EVALUATION OF ENVIROGRID™ TECHNOLOGY PERFORMANCE

Final Report
August 2012

Prepared for:

Sacramento Municipal Utility District

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Executive Summary

The Sacramento Municipal Utility District (SMUD) provided an incentive to five commercial facilities that responded to a solicitation to install REGEN Energy's EnviroGrid™ controllers to test the technology. The EnviroGrid™ controllers are intended to be installed at facilities with multiple rooftop packaged air conditioning units that individually can be cycled off for a period of time. The EnviroGrid controllers provide three capabilities to customers; Demand Management (DM), Demand Response (DR), and scheduled operation. In DM mode the units communicate with each other to decide when individual units will run or not and minimize the number of units running at one time as a way to reduce customer peak demand charges. In DR mode the utility requests load shedding, typically during peak hours on hot days when system peak loads are high. When signaled, the units can further reduce facility demand. Scheduled operation allows a customer to program periods that the units will be off to save energy otherwise wasted when no one is present at the business.

Four day type control strategies were set up and defined for use in this study as follows:

- Baseline: no control of the air conditioning (AC) units
- Demand Management: control to level out AC demand load
- Demand Response Level 1: 10% reduction in allowed operating time by from DM mode
- Demand Response Level 2: 20% reduction in allowed operating time by from DM mode

The participating businesses included a hardware store, two physical workout centers, a car dealership, and a multi-tenant office building. Power and temperature monitoring equipment was installed to quantify the findings of the study.

Monitoring showed that the EnviroGrid controllers cycled most AC units off at some time during DR events. This shows that the technology is successful in its claim to provide DR control remotely. The EnviroGrid controllers cycled most AC units off at some time during DM Periods. This should translate into reduced demand charges for GS rate customers.

The data were analyzed to determine average demand savings during the 4 to 7 PM super peak period. The projected air conditioning demand savings for a 100 °F day were 8%, 14%, and 21% respectively for DM, DR 10%, and DR 20% modes. By controlling the operating schedules for the sites, energy savings ranged from 5,961 to 19,310 kWh/yr. The energy savings ranged from 0.14 to 0.80 kWh/sf with an average of 0.42 kWh/sf.

No individuals were highly dissatisfied with temperatures maintained during DM and DR events, however they did feel that their work environment was a bit warm. No employees reported that their work performances were affected.

One criterion that should be part of further implementation of the technology would be to ensure that the AC Units are in proper working order prior to controller installation. Deployment of this technology would be most compatible in facilities with slow thermal response time such as big box department stores, large open retail stores, large open offices, cold storage warehouses, and grocery stores.

EnviroGrid™ Report

The Sacramento Municipal Utility District (SMUD) provided an incentive to commercial facilities that responded to a solicitation to install REGEN Energy's EnviroGrid™ controllers to test the technology. SMUD contracted ADM Associates (ADM) to monitor and evaluate the Demand Response capabilities of the EnviroGrid™ controllers. Additionally, as part of this evaluation effort ADM conducted customer satisfaction surveys.

The Technology

The EnviroGrid™ controllers are intended to be installed at facilities with multiple cooling loads that individually can be cycled off for a period of time. Rooftop packaged air conditioning units are among the more straightforward applications that meet these criteria. The EnviroGrid controllers provide two capabilities to customers; Demand Management (DM) and Demand Response (DR). In DM mode the units communicate with each other to decide when individual units will run or not and prevent having all the units running at one time. Simultaneous operation creates an increased peak demand load as well as a higher monthly demand charge, which is based on highest annual demand. The DM mode theoretically smoothes out the load and reduces the customer's peak demand charges. In DR mode the utility requests load shedding, typically during peak hours on hot days when system peak loads are high. When signaled, the units can reduce facility demand by limiting the number of units that will operate simultaneously even further. The controllers (see Figure 1) communicate wirelessly among themselves, with one controller connected to a cell modem to provide real-time access to users via the REGEN Energy website. Website access allows users to monitor present and past operation of air conditioning (AC) units, define and edit schedules of operation of individual AC units, percent run time for various modes of operation, pre-schedule events, and overrides. Various access permissions of read only to full edit options can be granted when a user account is set up. Additional and new features are described in the "Discussions" section at the end of the report.

Figure 1. EnviroGrid™ Controller

The Plan

SMUD wanted to test the DR and DM capabilities of the EnviroGrid system because it provides the opportunity to address a market segment otherwise out of reach. General Service (GS) rate

commercial customers (peak demand below 300 kW) do not have the option to participate in DR programs. Most customers in the GS classification do not have energy management systems (EMS) in their building facilities providing them the capability to control loads on special request.

The target group of customers SMUD wanted to participate was retail and office buildings under 300 kW demand with packaged rooftop air conditioning. SMUD provided a list of candidate customers from which REGEN Energy was to recruit for the pilot study. A recruitment letter was mailed by SMUD to the list of customers. After recruitment ADM visited the sites to verify their qualification to participate in this pilot study. SMUD provided incentives to participants covering 100% of equipment and installation costs for signing monitoring agreements lasting two years. REGEN Energy installed controllers at three new sites in the fall of 2010. Two other sites were continuations of installations in 2009. The two continuing sites had controllers upgraded with new control strategies. After the sites were signed up, monitoring equipment was installed to capture air conditioning use and indoor temperatures. Four different control strategies were set up and defined the four day types used in this study. The four day type classifications are:

- Baseline: no control of the AC units
- Demand Management (DM): control to level out AC demand load without impacting interior temperatures
- Demand Response Level 1 (10% DR), control of AC loads to reduce allowed operating time by 10% from DM mode during the three hour peak period
- Demand Response Level 2 (20% DR): control of AC loads to reduce allowed operating time by 20% from DM mode during the three hour peak period

A strategy was developed to determine the criteria when DR event days would be activated. ADM was assigned the task of tracking weather conditions and sending out email notification to all parties involved by noon the day before the event. The demand response period coincides with SMUD's super-peak period from 4 PM to 7 PM on weekdays from June through September.

The Sites

The marketing efforts by REGEN resulted in five sites that signed monitoring agreements. They were: Emigh Ace Hardware, Gold's Gym in Natomas (Sacramento), Gold's Gym in Elk Grove, Maita Chevrolet, and JAL Properties. The following are pictures from each of these sites. Table 1 provides a list of the five sites and number of AC units controlled. Six AC units at Gold's Gym Elk Grove and seven AC units at Gold's Gym Natomas were not controlled because they were in customer-sensitive areas. Nine AC units at JAL Properties had controllers; however, only four of these units were operating during the summer of 2011.

Emigh Ace Hardware

Emigh Hardware Packaged Rooftop AC

Gold's Gym – Natomas

Gold's Gym Natomas Packaged Rooftop AC

Gold's Gym – Elk Grove

Gold's Gym Elk Grove Packaged Rooftop AC

Maita Chevrolet – Elk Grove

Maita Packaged Rooftop AC

JAL – Downtown Sacramento

JAL Packaged Rooftop AC

Table 1. List of Sites and AC Units controlled.

Site Name	Business Type	# of AC Units with controllers
Emigh Hardware	Retail Building	4
Gold's Gym- Natomas	Health Club	13
Gold's Gym- Elk Grove	Health Club	14
Maita Chevrolet	Car Dealership	11
JAL Properties	Office Building	9 (only 4 ACs operated during 2011)

Monitoring Approach

ADM installed monitoring equipment in late April 2011. . Current transformers were installed in electrical breaker panels and an Enernet K-20 multi-channel meter recorder was used to monitor and record the power use of individual air conditioning units at each site. Data were recorded in 5-minute intervals. (It should be noted that one of the air conditioning units at Maita Chevrolet did not operate during the monitoring period.)

In addition, temperatures at the thermostats (or acceptable locations within zones) were monitored using battery operated Hobo temperature loggers. Outdoor temperature was obtained

from various local weather stations. The sites were visited periodically to download data from all the logging equipment.

ADM used the power loggers mounted near the electrical panels with current transformers mounted in the panels to independently measure energy use for the individual AC units at each of the sites. Identification of specific air conditioning unit circuits in the HVAC electrical panel was challenging. Data collected on individual units allows analysis and troubleshooting of problems. If the primary interest is the net result of all the controllers at a site, then monitoring on future projects can be simplified so that data collection is for the sum of all units. This approach may lead to fewer potential problems such as less equipment required on site, longer periods before the download of logger data, less circuit tracing, and possibly a shorter installation time.

However, another reason for measuring the load of each AC unit was to test the load measurements of the individual AC units that REGEN makes through the controllers and reports to customers via the REGEN Energy portal. If these load measurements can be trusted to be accurate, then independent metering is not necessary. A comparison of the two data sources is presented later in this report.

Power recorder mounted next to electrical panel on roof.

Hobo temperature logger attached to thermostat.

Load and Temperature Profiles

Part of the monitoring strategy was to capture different types of days and categorize them for analysis.

Table 2 shows a summary of the number of days of data that were collected for each of the temperature ranges and conditions.

Table 2. Number of Days by Mode and Ambient Temperature for All Sites.

Ambient Temp. Range		Baseline					Demand Management (DM)				
Min	Max	Emigh	GGN*	GGEG	Maita	JAL	Emigh	GGN	GGEG	Maita	JAL
70	90	31	26	22	30	27	23	24	22	17	16
91	94	7	10	8	4	8	12	8	8	9	4
95	99	9	7	8	11	14	10	10	10	5	5
100	104	2	3	3	3	4	4	3	3	2	1
Total days		49	46	41	48	53	49	45	43	33	26

Ambient Temp. Range		Demand Response 10% (10% DR)					Demand Response 20% (20% DR)				
Min	Max	Emigh	GGN	GGEG	Maita	JAL	Emigh	GGN	GGEG	Maita	JAL
70	90	2	0	0	0	0	1	1	1	1	5
91	94	1	1	2	3	3	4	2	3	4	0
95	99	2	1	1	2	2	4	2	2	4	3
100	104	1	1	1	1	1	0	0	0	0	0
Total days		6	3	4	6	6	9	5	6	9	8

* GGN = Gold's Gym Natomas (Sacramento), GGEG = Gold's Gym Elk Grove

Baseline days constituted days where the monitoring equipment was set to the 100% mode, effectively bypassing the controller. Demand Management mode levels the demand to avoid increasing the customers' peak kW. DM mode can also be used to curtail operation of the units during non-business hours. The first tier of demand response days implemented a 10% reduction in allowed operating time over the demand response window for each AC unit based on the demand management allowed operating time, and later a 20% reduction in allowed operating time. For example, if an AC unit is allowed to operate for 10 of 12 15-minute intervals in a three hour window, then a 10% DR mode will allow the unit to operate 90% of the DM level or 9 of the 12 15-minute intervals. The DR percent only signifies the most demand reduction that could occur and not necessarily the amount that will occur for each AC unit. The overall effect of reducing operating times of individual AC units at sites with many controllers allows optimization of which units are allowed to operate during a given 15-minute interval, providing a somewhat uniform reduction in demand over the entire demand response window.

Data were processed into 15-minute interval data for analysis and charting. Figure 2 through Figure 6 show two similar (although not consecutive) hot days at the five measured sites. One day is a Baseline day and the other is a DM with 10% DR day. This is a very busy graph intended primarily to give a feel for the amount of data collected. However, the chart does show a few things. The colored lines are individual AC units showing a lot of cycling on and off. Generally, there is more cycling during the demand response day than on the baseline day; this is better observed in the sites with more AC units. There is a concern that more duty cycles during

DM days compared to Baseline days may lead to more mechanical wear on the AC system, which would increase maintenance cost. Due to this concern, an analysis comparing duty cycles during Baseline days with that of DM days is explored later in this report. DR periods can only be implemented a maximum of 48 hours per year (12 days times four hours), so DRis not expected to have a significant impact on the overall difference in number of cycles per AC unit.. The black line is the sum of all the AC units and uses the secondary chart axis on the right. The black line peaks higher on the baseline day than the DM/DR day, showing that the controllers are being effective in reducing load, particularly peak load. The shaded light blue bands are the DR period from 4 to 7 PM.

Weather data is also shown in the figures below as black dotted lines. Outdoor temperature data is taken from the weather tower located at the Sacramento Executive Airport and sourced from the wunderground.com website.

