2009 Impact Evaluation of San Diego Gas & Electric's Participating Load Pilot Program

Part 1. Ex Post Final Report

Steven D. Braithwait,
Daniel G. Hansen,
David A. Armstrong, and
Jess D. Reaser

September 17, 2010

Christensen Associates Energy Consulting, LLC
800 University Bay Drive, Suite 400
Madison, WI 53705
(608) 231-2266

Table of Contents

TABLES

Figures

Abstract

This report describes several analyses conducted in association with a load impact evaluation of San Diego Gas and Electric Company's ("SDG&E") Participating Load Pilot ("PLP") Program during the 2009 program year. These analyses include estimation of ex post load impacts for each PLP event, a summary and description of the 1-minute telemetry data collected for the two PLP aggregators, and an assessment of the performance of the "meter-before/meter-after" baseline method that is used by the California ISO (CAISO) to confirm performance during events.

PLP participants may enroll directly or through a Curtailment Service Provider (CSP), or aggregator. Participants (who may be aggregators) submit monthly nominations of load curtailment amounts. PLP load curtailments are bid into the CAISO *ancillary services* market as non-spinning reserves. If the CAISO awards Non-Spin capacity, it notifies the utility, who then notifies PLP participants that they are required to curtail load by the agreed-upon amounts within 10 minutes (including the time since notification of the utility by the CAISO). Telemetry data allow CAISO to observe participants' load curtailments through 1-minute observations on their loads. However, 15-minute load data are used for settlement purposes. Program load reductions for an event are calculated relative to participant baseline usage measured as the average load in the 5 minutes prior to the event, which in practice becomes the average load in the 15 minutes prior to the event because of data limitations.

Resources Covered

Two program-types were available to customers. One was available for interruption during any hour of any day, while the other limited interruptions to 11 a.m. to 7 p.m. on weekdays. Two aggregators participated in the daytime option and one large directly enrolled customer, who tended to operate only during overnight and early morning hours, participated in the 24-hour option, though effectively only in overnight hours. One of the aggregators signed up two customers, while the other signed up eight. Accounting for multiple meters at some sites, a total of 17 meters were included in the pilot, accounting for 13.4 MW of maximum demand. Of the twenty-two events, seven were called during overnight hours.

Methodology

The PLP ex post load impacts for program-year 2009 were estimated using separate econometric models (*i.e.*, regression equations) for each enrolled participant (*e.g.*, the two aggregators and the directly enrolled customer), based on historical customer load data for August through December of 2009. The models were estimated using 15-minute interval load data, and assuming that participants' quarter-hourly loads are functions of weather data, time-based variables such as quarter-hour, day of week, and month, and program event information (*e.g.*, the days and quarter-hours in which events were called).

Ex Post Load Impacts

Load impacts were estimated for each quarter-hour of each event, for the directly enrolled customer and the two aggregators. The overall average estimated load impact for the directly enrolled customer was 854 kW across the seven overnight events, while the comparable average across the two aggregators for the events in which they participated was 595 kW (One aggregator participated in 10 events in the months for which it nominated load reductions, while the other aggregator participated in all 15 day-time events).

Descriptive statistics

In general, the telemetry data and the corresponding 15-minute metered data series match quite closely for both aggregators. The telemetry data show greater variability, as expected, though they follow the same pattern as the 15-minute data. On some days, however, the telemetry data for one of the aggregators showed a tendency to oscillate between very low levels and the level suggested by the metered data.

Baseline assessment

The final portion of the study involved an assessment of the accuracy of the meter-before/ meter-after" (MBMA) baseline method, which is used to calculate load impacts in the PLP program. That is, the baseline for an event is established by the metered load in the 15-minute interval prior to the event, where each event was two hours in length.[1] Since data for only two PLP aggregators were available for conducting the baseline study, the analysis was expanded to include 15-minute interval load data for the aggregators that participated in an analogous short-response program, the day-of option of SDG&E's Capacity Bidding Program (CBP). In all, three classes of data were used in the baseline analysis: 1) CBP-DO aggregator load data for selected event-type days in June through September that were not CBP or CPP event days; 2) PLP aggregator load data for selected non-event days; and 3) PLP load data for the actual PLP events during the period August through December, 2009.

For the cases involving event-type days, five separate two-hour simulated-events were created over the time period from 10 a.m. to 7 p.m., and baseline accuracy was assessed for each type of simulated-event, as well as across all events. The three MBMA baseline analyses produced three generally consistent findings:

1. The MBMA baseline can be reasonably accurate for time periods in which the participants' loads are relatively constant; however, accuracy falls off considerably for events (or simulated events) during which participants' loads would otherwise increase or decrease;
2. The MBMA baseline is more accurate for 15-minute intervals during the first hour of an event than during the second hour, in which the quarter-hour intervals are farther away in time from the meter-before baseline; and
3. The patterns of baseline errors varied substantially by the time period in which the event was assumed to occur (for event-type days) or actually occurred. In particular, in late morning hours in which participant loads tend to be increasing, the MBMA baseline tends to *under-state* the true baseline, and thus the PLP load impact, while in late afternoon hours the opposite is typically the case.

[1] In principle, the baseline is set by the average load in the 5 minutes prior to the event. However, the average load in the previous 15-minutes is used as a proxy due to unavailability of 5-minute data.

Improvements in baseline methods for PLP would probably be best focused on some type of day averaging, perhaps with a day-of adjustment (*e.g.*, adjusted 10-in10 method), as with the other baseline-dependent DR programs. CAISO's need for immediate feedback on PLP participant response to an event dispatch could still be met by the telemetry data. However, the CAISO should be aware that the longer into the event that it attempts to use the MBMA baseline method and telemetry data, the less accurate will be its estimation of the participant's continued performance, particularly during time periods in which the participant's loads are typically rising or falling.

EXECUTIVE SUMMARY

This report describes several analyses conducted in association with a load impact evaluation of San Diego Gas and Electric Company's ("SDG&E") Participating Load Pilot ("PLP") Program during the 2009 program year. These analyses include estimation of ex post load impacts for each PLP event, a summary and description of the 1-minute telemetry data collected for the two PLP aggregators, and an assessment of the performance of the "meter-before/meter-after" baseline method that is used by the California ISO (CAISO) to confirm performance during events.

ES.1 Background

PLP participants may enroll directly or through a Curtailment Service Provider (CSP), or aggregator. Participants (who may be aggregators) submit monthly nominations of load curtailment amounts. PLP load curtailments are bid into the CAISO *ancillary services* market as non-spinning reserves. If the CAISO awards Non-Spin capacity, it notifies the utility, who then notifies PLP participants that they are required to curtail load by the agreed-upon amounts within 10 minutes (including the time since notification of the utility by the CAISO). Telemetry data allow CAISO to observe participants' load curtailments through 1-minute observations on their loads. However, 15-minute load data are used for settlement purposes due to the fact that the telemetry data are not provided by a revenue-quality meter. Program load reductions for an event are calculated relative to participant baseline usage measured as the average load in the 5 minutes prior to the event, which in practice becomes the average load in the 15 minutes prior to the event because of data limitations.

PLP is designed to test the feasibility of retail demand response providing non-spinning reserve services at very short notice (10 minutes) through bids into the California ISO ancillary services markets. This application of demand response requires more refined communication and metering between customers, aggregators, the utility, and the CAISO than for DR programs that participate in *day-ahead* and *day-of* energy markets. In particular, telemetry capabilities are required that allow CAISO to observe the PLP loads in near real time to confirm that adequate loads are available for curtailment. For the pilot program, 15-minute data are used for settlement purposes due to concerns about the accuracy of the telemetry data. One objective of this study is to assess the validity of this concern by comparing the telemetry data to the 15-minute data.

PLP participants receive capacity-based Load Reduction Incentive Payments of approximately $20 per kW-month for nominated load curtailments, which are adjusted proportionately to account for their load-reducing performance during events. Up to five events, each lasting up to two hours were allowed to be called each month for the months of July through December 15. During the pilot period, events could be initiated by CAISO or by SDG&E for test purposes. Twenty-two events were called in total.

ES.2 Resources Covered

Two program-types were available to customers. One was available for interruption during any hour of any day, while the other limited interruptions to 11 a.m. to 7 p.m. on weekdays. In practice, two aggregators participated in the daytime option and one large directly enrolled customer, who tended to operate only during overnight and early morning hours, participated in the 24-hour option, though effectively in non-daylight hours. Of the twenty-two events, seven were called during overnight hours.

One of the aggregators signed up two customers, while the other signed up eight. Accounting for multiple meters at some sites, a total of 17 meters were included in the pilot, accounting for 13.4 MW of maximum demand.

ES.3 Methodology

The PLP ex post load impacts for program-year 2009 were estimated using separate econometric models (*i.e.*, regression equations) for each enrolled participant (*e.g.*, the two aggregators and the directly enrolled customer), based on historical customer load data for August through December of 2009. The models were estimated using 15-minute interval load data, and assuming that participants' quarter-hourly loads are functions of weather data, time-based variables such as quarter-hour, day of week, and month, and program event information (*e.g.*, the days and quarter-hours in which events were called).

ES.4 Ex Post Load Impact Evaluation

Load impacts were estimated for each quarter-hour of each event, for the directly enrolled customer and the two aggregators. The estimated load impacts compared reasonably closely to the estimates relative to the MBMA baseline, as reported in the draft report on program performance.[2] The overall average estimated load impact for the directly enrolled customer was 854 kW across the seven overnight events, while the comparable average across the two aggregators for the events in which they participated was 595 kW (One aggregator participated in 10 events in the months for which it nominated load reductions, while the other aggregator participated in all 15 day-time events).

ES.5 Descriptive Statistics and Baseline Assessment

This portion of the project dealt with summarizing the nature of the 1-minute telemetry and 15-minute metered load data, and conducting an assessment of the performance of the "meter-before/ meter after" (MBMA) baseline method. It illustrated the nature of the telemetry data and provided descriptive statistics that characterize its patterns and variability, and compared the telemetry data to the 15-minute interval load data.

ES.5.1 Descriptive statistics

Figure ES.1 illustrates the telemetry data and the corresponding 15-minute metered data (which appear as unconnected dots) for both aggregators, for October 1, 2009, on which a two-hour event was called for 14:05 through 16:05. In this case, the two data series match quite closely for both aggregators. The telemetry data show greater variability, as expected, though they follow the same pattern as the 15-minute data. On some days, however, the telemetry data for Aggregator 1 showed a tendency to oscillate between very low levels and the level suggested by the metered data. This phenomenon is illustrated by Figure ES.2, which shows data for October 5, 2009, a non-event day.

[2] SDG&E Participating Load Pilot; 2009 Commission Report, January 26, 2010.

Figure ES.1: Telemetry and 15-Minute Load Data, by Aggregator
(October 1, 2009)

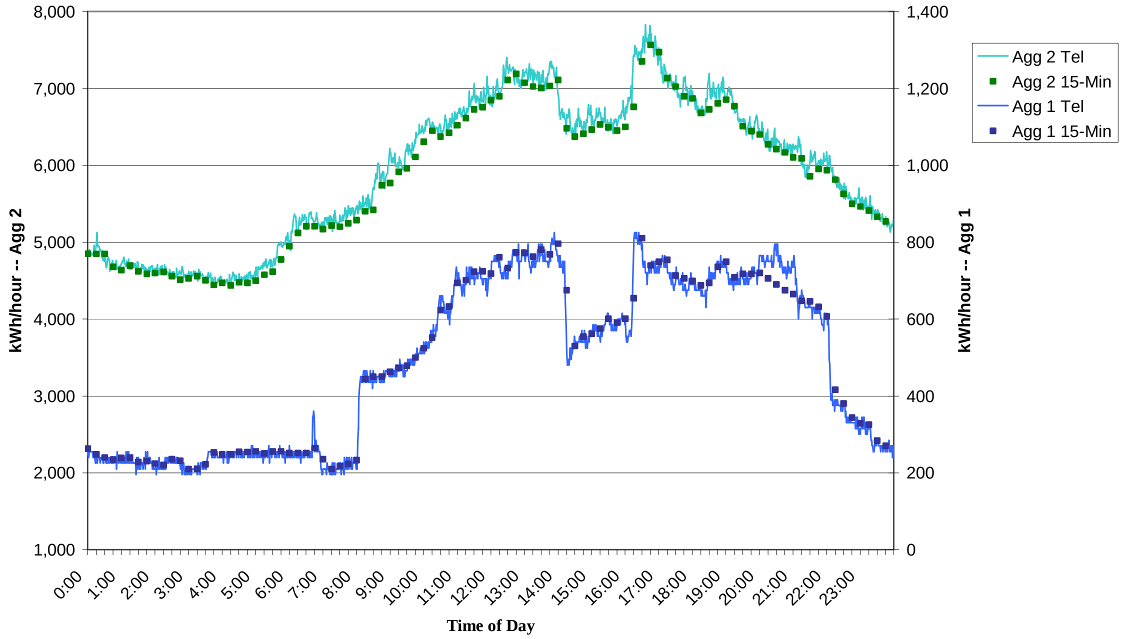
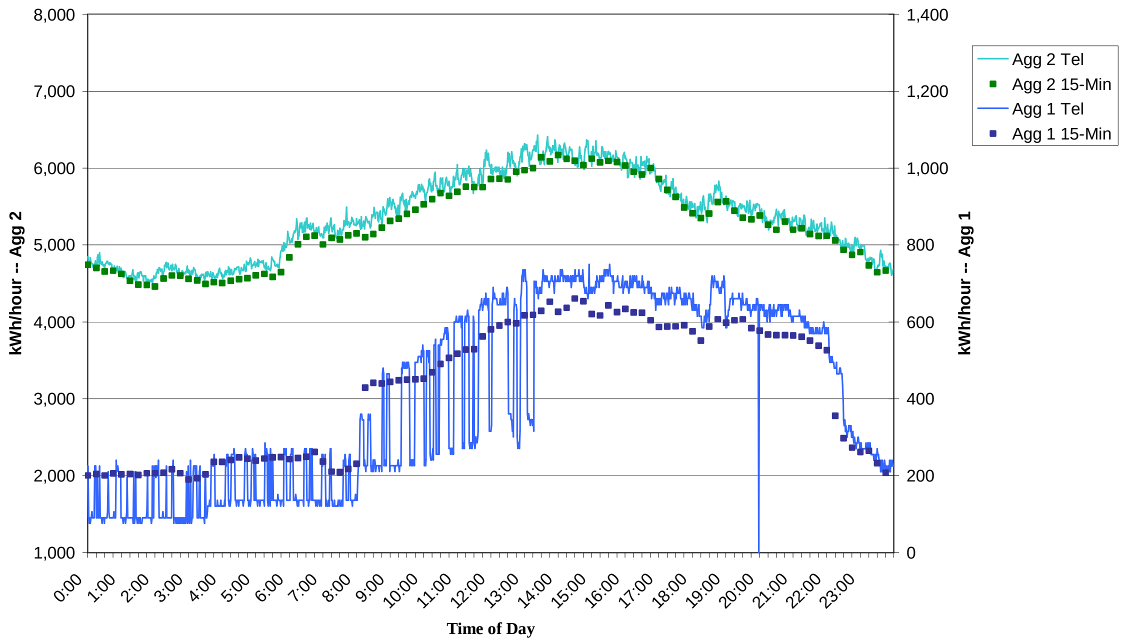


Figure ES.2: Telemetry and 15-Minute Load Data, by Aggregator
(October 5, 2009)



Overall, for Aggregator 2 in particular, the telemetry data and 15-minute data appear to represent the same loads reasonably closely, suggesting that the telemetry data could provide a reasonable indicator of performance during events. However, the occasional oscillating telemetry loads for Aggregator 1 raise concerns about the potential for such inaccurate readings to occur around the time of an event.

ES.5.2 Baseline assessment

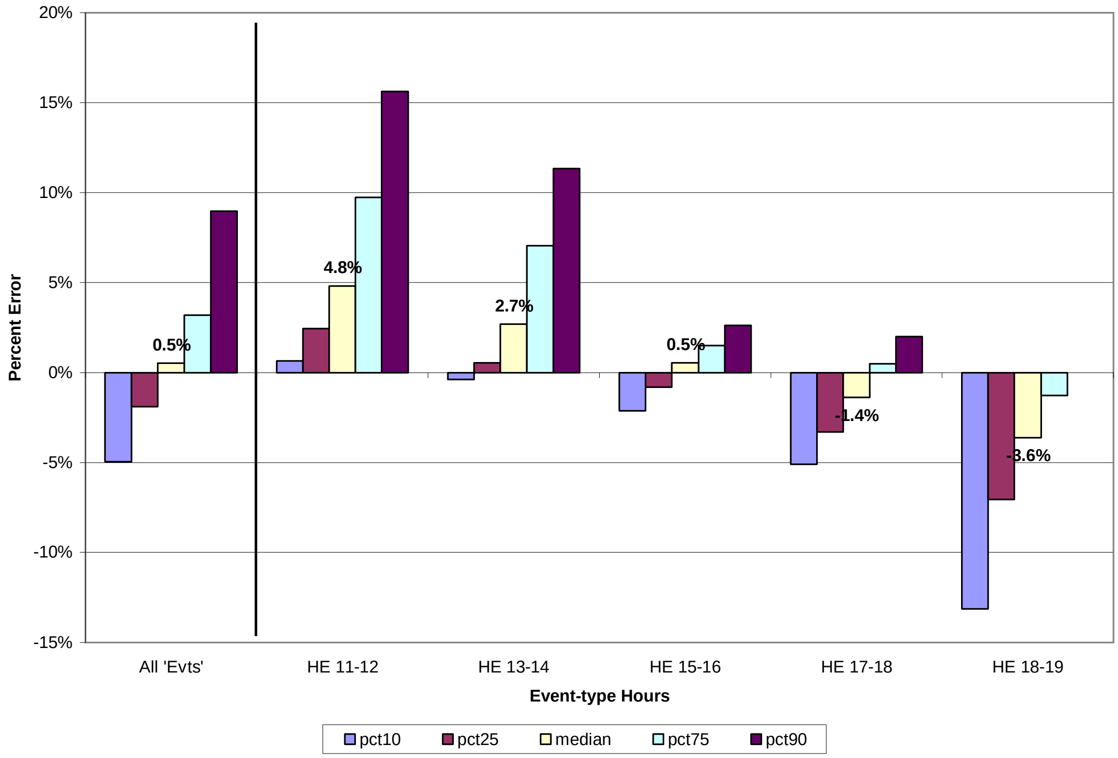
The final portion of the study involved an assessment of the accuracy of the meter-before/ meter-after" (MBMA) baseline method, which is used to calculate load impacts in the PLP program. That is, the baseline for an event is established by the metered load in the 15-minute interval prior to the event, each of which was two hours in length.[3] Since data for only two PLP aggregators were available for conducting the study, SDG&E suggested expanding the analysis to also include 15-minute interval load data for the aggregators that participated in the day-of option of SDG&E's Capacity Bidding Program (CBP). As a result, three classes of data were used in the study: 1) CBP-DO aggregator load data for selected event-type days in June through September that were not CBP or CPP event days; 2) PLP aggregator load data for selected non-event days; and 3) PLP load data for the actual PLP events during the period August through December, 2009.

For the cases involving event-type days, five separate two-hour simulated-events were created over the time period from 10 a.m. to 7 p.m., and baseline accuracy was assessed for each type of simulated-event, as well as across all events. For the case of PLP simulated events, the overall *mean* of the percent errors in the MBMA baseline is 1.1 percent, with values ranging from a positive value (under-statement) of nearly 7 percent for events in the mid-morning time period to a negative value (over-statement) of nearly 5 percent for events in the late afternoon time period.

Distributions of percent errors are illustrated in Figure ES.3 as percentiles of percent errors across the different simulated events. Overall, the median percent error is 0.5 percent, with a symmetric distribution around the median. However, the distributions of errors differ substantially from one time period to another. For the first two time periods, the MBMA baseline *under-states* the actual load in nearly every observation, with median errors of nearly 5 percent and 3 percent respectively. The errors are small for the third event. Then, for the last two event periods, occurring later in the afternoon and early evening, the MBMA baseline largely *over-states* the actual load by as much as 13 percent.

[3] In principle, the baseline is set by the average load in the 5 minutes prior to the event. However, the average load in the previous 15-minutes is used as a proxy due to unavailability of 5-minute data.

Figure ES.3: Percentiles of Percent Baseline Errors – PLP Event-Type Days



In summary, the three MBMA baseline analyses produced three generally consistent findings:

1. The MBMA baseline can be reasonably accurate for time periods in which the participants' loads are relatively constant; however, accuracy falls off considerably for events (or simulated events) during which participants' loads would otherwise increase or decrease;
2. The MBMA baseline is more accurate for 15-minute intervals during the first hour of an event than during the second hour, in which the quarter-hour intervals are farther away in time from the meter-before baseline; and
3. The patterns of baseline errors varied substantially by the time period in which the event was assumed to occur (for event-type days) or actually occurred. In particular, in late morning hours in which participant loads tend to be increasing, the MBMA baseline tends to *under-state* the true baseline, while in late afternoon hours the opposite is typically the case.

A final analysis examined patterns of 5-minute interval loads in an attempt to recommend improvements to the use of the 15-minute average load in the period prior to the event as the baseline. This analysis, combined with the baseline assessment suggests that the MBMA baseline accuracy issue dominates the question of whether the 15-minute average load can be improved. That is, in most cases, any adjustments to 15-minute average loads to better reflect changing loads within those periods will be swamped by likely errors in MBMA baseline approximation of aggregator loads during event periods. For example, 5-minute telemetry data suggested typical variation within 15-minute intervals of less than 0.5 percent. However, typical (median) errors of MBMA baselines' representation of "true" baseline loads during two-hour event periods ranged from 0.5 to 5 percent, but with half of the errors falling within the range of -7 percent to 10 percent, depending on when the event is called.

As a result, improvements in baseline methods for PLP would probably be best focused on some type of day averaging, perhaps with a day-of adjustment (*e.g.*, adjusted 10-in10 method), as with the other baseline-dependent DR programs. CAISO needs for immediate feedback on PLP participant response to an event dispatch could still be met by the telemetry data. However, the CAISO should be aware that the longer into the event that it attempts to use the MBMA baseline method and telemetry data, the less accurate will be its estimation of the participant's continued performance, particularly during time periods in which the participant's loads are typically rising or falling.

1. Introduction and Purpose of the Study

This report describes several analyses conducted in association with a load impact evaluation of San Diego Gas and Electric Company's ("SDG&E") Participating Load Pilot ("PLP") Program during the 2009 program year. These analyses include estimation of ex post load impacts for each PLP event, a summary and description of the 1-minute telemetry data collected for the two PLP aggregators, and an assessment of the performance of the "meter-before/meter-after" baseline method that is used by the California ISO (CAISO) to confirm performance during events.

