AUTOMATED DEMAND RESPONSE SYSTEM PILOT

Final Report
Volume 1

Introduction and Executive Summary

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Table of Contents

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^{o}F to105^{o}F. For SDG&E, the hottest temperatures experienced by ADRS homes ranged from 86^{o}F-95^{o}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.

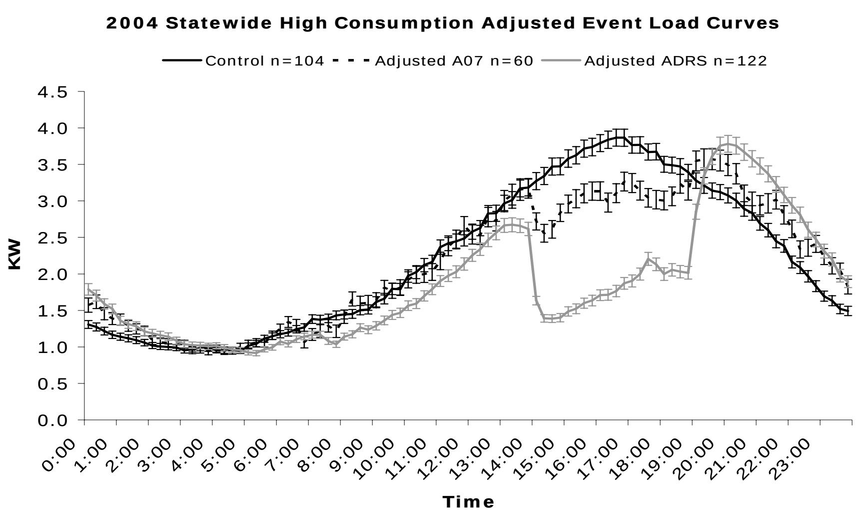
[14] However, water heating load control was not tested in this program.

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.

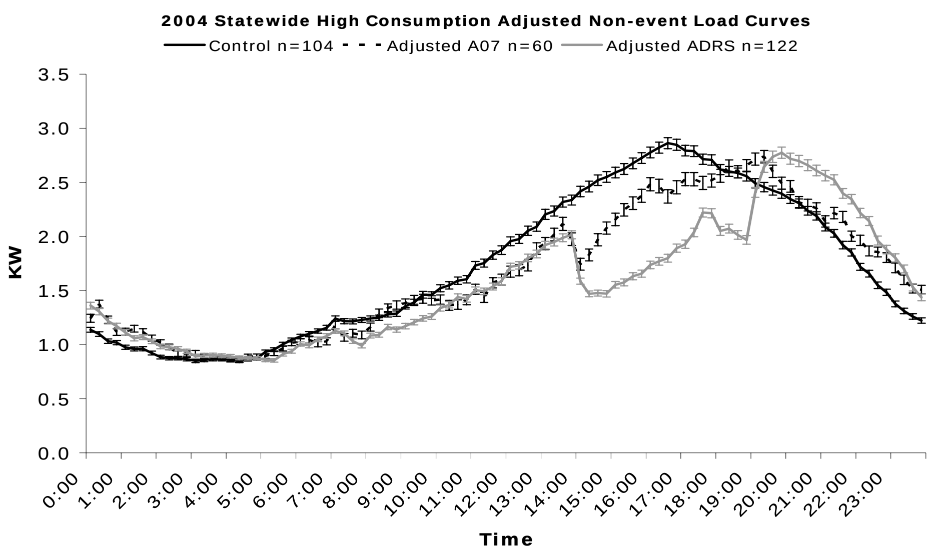
[15]Total reduction of Super Peak and peak period load by homes with pools is calculated algebraically rather than by direct measurement