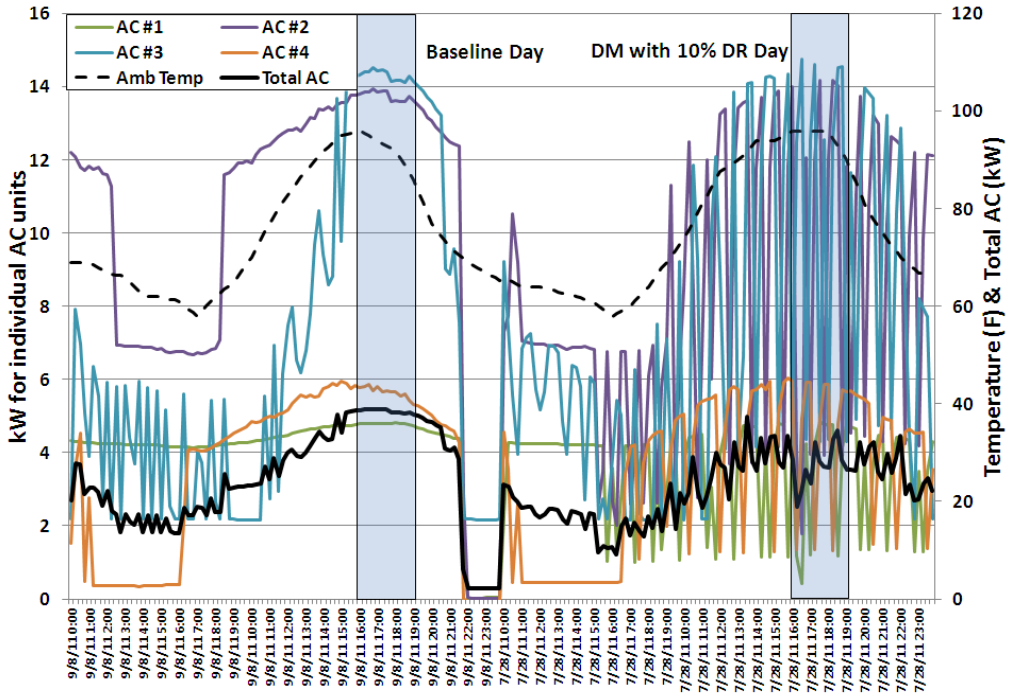

Figure 2. Two Similar Days at Emigh Hardware

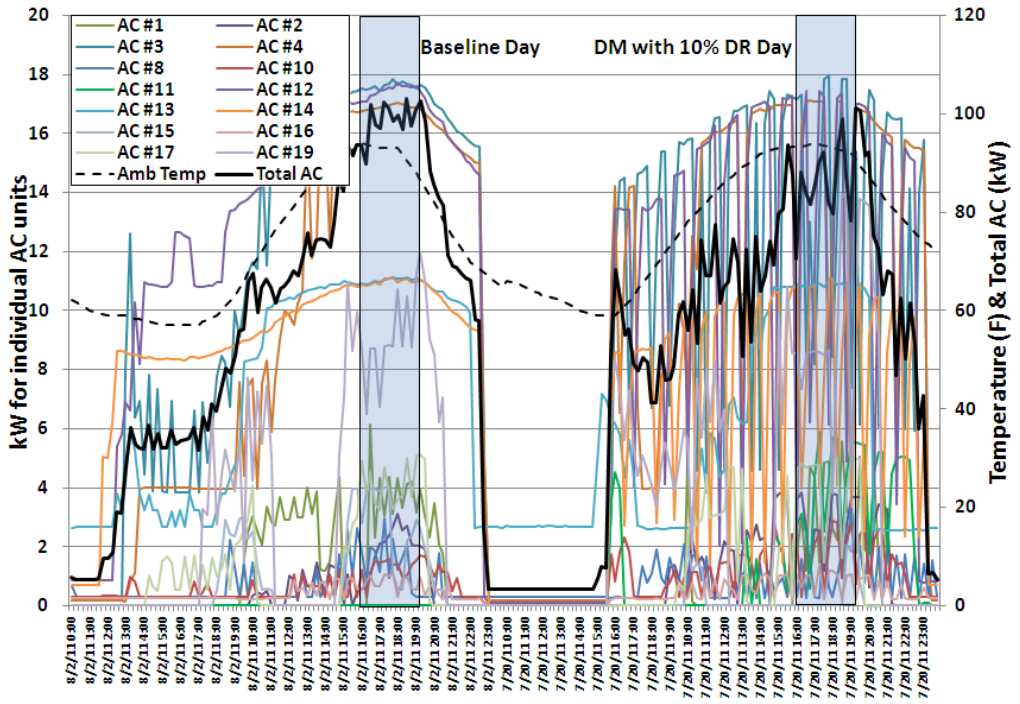

Figure 3. Two Similar Days at Gold's Gym Natomas

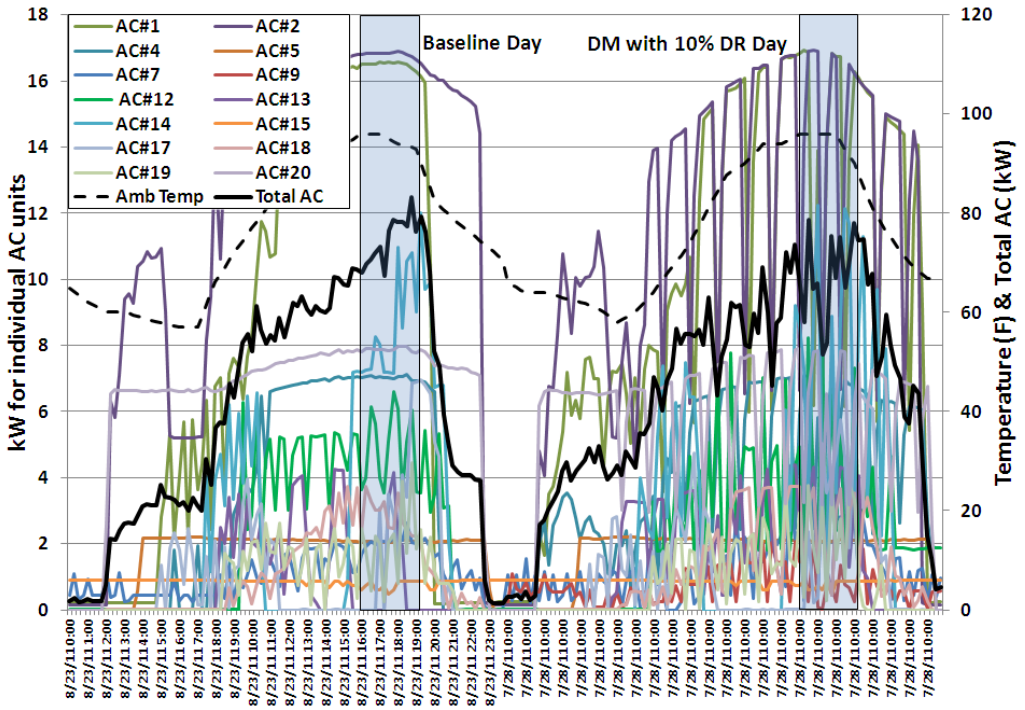

Figure 4. Two Similar Days at Gold's Gym Elk Grove

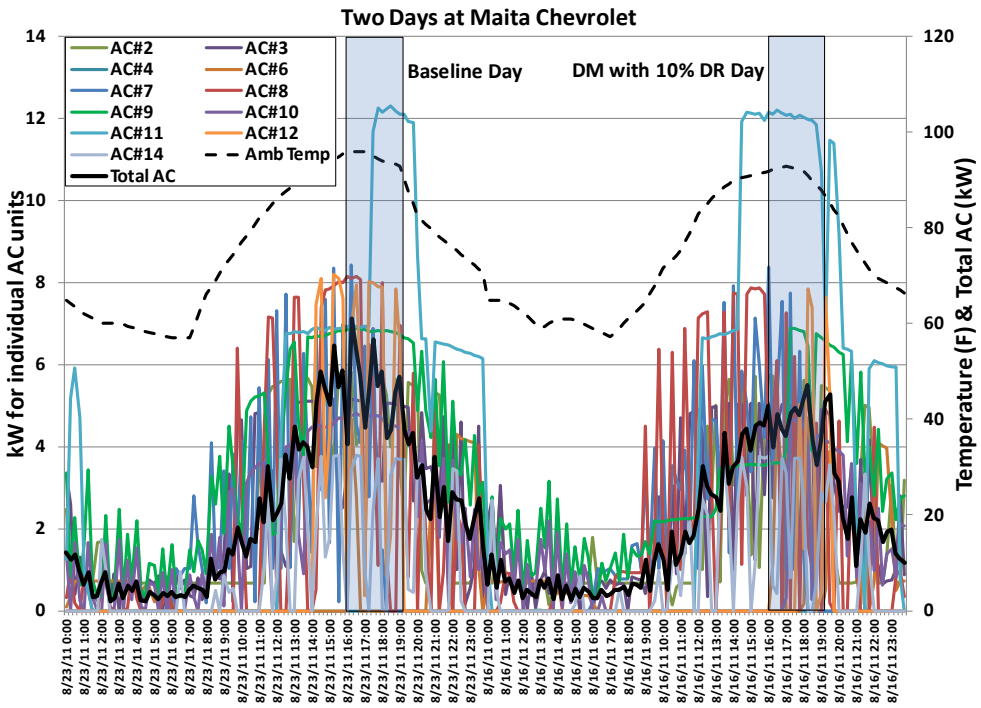

Figure 5. Two Similar Days at Maita Chevrolet

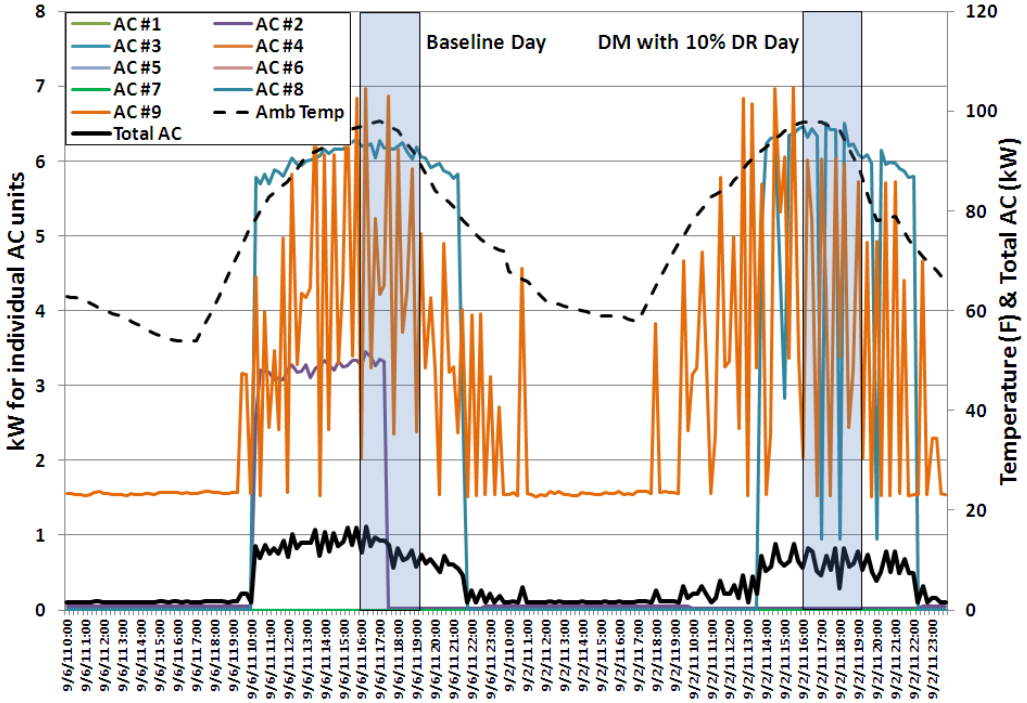

Figure 6. Two Similar Days at JAL Properties

The following pair of charts (Figure 7) shows evidence that the Demand Response capability of the EnviroGrid controllers functions. Both charts show AC demand profiles and outdoor ambient temperature for similarly hot days at Emigh Hardware. They compare a Baseline day with a DM day with a 10% DR event during the super peak hours. All hours that were not part of the DR period on September 2nd were operated in DM mode. During the Baseline day, some of the AC units operate continuously through the super peak period. However, on the DM/DR 10% day, all of the AC units show that they were cycled off several times during the super peak period.