PLP participants may enroll directly or through a Curtailment Service Provider (CSP), or aggregator. Participants (who may be aggregators) submit monthly nominations of load curtailment amounts. PLP load curtailments are bid into the CAISO *ancillary services* market as non-spinning reserves. If the CAISO awards Non-Spin capacity, it notifies the utility, who then notifies PLP participants that they are required to curtail load by the agreed-upon amounts within 10 minutes (including the time since notification of the utility by the CAISO). Telemetry data allow CAISO to observe participants' load curtailments through 1-minute observations on their loads. However, 15-minute load data are used for settlement purposes due to concerns about the accuracy of the telemetry data. Program load reductions for an event are calculated relative to participant baseline usage measured as the average load in the 5 minutes prior to the event, which in practice becomes the average load in the 15 minutes prior to the event because of data limitations.

Ex-post load impacts for PLP were estimated using econometric regression models applied to historical 15-minute load data for each aggregator and one directly enrolled customer.

The primary objectives of the study are the following:

1. Estimate the *ex post* load impacts of each PLP event in 2009;
2. Compare the load impacts estimated by the evaluation's *regression analysis* to the load impacts for the same events estimated by the *program baseline*, which is customers' usage during the 5-minutes prior to the event;
3. Provide descriptive statistics on the 1-minute telemetry data, compare the telemetry data to the 15-minute interval load data, and comment on any issues that may arise from using 1-minute data to verify a load drop;
4. Assess the accuracy of the "meter-before/ meter after" baseline method; and
5. Investigate possible methods for adjusting the pre-event 15-minute interval load observation, which is used by SDG&E as an approximation to the 5-minute load that is nominally called for to represent the baseline.

The report is organized as follows. Section 2 describes the PLP program, the enrolled customers, and the events called; Section 3 describes the methods used in the study; Section 4 contains the detailed ex post load impact results; Section 5 contains a review of the 15-minute and 1-minute telemetry load data and an analysis of program baseline issues; Section 6 contains an assessment of the validity of the study; and Section 7 provides recommendations.

2. Description of Resources Covered in the Study

2.1 Program Description

PLP is designed to test the feasibility of retail demand response providing non-spinning reserve services at very short notice (10 minutes) through bids into the California ISO ancillary services markets. This application of demand response requires more refined communication and metering between customers, aggregators, the utility, and the CAISO than for DR programs that participate in *day-ahead* and *day-of* energy markets. In particular, telemetry capabilities are required that allow CAISO to observe the PLP loads in near real time to confirm that adequate loads are available for curtailment. For the pilot program, 15-minute data are used for settlement purposes due to concerns about the accuracy of the telemetry data.[4] One objective of this study is to assess the validity of this concern by comparing the telemetry data to the 15-minute data.

PLP participants receive capacity-based Load Reduction Incentive Payments of approximately $20 per kW-month for nominated load curtailments, which are adjusted proportionately to account for their load-reducing performance during events. Up to five events, each lasting up to two hours were allowed to be called each month for the months of July through December 15. During the pilot period, events could be initiated by CAISO or by SDG&E for test purposes. Twenty-two events were called in total.

Two types of programs were available to customers. One was available for interruption during any hour of any day, while the other limited interruptions to 11 a.m. to 7 p.m. on weekdays. In practice, two aggregators participated in the daytime option and one large directly enrolled customer, who tended to operate only during overnight and early morning hours, participated in the 24-hour option, though effectively in non-daylight hours.

2.2 Participant Characteristics

2.2.2 Program Participants

The following tables summarize the characteristics of the participating customer accounts, including industry type and size. Table 2.1 shows the participant characteristics by industry group. The majority of the customer load is spread across three groups: Wholesale, transportation, and other utilities; Offices, hotels, health, and services; and Government, entertainment, and other services.

[4] Technically, the CAISO requires the baseline to represent 5-minute interval load. SDG&E used the load represented by 15-minute interval data as an approximation to the 5-minute data. One of the tasks of the study was to assess possible methods for adjusting the 15-minute average data to more accurately represent 5-minute sub-intervals.

Table 2.1: PLP Enrollees by Industry Type

Industry Type	Number of Meters	Sum of Max kW	Sum of Avg. kWh	% of Max kW	Avg. Size (kW)
1. Agriculture, Mining & Construction	0	0	0	0%	
2. Manufacturing	0	0	0	0%	
3. Wholesale, Transport, other Utilities	2	3,653	451	27%	1,826
4. Retail stores	2	875	489	7%	438
5. Offices, Hotels, Health, Services	6	3,898	2,568	29%	650
6. Schools	0	0	0	0%	
7. Government, Entertainment, Other Services	7	4,937	3,244	37%	705
Total	17	13,363	6,752		786

Table 2.2 shows enrollment by aggregator (or direct enrollment). Aggregator 2 had the largest share of load.

Table 2.2: PLP Enrollees by Aggregator

Aggregator	Program Type	Number of Meters	Sum of Max kW	Sum of Avg. kWh	% of Max kW	Avg. Size (kW)
Aggregator 1	Weekday Peak	2	875	489	7%	438
Aggregator 2	Weekday Peak	14	8,843	5,814	66%	632
Directly Enrolled	All Hours	1	3,645	449	27%	3,645
Total		17	13,363	6,752		786

2.3 Events

Twenty-two PLP events were called, fifteen during the 11 to 7 period and seven during the overnight hours, as shown in Table 2.3. The table shows the time at which each event was dispatched, as well as the starting time and ending time. The overnight events are indicated by shading. All events were two hours in duration, but were not necessarily called on the hour.[5]

[5] There was some initial confusion about the actual event times. The column labels in the original table of events (which was included in the preliminary version of this report) suggested that the Dispatch Time was the starting time of the event, and the End Time was the ending time of the event. However, the 2009 Commission Report on the operation of PLP ["SDG&E Participating Load Pilot," 2009 Commission Report, January 26, 2010, Version 1.0] clearly identifies the Dispatch Time as the time at which participants were *notified* of the event, and the actual start of the event as 10 minutes later, and the actual end time of the events as two hours after that.

Table 2.3: PLP Events

Event	Month	Date	Nominated MW	Dispatch Time	Start Time	End Time	Notes
1	Aug	13-Aug	0.30	14:00	14:10	16:10	CAISO Weekly test (Exceptional Dispatch)
2	Aug	20-Aug	0.30	13:55	14:05	16:05	CAISO Weekly test (Exceptional Dispatch)
3	Aug	27-Aug	0.30	13:55	14:05	16:05	CAISO Weekly test (Exceptional Dispatch)
4	Sep	10-Sep	0.60	14:00	14:10	16:10	CAISO Weekly test (Exceptional Dispatch)
5	Sep	17-Sep	0.60	13:55	14:05	16:05	CAISO Weekly test (Exceptional Dispatch)
6	Sep	18-Sep	0.60	15:55	**16:20**	**18:10**	CAISO Contingency Dispatch
7	Sep	23-Sep	1.20	23:35	23:45	1:45	APX Test
8	Sep	24-Sep	1.80	13:55	14:05	16:05	CAISO Weekly test (Exceptional Dispatch)
9	Sep	30-Sep	1.20	4:55	5:05	7:05	CAISO Weekly test (Exceptional Dispatch)
10	Oct	1-Oct	0.80	13:55	14:05	16:05	CAISO Weekly test (Exceptional Dispatch)
11	Oct	9-Oct	0.80	11:25	11:35	13:35	CAISO Weekly test (Exceptional Dispatch)
12	Oct	14-Oct	0.80	12:35	12:45	14:45	CAISO Weekly test (Exceptional Dispatch)
13	Oct	15-Oct	1.20	4:55	5:05	7:05	CAISO Weekly test (Exceptional Dispatch)
14	Nov	16-Nov	0.55	15:00	15:10	17:10	APX Test
15	Nov	18-Nov	1.20	1:00	1:10	3:10	APX Test
16	Nov	19-Nov	0.55	12:06	**12:20**	**14:20**	APX Test
17	Nov	24-Nov	0.55	15:00	15:10	17:10	APX Test
18	Dec	2-Dec	1.20	4:00	4:10	6:10	APX Test
19	Dec	3-Dec	0.50	14:55	15:05	17:05	CAISO Test (Exceptional Dispatch)
20	Dec	7-Dec	0.50	18:25	18:35	20:35	CAISO Contingency Dispatch
21	Dec	11-Dec	1.20	2:00	2:10	4:10	APX Test
22	Dec	15-Dec	1.20	2:30	2:40	4:40	APX Test

3. Study Methodology

3.1 Overview

The *ex post* load impact evaluation includes five major activities:

1. Develop estimates of *15-minute* load impacts for each PLP event in 2009;
2. Compare the load impacts estimated by this evaluation's *regression analysis* (see below) to the load impacts for the same events estimated by the *program baseline*, which is nominally customers' usage during the 5-minutes prior to the event;
3. Provide descriptive statistics on the 1-minute telemetry data, compare the telemetry data to the 15-minute interval load data, and comment on any issues that could arise from using 1-minute data to verify a load drop;
4. Assess the accuracy of the "meter-before/ meter after" baseline method; and
5. Investigate possible methods for adjusting the pre-event 15-minute interval load observation, which is used by SDG&E as an approximation to the 5-minute load that is nominally called for to represent the baseline.

The data to be used in the load impact analysis consist of integrated 15-minute load data for the pilot customers, daily observations on appropriate weather variables (to the extent that the participating customers are found to be weather sensitive), and information on the timing of events. Load impacts were estimated at the aggregator level (except for the one directly enrolled customer), after summing the loads of the individual customers enrolled by the aggregators as of the event dates. Load impacts at the program level may be obtained, where needed, by adding together the aggregator-level load impacts. Telemetry data for each participant, in the form of 1-minute interval load data were also obtained for purposes of comparing the interval metered data and the telemetry data. There are several levels of aggregator and customer data. First, aggregators contract with multiple "customers," or companies. Second, some customers have more than one site, or service account (SA_ID), and some of those have more than one meter.

3.2 Description of methods

3.2.1 Regression Model

Our typical *ex post* load impact models, after modification to use 15-minute rather than hourly load data, estimate load impacts for each *quarter-hour* of the event day, and control for factors such as weather conditions and regular daily and monthly usage patterns (*i.e*., accounting for differences in load levels across hours of the day, days of the week, and months of the year). For PLP, the regressions were estimated on 15-minute data, and thus estimated load impacts for each 15-minute period on the event day. Separate models were estimated for each aggregator (and the directly enrolled customer), with the dependent variable the total load across the aggregator's meters. A typical form for our *ex post* evaluation model is the following:

$$Q_t = a + \sum_{Evt=1}^{E} \sum_{i=1}^{96} (b_{i,Evt}^{PLP} \times h_{i,t} \times PLP_t) + \sum_{i=1}^{96} (b_i^{CDH} \times h_{i,t} \times CDH_t) + \sum_{i=2}^{96} (b_i^{MON} \times h_{i,t} \times MON_t)$$
$$+ \sum_{i=2}^{96} (b_i^{FRI} \times h_{i,t} \times FRI_t) + \sum_{i=2}^{96} (b_i^{h} \times h_{i,t}) + \sum_{i=2}^{5} (b_i^{DTYPE} \times DTYPE_{i,t}) + \sum_{i=7}^{12} (b_i^{MONTH} \times MONTH_{i,t}) + e_t$$

In this equation, Q_t represents demand for an aggregator (or directly enrolled customer) in quarter-hour t; the b's are estimated parameters; $h_{i,t}$ is a dummy variable for hour i; PLP_t is an indicator variable for program event day; E is the number of events in which the aggregator or customer participated; CDH_t is cooling degree hours;[6] MON_t is a dummy variable for Monday; FRI_t is a dummy variable for Friday; $DTYPE_{i,t}$ is a series of dummy variables for each day of the week; and $MONTH_{i,t}$ is a series of dummy variables for each month.

The first term with a summation sign is the component of the equation that allows estimation of *quarter-hourly load impacts* (the ${b_{t,Evt}}^{PLP}$ coefficients) for each event day. It does so via the 15-minute indicator variables h_i interacted with the event variables (indicated by PLP_t). The remaining terms in the equation are designed to control for the effects of weather and other periodic factors (*e.g.*, hours, days, and months) that determine customers' loads. The interaction of Monday and Friday indicators with the hourly indicators is designed to account for the typically different hourly load profiles of commercial and industrial customers on the first and last days of the workweek.

3.2.2 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.

[6] Cooling degree hours (CDH) was defined as MAX[0, Temperature – 50], where Temperature is the hourly temperature in degrees Fahrenheit. Customer-specific CDH values are calculated using data from the most appropriate weather station.

Specifically, we add the variances of the estimated load impacts across the aggregators/customers participating in the event in question. The uncertainty-adjusted scenarios were simulated under the assumption that each quarter-hour's load impact is normally distributed with the mean equal to the sum of the estimated load impacts and the standard deviation equal to the square root of the 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 with a summary of estimated *average quarter-hourly load impacts* for each event, with separate tables summarizing load impacts by aggregator. Tables of quarter-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 PLP event-day loads and load impacts.

4.1 Average Quarter-Hour Load Impacts

Tables 4.1 through 4.3 summarize estimated average quarter-hour load impacts by event and on average across events, for the directly enrolled customer and the two aggregators. The last three columns provide the following information:

- The nominated load for the month in which the event occurred;
- The estimate average quarter-hour load impact from the regression analysis; and
- The program estimate of the load impact relative to the "meter-before/ meter-after" baseline, as reported in the draft report on the operation of the PLP program.

Table 4.1: Average Quarter-Hourly Load Impacts by Event
Directly Enrolled Customer

Event Date	Notify	Start Time	End Time	Nominated Load Reduction (kW)	Estimated Load Impact (kW)	Program, per Baseline (kW)
9/23/2009	23:35	23:45	1:45	1,200	1,714	2,368
9/30/2009	4:55	5:05	7:05	1,200	468	3,008
10/15/2009	4:55	5:05	7:05	1,200	405	10
11/18/2009	1:00	1:10	3:10	1,200	-264	497
12/2/2009	4:00	4:10	6:10	1,200	915	1,343
12/11/2009	2:00	2:10	4:10	1,200	1,450	404
12/15/2009	2:30	2:40	4:40	1,200	1,336	2,042
Average				**1,200**	**861**	**1,382**
Std. Dev.				**0**	**699**	**1,131**

The nominated load reductions for the two aggregators changed over the period of the pilot. Aggregator 1 reduced its nominations from 170 kW in August, to 100 kW in October, and dropped to zero during the last two months, due to the holidays. Aggregator

2 increased nominations along with expanded enrollments from 155 kW in August to 700 kW in October, before reducing them to 550 kW in November.

The estimated load impacts (second to last column) based on the regression analysis compare reasonably closely to the estimates relative to the MBMA baseline (last column), as reported in the 2009 Commission Report. The overall average estimated load impact in this study for the directly enrolled customer was 861 kW, while the comparable average across the two aggregators was 595 kW.

Table 4.2: Average Quarter-Hourly Load Impacts by Event
Aggregator 1

Event Date	Notify	Start Time	End Time	Nominated Load Reduction (kW)	Estimated Load Impact (kW)	Program, per Baseline (kW)
8/13/2009	14:00	14:10	16:10	170	140	163
8/20/2009	13:55	14:05	16:05	170	108	144
8/27/2009	13:55	14:05	16:05	170	180	170
9/10/2009	14:00	14:10	16:10	150	176	205
9/17/2009	13:55	14:05	16:05	150	209	196
9/18/2009	15:55	**16:20**	**18:20**	150	-29	42
9/24/2009	13:55	14:05	16:05	150	222	218
10/1/2009	13:55	14:05	16:05	100	210	177
10/9/2009	11:25	11:35	13:35	100	96	72
10/14/2009	12:35	12:45	14:45	100	184	170
Average				**141**	**150**	**156**
Std. Dev.				**30**	**76**	**57**

Table 4.3.: Average Quarter-Hourly Load Impacts by Event
Aggregator 2

Event Date	Notify	Start Time	End Time	Nominated Load Reduction (kW)	Estimated Load Impact (kW)	Program, per Baseline (kW)
8/13/2009	14:00	14:10	16:10	155	134	355
8/20/2009	13:55	14:05	16:05	155	62	163
8/27/2009	13:55	14:05	16:05	155	746	372
9/10/2009	14:00	14:10	16:10	450	290	615
9/17/2009	13:55	14:05	16:05	450	536	360
9/18/2009	15:55	**16:20**	**18:20**	450	215	753
9/24/2009	13:55	14:05	16:05	450	1,385	735
10/1/2009	13:55	14:05	16:05	700	699	595
10/9/2009	11:25	11:35	13:35	700	318	216
10/14/2009	12:35	12:45	14:45	700	772	455
11/16/2009	15:00	15:10	17:10	550	520	569
11/19/2009	12:06	**12:20**	**14:20**	550	377	365
11/24/2009	15:00	15:10	17:10	550	365	405
12/3/2009	14:55	15:05	17:05	550	287	377
12/7/2009	18:25	18:35	20:35	550	59	169
Average				**474**	**446**	**434**
Std. Dev.				**187**	**350**	**186**

4.2 Protocol tables

In this section, 24 quarter-hour periods are presented from the full Protocol tables, including the eight periods before the event, the eight periods during the event, and the eight periods after the event. The accompanying Protocol spreadsheet presents all 96 quarter-hour results for each event day, with the exception of the event beginning at 11:45 p.m. on September 23 for the directly enrolled customer. In that case, the Protocol table presents 96 quarter-hour results for the September 23 event starting at 3:45 a.m. on September 23 and ending at 3:30 a.m. on September 24.

Tables presented in the text show results for the two aggregators and the directly enrolled customer for average event days, where averages are measured across the event days that had common starting event times and a constant number of participating SA IDs.

Table 4.4 presents the quarter-hour values of the estimated reference load, observed load, estimated load impacts, and uncertainty adjusted load impacts for the directly enrolled customer. The table averages two events with the common start time of 5:05 a.m. The directly enrolled customer had no other repeated start times.

Table 4.4: Quarter-Hourly Load Impacts for Average PLP Event, 5:05 Start Time
Directly Enrolled Customer

Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
3:15	2,059	3,120	-1,061	62	-2,039	-1,461	-1,061	-661	-84
3:30	1,991	3,202	-1,211	62	-2,188	-1,611	-1,211	-810	-233
3:45	1,922	3,115	-1,193	62	-2,171	-1,593	-1,193	-793	-215
4:00	1,754	1,829	-75	62	-1,052	-475	-75	326	903
4:15	1,654	1,478	176	62	-802	-224	176	576	1,153
4:30	1,510	1,550	-41	62	-1,019	-441	-41	359	937
4:45	1,368	1,550	-183	62	-1,161	-583	-183	217	795
5:00	1,335	1,397	-62	62	-1,040	-462	-62	338	916
5:15	1,267	62	1,204	62	226	804	1,204	1,604	2,182
5:30	975	48	927	62	-51	527	927	1,327	1,905
5:45	768	38	730	62	-248	329	730	1,130	1,707
6:00	325	34	292	62	-686	-108	292	692	1,270
6:15	148	38	109	60	-869	-291	109	509	1,087
6:30	132	43	89	60	-889	-311	89	489	1,067
6:45	110	38	71	60	-906	-329	71	472	1,049
7:00	102	34	68	60	-910	-332	68	468	1,046
7:15	76	38	38	63	-940	-362	38	438	1,015
7:30	80	34	46	63	-931	-354	46	446	1,023
7:45	78	38	40	63	-938	-360	40	439	1,017
8:00	59	34	26	63	-952	-374	26	426	1,003
8:15	34	38	-5	64	-983	-405	-5	395	973
8:30	35	34	2	64	-976	-398	2	402	979
8:45	35	48	-13	64	-991	-413	-13	387	965
9:00	35	53	-18	64	-995	-418	-18	382	960
	Reference Energy Use (kWh)	Observed Event-Day Energy Use (kWh)	Change in Energy Use (kWh)	Cooling Degree Hours (Base 75 °F)	Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th	30th	50th	70th	90th
Daily	55,796	58,762	-2,966	1.0	n/a	n/a	n/a	n/a	n/a

Figure 4.1 shows quarter-hour load impacts by event for the directly enrolled customer, as well as the customer's nominated load. Based on the regression model load impacts, the directly enrolled customer appears to have reduced its load by its nominated amount for the entire event period in 4 of 7 events. However, in other events, initial load reductions were consistent with nominated load, but declined over the event window. For example, in the September 30 event, the initial load reduction reached its nominated load level, but the load reduction declined to zero over the event window. This reduction in the estimated load impact occurred because the implied reference load decreased substantially over the event period. That is, the event was called at a time when the customer was typically reducing its load to near zero anyway.[7]

[7] As suggested by Table 4.1, at the time the event was called the customer's load was more than two times higher than its reference load. That is, in the quarter hour ending 4:45, the customer's load was 3,053 kW, compared to its estimated reference load level of 1,391 kW. By 5:15, the customer's load was 83 kW.

Figure 4.1: Quarter-Hourly PLP Load Impacts and Nominated Load by Event Directly Enrolled Customer

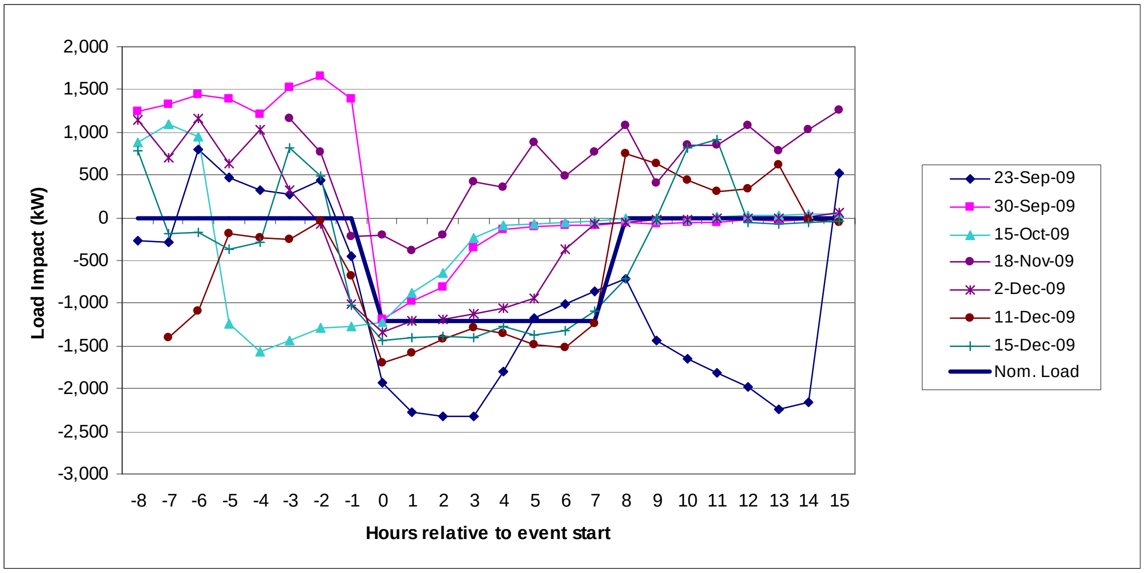


Table 4.5 presents the quarter-hour values of the estimated reference load, observed load, estimated load impact, and uncertainty adjusted load impacts for Aggregator 1, averaging over five events with the common start time of 14:05 (2:05 p.m.). Table 4.6 presents the average for two days with events beginning at 14:10 (2:10 p.m.).[8]

[8] Note that by convention, when an event started within a particular 15-minute interval, we interpreted that interval as part of the event period if at least 10 minutes of the 15 minutes were included in the event (*e.g.*, an event started at 14:05). In contrast, if only 5 minutes of the event were included (*e.g.*, the event started at 14:10), then that 15-minute interval was excluded from the event. Thus, in Table 4.5, the events are considered to begin in quarter-ending 14:15, whereas in Table 4.6, the events are considered to begin in quarter-ending 14:30.

