2011 Impact Evaluation Southern California Edison's Summer Discount Plan –

Localized Dispatch and Limited Test Events

Ex Post Report

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Abstract

This report describes the results of a load impact evaluation for the 2011 program year of portions of Southern California Edison's ("SCE") Summer Discount Plan ("SDP"), a direct load control air conditioner cycling program for residential, small commercial (less than 200 kW) and large commercial (greater than 200 kW) customers. In 2011, SCE conducted ten short localized dispatch test events for SDP, each ranging from about 30 minutes to an hour and involving participants associated with one of five A-Banks, or sub-transmission level step-down transformer stations. This evaluation covers only events and customers for which premise-level interval load data were available, not the entire SDP participant population.

Premise-level interval load data for this project for residential and *small* commercial customers were available for an initial group of SmartConnect-enabled customer accounts associated with two of the five A-Banks. Interval data for a subset of *large* commercial SDP customers who experienced SDP events were provided through premise-level interval meters previously available for customers of size greater than 200 kW. Use of these household and establishment-level interval load data marks a departure from previous evaluations at SCE, which have relied on small sub-samples of customers with dedicated metering of air conditioner loads, or on load impact information transferred from other utilities.

Resources Covered

SDP is an air conditioner (AC) cycling program with over 310,000 residential and 10,000 commercial customers enrolled. While the SDP was established over 25 years ago and is not enabled by SCE's SmartConnect infrastructure, it is expected to have a significant incremental impact on dually enrolled customers (i.e., customers enrolled in both SDP and another, SmartConnect-enabled program such as peak-time rebate). The SDP is currently an emergency triggered DR program and short system test events were conducted late in the 2011 summer. The residential portion of the program is anticipated to be converted to a price-based program beginning in 2012, and events will be implemented more frequently than has been the case historically for reliability purposes.

The SDP for residential and commercial customers offers two primary options for participation, and provides credits for customers with amounts that vary by option. The two options refer to the choice of cycling strategy and to limits on the number of hours or days that events may be called. Residential and commercial customers may choose a 100 percent or 50 percent cycling strategy (commercial customers may also select a 30 percent strategy).

This evaluation was conducted in large part using SmartConnect meter interval data for those SDP participants who have received SmartConnect meters, are being billed on the basis of the metered interval data, and are associated with A-Banks in which SDP test events were called. An additional set of data for large commercial SDP participants was also used. These two data sources are not designed as a representative sample of all SDP participants in the SCE service area, but form "convenience samples" of customers for whom interval meter data were available, and who experienced SDP events.

SmartConnect load data were available for approximately 24,000 residential SDP customers, accounting for about 110,000 tons of air conditioning, and for 86 small SDP commercial customers, accounting for about 2,000 tons of air conditioning. Interval data were also available for 93 large SDP commercial customers, accounting for about 17,000 tons of air conditioning. All of these customers were subject to SDP events for this study.

Methodology

The evaluation approach used in this project involved the estimation of aggregated, or average-customer demand equations for relevant groups of residential and commercial customers, primarily defined as associated with an A-bank for which events were called, and their selected *cycling strategy* (e.g., 100% cycling, or some degree of partial cycling). Program-level load impacts (for the portion of SDP customers for whom SmartConnect data were available) are constructed by aggregating across cycling strategy and location. The demand models involved the use of a **one-day differencing approach** in which the dependent variable (i.e., the variable to be explained) is the *difference* between the hourly (or 15-minute) load on a given day and the corresponding time period on the previous day. On events days, those hourly differences (after adjusting for the effects of other factors, such as day of week and weather conditions) represent the load impacts of the event.

Ex Post Load Impacts

For *residential* SDP, average estimated load impacts per customer for the one-hour September 8 event range from nearly 0.4 kW per service account for the 50 percent cycling group to just over 1 kW for the 100 percent cycling group which contained the vast majority of residential customers in this study. Load impacts per ton of air conditioning range from about 0.10 kW for partial cycling customers to 0.20 for 100 percent cycling.

Estimated load impacts for the *small commercial* customers associated with the Valley C A-Bank are statistically significant for three of the four event/cycling-strategies. Statistically significant estimated load impacts per customer range from 4.3 kW to 4.8 kW, representing percentage load reductions of 13 to 18 percent. Load impacts per ton of air conditioning are similar to but slightly larger than for the residential customers.

Estimated load impacts for the *large commercial* customers are statistically significant at the 90 percent level for one of the two A-Banks (Villa Park and Walnut) that include about two-thirds of all of the customers for which data were available, and are nearly significant for the other area. Statistically significant load impact estimates per customer range from about 100 kW to 180 kW, representing percentage load reductions of about 13 to 32 percent. Load impacts per ton are substantially larger (approximately two to four times larger) than for the residential and small commercial customers.

EXECUTIVE SUMMARY

This report describes the results of a load impact evaluation for the 2011 program year of portions of Southern California Edison's ("SCE") Summer Discount Plan ("SDP"), a direct load control air conditioner cycling program for residential, small commercial (less than 200 kW) and large commercial (greater than 200 kW) customers. In 2011, SCE conducted ten short localized dispatch test events for SDP, each ranging from about 30 minutes to an hour and involving participants associated with one of five A-Banks, or sub-transmission levelstep-down transformer stations. This evaluation covers only events and customers for which premise-level interval load data were available, not the entire SDP participant population.

ES.1 Background

Premise-level interval load data for this project for residential and *small* commercial customers were available for an initial group of SmartConnect-enabled customer accounts associated with two of the five A-Banks. Interval data for a subset of *large* commercial SDP customers who experienced SDP events were provided through premise-level interval meters previously available for customers of size greater than 200 kW. Use of these household and establishment-level interval load data marks a departure from previous evaluations at SCE, which have relied on small sub-samples of customers with dedicated metering of air conditioner loads, or on load impact information transferred from other utilities.

ES.2 Resources Covered

SDP program

SDP is an air conditioner (AC) cycling program with over 310,000 residential and 10,000 commercial customers enrolled. While the SDP was established over 25 years ago and is not enabled by SCE's SmartConnect infrastructure, it is expected to have a significant incremental impact on dually enrolled customers (i.e., customers enrolled in both SDP and another, SmartConnect-enabled program such as peak-time rebate). The SDP is currently an emergency triggered DR program and short system test events were conducted late in the 2011 summer. The residential portion of the program is anticipated to be converted to a price-based program beginning in 2012, and events will be implemented more frequently than has been the case historically for reliability purposes.[1]

The SDP for residential and commercial customers offers two primary options for participation, and provides credits for customers with amounts that vary by option. The two options refer to the choice of cycling strategy and to limits on the number of hours or days that events may be called. Residential and commercial customers may choose a 100 percent or 50 percent cycling strategy (commercial customers may also select a 30 percent strategy).

[1] Residential SDP participants will also have an override option, whose effect can be measured in the 2012 evaluation.

SDP participants

This evaluation was conducted in large part using SmartConnect meter interval data for those SDP participants who have received SmartConnect meters, are being billed on the basis of the metered interval data, and are associated with A-Banks in which SDP test events were called. An additional set of data for large commercial SDP participants was also used. These two data sources are not designed as a representative sample of all SDP participants in the SCE service area, but form "convenience samples" of customers for whom interval meter data were available, and who experienced SDP events.

SmartConnect load data were available for approximately 24,000 residential SDP customers, accounting for about 110,000 tons of air conditioning, and for 86 small SDP commercial customers, accounting for about 2,000 tons of air conditioning. Interval data were also available for 93 large SDP commercial customers, accounting for about 17,000 tons of air conditioning. All of these customers were subject to SDP events for this study.

SDP events

Ten brief test events (most lasted about 30 minutes, while two lasted nearly a full hour) were called from late July to late September, two each in five A-Bank distribution areas. Most events were called on days on which afternoon temperatures averaged in excess of 90 degrees.

ES.3 Methodology

Previous evaluations of air conditioner (AC) cycling programs for residential and commercial customers, including SDP, have used methods that differ from the regression analysis approach that has generally been used for demand response programs in California targeted at large commercial and industrial customers. A primary reason for these different methods has been a typical lack of availability of whole premise interval load data for smaller customers.

The approach used in this project involved premise-level load data and the estimation of aggregated, or average-customer demand models for relevant groups of residential and commercial customers, primarily defined by their association with an A-Bank for which test events were called, their selected *cycling strategy* (e.g., 100% cycling, or some degree of partial cycling). Program-level load impacts (for the portion of residential and small commercial SDP customers for whom SmartConnect data were available) were constructed by aggregating across cycling strategy and A-Banks. Similar methods were used for the large commercial customers in SDP.

Testing of a variety of alternative premise-level load models, primarily focusing on an appropriate set of weather variables, led to the use of a one-day differencing approach in which the dependent variable is the *difference* between the hourly (or 15-minute) load on a given day and the corresponding time period on the previous day. We use the same type of explanatory variables as in a typical ex post load impact regression equation to explain variations in the load differences, including hourly indicator variables interacted with each event day, day of week, weather variables, and load shape variables. Under this design, the estimated event-period coefficients represent direct estimates of hourly program load impacts. That is, they represent the effect of the SDP event, after accounting for all other known factors that differ between the event day and the previous non-event day.

ES.4 Ex Post Load Impacts

SDP load impacts for different customer types may be illustrated using observed load data for event days and other similar non-event days. For example, Figure ES-1 shows selected hourly load profiles for the average of the approximately 22,000 residential SDP participants associated with Valley C who selected the 100% cycling strategy. The figure compares average customer loads for six weather-based day-types, and for the two Valley C event days: July 26 and September 8.

The load profiles display expected weather sensitivity; the peak load on the hottest day-type (an average temperature of more than 100 degrees during the period from hours ending 13 (1 p.m.) to 18 (6 p.m.)) reaches nearly four times the level on the coolest day-type (less than 80 degrees). The load reduction in hour-ending (HE) 16 for the hour-long September 8 event (see circled point in the figure) is quite distinct, suggesting a load impact of approximately 1 kWh/hr (kW). The load impact of the July 26 event in HE 15 is less distinct (in fact, the regression analysis of these data found no statistically significant load reduction). This result is likely due to the twin factors of more moderate temperatures and an event of less than 30-minutes duration reflected in hourly data.

Figure ES-1: Residential Customer Loads by Temperature Day-Type – *Weekdays for Valley C Customers Selecting 100% Cycling Strategy*

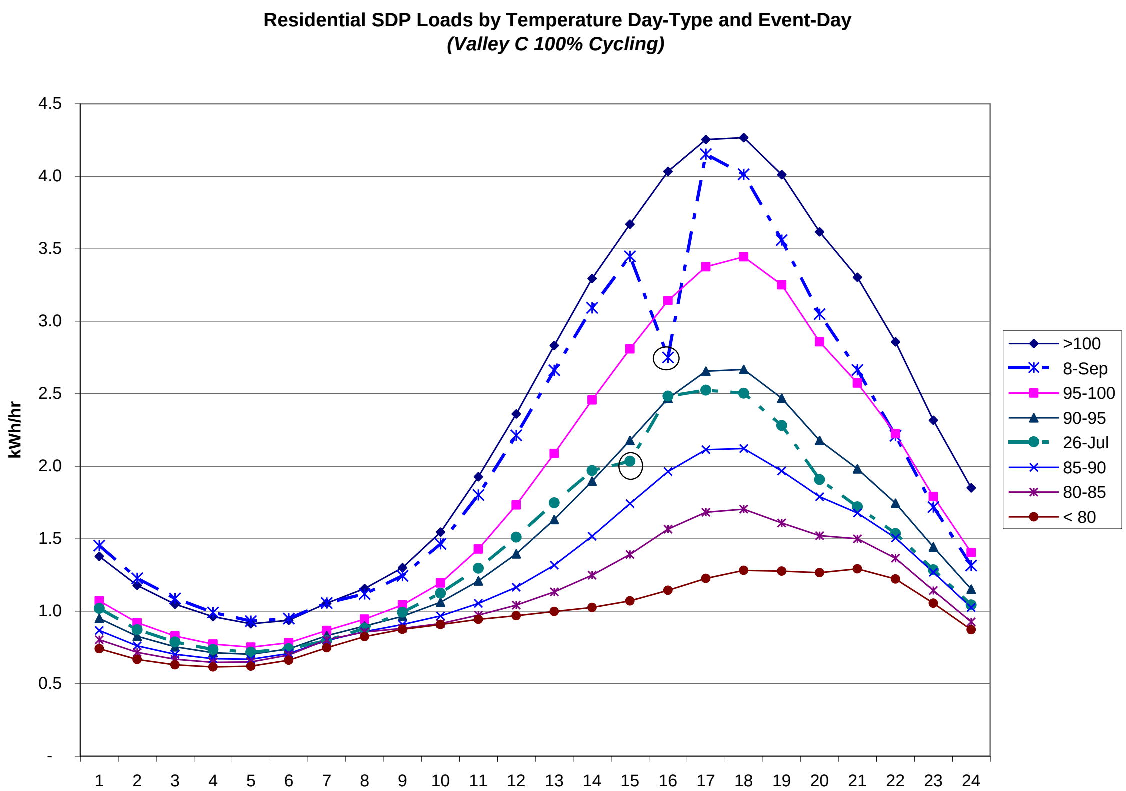


Figure ES-2 shows average weekday loads by temperature range and event day for the 64 SDP small commercial customers associated with Valley C who selected the 100% cycling strategy. Like the residential SDP customers, the small commercial customer loads show substantial weather sensitivity. Also similarly, the load reduction in HE 16 for the one-hour September 8 event is quite distinct, suggesting a load reduction of about 3 to 4 kW. A smaller load reduction for the 30-minute event on July 26 may also be seen.

Figure ES-2: Small Commercial Loads by Temperature Day-Type and Event Day – *Weekdays for Customers Selecting 100% Cycling Strategy*

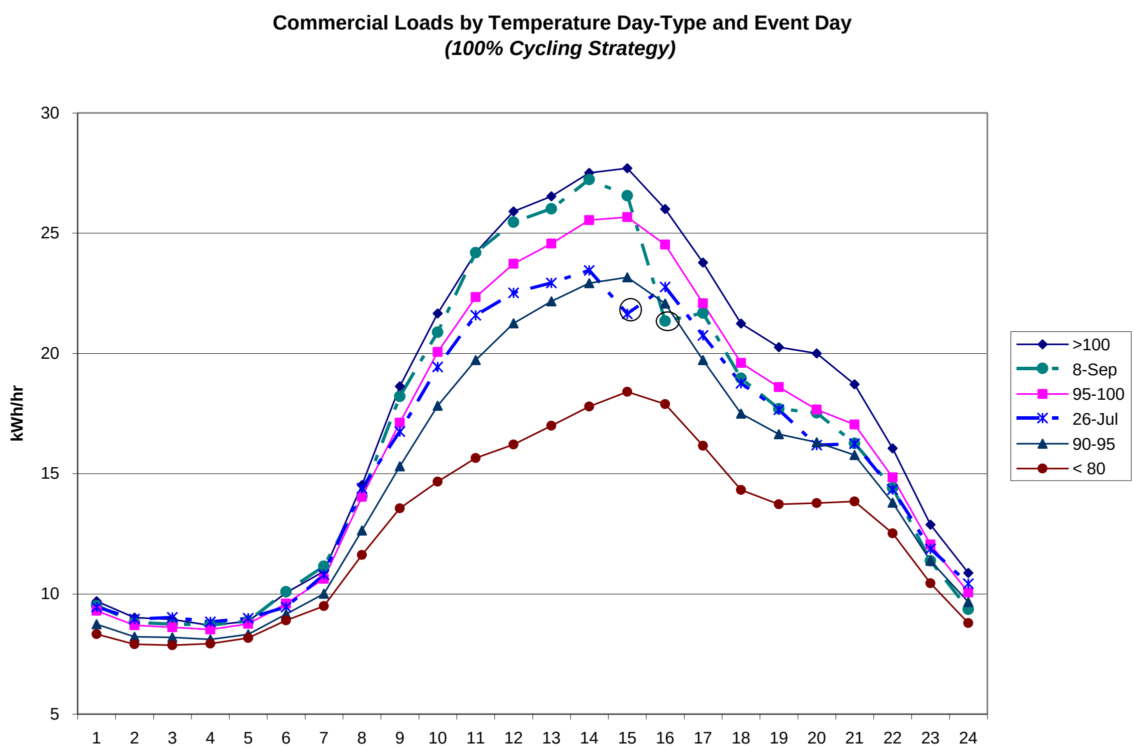
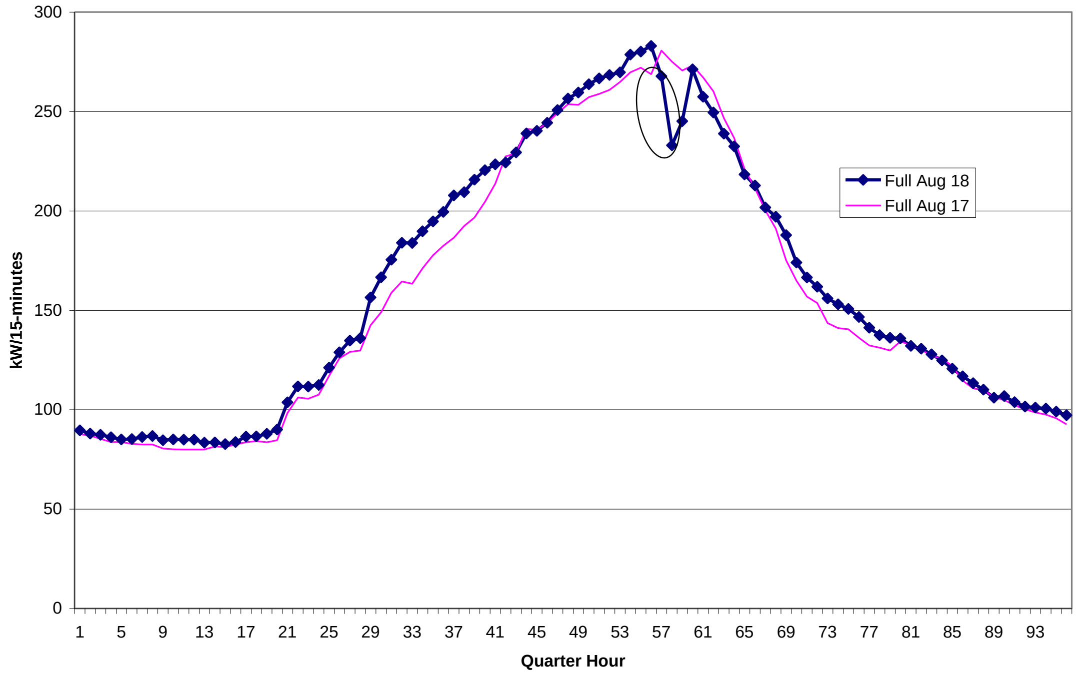


Figure ES-3 illustrates 15-minute large-commercial loads for the Walnut A-Bank for the August 18 event and the previous day, for the customers choosing the 100 percent cycling option. The impact of cycling is clearly observable.

Figure ES-3: Large Commercial 15-Minute Load Profiles (kWh/15-min) –
Walnut*; *100% Cycling; August 18 Event



Residential SDP load impacts

Estimated load impacts based on the regression analysis are generally consistent with the load reductions illustrated in the figures above. For residential SDP, average estimated load impacts per customer for the one-hour September 8 event range from nearly 0.4 kW for the 50 percent cycling group to just over 1 kW for the 100 percent cycling group which contained the vast majority of residential customers in this study. For the two half-hour events in the Mira Loma A-Bank, estimated load impacts were smaller, ranging from about 0.1 kW to 0.5 kW. Those values were adjusted to account for the measurement of a part-hour event using load data at hourly resolution. The adjustment were based on factors implied by comparing load impacts in the small commercial analysis described below, which were estimated on the basis of both hourly and 15-minute data.[2] Those adjustments result in per-customer load impacts for the half-hour events that range from 0.3 kW to 1.3 kW.

Percent load impacts and load impacts per ton of air conditioning for the most "well-behaved" estimates are summarized in the following table:

[2] The adjustment is based on the idea that the true magnitude of the load impact for a partial-hour event is greater than the value that is estimated using data at an hourly resolution. The availability of 15-minute data for the small commercial customers allows estimation of an appropriate adjustment factor for such events, using both hourly and 15-minute data.

Table ES-1: Percent Load Impact and Load Impact per AC Ton --
Residential

Strategy	Percent Load Impact	Load Impact per AC ton (kW)
100	25 - 27%	0.21
67	19%	0.17
50	10 - 15%	0.08

The pattern of values is as expected, with percent load impacts and load impact per AC ton higher for the 100 percent cycling strategy than for the two partial strategies. The *program-level* load impact for residential SDP for the hour-long September 8 event for the Valley C A-Bank with which most of the customers with available SmartConnect data were associated is approximately 66 MW.

Small commercial SDP load impacts

Estimated load impacts for the small commercial customers associated with Valley C are statistically significant for three of the four event/cycling-strategies. Statistically significant estimated load impacts per customer range from 4.3 kW to 4.8 kW, representing percentage load reductions of 13 to 18 percent, as shown in Table ES-2. Estimated load impacts per ton of air conditioning are similar in magnitude to those for the residential customers for the two cycling strategy categories.

Table ES-2: Percent Load Impact and Load Impact per AC Ton –
Small Commercial

Strategy	Percent Load Impact	Load Impact per AC ton (kW)
100	18%	0.22 - 0.25
Partial	13%	0.08 - 0.14

Large commercial SDP load impacts

Estimated load impacts for the large commercial customers are statistically significant at the 90 percent level for one of the two A-Banks (Villa Park and Walnut) that are associated with about two-thirds of all of the customers tested, and are nearly significant for the other. Statistically significant load impact estimates per customer range from about 100 kW to 180 kW, representing percentage load reductions of about 13 to 32 percent. Percentage load impacts and load impacts per AC ton are shown in Table ES-3. The load impacts per ton are substantially larger (approximately two to four times larger) than for the residential and small commercial customers.

Program level load impacts range from 2 MW to 5 MW for events for the two A-Banks with the largest number of participants. In these cases, load impacts appear to vary by temperature level; they are higher for two August events with afternoon average temperatures of about 87 degrees, than for two September events, which both occurred on more moderate days.

Table ES-3: Percent Load Impact and Load Impact per AC Ton –
Large Commercial

Strategy	Percent Load Impact	Load Impact per AC ton (kW)
100	13 - 22%	0.44 - 0.73
Partial	15 - 32%	0.3 - 0.6

ES.5 Conclusions

This study is limited by the design of the test events, by the fact that it covers only a portion of SDP participants due to limited interval meter data availability, and that many of the test events were a half-hour or less in duration. With the availability of only hourly interval data for the residential participants, estimated load impacts for part-hour events are under-stated. In those cases, we adjusted residential load impact estimates using factors based on the results for small commercial customers, using both 15-minute and hourly data. Both of these limitations should be resolved in future evaluations. Much more SmartConnect data will become available, and recommendations are to call more SDP events, presumably of longer duration, either through more test events or as a consequence of the transition of residential SDP to a price-based program.

