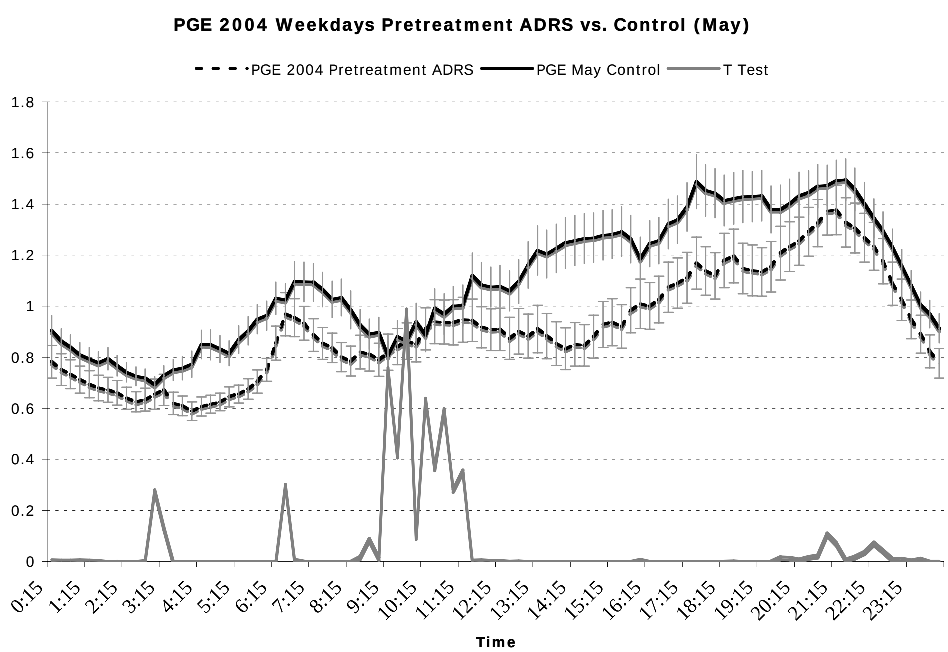
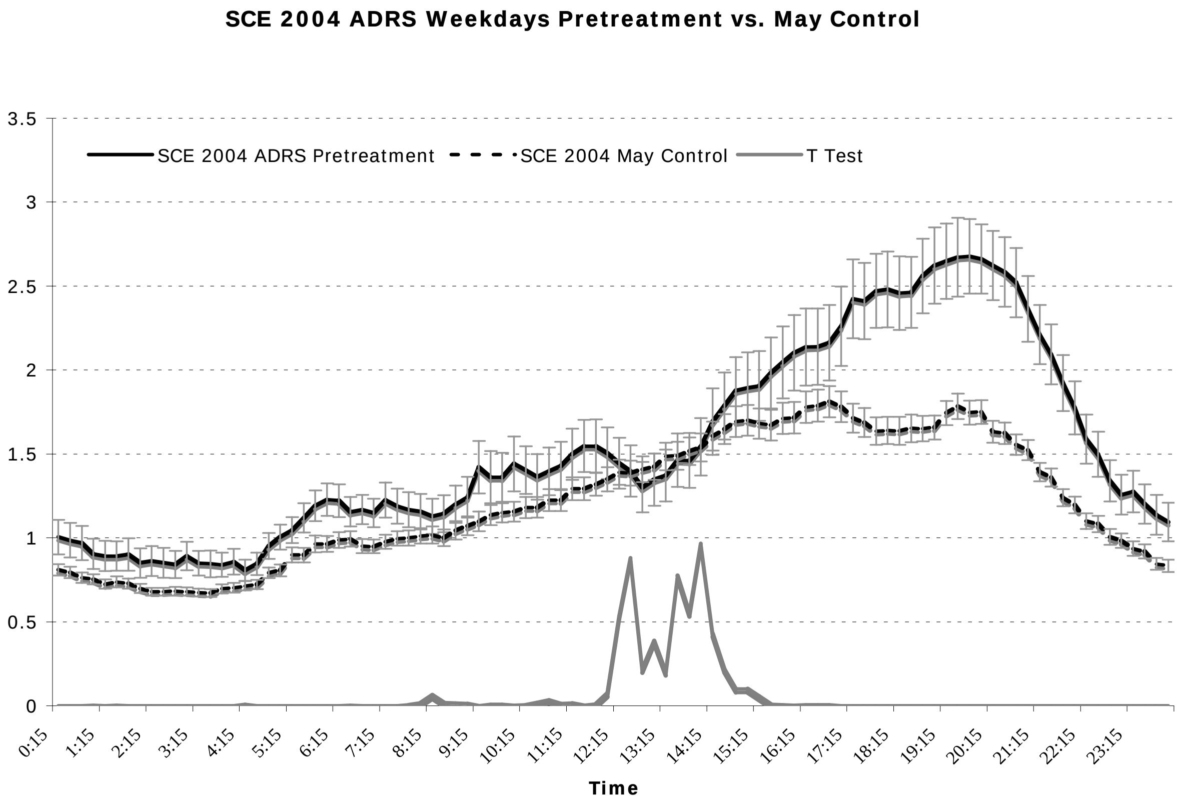


Figure 10. Comparison of ADRS vs. Control (Augmented) Consumption During Pretreatment Period, SCE



PG&E ADRS homes consumed less load than control homes by approximately 0.25 kW on average across the day. On the other hand, SCE ADRS homes consumed more load than the control homes by approximately 1 kW. This indicated that it would be inappropriate to apply the same differences correction across all utilities. The p-value generated using two-tailed t-test was close to zero throughout most of the average pretreatment day in both PG&E and SCE daily load profiles, indicating that differences between ADRS and control groups are statistically significant.

Table 7. Number of homes in ADRS and Control Groups Strata

	PG&E		SCE		SDG&E	
	ADRS	control	ADRS	control	ADRS	control
Low Consumption	24	2	4	14	15	3
High consumption	51	30	72	52	7	22
S2/S1	2.1	15	18	3.7	0.5	7.3

However, the size of the confidence intervals around each load value (at times nearly 0.5 kW) suggests that there may be ways of dividing the pretreatment data which would result in cleaner averages with less noise for use in a differences correction. Table 7 shows the number of homes in each stratum for each utility as well as the ratio between high and low consumption strata for each group. These differences in the relative numbers of ADRS versus control homes by stratum distorted the average load profiles of the ADRS versus control pretreatment data set as a whole (Figure 9 and Figure 10) and added noise as well.

A more detailed examination of the variations underlying the average load curves calculated for each utility was performed.

Table **8** shows the number of houses in the pretreatment data set for each weekday during the month of May. The count reveals that pretreatment data became progressively thinner later in the month as more and more houses were fitted with Goodwatts. A count of the number of pretreatment days each ADRS home had in the pretreatment data set is shown in Table 9. This analysis elicited another interesting result: each ADRS home *did not* have the same number of pretreatment days in the data set. Thus, each ADRS home was, in effect, weighted differently in the pretreatment data set. This uneven weighting of homes in the pretreatment sample during May 2004 introduced significant noise in the pretreatment data analysis. We next examined the data on a daily basis in to better understand these temporal variabilities.

Table 8. Count of Pretreatment Homes Through May

PG&E All Homes				**SCE All Homes**		
Date	ADRS	control		Date	ADRS	control
5/3/04	40	14		5/3/04	30	65
5/4/04	40	32		5/4/04	29	65
5/5/04	40	32		5/5/04	27	66
5/6/04	40	32		5/6/04	24	66
5/7/04	40	32		5/7/04	21	66
5/10/04	39	14		5/10/04	19	66
5/11/04	37	32		5/11/04	19	65
5/12/04	34	32		5/12/04	20	66
5/13/04	31	32		5/13/04	20	65
5/14/04	28	33		5/14/04	22	65
5/17/04	21	14		5/17/04	20	66
5/18/04	18	33		5/18/04	18	65
5/19/04	14	33		5/19/04	17	66
5/20/04	13	33		5/20/04	18	66
5/21/04	10	33		5/21/04	15	66
5/24/04	8	14		5/24/04	13	65
5/25/04	6	33		5/25/04	12	66
5/26/04	6	32		5/26/04	8	66
5/27/04	6	32		5/27/04	6	65
5/28/04	5	32		5/28/04	5	65

Table 9. Pretreatment Days Count by Home

PG&E ADRS				SCE ADRS	
Home ID	# Pretreatment days	Home ID	# Pretreatment days	Home ID	# Pretreatment days
D0056A	31	D0092A	11	1923063	31
D0063A	31	D0037A	10	2781874	31
D0078A	31	D0043A	10	1488196	28
D0086A	31	D0077A	9	1338434	27
D0105A	27	D0106A	7	2953927	26
D0062A	25	D0093A	5	6420672	26
D0060A	24	D0104A	4	3721380	25
D0029A	23	D0111A	1	4990698	25
D0041A	23	D0112A	1	6945018	25
D0022A	20			7025772	24
D0076A	20			6717363	21
D0094A	20			6639809	20
D0101A	20			2004217	19
D0036A	19			2396864	19
D0069A	18			1417171	18
D0074A	18			202195	17
D0080A	18			5517643	17
D0099A	18			1944323	15
D0049A	17			2669906	14
D0059A	17			4115019	14
D0072A	17			4442645	14
D0042A	16			4877233	13
D0045A	16			6604723	8
D0088A	16			2573075	7
D0067A	14			5502689	7
D0070A	14			856949	6
D0073A	14			4267602	6
D0084A	14			4474368	6
D0032A	13			6969859	6
D0075A	13			210547	5
D0110A	13			1148207	5
D0091A	12			1842240	5
D0100A	12			729204	4
D0107A	12			2256300	4
D0047A	11			6670610	4
D0058A	11			2724750	3
				2985786	3
				1344171	2

Figure 11 and Figure 12 show six daily charts from the pre-GoodWatts installation period for PG&E and SCE. Each chart displays average load consumption for ADRS and control homes in 15-minute intervals. The t-test p-value and difference between control and ADRS are also plotted for each corresponding interval. Eighty percent confidence intervals are drawn as bars around each data point. Average peak temperature and sample size are indicated on the legend for both ADRS and control samples.

Figure 11. PG&E Pretreatment Days

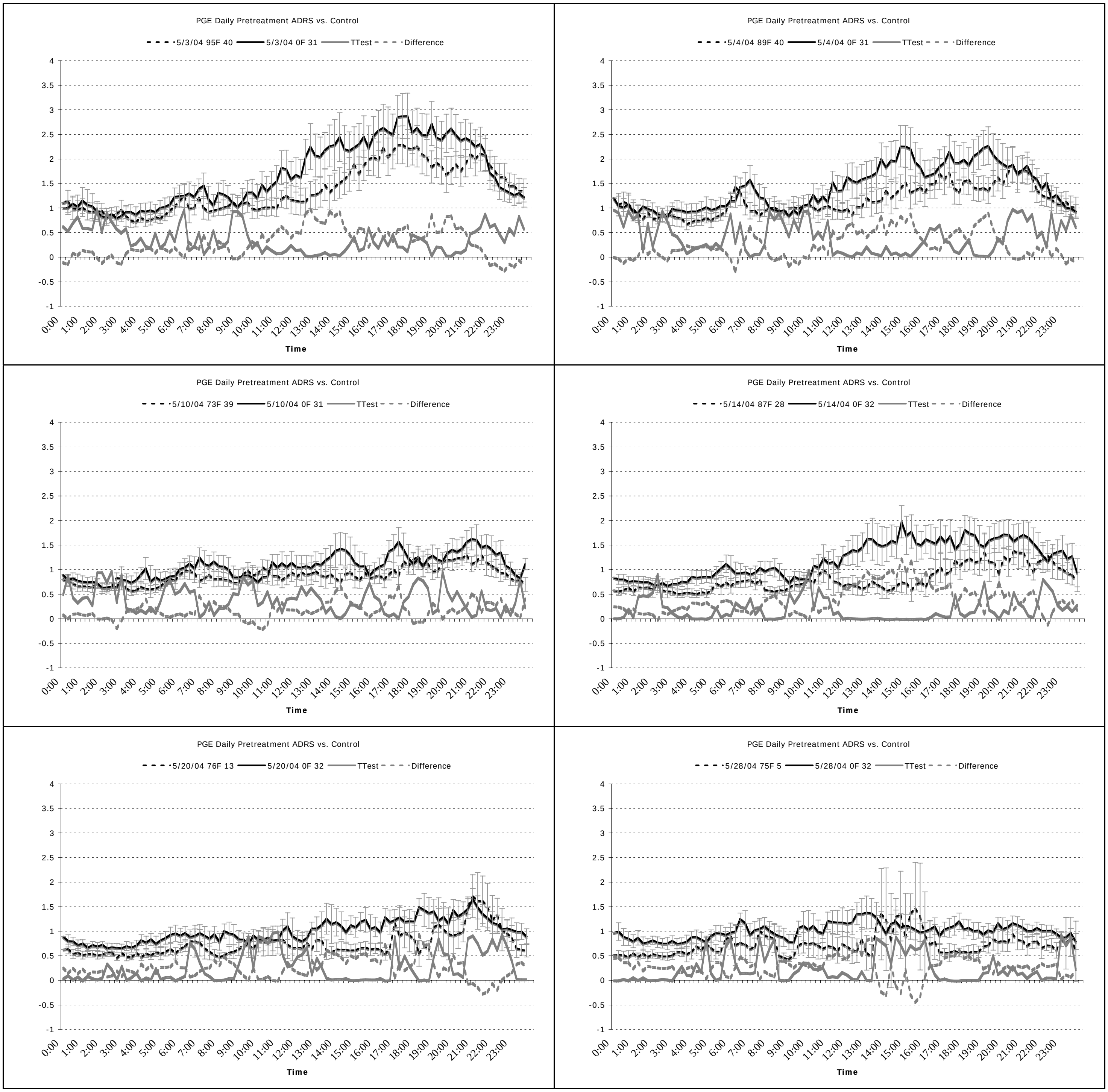
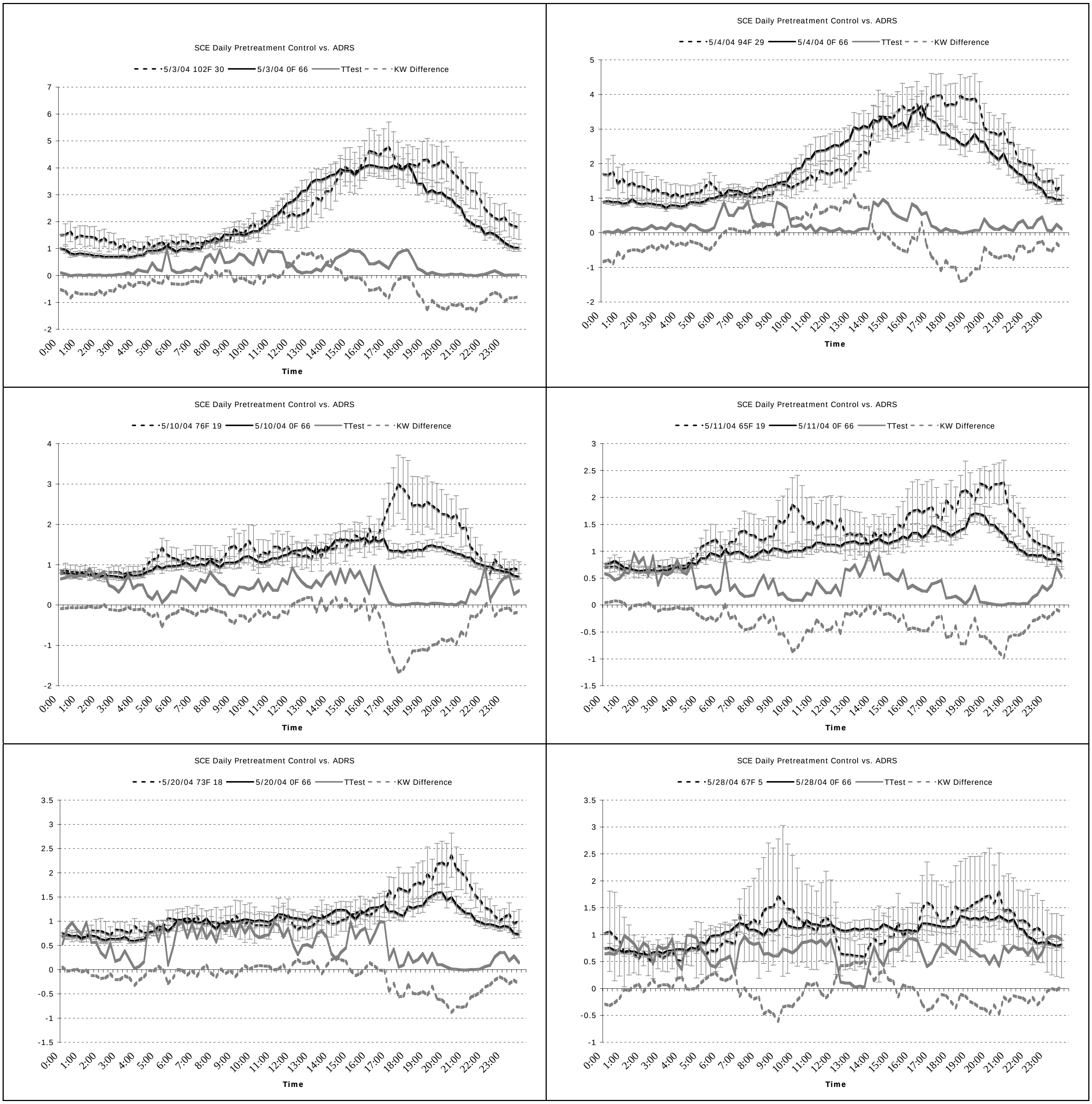


Figure 12. SCE Pretreatment Days



Looking across the individual days the ADRS and control curves did not seem significantly different based upon the T-test value and wide confidence intervals. T-test p-values frequently exceeded 0.05 and the confidence intervals between curves often overlapped. This observation was true for both PG&E and SCE. Each chart also displayed a lot of noise in the averages. The average daily load curves were not smooth but highly variable in an apparently random way. Furthermore, the shape of the load curves did not seem to follow any consistent pattern throughout the day. These characteristics suggested the need to segment the data to uncover a clearer signal in load consumption behavior.