Table 4.5: Quarter-Hourly Load Impacts for Average PLP Event, 14:05 Start Time
Aggregator 1

Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
12:15	839	796	43	90	-12	20	43	65	98
12:30	853	779	74	90	19	51	74	96	129
12:45	858	791	66	90	12	44	66	89	121
13:00	858	803	55	90	0	32	55	77	110
13:15	845	829	16	88	-39	-6	16	38	71
13:30	843	842	2	88	-53	-21	2	24	56
13:45	845	827	18	88	-37	-4	18	40	73
14:00	842	830	11	88	-43	-11	11	34	66
14:15	840	736	104	87	50	82	104	126	159
14:30	841	614	228	87	173	205	228	250	282
14:45	843	625	218	87	163	196	218	240	273
15:00	833	633	200	87	146	178	200	223	255
15:15	826	635	191	84	136	169	191	213	245
15:30	822	646	176	84	122	154	176	199	231
15:45	820	635	186	84	131	163	186	208	240
16:00	822	639	183	84	128	161	183	205	237
16:15	810	662	148	82	94	126	148	171	203
16:30	803	819	-16	82	-71	-39	-16	6	38
16:45	791	831	-41	82	-95	-63	-41	-19	14
17:00	782	808	-26	82	-80	-48	-26	-3	29
17:15	769	795	-26	79	-81	-49	-26	-4	28
17:30	764	783	-19	79	-73	-41	-19	3	35
17:45	753	771	-18	79	-72	-40	-18	5	37
18:00	741	753	-12	79	-66	-34	-12	10	43
	Reference Energy Use (kWh)	**Observed Event-Day Energy Use (kWh)**	**Change in Energy Use (kWh)**	**Cooling Degree Hours (Base 75 °F)**	**Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th**	**30th**	**50th**	**70th**	**90th**
Daily	52,910	51,162	1,749	96.8	n/a	n/a	n/a	n/a	n/a

Table 4.6: Quarter-Hourly Load Impacts for Average PLP Event, 14:10 Start Time
Aggregator 1

Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
12:30	788	798	-10	81	-65	-33	-10	12	44
12:45	792	799	-7	81	-61	-29	-7	15	47
13:00	793	806	-12	81	-66	-34	-12	10	42
13:15	793	824	-31	81	-85	-53	-31	-9	23
13:30	792	829	-36	81	-90	-59	-36	-14	18
13:45	795	817	-22	81	-76	-45	-22	0	32
14:00	791	822	-31	81	-85	-53	-31	-9	23
14:15	791	778	13	80	-41	-9	13	35	67
14:30	793	656	137	80	83	115	137	159	191
14:45	794	661	133	80	79	111	133	155	187
15:00	786	645	142	80	88	120	142	164	196
15:15	796	624	172	79	117	149	172	194	226
15:30	792	620	173	79	118	150	173	195	227
15:45	789	615	175	79	121	153	175	197	229
16:00	790	613	177	79	123	155	177	199	231
16:15	774	616	158	77	103	135	158	180	212
16:30	768	689	79	77	25	57	79	101	133
16:45	764	734	29	77	-25	7	29	51	83
17:00	763	719	44	77	-11	21	44	66	98
17:15	758	751	7	74	-47	-15	7	29	61
17:30	753	774	-21	74	-75	-43	-21	1	33
17:45	744	760	-16	74	-70	-38	-16	6	38
18:00	734	749	-15	74	-69	-37	-15	7	39
18:15	733	731	2	72	-52	-20	2	24	56
	Reference Energy Use (kWh)	**Observed Event-Day Energy Use (kWh)**	**Change in Energy Use (kWh)**	**Cooling Degree Hours (Base 75 °F)**	**Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th**	**30th**	**50th**	**70th**	**90th**
Daily	51,731	50,330	1,401	31.5	n/a	n/a	n/a	n/a	n/a

Figure 4.2 shows quarter-hourly load impacts by event for Aggregator 1. Based on regression model results, Aggregator 1 appears to have consistently reduced load by at least its nominated level for most intervals during most events. However, it appears to have delayed its response by 15 to 30 minutes in several events, and appears not to have responded at all to the September 18 event.

Figure 4.2: Quarter-Hourly PLP Load Impacts , by Event and Nominated Load Periods
Aggregator 1

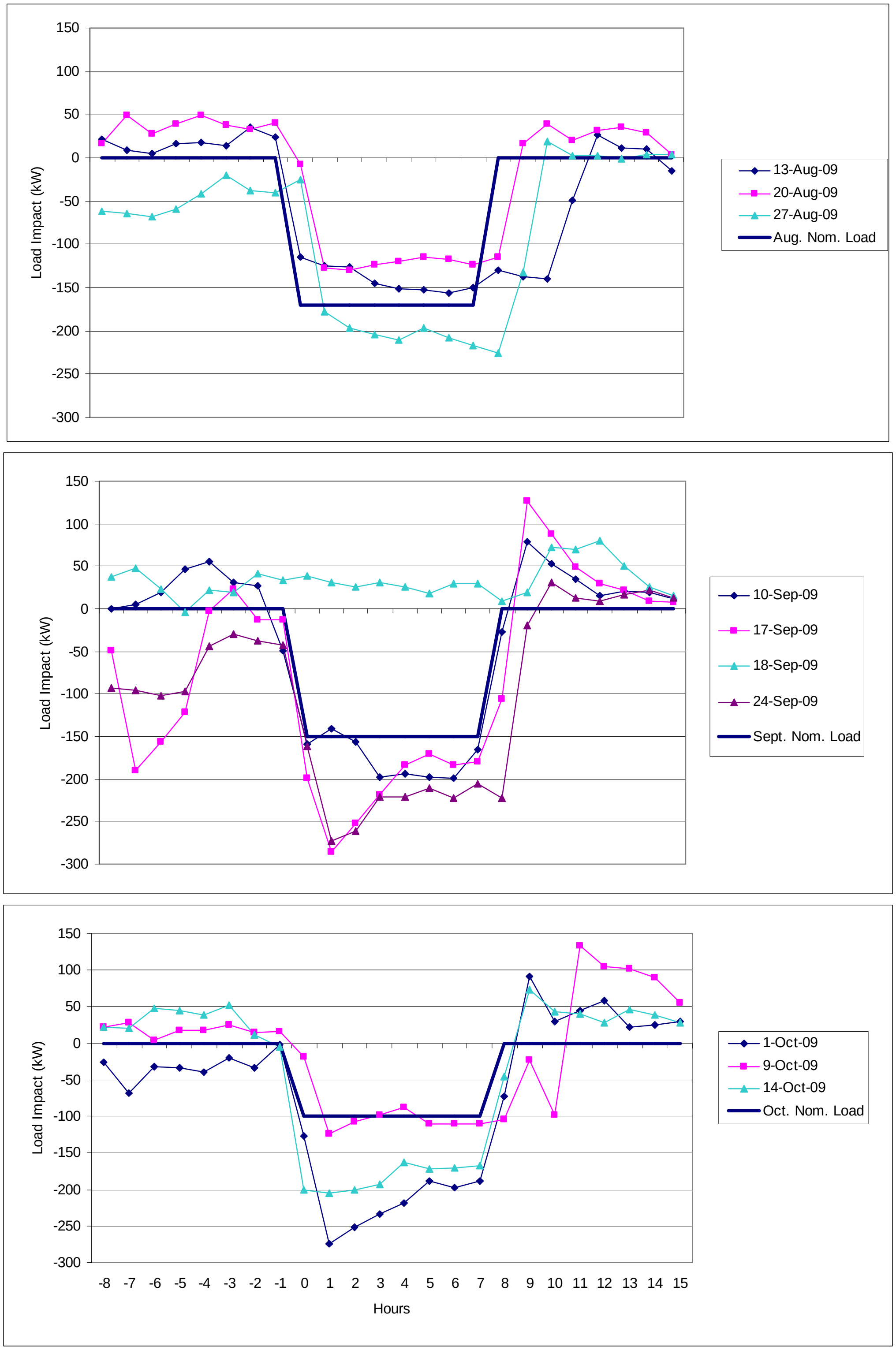


Table 4.7 presents the Protocol table for Aggregator 2 for two August events with the common start time of 14:05 (2:05 p.m.), when Aggregator 2 nominated load from four SA IDs. Table 4.8 shows similar results for two September events with the same common start time of 14:05, though with a larger nominated load from seven SA IDs. Table 4.9 shows results for two November events with the common start time of 15:10 (3:10 p.m.), for which the nominated load was from 11 SA IDs.

Table 4.7: Quarter-Hourly Load Impacts for Average PLP Event, 14:05 Start Time, *August, Aggregator 2*

Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
12:15	7,419	7,533	-114	83	-343	-208	-114	-20	115
12:30	7,455	7,500	-45	83	-274	-139	-45	49	184
12:45	7,478	7,546	-68	83	-297	-162	-68	26	161
13:00	7,511	7,567	-56	83	-285	-150	-56	37	173
13:15	7,501	7,558	-57	83	-285	-150	-57	37	172
13:30	7,509	7,564	-55	83	-283	-148	-55	39	174
13:45	7,509	7,651	-142	83	-370	-235	-142	-48	87
14:00	7,513	7,544	-31	83	-260	-125	-31	62	197
14:15	7,473	7,081	392	82	163	298	392	485	620
14:30	7,477	7,040	437	82	208	343	437	530	665
14:45	7,469	6,955	515	82	287	421	515	608	743
15:00	7,474	7,026	448	82	219	354	448	541	676
15:15	7,439	7,129	310	80	82	217	310	404	538
15:30	7,390	7,041	349	80	121	255	349	442	577
15:45	7,340	6,946	394	80	166	301	394	488	622
16:00	7,322	6,933	389	80	161	296	389	483	618
16:15	7,297	7,151	146	80	-82	53	146	240	375
16:30	7,313	7,486	-173	80	-402	-267	-173	-79	56
16:45	7,293	7,604	-311	80	-540	-405	-311	-217	-82
17:00	7,205	7,474	-269	80	-498	-363	-269	-176	-40
17:15	6,897	7,382	-485	77	-713	-578	-485	-391	-257
17:30	6,817	7,268	-452	77	-680	-545	-452	-358	-224
17:45	6,776	7,337	-562	77	-790	-655	-562	-468	-334
18:00	6,709	7,210	-501	77	-729	-594	-501	-408	-273
	Reference Energy Use (kWh)	**Observed Event-Day Energy Use (kWh)**	**Change in Energy Use (kWh)**	**Cooling Degree Hours (Base 75 °F)**	**Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th**	**30th**	**50th**	**70th**	**90th**
Daily	595,422	596,689	-1,267	62.3	n/a	n/a	n/a	n/a	n/a

Table 4.8: Quarter-Hourly Load Impacts for Average PLP Event, 14:05 Start Time, *September, Aggregator 2*

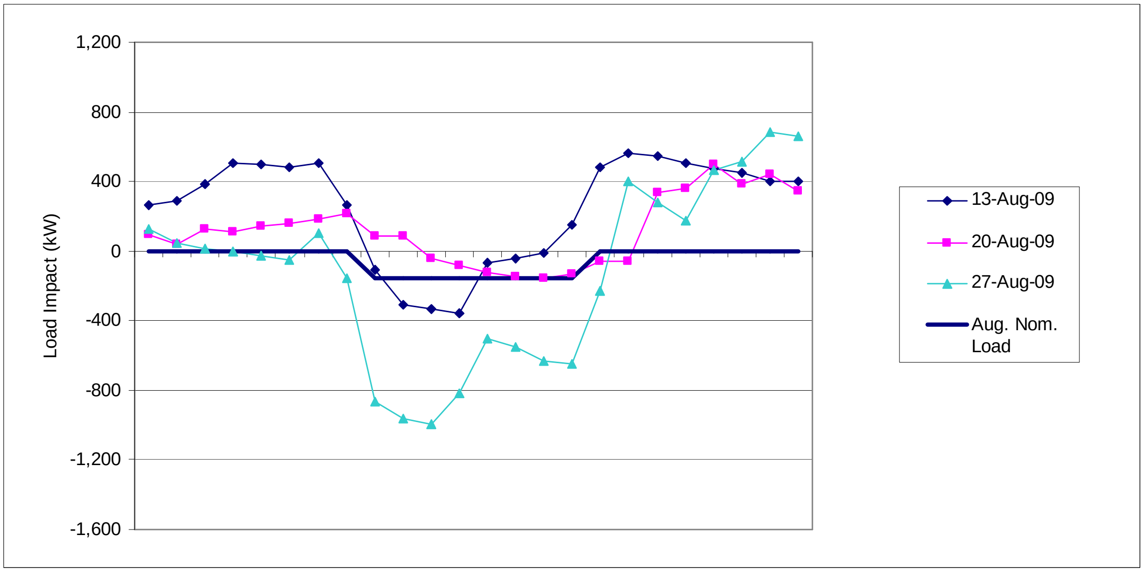
Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
12:15	7,496	7,239	257	86	27	163	257	351	486
12:30	7,533	7,312	220	86	-9	127	220	314	450
12:45	7,557	7,469	88	86	-141	-6	88	182	317
13:00	7,591	7,450	141	86	-88	47	141	235	370
13:15	7,544	6,918	626	84	398	532	626	719	854
13:30	7,553	6,983	571	84	342	477	571	664	799
13:45	7,553	7,016	536	84	308	443	536	630	765
14:00	7,556	7,092	464	84	235	370	464	557	692
14:15	7,497	6,668	829	83	601	736	829	922	1,057
14:30	7,500	6,502	998	83	770	905	998	1,092	1,226
14:45	7,492	6,407	1,085	83	857	992	1,085	1,179	1,314
15:00	7,497	6,392	1,105	83	877	1,012	1,105	1,198	1,333
15:15	7,449	6,519	930	81	702	837	930	1,024	1,158
15:30	7,398	6,498	900	81	673	807	900	994	1,128
15:45	7,347	6,431	917	81	689	823	917	1,010	1,145
16:00	7,330	6,408	922	81	694	829	922	1,015	1,150
16:15	7,289	6,861	428	81	200	335	428	521	656
16:30	7,305	7,079	226	81	-2	133	226	320	454
16:45	7,284	7,197	88	81	-141	-6	88	181	316
17:00	7,193	7,102	91	81	-137	-2	91	185	320
17:15	6,856	7,046	-190	77	-417	-283	-190	-97	37
17:30	6,776	7,255	-479	77	-706	-572	-479	-386	-252
17:45	6,735	7,196	-461	77	-688	-554	-461	-368	-233
18:00	6,669	7,025	-356	77	-583	-449	-356	-263	-129
	Reference Energy Use (kWh)	Observed Event-Day Energy Use (kWh)	Change in Energy Use (kWh)	Cooling Degree Hours (Base 75 °F)	Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th	30th	50th	70th	90th
Daily	593,086	582,336	10,750	63.3	n/a	n/a	n/a	n/a	n/a

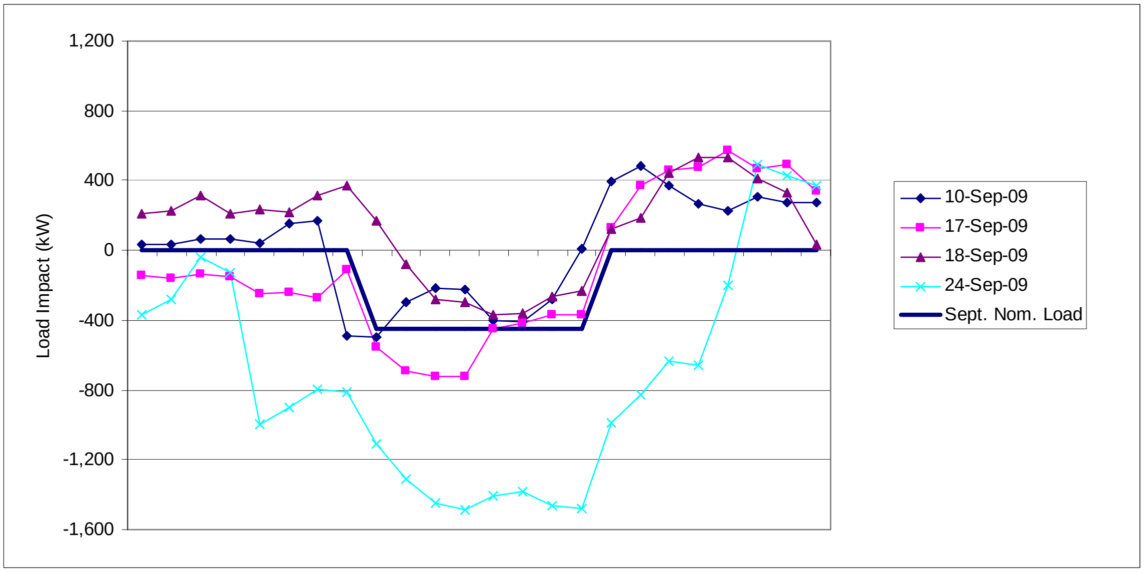
Table 4.9: Quarter-Hourly Load Impacts for Average PLP Event, 15:10 Start Time
Aggregator 2

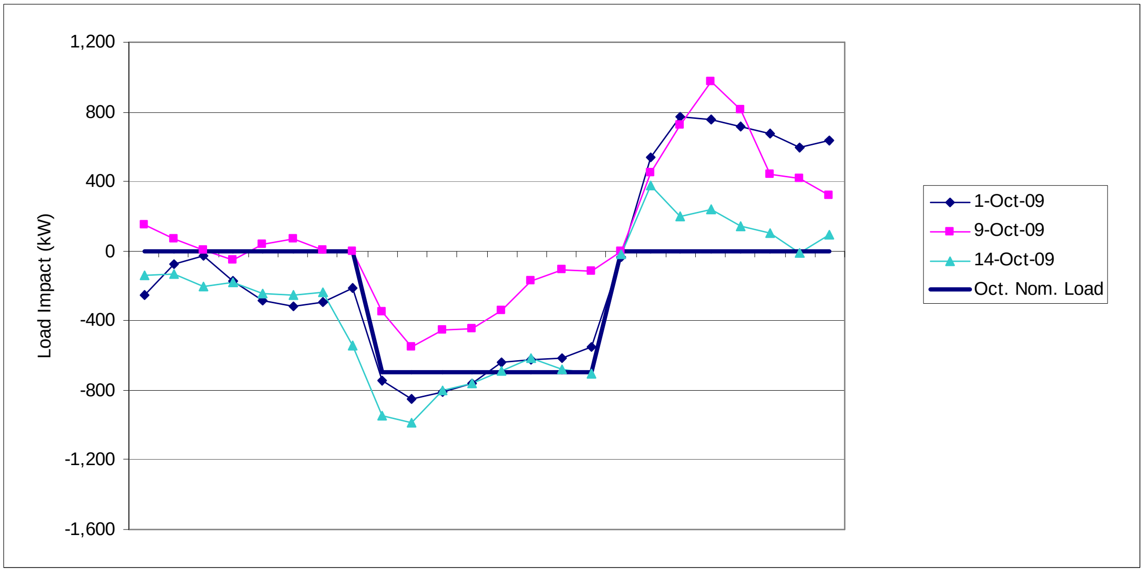
Quarter Hour Ending (Selected Periods)	Estimated Reference Load (kWh/hr)	Observed Event-Day Load (kWh/hr)	Estimated Load Impact (kWh/hr)	Weighted Average Temperature (°F)	Uncertainty Adjusted Impact (kWh/hr)- Percentiles 10th%ile	30th%ile	50th%ile	70th%ile	90th%ile
13:30	6,275	6,005	270	74	43	177	270	363	497
13:45	6,273	6,051	222	74	-5	129	222	315	449
14:00	6,289	6,052	237	74	10	144	237	330	464
14:15	6,244	6,065	179	73	-48	86	179	272	406
14:30	6,250	6,100	150	73	-77	58	150	243	378
14:45	6,240	6,110	130	73	-97	37	130	223	357
15:00	6,234	6,100	134	73	-93	41	134	227	361
15:15	6,125	5,774	351	70	124	258	351	444	578
15:30	6,101	5,560	541	70	314	448	541	634	768
15:45	6,083	5,549	533	70	306	440	533	626	761
16:00	6,050	5,565	485	70	258	392	485	578	712
16:15	6,010	5,603	408	69	180	315	408	501	635
16:30	5,994	5,582	412	69	184	319	412	504	639
16:45	5,981	5,512	469	69	242	376	469	562	697
17:00	5,970	5,506	464	69	237	371	464	557	691
17:15	5,765	5,536	228	66	1	135	228	321	455
17:30	5,696	5,964	-268	66	-495	-361	-268	-175	-41
17:45	5,637	5,820	-183	66	-411	-276	-183	-90	44
18:00	5,590	5,619	-29	66	-256	-122	-29	64	198
18:15	5,534	5,438	97	63	-131	4	97	190	324
18:30	5,509	5,376	133	63	-94	40	133	226	360
18:45	5,486	5,408	78	63	-149	-15	78	171	305
19:00	5,470	5,322	148	63	-79	55	148	241	376
19:15	5,378	5,335	43	60	-184	-50	43	137	271
	Reference Energy Use (kWh)	Observed Event-Day Energy Use (kWh)	Change in Energy Use (kWh)	Cooling Degree Hours (Base 75 °F)	Uncertainty Adjusted Impact (kWh/hour) - Percentiles 10th	30th	50th	70th	90th
Daily	504,365	496,872	7,493	0.0	n/a	n/a	n/a	n/a	n/a

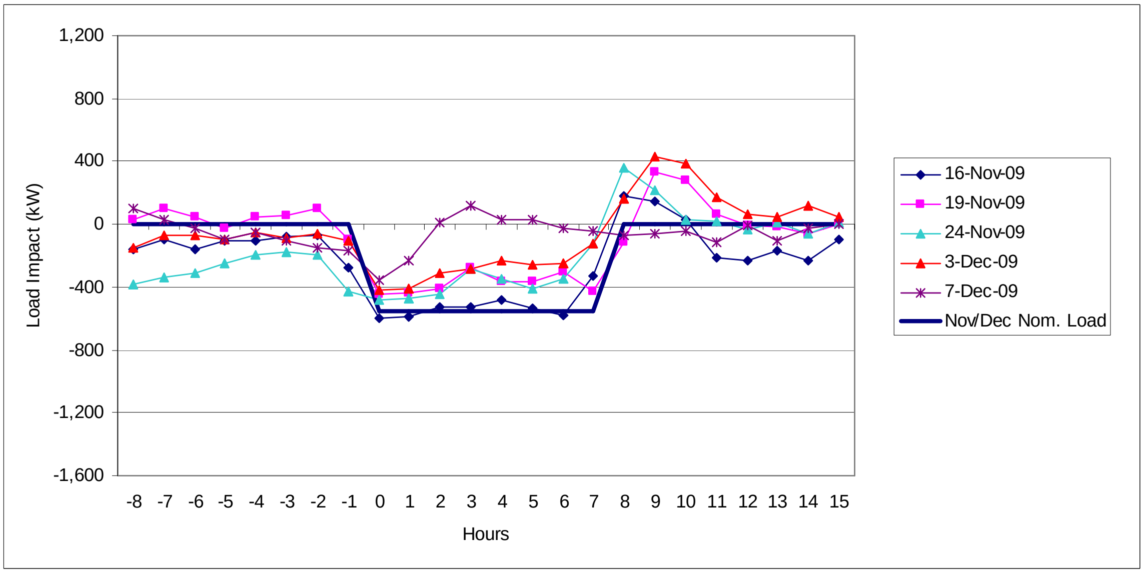
Figure 4.3 presents quarter-hour load impacts by event and by periods over which nominated load was constant (though participating SA IDs may not have been constant). According to the regression model results, Aggregator 2 typically reduced load by nearly its nominated load level for most event hours in most events from August through October. During events in November and December, however, Aggregator 2 typically did not reduce load by its nominated amount.