[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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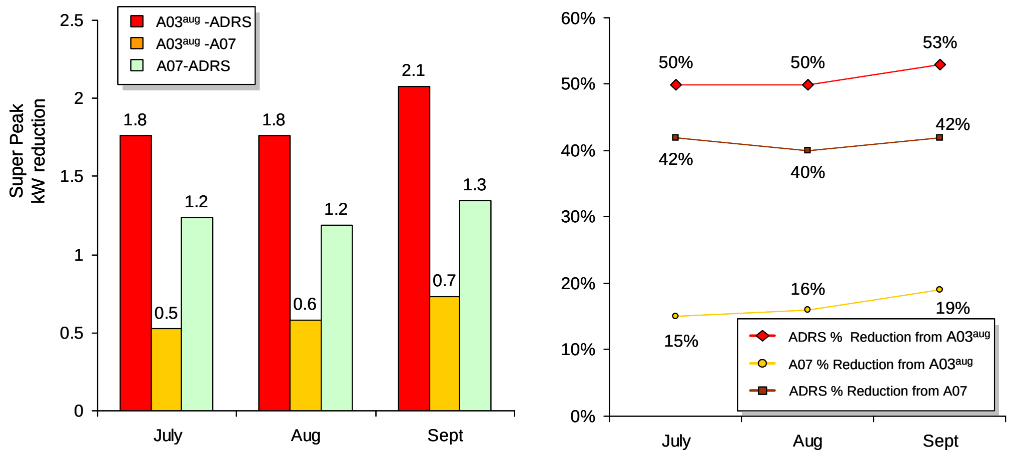
[17] Confidence intervals were calculated for each 15-minute interval as described in Appendix A, of the essential companion document to this report, *Automated Demand Response System Pilot, 2005 Summer Load Impact Results and Comparison of 2005 with 2004 Summer Load Impact Results*. Super Peak 90% confidence 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.

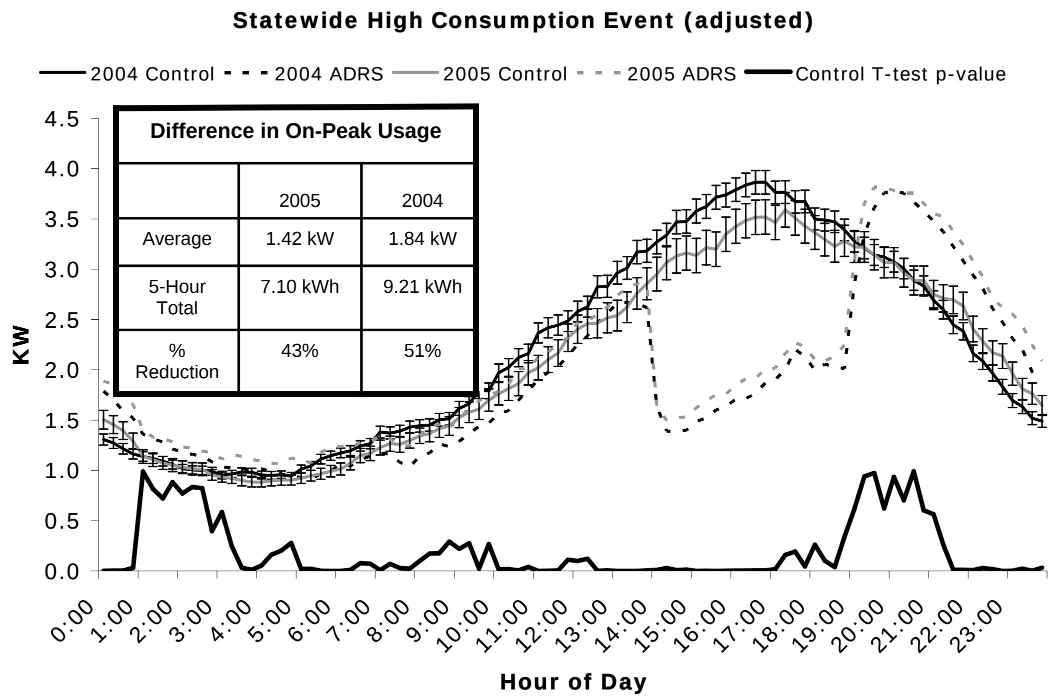
The residual differences in load impact results in Table 5 between CRA, the CEC, and RMI are due to the different control home samples and slight differences in the A07 homes evaluated in each study. The homes evaluated by CRA and CEC for the SPP program include both single and multifamily homes in climate 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



	2005	2004
Average	1.42 kW	1.84 kW
5-Hour Total	7.10 kWh	9.21 kWh
% Reduction	43%	51%

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.