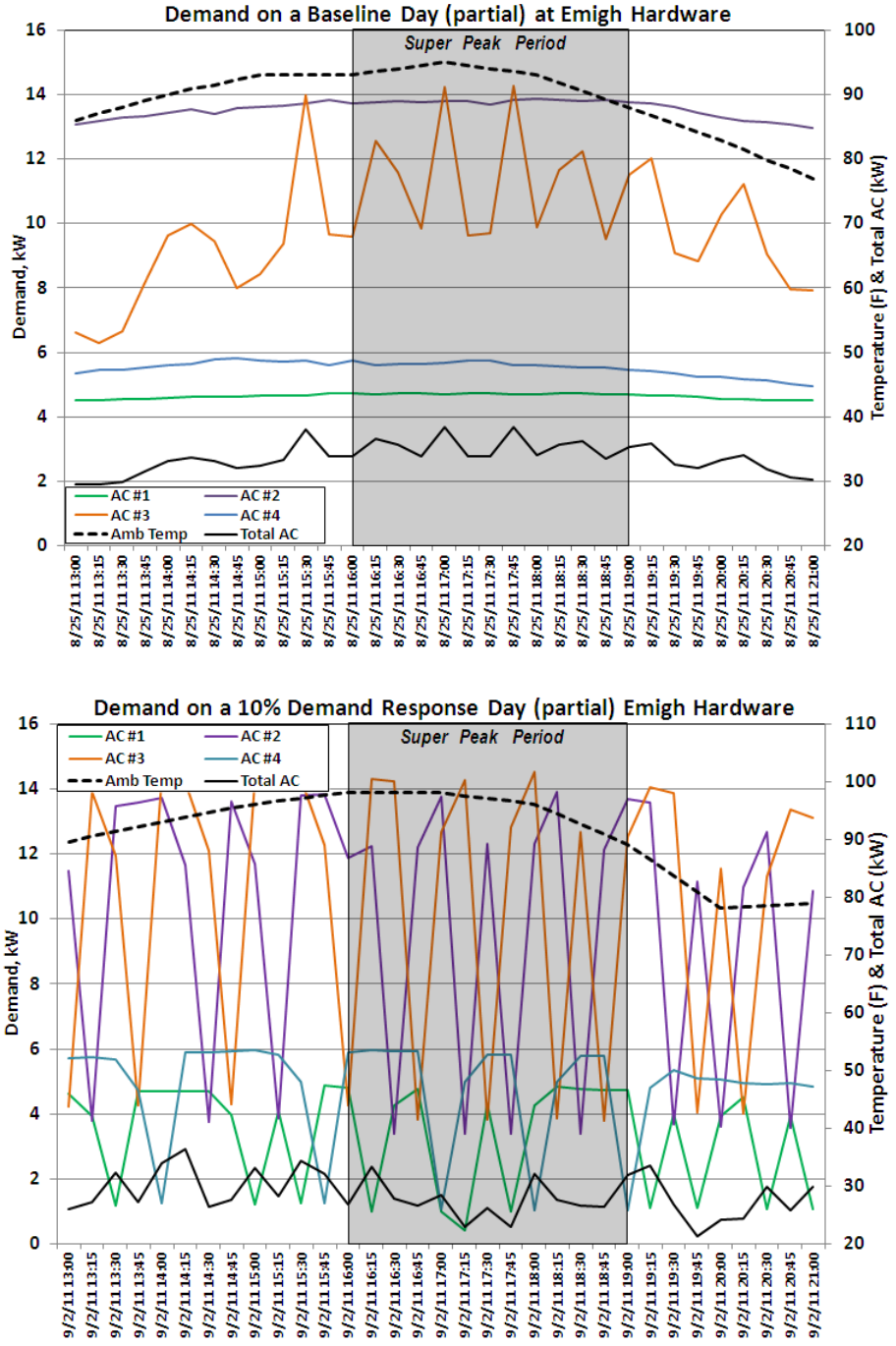

Figure 7. Emigh Hardware – AC Unit Profiles for Baseline and 10% DR Days

The next pair of charts (Figure 8) shows the hourly outdoor and 15-minute indoor temperatures at Emigh Hardware for the same set of days as above in Figure 7. The DM/DR10% day shows more variability in temperatures across zones and an indoor temperature increase when compared to the Baseline day.

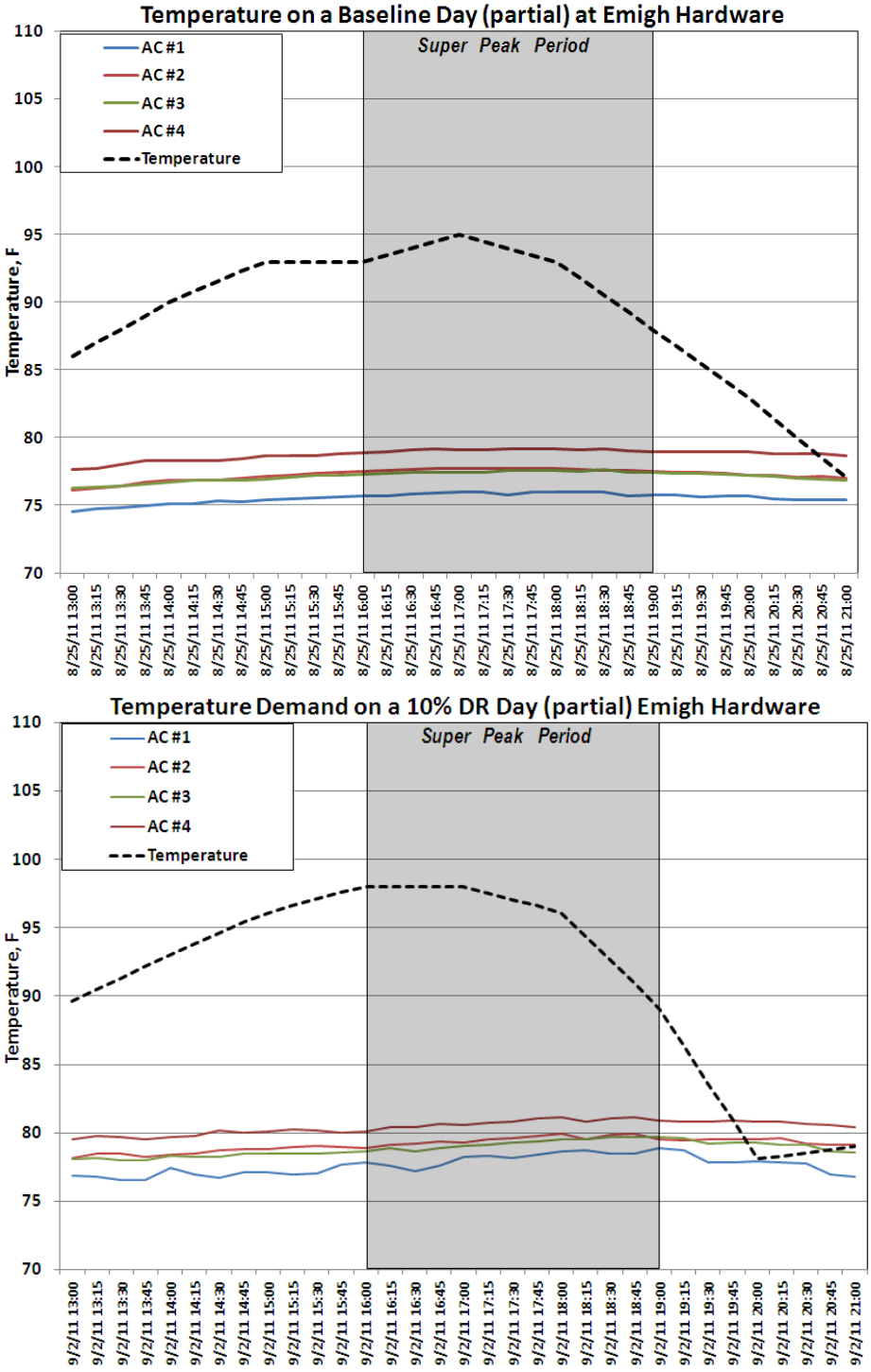

Figure 8. Emigh Hardware – Temperature Profiles for Baseline and 10% DR Day

The next set of charts shows AC demand profiles and hourly outdoor temperature for similarly hot days at Gold's Gym Natomas (see Figure 9 below). The chart on top is a Baseline day showing that some of the AC units, including the largest, operate continuously through the super peak period. The chart on the bottom is a Baseline day with a 10% DR event during the super peak hours showing that all of the AC units were cycled off at least once during the super peak period. The Gold's Gym Natomas site illustrates more clearly the complexity (due to the greater quantity of AC units) of the EnviroGrid controls during a demand response day when compared to the Emigh Hardware site.

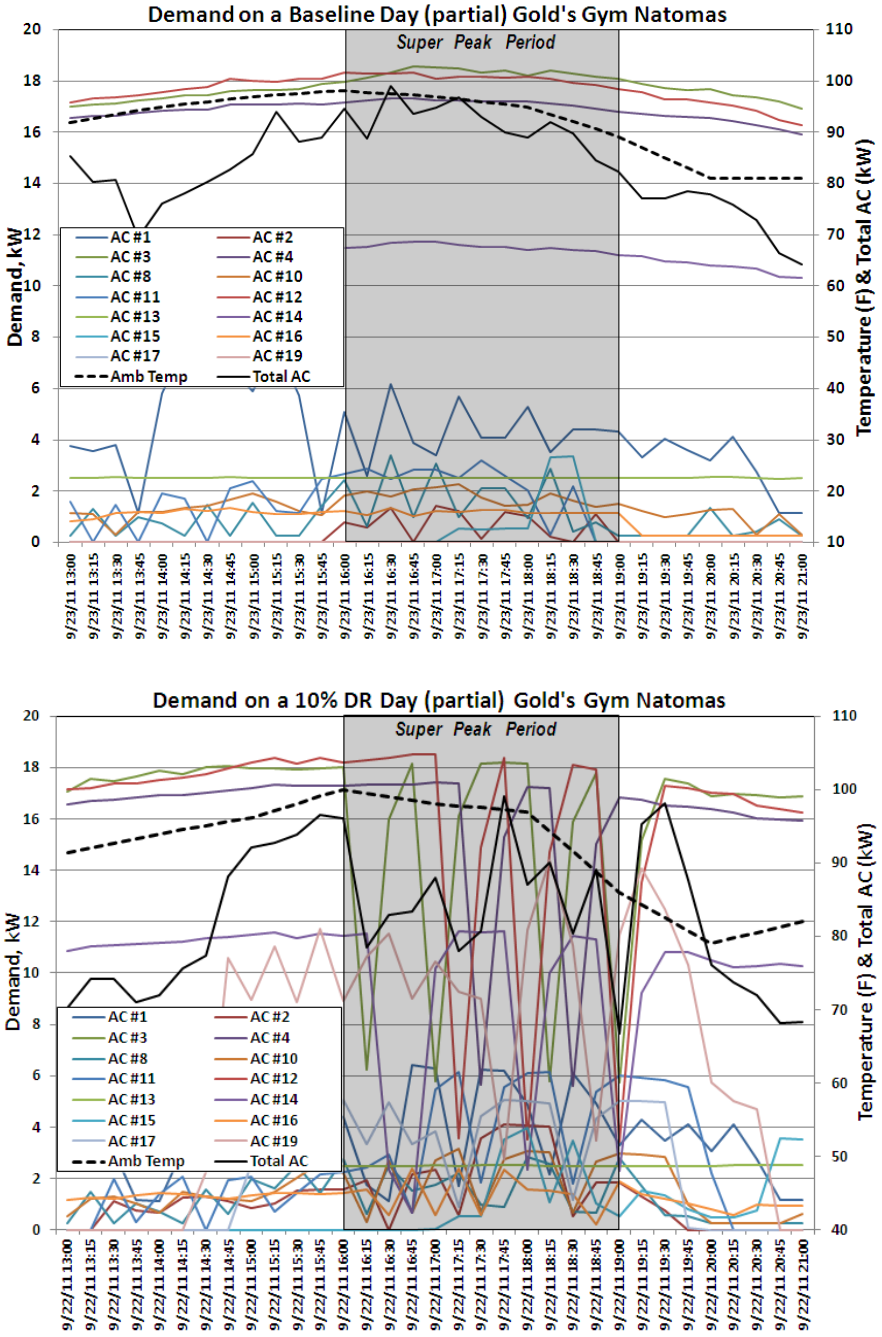

Figure 9. Gold's Gym Natomas – AC Unit Profiles for Baseline and 10% DR Days

Figure 10 shows the outside and inside temperatures at Gold's Gym Natomas for the same pair of days as Figure 9 above. Again, the Demand Response day shows more variability in temperatures across zones when compared to the Baseline day.

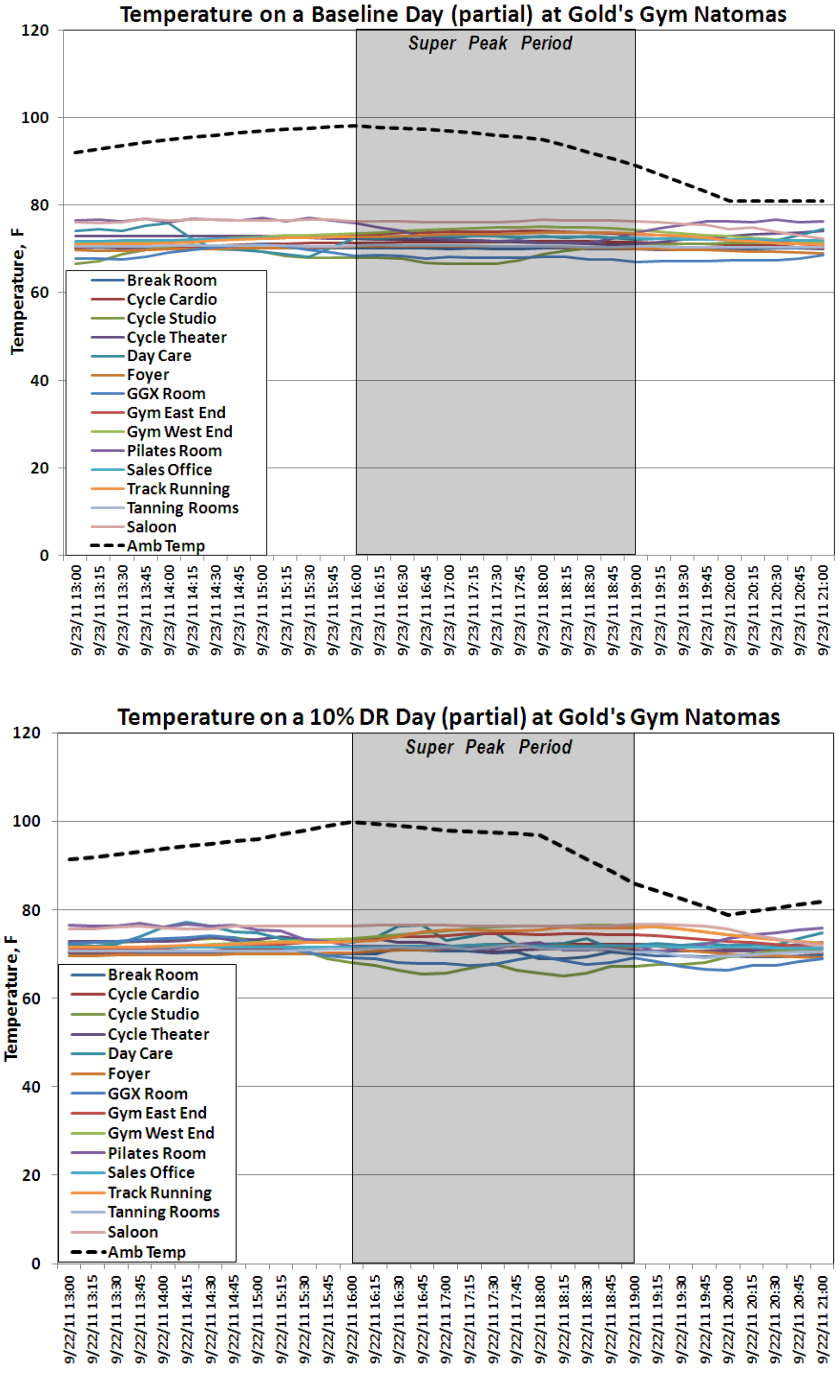

Figure 10. Gold's Gym Natomas – Temperature Profiles for Baseline and 10% DR days