Figure 4.3: Quarter-Hourly PLP Load Impacts , by Event and Nominated Load Periods
Aggregator 2






1,200
800
400
0
-400
-800
-1,200
-1,600
Load Impact (kW)
1-Oct-09
9-Oct-09
14-Oct-09
Oct. Nom. Load


1,200
800
400
0
-400
-800
-1,200
-1,600
Load Impact (kW)
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Hours
16-Nov-09
19-Nov-09
24-Nov-09
3-Dec-09
7-Dec-09
Nov/Dec Nom. Load

5. Data Assessment and Baseline Analysis

This section addresses the last three project objectives, dealing with data description and baseline accuracy. It first illustrates the nature of the 1-minute telemetry data and provides descriptive statistics that characterize its patterns and variability. It then compares the telemetry data to the 15-minute interval load data, and comments on any issues that may arise from using 1-minute data to verify a load drop. The third sub-section contains an assessment of the performance of the "meter-before/ meter after" (MBMA) baseline method. Finally, the last sub-section examines patterns of 5-minute interval loads in an attempt to recommend improvements to the use of the 15-minute load in the period prior to the event as the baseline.

5.1 Review Telemetry Data

We use a combination of statistics and load plots to characterize the nature of the 1-minute telemetry data. The telemetry data would be expected to exhibit greater variability than 15-minute or hourly load data, due to the shorter time interval. One measure of that variability is the *standard deviation* of the *percentage differences* between the *averages* of the fifteen 1-minute values during each quarter hour, and *each 1-minute load* observation during those periods.[9] Those standard deviations are 6.6 percent and 1.9 percent for Aggregators 1 and 2 respectively, across hours-ending 11–19, and all non-event days. The relatively small value for Aggregator 2 in particular indicates that the 1-minute data do not display an extremely high degree of volatility. As seen below, the somewhat larger value for Aggregator 1 was likely caused by apparently random patterns of unusually low recorded loads during some periods on some days rather than by inherent load volatility.

Figures 5.1 through 5.3 illustrate the telemetry data and the corresponding 15-minute metered data (which appear as unconnected dots) for both aggregators, for three different days in October 2009. Figure 5.1 shows the loads for October 1, on which a two-hour event was called for 14:05 through 16:05. In this case, the two data series match quite closely for both aggregators. The telemetry data show greater variability, as expected, though they follow the same pattern as the 15-minute data.

[9] We limited calculations to the potential event window of 10 a.m. to 7 p.m.

Figure 5.1: Telemetry and 15-Minute Load Data, by Aggregator
(October 1, 2009)

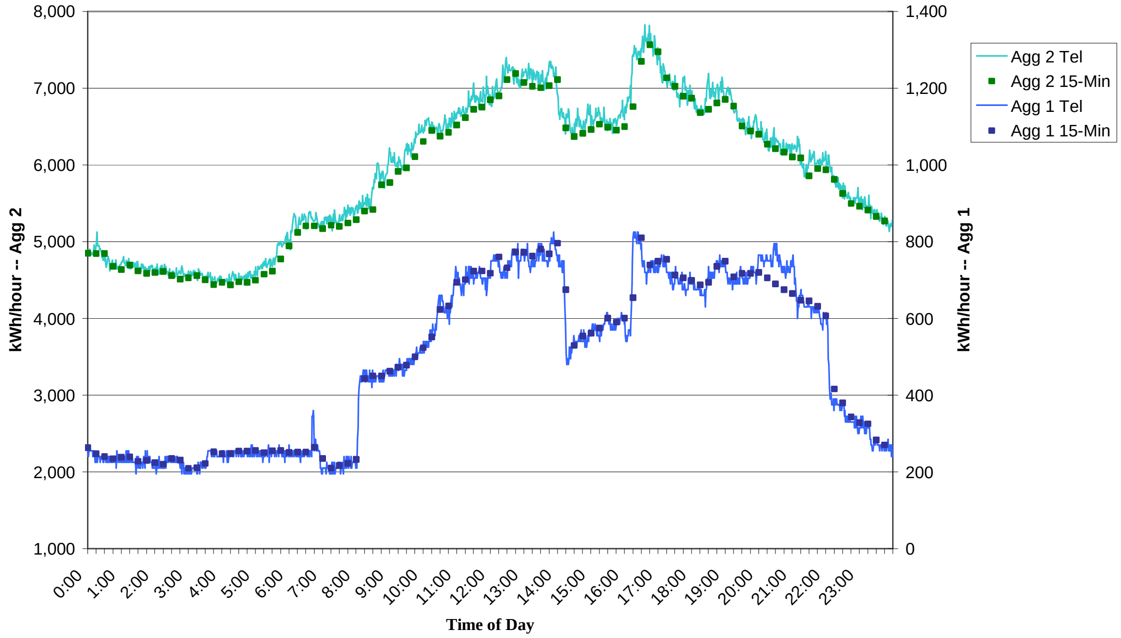


Figure 5.2 shows data for October 5, a non-event day, on which the telemetry data for Aggregator 1 appear to oscillate between the level of the 15-minute data and approximately 100 kW to 500 kW below that level (see right vertical axis), until achieving a more normal pattern by mid-day. This oscillating pattern appears to have occurred on a number of days during the period of the pilot.

Figure 5.2: Telemetry and 15-Minute Load Data, by Aggregator
(October 5, 2009)

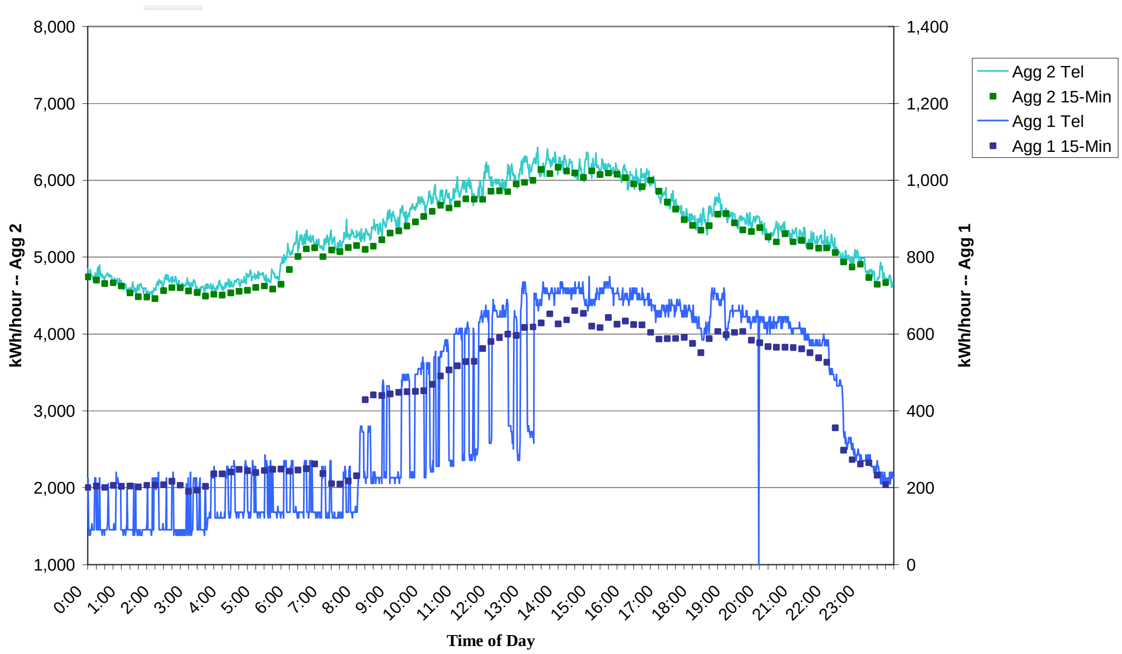
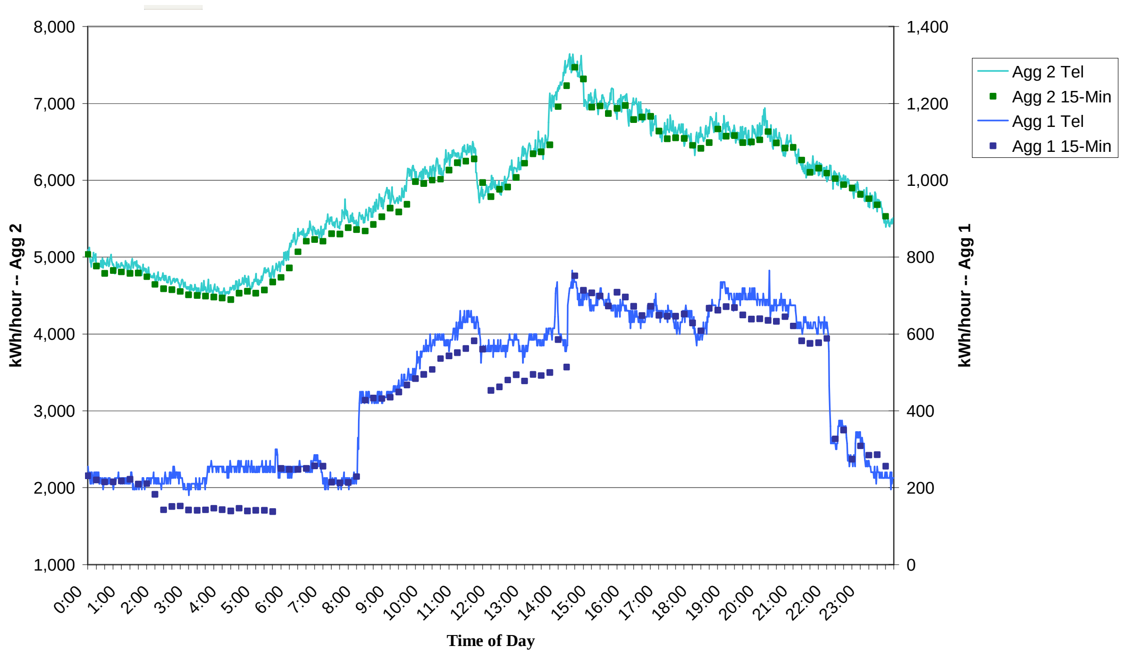


Figure 5.3 shows data for October 9, on which an event was called from 11:35 a.m. to 1:35 p.m. The two series of loads for Aggregator 2 appear consistent. However, the two series for Aggregator 1 diverge for some periods, including the two event hours.

Figure 5.3: Telemetry and 15-Minute Load Data, by Aggregator
(October 9, 2009)



5.2 Compare 15-Minute and Telemetry Data

This section provides statistics on comparability of the telemetry and 15-minute load data. Table 5.1 reports comparative statistics for both aggregators at two levels of detail. First, the fifteen 1-minute load observations for each quarter hour were averaged, to produce estimates of average 15-minute interval loads, and then compared to the 15-minute metered interval load data. The first three columns in the table report the mean and median % difference and *relative root mean square error* (RRMSE) between the two series (Telemetry – Metered), where the RRMSE characterizes the relative similarity between the two series of 15-minute load observations (limiting the comparison to the 10 a.m. to 7 p.m. period).[10] The two series differ considerably for Aggregator 1, with mean and median percent differences of -7.6% and -1.6% respectively (the negative values indicate the tendency of the Telemetry loads to fall below the Metered loads), and an average difference of 21.5%. The average tendency of the telemetry data to fall below the interval metered data is presumably due to the occasional low values and lack of regularity of the telemetry data. In contrast, the two data series for Aggregator 2 differ by only 2.4 % on average, and the positive mean and median percent errors indicate a tendency of the Telemetry loads to exceed the Metered loads by a very small amount.

Second, to examine the volatility of the telemetry data, the 15-minute average telemetry load data were compared to *each* individual 1-minute observation within the relevant quarter hour. The second and third columns of the table report the means and standard

[10] See Section 5.3.1 below for a formal definition of the RRMSE statistic.

deviations of the *percentage differences* between the fifteen-minute values and *each 1-minute load* observation over the event-window periods. The mean values of those differences are zero, as expected. The 6.6 percent standard deviation of the differences for Aggregator 1 indicates some degree of volatility. However, the 2 percent standard deviation value for Aggregator 2 again attests to the stability of that series.

Table 5.1: Statistics on Differences between Telemetry and 15-Minute Interval Data

	15-min Meter vs. Ave. 15-min Telemetry			15-min vs. Individual 1-min Telemetry Observations	
	Mean % Diff.	Median % Diff.	RRMSE	Mean	SD
Agg 1	-7.6%	-1.56%	21.5%	0%	6.6%
Agg 2	0.17%	0.29%	2.4%	0%	1.9%

For Aggregator 2 in particular, the telemetry data and 15-minute data appear to represent the same loads reasonably closely, suggesting that the telemetry data could provide a reasonable indicator of performance during events. However, the occasional oscillating telemetry loads for Aggregator 1 raise concerns about the potential for inaccurate readings around the time of a particular event.

5.3 Baseline Analysis

This portion of the study involved an assessment of the accuracy of the meter-before/ meter-after" (MBMA) baseline method, which is used to calculate load impacts in the PLP program. That is, the baseline for an event is established by the metered load in the 15-minute interval prior to the event, each of which was two hours in length.[11] Since data for only two PLP aggregators were available for conducting the study, SDG&E suggested expanding the analysis to include 15-minute interval load data for the aggregators that participate in the day-of option of SDG&E's Capacity Bidding Program (CBP). As a result, three classes of data were used in the study:

1. CBP-DO aggregator load data for selected event-type days in June through September, which were not CBP or CPP event days;
2. PLP aggregator load data for selected non-event days during the same period; and
3. PLP aggregator load data for the actual PLP events during the period August through December, 2009.

For the cases in which event-type days were used, the actual observed 15-minute interval load (in kWh/hour) during "simulated-events" was used as the true baseline to which the MBMA baseline was compared. In the case involving actual PLP events, the "true" baseline was constructed by adding our estimated 15-minute load impacts to the observed aggregator loads during each event to produce an implied reference load to which the MBMA baseline was compared. For the cases using event-type days, five separate two-hour simulated-events were created over the time period from 10 a.m. to 7 p.m., and

[11] In principle, the baseline is set by the average load in the 5 minutes prior to the event. However, the average load in the previous 15-minutes is used as a proxy due to unavailability of 5-minute data.

baseline accuracy was assessed for each type of simulated-event, as well as across all events, as described below.

5.3.1 Measures of baseline performance

Performance of the MBMA baseline method was measured primarily by two statistics that have been used in previous baseline studies. Baseline **accuracy** was measured using the *relative root mean square error* statistic (RRMSE, sometimes referred to as the Theil U-statistic). This statistic measures the degree of difference, or error, between two data series, which in this case are the observed loads during each event (or the implied reference loads in the case of PLP events) and the MBMA baselines. The differences were calculated for each quarter-hour for both hours of each event. The RRMSE statistic is nominally bounded by 0 and 1, with values closer to 0 indicating greater accuracy. Since the root-mean squared *errors* are normalized by the root-mean squared *load* levels, the resulting statistic is a normalized, or percentage measure of accuracy relative to the true baseline. For example, a value of 5 percent indicates an average 5 percent error in the MBMA baseline (or difference from the "true" baseline) relative to the mean value of the true baseline, across event days, hours, and customers (see below).

The formula for this statistic is the following:

$$U\text{-}statistic = [(1/n) \sum (e_h)^2]^{1/2} \,/\, [(1/n) \sum (L^A{}_h)^2]^{1/2} ,$$

where in this case

e_h = $(L^A{}_h - L^P{}_h)$,

$L^A{}_h$ is the actual or regression-based baseline load, in time period *h*

$L^P{}_h$ is the MBMA baseline loads,

n is the total number of aggregator event days or event-type days, and 15-minute periods, and the sum is across event days, time periods, and customers, at the relevant level of aggregation (*e.g.*, all customers, or by industry type).

Bias was measured using the *median percent error*, or difference, where the percent error is defined as the *difference* between the "true" baseline load and the MBMA estimate of the baseline load, divided by the *level* of the true baseline, calculated across customers and event hours, for each industry type. Using this convention, positive errors indicate *downward bias* (*i.e.*, the true baseline exceeds the estimated baseline), and negative errors indicate *upward bias* (*i.e.*, the estimated baseline exceeds the true baseline).

While the median statistic serves to indicate the *typical* bias tendency, examining the *distribution* of percent errors provides greater insight into the full range of baseline errors. Thus, we also show *percentiles* of the distribution of percent errors (where the 50 percentile value is the median value of the distribution). Finally, we also report means and standard deviations of the distributions of percent errors.

5.3.2 Baseline performance results

<u>*CBP-DO Event-Type Days*</u>

Fourteen event-type days were selected during the July to September period on days that were not CBP or CPP events, but where SDG&E system loads reached at least moderate levels. For each event-type day, five pseudo events were designated over the 10 a.m. to 7 p.m. time frame, for the following 2-hour periods:

HE 11-12
HE 13-14
HE 15-16
HE 17-18
HE 18-19.

Baseline accuracy and bias statistics for the MBMA baseline were calculated across all events and all hours, as well as for various sub-sets of event-types (*e.g.*, by time of the event) and hours within the events (*e.g.*, during the first or second hour of the event). The unit of observation was 15-minute loads at the aggregator level, for the six CBP-DO aggregators.

To examine potential differences in baseline performance by customer type, customers were classified into two categories—*Industrial-type* customers (which included Industry groups 1, 2, and 3, as defined below), who are assumed to be not particularly weather sensitive; and *Commercial-type* customers (Industry groups 4, 5, 6 and 7), who are presumed to be weather sensitive. The eight industry groups, which have been used in the DR load impact evaluations, are defined according to their applicable two-digit NAICS codes:[12]

1. Agriculture, Mining and Oil and Gas, Construction: 11, 21, 23
2. Manufacturing: 31-33
3. Wholesale, Transport, other Utilities: 22, 42, 48-49
4. Retail stores: 44-45
5. Offices, Hotels, Finance, Services: 51-56, 62, 72
6. Schools: 61
7. Entertainment, Other services and Government: 71, 81, 92
8. Other or unknown.

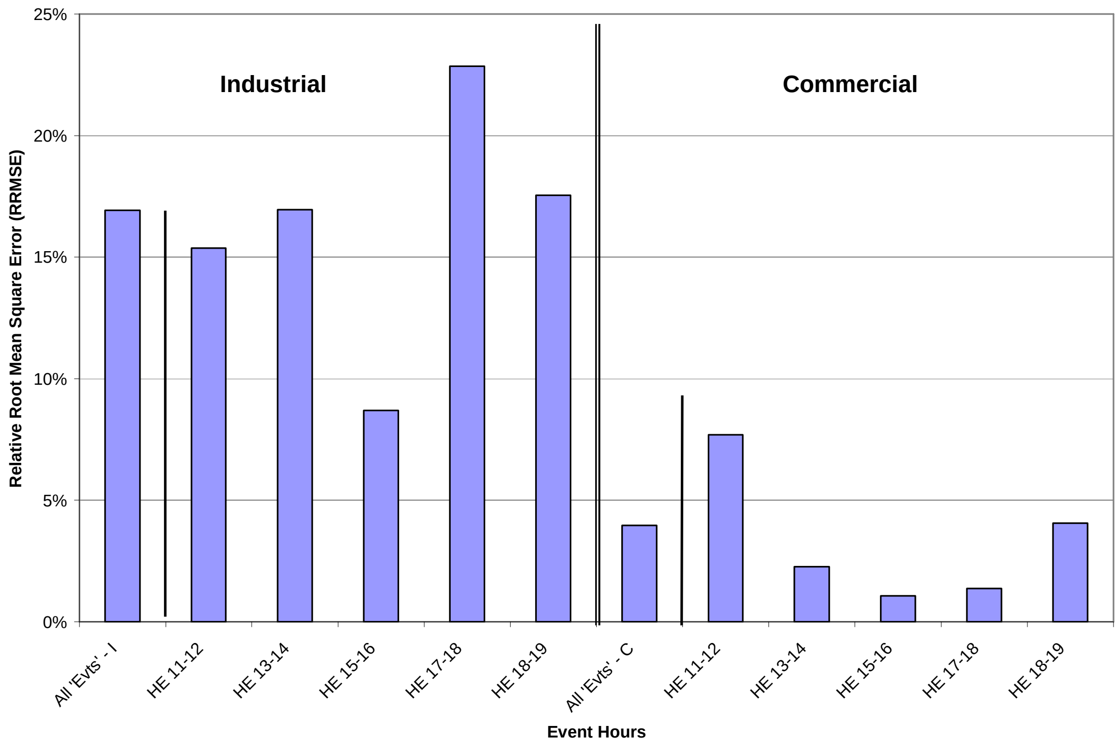
Baseline accuracy

Figure 5.4 reports RRMSE values for all event-type days and for each of the 5 time periods during the events, for aggregations of both Industrial-type and Commercial-type customers of the CBP-DO aggregators. The overall error of the MBMA baseline was about 17 percent for Industrial, and 4 percent for Commercial. Looking across time periods, the baseline errors for Industrial were smallest (8%) during the HE 15-16 events and largest during the following two-hour period (more than 20%). In contrast, for Commercial-type customers, baseline errors were greatest (7.5%) in the first event period

[12] SCE provided SIC codes in place of NAICS codes. The industry groups were therefore defined according the following SIC codes: 1 = under 2000; 2 = 2000 to 3999; 3 = 4000 to 5199; 4 = 5200 to 5999; 5 = 6000 to 8199; 6 = 8200 to 8299; 7 = 8300 and higher.

and lowest (less than 3%) in the middle three periods. Additional insight into the nature of those errors is provided in the following figures, which show distributions of the percent errors, preserving the sign of the errors, and average daily loads by customer type.