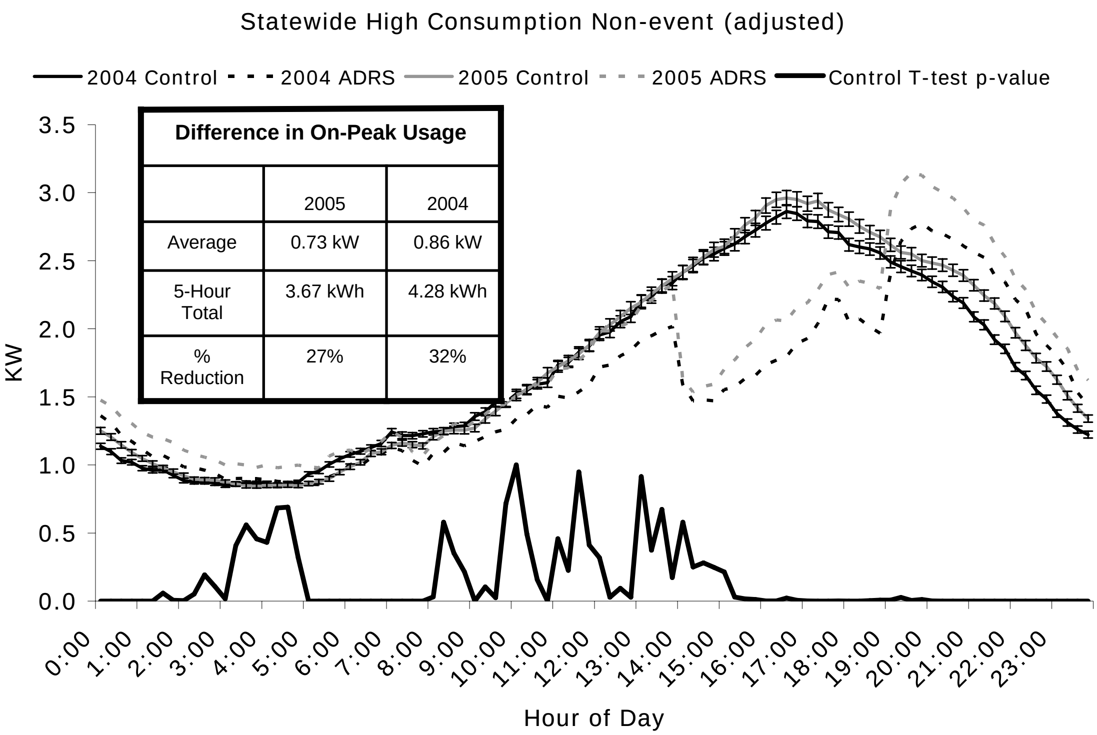
[20]Note that average peak temperatures were calculated based on data for specific zip codes where ADRS and control homes were located. Thus, the observation that 2005 was hotter than 2004 may not be true for all areas within each utility's service territory.

[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.

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[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.

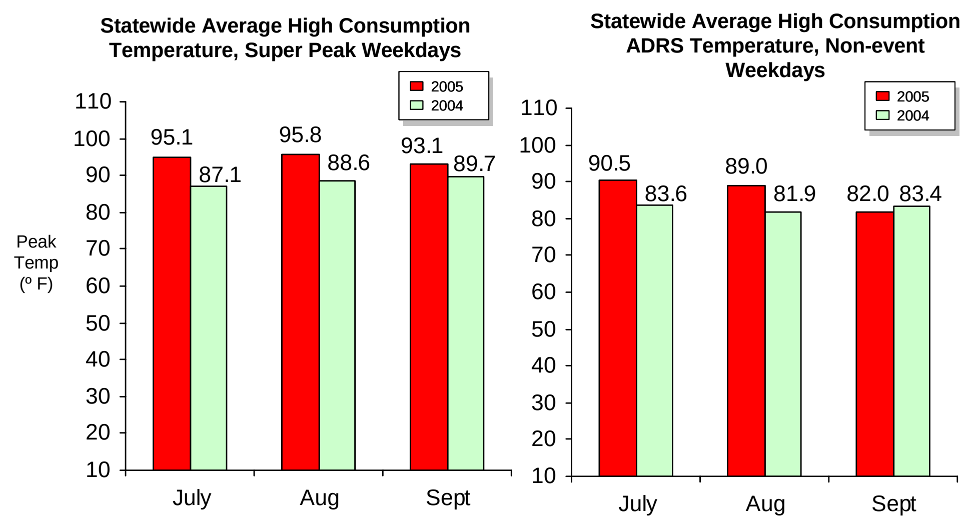
Results also varied by utility, with average load reductions equal to or higher in 2004 compared to 2005. For high consumption ADRS customers in PG&E territory, Super Peak period load reduction was 36% lower in 2005 than 2004. Super Peak period load reduction in 2005 was 0.8 kW, compared to 1.3 kW in 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^{o}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^{o}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