)<u>Temperature</u>

The first attempt at segmenting the pretreatment data looked at whether differences in pretreatment consumption varied with temperature. Comparing load profiles from hot and cold days, temperature appeared to be a dominant exogenous factor in determining load. For example, compare ADRS and control loads on May 3rd and May 10th for PG&E shown in Figure 11 (95°F and 73°F, respectively) and May 3rd and May 11th for SCE shown in Figure 12. (102°F and 65°F, respectively). The hot day of May 3rd exhibited a more pronounced increase in the load difference between ADRS customers and the control group, from minimal differences in early morning to a maximum load difference of 0.9 kW by 1 p.m. (SCE) and 2 p.m. (PG&E). The cool days in May exhibited less load differences between ADRS and control customers, from minimal differences in the morning to 0.7 kW difference by 2:30 p.m. (PG&E on May 10th) and 0.5 kW difference by 5:00 p.m. (SCE on May 11th). We thus hypothesized that the largest differences between control and ADRS loads also happened on the hottest days.

The maximum ADRS and control load differences vs. the average maximum temperature were plotted by for every weekday during the pretreatment period. If RMI's hypothesis about greater control-ADRS consumption differences on hotter days were true, we would expect to see a strong correlation between the two variables. Figure 13 and Figure 14 show these scatter plots for PG&E and SCE, respectively. The correlation coefficient for the chart was nearly zero, indicating that there was *no* correlation in average peak temperature and maximum kW difference for any utility. Thus the hypothesis about temperature and load difference was incorrect, and we next examined the possible relationship between load and geographical location of ADRS customers to discover a clearer signal in the pretreatment data.

Figure 13. PG&E Temperature Correlation

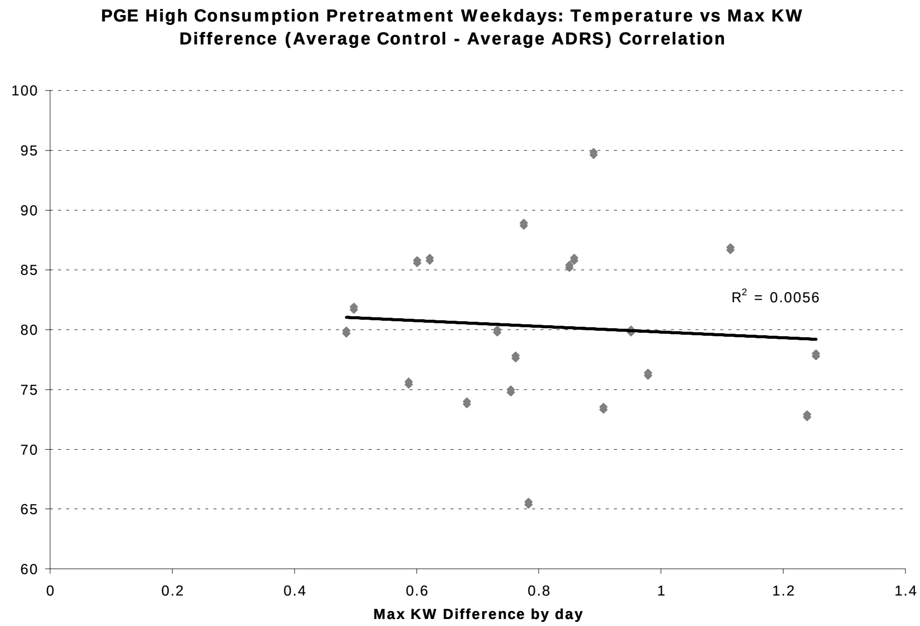
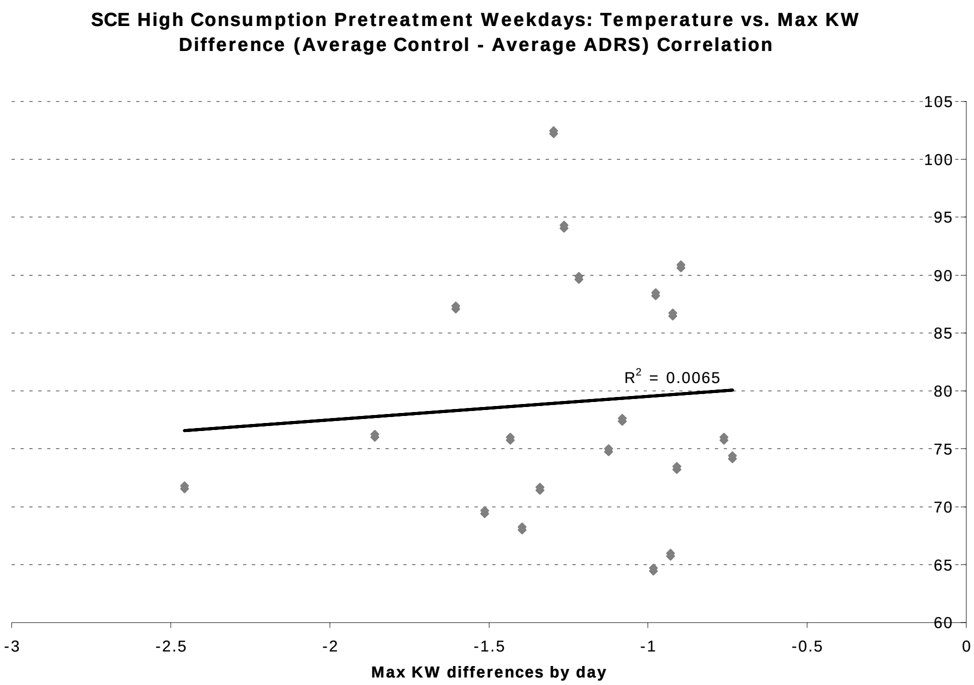


Figure 14. SCE Temperature Correlation



)Geography

Given the lack of results in the temperature study, we researched the geographic locations of ADRS homes to study whether they were possibly affecting the temperature analysis and load bias. Figure 15 maps of the locations of all the ADRS homes for each utility throughout the state of California. Figure 16 shows the locations for all the control homes throughout California. Figure 17 is a map of the Los Angeles basin indicating the specific locations of the SCE ADRS and control homes.

Figure 15. ADRS Customer Locations PG&E, SCE, SDG&E

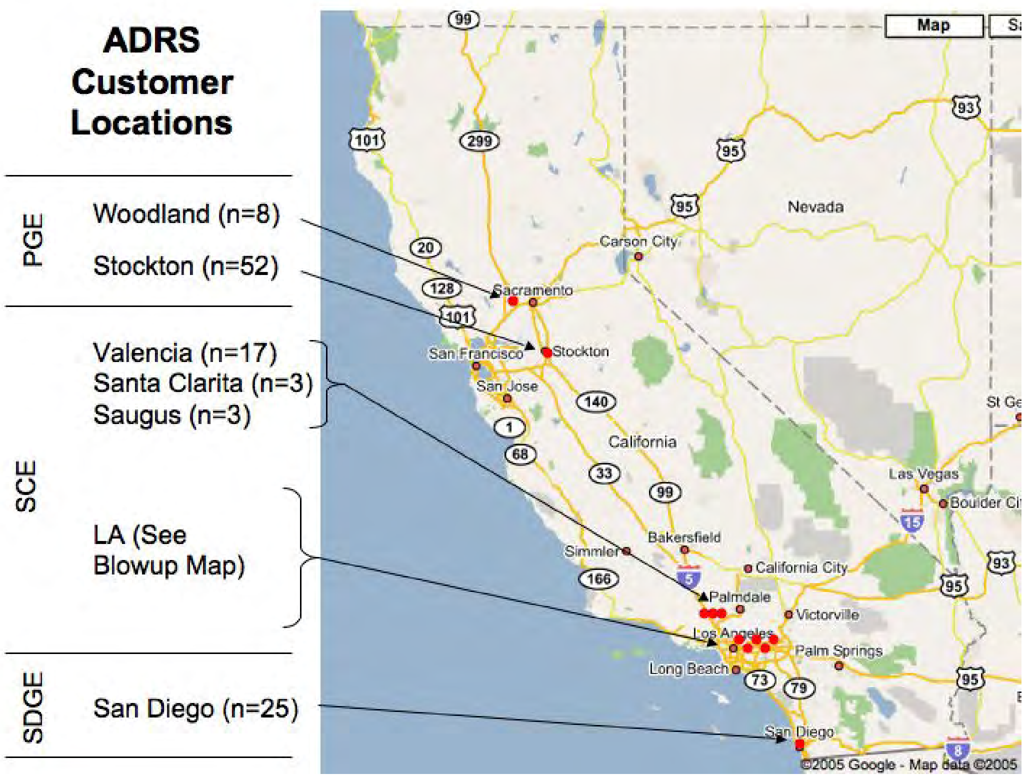


Figure 16. Control Homes Locations PG&E, SCE, SDG&E

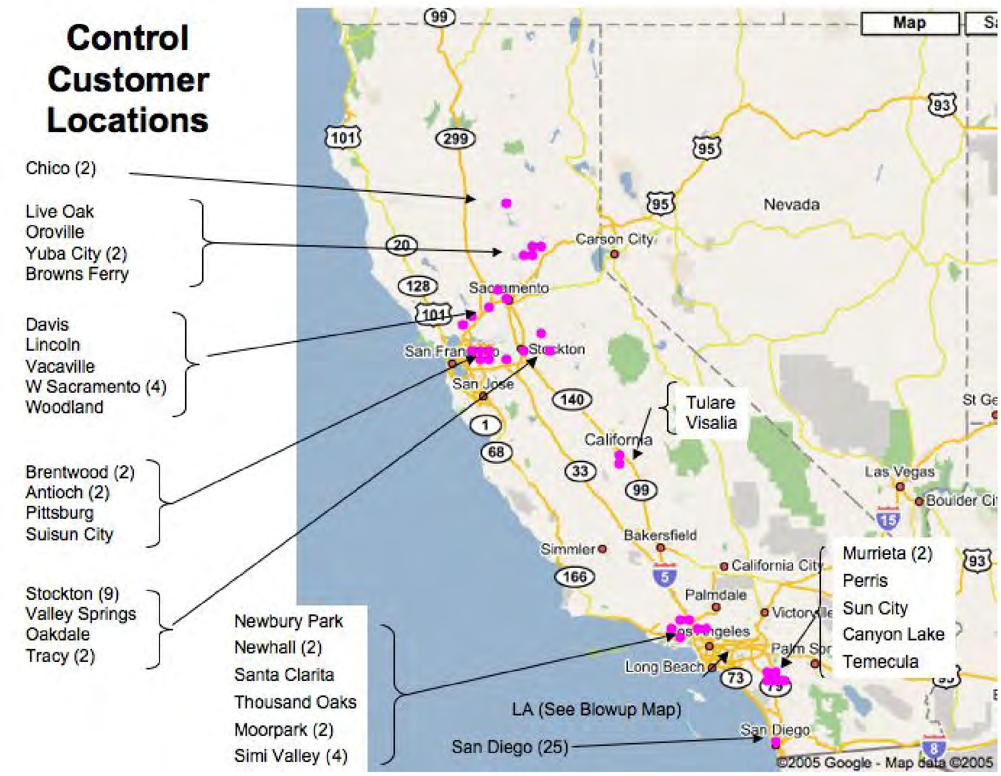
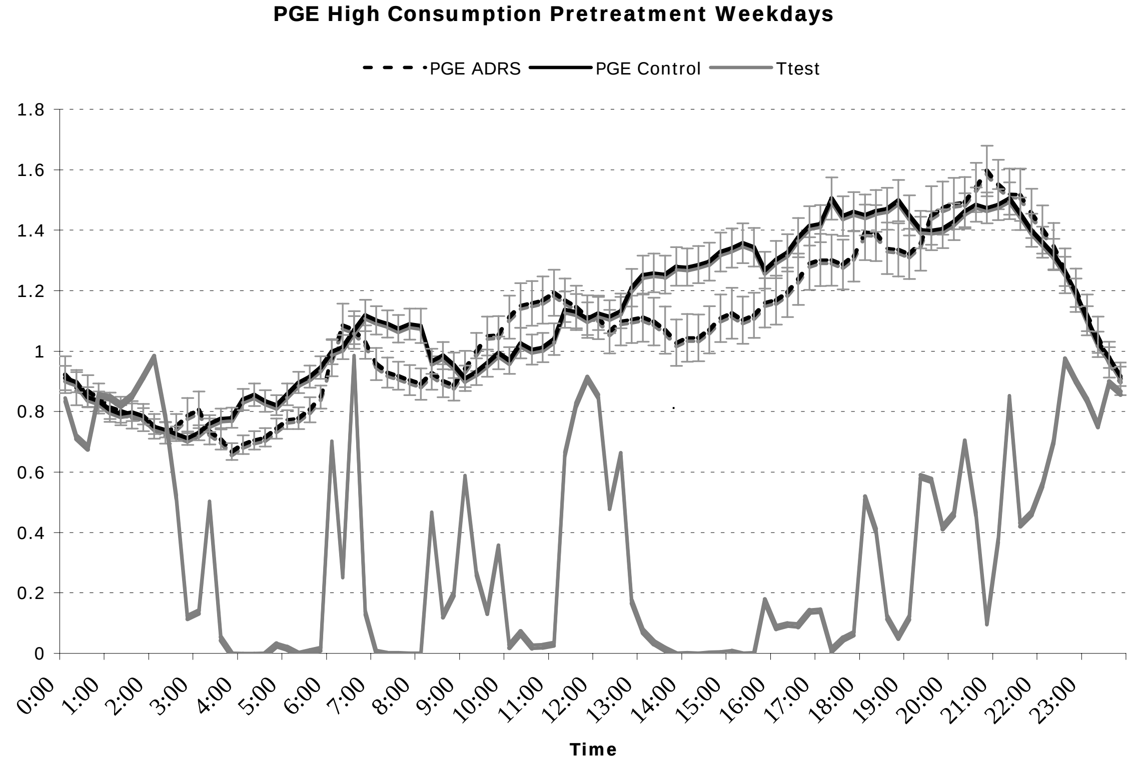


Figure 17. SCE ADRS and Control Homes

PG&E ADRS and control homes are in distinct locations. The PG&E ADRS homes are all located in the Central Valley, while the control homes are dispersed much more broadly: some in the Central Valley, some closer to the foothills of the Sierra Nevada mountains, and some in the East San Francisco Bay area and along the Sacramento River Delta. The Central Valley is generally the hottest region among the regions of interest here, and so it follows that those homes located in the Central Valley would have the highest loads, especially compared to the slightly milder East Bay area. Since ADRS homes were exclusively in the Central Valley, and control homes were spread more widely into milder summer climates, it was hypothesized that the ADRS group's average load would be higher than control's due to higher peak temperatures.

The actual load averages indicated the opposite trend. Figure 18 shows that ADRS customers' average loads in PG&E territory were consistently *lower* than control customers'. RMI cannot explain this behavior with only temperature and interval load data. As such, geography was not considered to be a salient factor for PG&E homes.

Figure 18. PG&E High Consumption Pretreatment Weekdays



A similar analysis was performed on the ADRS and control homes in SCE territory. The SCE ADRS homes were all located in a smaller geographical area than PG&E homes. SCE control homes were confined to the Pomona-Claremont area while SCE ADRS homes were distributed more broadly from East LA to San Bernardino. Even if one were to assume an eastward trend towards higher temperatures, there would be no qualitative inferences one could make in comparing ADRS and control geography. Thus geography was concluded to not have any discernible influence among SCE control and ADRS homes.

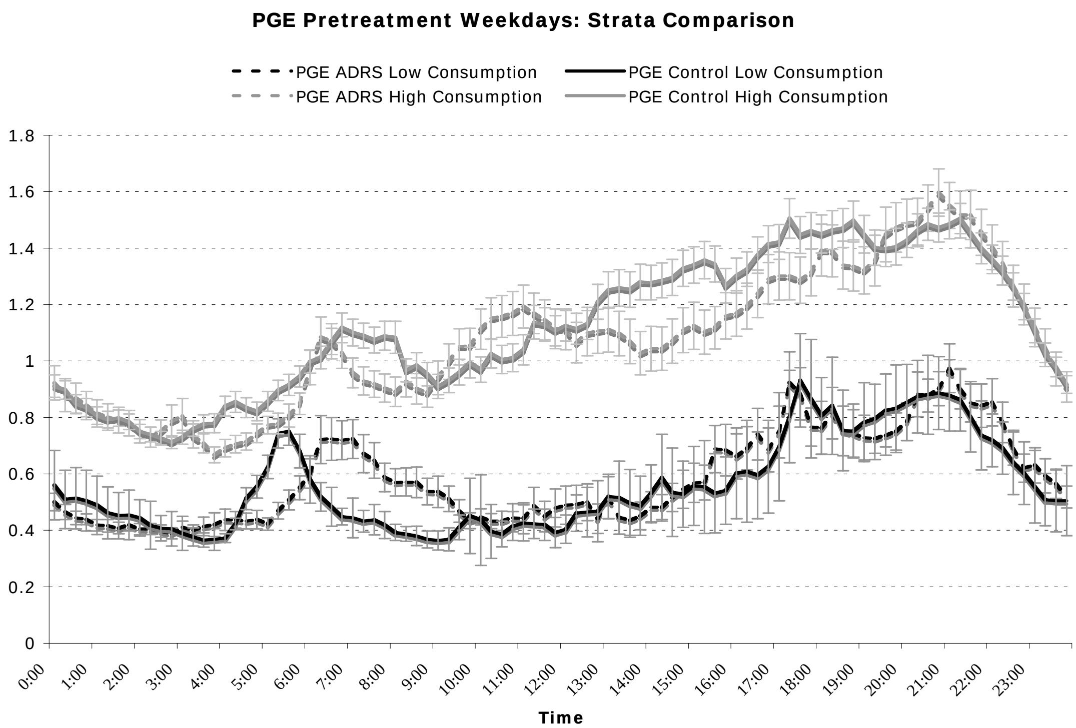
The same conclusion was drawn after examining the geography of SDG&E ADRS and control homes. All SDG&E homes were distributed around the City of San Diego, which was the most confined distribution of any of the utilities. Thus geographic distribution was dismissed as a salient factor in all three utilities.

)<u>Consumption Stratum</u>

The ADRS and control homes had each been divided into strata for high consumption (stratum 2) and low consumption (stratum 1). The third analysis of the pretreatment data was of stratum.