The following pair of charts (Figure 11) show AC demand profiles for similarly hot days at Gold's Gym Elk Grove. The chart on top is a baseline day and similar to the other sites

illustrates that some of the AC units operate continuously through the super peak period. The chart on the bottom is 9/22/11 and was a Baseline day with a 10% DR event during the super peak hours at all sites. The chart shows that all of the AC units were cycled off at least once during the super peak period. The two AC units with the highest demand can be seen to cycle off at the same time on the 10% DR day. This is an observation and not necessarily a flaw in the EnviroGrid controllers. Some of the smaller AC units were turned off when the larger AC units were turned on. This offsetting between the large and small AC units is part of the EnviroGrid control strategy. It generally leads to a lower total AC demand than would have happened without the devices. A solid black line showing the total AC demand has been added to these two figures. Note that the 15-minute peak for both days is approximately 85 kW so there is no demand reduction on the customer's meter. However, the average demand over the three hour utility super peak period is reduced from 79 kW on the baseline day to 67 kW on the 10% DR day.

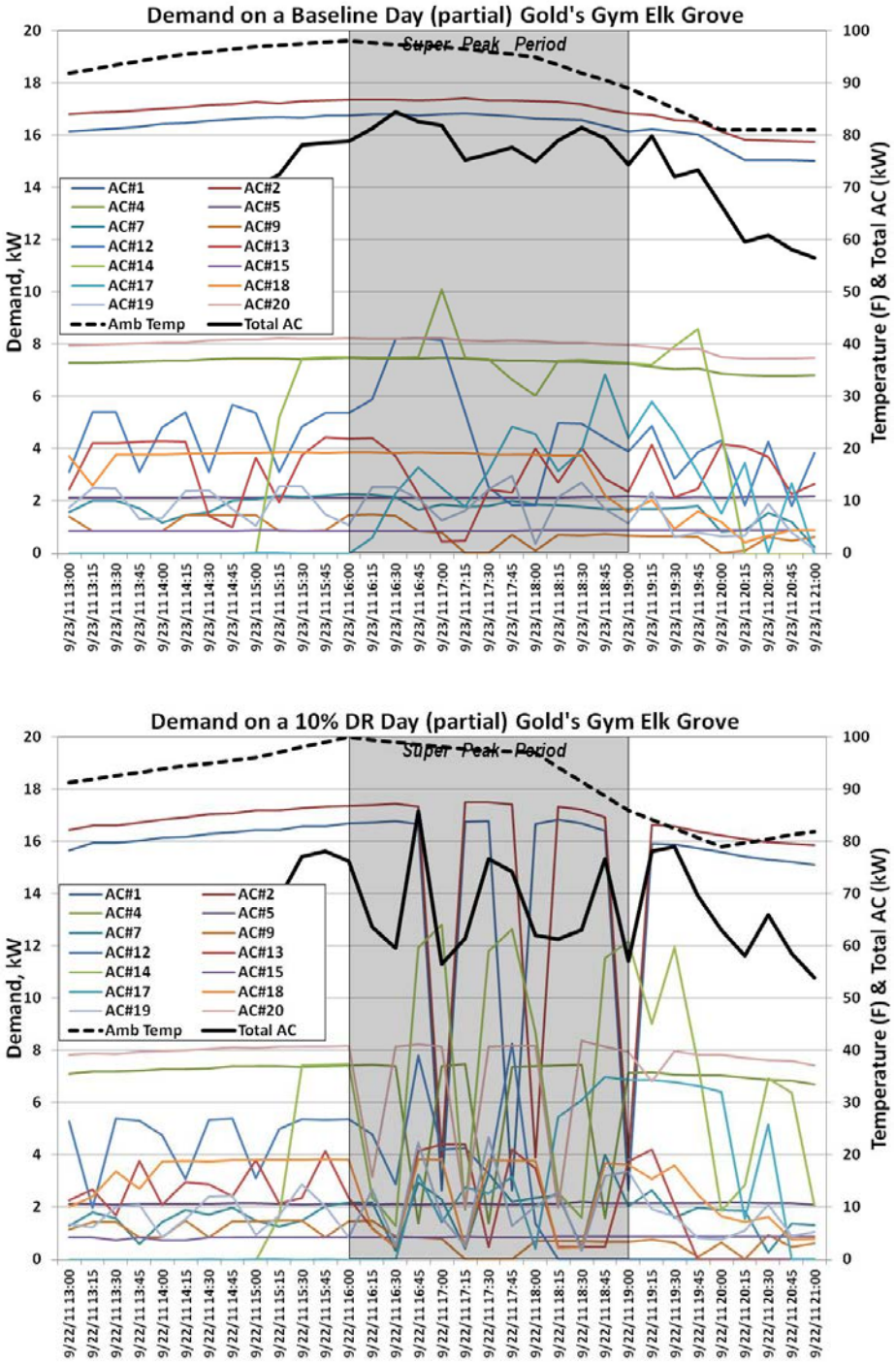

Figure 11. Gold's Gym Elk Grove– AC Unit Profiles for Baseline and 10% DR Days

Figure 12 shows the outside and inside temperatures at Gold's Gym Elk Grove for the same pair of days as Figure 11. The 10% DR period shows two zones that have more variability, one of which has a higher average temperature when compared to the Baseline day, but most zones show similar temperatures for both days.

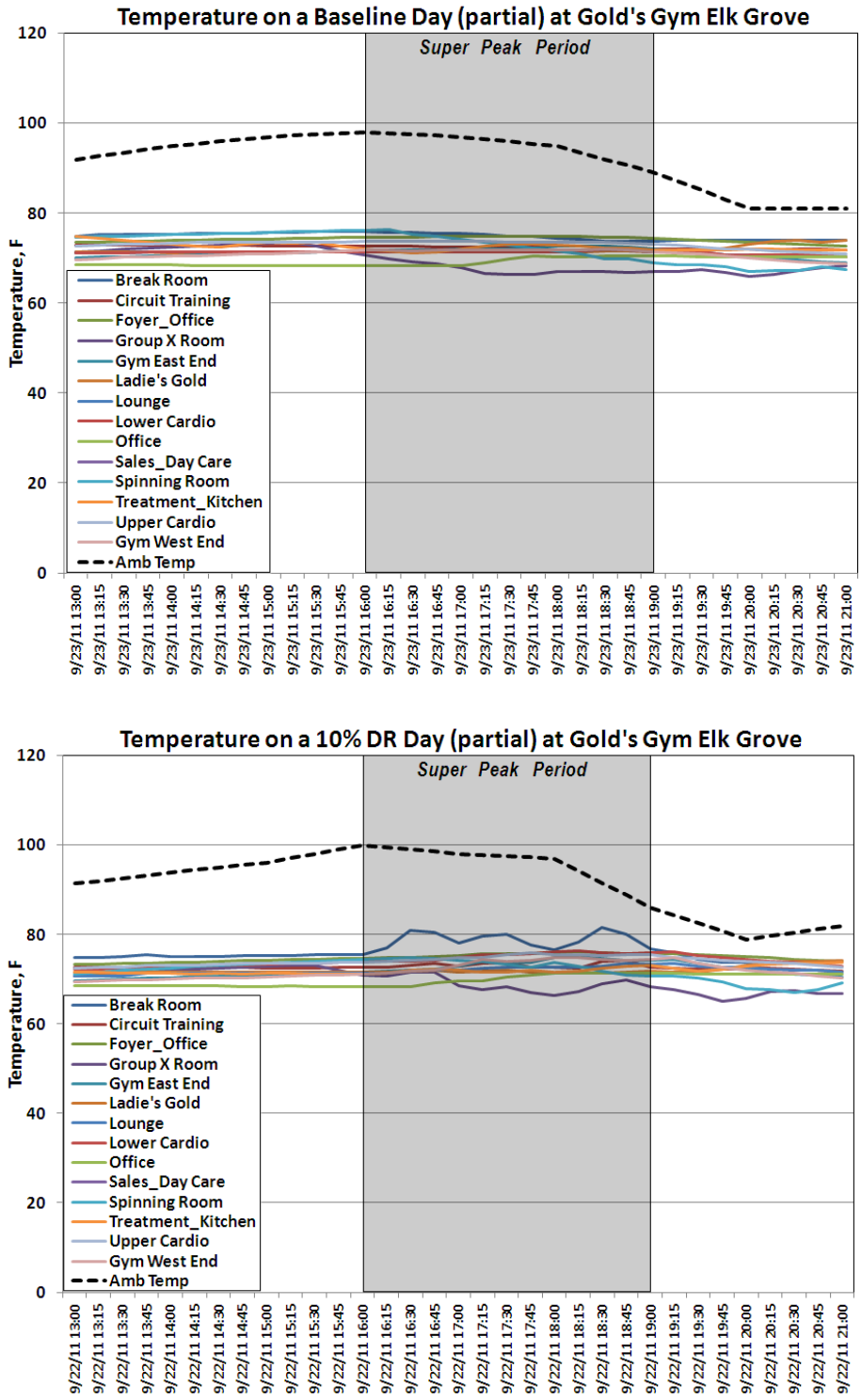

Figure 12. Gold's Gym Elk Grove – Temperature Profiles for Baseline and 10% DR days

Figure 13 shows AC demand profiles for similarly hot days at Maita Chevrolet. The top chart is a Baseline only day and illustrates that a few of the AC units operate throughout the super peak period. The chart on the bottom is a Baseline day with a 10% DR event during the super peak

hours and all of the AC units cycled off at least once during the super peak period, although one of the units cycles off just at the tail end of the period.

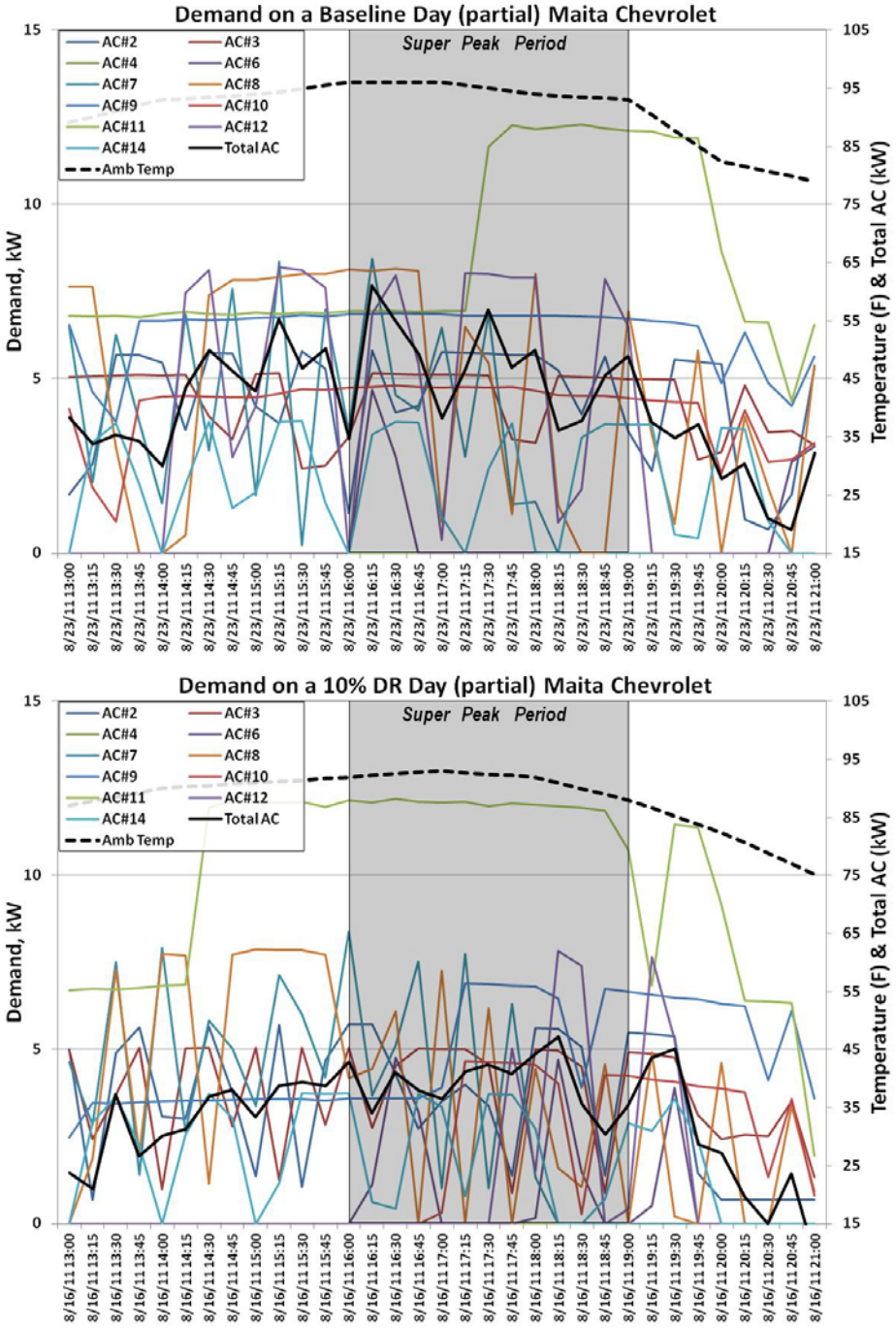

Figure 13. Maita Chevrolet – AC Unit Profiles for Baseline and 10% DR Days

The next pair of charts (Figure 14) shows the outside and inside temperatures at Maita Chevrolet for the same pair of days as Figure 13. The Baseline/DR10% day shows similar temperatures for most of the zones when compared to the Baseline only day. A couple zones have higher temperatures on the 10% DR day when compared to the Baseline day.