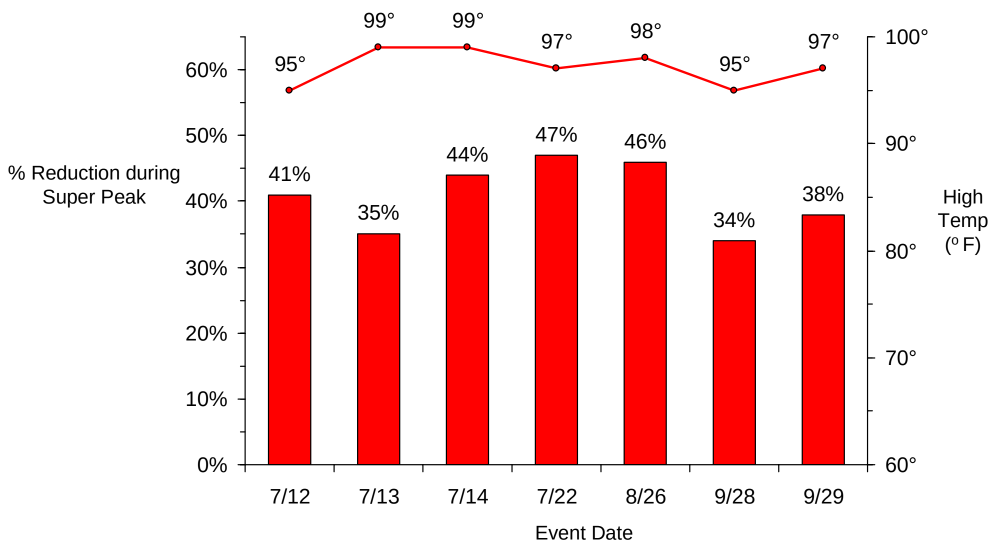
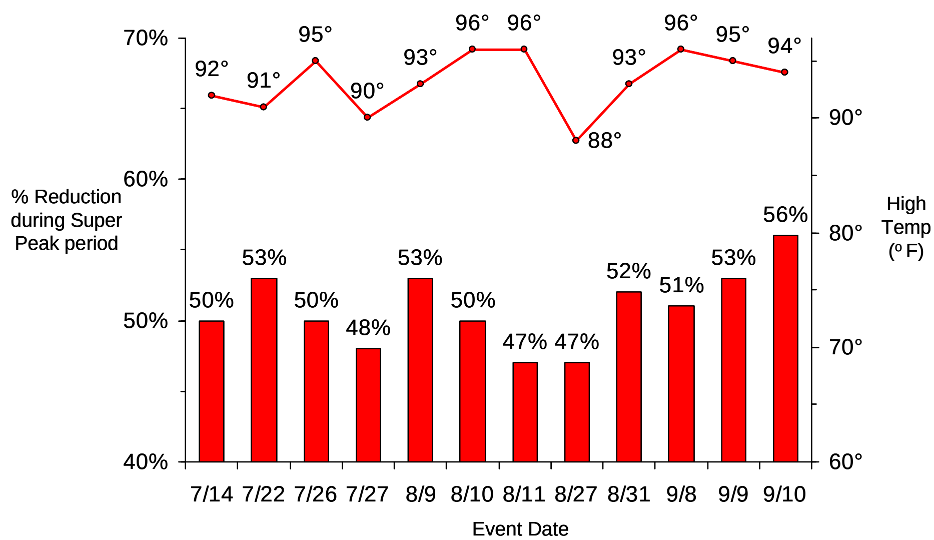


Figure 8: Percent load reductions by event day statewide, high consumption ADRS homes in 2004



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^{o}F on event and non-event days. For SDG&E, load reductions were stable and consistent for homes experiencing maximum temperatures above 86^{o}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:

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[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

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[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.