The segmentation of pretreatment data by consumption strata is shown in Figure 19 and Figure 20, for PG&E and SCE, respectively. Both figures indicate consumption differences between control and ADRS customers. For PG&E, there did not appear to be significant differences between ADRS and control in the high consumption with the exception of hours 2 p.m. through 5 p.m., the first three hours of the peak period. During this period, PG&E high consumption ADRS customers consumed less load than control customers. Low consumption ADRS customers consumed about the same as low consumption control homes, except for the morning hours of 6 a.m. to 10 a.m. when ADRS loads were somewhat higher. During the peak period, however, PG&E low consumption ADRS homes consumed about the same load as control homes. Overall, the noise in each stratum was similar to when all data were pooled together (Figure 19) despite the decreased sample size, indicating a relatively stronger signal.

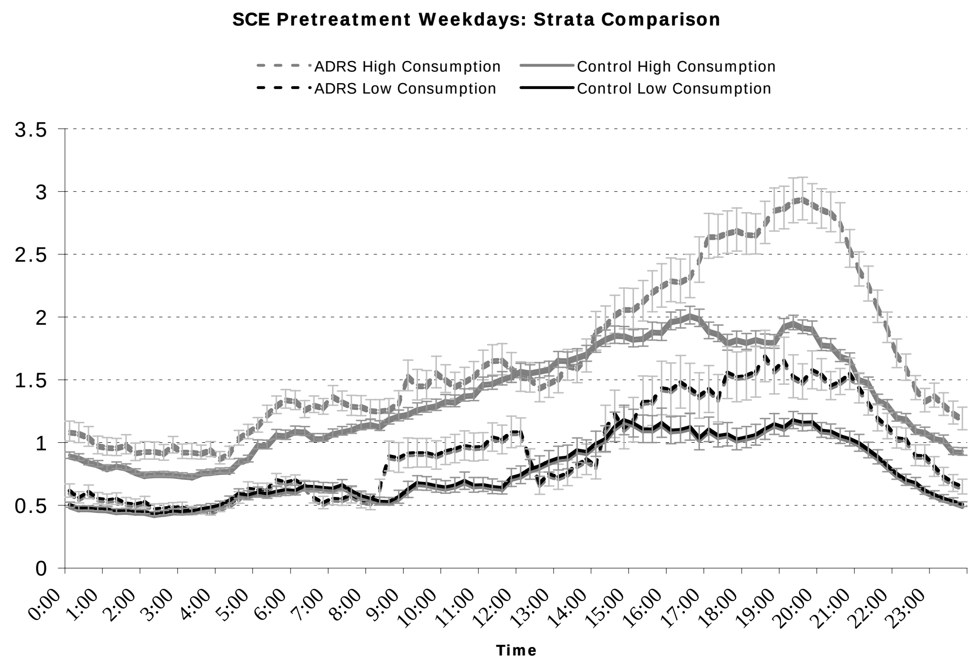
Figure 19. PG&E Strata Comparison



In each ADRS consumption stratum for SCE shown in Figure 20, there was also no significant difference observed for most time intervals except during the last three hours of the peak period, from 4 p.m. to 7 p.m. The differences were significant both for the high and low consumption strata. The high consumption stratum showed a maximum difference of almost 1 kW in the peak period while the low consumption stratum showed a maximum difference of about 0.5 kW between ADRS and control in the peak period. In contrast to the PG&E analysis, ADRS customer loads were greater than control home loads during the last three hours of the peak period for both strata.

The results of pretreatment data division by strata indicated that differences between ADRS and control for both PG&E and SCE were not significant with the exception of the peak periods. For PG&E high consumption customers, ADRS loads were less than control loads during the peak period. For SCE customers, ADRS loads were greater than control loads during most of the peak period. However, the fundamental difficulties inherent to the pretreatment data set, such as small pretreatment sample size and the decline in quantity of pretreatment data throughout May make the conclusion that differences between ADRS and control are significant tenuous. Hence, the data from the summer 2004 weekends were also analyzed.

Figure 20. SCE Strata Comparison



Summer 2004 weekends analysis

ADRS was a technology-based pricing pilot where consumption was reduced according to the way homeowners programmed their ADRS technology, rather than by changing their own behavior. In the ADRS program, weekends featured "off-peak" electricity prices, which were similar to pre-ADRS program electric prices in two respects. First, prices were similar in magnitude to pre-ADRS program prices. Second, electric price behavior during the weekends was similar to pre-ADRS program prices in that they remained constant in magnitude throughout the day. With off-peak electric pricing on weekends, participants would presumably program their ADRS thermostats similar to “default” settings. Hence, summer 2004 weekends load consumption behavior represented the next best proxy for adequate pretreatment data.

Fifteen-minute interval load data for ADRS and control homes were gathered from all three utilities for all weekends and holidays from June-September 2004. The data were then segmented according to high and low consumption strata. Figure 21, Figure 22, and Figure 23 show the high consumption stratum weekend data of the 2004 summer for PG&E, SCE, and SDG&E respectively. ADRS and control home load data on weekend days were gathered for all high consumption homes and average load profiles were calculated from each. Average load profiles for all three utilities exhibit much smoother profiles than the pretreatment data, indicating a more robust data set. All three utilities also exhibit significant differences in consumption between ADRS and control homes during most or all of the peak period. P-values for t-test were close to zero for the majority of time periods in all three utilities. This is consistent with the findings of the pretreatment strata analyses.

Figure 21. PG&E High Consumption Weekends

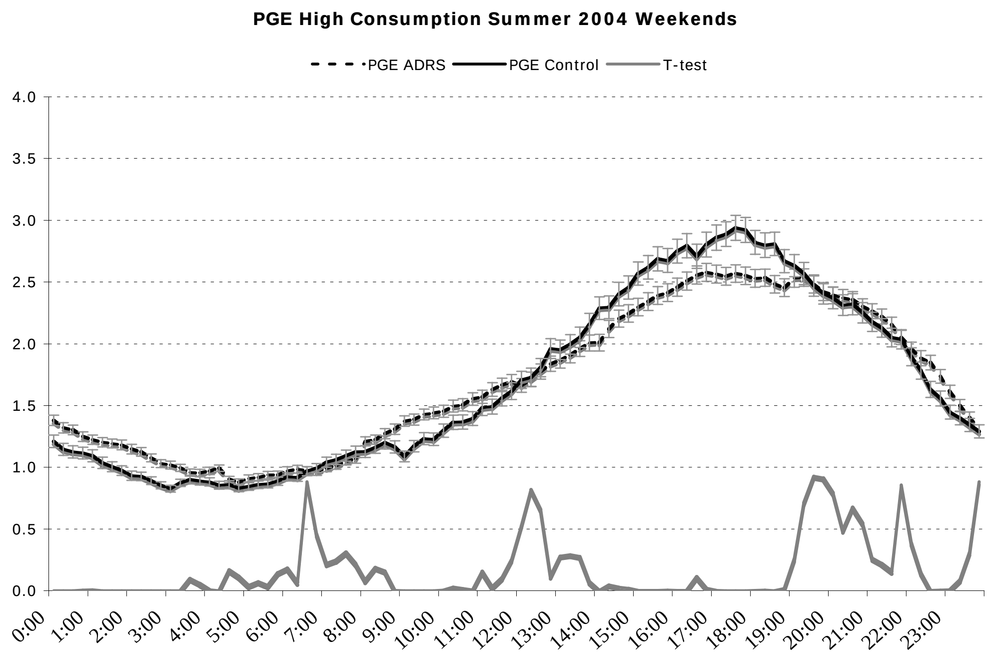


Figure 22. SCE High Consumption Weekends

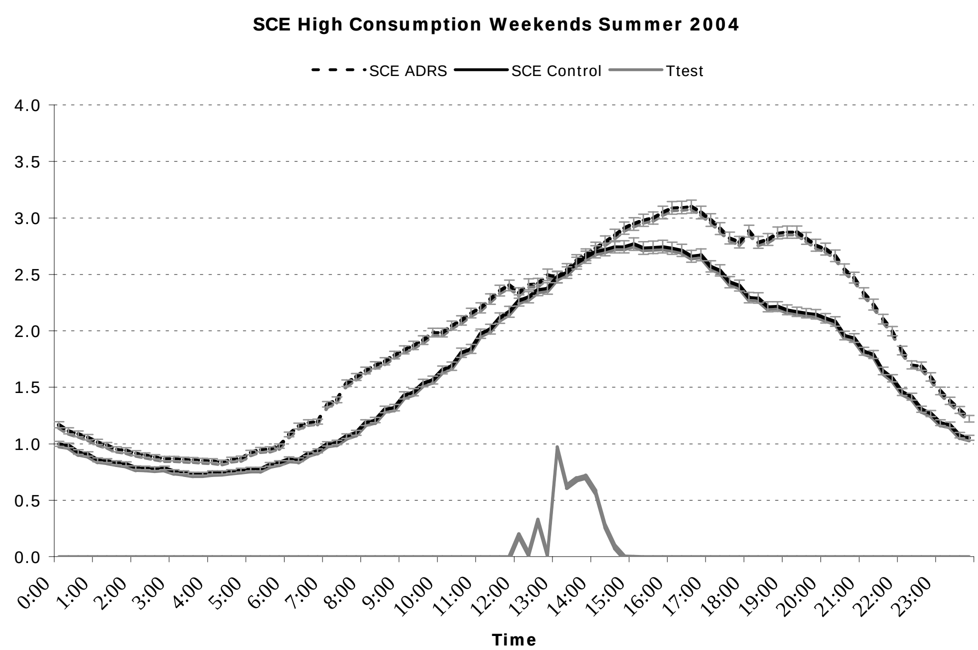
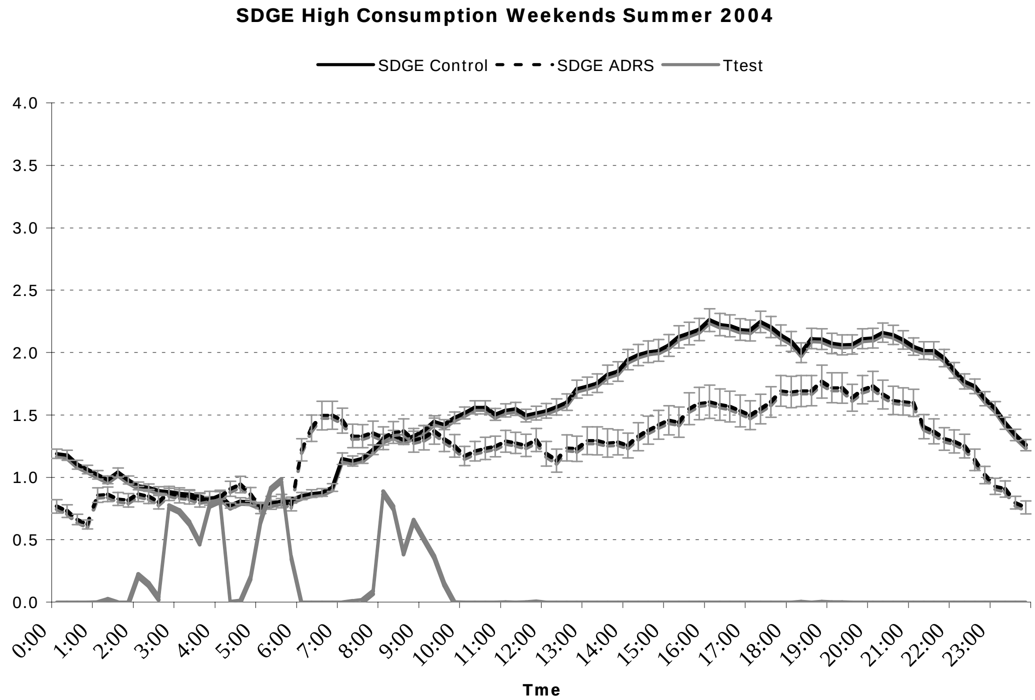


Figure 23. SDG&E Weekends



Given the paucity of homes in the low consumption stratum (see Table 7), the weekends load profiles were even more variable and had more noise. Nevertheless, significant differences were found in similar patterns to the high consumption stratum. PG&E had high t-test p-values values during the morning hours, when ADRS and control had almost identical loads, but those plummeted to zero during the peak period as control homes' average load grew to 1.7 kW beyond the ADRS homes' average load. SCE's low consumption stratum loads featured small differences in the morning that grew to 1 kW during the peak period as the ADRS homes' consumption outpaced the control homes'. SDG&E's low consumption stratum loads were the most jagged, but ADRS and control homes matched each other closely for a majority of the day. During the peak period, control homes' averages exceeded the ADRS homes' load by 0.5 kW.

)<u>Comparison of pretreatment and weekend analyses</u>

The relative magnitude of ADRS consumption compared to control is consistent between the pretreatment weekday and summer 2004 analyses. In the case of SCE, ADRS homes exhibit higher loads compared to control for both high and low strata. This implies that any adjustments for bias in the ADRS participants would be in the positive direction. That is, SCE ADRS load savings relative to control should be increased during the peak period on event and non-event days compared to the simple difference method used in 2004. In the cases of PG&E and SDG&E, ADRS homes exhibit lower load consumption compared to control homes. This implies that adjustments for PG&E and SDG&E ADRS savings using a simple differences comparison would be reduced.

The statistical conclusions between pretreatment and weekends load data, produced similar conclusions. The analysis comparing average weekdays load data prior to GoodWatts technology installation in ADRS homes (pretreatment) showed no statistically significant differences relative to control homes within a specific consumption stratum (high vs. low) with the exception of peak periods. ADRS consumption by strata on Summer 2004 weekends also revealed statistically significant differences relative to the control group, particularly during the peak period.

Given that both pretreatment and weekend data sets were imperfect in their ability to conclusively determine ADRS bias, it would be imprudent to combine the results of both analyses to quantify an "average" difference adjustment for ADRS relative to control homes. From a statistical standpoint, such a combination of results would actually multiply, not reduce, the error of the difference adjustment. A better alternative would be to choose one data set over the other.

Figure 24 and Figure 25 show the average daily differences between ADRS and control homes calculated using pretreatment and summer 2004 weekend data for PG&E and SCE high consumption stratum, respectively. SDG&E was omitted in this comparison given the lack of pretreatment data. The differences adjustment calculated using summer 2004 and pretreatment data match up closely, particularly for PG&E. PG&E's t-test average p-value calculated over the peak period intervals was 0.56 and 0.43 for the whole day. SCE's average t-test for SCE was 0.58 for the peak period and 0.33 for the whole day. Thus, we concluded that the differences from pretreatment and summer 2004 weekends were statistically similar. The pretreatment analysis suffered from inadequate data and the summer 2004 weekends data set was generally three times larger than that of the pretreatment. Therefore, the results of the weekend analysis were more statistically robust. The prudent step was to use the summer 2004 weekend data set to quantify the difference adjustment for ADRS by utility and consumption stratum.

2003 monthly billing data

The first source of data for investigating pre-existing consumption differences between ADRS participants and control homes was monthly billing information from 2003. Consumption data from summer 2003 were the most ideal source to use because they were categorically from the "pretreatment" period, before participants were aware of ADRS technology and before participants were subject to critical peak pricing. Unfortunately, detailed fifteen minute interval load data for ADRS and control homes were not available for the summer of 2003. Thus, RMI requested monthly billing data from each of the three utilities.

Because the 2003 billing data and 2004 weekend load data were in different units (kWh per month and kW per 15-minute interval, respectively), Average Daily Usage (ADU) was used as a common metric for a consistent basis of comparisons. Figure 26, Figure 28, and Figure 30 show the ADU calculated for May through September from the 2003 monthly billing data for PG&E, SCE, and SDG&E respectively. The monthly kWh consumed from each home was divided by the number of days in the billing cycle to produce an ADU for the month for each home. PG&E's and SDG&E's 2003 ADU show control homes' average ADU consistently above the ADRS homes' average ADU but with no statistically significant differences. SCE's 2003 ADU shows the ADRS homes' ADU consistently above the control homes' average ADU with no statistically significant differences between the two.

Figure 24. PG&E difference comparison using pretreatment and weekends data

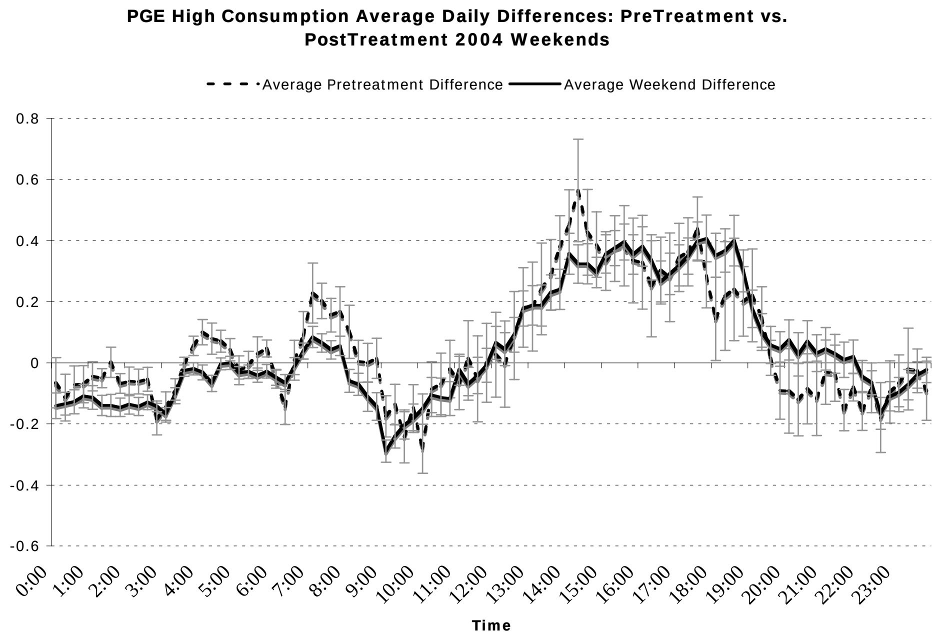
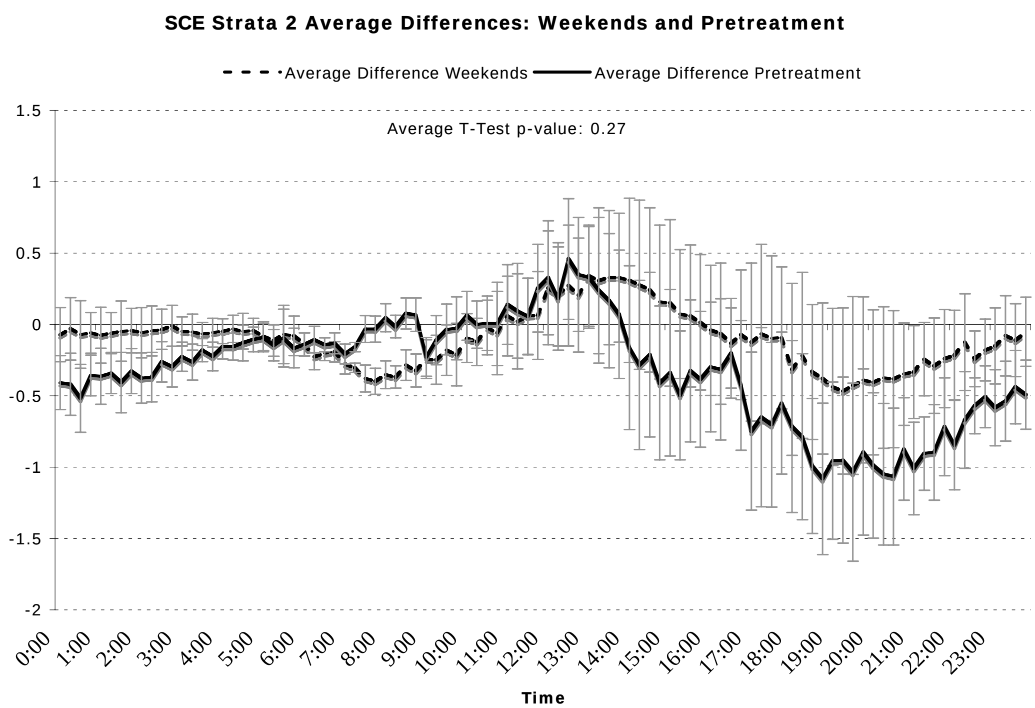


Figure 25. SCE difference comparison using pretreatment and weekends data



The 2003 ADU data represent a true snapshot of pretreatment, but of much lower resolution. The hypothesis was that if the 2004 weekend data were truly different from pretreatment, this difference might be shown in a comparison of 2003 monthly ADU and 2004 monthly ADU based on the weekend data. For example, if the 2004 PG&E control homes' ADU were significantly *lower* than ADRS homes' ADU while 2003 PG&E control homes' ADU were higher (but insignificant), this would support the hypothesis that 2004 weekend data were different from pretreatment data, and therefore might *not* be a suitable proxy for pretreatment. Note that it is only appropriate to compare relative patterns in the data between years, since there were many factors (such as temperature), which varied between summers.