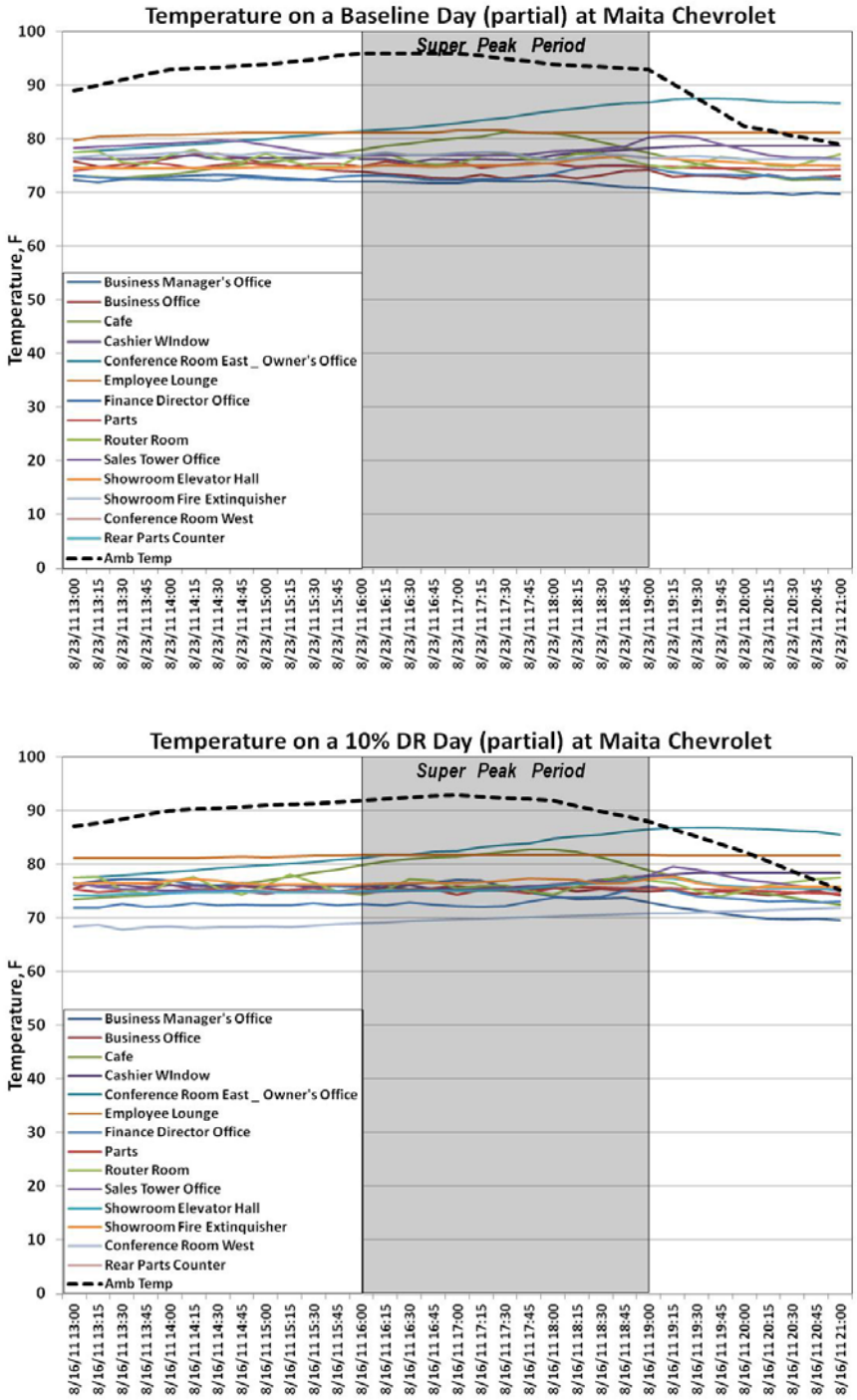

Figure 14. Maita Chevrolet – Temperature Profiles for Baseline and 10% DR days

The next two charts (Figure 15) show AC demand profiles and outdoor temperature for similarly hot days at JAL Properties. The chart on the top is a Baseline only day and shows that most of the AC units cycled off during the super peak period except for one. The chart on the bottom is a Baseline day with a 10% DR event during the super peak hours but shows that not all of the AC units were cycled off at least once during the super peak period. Only a few of the nine AC units at the site were actively used this year (with most of these units in poor working order). This

reduced the overall effectiveness of the controllers and may explain why there was no observed change in the number of cycles between the Baseline only day and Baseline/10% DR day.

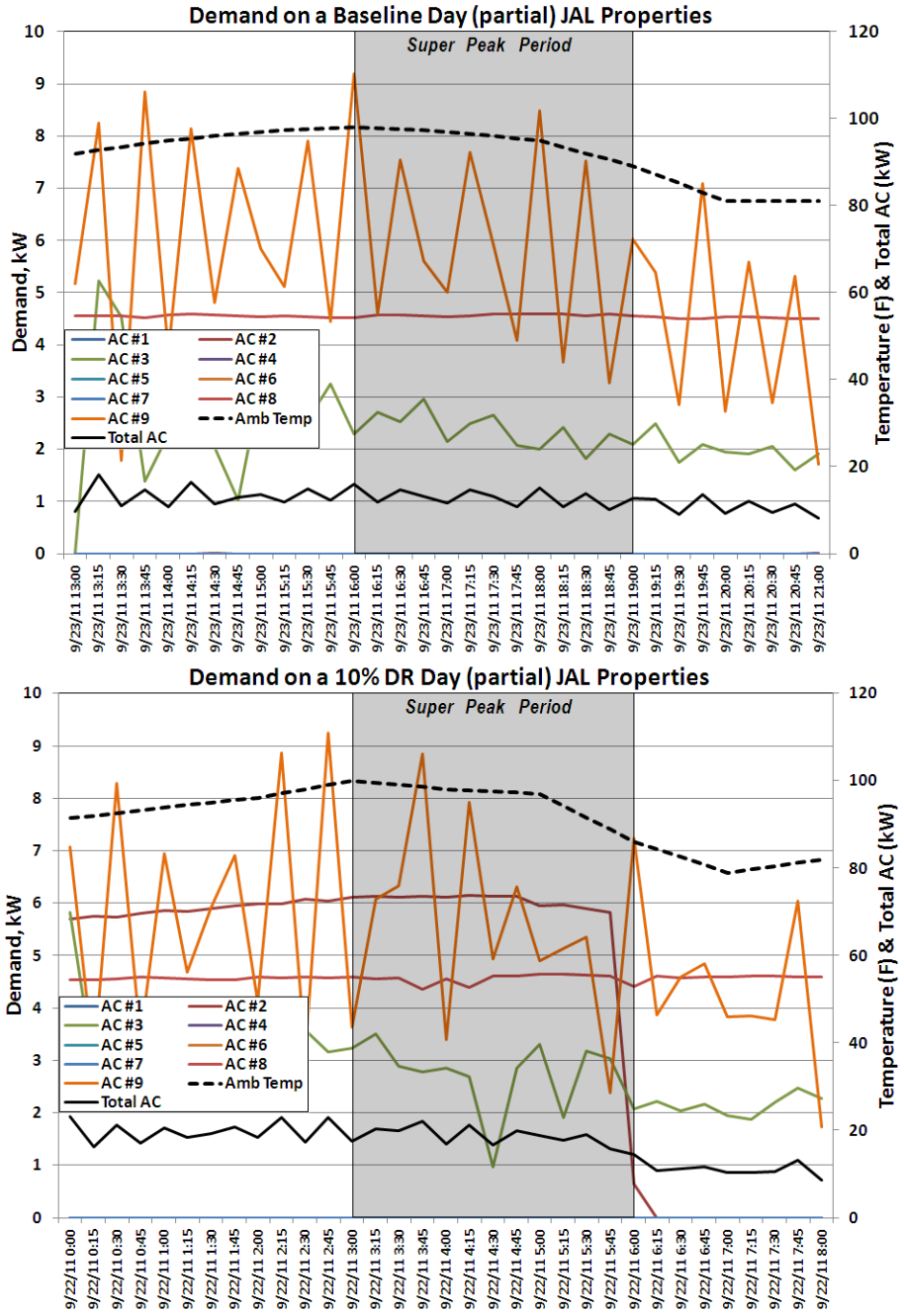

Figure 15. JAL Properties – AC Unit Profiles for Baseline and 10% DR Days

The next pair of charts (Figure 16) shows the inside temperatures at JAL Properties for the same pair of days as above. The Baseline/10% DR day shows similar temperatures for three of the zones when compared to the Baseline only day and one zone that is slightly cooler.

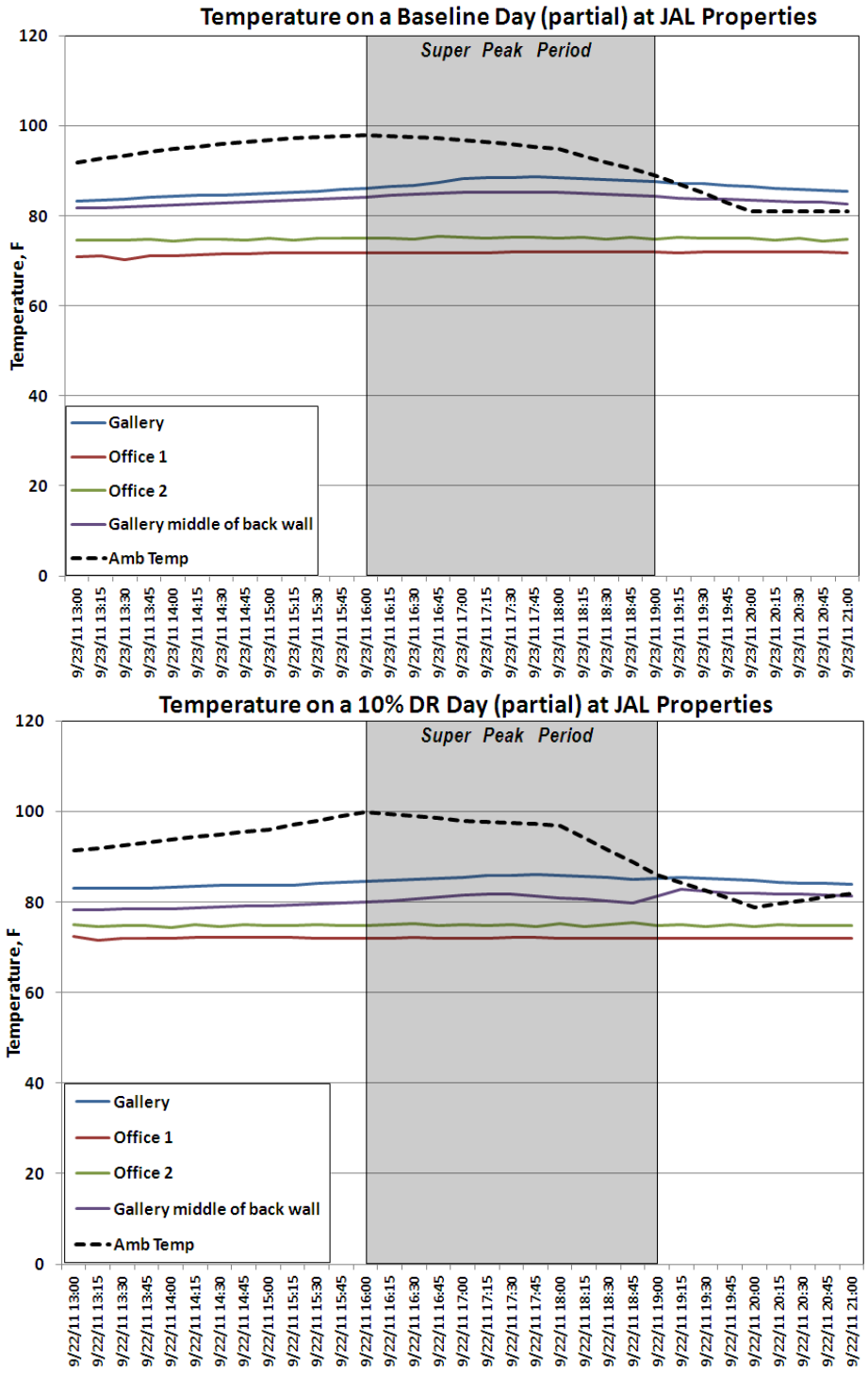

Figure 16. JAL Properties – Temperature Profiles for Baseline and 10% DR days

Peak Load Analysis

The 15-minute data were analyzed further (see Figure 17 through Figure 25 on the following pages). The 15-minute maximum peak load during the super peak period across all the units at a

site was tabulated by day type. This is representative of the impact the customer would expect to see on their bill. One would expect the Baseline days to have the highest demand for a given outside temperature followed by the DM days, 10% DR days and the 20% DR days with the lowest demand. Demand is a function of temperature, therefore as the ambient outdoor temperature rises, so should the savings. At the Emigh Hardware site in Figure 17, the DM days only show demand savings in comparison to Baseline days at high outdoor ambient temperatures. Savings are not expected at low outdoor temperatures since AC units are not running at capacity under those conditions independent of the control mode. However, the 10% DR days showed savings when compared to the baseline days and the 20% DR days showed demand savings when compared to the 10% DR days. The DR days' demands are level with temperature. This could be due to the AC units running at full load when allowed to run as set by the EnviroGrid controls, so inside temperatures will rise.