Figure 5.4: Accuracy of MBMA Baseline – CBP-DO Event-Type Days,
by Customer Type



Baseline bias

Tables 5.2 and 5.3 summarize the distributions of percent errors for the Industrial-type and Commercial-type customers respectively, and include the mean and standard deviation values.

Table 5.2: Distributions of Percent Errors – CBP DO Event-Type Days
Industrial-type Customers

Industrial	10th Pctile	25th Pctile	Median	75th Pctile	90th Pctile	Mean	SD
All 'Evts'	-10.6%	-3.0%	0.6%	5.3%	16.7%	3.5%	24.7%
HE 11-12	-3.5%	0.0%	3.7%	9.3%	20.8%	7.6%	21.6%
HE 13-14	-15.9%	-4.3%	0.0%	2.8%	6.9%	-2.3%	15.8%
HE 15-16	-6.8%	-2.6%	0.2%	2.8%	6.6%	-0.9%	8.7%
HE 17-18	-6.2%	-2.5%	0.8%	6.2%	44.6%	13.0%	39.6%
HE 18-19	-23.8%	-6.9%	-1.6%	7.9%	22.1%	0.1%	22.6%

Table 5.3: Distributions of Percent Errors – CBP DO Event-Type Days
Commercial-type Customers

Commercial	10th Pctile	25th Pctile	Median	75th Pctile	90th Pctile	Mean	SD
All 'Evts'	-4.2%	-1.5%	0.1%	2.1%	6.1%	0.9%	7.0%
HE 11-12	0.0%	1.7%	4.9%	12.7%	25.0%	8.7%	9.7%
HE 13-14	-1.5%	0.1%	1.4%	3.2%	5.0%	1.5%	2.7%
HE 15-16	-1.7%	-0.8%	0.0%	1.0%	2.0%	0.1%	1.8%
HE 17-18	-3.7%	-1.9%	-0.6%	0.2%	1.5%	-0.9%	2.5%
HE 18-19	-12.8%	-6.5%	-3.2%	-1.3%	-0.1%	-5.0%	5.8%

Figure 5.5 illustrates the percentiles of percent errors for Industrial-type customers shown in Table 5.2, for the different simulated-event periods. The median value across all events implies a typical downward bias of less than 1 percent. However, the errors range widely around that value, from over-stated baselines of more than 10 percent to under-stated baselines of nearly 17 percent, at the 10th and 90th percentiles. Looking across the different simulated-event windows, the MBMA baseline tends to be biased downward (positive errors) more than half the time, with a quarter of the errors 10 percent or greater. The errors in the next two event periods are relatively small, and then turn toward a strong downward bias in the next period and a mix of upward and downward biases in the last event period.

As shown in Table 5.2, the mean percent error across all event hours is 3.5 percent, with a sizeable standard deviation of nearly 25 percent, which is reflected in the rather wide distributions of percent errors.

Figure 5.5: Percentiles of Percent Errors – CBP-DO Event-Type Days
Industrial-Type Customers

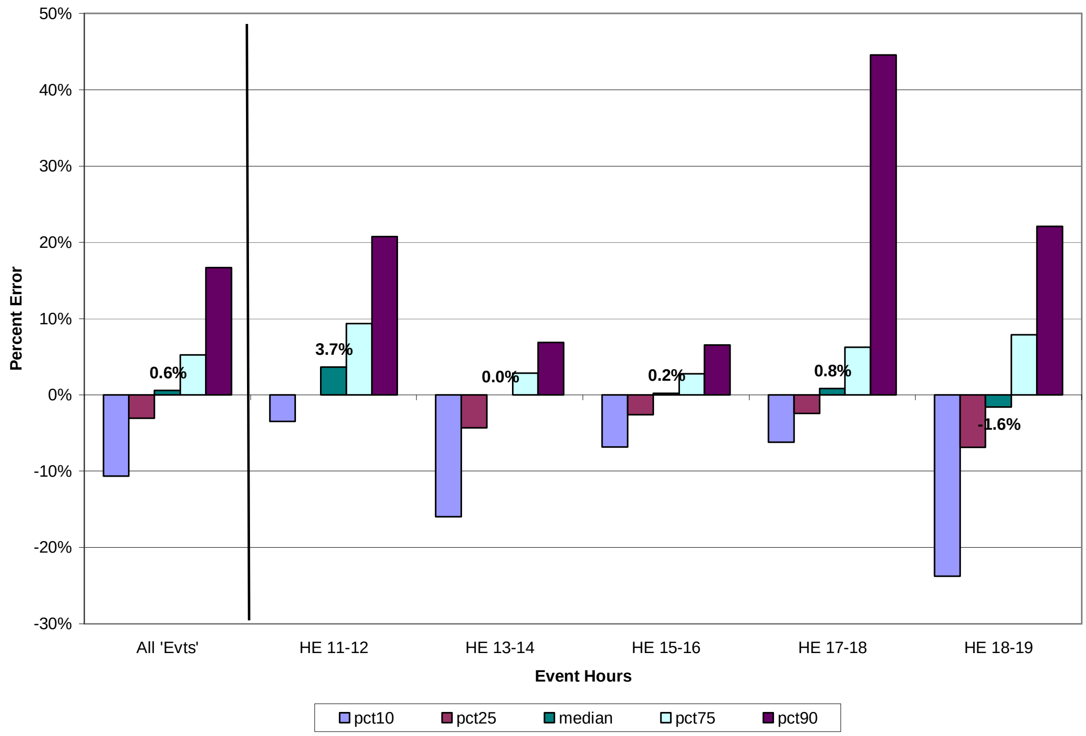


Figure 5.6 shows comparable distributions of percent errors for Commercial-type customers. In this case, the percent errors are substantially smaller; only in the first event period is there a strong tendency for downward bias (*i.e.*, positive values), while there is a substantial tendency toward upward bias in the last period. Percentage errors in the middle event periods are generally small. As shown in Table 5.3, the mean of the percent errors across all event hours is less than one percent. The standard deviation is seven percent, largely driven by the relatively large errors in the first and last event period.

Figure 5.6: Percentiles of Percent Errors – CBP-DO Event-Type Days
Commercial-Type Customers

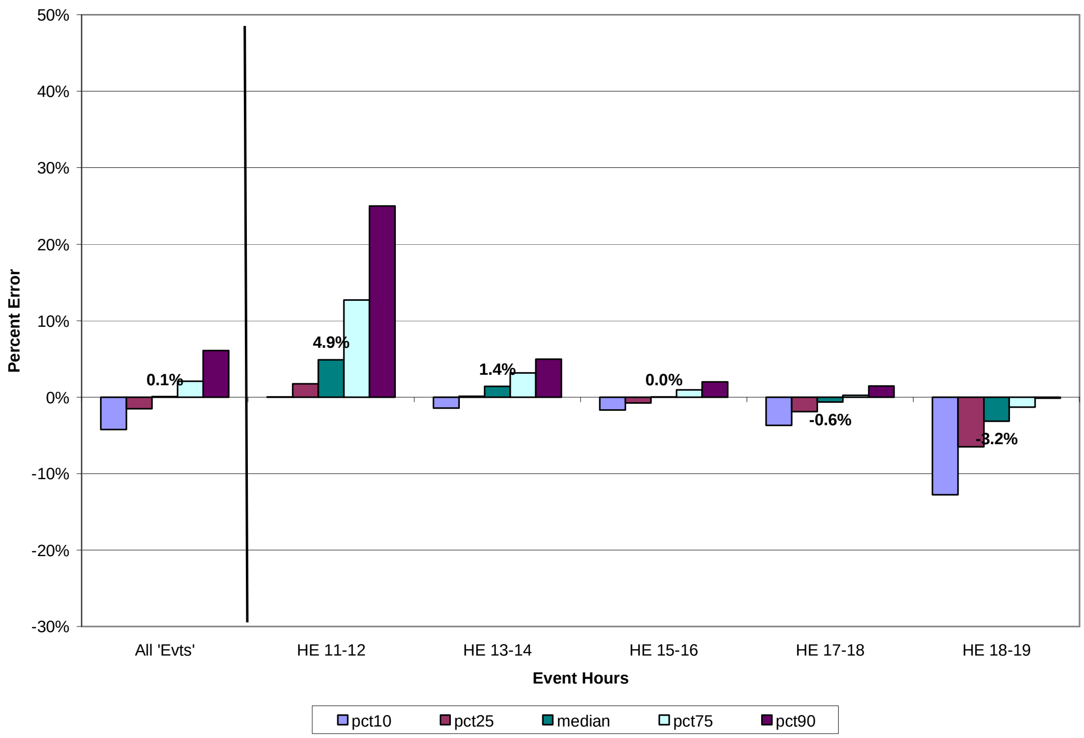


Figure 5.7 provides an indication of the reasons underlying the patterns of MBMA baseline errors for the different event time periods. It shows average daily loads for Industrial and Commercial-type customers, where the loads are summed across aggregators and then averaged across the simulated-event days. Also shown are indications of the beginning and ending periods of the simulated events (see vertical lines). The Industrial load is relatively flat, with a noticeable dip in load between peak hours of 8 a.m. and 10 p.m. The patterns in errors must be driven by variability in the loads that underlie the average load shown.

In contrast, the diurnal load pattern of the Commercial customers suggests clear reasons for the pattern of errors shown in Figure 5.6. For example, the MBMA baseline for the first event period would be based on a 15-minute value in the interval just prior to the first vertical line. Since the load is rising steadily over the event period, the MBMA baseline would tend to increasingly under-state the load over that time period (which is the result observed in Figure 5.6). This tendency would continue until the third event period, in which the flatter portion of the load would produce smaller errors for the MBMA baseline. Finally, as the load curve begins to fall, the MBMA baseline would tend to over-state the actual load, as indicated by the largely negative percent errors in the last two event periods in Figure 5.6.

Figure 5.7: Average Event-Type Day Loads –
Industrial and Commercial-Type Customers

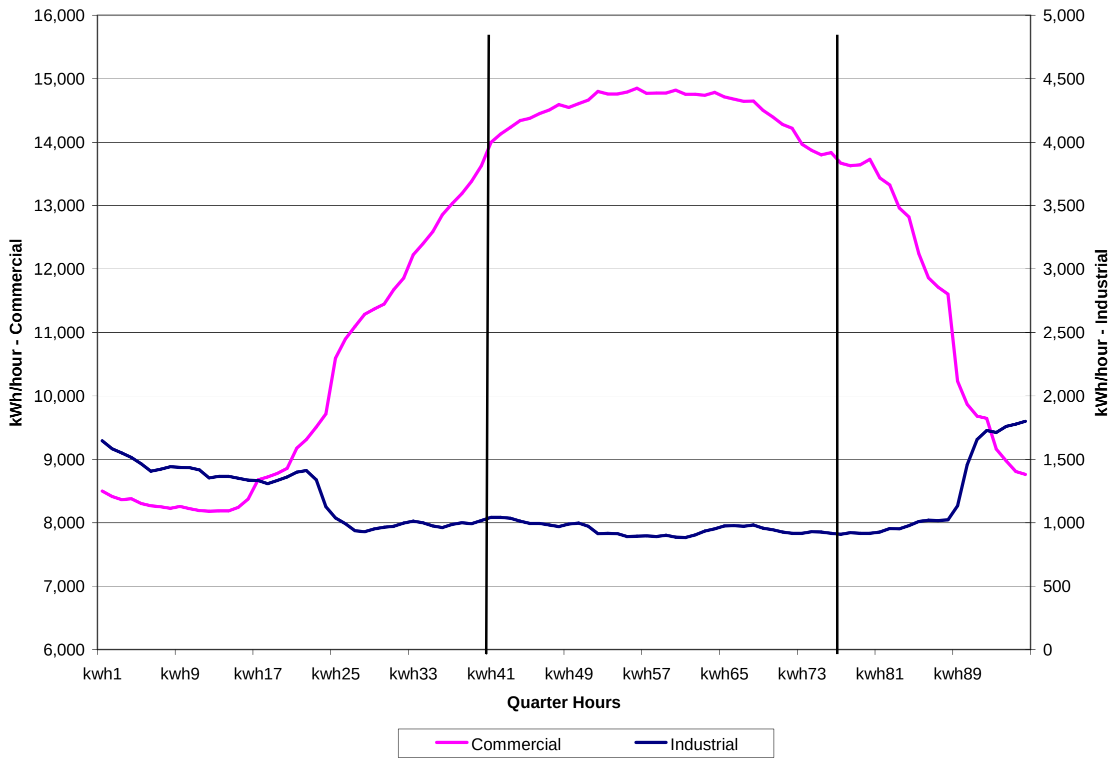
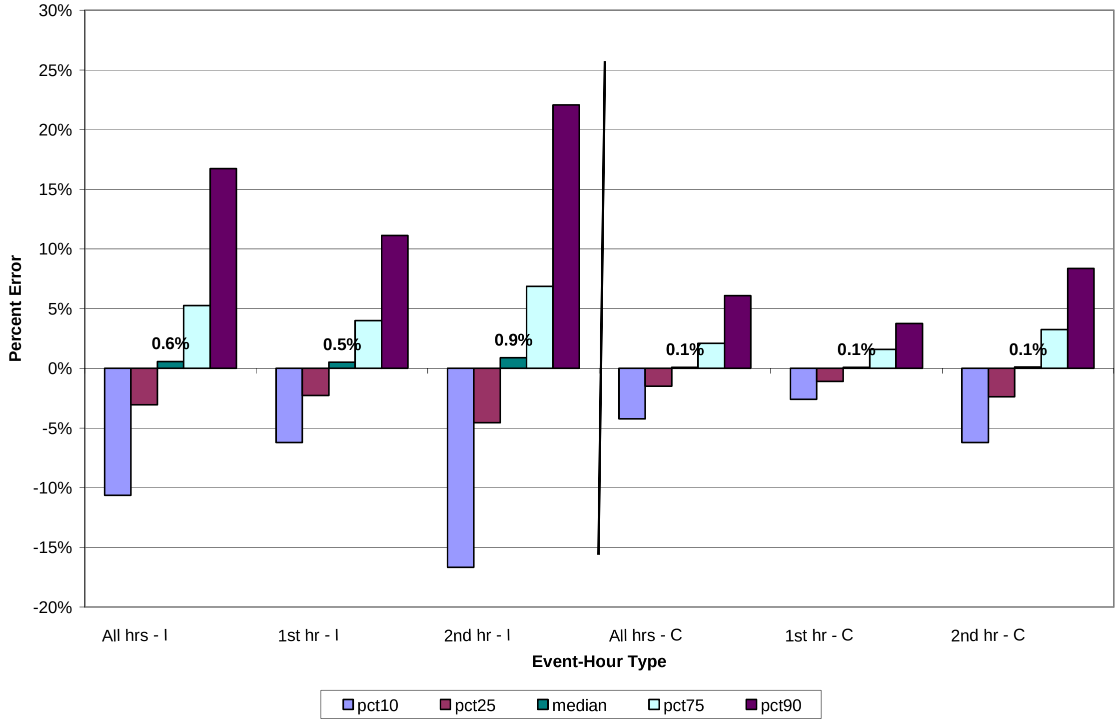


Figure 5.8 examines the range of percent errors in the two individual hours of the simulated events separately, as well as both hours combined. The left panel shows results for Industrial, while the right panel shows them for Commercial. The first set of bars in each panel is the same as the first set in Figures 5.4 and 5.5, covering all events and hours. However, the next two sets of bars show the distribution of percent errors for the first and second hours of the events. In all cases, the level and range of errors is smaller in the first hour than in the second hour. This result is consistent with the finding above on trends across the events. It is also consistent with the fact that the MBMA baseline load is established closest in time to the first hour of the event.

Figure 5.8: Percentiles of Percent Errors – CBP-DO Event-Type Days
by Customer Type and Hour of Event



PLP Event-Type Days

This section summarizes MBMA baseline performance on twenty selected PLP non-event days between August 12 and December 11, 2009, on which the same type of five simulated two-hour events as for the CBP-DO aggregators were examined. In this case, observations included aggregator-level data for the two PLP aggregators combined. Figure 5.9 shows RRMSE values for all simulated events and for each of the five simulated events. Overall MBMA accuracy is characterized by RRMSE of less than 4.5 percent. Looking across event periods, accuracy is greatest (less than 2 percent error) in the middle event, while overall inaccuracy rises to more than 6 percent in the first and last simulated event.

Figure 5.9: Accuracy of MBMA Baseline – PLP Event-Type Days

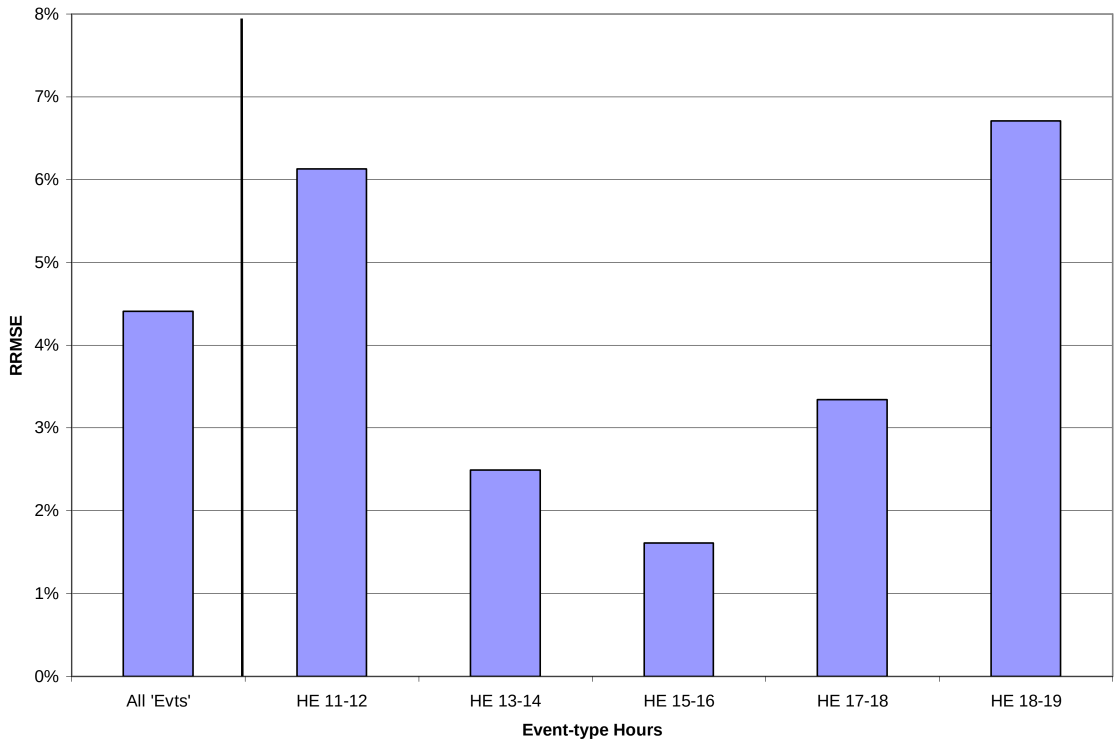


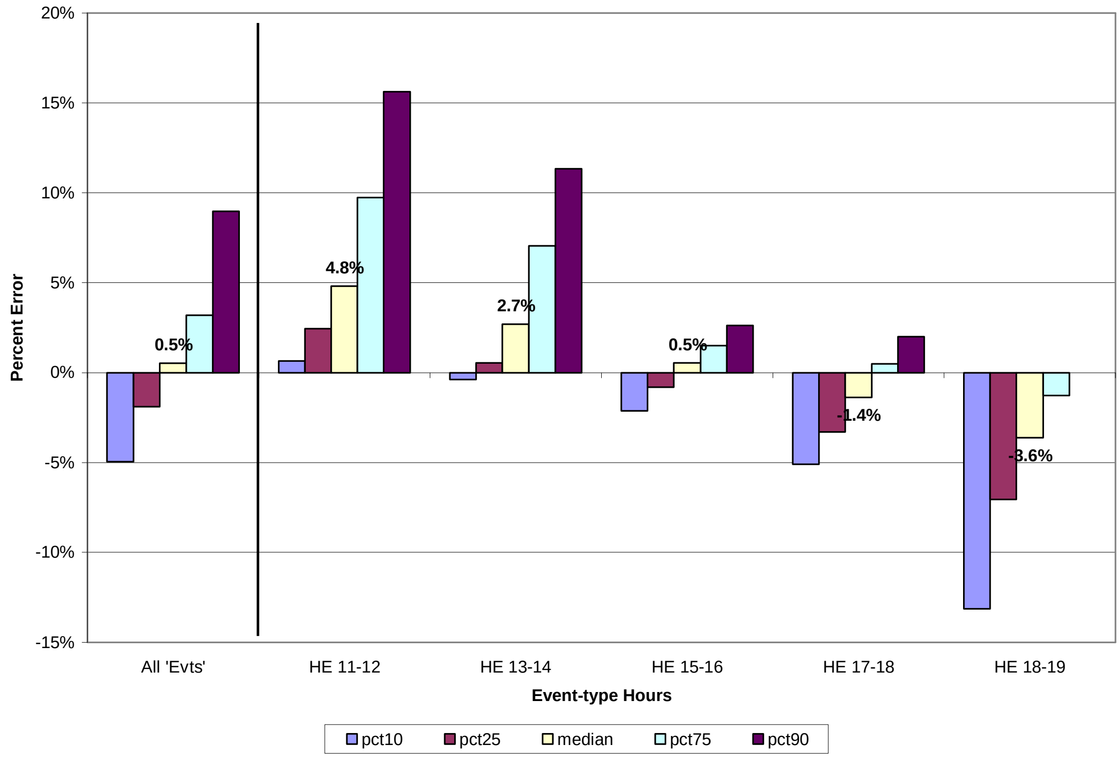
Table 5.4 summarizes the distributions of percent errors, and includes the mean and standard deviation values. The overall *mean* of the percent errors is 1.1 percent, with values ranging from a positive value (under-statement) of nearly 7 percent in the first time period to a negative value (over-statement) of nearly 5 percent in the last time period.

Bias results from Table 5.4 are illustrated in Figure 5.10 as percentiles of percent errors for the different simulated events. Overall, the median percent error is 0.5 percent, with a symmetric distribution around the median. However, the distributions of errors differ substantially from one time period to another. For the first two time periods, the MBMA baseline *under-states* the actual load in nearly every observation, with median errors of nearly 5 percent and 3 percent respectively. The errors are small for the third event. Then, for the last two event periods, occurring later in the afternoon and early evening, the MBMA baseline largely *over-states* the actual load.