Figure 27, Figure 29, and Figure 31 show the monthly ADU calculated from the summer 2004 weekends data. There were several steps involved in converting the weekend load data to ADU values for each month. First, all the weekend load data were divided by month, and then the total daily consumption was calculated for each home on each day of weekend data. Then, each home's daily consumption values were averaged in each month, resulting in a monthly ADU for each home. All the monthly ADUs for each home were averaged together by month, resulting in the ADUs represented in the figures.

Figure 26. PG&E High Consumption 2003 ADU

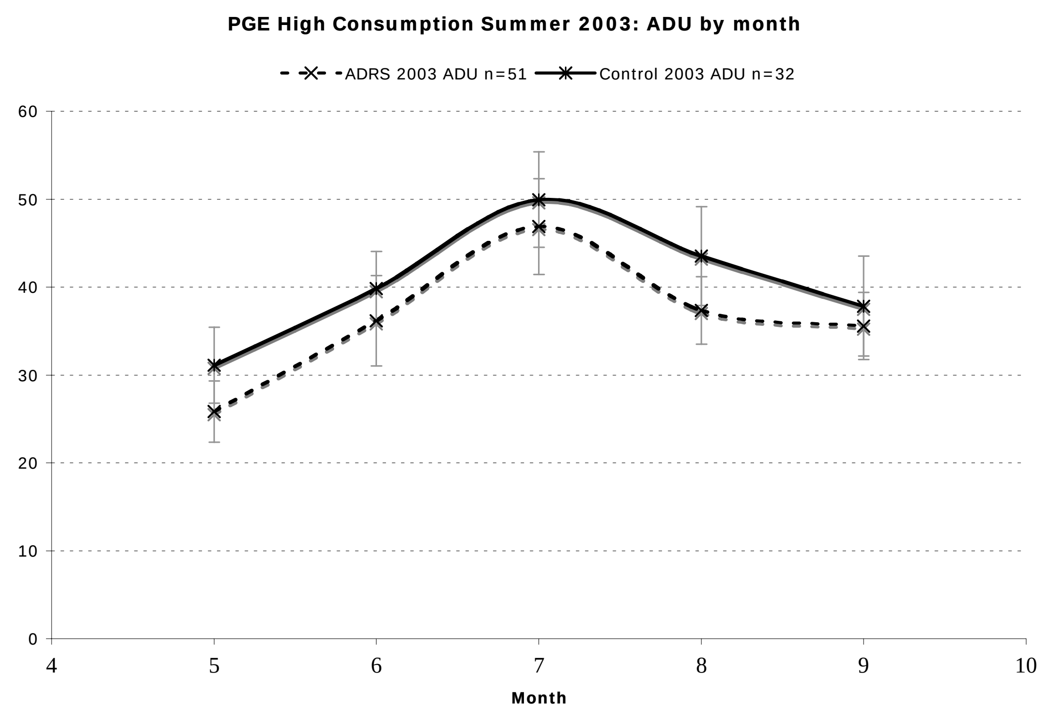


Figure 27. PG&E High Consumption 2004 Weekend ADU

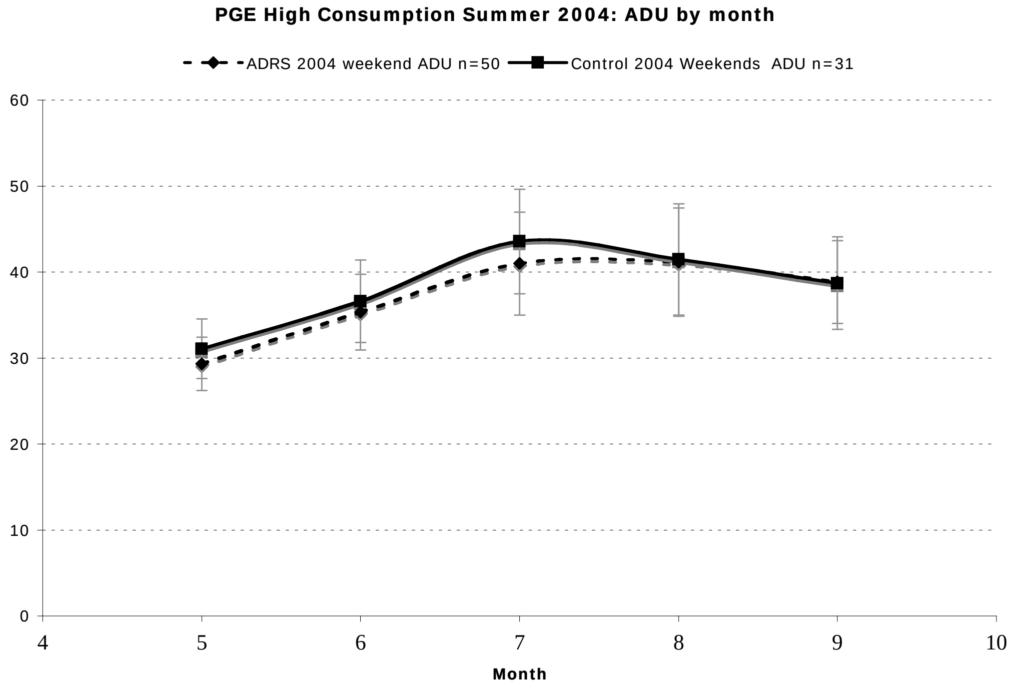


Figure 28. SCE High Consumption 2003 ADU

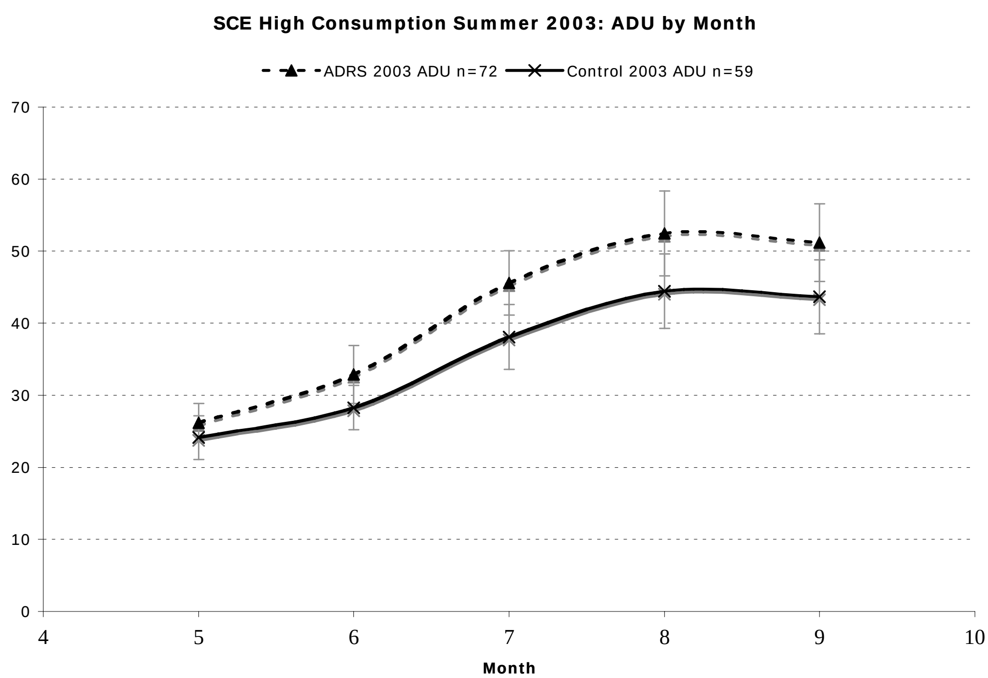


Figure 29. SCE High Consumption 2004 ADU Weekends

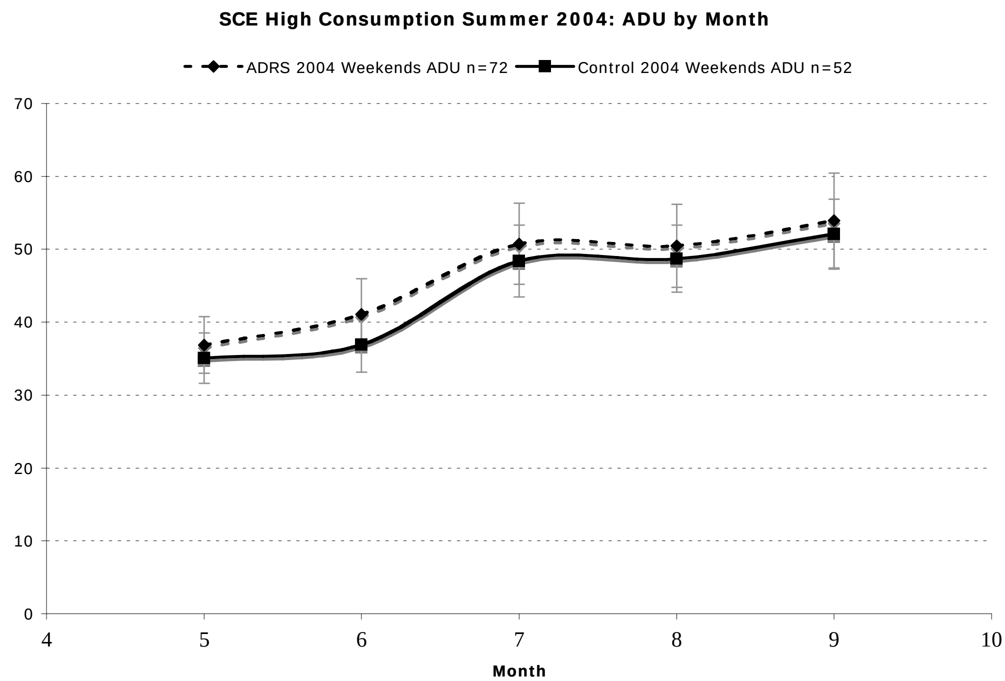


Figure 30. SDG&E 2003 ADU

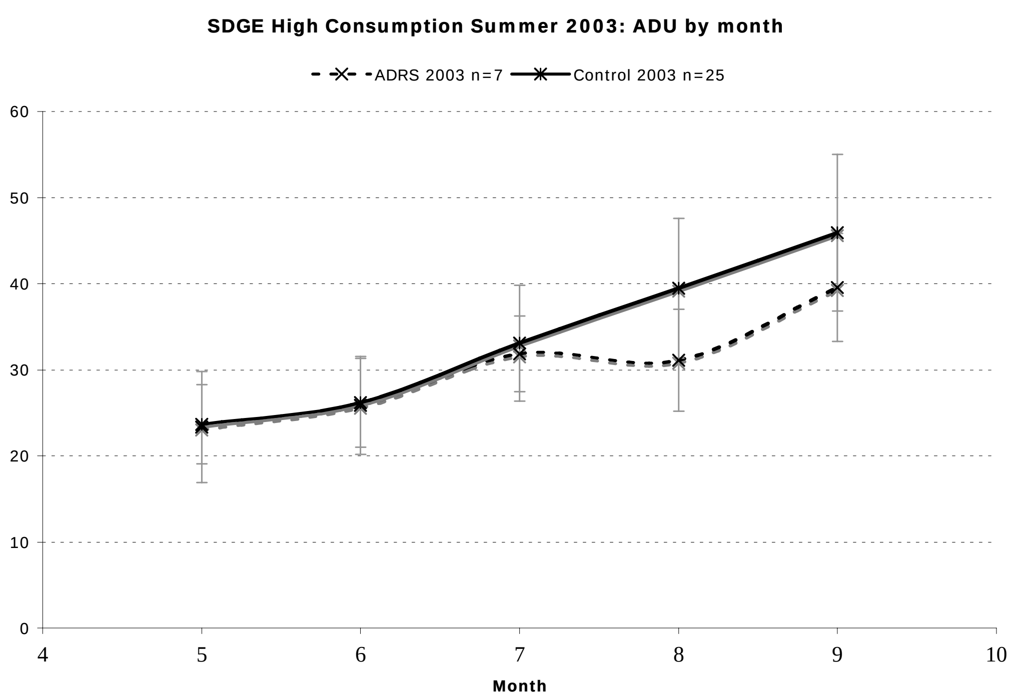
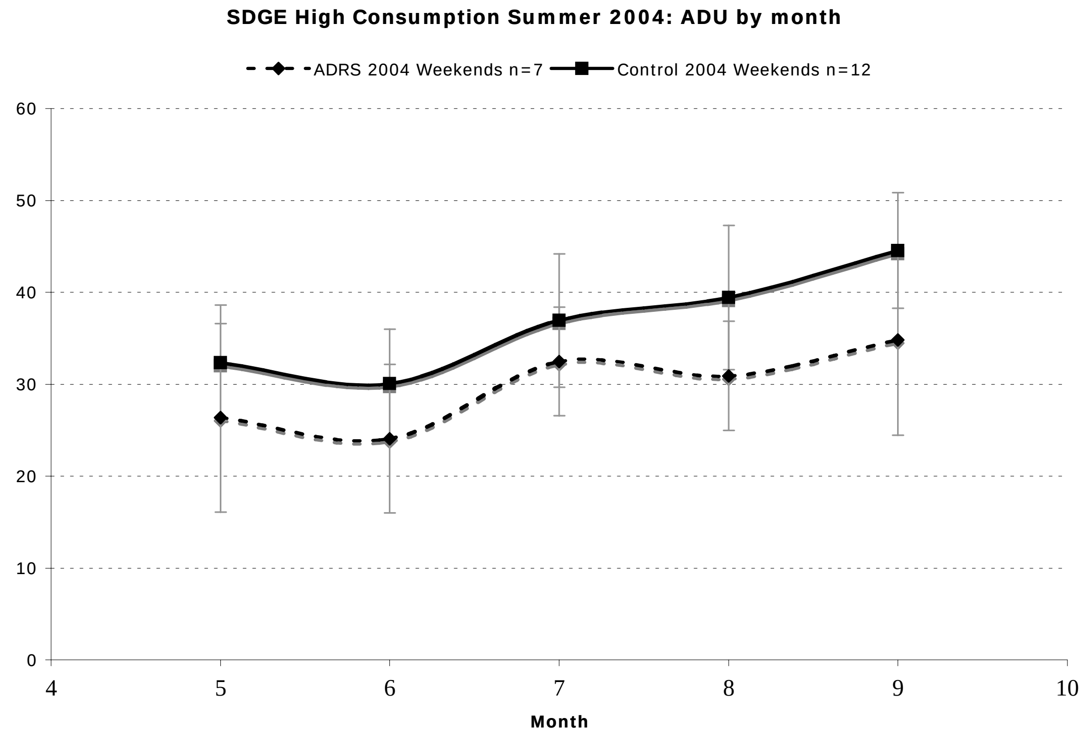


Figure 31. SDG&E 2004 ADU



The figures produce consistent results with pretreatment and weekend analyses. In PG&E and SDG&E territories, the average ADU for control homes is slightly more than the ADU for ADRS homes, though not significantly different. SCE's 2004 ADUs for control homes are consistently less than ADRS's average ADUs, but not significantly different. All these observations conform exactly with the observations from the 2003 ADU data.

Given these similarities in comparison, 2004 weekend data could not be considered different from 2003 monthly billing data based on this analysis. The summer of 2004 weekend data had passed the two tests used to validate them. Thus, the summer 2004 weekend data were accepted as a proxy for pretreatment data and the differences were calculated for each of the three utilities between control and ADRS by stratum.

Applying the differences adjustment

Figure 32, Figure 33, and Figure 34 show the result of applying the differences adjustment for high consumption stratum of PG&E, SCE, and SDG&E, respectively, using the difference values calculated from summer 2004 weekends data. The charts show the ADRS load profiles for each utility before and after application of the differences adjustment on event and non-event days. The thickest black line close to the x-axis plots the differences adjustment in each chart for each utility.