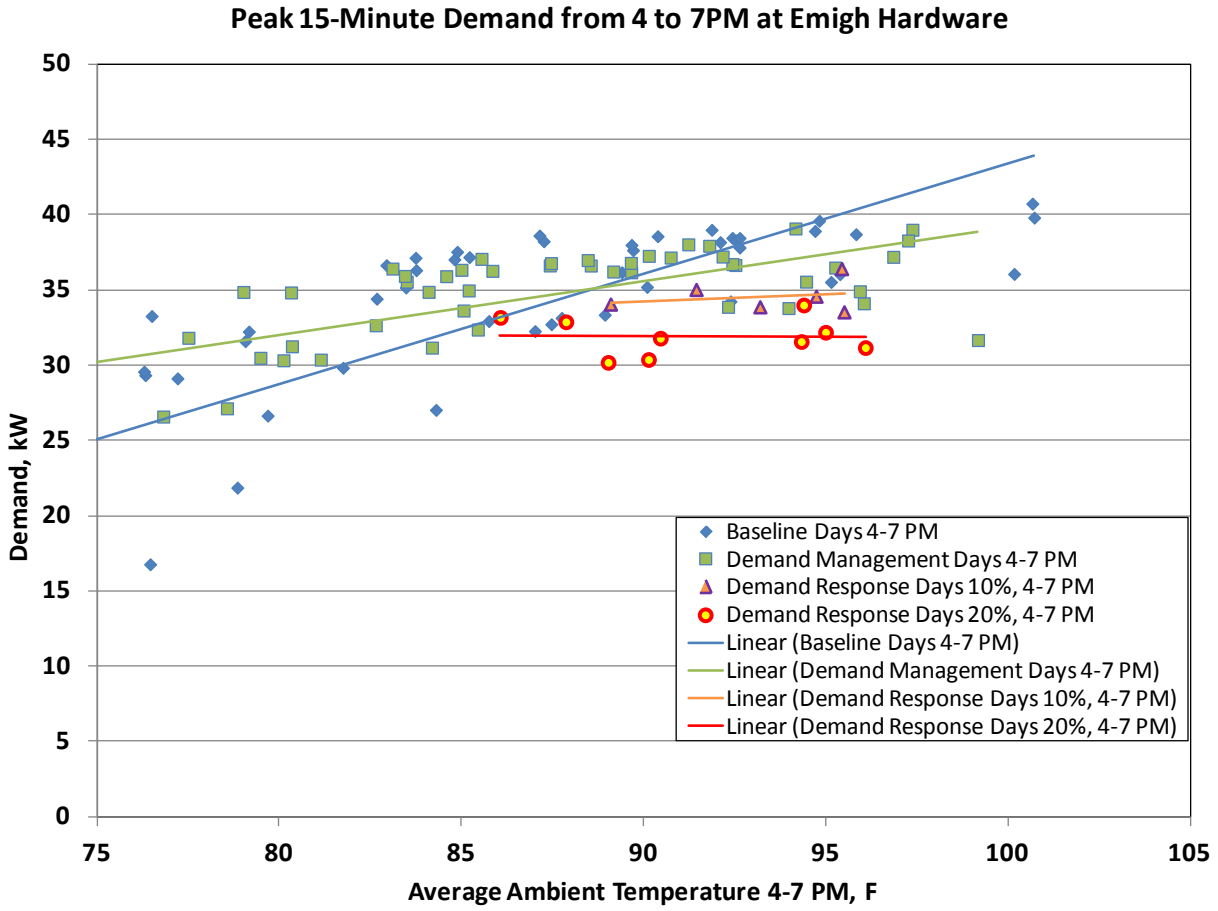

Figure 17. Maximum Peak 15-Minute Demand from 4PM to 7PM at Emigh Hardware

The average demand during the entire super peak period across all the units at a site was also tabulated by day type in Figure 18. This is representative of the average demand savings the utility will see from the customer across the entire super peak period. At Emigh Hardware there was a stronger correlation between day types from this measurement approach.

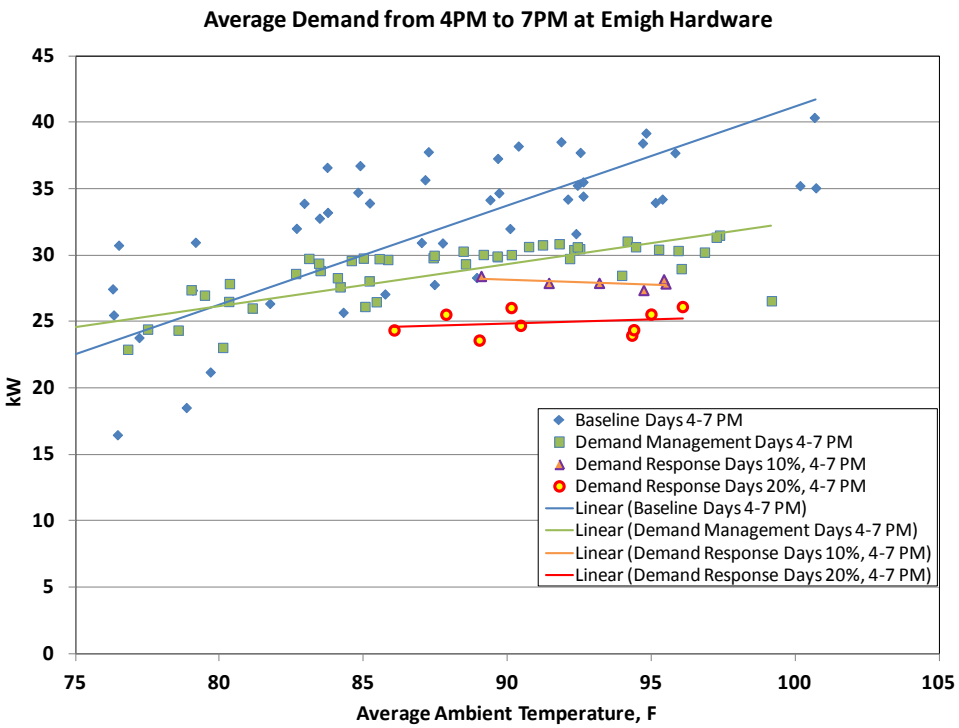

Figure 18. Average Demand from 4PM to 7PM at Emigh Hardware

Similar analysis was performed for Gold's Gym Natomas. At Gold's Gym Natomas (Figure 19 and Figure 20) there was less correlation between day types. The 10% demand response level data cannot be used to project if peak 15 minute demand savings from this site can be obtained. The reason behind the anomaly in some of the results may have been from the limited number of days in the DR modes, making it harder to draw reliable conclusions.

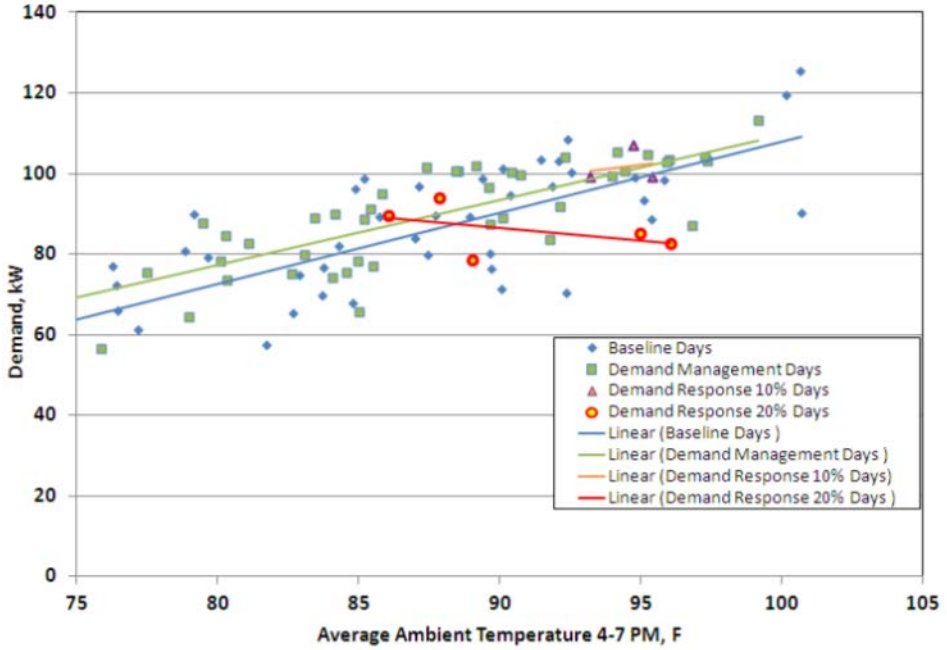

Figure 19. Maximum Peak 15-Minute Demand from 4PM to 7PM at Gold's Gym Natomas

At Gold's Gym Natomas there was considerable difference in the correlations between the 15-minute peak and the average demand for the super peak period. The 15-minute peak demand represents the single 15-minute interval with the highest demand. It may be that the single peak 15-minute interval is less correlated to temperature and more correlated to which size AC unit happens to be selected to cycle off or that there are not sufficient DR days to develop the trend. There is an indication of demand savings during both types of demand response days..

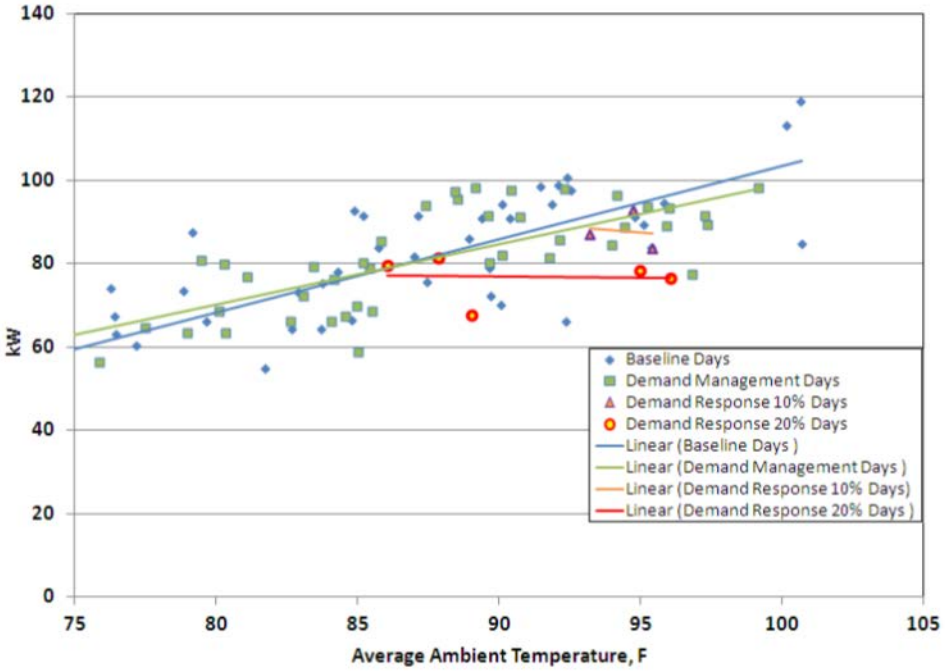

Figure 20. Average Demand from 4PM to 7PM at Gold's Gym Natomas

The next chart (Figure 21) illustrates the peak 15-minute analysis of Gold's Gym Elk Grove. Similar to the Natomas site, there is no indication of demand savings at the 10% demand response level. The reason for this is likely based on which size AC units were allowed to run at that interval. Also, there were reports that the DM duty cycle settings for a few units were increased during the summer in response to customer comfort complaints. After the fact the zones with customer complaints were identified as areas served by units without controllers. These actions were well-meaning but may have impacted the system's ability to reduce peak demand effectively. Had these actions not taken place, peak demand reductions may have improved. There is an indication of savings at the 20% demand response level.