1. Introduction and Purpose of the Study

This report describes the results of a load impact evaluation for the 2011 program year of portions of Southern California Edison's ("SCE") Summer Discount Plan ("SDP"), a direct load control air conditioner cycling program for residential, small commercial (less than 200 kW) and large commercial (greater than 200 kW) customers. In 2011, SCE conducted ten short localized dispatch test events for SDP, each ranging from about 30 minutes to an hour and involving participants associated with one of five A-Banks, or step-down transformers. This evaluation covers only events and customers for which premise-level interval load data were available.

Premise-level interval load data for this project for residential and *small* commercial customers were available for an initial group of SmartConnect-enabled customer accounts associated with two of the five A-Banks. Interval data for a subset of *large* commercial SDP customers who experienced SDP events were provided through premise-level interval meters previously available for customers of size greater than 200 kW. Use of these household and establishment-level load data marks a departure from previous evaluations, which have relied on small sub-samples of customers with dedicated metering of air conditioner loads, or on borrowed information from other utilities.

While SDP has been in place for a number of years and is not a specific element of the SmartConnect process, this evaluation is being conducted through a broad SmartConnect evaluation project. As a result, part of the evaluation directly covers only the portion of residential and small commercial SDP customer accounts that had begun billing through SmartConnect meter data prior to the summer of 2011 and were associated with A-Banks for which events were called. The impact evaluation analysis includes estimation of ex post load impacts for residential, small commercial and large commercial customers by SDP event (data permitting), and for alternative cycling strategies chosen by consumers.

The report is organized as follows. Section 2 describes the SDP program, the enrolled customers, and the events called; Section 3 describes the analysis methods used in the study; and Section 4 contains the ex post load impact results.

2. Description of Resources Covered in the Study

2.1 Program Description

SDP is an air conditioner (AC) cycling program with over 310,000 residential and 10,000 commercial customers enrolled. While the SDP was established over 25 years ago and is not enabled by SCE's SmartConnect infrastructure, it is expected to have a significant incremental impact on dually enrolled customers (i.e., customers enrolled in both SDP and another, SmartConnect-enabled program such as peak-time rebate). The SDP is currently an emergency triggered DR program and short system test events were conducted late in the 2011 summer. The residential portion of the program is anticipated to be converted to a price-based program beginning in 2012, and events will be implemented more frequently than has been the case historically for reliability purposes.[3]

The SDP for residential and commercial customers offers two primary options for participation, and provides credits for customers with amounts that vary by option. The two options refer to the choice of cycling strategy and to limits on the number of hours or days that events may be called. Residential and commercial customers may choose a 100 percent or 50 percent cycling strategy (commercial customers may also select a 30 percent strategy).

The options include the following features:

- Residential customers may choose from two cycling strategies: 50% (the AC unit is restricted from running for 15 minutes out of each 30 minutes in an event), and 100% (AC unit is turned off continuously for the entire event).[4]
- Commercial customers may choose from three cycling strategies: 30% (the AC unit is restricted from running for 9 minutes out of each 30 minutes in an event), 50% (the AC unit is off for 15 minutes out of each 30 minutes in an event), and 100% (AC unit is turned off continuously for the entire event).
- Both types of customers may also choose from two options on limits to the frequency of interruption events:
    - The Base plan, which allows SCE to control AC units for a maximum of 15 times during the summer season, for up to six hours per event.
    - The Enhanced plan, which allows an unlimited number of events during the summer season.

2.2 Participant Characteristics

As noted in the introduction, this evaluation was conducted in large part using SmartConnect data for those residential and small commercial SDP participants who have received SmartConnect meters, are being billed on the basis of the metered interval data, and are associated with A-Banks for which SDP events were called. An additional set of data for large commercial SDP participants was also used. These two data sources are not designed as a representative sample of all SDP participants in the SCE service area, but form "convenience samples" of customers for which interval meter data were available, and who experienced SDP events.

Table 2-1 summarizes the characteristics of the residential SDP participants included in the analysis. The first two columns indicate A-Bank and cycling strategy selected. The next three columns show the number of participants (service accounts), their total number of AC units, or devices, and the total AC tons of those devices. The final three columns indicate the average AC tons per account, AC tons per device, and Devices per SAID. The sizes of the AC units, shown in the second to last column, are quite consistent across A-Banks and cycling strategies, averaging about 3.7 tons. The number of devices per

[3] Residential SDP participants will also have an override option, whose effect can be measured in the 2012 evaluation.

[4] Some participants remain on a 67% cycling strategy that is no longer available for new participants.

customer varies somewhat, and is largest for 100 percent cycling in Valley C, the largest category.

Table 2-1: Characteristics of SDP Residential Participants

A-Bank	Cycling Strategy (%)	Service Accounts	Devices	AC Tons	AC Tons / SAID	AC Tons / Device	Devices / SAID
MIRA LOMA	50	10	10	35	3.5	3.5	1.00
	67	45	48	167	3.7	3.5	1.07
	100	609	651	2,393	3.9	3.7	1.07
Total / Ave.		664	709	2,595	3.9	3.7	1.07
VALLEY C	50	412	473	1,725	4.2	3.6	1.15
	67	1,437	1,660	5,743	4.0	3.5	1.16
	100	21,914	27,600	101,645	4.6	3.7	1.26
Total / Ave.		23,763	29,733	109,114	4.6	3.7	1.25
Grand Total		24,427	30,442	111,708	4.6	3.7	1.25

Table 2-2 provides similar information for the SDP small commercial customers. All of the small commercial accounts were located in the Valley C A-Bank. Due to the small number of participants choosing the 30 percent cycling strategy, they were combined with the 50 percent group and labeled "Partial". The sizes of devices are somewhat larger than for the residential accounts, as are the number of devices per account.

Table 2-2: Characteristics of SDP Small Commercial Participants

A-Bank	Strategy	Service Accounts	Devices	AC Tonnage	AC Tons / SAID	AC Tons / Device	Devices / SAID
VALLEY C	Partial	27	151	835	30.9	5.5	5.6
	100	59	262	1,144	19.4	4.4	4.4
Total		86	413	1,979.6	23.0	4.8	4.8

Table 2-3 displays the characteristics of the large commercial SDP participants who are associated with the A-Banks for which SDP test events were called in 2011. The majority of participating service accounts, AC devices and AC tonnage are accounted for by customers choosing the 100 percent (Full) cycling strategy, and are associated with the Villa Park and Walnut A-Banks.[5] Almost all of the accounts choosing less than 100 cycling chose the 50 percent (Partial) option. While industry type is not shown, the bulk of the large commercial service accounts represented elementary and secondary public schools.

The amount of AC devices and tonnage per account is considerably larger for the large commercial than for the small commercial customers, as expected. The average size of the AC devices is also somewhat larger, particularly for those customers choosing 100 percent cycling.

[5] Customers are allowed to select a cycling strategy for each AC device on the premise. Most customers chose the same strategy for all devices. Those who chose mixed strategies were assigned to the strategy selected for the majority of their devices.

Table 2-3: Characteristics of SDP Large Commercial Participants

	Service Accounts		AC Devices		AC Tonnage		AC Tons / SAID		AC Tons / Device		Devices / SAID	
Strategy	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial	Full	Partial
A-Bank												
Chino	6	5	189	299	1,319	1,489	220	298	7.0	5.0	31.5	59.8
Mira Loma	7	0	47	0	631	0	90		13.4		6.7	
Valley C	5	1	90	30	764	140	153	140	8.5	4.7	18.0	30.0
Villa Park	32	5	861	111	4,675	506	146	101	5.4	4.6	26.9	22.2
Walnut	31	1	1,054	46	7,820	233	252	233	7.4	5.1	34.0	46.0
Total	**81**	**12**	**2,241**	**486**	**15,207**	**2,368**	**188**	**197**	6.8	4.9	27.7	40.5

2.3 Events

The dates, times and A-Banks for the SDP test events in 2011 are shown in Table 2-4. Nearly all of the SmartConnect load data available for this project were for residential and small commercial customers in the two highlighted A-Banks: Mira Loma and Valley C.[6] As a result, only the four indicated events are included in that portion of the evaluation. Three of those events were approximately 30-minutes in length, while the September 8 event lasted nearly an hour.[7] The large commercial customers spanned all five A-Banks, but were concentrated in Villa Park and Walnut, as noted above.

Table 2-4: Summer Discount Plan Events in 2011

Num	A-Bank	Date	Scheduled Dispatch Time	Scheduled Restore Time	Actual Dispatch Time	Actual Restore Time	Length of Test	QE
1	VALLEY C	7/26/2011	14:00	14:25	14:03	14:30	0:27	58-59*
2	MIRA LOMA	8/3/2011	14:00	14:25	14:00	14:28	0:28	57-58
3	CHINO	8/8/2011	13:00	13:25	13:09	13:32	0:23	53-54
4	WALNUT	8/18/2011	14:00	14:25	14:03	14:26	0:23	57-58
5	VILLA PARK	8/26/2011	15:00	15:25	15:00	15:25	0:25	61-62
6	MIRA LOMA	8/30/2011	15:00	15:25	14:59	15:27	0:28	61-62
7	CHINO	9/6/2011	15:30	15:55	15:31	15:57	0:26	63-64
8	VALLEY C	9/8/2011	15:00	15:25	15:00	15:53	0:53	61-64
9	WALNUT	9/20/2011	15:00	15:25	15:00	15:26	0:26	61-62
10	VILLA PARK	9/29/2011	15:00	15:25	15:00	16:00	1:00	61-64

* Dispatch delay resulted in most customers curtailed near 14:15, and restored about 14:40.

To place the events in context with regard to weather conditions, Figure 2-1 shows daily values of average late-afternoon (hours ending 13 – 18) temperatures for the weather station (121) in which nearly all of the SmartConnect SDP participants were located. The four event days included in that portion of the analysis are circled, showing that three of the four were called on days with average afternoon temperatures above 90 degrees, and two of those had afternoon temperatures above 95 degrees. The remaining events, which

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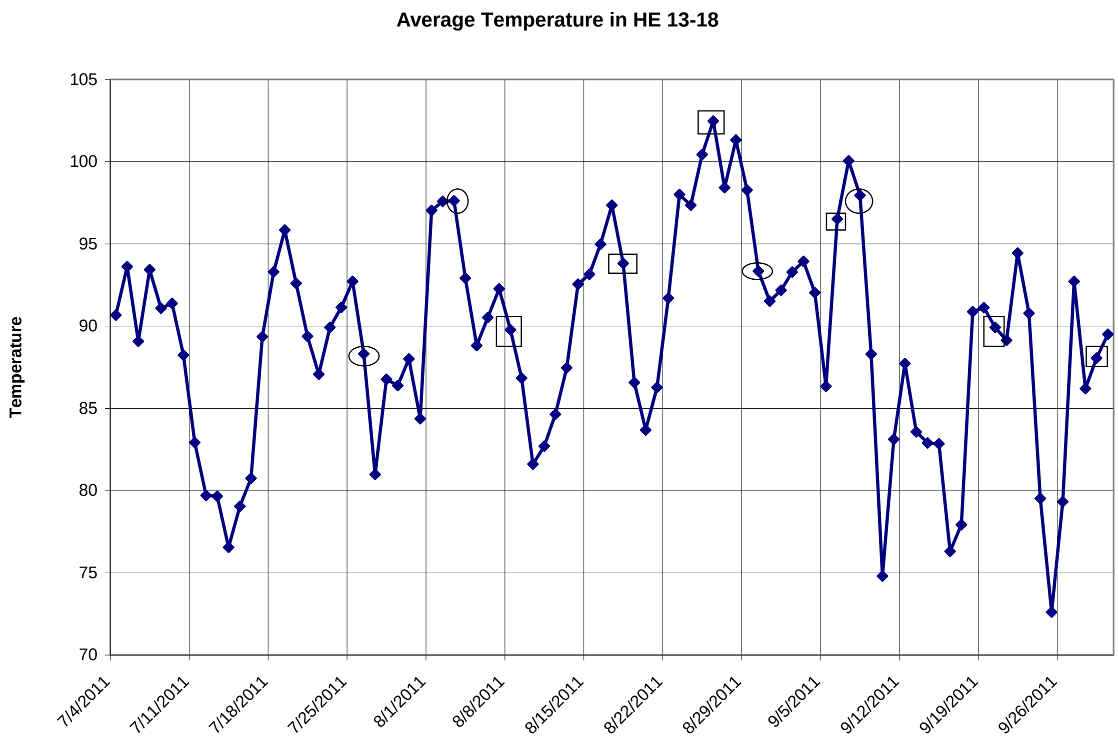
[6] The small commercial participants were all located in Valley C.

[7] SCE reported some technical issues that delayed the start of the July 26 event for most participants by ten to fifteen minutes. This delay may be seen in the figures below based on 15-minute data for small commercial customers.

applied to the large commercial customers in the study, are indicated by squares. The availability of a number of days of comparably hot weather conditions to the SDP event days provides some confidence in the ability of regression analysis to separately distinguish the positive effects of temperatures and the negative effects of SDP curtailments on customers' loads.

Figure 2-1: Daily Average Afternoon Temperatures – July 4 – September 30, 2011



3. Study Methodology

3.1 Overview

The overall goals of the *ex post* load impact evaluation were summarized in Section 1. A traditional demand response (DR) load impact evaluation involves the following activities:

1. Estimate program-wide (aggregate) and per-called customer hourly load impacts and average daily load impacts for each SDP event day in 2011;
2. Estimate the uncertainty-adjusted range of load impacts, on an aggregate and per-called customer basis;
3. Estimate the *distribution* of hourly and average daily impacts provided by different customer segments for the *average event* (e.g., "X" percent of the load impact was provided by "Y" percent of the enrolled customers).

The data to be used in the load impact analysis consist of hourly (or, in the case of commercial customers, 15-minute) integrated load data for the program participants, hourly observations on appropriate weather variables for relevant weather stations, information on customer characteristics, and information on the timing of events.

3.2 Description of methods

3.2.1 Background

Certain analysis methods for recent load impact evaluations of non-residential dynamic pricing and demand response programs in California have generally involved conducting customer-level regression analysis using available hourly load data for participants, and have developed program-level load impacts by adding up the estimated load impacts of each participating customer account.

In contrast, previous evaluations of air conditioner cycling programs that include residential and commercial customers, including SDP, have used very different methods. Two primary reasons for these different methods have been a typical lack of availability of interval load data for participating customers, and the fact that the programs target and control a specific technology, i.e., air conditioners. As a result, previous evaluations have been focused on end-use impacts, and have often involved installation of data logging equipment on the AC units of a small sample[8] of participants, and analysis of recorded data during event periods. We expect that the growing availability of interval load data from smart metering equipment, such as that from SCE's SmartConnect, will lead to its widespread use in future evaluations of AC cycling programs.

In the case of SDP in 2011, load data are available for only a subset of participants, as described in Section 2. Thus, the load impact evaluation covers only that subset of participants directly.

Several features of SDP suggest certain modifications to the customer-level approach described above. These features include the following:

- The large number of residential participants (i.e., more than 20,000) creates practical issues regarding estimation and processing of such a large number of regressions.
- Residential consumer loads are more responsive to weather conditions than are commercial customers, suggesting a need to conduct careful model testing to assess the degree to which weather effects are accurately accounted for. This testing is more practically conducted on aggregated data.
- Residential loads typically display more variability than commercial loads, which implies difficulty in accurately estimating load impacts for the brief-duration SDP test events in 2011 (i.e., three events of approximately 30 minutes, and one of nearly an hour) using hourly load data.

[8] The size of data logging samples is generally limited by relatively high costs of equipment installation, monitoring, and removal.

As a result of these conditions, our basic evaluation approach has involved the estimation of aggregated, or average-customer demand models for relevant groups of residential and commercial customers, primarily defined by the A-bank with which they are associated and their selected *cycling strategy* (e.g., 100% cycling, or some degree of partial cycling). Program-level load impacts (for the portion of SDP customers for whom SmartConnect data were available) are constructed by aggregating across cycling strategy. Similar methods were used for the large commercial customers.

3.2.2 Regression models used in ex post evaluation

We tested a variety of regression models using average-customer loads, focusing in particular on an appropriate set of weather variables to explain changes in weather-sensitive loads. Many of the models produced estimated load impacts of an appropriate *shape* (e.g., a downward spike in load during event periods), but with a *level* that implied higher loads than on non-event days. The presumed cause was an overstated implied reference load, such that the event-period coefficient (which is designed to represent the load impact of an event) was smaller than the coefficients for surrounding hours, but still positive.

We then turned to a one-day differencing approach in which the dependent variable is the *difference* between the hourly (or 15-minute) load on a given day and the corresponding time period on the previous day. We use the same type of explanatory variables as in a typical ex post load impact regression, including hourly indicator variables interacted with each event day, weather variables, and load shape variables. Under this design, the estimated event-period coefficients again represent direct estimates of program load impacts. That is, they represent the effect of the SDP event, after accounting for all other known factors that differ between the event day and the previous day.

The general form of the *ex post* load impact difference model is the following:

$$DQ_t = a + \sum_{Evt=1}^{E} \sum_{i=1}^{24} (b_{i,Evt} \times h_i \times dSDP_{t,Evt}) + \sum_{i=1}^{24} (b_i^{CDH} \times h_i \times dCDH_{t,i}) + \sum_{i=1}^{24} (b_i^{CDD} \times h_i \times dCDD_t)$$
$$+ \sum_{i=1}^{24} (b_i^{LagCDH} \times h_i \times dLagCDH_{t,i}) + \sum_{i=1}^{24} (b_i^{LagCDD} \times h_i \times dLagCDD_t) + \sum_{DT=1}^{5} \sum_{i=1}^{24} (b_{i,DT}^{DTYPE} \times h_i \times dDTYPE_{t,DT}) + e_t$$

In this equation, DQ_t represents the difference between the average hourly (or 15-minute) usage in time period t on a given day and the same time period's load on the previous day; the b's are estimated parameters; h_i is an indicator variable for hour (or 15-minute period) i; $dSDP_{t,Evt}$ is an indicator variable for SDP event days (equaling 1 on an event day and -1 on the day following an event day); $dCDH_{t,i}$ is the difference between cooling degree hours in hour i on the current and previous day[9]; $dCDD_t$ is the difference between cooling degree days on the current and previous day; $dLagCDH_{t,i}$ is the difference between cooling degree hours in hour i on the previous day and two days prior; $dLagCDD_t$ is the difference between cooling degree days on the previous day and two

[9] After testing a number of specifications, cooling degree *hours* were defined relative to a reference temperature of 75 degrees, while cooling degree days were defined relative to 65 degrees.

days prior; $DTYPE_{t,DT}$ is an indicator variable for day of the week (there are five of these terms, one for each weekday), where the interaction with the hourly indicators allows estimation of load shape differences for each day type; and e_t is the error term.

The first term with the double summation signs is the component of the equation that allows estimation of *hourly (or 15-minute) load impacts* (the $b_{i,Evt}$ coefficients) for each event day. It does so via the hourly indicator variables h_i interacted with the event variables (indicated by $dSDP_{t,Evt}$), where the coefficients reflect hourly differences between the loads on event days and on previous days. The remaining terms in the equation are designed to control for weather and other periodic factors (i.e., hourly shapes on different day types) that affect the differences in customers' loads. The multiple weather variables were designed to account for three primary effects: the immediate effect of current hourly temperatures on current load (through cooling degree hours); the overall effect of differences in daily temperatures (through cooling degree days); and weather build-up effects (through lagged CDH and CDD variables).

3.2.3 Development of Uncertainty-Adjusted Load Impacts

The Load Impact Protocols require the estimation of uncertainty-adjusted load impacts. In the case of *ex post* load impacts, the parameters that constitute the load impact estimates are not estimated with certainty. Therefore, we base the uncertainty-adjusted load impacts on the variances associated with the estimated load impacts.

Specifically, we add the variances of the estimated cell-level load impacts climate zones (using appropriate sample weights). The uncertainty-adjusted scenarios were simulated under the assumption that each hour's load impact is normally distributed with the mean equal to the weighted sum of the estimated load impacts and the standard deviation equal to the square root of the weighted sum of the variances of the errors around the estimates of the load impacts. Results for the 10^{th}, 30^{th}, 70^{th}, and 90^{th} percentile scenarios are generated from these distributions.

4. Detailed Study Findings

This section begins by illustrating observed SDP average-participant loads for a number of event and non-event days, with the objective of providing an indication of the nature and magnitude of load impacts that might be expected from regression analysis of the data. Estimated load impacts from the regression analysis are then presented. Tables of hourly load impacts are then presented in the format required by the Load Impact Protocols adopted by the California Public Utilities Commission (CPUC) in Decision (D.) 08-04-050 ("the Protocols"), including uncertainty-adjusted load impacts at different probability levels, and figures that illustrate the SDP event-day loads and load impacts.

4.1 Observed Participant Loads – Selected Day-types and Events

This sub-section lays the groundwork for estimating the SDP load impacts by illustrating observed load profiles for selected A-Banks, on event and non-event days. We begin by focusing on residential SDP customers, and then show results for small and large commercial SDP customers.

4.1.1 Residential customer load profiles

Figure 4-1 shows selected average hourly load profiles for the approximately 22,000 residential SDP participants associated with the Valley C A-Bank who selected the 100% cycling strategy. The figure compares average customer loads for six weather-based day-types, and for the two event days that were called in that area: July 26 and September 8. The load profiles display expected weather sensitivity; the peak load on the hottest day-type (an average temperature of more than 100 degrees during the period from hours ending 13 (1 p.m.) to 18 (6 p.m.)) reaches nearly four times the level on the coolest day-type (less than 80 degrees). The load reduction in hour-ending (HE) 16 for the hour-long September 8 event (see circled point in the figure), which was on a hot day following an even hotter day, is quite distinct, suggesting a load impact of approximately 1 kWh/hr (1 kW). The load impact of the July 26 event in HE 15 is less distinct. This result is due to the twin factors of more moderate temperatures and an event of less than 30-minutes duration reflected in hourly data.