Table 5.4: Distributions of Percent Errors – PLP Event-Type Days

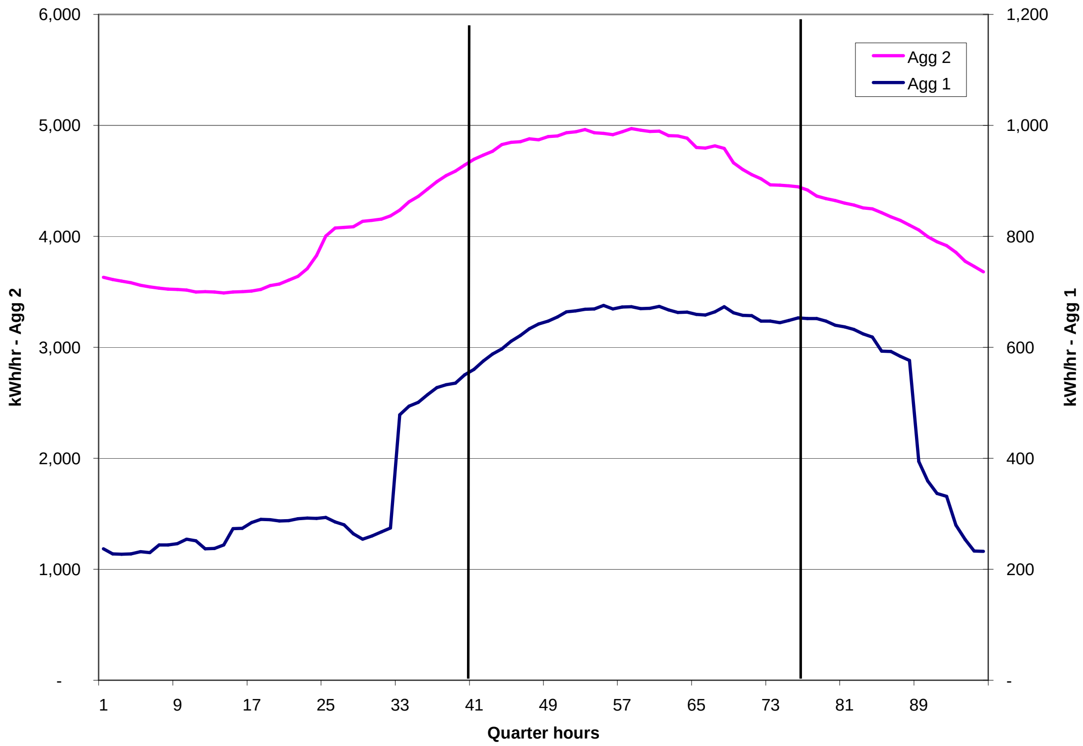
Event-Type	10th Pctile	25th Pctile	Median	75th Pctile	90th Pctile	Mean	SD
All 'Evts'	-5.0%	-1.9%	0.5%	3.2%	9.0%	1.1%	6.3%
HE 11-12	0.6%	2.4%	4.8%	9.7%	15.6%	6.8%	6.5%
HE 13-14	-0.4%	0.5%	2.7%	7.0%	11.3%	4.5%	5.4%
HE 15-16	-2.1%	-0.8%	0.5%	1.5%	2.6%	0.4%	2.1%
HE 17-18	-5.1%	-3.3%	-1.4%	0.5%	2.0%	-1.1%	3.7%
HE 18-19	-13.1%	-7.1%	-3.6%	-1.3%	0.0%	-4.9%	5.1%

Figure 5.10: Percentiles of Percent Errors – PLP Event-Type Days



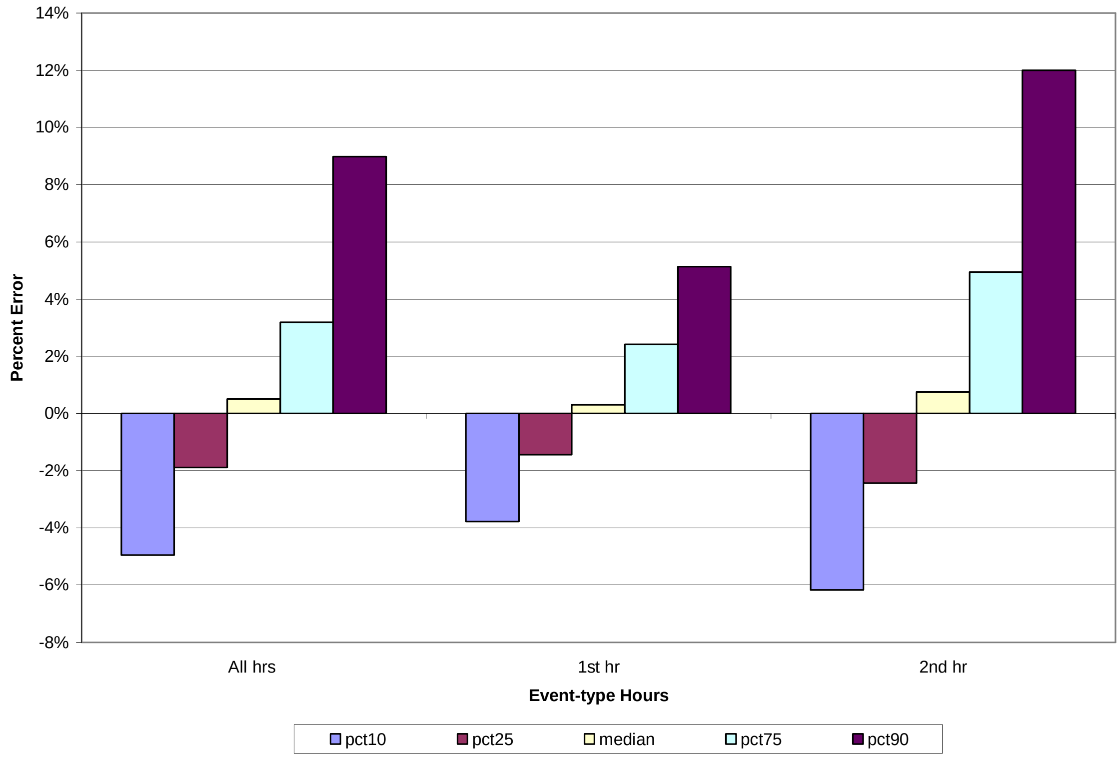
The likely reason for this pattern of baseline errors may be seen in Figure 5.11, which shows the average load profile for each aggregator over the simulated event days. Both loads increase over the first few hours of the event window, then level off and finally begin falling. As discussed above, during periods of increasing (decreasing) loads, the MBMA baseline will tend to under-state (over-state) the actual pattern of the load that would have occurred in the absence of an event. Only during periods when the load is relatively flat will the MBMA baseline tend to be accurate.

Figure 5.11: Average PLP Event-Type Day Loads



Finally, Figure 5.12 illustrates the range of percent errors in the two individual hours of the simulated events, as well as for both hours combined. As for the case of CBP, the first set of bars is the same as the first set in Figure 5.7, covering all events and hours. However, the next two sets of bars show the distribution of percent errors for the first and second hours of the simulated events. In both cases, the levels and ranges of errors are smaller in the first hour than in the second hour. This result is consistent with the finding above on trends across the event periods. It is also consistent with the fact that the MBMA baseline load is established closest in time to the first hour of the event.

Figure 5.12: Percentiles of Percent Errors – PLP Event-Type Days
by Hour of Event



PLP Events

This section provides MBMA baseline performance statistics for the actual day-time PLP events, where the baseline performance is relative to event-period reference loads that are inferred from the load impact regression coefficients. Observations consisted of 15-minute load data for each of the two aggregators during each two-hour event. Figure 5.13 shows RRMSE values for all event hours (first bar) and for the first and second hours of all events separately (second and third bar). Overall relative errors averaged about 12.5 percent. As in the previous simulated-event cases, errors for the first hour of each event (12.3 percent) were smaller than those for the second hour (12.7 percent), although the differences between hours were quite small.

Figure 5.13: Accuracy of MBMA Baseline – PLP Event Days

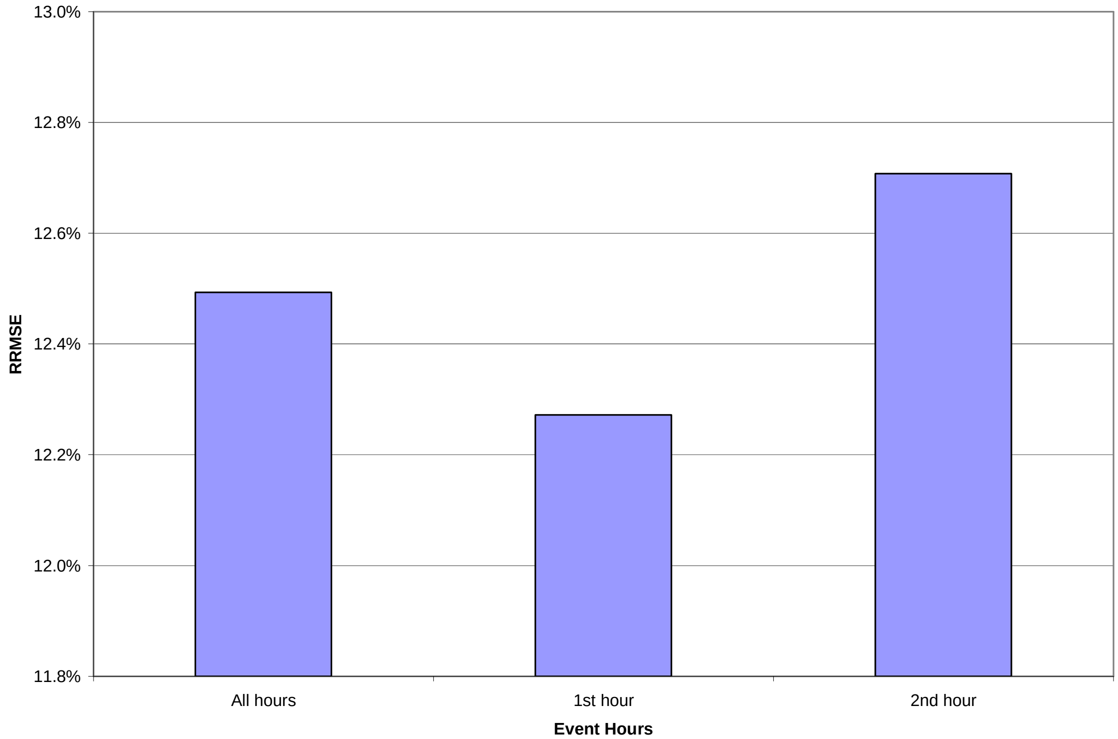
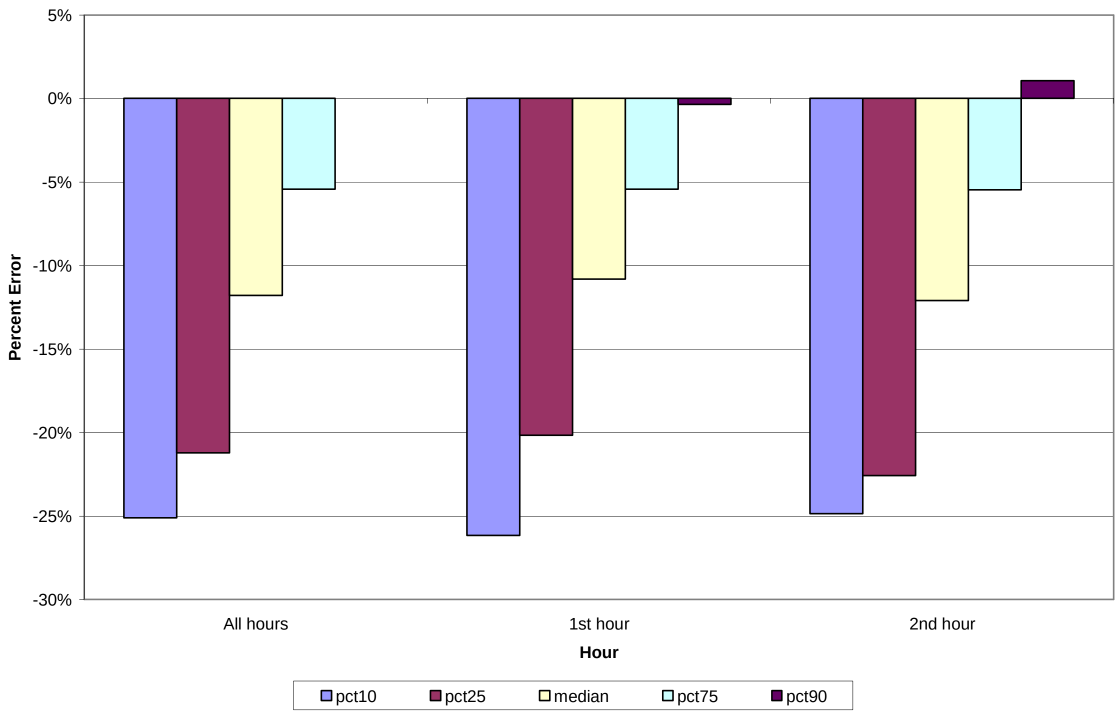


Figure 5.14 reports the percentiles of percent errors, again for both all event hours and the first and second event-hour separately. The distributions of errors are noticeably skewed toward upward bias (negative percent errors) relative to the regression-based baselines. The overall median value of the percent errors was –11.8 percent, while the median percent errors for the first and second event hours were about –10.8 and –12.1 percent respectively. (The corresponding mean and standard deviation were –11.3 percent and 16 percent respectively.) These results are consistent with the fact that most of the events occurred in late afternoon (twelve of the fifteen daytime PLP events occurred in the period of approximately HE 17 to 18, or later), a time period for which the previous simulated-event results suggest is characterized by the MBMA baseline *over-stating* the true baseline load (see the largely negative percent errors in the last two sets of error bars in Figure 5.7). Also consistent with previous results is the fact that the over-statement is greater for the second hour of the events than for the first hour, though not by a large amount.

Figure 5.14: Percentiles of Percent Errors – PLP Event Days
by Hour of Event



5.3.3 Baseline conclusions

The three MBMA baseline analyses reported above produced three consistent findings:

1. The MBMA baseline can be reasonably accurate for time periods in which the participants' loads are relatively constant; however, accuracy falls off considerably for events (or simulated events) during which participants' loads would otherwise increase or decrease during the event period;
2. The MBMA baseline is more accurate for 15-minute intervals during the first hour of an event than during the second hour, in which the quarter-hour intervals are farther away in time from the meter-before baseline; and
3. The patterns of baseline errors varied substantially by the time period in which the event was assumed to occur (for event-type days) or actually occurred. In particular, in late morning hours in which participant loads tend to be increasing, the MBMA baseline tends to *under-state* the true baseline, while in late afternoon hours, in which participant loads tend to be falling, the opposite is typically the case.

These results are logical, since the MBMA baseline is established in the 5-minute (in practice, 15-minute) period prior to the start of a PLP event. It is thus most accurate for cases in which the participants' load would otherwise have remained at approximately the same level for the subsequent two hours.

These results also suggest possible ways of improving on the 15-minute average load that currently serves as the basis for the MBMA method. We explore one such method in Section 5.4 below.

5.4 Potential Modifications of 15-Minute Load to Improve MBMA Baseline

The PLP tariff states that the "meter-before" baseline should be based on participants' 5-minute interval load "prior to a PLP event." However, customers' loads were only metered in 15-minute intervals, thus requiring approximation to the 5-minute pre-event interval loads by the average load in a corresponding 15-minute interval. In addition, the PLP report on operational issues states that "specific implementation of this baseline selects the first metered interval ending *at or before the time of dispatch* from the CAISO." For example, if an event were dispatched at HE 13:55, implying a start time of 14:05, then the MBMA baseline should be established using the 15-minute load level in quarter-ending 13:45, which ends prior to the interval in which the event was dispatched.

To explore methods for adjusting the available 15-minute metered data to better represent the desired 5-minute sub-intervals, we first examined patterns of the known telemetry data averaged to the 5-minute level.

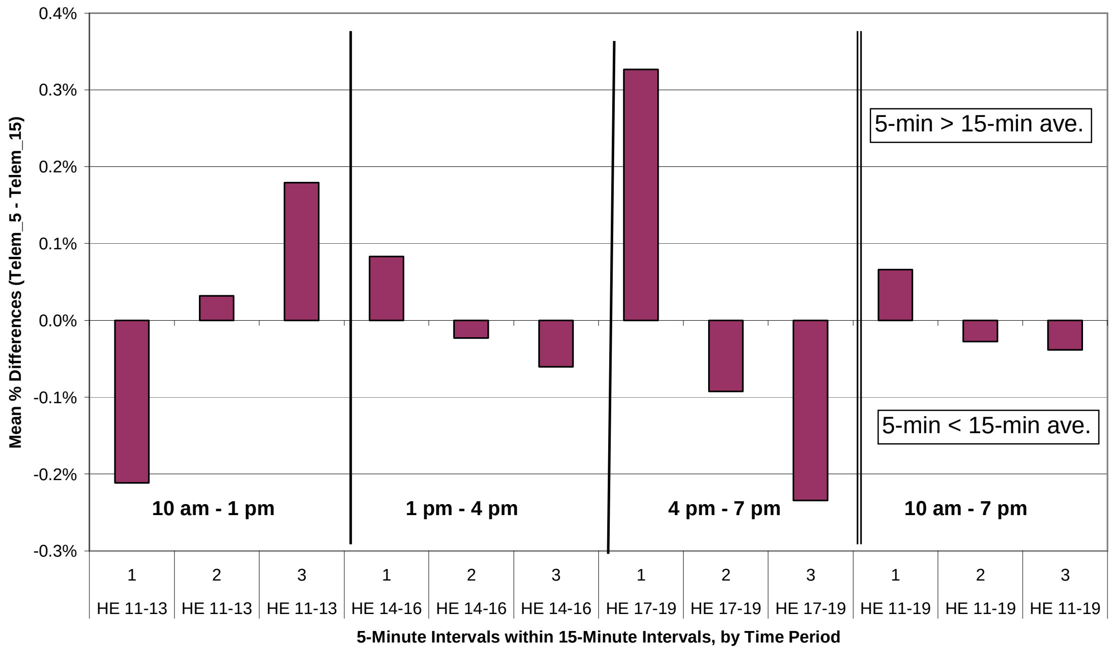
5.4.1 Comparison of 5-minute and 15-minute telemetry data

The analysis summarized in this sub-section used the telemetry data to examine patterns of differences between average loads for 15-minute intervals to the average loads for each 5-minute period during those intervals. Data were used for the overall 10 a.m. to 7 p.m. time period, as well as three three-hour sub-periods, for Aggregator 2 (whose telemetry data corresponded most closely to the 15-minute metered data). The average percent differences between the 5-minute and 15-minute interval data are shown in Figure 5.15, where *positive* values indicate that the 5-minute average load is greater than the 15-minute average, and *negative* values indicate the opposite. Several patterns are evident, including the following:

- Overall, the average differences are generally quite small, less than 0.1 percent, and standard deviations are generally less than 1.5 percent.
- Over the entire period (last panel) there is a slight tendency for the 5-minute average loads to become progressively smaller, such that the load in the first interval is larger than the 15-minute average, and those in the second and third intervals are smaller.
- In the late morning hours (first panel), the opposite is true; as the load is generally rising, the load in the first interval is less than the 15-minute average load, and those in the next two intervals are larger;
- In the 1 p.m. to 4 p.m. period, the load is relatively flat, and the three 5-minute loads take on similar values;
- Finally, in the late afternoon period, the load is generally falling, such that the magnitude of differences is the greatest of the three time periods.

These results suggest that the use of the 15-minute interval data rather than 5-minute telemetry loads to approximate usage in 5-minute intervals results in the above relatively small magnitude and pattern of errors. We now turn to the situation in which only 15-minute data are available.

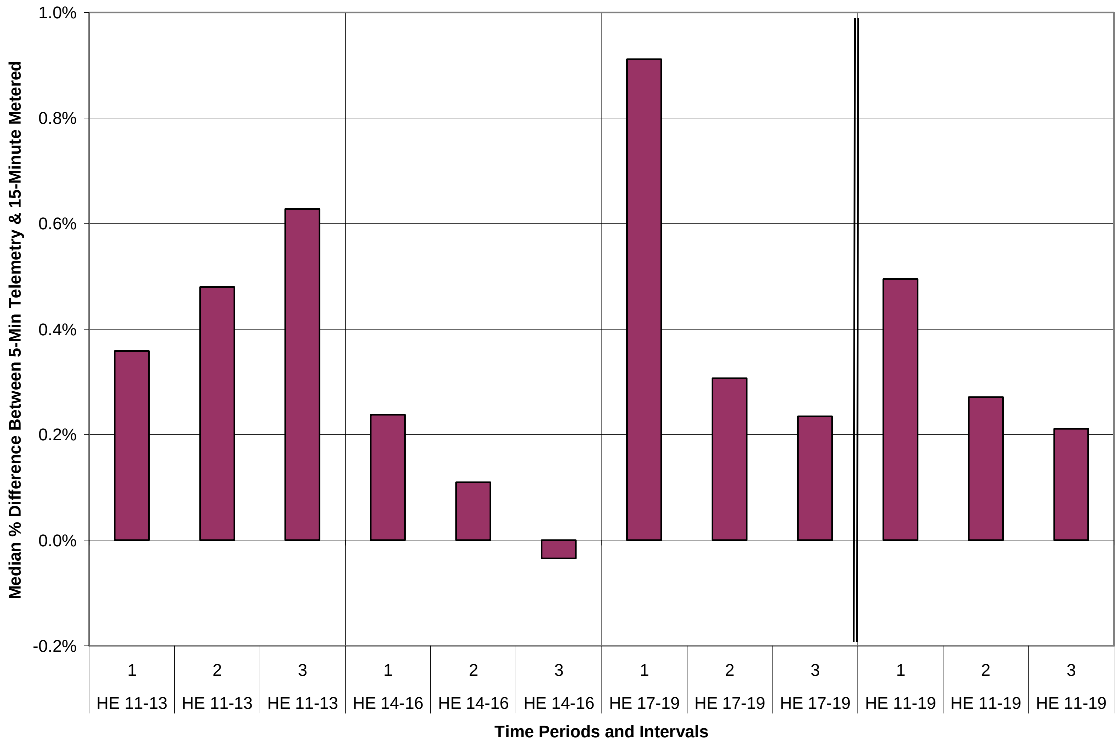
Figure 5.15: Percent Differences Between 5-Minute and 15-Minute Average Telemetry Loads, *by Time Period*



5.4.2 Comparison of 5-minute telemetry and 15-minute interval data

To assess possible errors in using unadjusted 15-minute average metered loads to represent the desired 5-minute load data, we calculated percentage differences between the known 5-minute average telemetry loads and average 15-minute metered loads (both in units of kWh/hour). In this case, we calculated percentiles of the distributions of differences between the two series, and show the median percent differences in Figure 5.16. The figure shows a similar pattern of the percent differences to that in Figure 5.15 above, which is to be expected given the similarity of the 15-minute versions of the telemetry and metered data. However, the larger percent differences reported in Figure 5.16 compared to Figure 5.15 illustrate the finding in Table 5.1 that the telemetry loads were slightly larger than the metered loads (mean and median differences of 0.17 and 0.29 percent, respectively).