PG&E difference adjustments are small (± 0.1 kW) through most of the day, and increase to 0.4 kW during the peak period. SCE differences are all negative, reflecting the higher consumption of ADRS customers compared to control customers. SCE’s peak period differences start at 0.2 kW and decrease steadily through the period down to -0.2 kW. SDG&E's differences vary between -0.5 kW at dawn to 0.6 kW during the peak period. SDG&E's differences are not quite as smooth as PG&E's or SCE's, which is likely an effect of the small number of high consumption stratum ADRS homes (see Table 7).

Figure 32. PG&E High Consumption Adjustment Chart

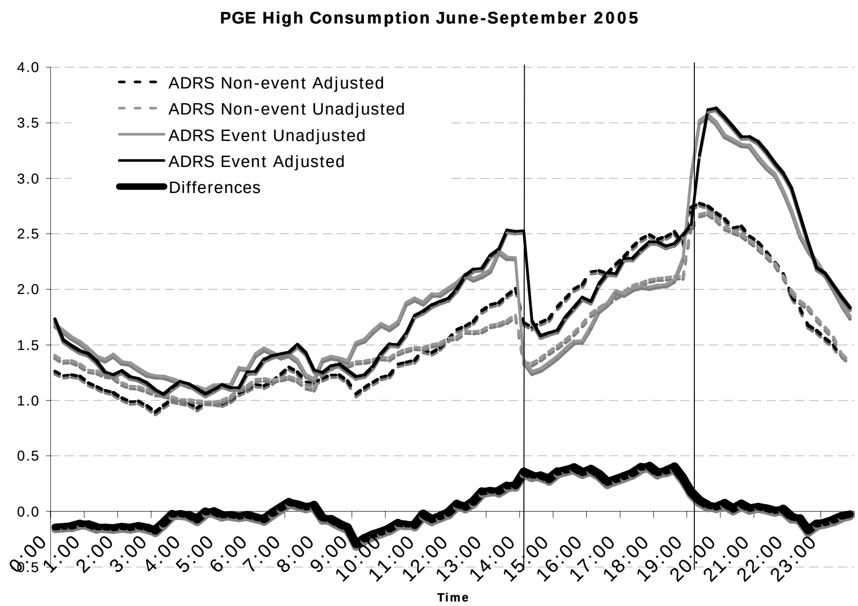


Figure 33. SCE High Consumption Adjustment

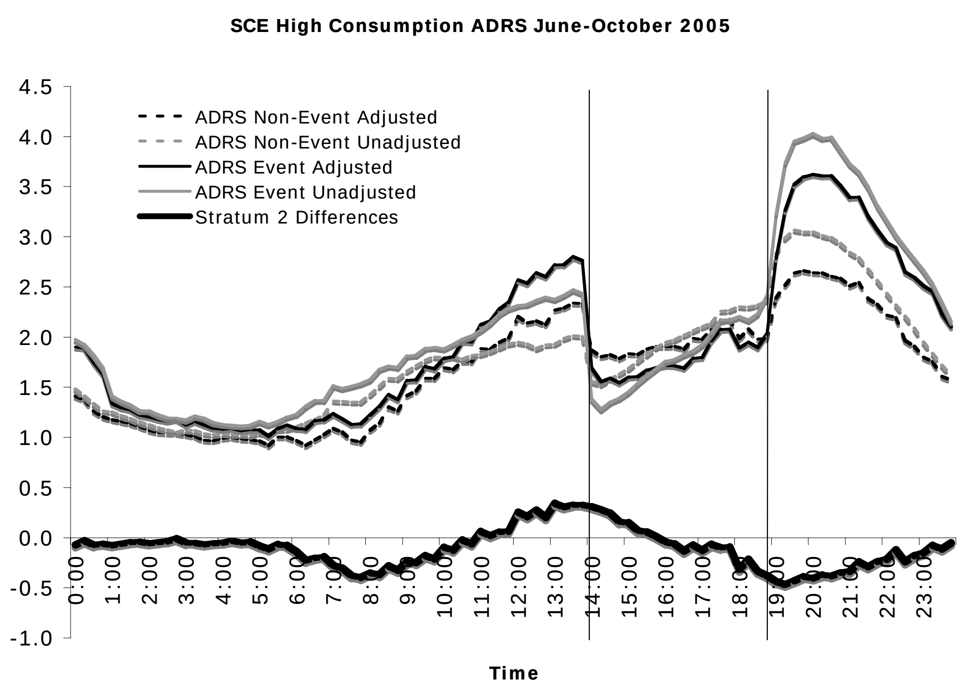


Figure 34. SDG&E High Consumption Adjustment

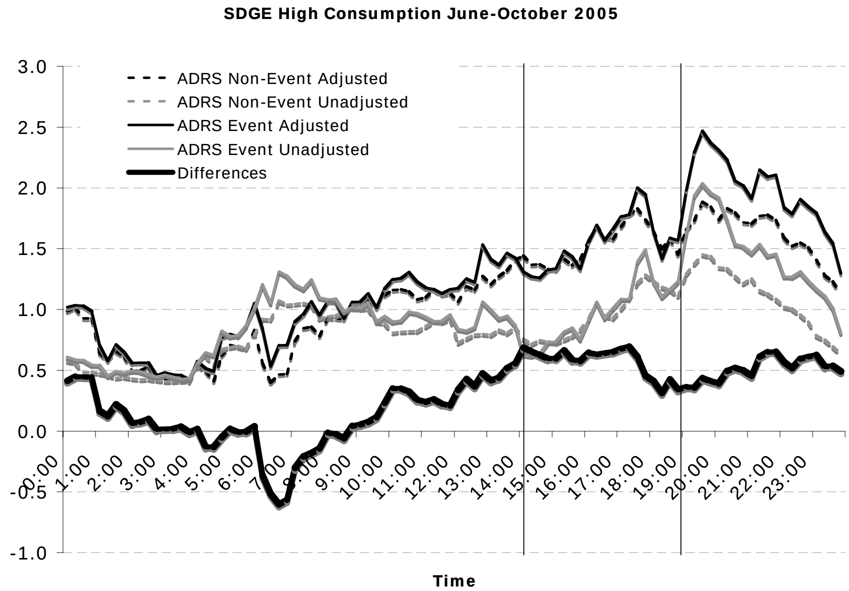


Figure 35. PG&E Low Consumption Adjustment

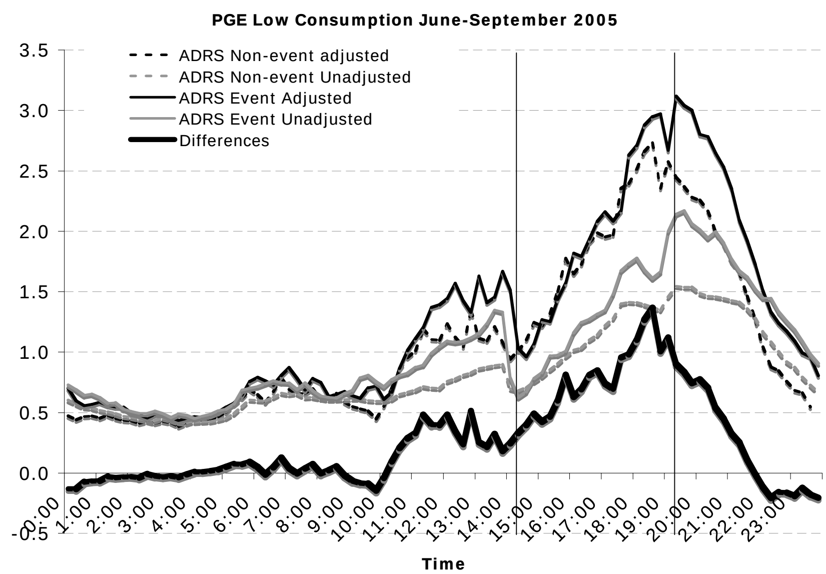


Figure 35 is a chart of PG&E's low consumption stratum adjustment, which is typical of the low consumption stratum adjustments for SCE and SDG&E as well. The differences curve is noisier and more extreme than any of the high consumption stratum adjustments. Differences are nearly zero throughout the early morning while the peak period rises from 0.3 kW up to 1.4 kW. The low consumption stratum differences exhibit these extreme characteristics as a result of a limited data set (see Table 7). In PG&E service territory, there are only two control homes in the low consumption stratum.

ADRS selection bias analysis summary

In summary, RMI turned to four sources of information in our investigation into ADRS customer selection bias: ADRS program recruiting and welcome materials, interval meter data during ADRS "pretreatment" weekdays prior to ADRS (GoodWatts) technology installation, interval meter data during 2004 summer weekends, and monthly kWh billing meter data from summer 2003. The first source was qualitative and the last three sources were quantitative evaluations. The three quantitative sources provided us with data in varying levels of detail and quality.

The three quantitative data sources all produced consistent patterns in the orientation of ADRS participant consumption compared to control homes. Moreover, the orientations were utility specific. For PG&E and SDG&E, the pretreatment data, summer 2004 weekends, and 2003 monthly billing data all concluded that ADRS customers consumed less load than control customers. For SCE, the quantitative analyses all concluded that ADRS customers consumed more load than control customers.

The fifteen minute interval data available for pretreatment and summer 2004 weekends analyses revealed furthermore that differences in control and ADRS customers consumption were statistically significant during the hours of 2 p.m. to 7 p.m., when ADRS customers are charged higher electric rates during event and non-event days, according to the CPP-F experimental rate schedule. Because the pretreatment data were particularly problematic and the summer 2004 weekends data were more robust, and because the utility specific differences between the pretreatment and weekends data were similar, RMI decided to apply the adjustments resulting from the weekends analysis to all subsequent ADRS pilot load impact evaluations.

Table 10. Summary of hourly peak period selection bias adjustments, based on control-ADRS customers' average consumption differences using summer 2004 weekends data

	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.	Average
PGE Difference High Stratum	0.325	0.370	0.318	0.368	0.355	0.347
SCE Difference High Stratum	0.247	0.074	-0.078	-0.095	-0.311	-0.033
SDGE Difference High Stratum	0.640	0.606	0.641	0.609	0.372	0.574
PGE Difference Low Stratum	0.366	0.575	0.745	0.842	1.186	0.743
SCE Difference Low Stratum	-0.736	-0.842	-0.959	-0.958	-0.824	-0.864
SDGE Difference Low Stratum	-0.358	-0.309	-0.203	-0.236	-0.250	-0.271
Statewide High Only	0.248	0.163	0.071	0.067	-0.077	0.094
Statewide ALL	0.260	0.202	0.116	0.070	-0.050	0.119

Although the average load differences between control and ADRS customers were statistically significant, the magnitude of the differences was small with few exceptions (Table 10). The PG&E service territory high consumption differences varied little from 0.3 kW across the 5 hour peak period. Control-ADRS differences for PG&E low consumption customers varied more between, 0.4

kW at 2 p.m. increasing gradually to 1.2 kW at 6 p.m. For SCE customers, high consumption differences ranged from a high of 0.25 kW at 2 p.m. to a low of -0.3 kW at 6 p.m. Control-ADRS differences for SCE low consumption customers varied between -0.7 kW to -0.9 kW across the peak period. Finally, for SDG&E high consumption customers, control-ADRS differences were consistently 0.6 kW from 2 p.m. to 5 p.m., dropping to 0.3 kW at 6 p.m. Differences for SDG&E low consumption customers also exhibited small variation, ranging from 0.4 kW at 2 p.m. to 0.2 kW at 6 p.m.

The statewide differences adjustments were derived from the weighted average of the difference adjustments calculated for each utility. Because the orientation of ADRS load consumption compared to control were in opposite directions between SCE and PG&E and SDG&E, the resulting statewide difference adjustments were close to zero (Table 10).

Appendix D
Low Consumption ADRS
2005 and 2004 Load Impact Results Charts

Figure 36: 2005 Statewide low consumption homes: average of event days load curves

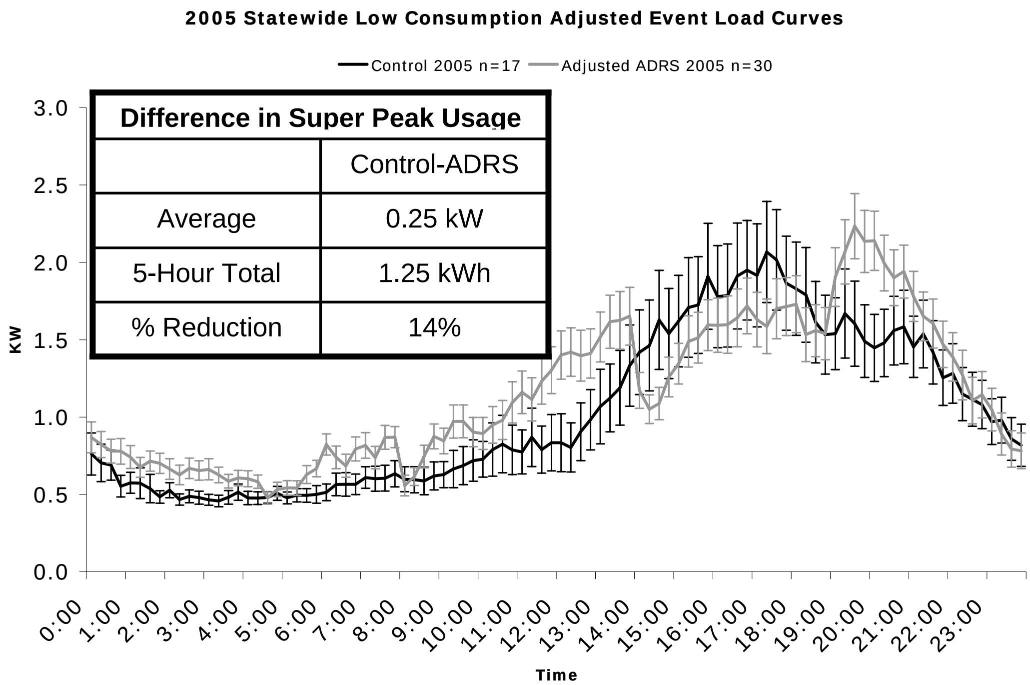


Figure 37: 2005 Statewide low consumption homes: average of non-event weekdays load curves

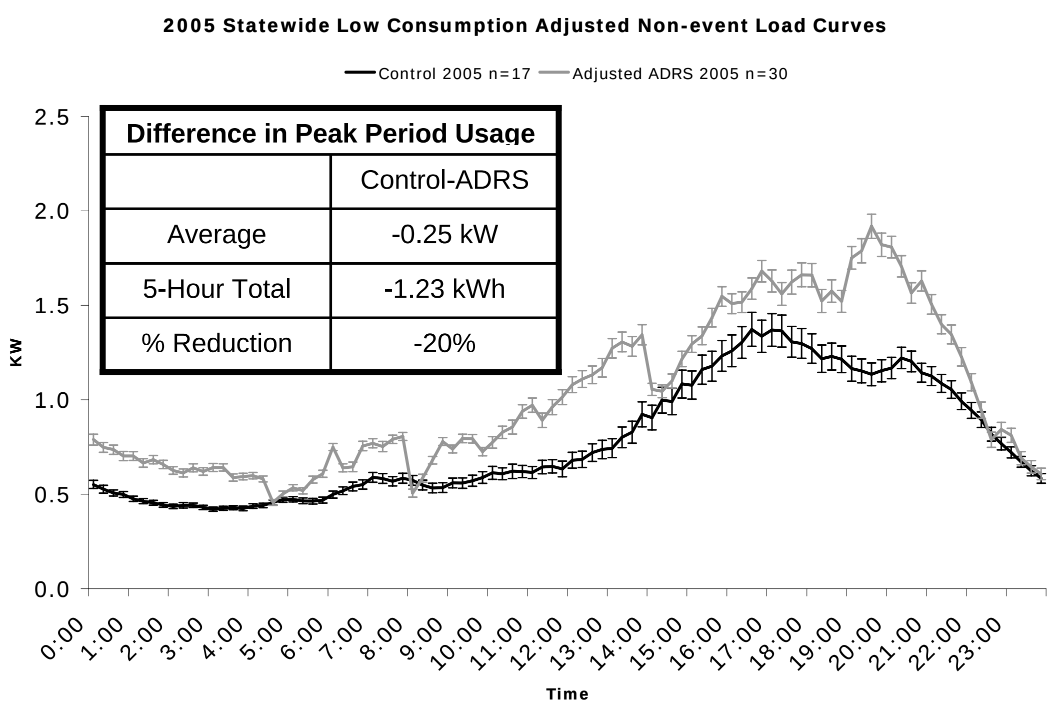


Figure 38: 2005 Statewide low consumption homes: hourly Super Peak period load reductions

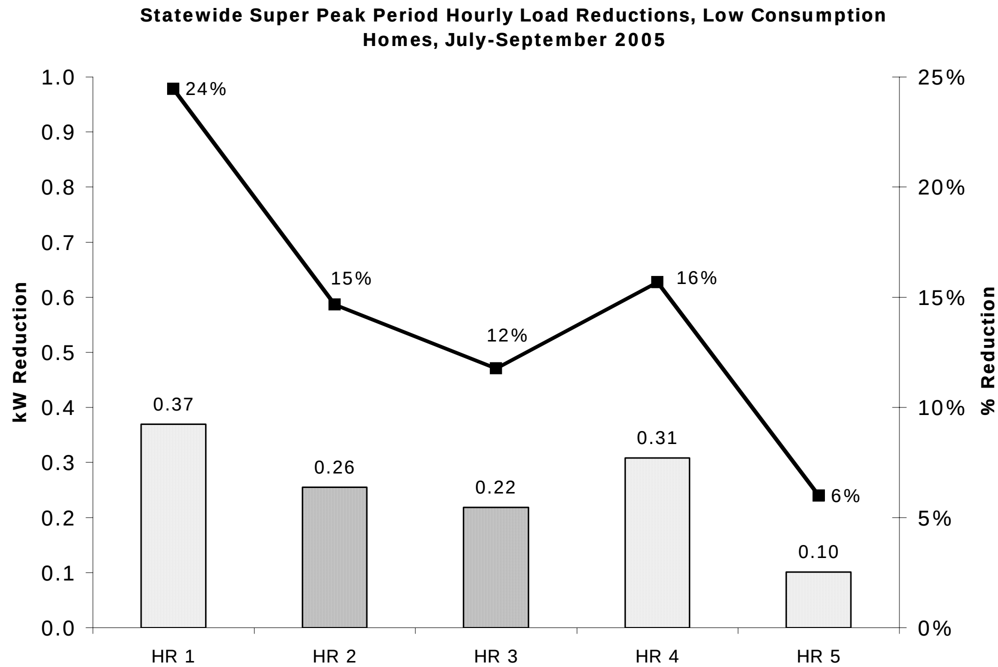


Figure 39: 2005 Statewide low consumption homes: hourly peak period load reductions