Figure 4-1: Residential Customer Loads by Temperature Day-Type – *Weekdays for Valley C Customers Selecting 100% Cycling Strategy*

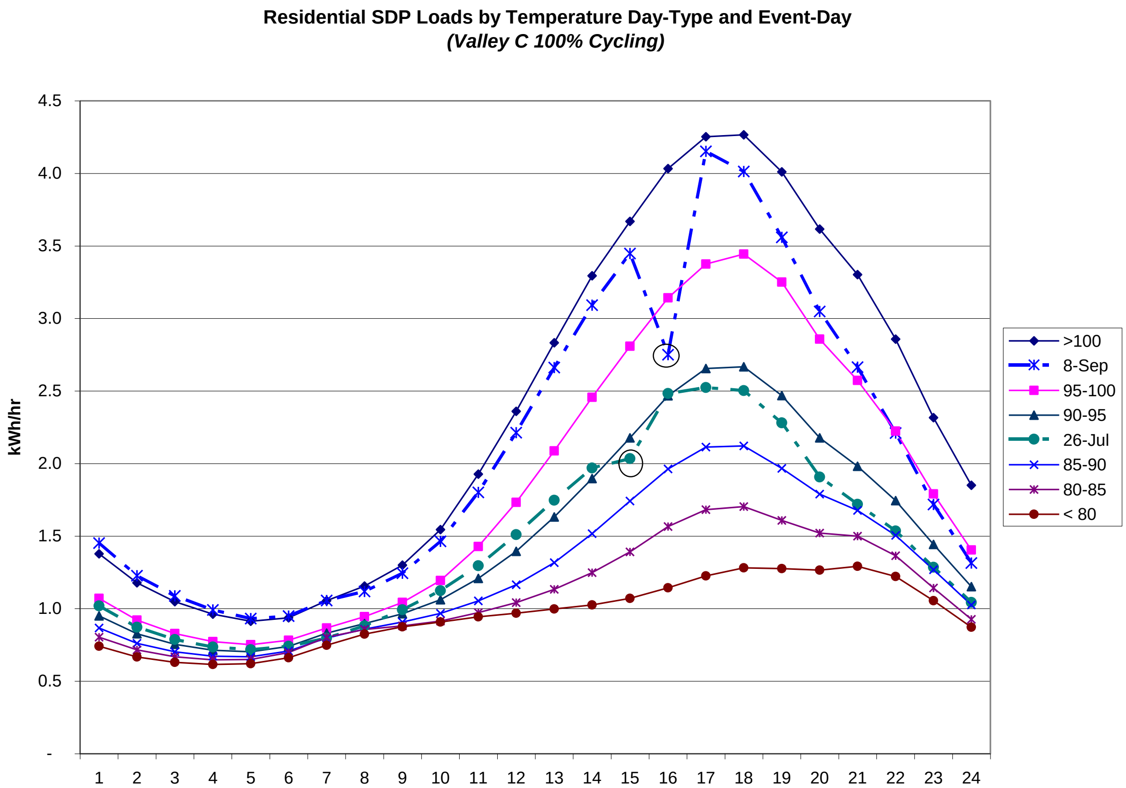


Figure 4-2 provides similar information for the approximately 1,400 customers associated with Valley C A-Bank who selected the 67 % cycling strategy. The load reduction on the September 8 event is again quite distinct, though smaller (about 0.5 kW) than that for the 100% cycling customers, as expected. However, any load impact for the July 26 half-hour event is barely noticeable.

Figure 4-2: Residential Customer Loads by Temperature Day-Type – ***Weekdays for Valley C Customers Selecting 67% Cycling Strategy***

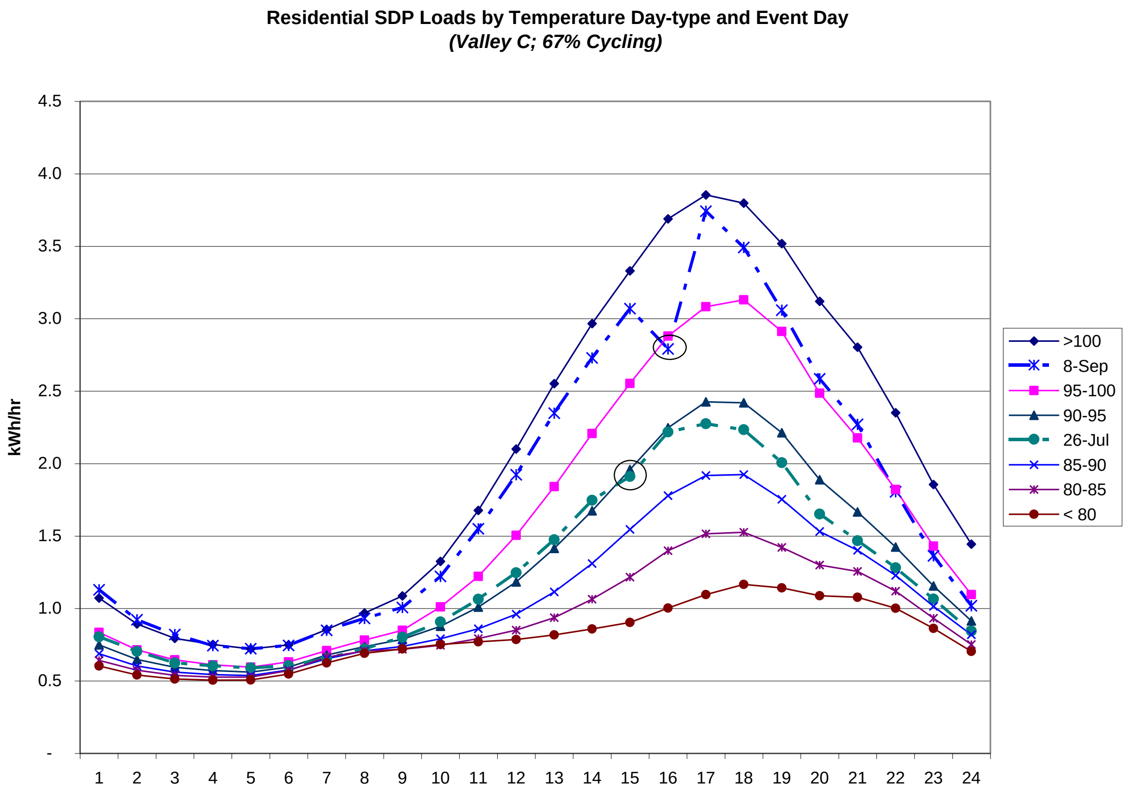


Figure 4-3 provides comparable information for the approximately 400 customers associated with Valley C who selected the 50 % cycling strategy. The load reduction on the September 8 event is again distinct, though even smaller (less than 0.5 kW). The load impact for the July 26 half-hour event appears as a kink in the load at HE 15.

Figure 4-3: Residential Customer Loads by Temperature Day-Type – *Weekdays for Valley C Customers Selecting 50% Cycling Strategy*

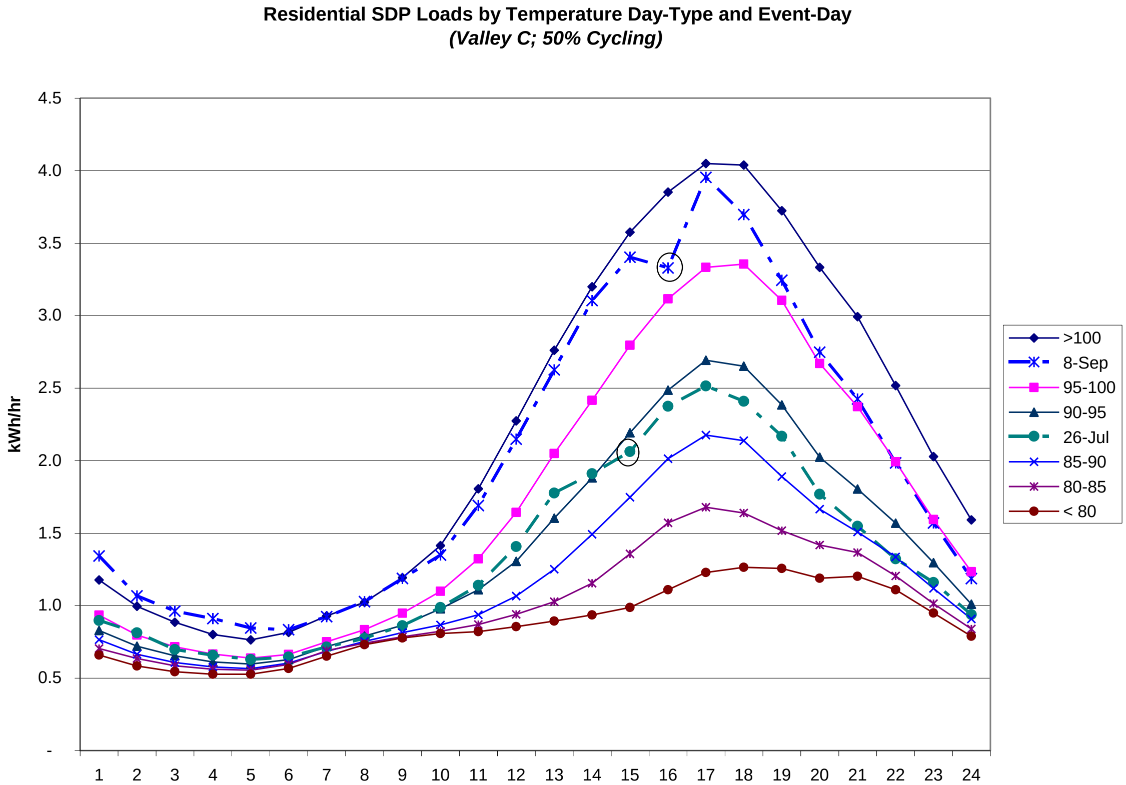


Figure 4-4 provides the same set of information for the approximately 600 customers associated with Mira Loma who selected the 100% cycling strategy. The load reductions on the August 3 and August 30 events (see circled data points) are reflected in “kinks” in the loads that are somewhat comparable to those for the 30-minute event for Valley C.

Figure 4-4: Residential Customer Loads by Temperature Day-Type – *Weekdays for Mira Loma Customers Selecting 100% Cycling Strategy*

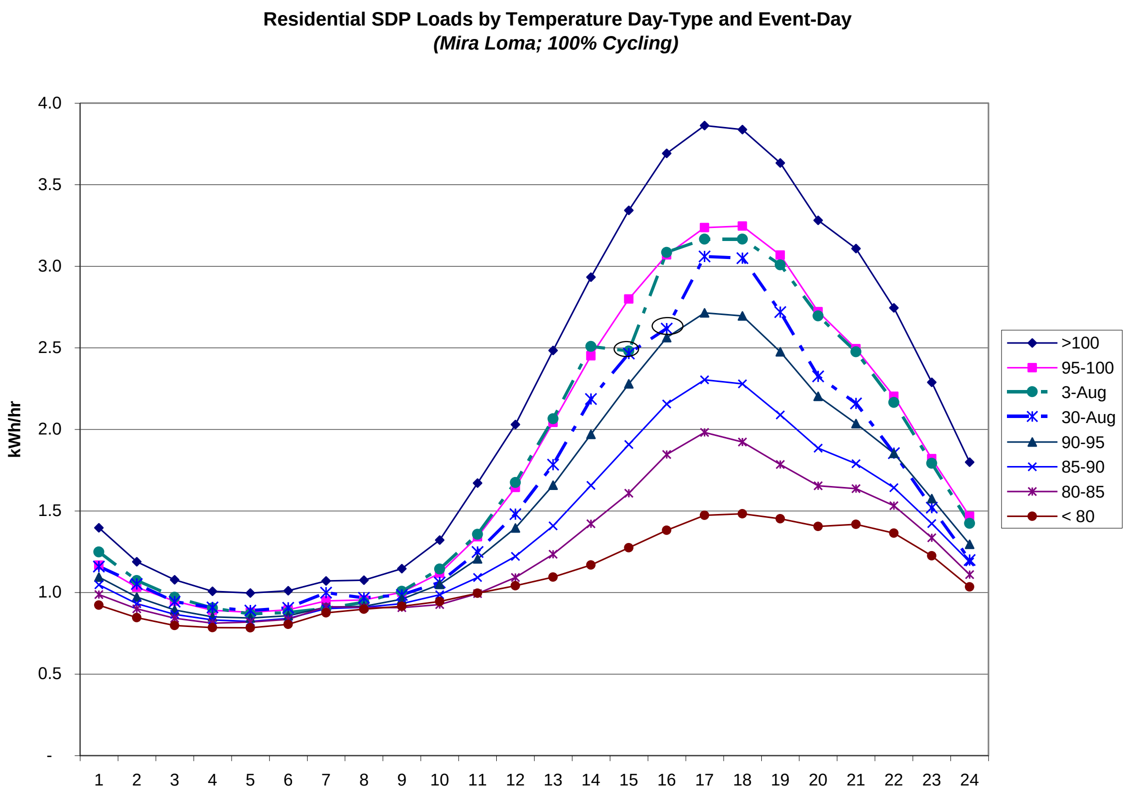
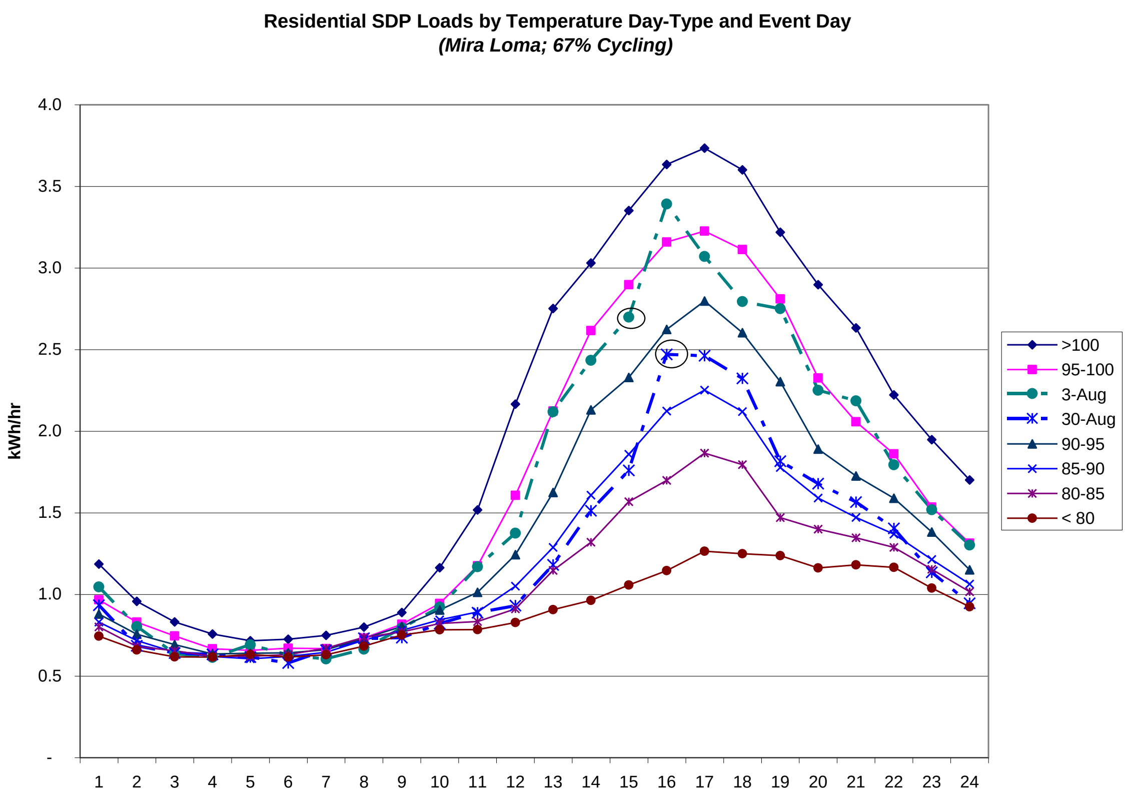


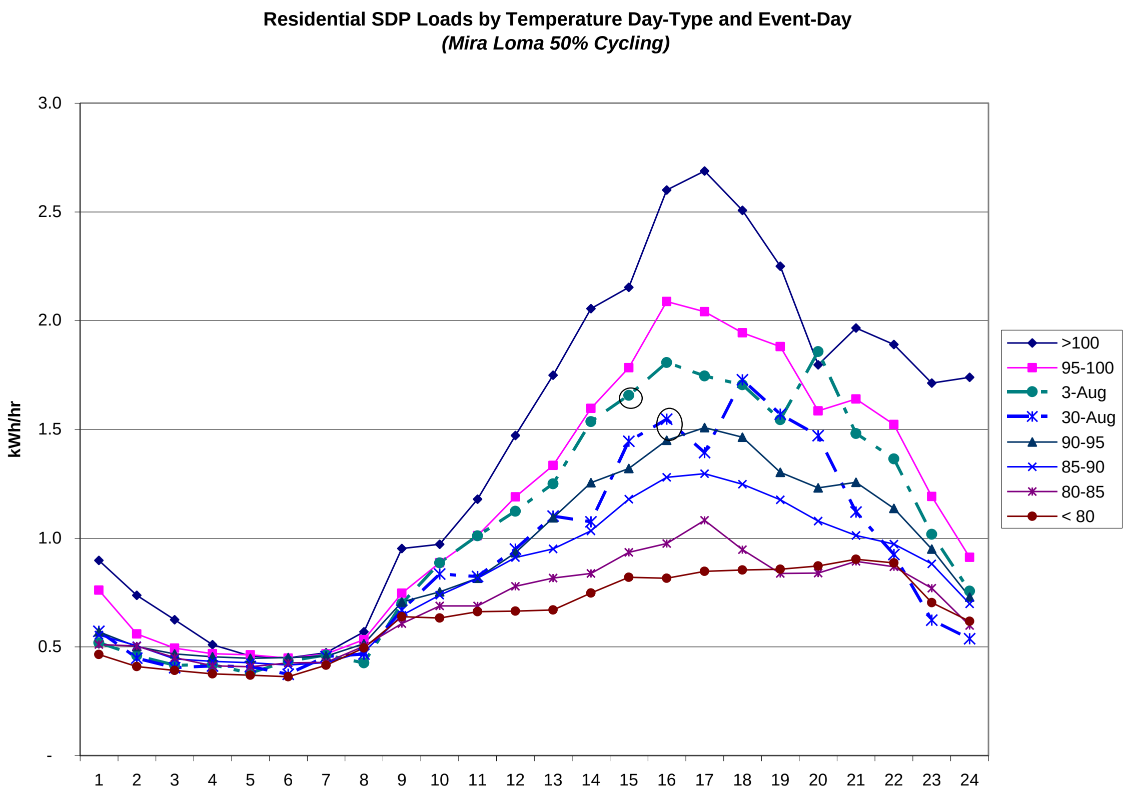
Figure 4-5 shows comparable loads for the approximately 45 customers associated with Mira Loma who selected the 67% cycling strategy. The load reduction on the August 3 event has the familiar "kink" in HE 15. However, the load for the August 30 event appears to rise in the hour in which the event occurred. It is likely that the loads for this group and the following one have more variability across days due to the relatively small number of customers included.

Figure 4-5: Residential Customer Loads by Temperature Day-Type – *Weekdays for Mira Loma Customers Selecting 67% Cycling Strategy*



Finally, Figure 4-6 shows loads for the 10 Mira Loma customers who selected the 50% cycling strategy. The load reduction on the August 3 event has a barely discernable kink in HE 15. However, the load on the August 30 event day is quite variable, with little indication of a load reduction in HE 16, in which the event occurred.

Figure 4-6: Residential Customer Loads by Temperature Day-Type – *Weekdays for Mira Loma Customers Selecting 50% Cycling Strategy*



The above figures illustrate the weather-sensitivity of the residential SDP loads, and the apparent load reductions during several of the events described in Section 2 for most of the customer groups. Load impacts for 30-minute events and a less than 100% cycling strategy appear relatively small. Given the inherent variability of residential customer loads, such relatively small expected load impacts pose a challenge to estimation. Quantitative results of that estimation are presented in Section 4.2 below.

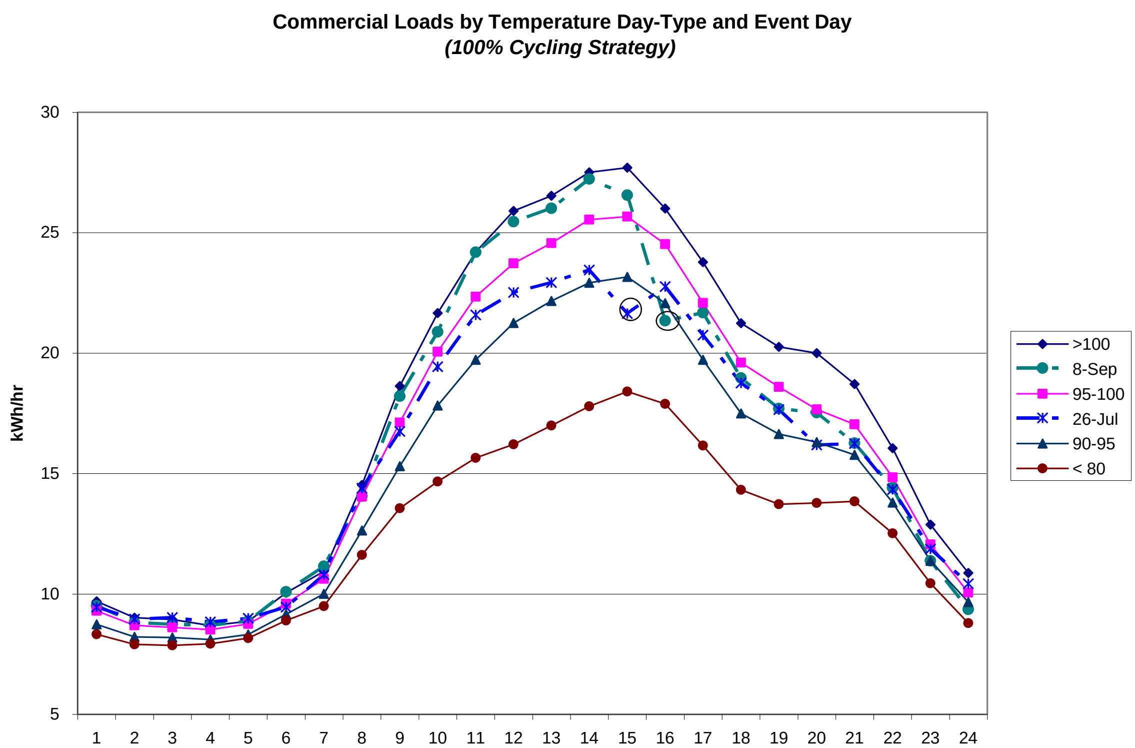
4.1.2 Small commercial customer load profiles

We begin this section by showing two figures of commercial customer loads that are aggregated to the hourly level from the available 15-minute data.[10] A range of loads averaged across days defined by temperatures in the afternoon HE 13 to 18 period are shown, along with loads for the two Valley C events, with which nearly all of the commercial customers were associated. These are followed by figures showing event-day loads in both 15-minute and hourly form.

Load profiles by temperature day-type

Figure 4-7 shows average weekday loads by temperature range and event day for the 64 SDP small commercial customers associated with Valley C who selected the 100% cycling strategy. The commercial customer loads show substantial weather sensitivity, though not quite as much as the residential customers.[11] The load reduction in HE 16 for the one-hour September 8 event is quite distinct, suggesting a load reduction of about 3 to 4 kW. A smaller load reduction for the 30-minute event on July 26 may also be seen.