Figure 5.16: Median Percent Differences Between 5-Minute Telemetry and 15-Minute Average Metered Loads, *by Time Period*

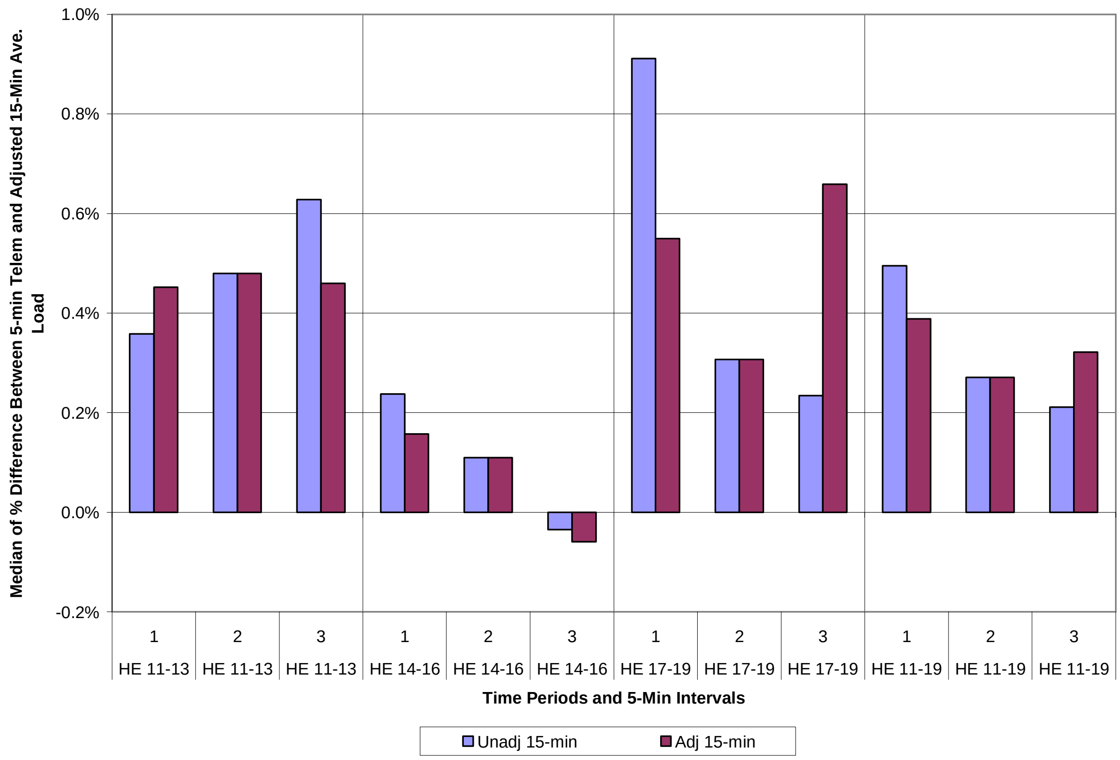


5.4.3 Comparison of 5-minute telemetry and *adjusted* 15-minute interval data

We then applied a straightforward adjustment approach that allocates differences between two sequential 15-minute loads to infer loads for 5-minute sub-intervals within the latter of the two 15-minute intervals. Specifically, we calculated differences between each 15-minute average load during the potential event period, divided the difference into thirds, and created three 5-minute sub-interval loads by the following process: 1) create the first sub-interval load by *subtracting* one-third of the difference from the 15-minute average load, 2) create the third sub-interval load by *adding* one-third of the difference to the 15-minute average load, and 3) let the second sub-interval load equal the 15-minute average load. This process has the effect of creating *increasing* 5-minute sub-interval loads in cases where the corresponding 15-minute load was larger than the previous 15-minute load, and *decreasing* 5-minute sub-interval loads in the opposite case. The approach will likely have difficulty representing sub-interval loads near inflection points in the 15-minute loads.

Figure 5.17 shows median percentage differences between the 5-minute average telemetry loads and the *adjusted* 5-minute sub-interval loads (both again in units of kWh/hour), shown next to the percent differences for the comparable unadjusted loads, as shown in Figure 5.16. Note that since no adjustment was made to the second sub-interval loads, those bars are identical. Overall, the adjustment appears to reduce the differences in the first interval, but increase them in the third interval. These effects are amplified in the HE 17-19 period. In addition, differences between overall RRMSE values for the unadjusted and adjusted results were negligible across all hours at about 2.6 percent.

Figure 5.17: Median Percent Differences Between 5-Minute Telemetry and Adjusted 5-Minute Sub-interval Metered Loads, ***by Time Period***



These results suggest that there could be room for improving on the use of the pre-event 15-minute average metered load as the basis for the meter-before baseline. However, the straightforward adjustment described in this section to create a pseudo 5-minute load does not seem to consistently produce improvements to the estimate of the load implied by the underlying 5-minute telemetry data. In any case, the differences between the unadjusted and adjusted load estimates in approximating the 5-minute telemetry loads were quite small.

5.4.4 Summary regarding MBMA baseline analysis

The results in the previous two subsections regarding MBMA baseline performance and the potential for improving on the use of unadjusted 15-minute average metered load data to represent 5-minute pre-event loads suggests that the former issue dominates the latter one. That is, in most cases, any adjustments to 15-minute average loads to better reflect changing loads *within* those periods will be swamped by likely errors in MBMA baseline approximation of aggregator loads during two-hour event periods. For example, 5-minute telemetry data suggested typical variation within 15-minute intervals of less than 0.5 percent. However, typical (median) errors of MBMA baselines' representation of "true" baseline loads during two-hour event periods range from 0.5 to 5 percent, but with half of the errors falling within the range of -7 percent to 10 percent depending on when the event is called.

Thus, improvements in baseline methods for PLP would probably be best focused on some type of day averaging, perhaps with a day-of adjustment (*e.g.*, adjusted 10-in10 method), as with the other baseline-dependent DR programs. CAISO's needs for immediate feedback on PLP participant response to an event dispatch could still be met by the telemetry data. However, the CAISO should be aware that the longer into the event that it attempts to use the MBMA baseline method and telemetry data, the less accurate will be its estimation of the participant's continued performance, particularly during time periods in which the participant's loads are typically rising or falling.

6. Validity Assessment

In this project, we estimated program load impacts using data aggregated to the level of the two aggregators for the daytime event window option, and customer-specific data for the one customer participating in the 24/7 event window option (though in practice, just the overnight hours). Three regressions were estimated—one for the individual customer that participated in overnight events, and one each for the two aggregators. The Adjusted R-Squared value for the individual customer regression was 0.49, largely due to a variable load pattern that included near-zero loads during most daytime hours. R-Squared values for the two aggregator equations were 0.96 for Aggregator 1 and 0.94 for Aggregator 2.

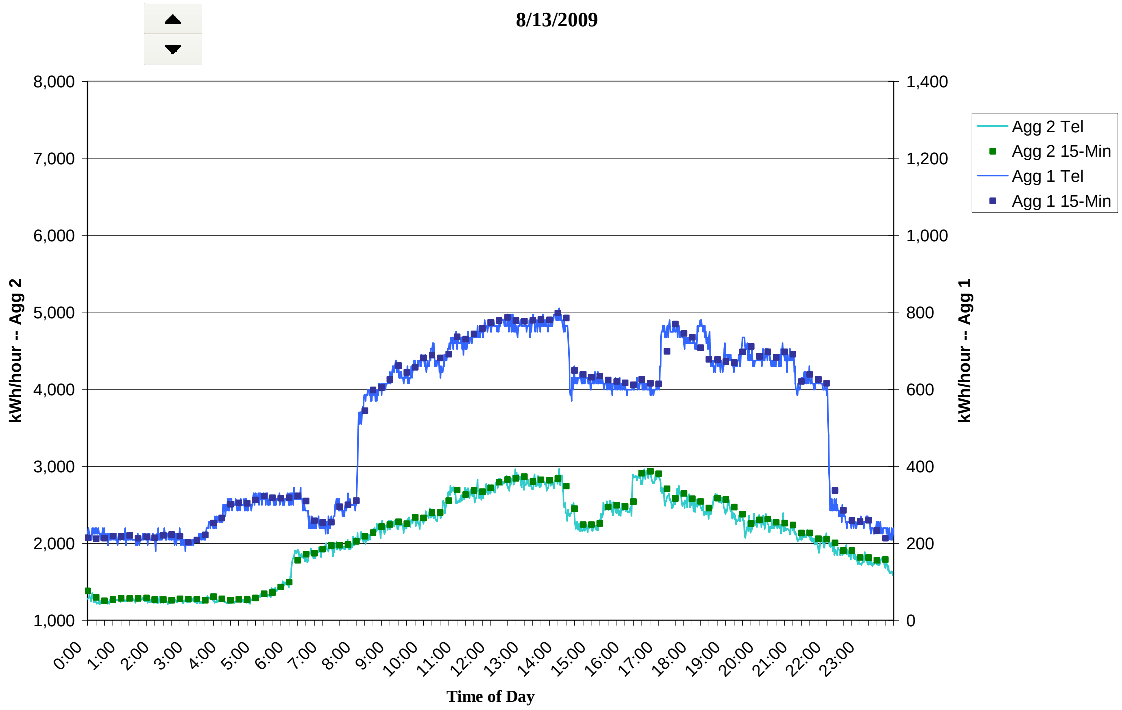
Estimated load impacts for the individual customer were marginally statistically significant, with typical t-statistics ranging from 1.5 to 2.0. In contrast, estimated load impacts for Aggregator 1 were generally strongly significant, with t-statistics ranging from 3 to 6 for all but one event. Estimated load impacts for Aggregator 2 were somewhat more variable across events, being strongly significant for eight of the fifteen events in which it participated.

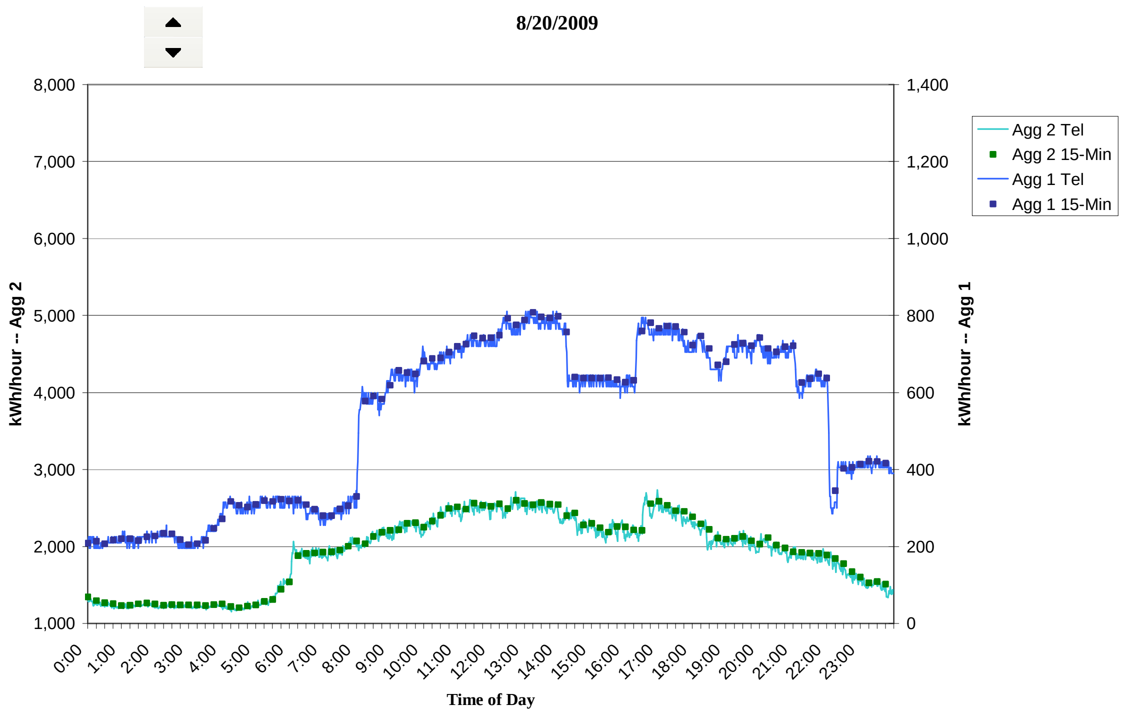
7. Recommendations

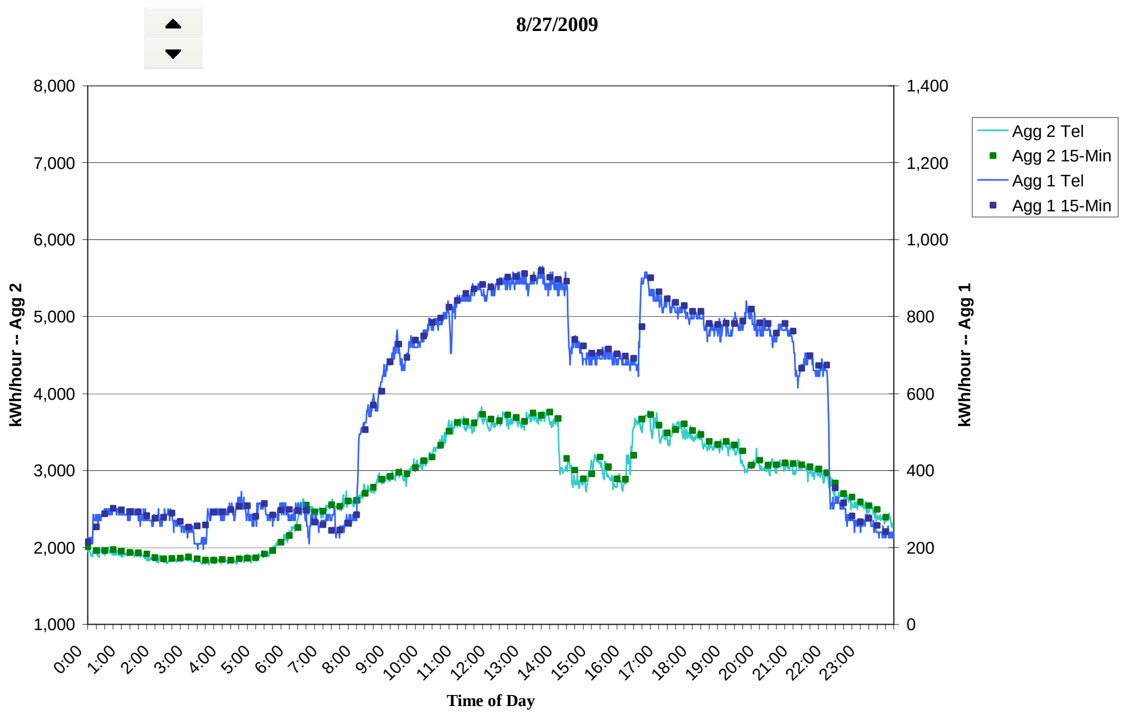
On the topic of load impacts, our results demonstrate that customers can provide load reductions in response to 10-minute notice, on a reasonably consistent basis. However, delayed response by Aggregator 1 on a few occasions suggests a possible need for assistance in understanding the timing of notices and events.

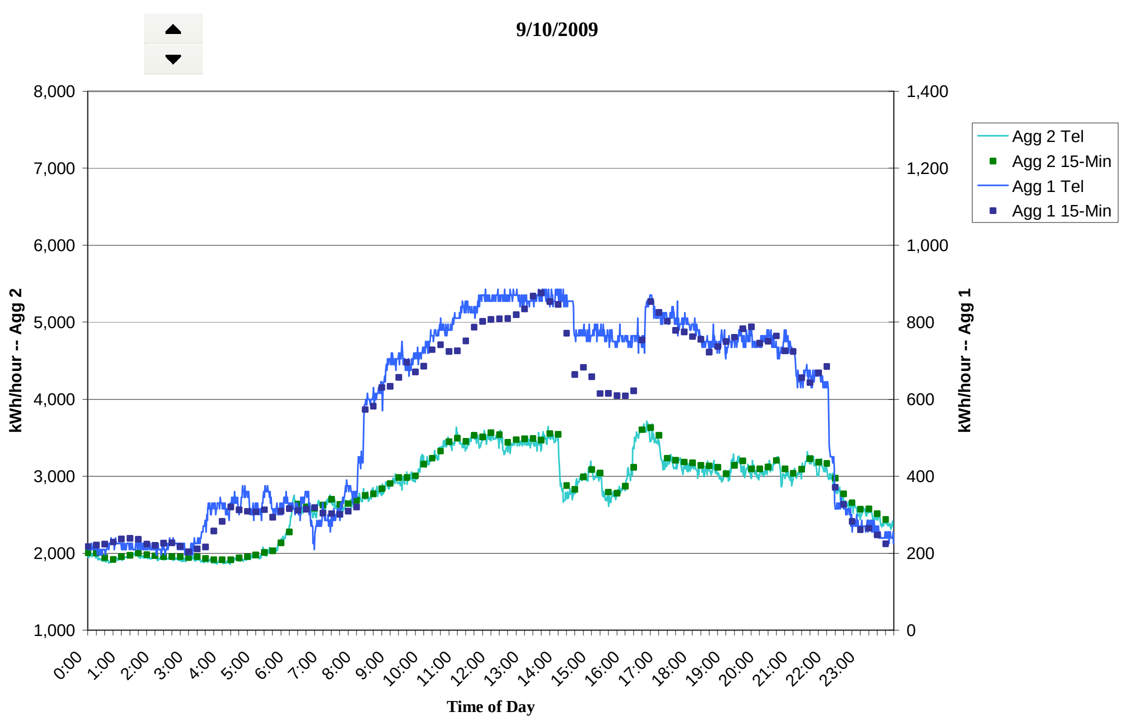
On the topic of the meter-before/ meter-after baseline, our baseline assessment suggests that the MBMA baseline is likely to understate or overstate customers' or aggregators' true baseline during certain periods of the day where loads are typically increasing (*e.g.*, mid-morning) or falling (*e.g.*, late afternoon). A more accurate baseline for billing purposes would likely be one that takes into account the customers' or aggregators' normal load profile, such as averaging their load over previous days, as with other demand response programs.