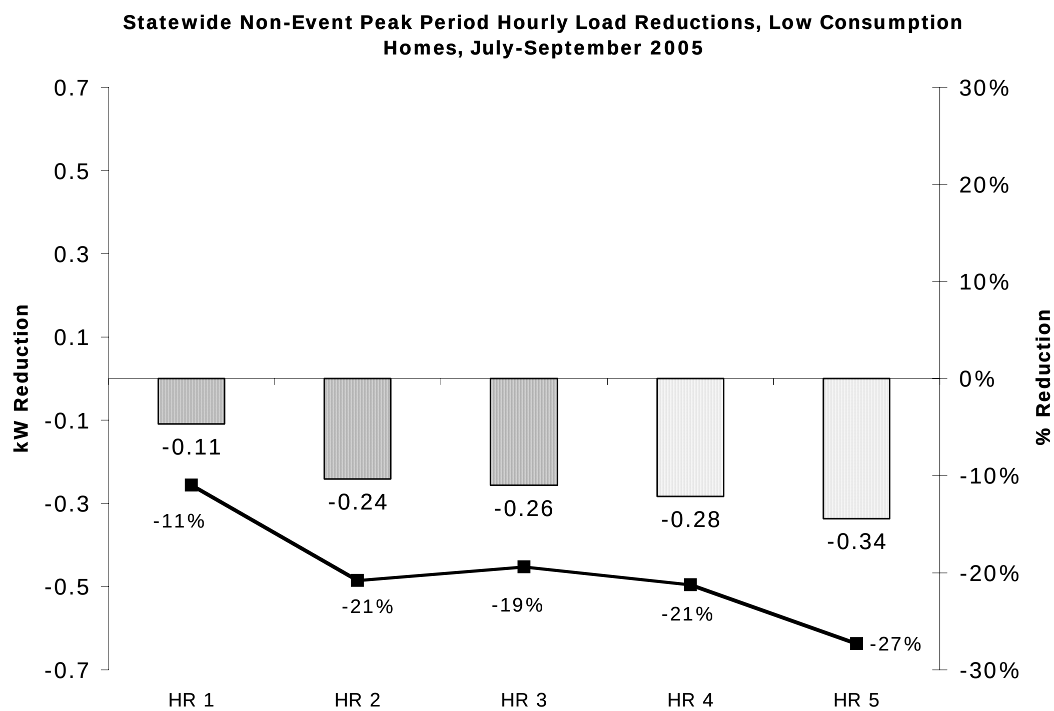


Figure 40: PG&E low consumption homes: average of event days load curves, 2005

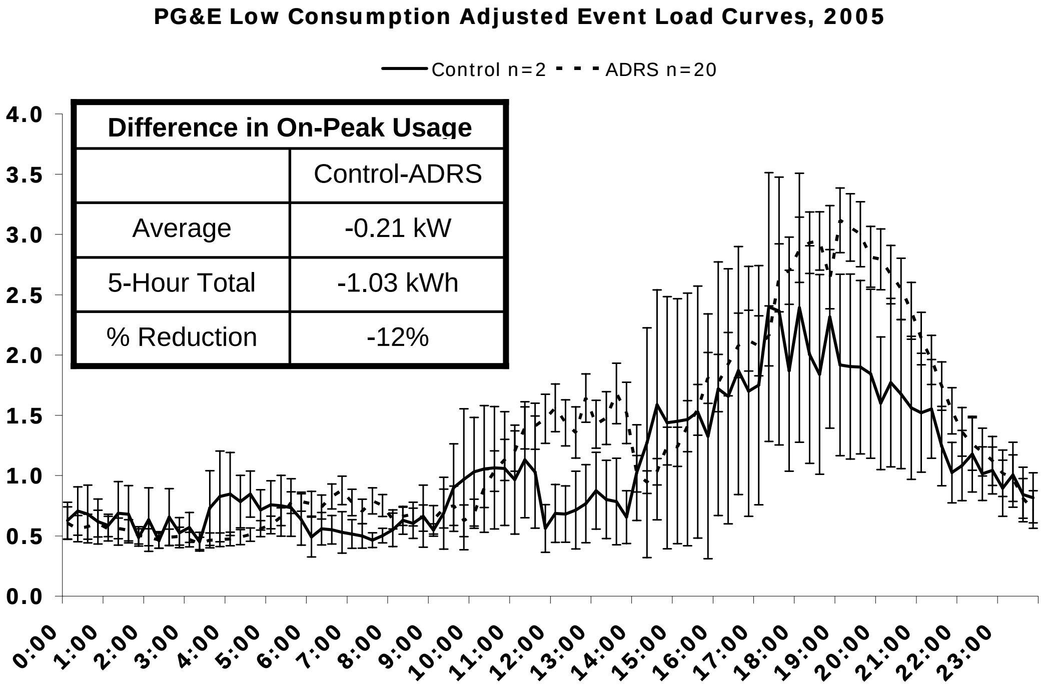


Figure 41: PG&E low consumption homes: average of non-event weekdays load curves, 2005

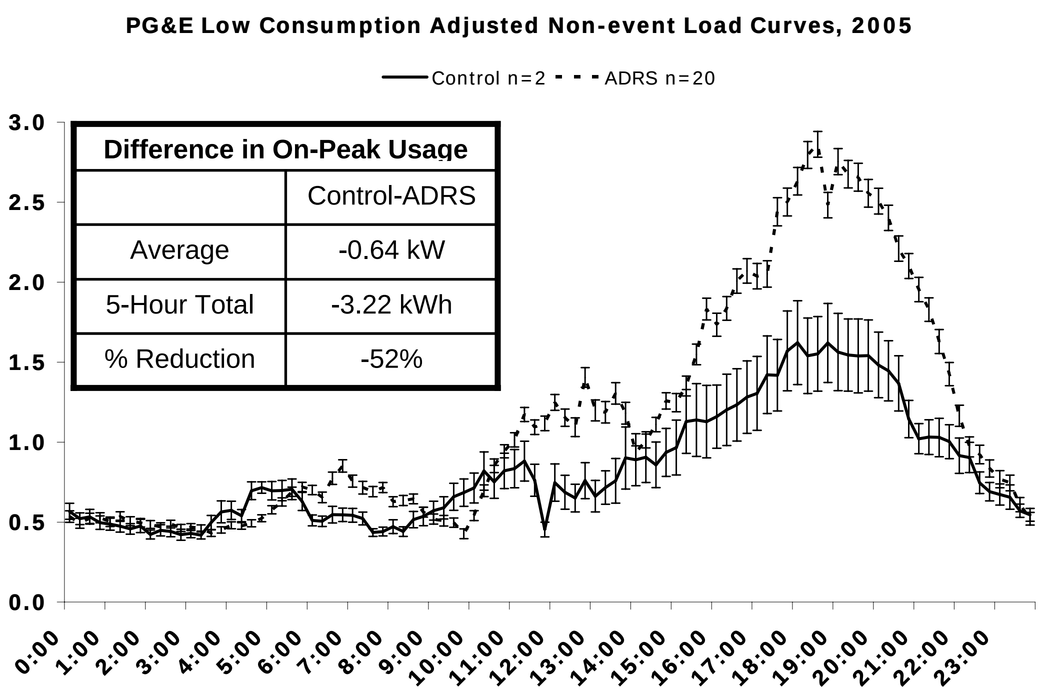


Figure 42: PG&E low consumption homes: hourly Super Peak period load reductions, 2005

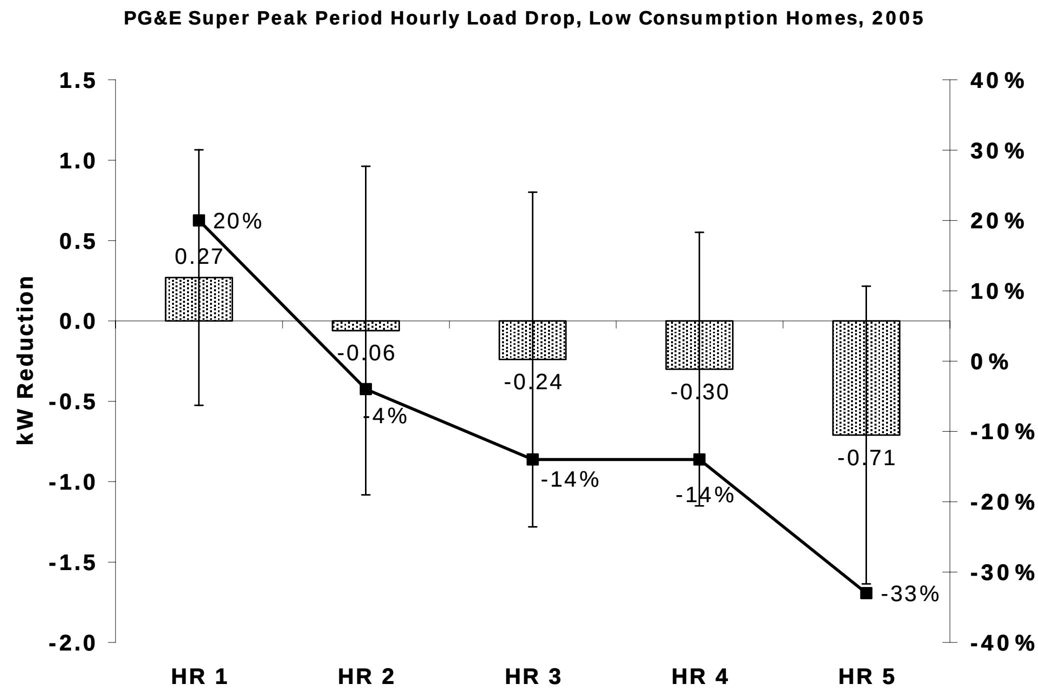


Figure 43: PG&E low consumption homes: hourly peak period load reductions, 2005

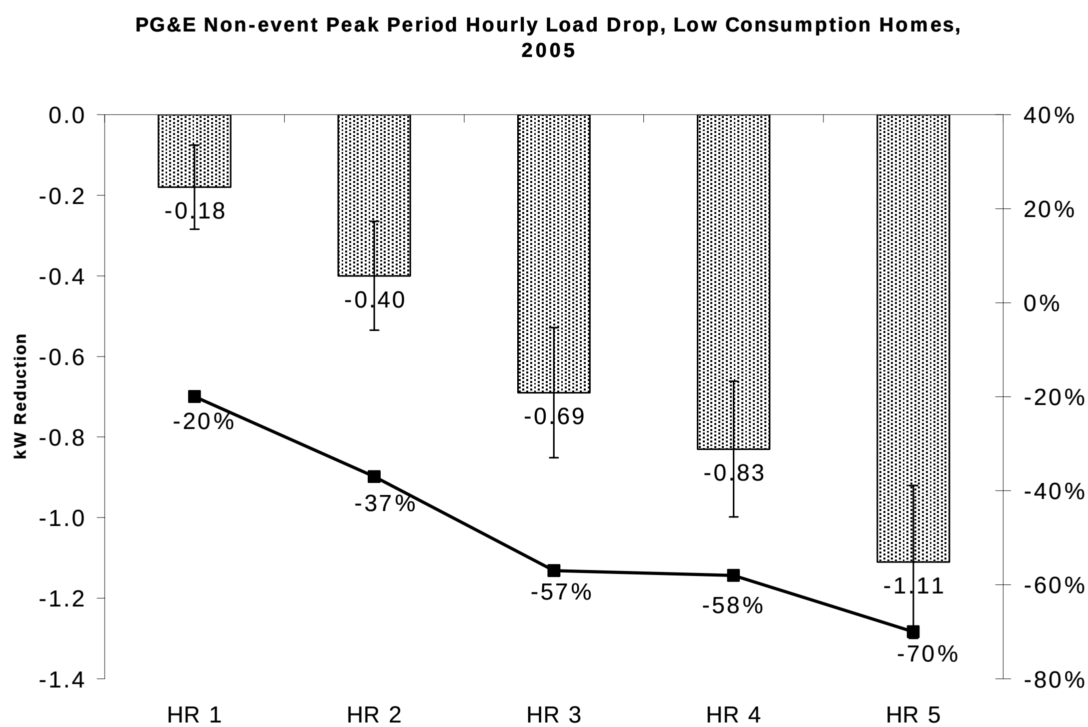


Figure 44: SCE low consumption homes: average of event days load curves, 2005

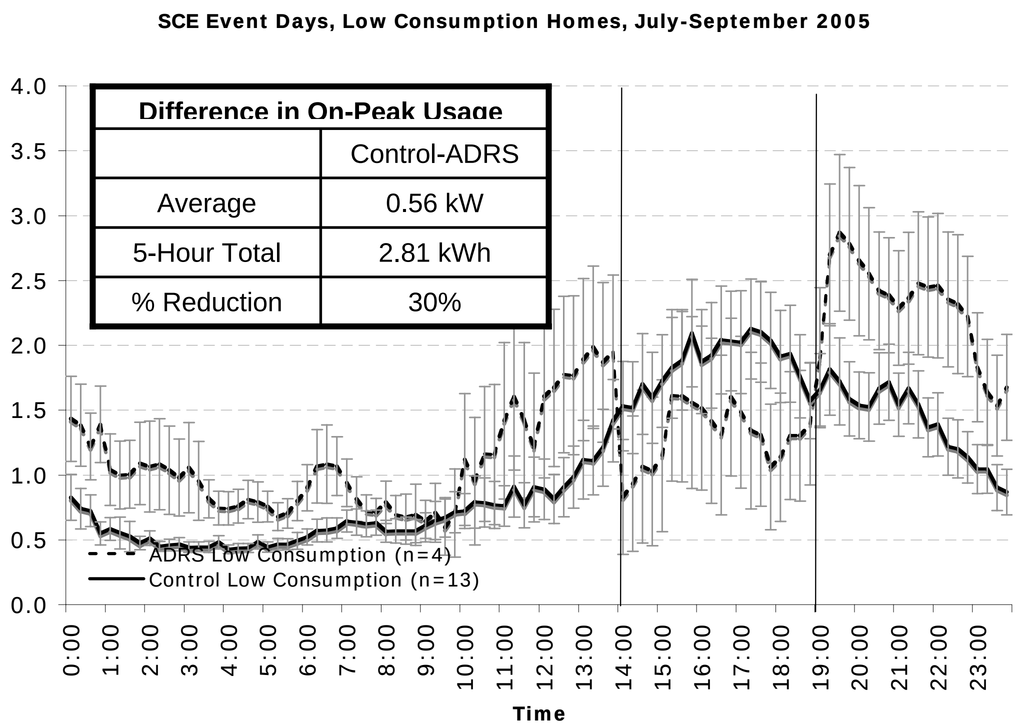


Figure 45: SCE low consumption homes: average of non-event weekdays load curves, 2005

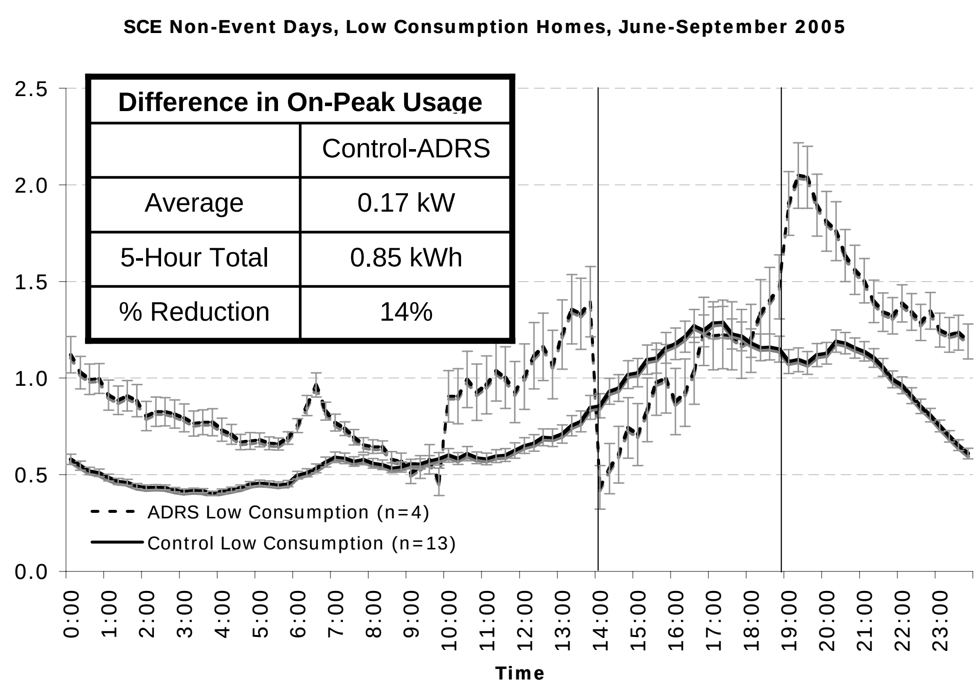


Figure 46: SCE low consumption homes: hourly Super Peak period load reductions, 2005