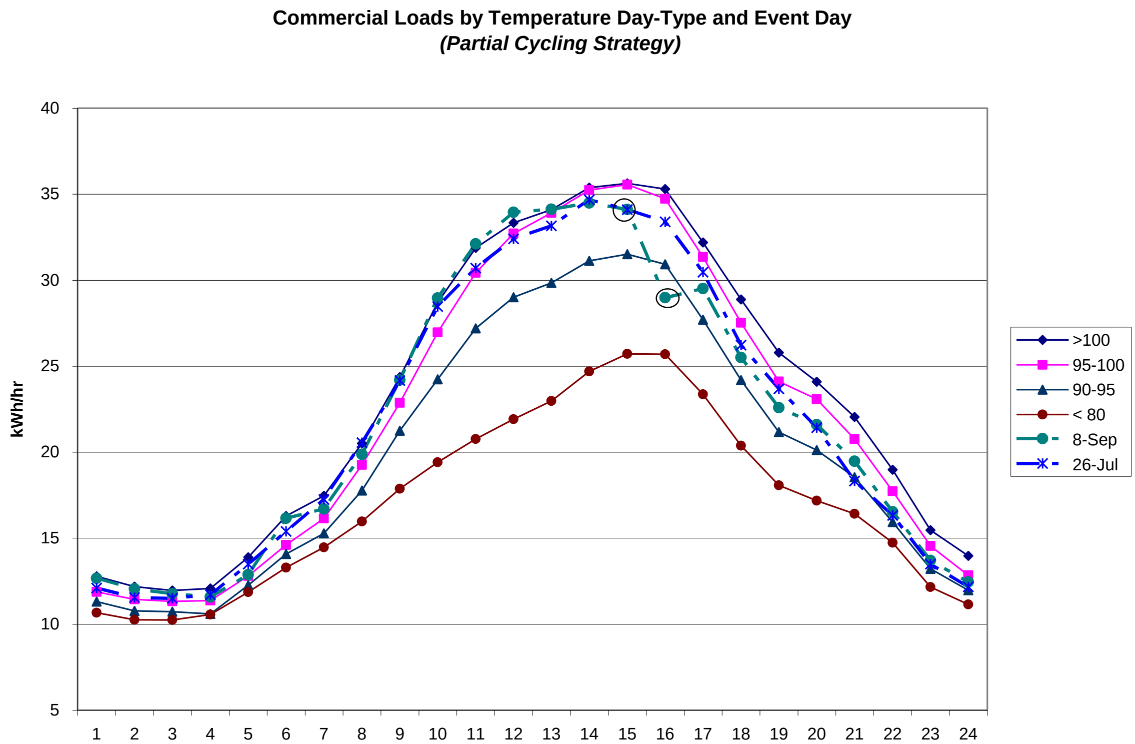
Figure 4-7: Small Commercial Loads by Temperature Day-Type and Event Day – ***Weekdays for Customers Selecting 100% Cycling Strategy***



[10] As described below, hourly loads were developed by summing the 15-minute data for the four relevant intervals within each hour.
[11] Load profiles for two of the temperature day-types between 80 and 90 degrees are not shown for purposes of clarity with respect to the event-day profiles.

Figure 4-8 shows average weekday loads by temperature range and event day for the 25 SDP commercial customers associated with Valley C who selected a partial cycling strategy. The load reduction in HE 16 for the one-hour September 8 event is again distinct, suggesting a load reduction of less than 3 kW. Any load reduction for the 30-minute event on July 26 is difficult to see in the figure.

Figure 4-8: Small Commercial Loads by Temperature Day-Type and Events – ***Weekdays for Customers Selecting Partial Cycling Strategy***



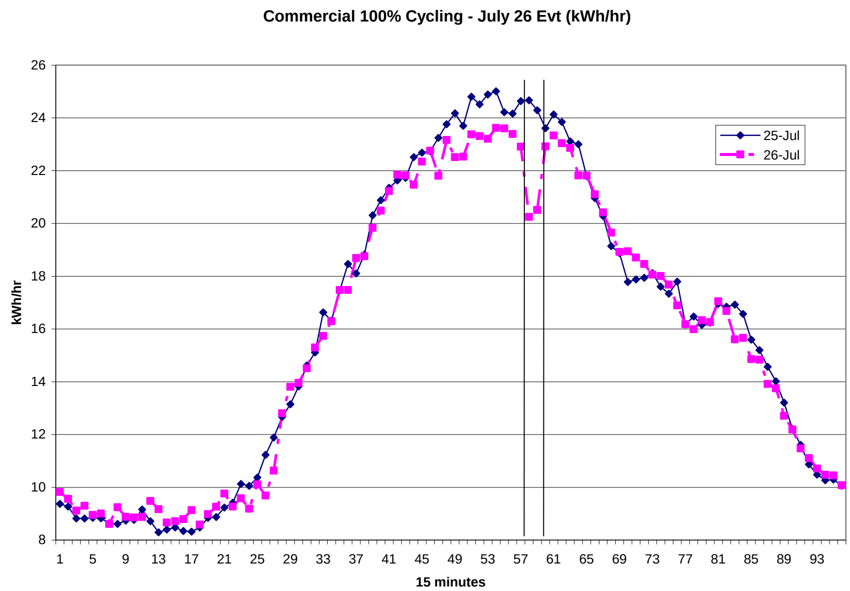
Comparisons of 15-minute and hourly load profiles

The next set of figures compares loads for SDP commercial customers on event days and nearby comparable days at the 15-minute and hourly levels. Separate loads are shown for customers selecting the alternative cycling strategies. The objective of the comparisons is to illustrate the extent to which load impacts for events of duration less than an hour may be observed in the hourly data. These findings may be useful in analyzing the load impacts for residential customers, for which only hourly data are available. By SCE convention, the 15-minute data represent metered energy consumption over each 15-minute period, and thus represent units of kWh per 15-minutes. For purposes of comparing the loads at alternative time resolutions, we developed hourly loads by summing the relevant four 15-minute loads to produce loads in units of kWh per hour, which are typically referred to as kW. For direct comparison, we also convert the 15-minute loads to units of the rate of consumption per hour (i.e., kWh per hour) by multiplying each observation by four.

Figure 4-9 shows loads for the 100% cycling customers for the July 26 event and the prior day. The top panel shows 15-minute load data, while the bottom panel shows hourly data. The load reduction in the second and third 15-minute intervals of HE 15 (i.e., quarter-hours ending 58 and 59) is clearly visible in the top panel, while the effect of that load reduction averaged across HE 15 may be seen in the bottom panel.[12]

[12] As shown in the event listing in Table 2-2, the July 26, 2011 event was nominally dispatched at 4:00 p.m., and lasted 27 minutes. This implies that the load reductions should occur in quarter-hours ending 57 (i.e., ending at 4:15 p.m.) and 58 (ending at 4:30 p.m.), or 15-minutes earlier than as shown in the figure. SCE has confirmed that dispatch problems did delay this event by nearly 15 minutes, which is consistent with the data shown in the figure.

Figure 4-9: Small Commercial Hourly and 15-Minute Load Profiles (kWh/hr) –
100% Cycling; July 26 Event



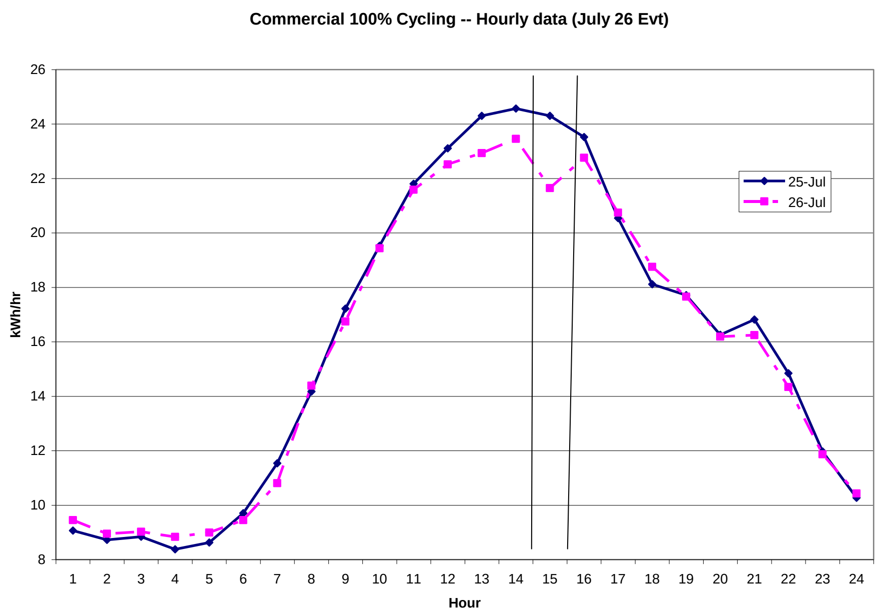
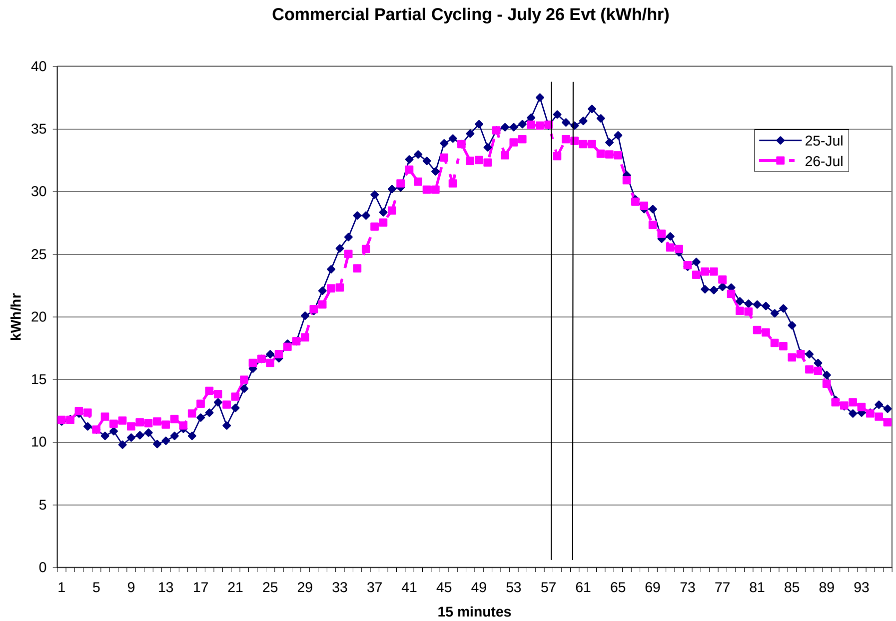
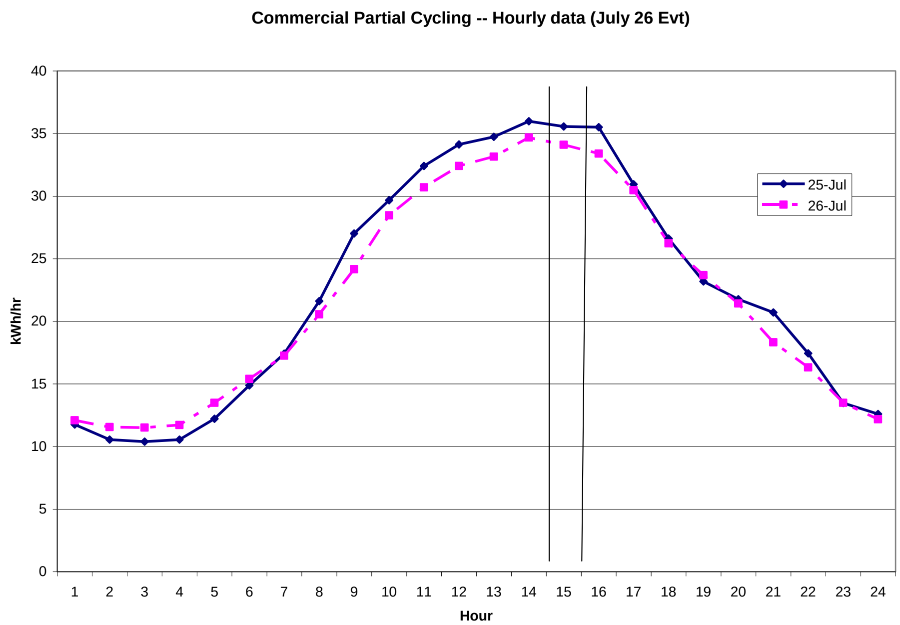


Figure 4-10 provides a similar comparison for the customers who selected a *partial* cycling strategy (primarily 50%). These customers are somewhat larger on average than the 100% cycling customers. The 15-minute data seem to indicate a load reduction in the first 15-minute interval of the event, with some load releasing in the second interval.[13] At the hourly level of resolution, there is no discernable load reduction.

[13] The load reductions again appear in intervals 58 and 59 rather than 57 and 58.

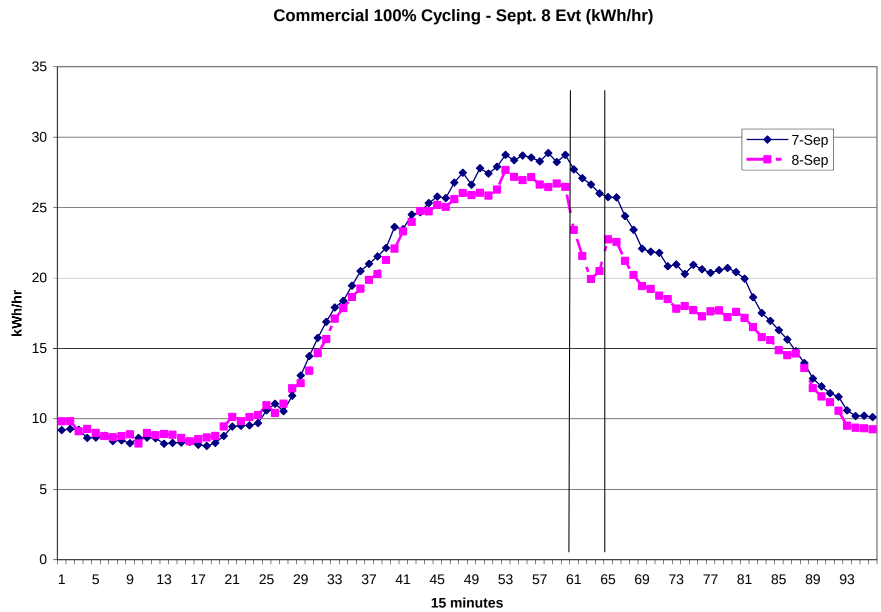
Figure 4-10: Small Commercial Hourly and 15-Minute Load Profiles (kWh/hr) – ***Partial Cycling; July 26 Event***





Figures 4-11 and 4-12 compare the two sets of load profiles for the 100% cycling and partial cycling customers respectively, for the one-hour September 8 event and the previous day. In both cases, the 15-minute data show load reductions in all four intervals of HE 16, while the hourly data show a distinct load reduction averaged over those intervals.

Figure 4-11: Small Commercial Hourly and 15-Minute Load Profiles (kWh/hr) – *100% Cycling; September 8 Event*



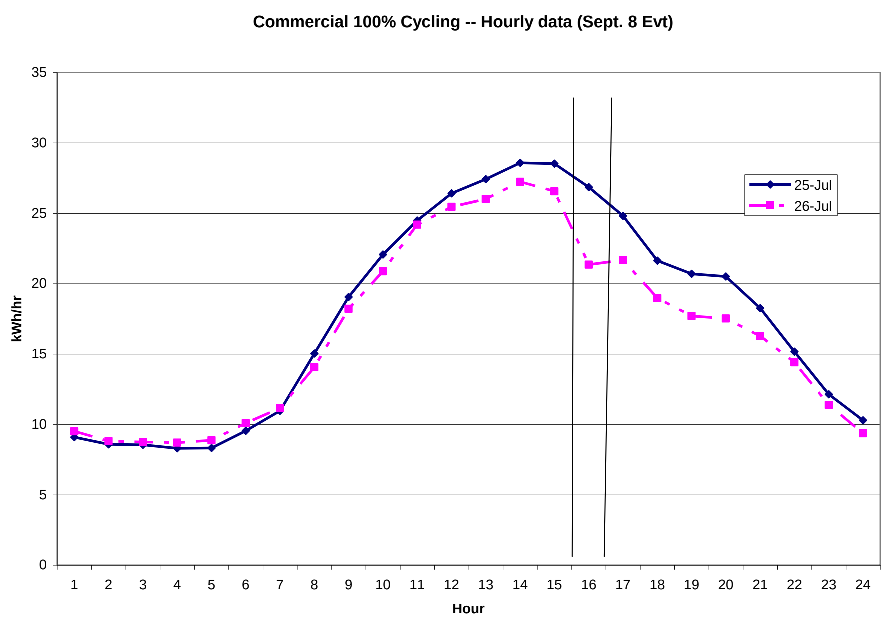
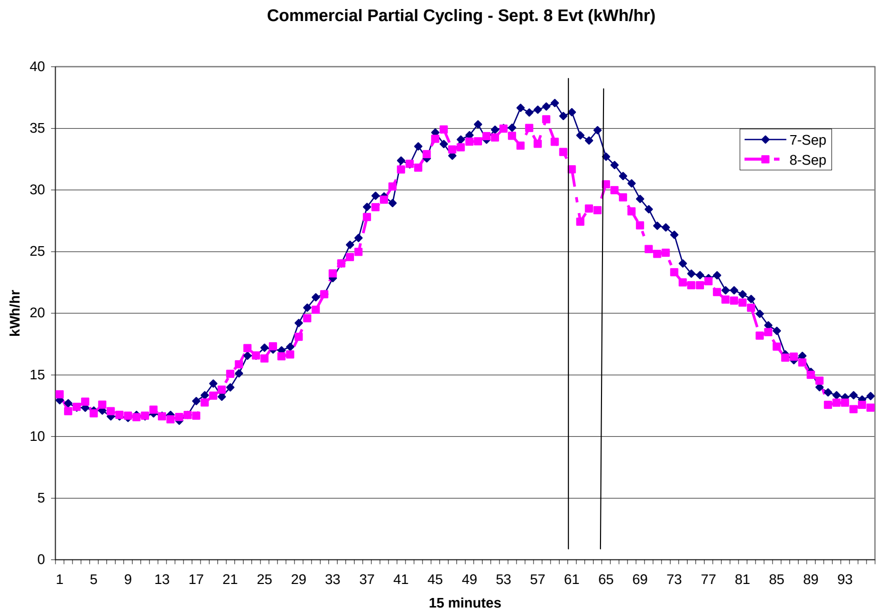
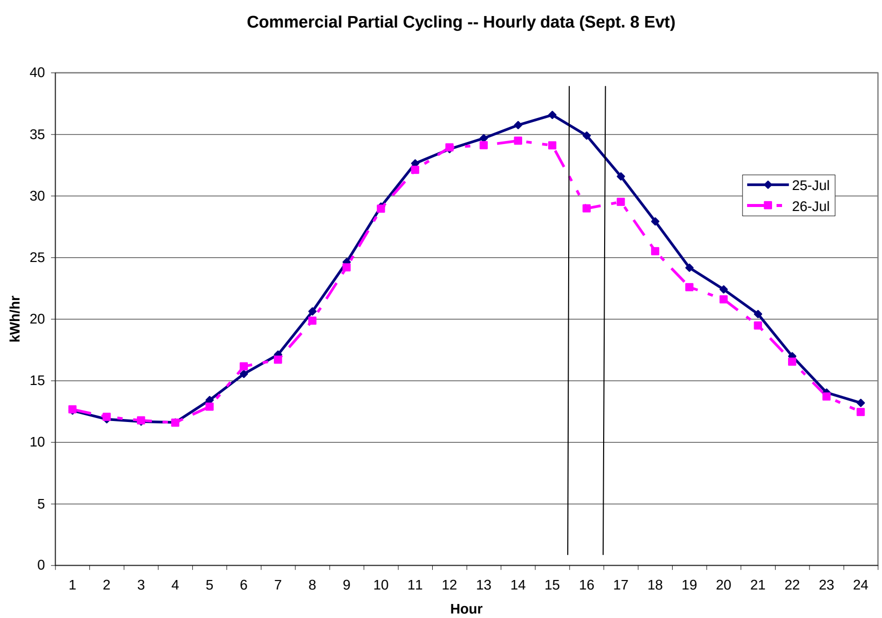


Figure 4-12: Small Commercial Hourly and 15-Minute Load Profiles (kWh/hr) – ***Partial Cycling; September 8 Event***





The above figures suggest that SDP load impacts for the commercial customers should be readily estimable by regression analysis of the 15-minute load data. Comparison with the hourly data suggests that in most cases load impacts could also be estimated using those data, although the issue of how to adjust the estimate to the actual duration of the event would remain. The one exception to the ability to estimate load impacts from hourly data, similar to the case of the residential customers, is the 30-minute event on July 26 for the customers selecting a partial control strategy.

4.1.3 Large commercial customer load profiles

This section illustrates average 15-minute loads for the two groups of large commercial customer accounts, defined by A-Bank and cycling strategy, that have the largest number of AC units and tonnage. These are the accounts associated with Villa Park and Walnut that selected full, or 100 percent cycling. Loads are shown for both event days in each area, along with the prior or following non-event day to help illustrate the load reductions. Note that the loads are shown in units of kWh per 15-minutes. They require scaling up by a factor of four to represent values in units of kW (kWh per hour).

Figures 4-13 and 4-14 show loads associated with Walnut for the August 18 (QE 57-58) and September 20 (QE 61-62) events. Both were approximately half-hour events. The observed loads within the event window are indicated by ovals. The effect of the full cycling is clearly observable for the August 18 event in Figure 4-13, suggesting a load reduction during the event of about 50 kWh per 15-minutes for the second interval (which translates into 200 kW). However, the small reduction in the first event interval and the continued reduction in the interval following the event suggest that the event may have been dispatched slightly later than the nominal time of 14:03, near the beginning of quarter-ending 57. The load reduction is less obvious for the September 20 event, as it occurs during the afternoon period in which the load is falling rather steeply.