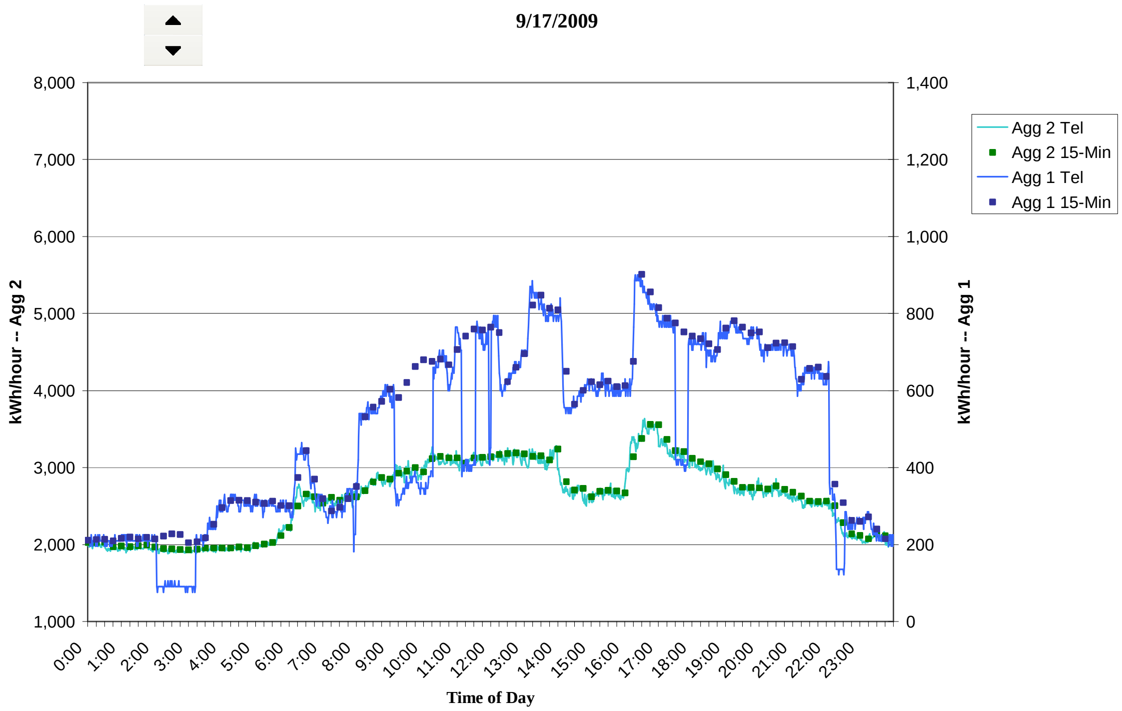
APPENDIX: PLP Event Plots

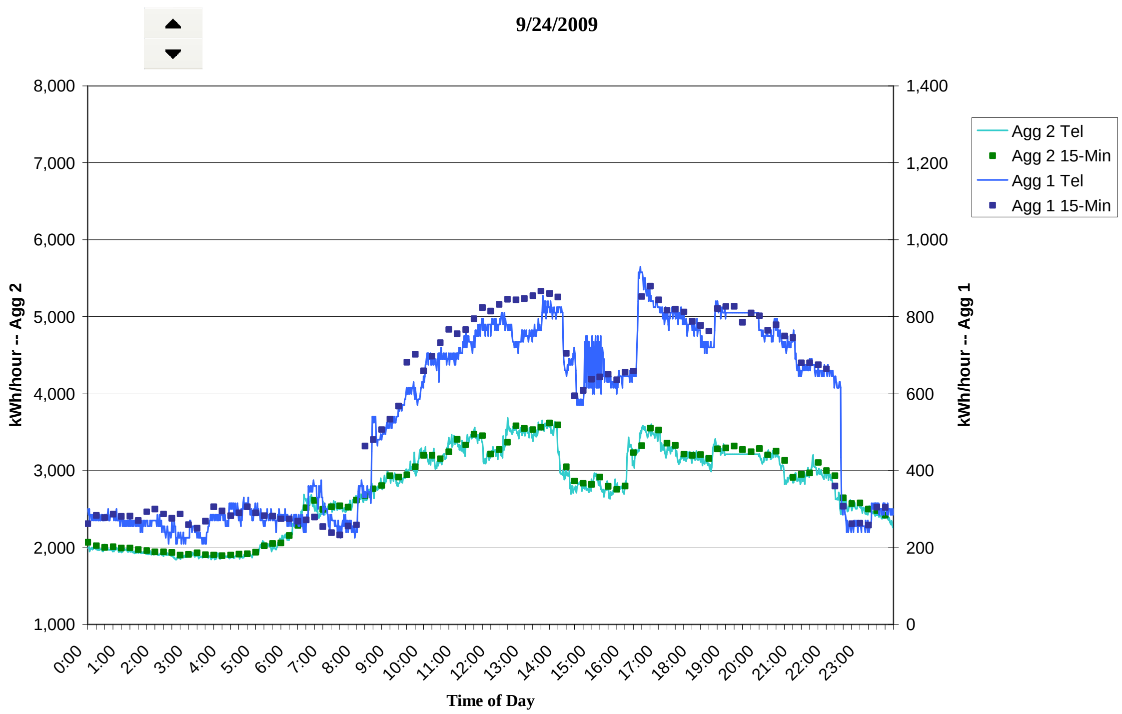


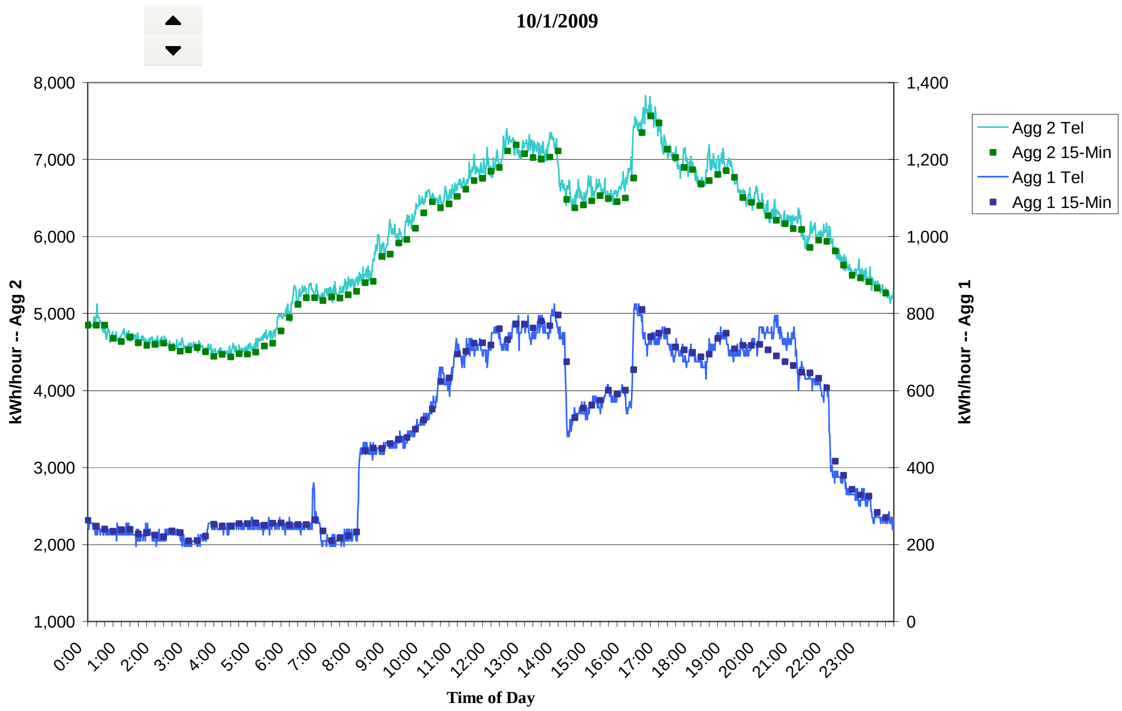


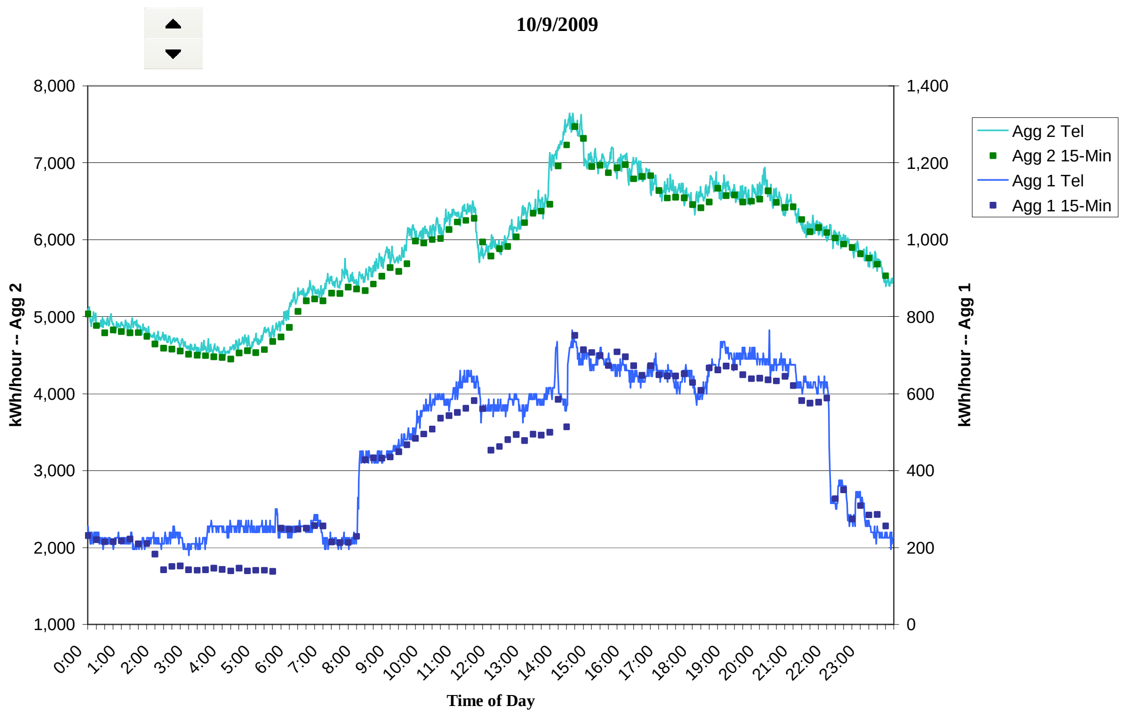

8/27/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
kWh/hour -- Agg 2
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Time of Day

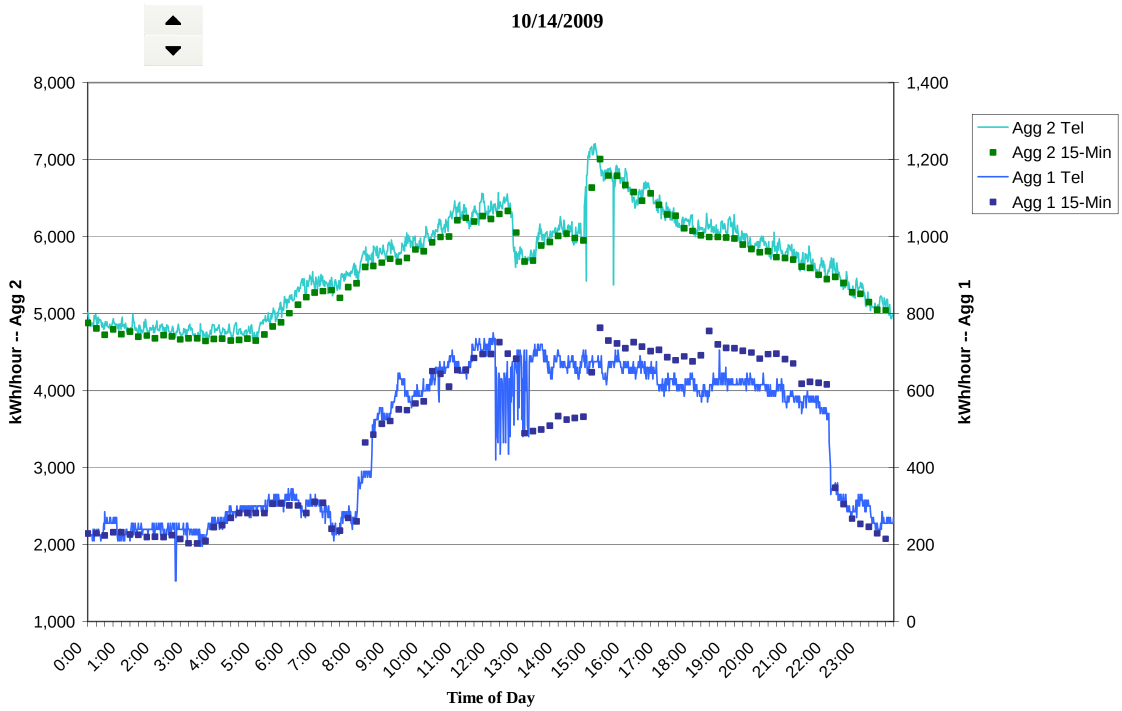

9/10/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
kWh/hour -- Agg 2
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Time of Day

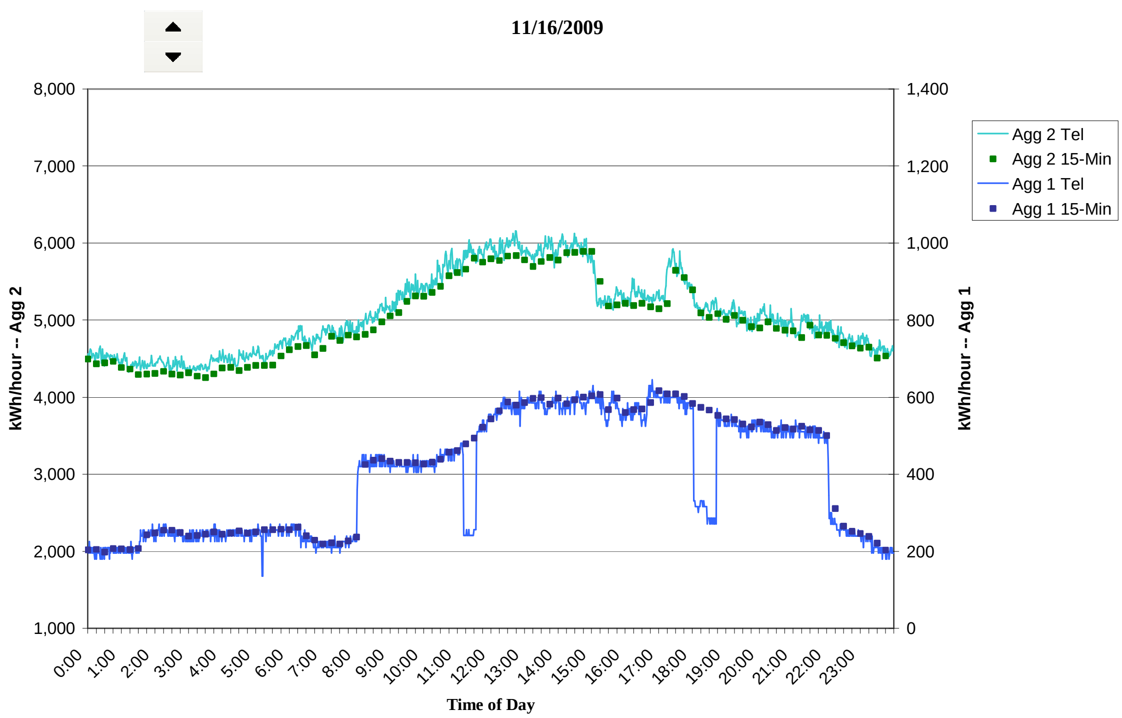

9/17/2009
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Time of Day
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

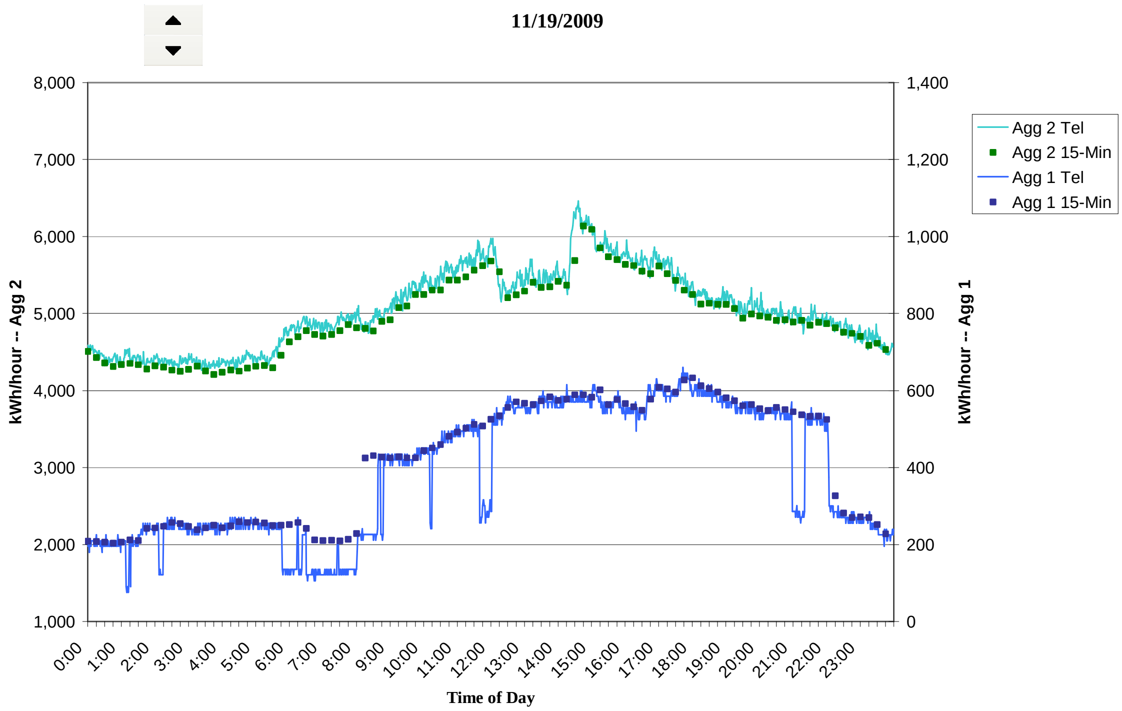

9/24/2009
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Time of Day
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00

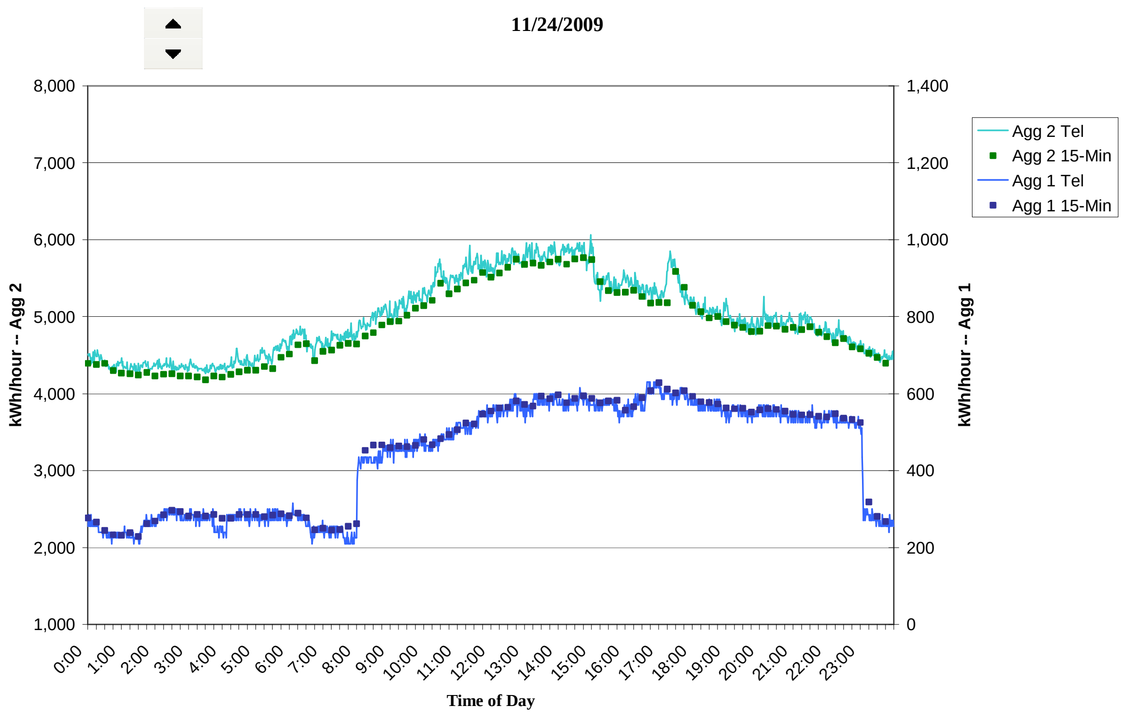

10/1/2009
kWh/hour -- Agg 2
kWh/hour -- Agg 1
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Time of Day
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min

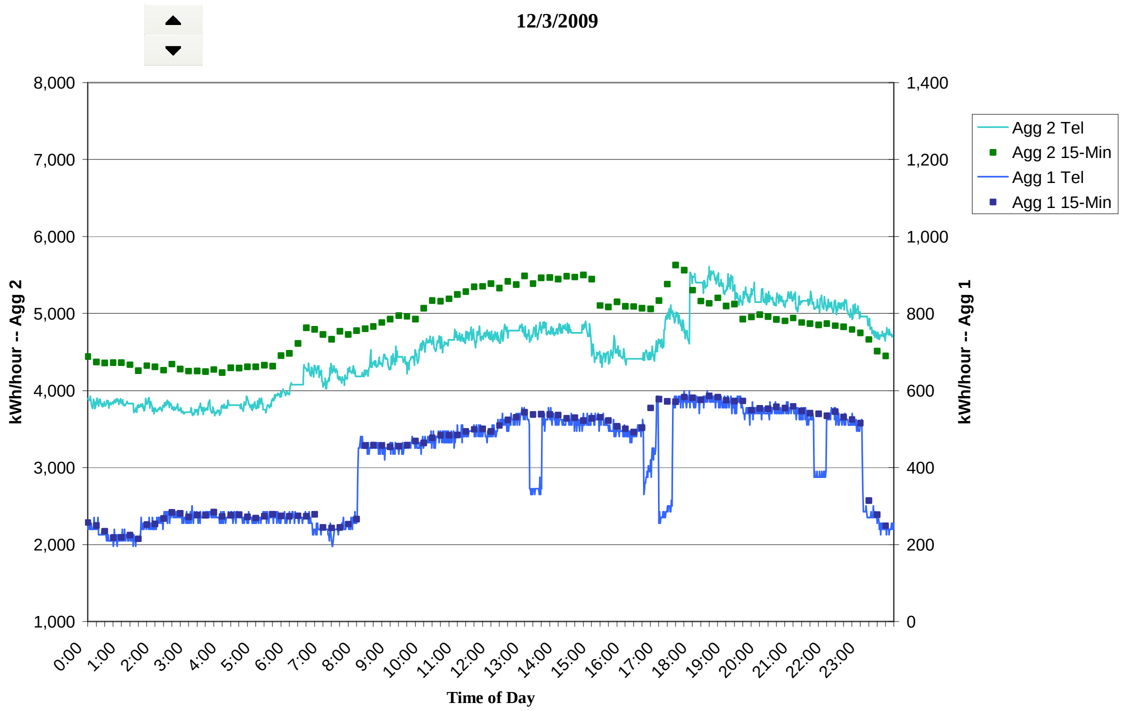

10/9/2009
kWh/hour -- Agg 2
kWh/hour -- Agg 1
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
0:00 1:00 2:00 3:00 4:00 5:00 6:00 7:00 8:00 9:00 10:00 11:00 12:00 13:00 14:00 15:00 16:00 17:00 18:00 19:00 20:00 21:00 22:00 23:00
Time of Day
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min

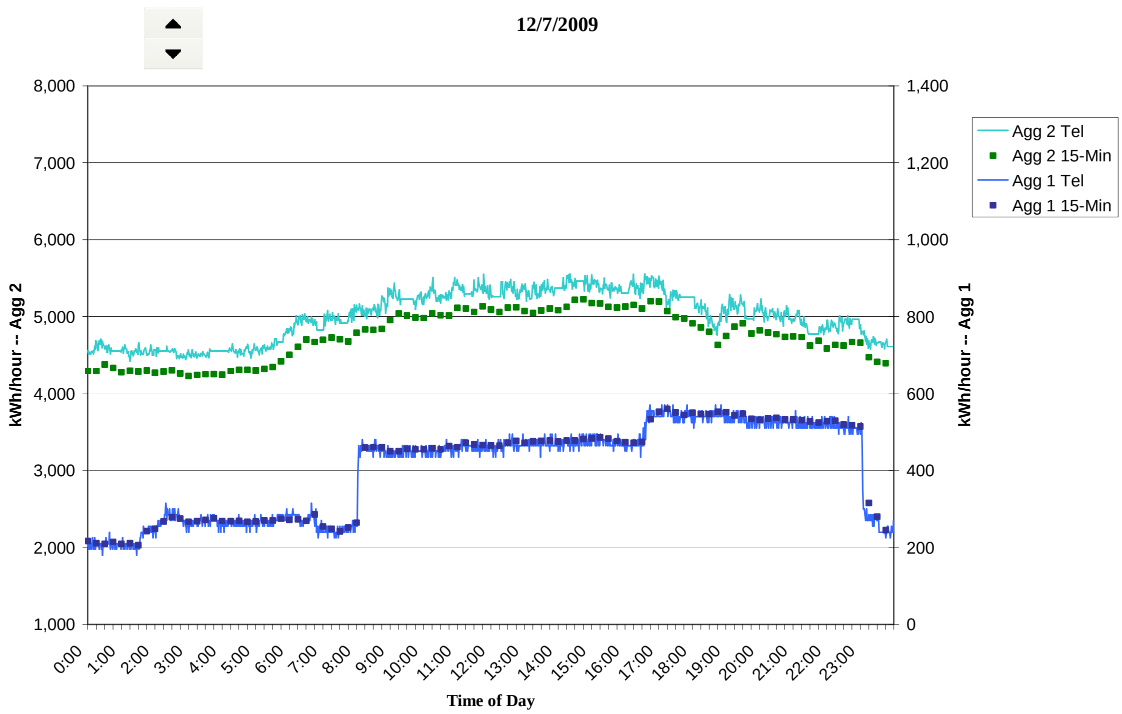

10/14/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


11/16/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


11/19/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


11/24/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


12/3/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day


12/7/2009
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
1,400
1,200
1,000
800
600
400
200
0
kWh/hour -- Agg 2
kWh/hour -- Agg 1
Agg 2 Tel
Agg 2 15-Min
Agg 1 Tel
Agg 1 15-Min
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time of Day