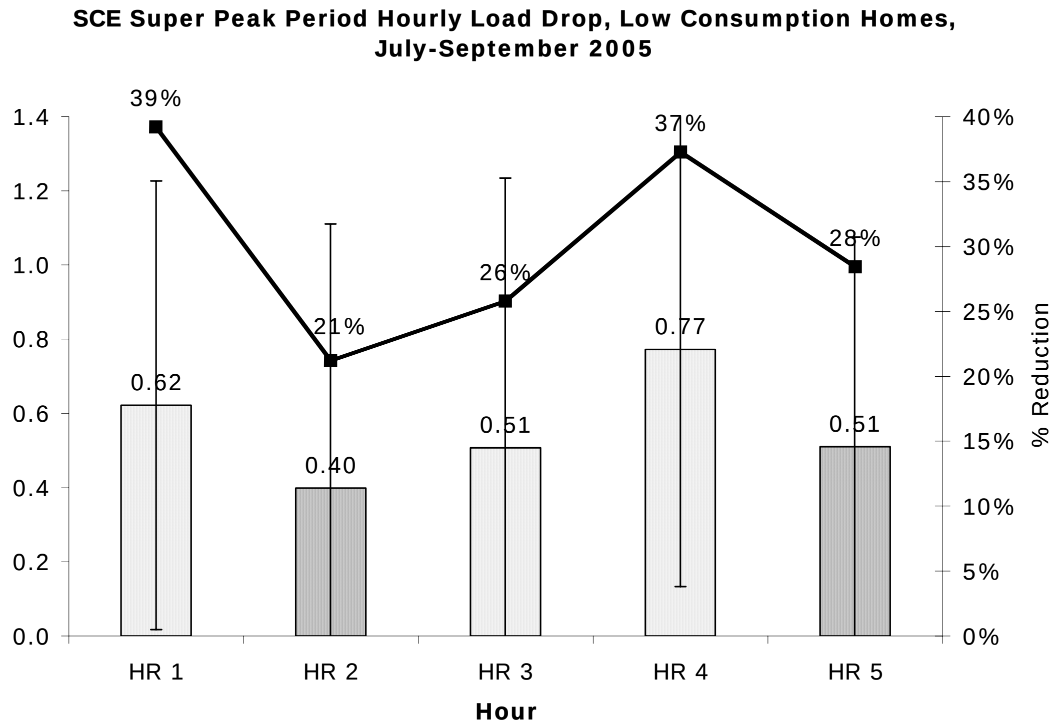


Figure 47: SCE low consumption homes: hourly peak period load reductions, 2005

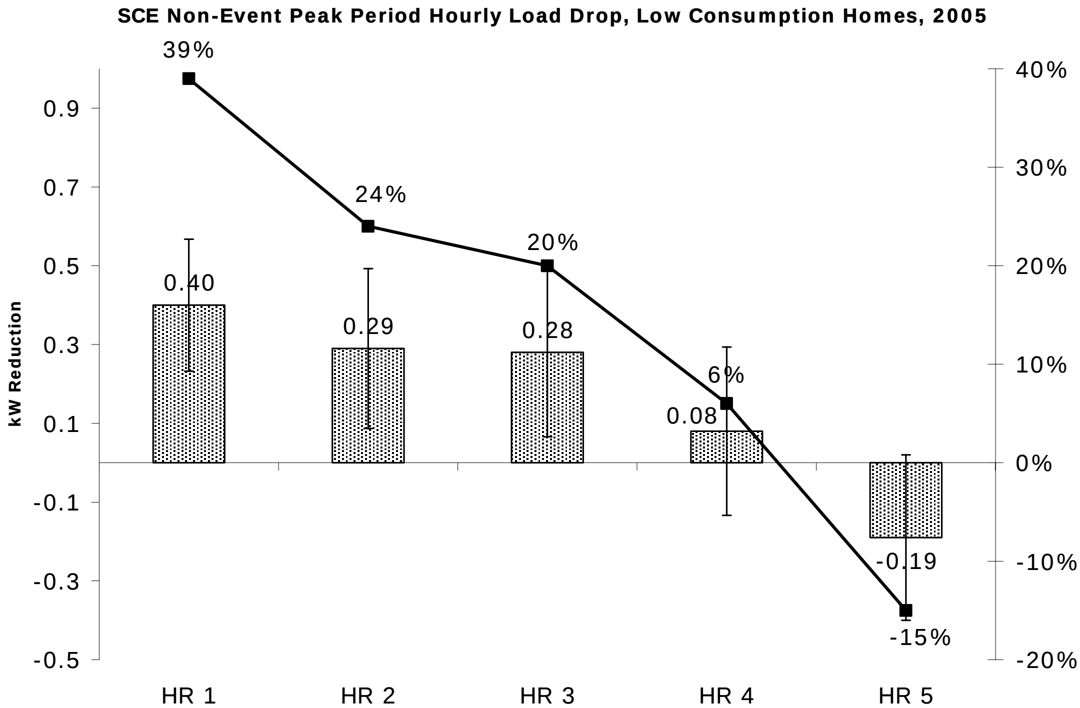


Figure 48: SDG&E low consumption average of event days load curves, 2005

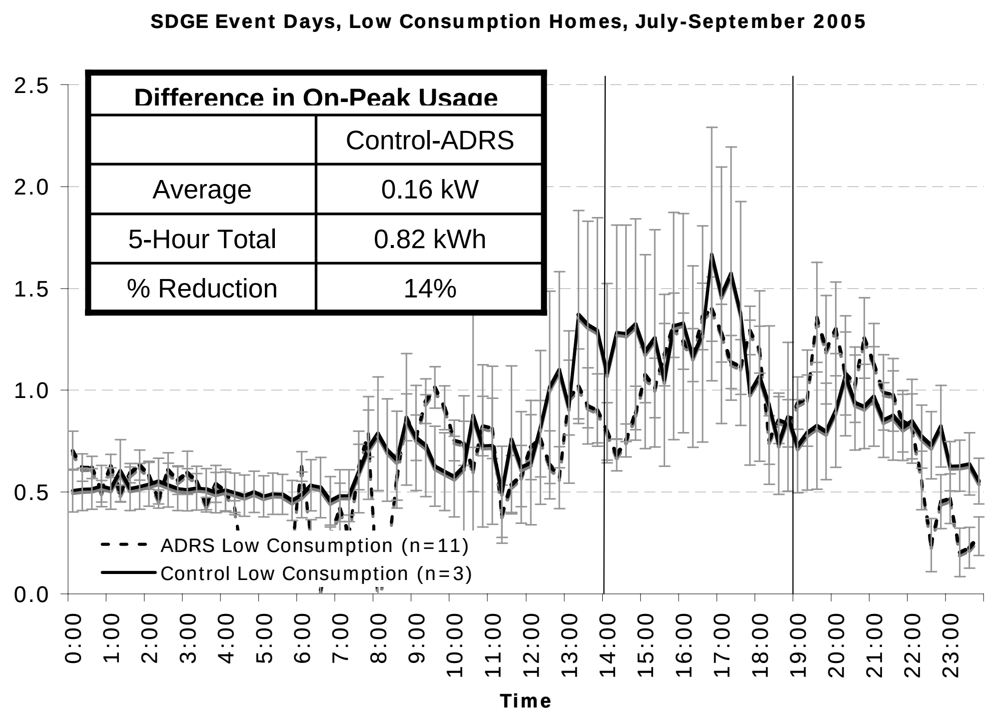


Figure 49: SDG&E low consumption average of non-event weekdays load curves, 2005

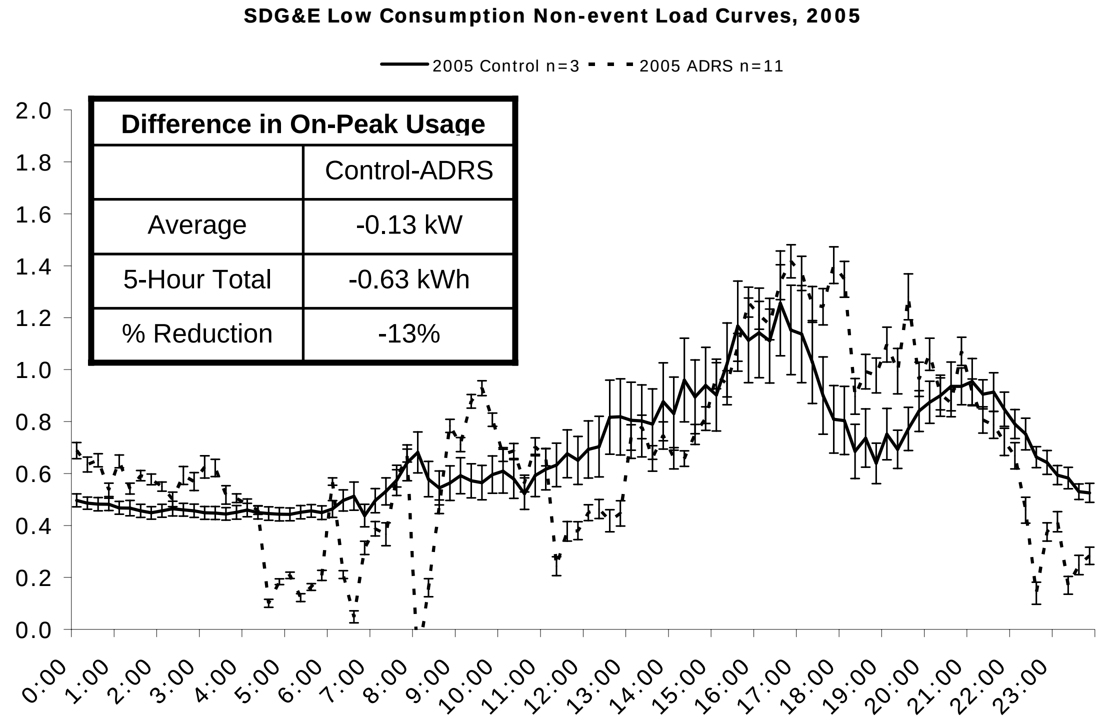


Figure 50: SDG&E low consumption homes: hourly Super Peak period load reductions, 2005

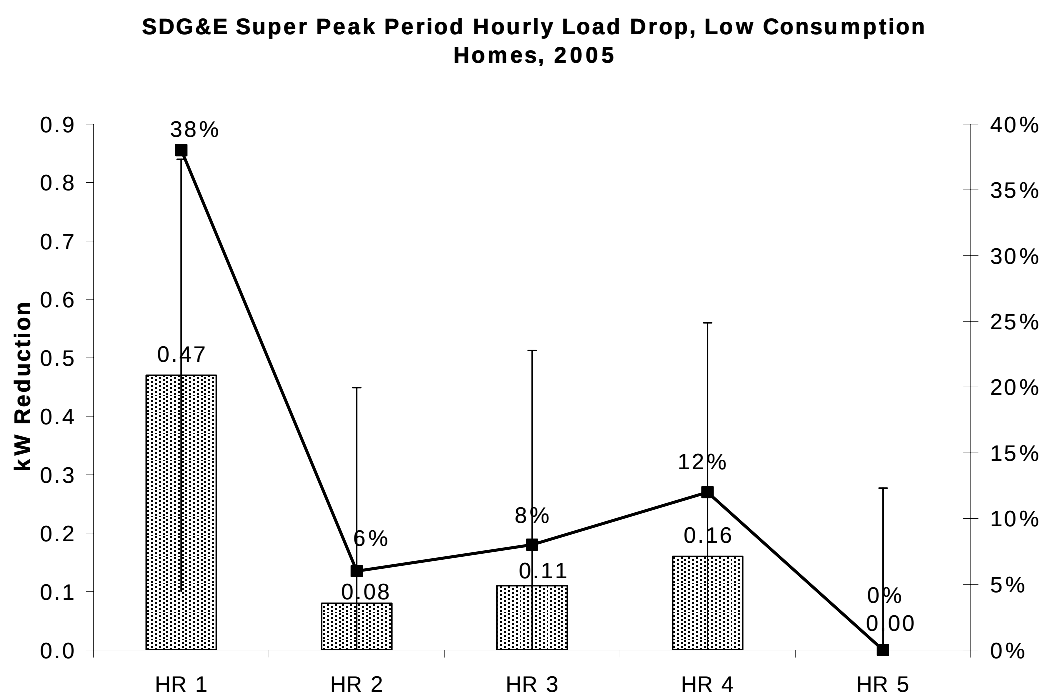


Figure 51: SDG&E low consumption homes: hourly peak period load reductions, 2005

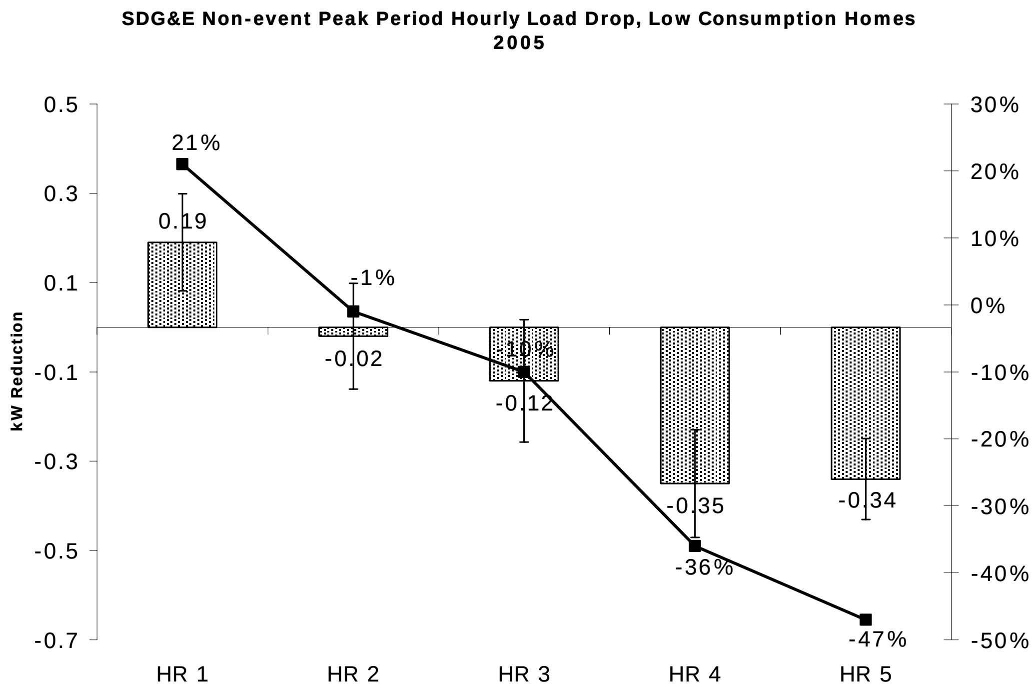


Figure 52: Comparison of 2005 and 2004 statewide low consumption homes: average of event days load curves

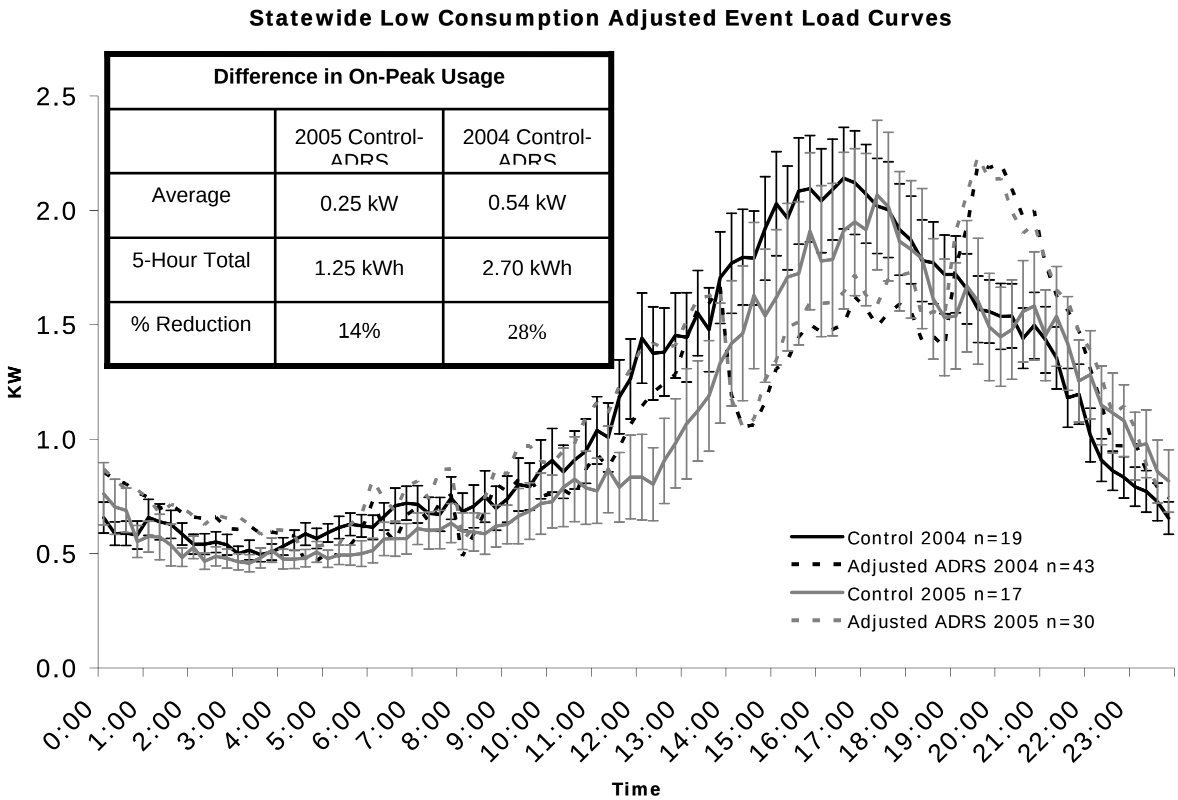


Figure 53: Comparison of 2005 and 2004 statewide low consumption homes: average of non-event weekdays load curves