Figure 4-13: Large Commercial 15-Minute Load Profiles (kWh/15-min) –
Walnut*; *100% Cycling; August 18 Event

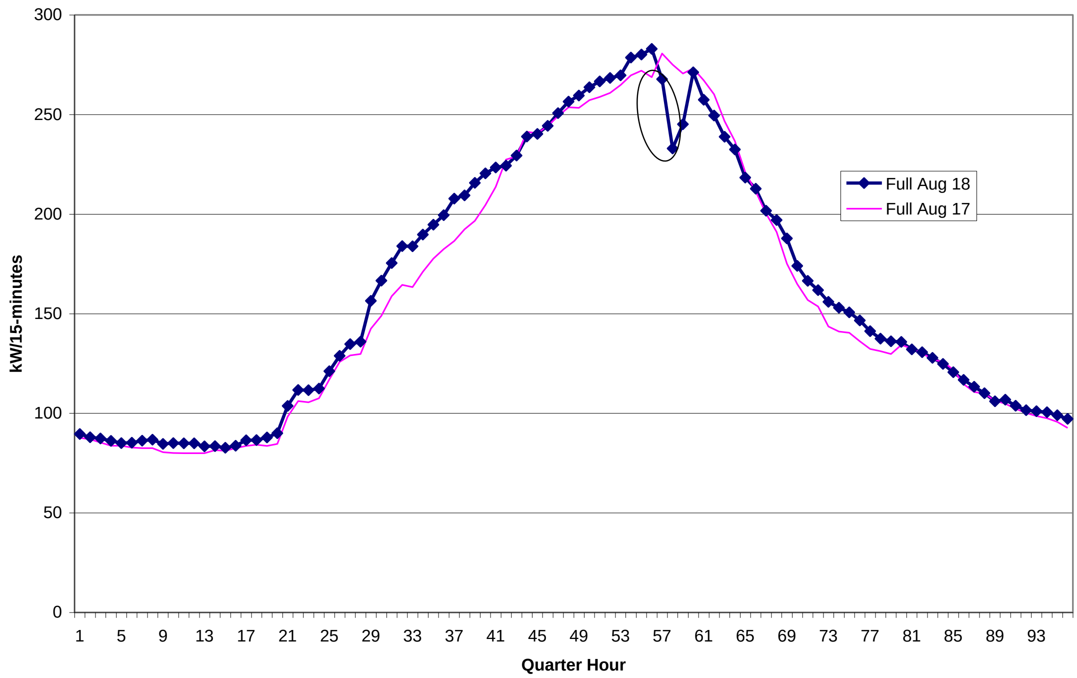


Figure 4-14: Large Commercial SDP 15-Minute Load Profiles (kWh/15-min) –
Walnut*; *100% Cycling; September 6 Event

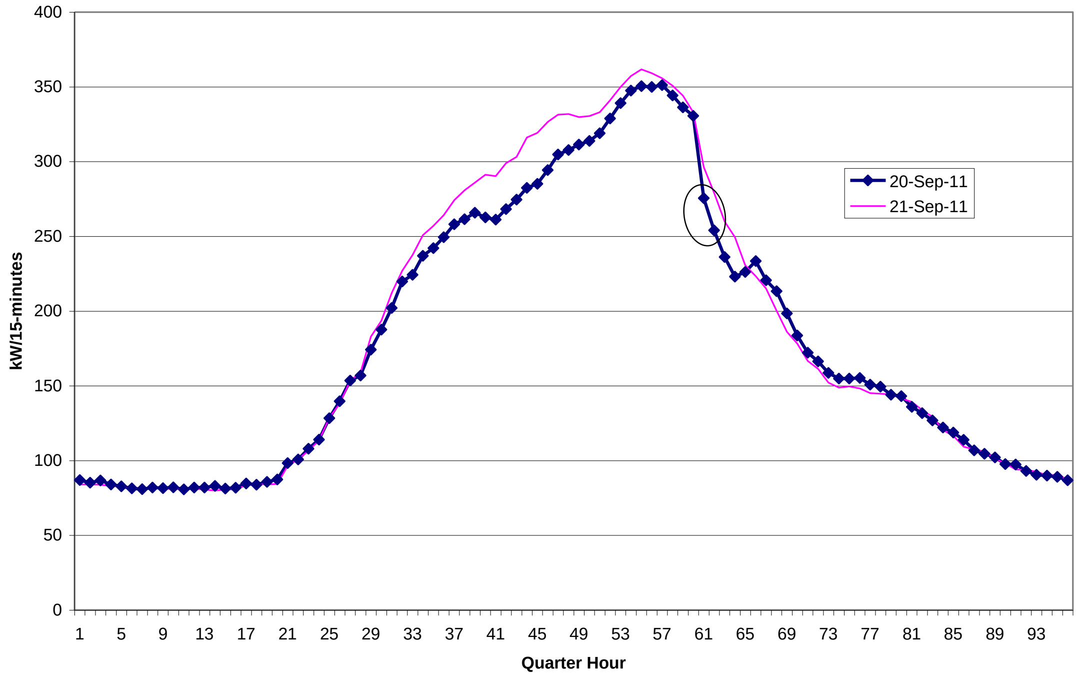


Figure 4-15 and 4-16 show loads for Villa Park for the August 26 (QE 61-62) and September 29 (61-64) events respectively. The September event lasted for a full hour beginning at 3 p.m. Note that the loads for many of the large commercial groups begin dropping off rather quickly in the 3 p.m. to 4 p.m. period, presumably because the participants include many elementary and secondary schools.

Figure 4-15: Large Commercial SDP 15-Minute Load Profiles (kWh/15-min) –
Villa Park*; *100% Cycling; August 26 Event

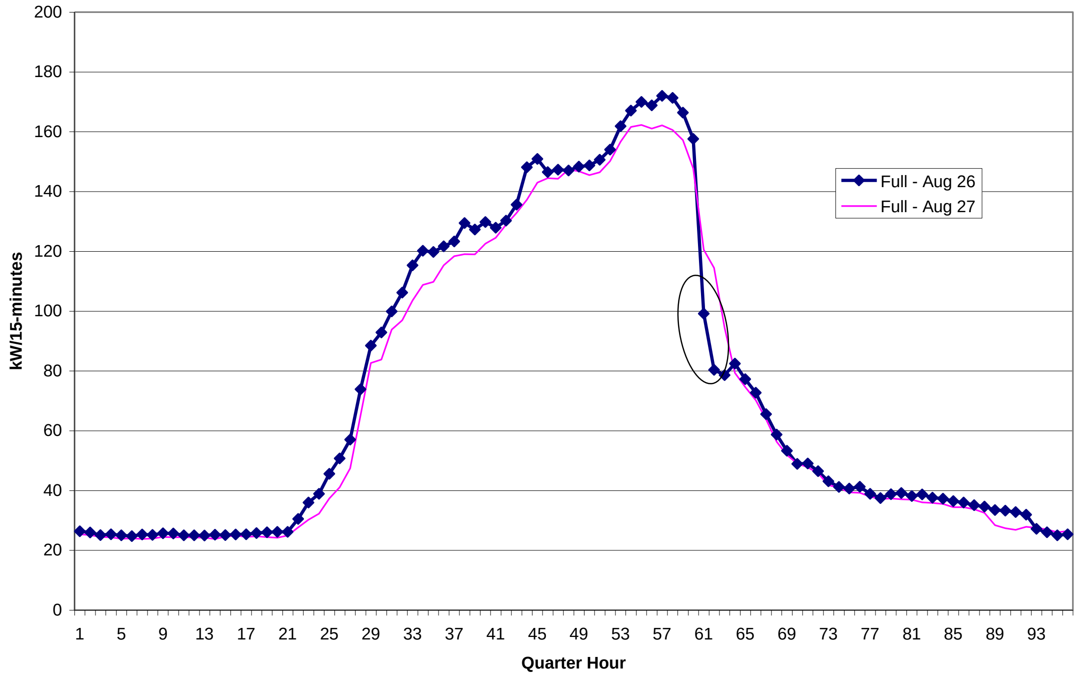
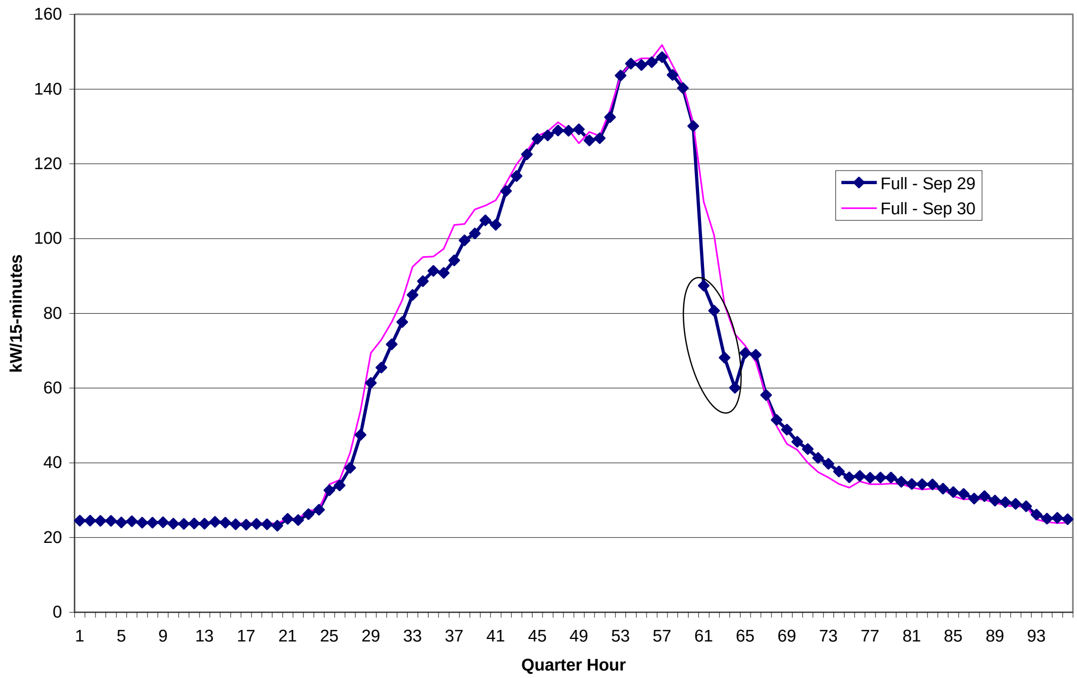


Figure 4-16: Large Commercial SDP 15-Minute Load Profiles (kWh/15-min) –
Villa Park; *100% Cycling; September 29 Event*



4.1.4 SDP load impacts approximated from observed data – *Residential*

Table 4-1 summarizes the observed load data illustrated in Figures 4-1 through 4-6, showing an approximated reference load, the observed load, approximated load impact, and percent load impact for each of the Valley C and Mira Loma event days, for the average residential customer choosing each cycling strategy. For purposes of this table, the estimated reference loads, which are intended to represent customers' load levels in the absence of an event, were calculated by multiplying the load in the pre-event hour on an event day by the ratio of the loads in the event-hour and previous hour, for the non-event temperature day-type load profile that most closely matches the relevant event-day load. This approach has the effect of approximating the event-period reference load by adjusting the pre-event load observation by the slope of the relevant temperature day-type load profile.

The approximated load impact is then calculated as the difference between the estimated reference load and the observed load during the event.[14] Since three of the four events lasted for less than one-half hour, the observed load values for those events represent consumption during the entire hour in which the event occurred, including the portion of the hour in which load was no longer curtailed.[15]

It is useful to examine first the one-hour event on September 8 for Valley C. In this case, the observed event-hour load represents nearly entirely load curtailed during the event. For this event, the load impacts and percent load impacts for the alternative cycling strategies follow the expected pattern of being largest for 100% cycling (e.g., 1 kW and 27.4%), somewhat less (0.6 kW and 17.9%) for two-thirds cycling, and least (0.4 kW and 11.7%) for 50% cycling.

The load impact levels and percent load impacts for the three half-hour events are substantially less than for the September 8 one-hour event, since the observed load during the hour in which those events occurred includes non-curtailed load during half of the hour that includes the event. Section 4.2.2 below contains comparisons of load impact results using both 15-minute and hourly data for the commercial customers, and provides some indication of the relationship between load impacts for events lasting less than an hour as measured by load data at the different time-period resolutions.

[14] In the regression analysis reported in Section 4.2 below, estimated load impacts are derived from the estimated coefficients on event-day variables, and the implied, or estimated reference loads are constructed as the sum of the observed load and the amount of the estimated load impact during the event.

[15] The availability of 15-minute load data for the commercial customers provides an opportunity to examine the relationship between load impacts measured using both 15-minute and hourly load data.

Table 4-1: Residential SDP Load Impacts Approximated from Observed Data --
(Average per participant, by cycling strategy, in kWh/hour)

	Event	July 26 (27 minutes; 88.3)				Sept. 8 (53 minutes; 98.0)			
Area	**Strategy**	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**
Valley C	100%	2.26	2.03	0.23	10.0%	3.79	2.75	1.04	27.4%
	67%	2.04	1.91	0.13	6.5%	3.40	2.79	0.61	17.9%
	50%	2.23	2.06	0.16	7.4%	3.77	3.33	0.44	11.7%
	Event	**Aug. 3 (28 minutes; 97.6)**				**Aug. 30 (28 minutes; 93.4)**			
	Strategy	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**
Mira Loma	100%	2.86	2.48	0.38	13.4%	2.77	2.62	0.16	5.6%
	67%	2.70	2.70	0.00	-0.1%	3.15	2.57	0.58	18.5%
	50%	1.71	1.66	0.06	3.4%	1.59	1.55	0.04	2.5%

4.1.5 SDP load impacts approximated from observed data – *Small commercial*

Table 4-2 quantifies the values underlying Figures 4-7 through 4-12 for small commercial customers, showing approximated reference load, observed load, approximated load impact, and percent load impact for both Valley C event days and for the average customer choosing the 100% and partial cycling strategy.[16] For illustrative purposes, results are shown for both the 15-minute and hourly data. As for the residential customers, the reference loads, which are intended to represent load levels in the absence of an event, were calculated by multiplying the load in the pre-event hour on an event day by the ratio of the event-hour and previous hour load for the non-event temperature day-type profile that most closely matches the event-day load. One outcome of this approach is that the estimated reference loads shown for both the 15-minute and hourly data are the same.

Load impacts are calculated as the difference between the estimated reference load and the observed load during the event.[17] Note that the 15-minute and hourly results for the nearly one-hour event on September 8 are identical, since the hourly loads are simply the sum of the 15-minute loads within the hour.[18] However, those results differ for the half-hour event on July 26 because the observed load values are averaged over only the two 15-minute loads during the event, while the hourly values represent observed consumption during the entire hour in which the event occurred.

The percent load impacts on the September 8 event for both the 100% and partial cycling strategy groups are approximately 14 percent of the reference load (the reference load level for the partial cycling group is about 50 percent higher than that for the 100% cycling group). For the half-hour event on July 26, the event-period load impact for the

[16] As noted above, the “partial” strategy combines customers selecting the 30% and 50% strategies.
[17] In the regression analysis reported below, estimated load impacts are derived from the estimated coefficients on event-day variables, and estimated reference loads are constructed as the sum of the observed load and the amount of the estimated load impact during the event.
[18] As noted earlier, the 15-minute values in the table have been converted to units of kWh/hour by multiplying the observed 15-minute integrated kWh values by 4, thus showing the hourly “rate” of usage in each time period.

100% cycling group, as measured by the 15-minute data is also nearly 14 percent.[19] However, it is only about 4 percent for the partial cycling group. Also, the load impacts for that event measured by the hourly data are substantially less, because they include two 15-minute non-event hours when loads are not curtailed.

Table 4-2: Small Commercial SDP Load Impacts Approximated from Observed Data -- *(Average per participant, by cycling strategy)*

Event		July 26 (27 minutes; 88.3)				Sept. 8 (53 minutes; 98.0)			
Data	**Strategy/ Partic.**	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**	**Ref. Load**	**Observed Load**	**Load Impact**	**% LI**
15-minute (kWh/hr)	100% (64)	23.6	20.4	3.2	13.5%	24.9	21.3	3.6	14.4%
	Partial (27)	35.0	33.5	1.5	4.2%	33.8	29.0	4.8	14.2%
Hourly (kWh/hr)	100% (64)	23.6	21.6	1.9	8.1%	24.9	21.3	3.6	14.4%
	Partial (27)	35.0	34.1	0.9	2.5%	33.8	29.0	4.8	14.2%

4.2 Ex Post Estimated Load Impacts

4.2.1 Residential SDP load impacts

Table 4-3 summarizes estimated load impact results based on regression analysis described in Section 3 for the average residential customer in each cycling strategy group (i.e., estimated load impacts are values of the estimated coefficients on the event-period variables interacted with hourly indicator variables). Results are shown for each event and A-bank, by cycling strategy and in total. From left to right, the columns characterize each event, including A-bank, hour and duration, and average temperature in the HE 13-to-18 period. There are four rows for each event, three showing results by cycling strategy (numbers of participants with that strategy are also indicated), and one showing total participants and participant-weighted averages of loads and load impacts. Event period results shown are the estimated reference load, observed load, estimated load impact, percent load impact (load impact as a percentage of the reference load), and the t-statistic on the estimated event period coefficient.

Statistically significant load impacts (i.e., where the t-statistic on the load impact coefficient exceeds 2.0 in magnitude) were estimated for about half of the customer groups and event days. The 100 percent cycling customers were most likely to have statistically significant load reductions and all of the Valley C customer groups reduced load significantly on the September 8 event. The estimated load impacts for that event range from 0.38 kW for the 50 percent cycling group, to just over 1 kW for the 100 percent cycling group. Load impacts for the July 26 event are estimated very imprecisely, actually representing small load *increases* that are not statistically significantly different from zero.

[19] As noted in the context of the load figures in Section 4.1.1, the load reductions for the July 26, 2011 appear to occur during quarter hours-ending 58 and 59, or 15-minutes later than the time shown as the dispatch time for the event. The load impacts in the table are calculated for the time periods in which the load reductions appear to occur, despite the apparent discrepancy with the program event time.

Table 4-3: Estimated Residential SDP Load Impacts by Event and Cycling Strategy – *Per-Customer*

Evt	Date	Day of Week	Hour Ending	A-bank	Duration	Temp.	Strategy	Partic.	Estimated Reference Load (kWh/hr)	Observed Load (kWh/hr)	Estimated Load Impact (kWh/hr)	% Load Impact	t-stat
1	26-Jul	Tues	15	Valley C	27 min	88.3							
							100%	21,893	2.00	2.03	-0.033	-1.7%	-0.3
							67%	1,437	1.78	1.91	-0.135	-7.6%	-1.3
							50%	411	2.00	2.06	-0.060	-3.0%	-0.5
							Total/Ave.	23,741	1.99	2.03	-0.040	-2.0%	
2	3-Aug	Wed	15	Mira Loma	28 min	97.6							
							100%	609	2.99	2.48	**0.508**	**17.0%**	**4.8**
							67%	45	2.92	2.70	0.219	7.5%	1.5
							50%	10	1.74	1.66	0.088	5.1%	0.5
							Total/Ave.	664	2.96	2.48	0.482	16.3%	
3	30-Aug	Tues	16	Mira Loma	28 min	93.4							
							100%	609	2.91	2.62	**0.292**	**10.0%**	**2.7**
							67%	45	3.02	2.57	**0.450**	**14.9%**	**3.0**
							50%	10	1.64	1.55	0.097	5.9%	0.5
							Total/Ave.	664	2.90	2.60	0.299	10.3%	
4	8-Sep	Thurs	16	Valley C	53 min	98.0							
							100%	21,913	3.79	2.75	**1.036**	**27.4%**	**9.3**
							67%	1,437	3.45	2.79	**0.659**	**19.1%**	**6.6**
							50%	412	3.71	3.33	**0.377**	**10.2%**	**3.4**
							Total/Ave.	23,762	3.76	2.76	1.001	26.6%	

We can provide information on the uncertainty around the estimated load impacts using the variances of the estimated event-hour coefficients. We calculate average standard errors as a percent of the reference load by event to be 5.6%, 3.7%, 3.8% and 2.9% for the four events. That is, the nearly 27 percent overall average load impact for the September 8 event has a standard error of only 3 percent, while the 10 percent overall average load impact for the August 30 event has a standard error of nearly 4 percent.

Figures 4-17 and 4-18 illustrate the nature of the estimated hourly load impacts for the September 8 event, which are estimated very precisely, and the July 26 event, where the estimates are not significant. For the September 8 event, the estimated load impact coefficients are close to zero in all hours leading up the event, and then spike downward in HE 16 showing the expected effects of the curtailment on the different cycling strategy groups. In contrast, the estimated load impact coefficients for the July 26 show a pattern across the day that is logically not due to the curtailment effect, but to some unique aspect of the day that is not accounted for in the model. The circled event-hour (HE 15) values for all three cycling strategies are all smaller than the previous hour, suggesting modest event-induced load reductions; however, the values during the afternoon hours are all positive, representing event-day load increases.