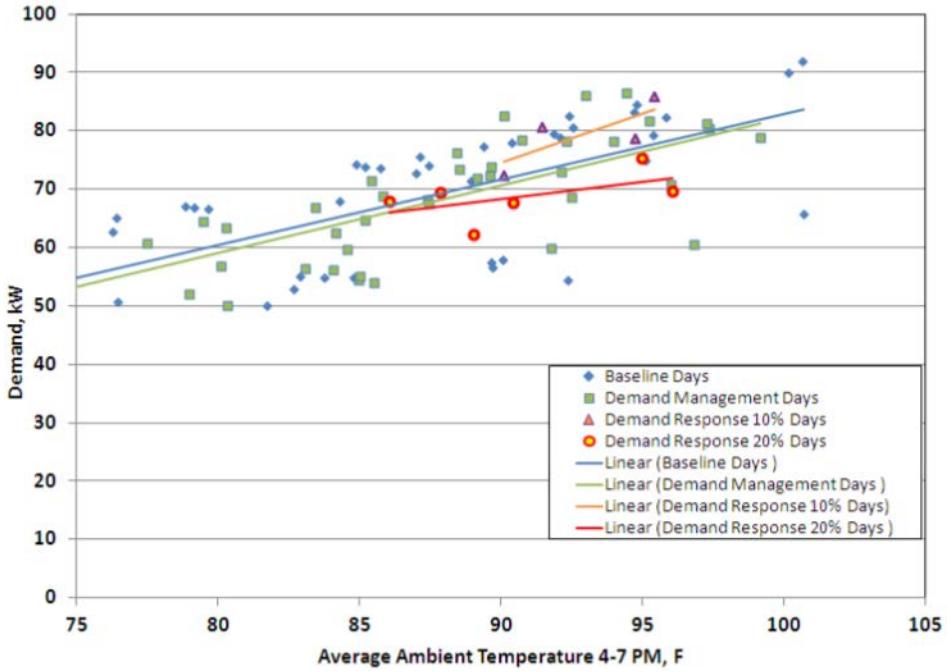

Figure 21. Maximum Peak 15-Minute Demand from 4PM to 7PM at Gold's Gym Elk Grove

The average demand for the super peak period was also calculated for this site (see Figure 22). The results of this graph indicate the expected relationship between the baseline days, demand management days, the 10% demand response days and the 20% demand response days.

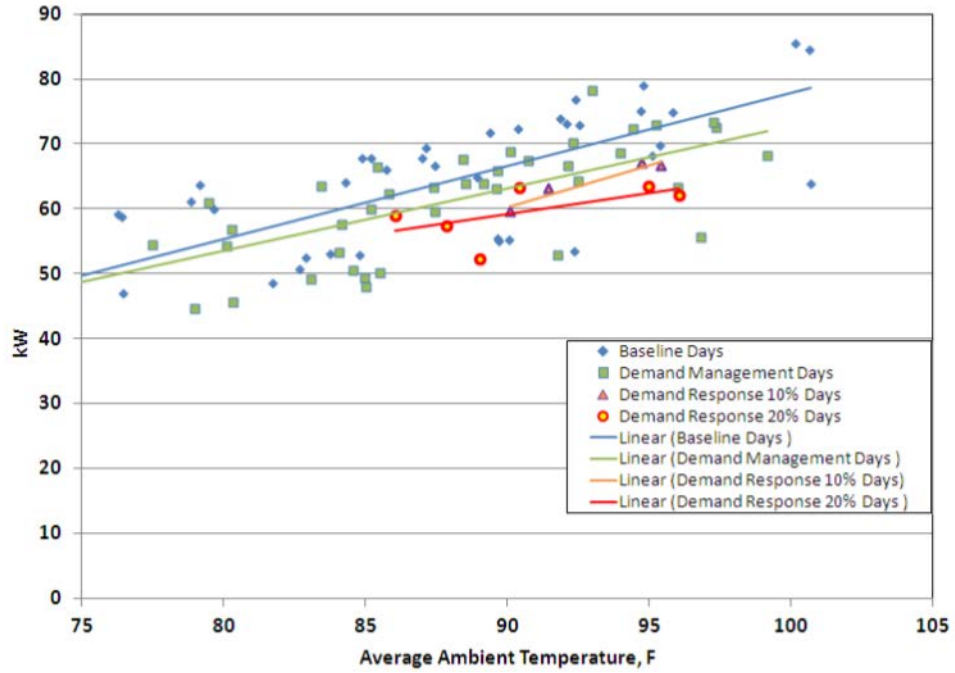

Figure 22. Average Demand from 4PM to 7PM at Gold's Gym Elk Grove

The peak 15 minute demand was also explored at the Maita Chevrolet site (illustrated in Figure 23). The data does not clearly indicate the expected demand savings for the either the 10% or

the 20% demand response days. Three of 20% DR days do not fit the expected trend. Some inconsistencies could be attributed to how the unit controllers measure and report unit peak demand to the other controllers. In some instances units will see a one-time spike in demand that is beyond the operating range of the unit and report this new value to the controllers. REGEN Energy is addressing this issue and it is described further in the Discussion section at the end of the report.

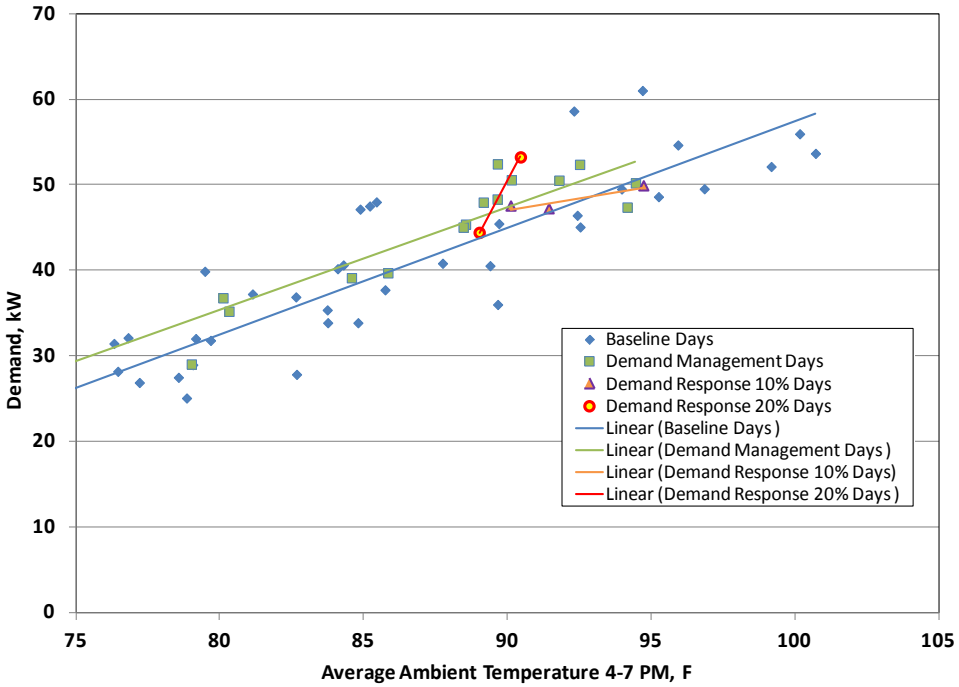

Figure 23. Maximum Peak 15-Minute Demand from 4PM to 7PM at Maita Chevrolet

The average peak loads were also explored (see Figure 24). It shows the same relationship in demand savings at the 20% demand response level. With the exception of three 20% DR days when the temperature was around 90°F, the correlations look good.

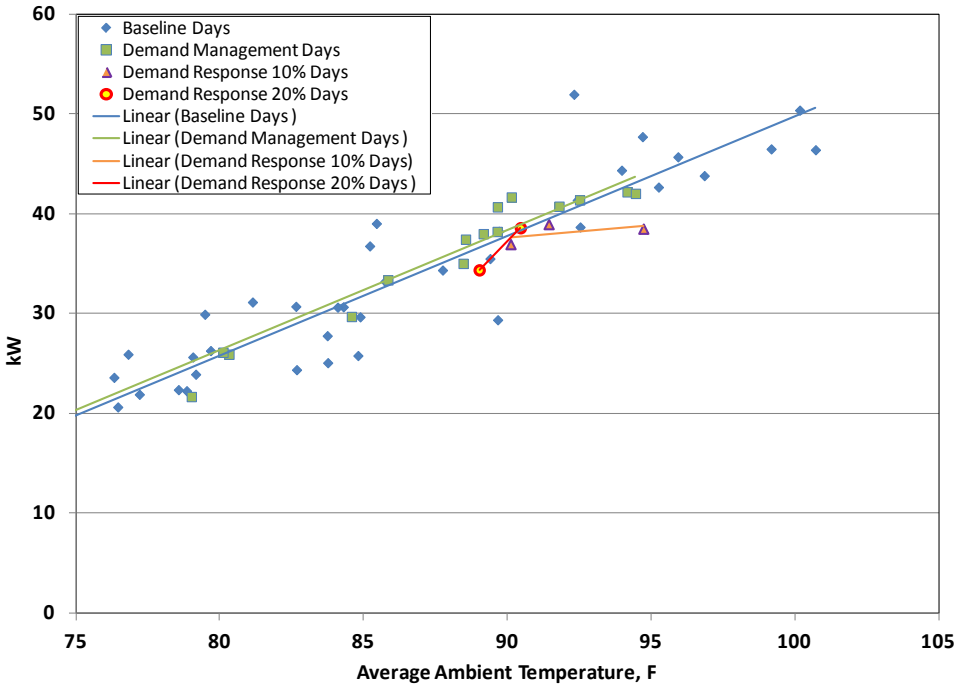

Figure 24. Average Demand from 4PM to 7PM at Maita Chevrolet

The analysis for JAL Properties did not indicate a clear trend in the data as there was considerably more dispersion in the data when compared to the other sites. Therefore, no conclusion could be drawn from the JAL Properties site. Only four of the nine AC units operated consistently throughout the summer. In addition, it appears that not all of the air conditioning units at the JAL property are properly maintained. Poorly maintained air conditioning units would adversely affect the result by not showing the full extent of the savings that could be realized. Figure 25 is the only chart shown for JAL Properties because the average demand chart is similar.

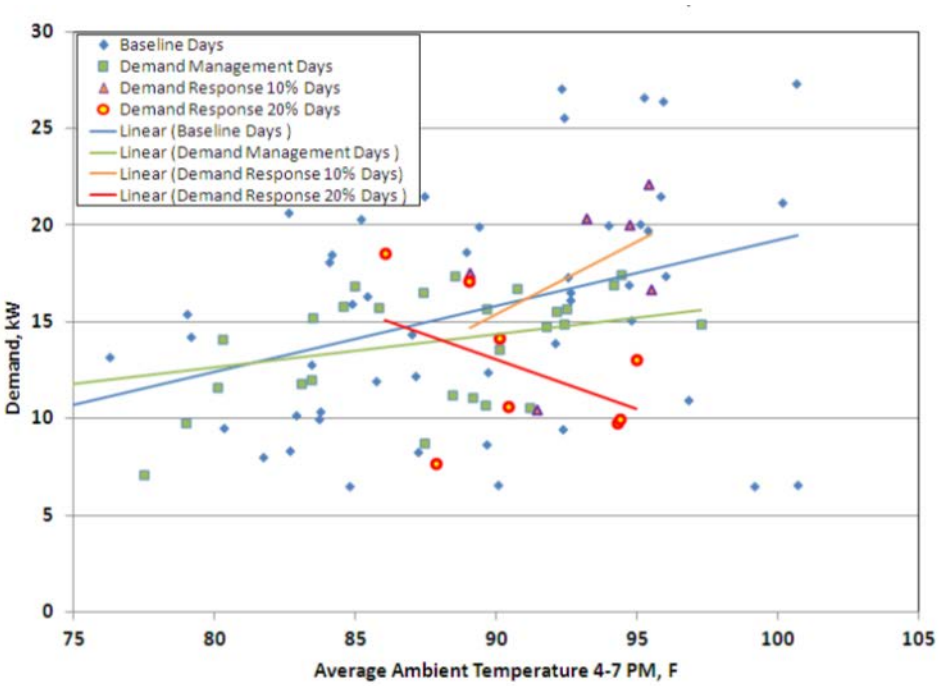

Figure 25. Maximum Peak 15-Minute Demand from 4PM to 7PM at JAL Properties

Statistical Significance of Peak Load Savings

Two analyses of the statistical significance of the maximum peak 15-minute demand and average peak period demand during the 4 PM to 7 PM period for various operating modes were investigated. Regressions of demand versus ambient outdoor temperature were run comparing Baseline to DM, DM to DR10%, and DM to DR 20%. The regressions were run with a dummy variable applied to the ambient temperature as a treatment group. R-squared, number of observations and regression P-value are reported for the first analysis. The two modes become more statistically different from each other and temperature dependent the smaller the P-value. For example, a P-value of 0.1 represents that the two modes can be accepted as statistically different with a 90% probability. The second analysis is a Type III T-test[1]. To run the T-test the demand measurements were normalized to set point adjusted temperatures. For uniformity set points of 65°F were used for all cases. As with the regression P-value, a small T-test P-value represents the means of the normalized data sets are different from each other. For example a T-test P-value of 0.1 represents there is only a 10% chance that the means of the two data sets are the same. Table 3 presents both analysis results for maximum peak 15-minute demand while Table 4 presents both analysis results for the average demand during the super peak period. The sites and operating modes highlighted in bold are statistically different at the 90% confidence level.