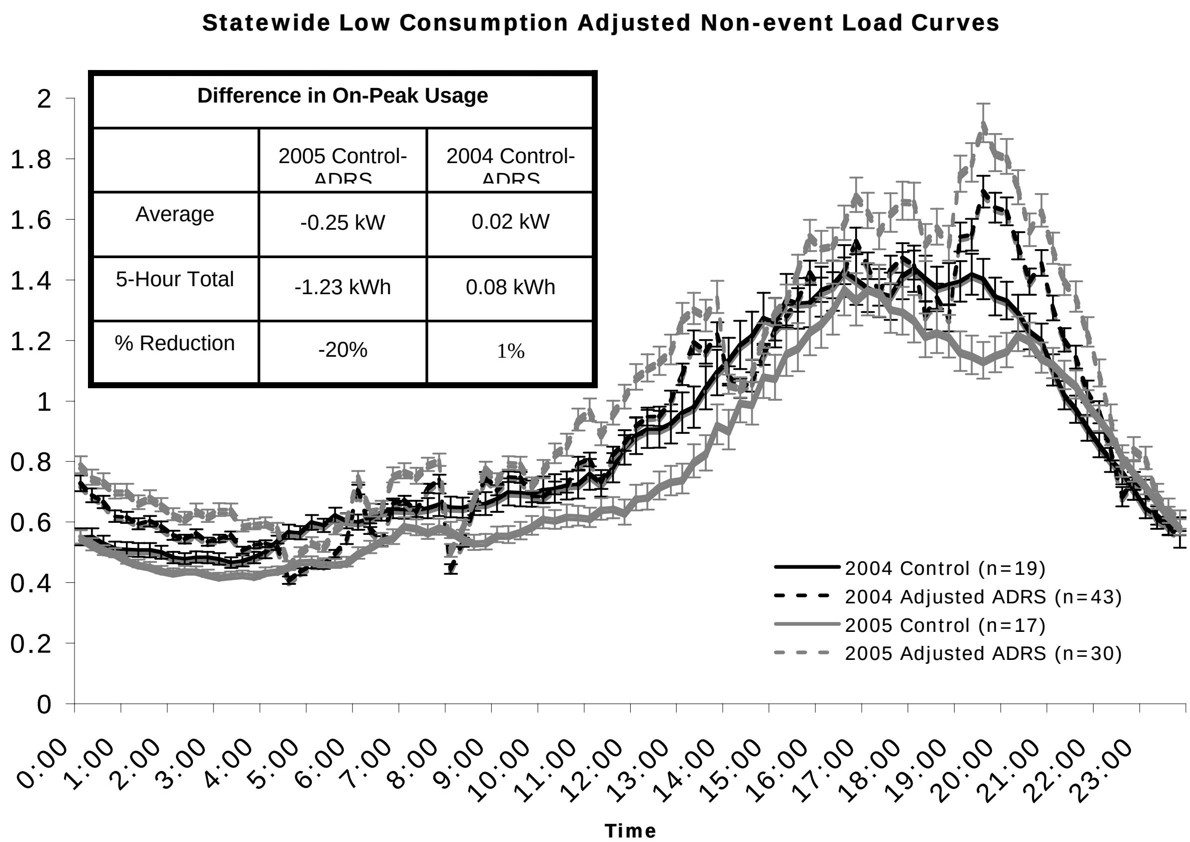
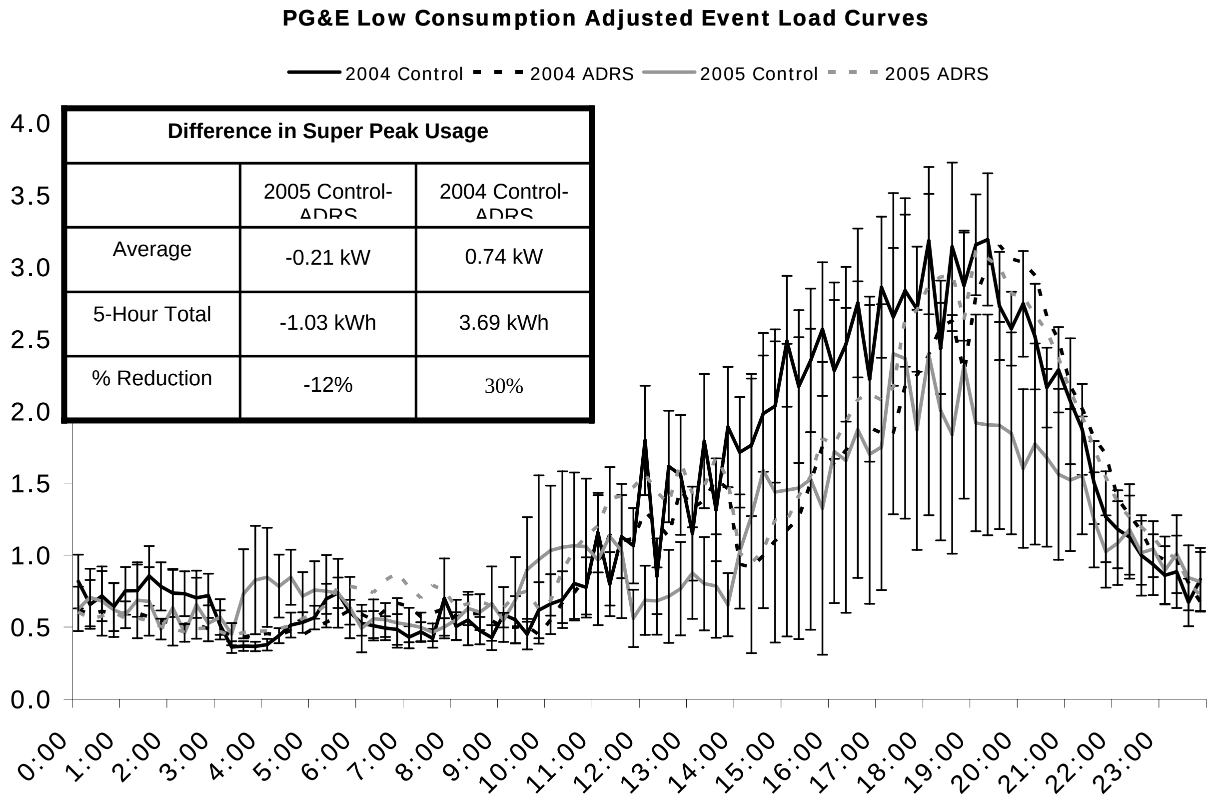

Statewide Low Consumption Adjusted Non-event Load Curves
Difference in On-Peak Usage
2005 Control-ADRS
2004 Control-ADRS
Average
-0.25 kW
0.02 kW
5-Hour Total
-1.23 kWh
0.08 kWh
% Reduction
-20%
1%
2004 Control (n=19)
2004 Adjusted ADRS (n=43)
2005 Control (n=17)
2005 Adjusted ADRS (n=30)
Time

Figure 54: Comparison of 2005 and 2004 PG&E low consumption homes: average of event days load curves



Difference in Super Peak Usage		
	2005 Control-ADRS	2004 Control-ADRS
Average	-0.21 kW	0.74 kW
5-Hour Total	-1.03 kWh	3.69 kWh
% Reduction	-12%	30%

Figure 55: Comparison of 2005 and 2004 PG&E low consumption homes: average of non-event weekdays load curves

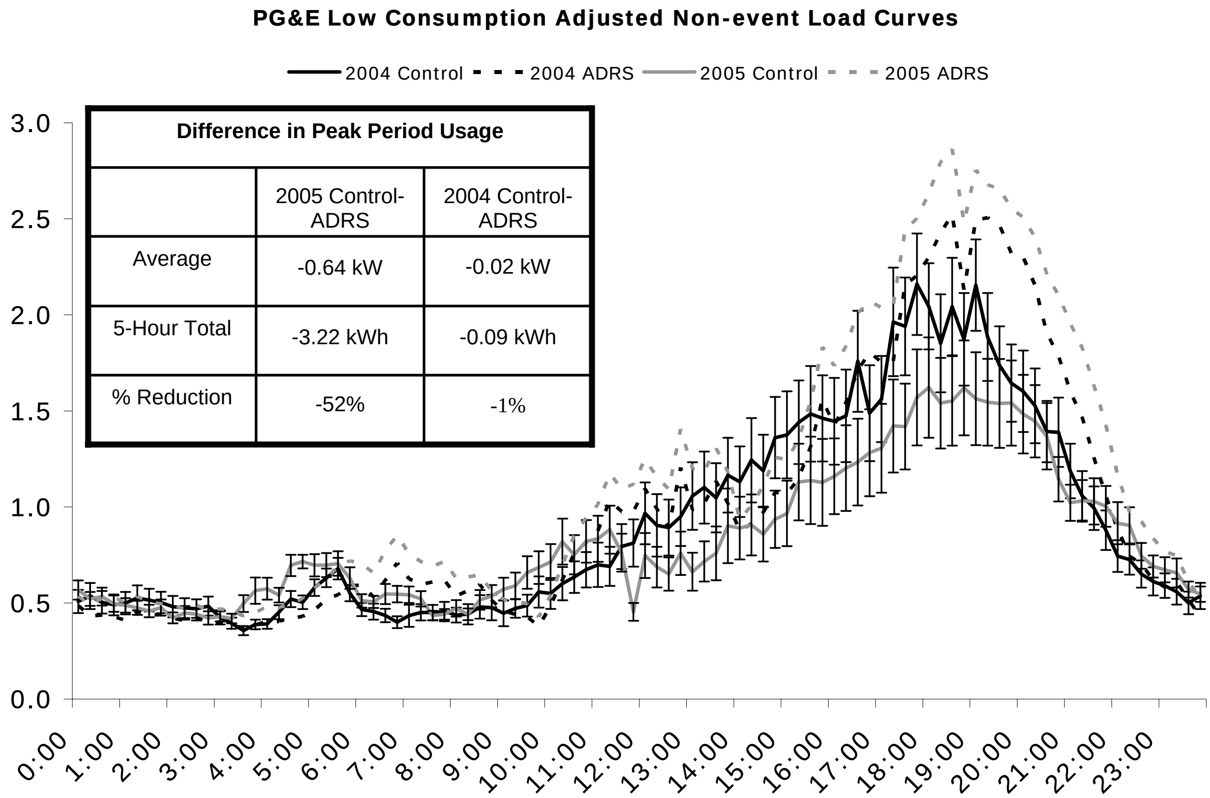


Figure 56: Comparison of 2005 and 2004 SCE low consumption homes: average of event day load curves

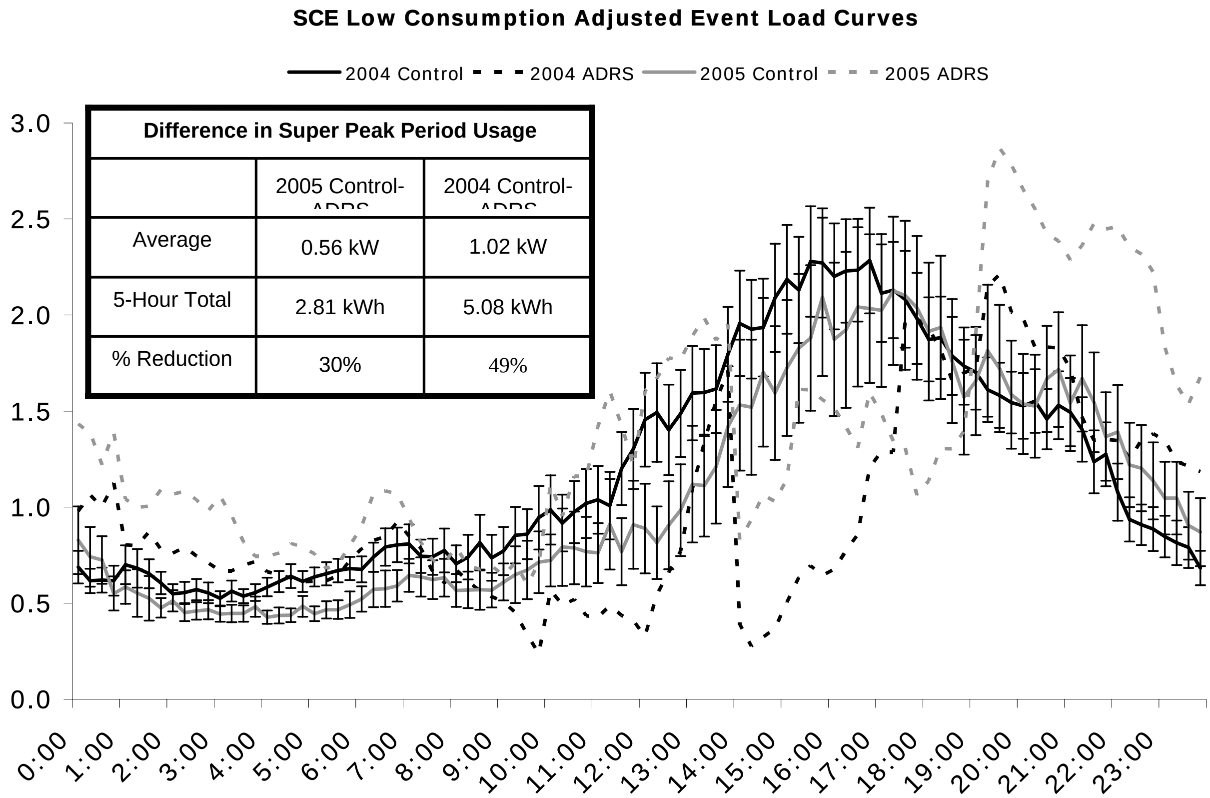


Figure 57 Comparison of 2005 and 2004 SCE low consumption homes: average of non-event weekdays load curves

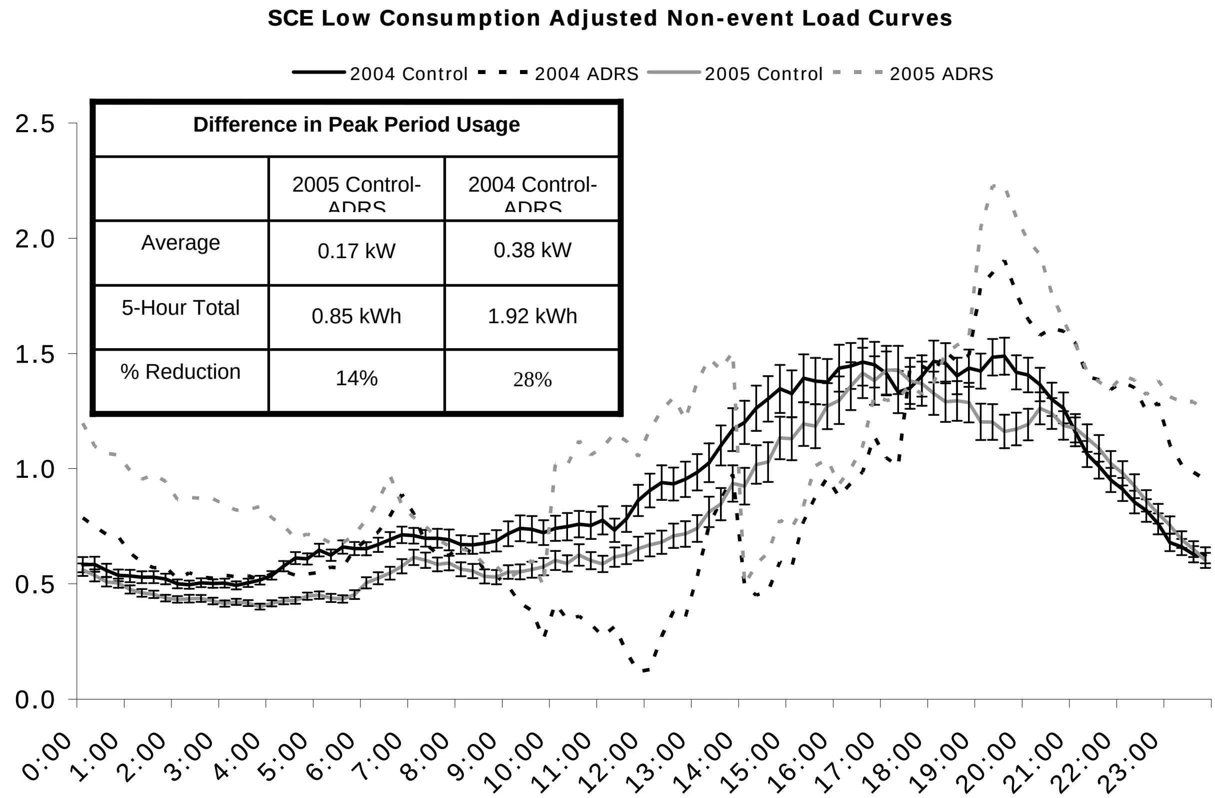


Figure 58: Comparison of 2005 and 2004 SDG&E low consumption homes: average of event day load curves

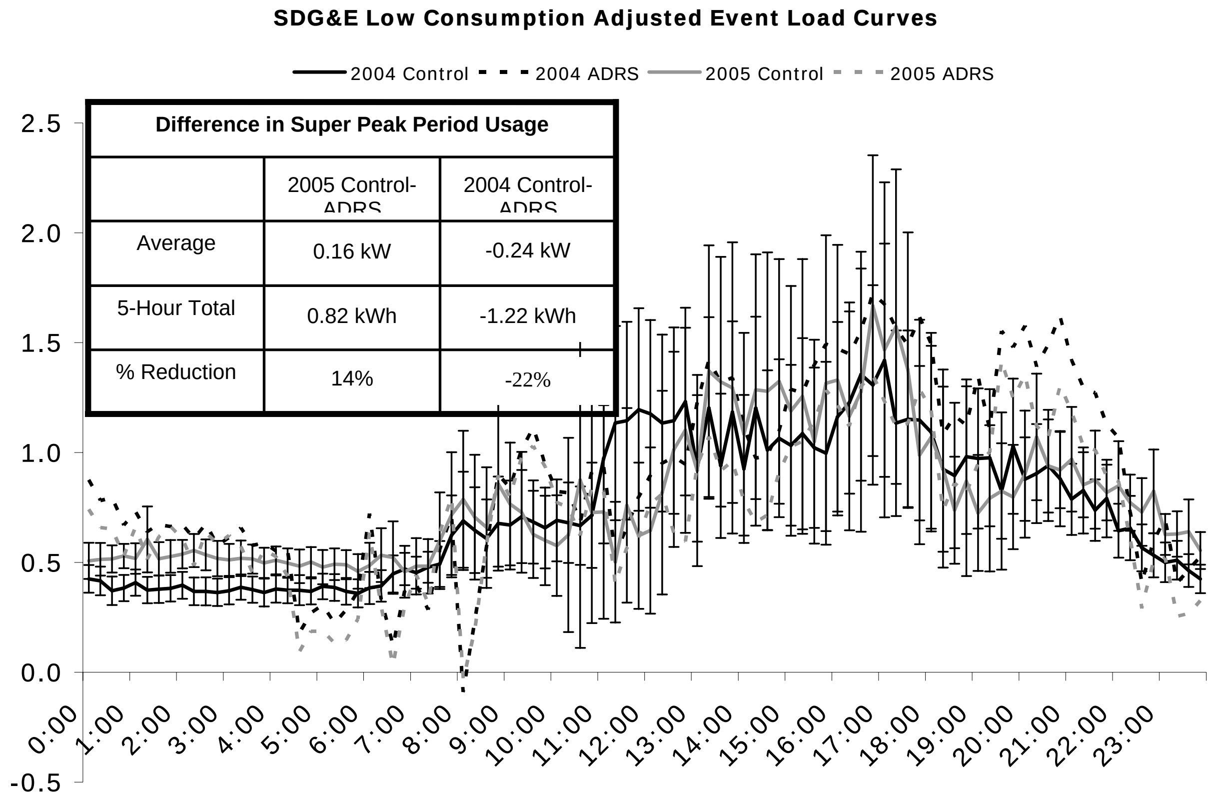


Figure 59: Comparison of 2005 and 2004 SDG&E low consumption homes: average of non-event weekdays load curves