Figure 4-17: Estimated Residential Load Impacts, by Cycling Strategy – ***September 8 Event***

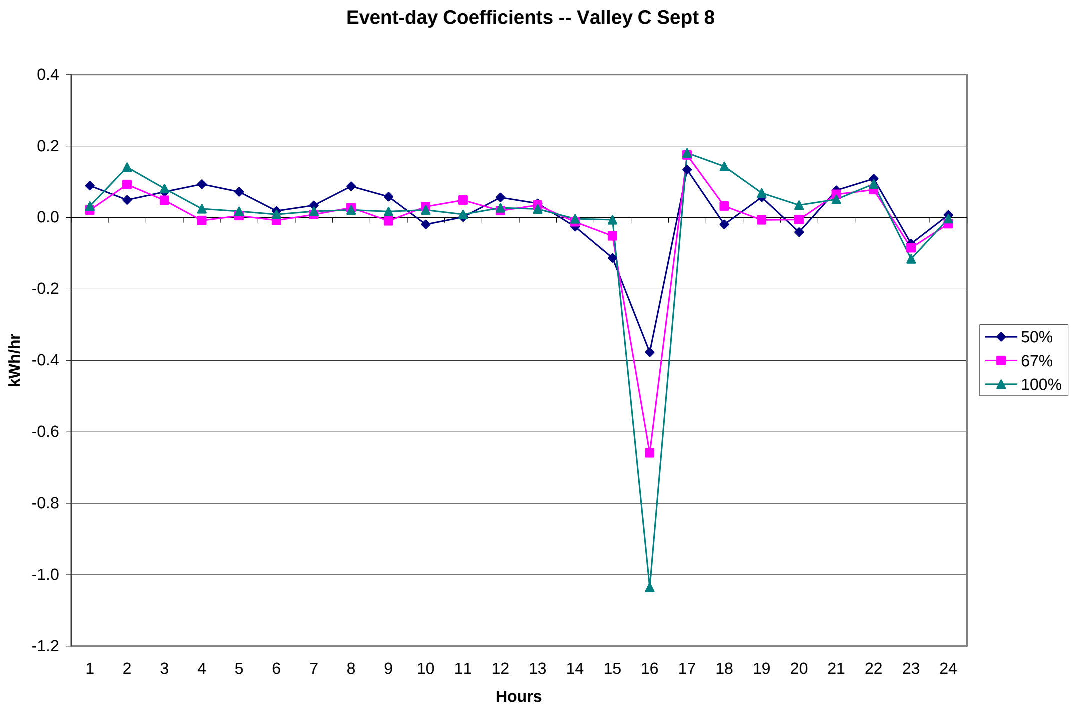
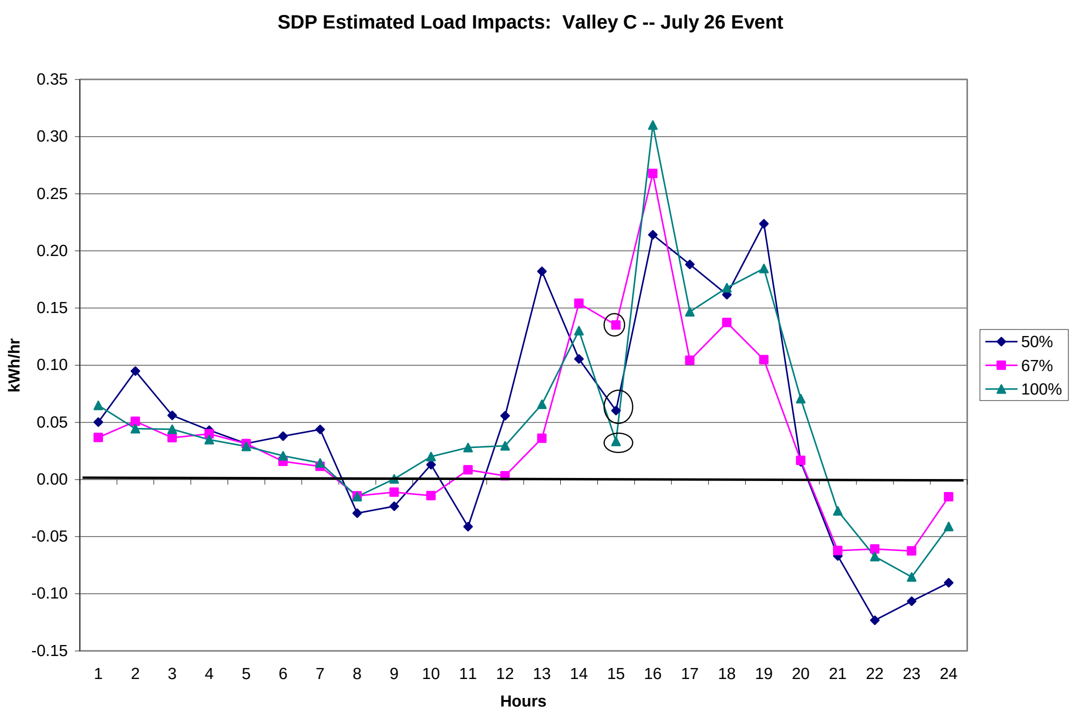


Figure 4-18: Estimated Residential Load Impacts, by Cycling Strategy – ***July 26 Event***



As discussed previously, the primary reason that the estimated load impacts are smaller for the first three events than for the September 8 event is that they were dispatched for less than an hour, while the available data for measurement was at a one-hour resolution. As a result, air conditioners were not controlled during half of the one-hour observation period for those events. One might expect that the actual load reduction during the half-hour events would be about twice the amount estimated from the hourly data.[20] Potential information on this relationship can be developed from the commercial SDP customers due to the availability of higher resolution 15-minute load data.

In Section 4.2.2 below we compare load impact estimates based on 15-minute and hourly load data, using data for a subset of the commercial customers with less than the average amount of air conditioning tonnage. We then use that relationship to adjust the values of the estimated load impacts for the half-hour events in Table 4-3. These adjusted load impacts are shown in Table 4-4. An additional column is added to show estimated load impacts per AC ton, using average participant AC tonnage shown in Table 2-1 above. Load impacts were adjusted only for the second and third events, and the adjusted values are shown in italics. The fourth event required no adjustment because it lasted nearly an hour. For the first event, which occurred on the coolest of the four event days, rather than making the estimated load increase even larger, we set the load impact to zero given the very imprecise estimate.

After the adjustments, the estimated load impacts and percent load impacts for the second and third half-hour events are more similar to those for the hour-long event on September 8, especially when comparing load impacts per AC ton. The results for the August 30 event are somewhat of an exception, with the magnitudes of estimated load impacts seemingly reversed for the 100 percent and 67 percent cycling groups. One likely source of the unexpected relative magnitudes is the sample size of only 45 for the 67 percent cycling group.

[20] Possible post-event load changes, particularly for 100 percent cycling customers, may affect the relationship between the two sources of estimates.

Table 4-4: Estimated Residential SDP Load Impacts by Cycling Strategy –
Per-Customer (Adjusted for Difference between 15-Minute and Hourly Data)

Evt	Date	Day	Hour End.	A-bank	Dur.	Tmp.	Strategy	Partic.	Est. Ref. Load (kWh/hr)	Obs. Load (kWh/hr)	Est. Load Impact (kWh/hr)	% Load Impact	LI per AC ton
1	26-Jul	Tues	15	Valley C	27 min	88.3							
							100%	21,893	2.03	2.03	0.0	0.0%	0.0
							67%	1,437	1.91	1.91	0.0	0.0%	0.0
							50%	411	2.06	2.06	0.0	0.0%	0.0
							Total/Ave.	23,741	2.03	2.03	0.0	0.0%	0.0
2	3-Aug	Wed	15	Mira Loma	28 min	97.6							
							100%	609	3.30	2.48	*0.825*	*25.0%*	0.21
							67%	45	3.33	2.70	*0.633*	*19.0%*	0.17
							50%	10	1.91	1.66	*0.256*	*13.4%*	0.07
							Total/Ave.	664	3.29	2.48	*0.803*	*24.5%*	0.21
3	30-Aug	Tues	16	Mira Loma	28 min	93.4							
							100%	609	3.09	2.62	*0.473*	*15.3%*	0.12
							67%	45	3.87	2.57	*1.301*	*33.6%*	0.35
							50%	10	1.83	1.55	*0.280*	*15.3%*	0.08
							Total/Ave.	664	3.12	2.60	*0.527*	*16.9%*	0.13
4	8-Sep	Thurs	16	Valley C	53 min	98.0							
							100%	21,913	3.79	2.75	1.036	27.4%	0.22
							67%	1,437	3.45	2.79	0.659	19.1%	0.17
							50%	412	3.71	3.33	0.377	10.2%	0.09
							Total/Ave.	23,762	3.76	2.76	1.001	26.6%	0.22

Finally, in Table 4-5 we expand the adjusted per-customer SDP load impacts in Table 4-4 by the number of participants for whom SmartConnect data were available, and report those values in Table 4-5, using units of MWh/hr. Total load impacts for Valley C for the September event are nearly 24 MW.

Table 4-5: Estimated Residential SDP Load Impacts by Cycling Strategy –
Program-Level (SmartConnect meters only)

Evt	Date	Day	HE	A-bank	Dur.	Tmp	Strategy	Partic.	Est. Ref. Load (MWh/hr)	Observed Load (MWh/hr)	Est. Load Impact (MWh)	% Load Impact
1	26-Jul	Tues	15	Valley C	27 min	88.3						
							100%	21,893	44.539	44.539	0.000	0.0%
							67%	1,437	2.746	2.746	0.000	0.0%
							50%	411	0.848	0.848	0.000	0.0%
							Total	23,741	48.133	48.133	0.000	0.0%
2	3-Aug	Wed	15	Mira Loma	28 min	97.6						
							100%	609	2.013	1.510	0.502	25.0%
							67%	45	0.150	0.121	0.028	19.0%
							50%	10	0.019	0.017	0.003	13.4%
							Total	664	2.182	1.648	0.533	24.5%
3	30-Aug	Tues	16	Mira Loma	28 min	93.4						
							100%	609	1.882	1.594	0.288	15.3%
							67%	45	0.174	0.115	0.059	33.6%
							50%	10	0.018	0.015	0.003	15.3%
							Total	664	2.074	1.725	0.350	16.9%
4	8-Sep	Thurs	16	Valley C	53 min	98.0						
							100%	21,913	82.950	60.256	22.694	27.4%
							67%	1,437	4.958	4.010	0.948	19.1%
							50%	412	1.527	1.372	0.155	10.2%
							Total	23,762	89.434	65.638	23.797	26.6%

4.2.2 Small commercial SDP load impacts

Table 4-6 summarizes estimated small commercial per-customer load impact results from the regression analysis described in Section 3, applied to 15-minute load data. Results are shown for both Valley C events, by cycling strategy and on average for all participants. Estimated load impacts are statistically significant for three of the four event/cycling-strategies, as shown by *t*-statistics and numbers in bold. Statistically significant estimated load impacts per customer range from 4.3 kWh/hr to 4.8 kWh/hr, representing percentage load reductions of 13 to 18 percent. Estimated load impacts per AC ton, shown in the last column, are reasonably consistent across the two events (e.g., both values are larger on the hotter September 8 event, and the 100 percent cycling value is greater than that for partial cycling), and are also similar to the estimates for residential SDP customers shown in Table 4-4.

Table 4-6: Estimated Small Commercial SDP Load Impacts by Event and Cycling Strategy – *Per-Customer*

Evt	Date	Day	Start	Restore	Dur.	Tmp	Strategy	Partic.	Est. Ref. Load (kWh/hr)	Obs. Load (kWh/hr)	Est. Load Impact (kWh/hr)	% Load Impact	t-stat	LI / AC Ton
1	26-Jul	Tues	14:03	14:30	27 min	88.3								
							100%	56	24.7	20.4	**4.28**	**17.3%**	**3.6**	0.22
							Partial	25	35.9	33.5	2.36	6.6%	1.3	0.08
							Total/Ave.	81	28.1	24.4	3.68	13.1%		0.16
2	8-Sep	Thurs	15:00	15:53	53 min	98.0								
							100%	58	26.1	21.3	**4.79**	**18.3%**	**3.9**	0.25
							Partial	27	33.3	29.0	**4.34**	**13.0%**	**2.2**	0.14
							Total/Ave.	85	28.4	23.8	4.65	16.4%		0.20

Similar to the case of residential load impacts, we can provide information on the uncertainty around the estimated load impacts using the variances of the estimated event-hour coefficients. We calculate average standard errors as a percent of the reference load to be about 5 percent for both events. That is, both the 16.5 percent overall average load impact for the September 8 event, where the load impacts are estimated more precisely, and the 13.3 percent load impact for the July 26 event have standard errors of about 5 percent.

Figures 4-19 and 4-20 show the hourly pattern of the estimated load impact coefficients on those two event days. Figure 4-19 shows substantial load reductions in all four quarter hours of the nearly hour-long event on September 8. Figure 4-20 shows load reductions in the second and third quarter hour within HE 15, with the reduction for the 100% (Full) cycling strategy substantially larger than that for the partial strategy. Note that the coefficients, which are based on the 15-minute load data, are in units of kWh/15-minutes, and are thus one-fourth the magnitude of the values in Table 4-6, which have been converted to units of kWh/hour.

Figure 4-19: Estimated Small Commercial Load Impacts, by Cycling Strategy – *September 8 Event (kWh/15-minutes)*

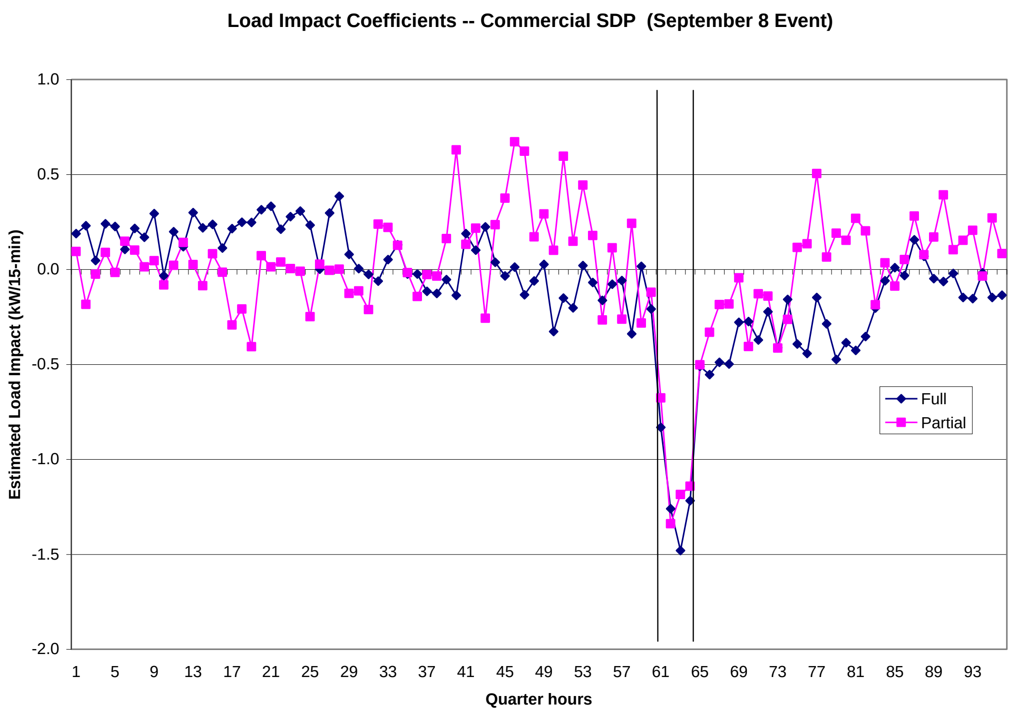


Figure 4-20: Estimated Small Commercial Load Impacts, by Cycling Strategy – *July 26 Event*

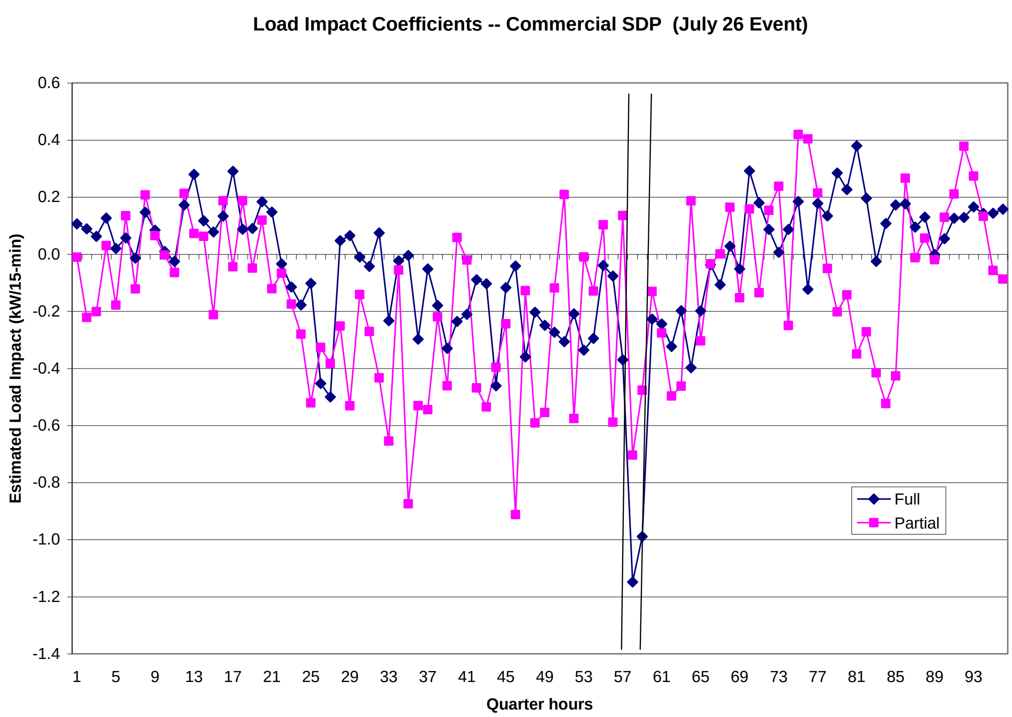


Table 4-7 expands the per-customer results to the program level, as represented by the approximately 90 commercial customers with SmartConnect data, and reports loads and load impacts in units of MWh/hr. Total load impacts are about 0.3 MW for the July 26 event, and 0.4 MW for the September 8 event.

Table 4-7: Estimated Small Commercial SDP Load Impacts by Cycling Strategy – *Program Level*

Evt	Date	Day	Start	Restore	Dur.	Tmp	Strategy	Partic.	Est. Ref. Load (MWh/hr)	Obs. Load (MWh/hr)	Est. Load Impact (MWh/hr)	% Load Impact
1	26-Jul	Tues	14:03	14:30	27 min	88.3						
							100%	56	1.38	1.14	0.24	17.3%
							Partial	25	0.90	0.84	0.06	6.6%
							Total	81	2.28	1.98	0.30	13.1%
2	8-Sep	Thurs	15:00	15:53	53 min	98.0						
							100%	58	1.52	1.24	0.28	18.3%
							Partial	27	0.90	0.78	0.12	13.0%
							Total	85	2.42	2.02	0.40	16.4%

We conducted additional analyses to explore the relationship between load impacts estimated with 15-minute data and those estimated with hourly data, with the objective of potentially applying information on that relationship to the residential load impact estimates, for which only hourly data are available. We restricted this analysis to commercial customers with AC tonnage of less than 15 to best approximate conditions in residential households.

Table 4-8 shows estimated load impacts for the smaller commercial customers for both Valley C events, showing results using 15-minute load data in the first panel and hourly data in the second panel. Focusing on the July 26 half-hour event (the estimates for the hour-long event on September 8 are essentially identical), the kWh/hour load impacts estimated using hourly data are about 62 and 35 percent of the estimates based on 15-minute data, for the 100% and partial cycling strategy customers respectively. These values are shown in Table 4-9. As described in the previous section, these values were used to adjust the estimated residential SDP load impacts for the half-hour events.

Table 4-8: Estimated Load Impacts for Low–AC-Tonnage Small Commercial SDP Customers by Cycling Strategy – *Per-Customer*

Evt	Date	Day of Week	Start	Restore	Duration	Temp.	Strategy	Partic.	Estimated Reference Load (kWh/hr)	Observed Load (kWh/hr)	Estimated Load Impact (kWh/hr)	% Load Impact	t-stat
Data: 15-minute													
1	26-Jul	Tues	14:03	14:30	27 min	88.3							
							100%	34	18.4	16.0	**2.48**	**13.5%**	**2.9**
							Partial	10	22.6	20.7	1.91	8.4%	1.1
2	8-Sep	Thurs	15:00	15:53	53 min	98.0							
							100%	36	19.6	16.8	**2.71**	**13.9%**	**3.1**
							Partial	11	23.8	20.4	**3.43**	**14.4%**	**2.0**
Data: Hourly													
1	26-Jul	Tues	14:03	14:30	27 min	88.3							
							100%	34	18.3	16.8	**1.53**	**8.3%**	**2.0**
							Partial	10	21.8	21.1	0.66	3.0%	0.5
2	8-Sep	Thurs	15:00	15:53	53 min	98.0							
							100%	36	19.6	16.8	**2.71**	**13.9%**	**3.4**
							Partial	11	23.8	20.4	**3.43**	**14.4%**	**2.5**

Table 4-9: Relationship between Estimated Load Impacts Using 15-Minute and Hourly Load Data *(Low–AC-Tonnage Small Commercial SDP Customers, by Cycling Strategy)*

Data	Estimated Load Impact (kWh/hr)	
	100%	**Partial**
15-min	2.48	1.91
Hourly	1.53	0.66
Ratio	62%	35%

4.2.3 Large commercial SDP load impacts

Table 4-10 summarizes estimated load impacts per customer for the large commercial customers from the regression analysis described in Section 3, applied to 15-minute load data. Results, which are scaled to units of kWh per hour[21], are shown for each event for the indicated A-Bank, and are distinguished by customers who selected the full or partial cycling strategy. Information is shown for a number of factors, including day of week, the quarter hours in which events occurred, average temperature in the late afternoon period (HE 13-18) in which all events were called, and the number of participants in each group. The last six columns contain estimated reference load, observed load, estimated load impact, percentage load impact, the average *t*-statistic associated with the estimated load impacts, and load impact per AC ton.

Estimated load impacts are statistically significant at the 90 percent level for seven of the eighteen event/cycling-strategies, as shown by bold *t*-statistic values, and are nearly significant (*t*-statistic greater than 1.5) in four other cases. Statistically significant load impact estimates per customer range from about 100 kWh/hr to 180 kWh/hr, representing

[21] The 15-minute load data represent energy consumed within that interval. To convert those values to the rate of usage per hour, we multiply the 15-minute values, including load impact estimates, by a factor of 4.

percentage load reductions of about 13 to 32 percent. Estimated load impacts per AC ton, shown in the last column, are reasonably consistent across the statistically significant estimates, ranging from about 0.6 to 1.3 kW. These values are somewhat higher than the estimates for residential and small commercial SDP customers shown above.

Table 4-10: Estimated Large Commercial SDP Load Impacts (kW) by Event – *Per-Customer*

Evt	Date	Day	A-Bank	Time (QE)	Tmp	Strategy	Partic	Est. Ref. Load (kWh/hr)	Obs. Load (kWh/hr)	Est. Load Impact (kWh/hr)	% Load Impact	t-stat	LI / AC Ton (kW)
1	26-Jul	Tues	Valley C	58-59									
					88.3	100%	5	237	209	27.6	11.6%	0.90	0.18
					88.3	Partial	1	557	425	131.5	23.6%	**2.79**	0.94
						Total/Ave.	6	290	245	44.9	15.5%		0.30
2	3-Aug	Wed	Mira L	57-58									
					97.0	100%	7	1,437	1,431	6.6	0.5%	0.18	0.07
						Partial							
						Total/Ave.	7	1,437	1,431	6.6	0.5%		0.07
3	8-Aug	Mon	Chino	53-54									
					86.4	100%	6	465	383	82.0	17.6%	1.12	0.37
					87.2	Partial	5	559	379	179.7	32.2%	**2.27**	0.60
						Total/Ave.	11	508	381	126.4	24.9%		0.50
4	18-Aug	Thur	Walnut	57-58									
					87.3	100%	31	1,158	1,001	156.3	13.5%	**2.62**	0.62
					87.3	Partial	1	794	674	119.6	15.1%	1.65	0.51
						Total/Ave.	32	1,146	991	155.2	13.5%		0.62
5	26-Aug	Fri	Villa Pk	61-62									
					87.9	100%	32	465	359	106.3	22.8%	1.81	0.73
					85.2	Partial	5	290	246	44.2	15.2%	1.24	0.44
						Total/Ave.	37	442	344	97.9	22.2%		0.70
6	30-Aug	Tues	Mira L	61-62									
					93.1	100%	7	1,467	1,418	49.0	3.3%	1.33	0.54
						Partial							
						Total/Ave.	7	1,467	1,418	49.0	3.3%		0.54
7	6-Sep	Tues	Chino	63-64									
					96.6	100%	6	894	781	113.2	12.7%	1.53	0.51
					96.9	Partial	5	899	853	46.3	5.2%	0.58	0.16
						Total/Ave.	11	897	814	82.8	9.2%		0.32
8	8-Sep	Thurs	Valley C	61-64									
					98.0	100%	5	451	353	98.5	21.8%	**3.16**	0.65
					98.0	Partial	1	716	531	184.7	25.8%	**3.83**	1.32
						Total/Ave.	6	496	383	112.9	22.8%		0.75
9	20-Sep	Tues	Walnut	61-62									
					80.3	100%	31	1,201	1,059	142.1	11.8%	**2.36**	0.56
					80.3	Partial	1	910	724	185.7	20.4%	**2.55**	0.80
						Total/Ave.	32	1,192	1,049	143.4	12.0%		0.57
10	29-Sep	Thurs	Villa Pk	61-64									
					75.2	100%	32	360	296	63.8	17.7%	1.59	0.44
					72.8	Partial	5	278	247	30.4	10.9%	1.27	0.30
						Total/Ave.	37	349	290	59.3	17.0%		0.42

Figures 4-21 through 4-24 show the hourly patterns of the estimated load impact coefficients for the average customer on each cycling strategy for the four event days that applied to the two A-Banks associated with the greatest number of customers – Walnut and Villa Park. Figure 4-21 illustrates load reductions in quarter hours-ending 57-58 for the August 18 event for Walnut, while Figure 4-22 shows load reductions in QE 61-62 for the August 26 event for Villa Park. Note that the coefficients, which are based on the 15-minute load data, are in units of kWh/15-minutes, and are thus one-fourth the magnitude of the values in Table 4-10, which have been converted to units of kWh/hour (and also follow the convention of reporting load reductions as positive values).

Figure 4-21: Estimated Large Commercial Load Impacts, by Cycling Strategy – ***August 18 Event (QE 57-58); Walnut***

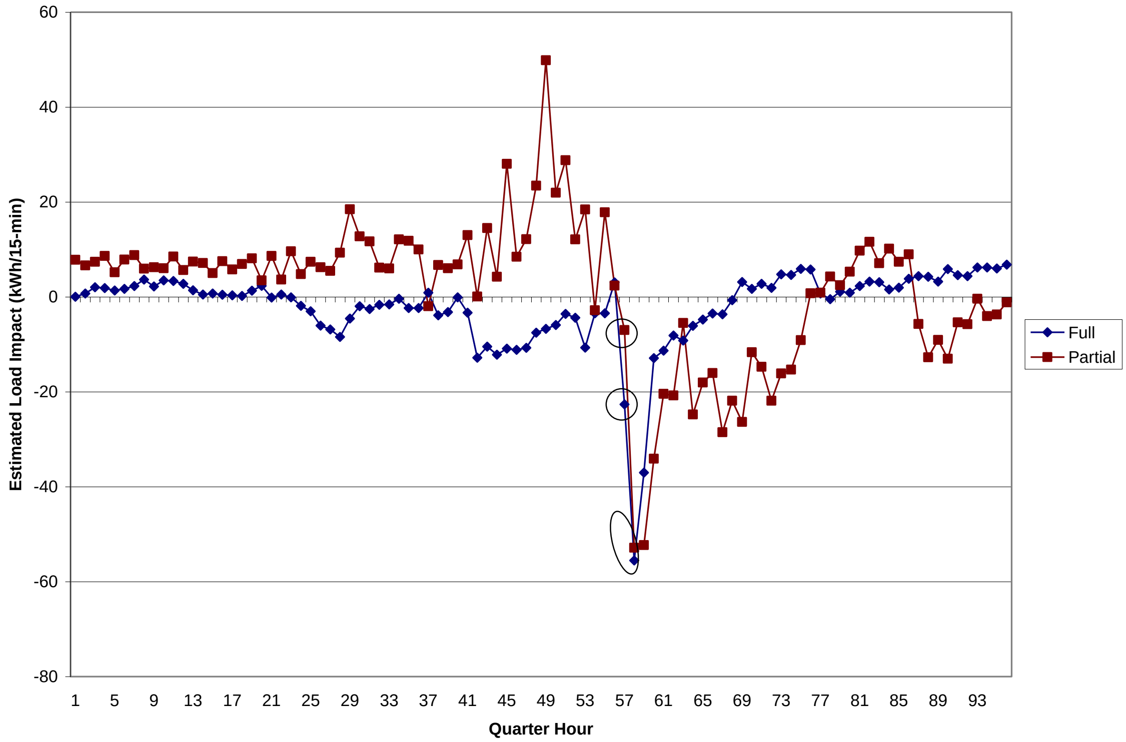


Figure 4-22: Estimated Large Commercial Load Impacts, by Cycling Strategy – ***August 26 Event (QE 61-62); Villa Park***

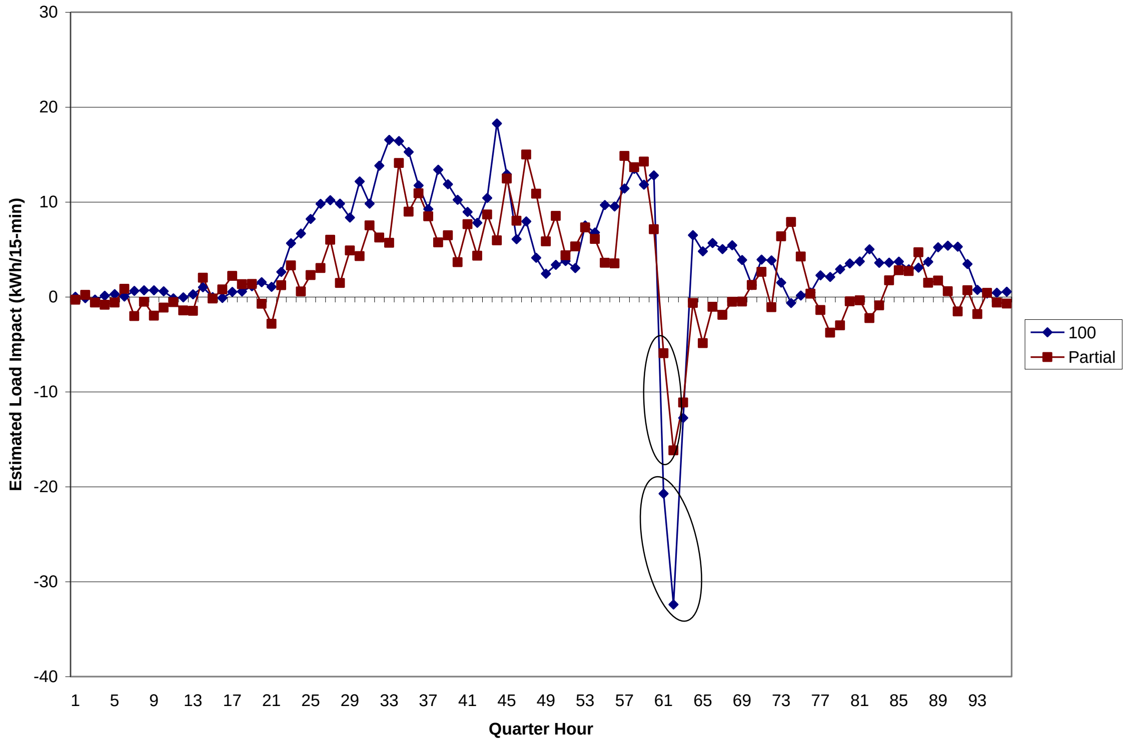


Figure 4-23 shows load reductions in QE 61-62 for Walnut on September 20, while Figure 4-24 shows load reductions in QE 61-64 for the hour-long Villa Park event on September 29.

Figure 4-23: Estimated Large Commercial Load Impacts, by Cycling Strategy – ***September 20 Event (QE 61-62); Walnut***

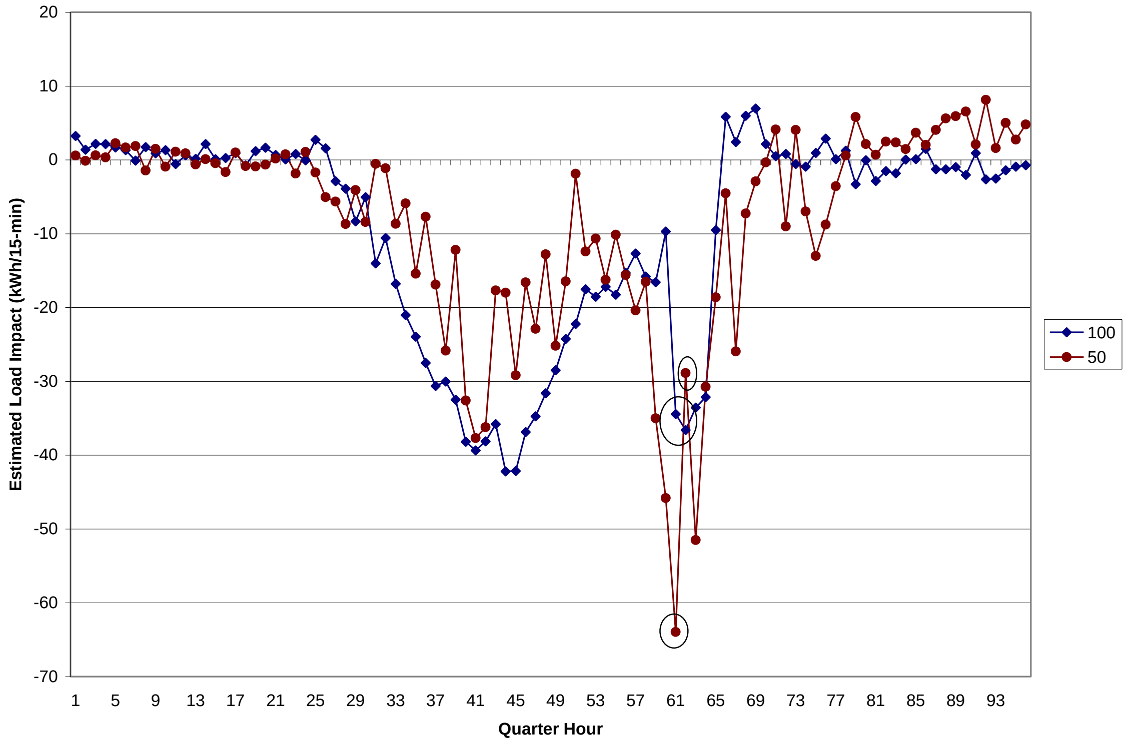


Figure 4-24: Estimated Large Commercial Load Impacts, by Cycling Strategy – ***September 29 Event (QE 61-64); Villa Park***

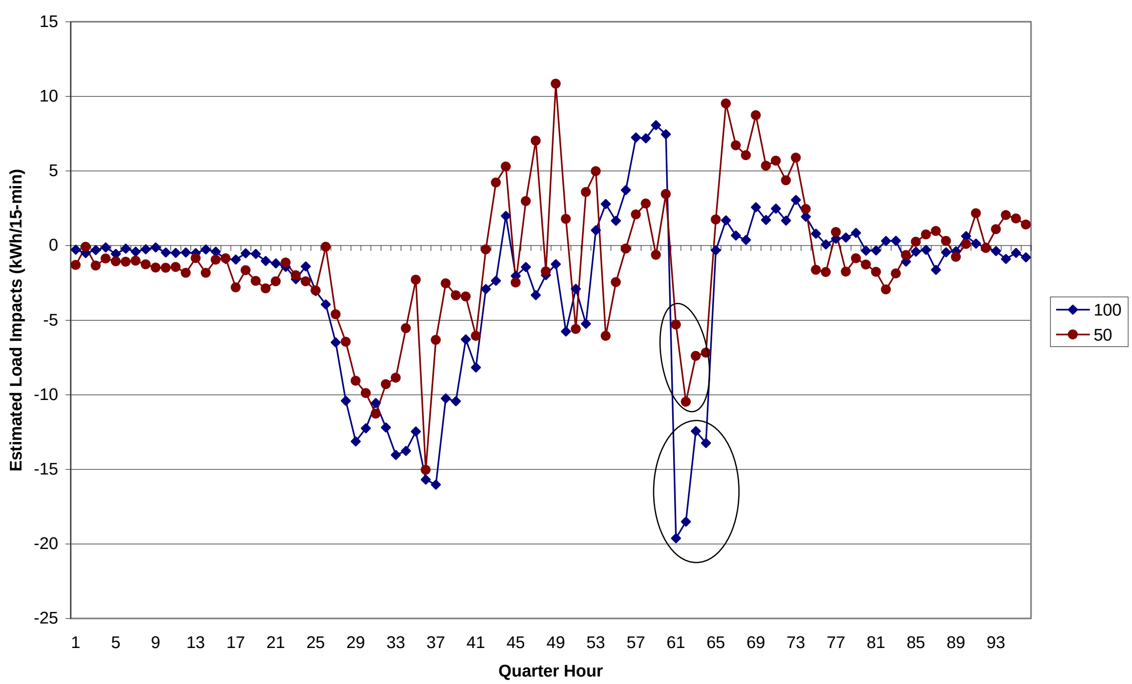


Table 4.11 expands the per-customer results to the program level represented by this subset of large commercial customers. It does so by multiplying per-customer results by the number of customer accounts participating in each event and reporting load values in units of MWh per hour, or MW. Estimated overall load impacts range across events from about 0.05 MW to 0.4 MW for events associated with relatively few participants (e.g., Valley C, Mira Loma, and Chino), and from 2 MW to 5 MW for events for A-Banks associated with more than thirty participants (Villa Park and Walnut). In the latter two cases in particular, load impacts appear to vary by temperature level; they are higher for events 4 and 5, for which afternoon average temperatures averaged about 87 degrees, than for events 9 and 10, which both occurred on more moderate days.

Table 4-11: Estimated Large Commercial SDP Load Impacts (MW) by Event – *Program Level*

Evt	Date	Day	A-Bank	Time (QE)	Tmp	Strategy	Partic	Est. Ref. Load (MWh/hr)	Obs. Load (MWh/hr)	Est. Load Impact (MWh/hr)	% Load Impact
1	26-Jul	Tues	Valley C	58-59							
					88.3	100%	5	1.18	1.05	0.14	11.6%
					88.3	Partial	1	0.56	0.43	0.13	23.6%
						Total/Ave.	6	1.74	1.47	0.27	15.5%
2	3-Aug	Wed	Mira L	57-58							
					97.0	100%	7	10.06	10.02	0.05	0.5%
						Partial					
						Total/Ave.	7	10.06	10.02	0.05	0.5%
3	8-Aug	Mon	Chino	53-54							
					86.4	100%	6	2.79	2.30	0.49	17.6%
					87.2	Partial	5	2.79	1.89	0.90	32.2%
						Total/Ave.	11	5.58	4.19	1.39	24.9%
4	18-Aug	Thur	Walnut	57-58							
					87.3	100%	31	35.89	31.04	4.85	13.5%
					87.3	Partial	1	0.79	0.67	0.12	15.1%
						Total/Ave.	32	36.68	31.71	4.97	13.5%
5	26-Aug	Fri	Villa Pk	61-62							
					87.9	100%	32	14.89	11.49	3.40	22.8%
					85.2	Partial	5	1.45	1.23	0.22	15.2%
						Total/Ave.	37	16.34	12.72	3.62	22.2%
6	30-Aug	Tues	Mira L	61-62							
					93.1	100%	7	10.27	9.93	0.34	3.3%
						Partial					
						Total/Ave.	7	10.27	9.93	0.34	3.3%
7	6-Sep	Tues	Chino	63-64							
					96.6	100%	6	5.37	4.69	0.68	12.7%
					96.9	Partial	5	4.50	4.26	0.23	5.2%
						Total/Ave.	11	9.86	8.95	0.91	9.2%
8	8-Sep	Thurs	Valley C	61-64							
					98.0	100%	5	2.26	1.76	0.49	21.8%
					98.0	Partial	1	0.72	0.53	0.18	25.8%
						Total/Ave.	6	2.97	2.30	0.68	22.8%
9	20-Sep	Tues	Walnut	61-62							
					80.3	100%	31	37.24	32.84	4.40	11.8%
					80.3	Partial	1	0.91	0.72	0.19	20.4%
						Total/Ave.	32	38.15	33.56	4.59	12.0%
10	29-Sep	Thurs	Villa Pk	61-64							
					75.2	100%	32	11.52	9.48	2.04	17.7%
					72.8	Partial	5	1.39	1.24	0.15	10.9%
						Total/Ave.	37	12.91	10.72	2.19	17.0%

4.3 Hourly Loads and Load Impacts

This section illustrates hourly load impacts for several of the 2011 SDP events, for the residential, small commercial and large commercial SDP participants covered by this study. The loads and load impacts, including uncertainty ranges, are in the format required by the DR Protocols. Tables for all events and cycling strategies are provided in table generator spreadsheets listed in the Appendix.

4.3.1 Residential SDP

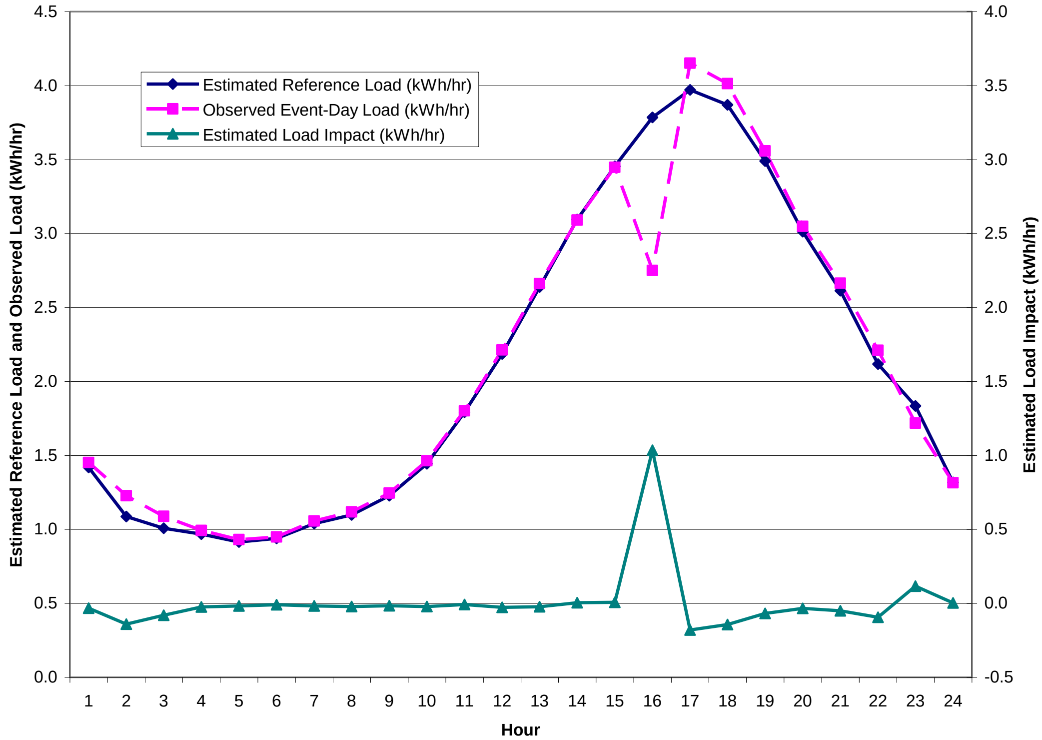
Table 4-12 shows results for the September 8 Valley C event, for the 100 percent cycling strategy which most of the residential participants for whom SmartConnect data were available experienced. The values represent program-level results (in units of MWh/hour) after applying the number of participants in the relevant area/strategy group to the per-customer estimates. The first four columns show the estimated reference load, observed event-day load, estimated load impact, and temperature for each hour. The next five columns report uncertainty-adjusted load impacts at the 10th, 30th, 50th, 70th and 90th percentile, based on variances of the estimated load impact coefficients. For the event shown, the 10th and 90th percentile values range only 0.1 percent above and below the estimated load impact of 27.4 percent.

Table 4-12: Loads and Load Impacts – Residential SDP; Valley C; 100% Cycling Strategy; September 8 Event; *Program Level*

Hour Ending	Estimated Reference Load (MWh/hr)	Observed Event-Day Load (MWh/hr)	Estimated Load Impact (MWh/hr)	Average Temperature (°F)	Uncertainty Adjusted Impact (MWh/hr) - Percentiles				
					10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
1	31.1	31.8	-0.7	77.0	-0.7	-0.7	-0.7	-0.7	-0.7
2	23.8	26.9	-3.1	75.9	-3.1	-3.1	-3.1	-3.1	-3.1
3	22.1	23.9	-1.8	74.0	-1.8	-1.8	-1.8	-1.8	-1.7
4	21.2	21.7	-0.5	72.3	-0.6	-0.5	-0.5	-0.5	-0.5
5	20.0	20.4	-0.4	72.3	-0.4	-0.4	-0.4	-0.4	-0.4
6	20.6	20.8	-0.2	69.7	-0.2	-0.2	-0.2	-0.2	-0.2
7	22.8	23.1	-0.4	72.2	-0.4	-0.4	-0.4	-0.4	-0.4
8	24.0	24.5	-0.5	78.5	-0.5	-0.5	-0.5	-0.5	-0.4
9	26.9	27.3	-0.4	84.9	-0.4	-0.4	-0.4	-0.4	-0.3
10	31.6	32.1	-0.5	91.0	-0.5	-0.5	-0.5	-0.5	-0.4
11	39.3	39.5	-0.2	95.5	-0.2	-0.2	-0.2	-0.2	-0.2
12	47.9	48.5	-0.6	97.7	-0.6	-0.6	-0.6	-0.6	-0.6
13	57.8	58.3	-0.5	99.6	-0.5	-0.5	-0.5	-0.5	-0.5
14	67.8	67.7	0.1	100.2	0.1	0.1	0.1	0.1	0.1
15	75.7	75.5	0.1	100.1	0.1	0.1	0.1	0.2	0.2
16	82.9	60.3	22.7	99.1	22.7	22.7	22.7	22.7	22.7
17	87.0	91.0	-4.0	97.4	-4.0	-4.0	-4.0	-3.9	-3.9
18	84.8	87.9	-3.1	91.3	-3.2	-3.1	-3.1	-3.1	-3.1
19	76.5	78.0	-1.5	84.3	-1.5	-1.5	-1.5	-1.5	-1.5
20	66.0	66.8	-0.8	80.1	-0.8	-0.8	-0.8	-0.7	-0.7
21	57.3	58.4	-1.1	77.3	-1.1	-1.1	-1.1	-1.1	-1.1
22	46.4	48.4	-2.1	74.9	-2.1	-2.1	-2.1	-2.0	-2.0
23	40.2	37.7	2.5	72.6	2.5	2.5	2.5	2.6	2.6
24	28.9	28.8	0.1	70.5	0.0	0.1	0.1	0.1	0.1
	Reference Energy Use	Event-Day Energy Use	Change in Energy Use	Hours (Base 75° F)	Uncertainty Adjusted Impact (MWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
Daily	1,103	1,099	3.4	229.9	n/a	n/a	n/a	n/a	n/a

Figure 4-25 illustrates the loads and load impacts for the same event as in Table 4-12, but on a per-customer basis. The load reduction for the one-hour event is followed by small increases in usage over the next several hours.

Figure 4-25: Loads and Load Impacts – Residential SDP; Valley C; 100% Cycling Strategy; September 8 Event; *Per-Customer Level*



4.3.2 Small commercial SDP

Table 4-13 shows hourly loads and load impacts for small commercial SDP for the September 8 Valley C event, for the 58 participants choosing the 100 percent cycling strategy. The values represent program-level results (in units of kWh/hour) after applying the number of participants in the area/strategy group to the per-customer estimates. The 10^{th} and 90^{th} percentile values range 4.1 percent above and below the estimated load impact of 17.7 percent.[22]

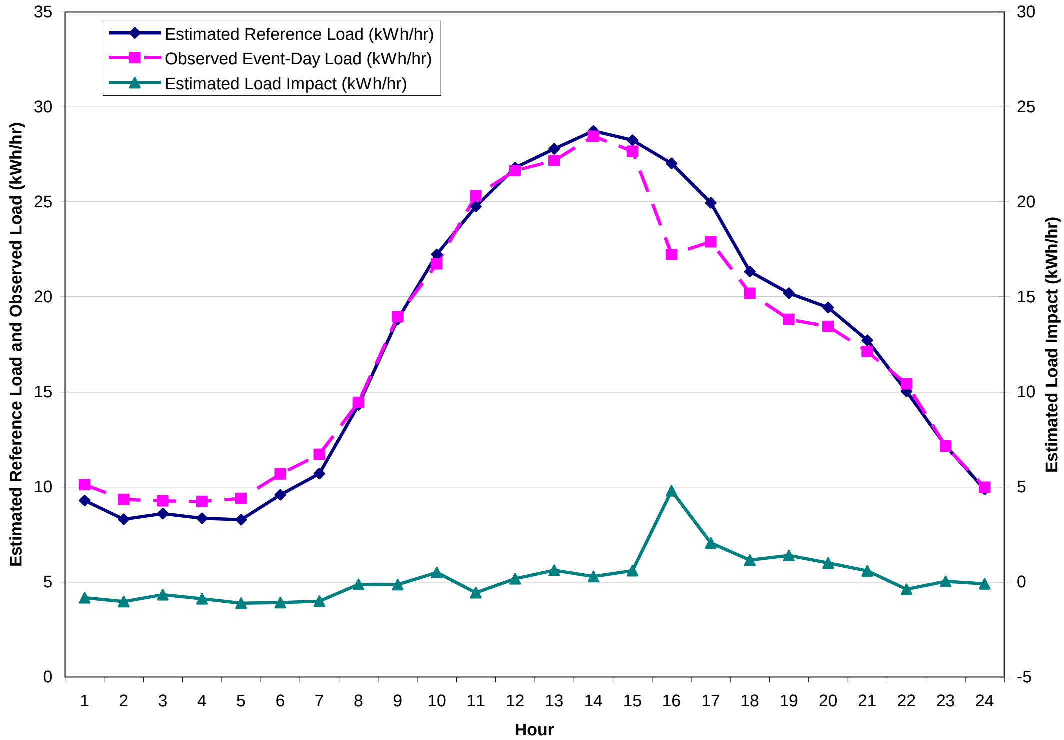
[22] For convenience of presentation, the table and figure are based on estimates using hourly data, rather than the 15-minute data used in reporting average event period load impacts in Table 4-6. For the hour-long September 8 event, there is no difference in the average estimated load impact for the full hour.

Table 4-13: Loads and Load Impacts – Small Commercial SDP; Valley C; 100% Cycling Strategy; September 8 Event; *Program Level*

Hour Ending	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
1	538.5	586.4	-47.9	77.0	-59.1	-52.5	-47.9	-43.4	-36.8
2	481.3	541.4	-60.0	75.9	-72.8	-65.3	-60.0	-54.8	-47.3
3	498.5	537.6	-39.1	74.0	-51.3	-44.1	-39.1	-34.1	-26.8
4	484.1	535.2	-51.0	72.3	-62.4	-55.7	-51.0	-46.4	-39.7
5	480.1	544.9	-64.7	72.3	-76.1	-69.4	-64.7	-60.1	-53.4
6	556.1	619.1	-63.1	69.7	-74.4	-67.7	-63.1	-58.4	-51.7
7	620.8	679.4	-58.6	72.2	-70.0	-63.3	-58.6	-54.0	-47.2
8	830.2	837.7	-7.4	78.5	-18.8	-12.1	-7.4	-2.8	3.9
9	1,091.3	1,099.1	-7.8	84.9	-19.2	-12.5	-7.8	-3.2	3.5
10	1,289.9	1,260.8	29.1	91.0	17.8	24.5	29.1	33.8	40.5
11	1,436.1	1,468.8	-32.7	95.5	-44.1	-37.4	-32.7	-28.1	-21.3
12	1,554.7	1,545.2	9.5	97.7	-1.9	4.8	9.5	14.1	20.9
13	1,611.6	1,575.9	35.7	99.6	24.3	31.1	35.7	40.4	47.1
14	1,666.7	1,649.9	16.8	100.2	5.5	12.2	16.8	21.5	28.2
15	1,638.5	1,604.3	34.2	100.1	22.9	29.6	34.2	38.9	45.6
16	1,567.1	1,289.3	277.9	99.1	266.5	273.2	277.9	282.5	289.2
17	1,446.8	1,327.8	119.0	97.4	107.7	114.4	119.0	123.7	130.4
18	1,237.3	1,170.8	66.5	91.3	55.1	61.8	66.5	71.1	77.8
19	1,171.6	1,091.0	80.6	84.3	69.2	75.9	80.6	85.2	91.9
20	1,127.5	1,069.6	57.9	80.1	46.3	53.2	57.9	62.7	69.5
21	1,027.4	993.3	34.1	77.3	22.0	29.1	34.1	39.0	46.1
22	871.6	894.2	-22.6	74.9	-36.3	-28.2	-22.6	-17.0	-8.9
23	705.7	704.1	1.5	72.6	-12.4	-4.2	1.5	7.2	15.4
24	572.7	578.4	-5.7	70.5	-19.7	-11.4	-5.7	0.1	8.4
	Reference Energy Use	Event-Day Energy Use	Change in Energy Use	Hours (Base 75° F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
Daily	24,506	24,204	302.1	229.9	n/a	n/a	n/a	n/a	n/a

Figure 4-26 illustrates the loads and load impacts for the same event as in Table 4-13, but on a per-customer basis. In contrast to the residential case, the load reduction for the one-hour event in HE 16 is followed by additional reductions in usage over the next several hours.

Figure 4-26: Loads and Load Impacts – Small Commercial SDP; Valley C; 100% Cycling Strategy; September 8 Event; *Per-Customer Level*



4.3.3 Large commercial SDP

Tables 4-14 and 4-15 show quarter-hourly loads and load impacts for large commercial SDP for two events for Walnut and Villa Park, with which the largest number of customers are associated. Table 4-14 shows results for the August 18 event for Walnut for the 31 participants choosing the 100 percent cycling strategy. In this case the values represent customer-level results (in units of kWh/hour), and for space reasons are shown only for the afternoon hours from noon to 6 p.m. (HE 13 to 18). The event period of QE 57-58 is highlighted. The 10^{th} and 90^{th} percentile values range 8.8 percent above and below the average load impact of 13.5 percent across the two quarter hours.

Table 4-14: Loads and Load Impacts – Large Commercial SDP; Walnut; 100% Cycling Strategy; August 18 Event (QE 57-58); *Per-Customer Level*

Interval Ending	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Average Temp. (°F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
49	1,064.9	1,038.1	26.8	86.2	13.2	21.2	26.8	32.4	40.5
50	1,078.3	1,054.7	23.6	86.2	10.0	18.1	23.6	29.2	37.3
51	1,080.5	1,066.3	14.2	86.2	0.6	8.6	14.2	19.8	27.9
52	1,090.9	1,073.5	17.5	86.2	3.8	11.9	17.5	23.1	31.1
53	1,121.5	1,078.8	42.7	88.6	29.1	37.1	42.7	48.3	56.4
54	1,128.4	1,114.5	13.8	88.6	0.2	8.2	13.8	19.4	27.5
55	1,134.3	1,120.4	13.8	88.6	0.2	8.2	13.8	19.4	27.5
56	1,119.5	1,131.9	-12.3	88.6	-26.0	-17.9	-12.3	-6.7	1.4
57	1,161.3	1,070.8	90.5	89.9	76.8	84.9	90.5	96.1	104.2
58	1,153.9	931.8	222.1	89.9	208.4	216.5	222.1	227.7	235.8
59	1,128.6	980.5	148.1	89.9	134.3	142.4	148.1	153.7	161.8
60	1,136.4	1,084.8	51.6	89.9	37.9	46.0	51.6	57.2	65.3
61	1,074.6	1,029.4	45.2	88.8	31.6	39.7	45.2	50.8	58.9
62	1,030.6	998.0	32.6	88.8	18.9	27.0	32.6	38.2	46.2
63	992.1	955.4	36.7	88.8	23.1	31.1	36.7	42.3	50.4
64	954.0	929.8	24.3	88.8	10.6	18.7	24.3	29.9	37.9
65	892.6	873.5	19.1	86.8	5.3	13.4	19.1	24.7	32.8
66	865.0	851.0	13.9	86.8	0.1	8.3	13.9	19.6	27.7
67	821.6	806.9	14.7	86.8	0.9	9.1	14.7	20.4	28.5
68	790.7	788.0	2.7	86.8	-11.1	-2.9	2.7	8.4	16.5
69	738.8	751.3	-12.6	83.5	-26.5	-18.3	-12.6	-6.9	1.4
70	689.3	696.2	-6.9	83.5	-20.8	-12.6	-6.9	-1.2	7.1
71	654.7	665.8	-11.0	83.5	-25.0	-16.7	-11.0	-5.3	2.9
72	639.6	647.3	-7.7	83.5	-21.6	-13.4	-7.7	-2.0	6.3
	Reference Energy Use	Observed Event-Day Energy Use	Change in Energy Use	Cooling Degree Hours (Base 75o F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
Daily	23,542	22,739	803.7	295.2	n/a	n/a	n/a	n/a	n/a

Figure 4-27 illustrates the loads and load impacts in Table 4-14. Note the unexpectedly low estimated load reduction in the first interval of the event, and the continuation of the load reduction into the interval following the event (QE 59). Both suggest a possible delay in the actual dispatch of the event.

Figure 4-27: Loads and Load Impacts – Large Commercial SDP; Walnut; 100% Cycling Strategy; August 18 Event (QE 57-58); *Per-Customer Level*

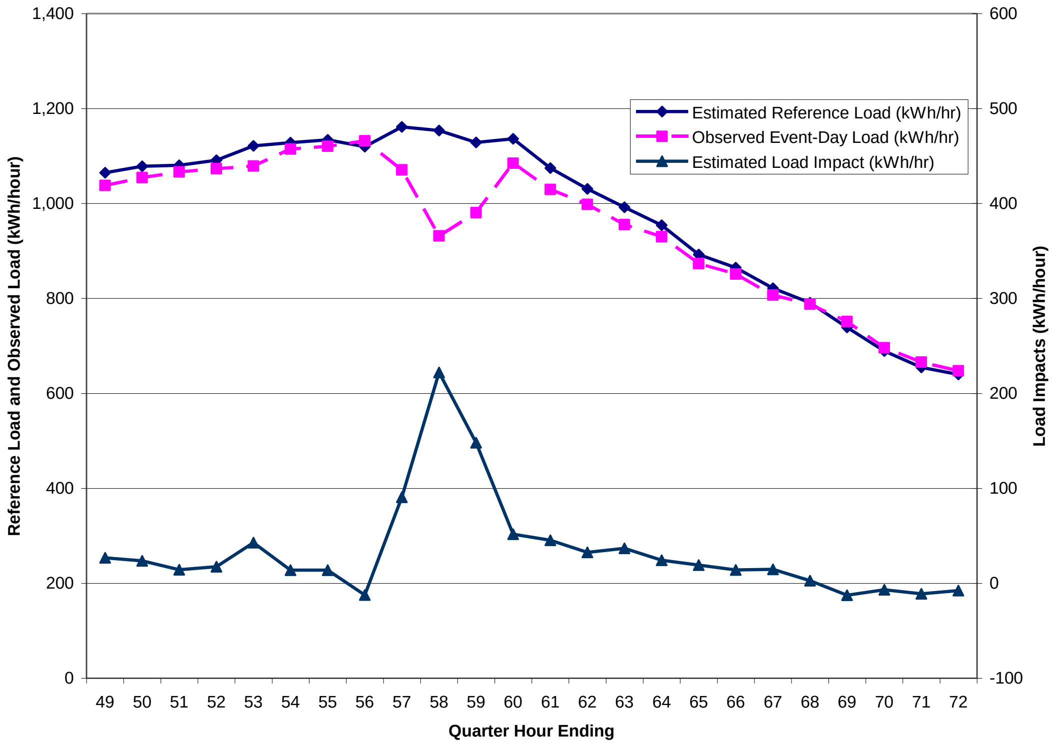


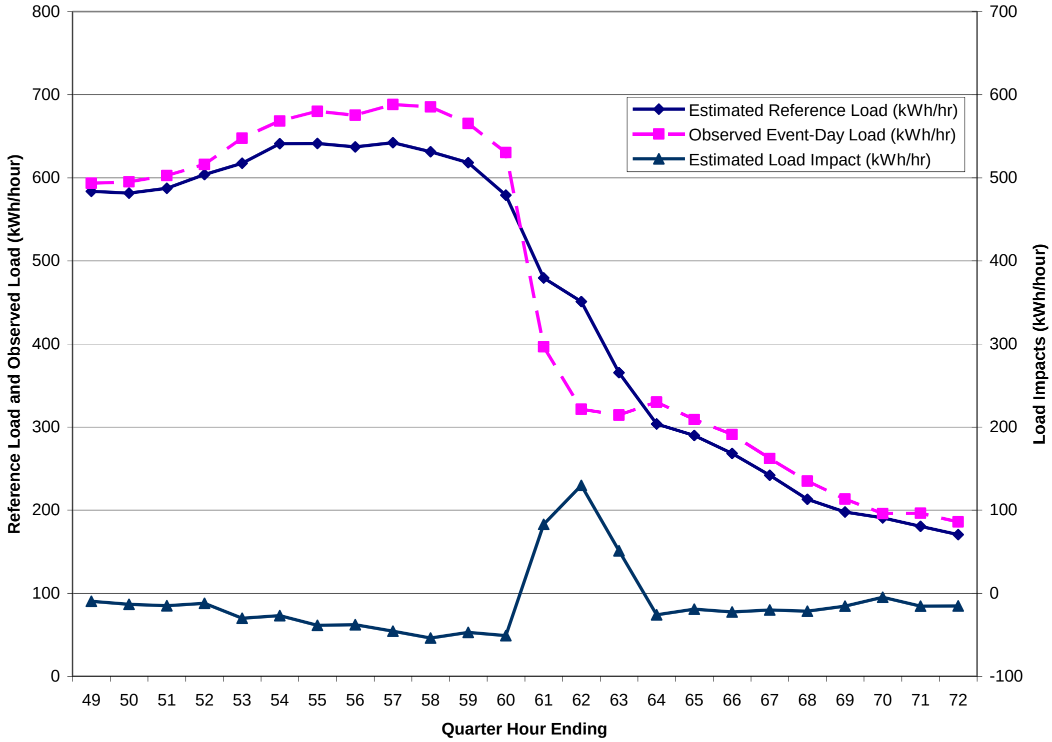
Table 4-15 shows results for the August 26 event for Villa Park, for the 32 participants choosing the 100 percent cycling strategy. The event period in this case is QE 61-62. The 10th and 90th percentile values range 12.5 percent above and below the average load impact of 22.8 percent across the two quarter hours.

Table 4-15: Loads and Load Impacts – Large Commercial SDP; Villa Park; 100% Cycling Strategy; August 26 Event (QE 61-62); *Per-Customer Level*

Interval Ending	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Average Temp. (°F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
49	583.6	593.4	-9.8	90.3	-23.1	-15.2	-9.8	-4.4	3.4
50	581.5	595.0	-13.6	90.3	-26.8	-19.0	-13.6	-8.1	-0.3
51	587.3	602.5	-15.2	90.3	-28.4	-20.6	-15.2	-9.8	-1.9
52	603.9	616.0	-12.1	90.3	-25.4	-17.6	-12.1	-6.7	1.1
53	617.4	647.5	-30.1	89.5	-43.2	-35.5	-30.1	-24.8	-17.1
54	641.0	668.2	-27.2	89.5	-40.2	-32.5	-27.2	-21.8	-14.1
55	641.2	679.9	-38.7	89.5	-51.8	-44.1	-38.7	-33.4	-25.7
56	637.2	675.3	-38.1	89.5	-51.1	-43.4	-38.1	-32.7	-25.0
57	642.3	688.1	-45.7	87.4	-59.0	-51.1	-45.7	-40.3	-32.5
58	631.3	685.3	-54.0	87.4	-67.2	-59.4	-54.0	-48.6	-40.7
59	618.2	665.4	-47.3	87.4	-60.5	-52.7	-47.3	-41.9	-34.0
60	579.1	630.3	-51.2	87.4	-64.4	-56.6	-51.2	-45.8	-38.0
61	479.5	396.6	82.9	89.3	69.6	77.5	82.9	88.3	96.2
62	450.9	321.3	129.6	89.3	116.3	124.2	129.6	135.1	142.9
63	365.2	314.2	51.0	89.3	37.7	45.5	51.0	56.4	64.3
64	303.7	329.8	-26.0	89.3	-39.4	-31.5	-26.0	-20.6	-12.7
65	289.7	308.9	-19.2	88.3	-32.7	-24.7	-19.2	-13.7	-5.7
66	268.2	291.0	-22.7	88.3	-36.2	-28.3	-22.7	-17.2	-9.3
67	241.9	262.1	-20.2	88.3	-33.6	-25.7	-20.2	-14.6	-6.7
68	213.0	234.7	-21.8	88.3	-35.2	-27.3	-21.8	-16.2	-8.3
69	197.7	213.3	-15.5	82.3	-29.4	-21.2	-15.5	-9.9	-1.7
70	190.6	195.6	-5.0	82.3	-18.9	-10.7	-5.0	0.6	8.8
71	180.4	196.2	-15.8	82.3	-29.6	-21.4	-15.8	-10.1	-1.9
72	170.3	185.7	-15.4	82.3	-29.3	-21.1	-15.4	-9.8	-1.6
	Reference Energy Use	Observed Event-Day Energy Use	Change in Energy Use	Cooling Degree Hours (Base 75o F)	Uncertainty Adjusted Impact (kWh/hr) - Percentiles				
					10th	30th	50th	70th	90th
Daily	10,715	10,996	-281.1	308.5	n/a	n/a	n/a	n/a	n/a

Figure 4-28 illustrates the loads and load impacts in Table 4-15.

Figure 4-28: Loads and Load Impacts – Large Commercial SDP; Villa Park; 100% Cycling Strategy; August 26 Event (QE 61-62); *Per-Customer Level*



5. Validity Assessment

The validity of the results from this study may be assessed with regard to two factors. One has to do with how well the regression models fit the data, which in the case of this study is represented by day-to-day differences in the average loads of SDP participants grouped by location and cycling strategy chosen. Measures of goodness of fit are provided in Table 5-1. More than half of the R-squared values exceed 0.7 in value.

Table 5-1: R-Squared Values for Regression Equations, by Customer Type, A-Bank Area, and Cycling Strategy

A-Bank	Residential		Small Commercial		Large Commercial	
	Strategy (%)	R - Squared	Strategy (%)	R - Squared	Strategy (%)	R - Squared
Chino					Full	0.535
Chino					Partial	0.566
Mira Loma	100	0.757			Full	0.878
Mira Loma	67	0.666				
Mira Loma	50	0.414				
Valley C	100	0.819	Full	0.775	Full	0.453
Valley C	67	0.827	Partial	0.778	Partial	0.739
Valley C	50	0.821				
Villa Park					Full	0.556
Villa Park					Partial	0.675
Walnut					Full	0.859
Walnut					Partial	0.685

The other factor has to do with the precision and reliability of the estimated load impacts. One issue related to this factor for the residential portion of the analysis is that the duration of most of the SDP test events was 30 minutes or less, while the SmartConnect data available for the residential customers were hourly in resolution. As a result, the estimated load impacts for the one hourly event (on September 8), which was experienced by most of the residential SDP participants included in the study, may be viewed with considerable confidence. However, the estimated load impacts for the half-hour events understate the actual load reductions that occurred during the specific period of load control. We used information from analysis of a subset of the small commercial customers, using data at both hourly and 15-minute resolution, to construct factors for adjusting the residential load impacts for part-hour events. While the approach and magnitude of adjustment factors are reasonable, they are based on data for only one event, and no higher-resolution data for the residential customers are available for verification. In future years, this issue should be less of a factor, as more and longer (e.g., one-hour) events are planned.

6. Conclusions and Recommendations

This study is one of first to make use of interval load data from SCE's SmartConnect metering system in a load impact evaluation, and to apply the premise-level SmartConnect data to estimate load impacts from the Summer Discount Plan, a direct load control air conditioner cycling program. Previous evaluations of AC cycling programs have relied on data from direct installation of meters or data loggers on small samples of participants' AC units, or on estimates borrowed from other utilities. Load impacts were estimated for residential and small commercial SDP participants who experienced localized dispatch SDP test events in 2011, and who had begun receiving bills based on SmartConnect meters. Load impacts were also estimated for large commercial SDP participants, the majority of which were schools, using interval load data from interval data recorders (IDR) that have been in place for several years.

This study is limited by the design of the test events, by the fact that it covers only a portion of SDP participants due to limited interval meter data availability, and that many of the test events were a half-hour or less in duration. With the availability of only hourly interval data for the residential participants, estimated load impacts for part-hour events are under-stated. In those cases, we adjusted residential load impact estimates using factors based on the results for small commercial customers, using both 15-minute and hourly data. Both of these limitations should be resolved in future evaluations. Much more SmartConnect data will become available, and recommendations are to call more SDP events, presumably of longer duration, either through more test events or as a consequence of the transition of residential SDP to a price-based program.

Appendices

The following Appendices accompany this report. Each is an Excel file that can produce the ex post tables required by the Protocols.

Appendix A: SCE SDP Ex Post Protocol Tables Residential
Appendix B: SCE SDP Ex Post Protocol Tables Small Commercial
Appendix C: SCE SDP Ex Post Protocol Tables Large Commercial