[1] The Type III test is specified when examining two distributions that have unequal size and unequal variance.

Table 3. Statistical Significance of Maximum Peak Demand for Various Operating Modes by Site.

Site and Operating Modes	R-Squared	N Observations	P-Value from Regression	P-Value from T-Test
Emigh Hardware				
Baseline vs. DM	0.77	110	**<0.0001**	0.118
DM vs. DR 10%	0.47	58	0.57	**<0.0001**
DM vs. DR 20%	0.49	61	0.17	**<0.0001**
Gold's Gym Natomas				
Baseline vs. DM	0.76	98	0.51	0.106
DM vs. DR 10%	0.69	48	0.88	**<0.0001**
DM vs. DR 20%	0.66	50	**0.02**	**0.038**
Gold's Gym Elk Grove				
Baseline vs. DM	0.66	91	0.88	**0.052**
DM vs. DR 10%	0.61	46	0.74	**0.019**
DM vs. DR 20%	0.56	48	0.46	**0.014**
Maita Chevrolet				
Baseline vs. DM	0.80	69	0.66	0.217
DM vs. DR 10%	0.90	20	0.46	**0.018**
DM vs. DR 20%	0.90	19	0.10	0.335
JAL Properties				
Baseline vs. DM	0.20	82	0.32	0.972
DM vs. DR 10%	0.33	35	0.28	0.423
DM vs. DR 20%	0.18	37	**0.05**	**0.052**

Table 4. Statistical Significance of Average Peak Period Demand for Various Operating Modes by Site.

Site and Operating Modes	R-Squared	N Observations	P-Value from Regression	P-Value from T-Test
Emigh Hardware				
Baseline vs. DM	0.78	110	**<0.001**	**0.030**
DM vs. DR 10%	0.57	58	0.24	**<0.001**
DM vs. DR 20%	0.63	61	0.18	**<0.001**
Gold's Gym Natomas				
Baseline vs. DM	0.75	98	0.18	**0.067**
DM vs. DR 10%	0.61	48	0.70	**<0.001**
DM vs. DR 20%	0.60	50	0.11	**0.019**
Gold's Gym Elk Grove				
Baseline vs. DM	0.71	91	0.36	**0.042**
DM vs. DR 10%	0.55	46	0.81	**<0.001**
DM vs. DR 20%	0.53	48	0.63	**0.004**
Maita Chevrolet				
Baseline vs. DM	0.92	69	0.94	0.178
DM vs. DR 10%	0.96	20	**0.09**	**0.021**
DM vs. DR 20%	0.96	19	0.35	**0.044**
JAL Properties				
Baseline vs. DM	0.25	82	0.57	0.370
DM vs. DR 10%	0.31	35	0.33	0.733
DM vs. DR 20%	0.25	37	**0.02**	0.109

Energy Use Analysis

In addition to demand, energy use was analyzed in this report as shown in Figure 26 through Figure 30 on the following pages. Daily energy use for baseline days and demand management days were compared with two expected outcomes. First, the sites are expected to show a positive relationship between energy use and daily maximum ambient temperature. Second, there is an expectation that the baseline days measurements will show higher energy use than the demand management days. The reason for the expected energy savings is that on Demand Management days the EnviroGrid controllers are scheduled to curtail AC use during non-business hours. The savings are derived from optimized schedule of operation and not demand management during business hours. At the Emigh Hardware site, Figure 26, these outcomes were mostly met. There is an upward trend during both the baseline days and the demand management days. Also, the demand management days indicated less energy use than the baseline days for most of the temperature range.

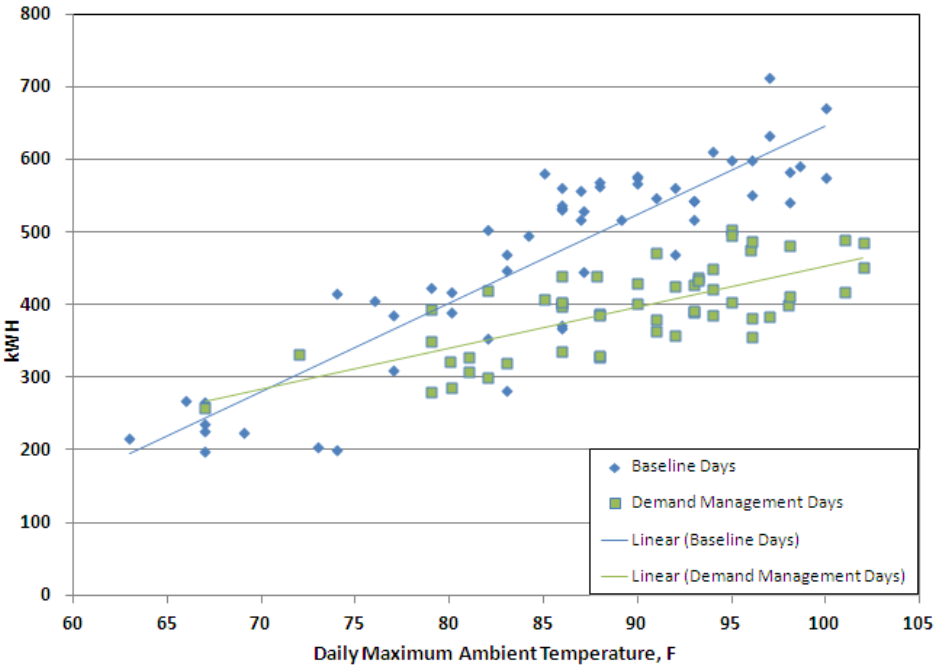

Figure 26. Daily Energy Use at Emigh Hardware

Figure 27 below shows that energy savings is less clearly defined at the Gold's Gym in Natomas. There is a lot of overlap between the baseline days and demand management days when ambient temperature was similar. Despite this, the trend lines indicate energy savings throughout the measured period increasing with maximum daily temperature. Although this difference is small, as discussed later, it is statistically significant.

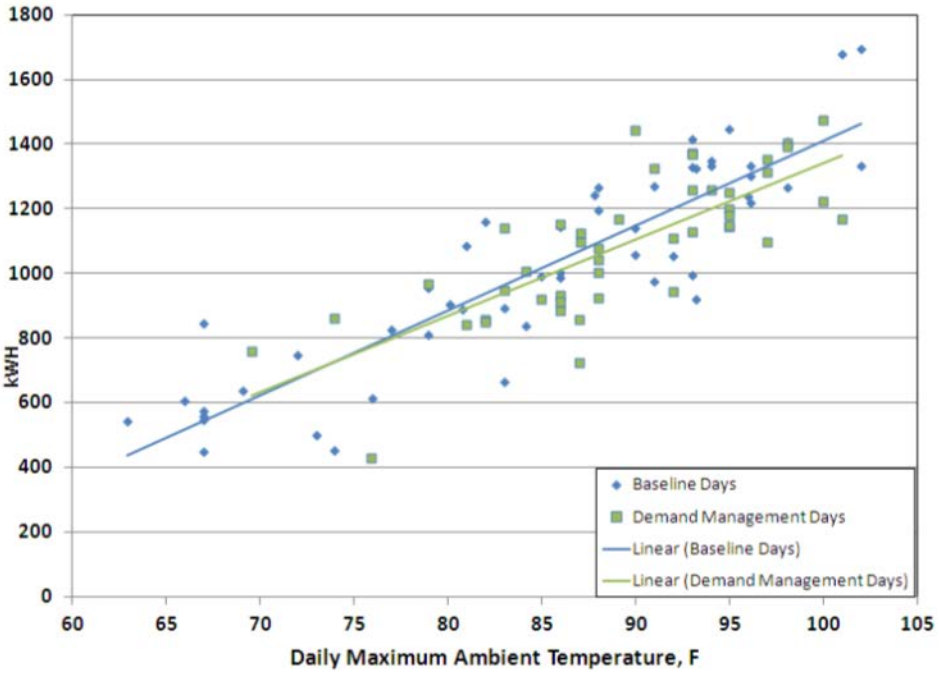

Figure 27. Daily Energy Use at Gold's Gym Natomas

The Gold's Gym at Elk Grove and the Maita Chevrolet sites, Figure 28 and Figure 29 respectively, each illustrate a contrast between the baseline and demand response days. As with the prior sites, there is noticeable overlap between the two day types throughout the temperature range. Overall, there is an indication of energy savings for both of these sites. The data for Maita Chevrolet indicates the energy savings is relatively constant with maximum daily temperature.

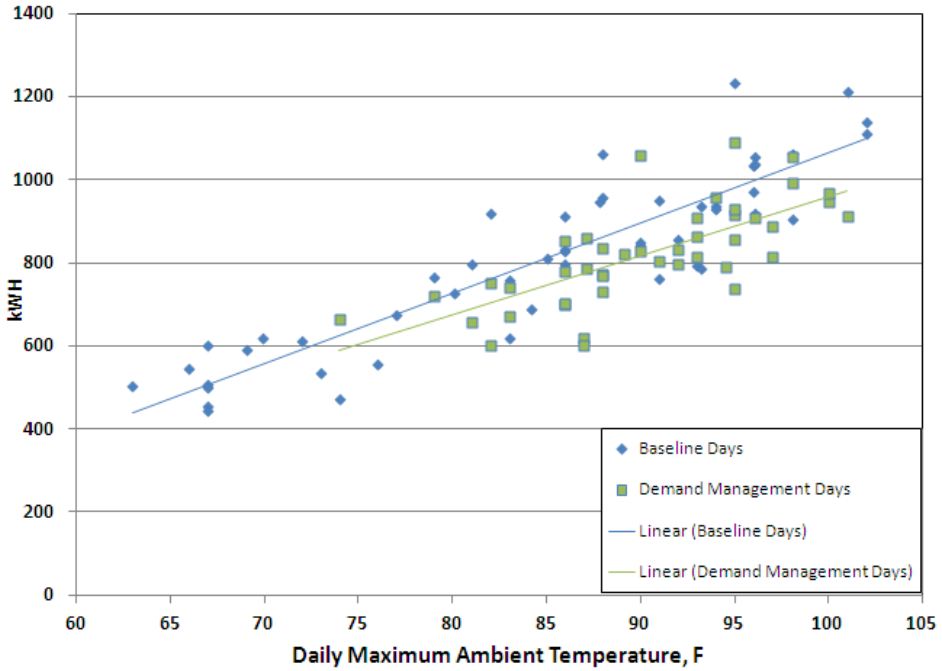

Figure 28. Daily Energy Use at Gold's Gym Elk Grove

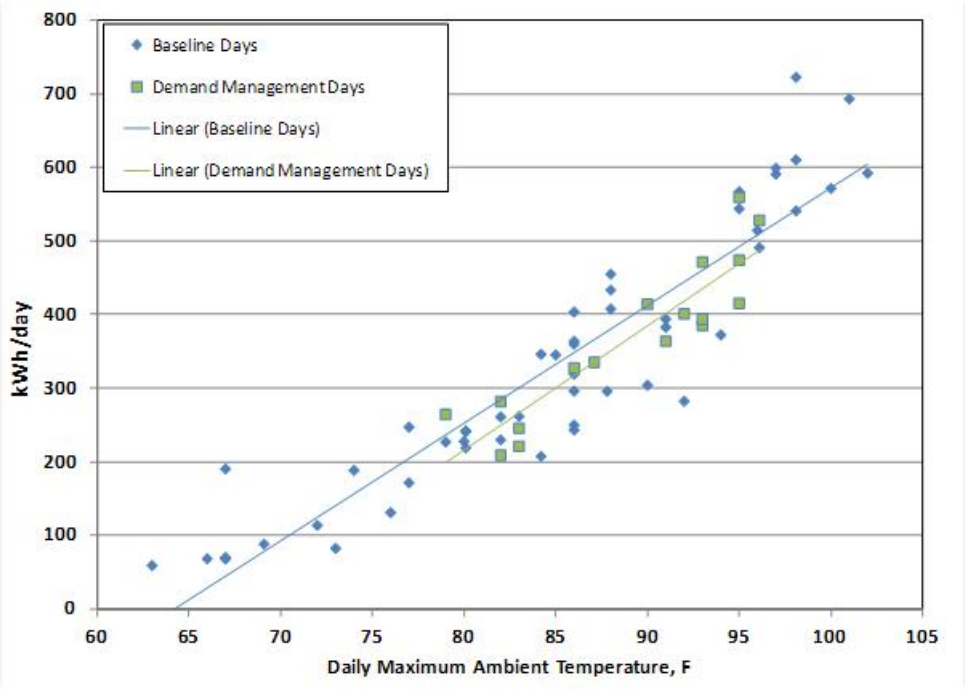

Figure 29. Daily Energy Use at Maita Chevrolet

JAL Properties site shows a considerable overlap between the baseline days and demand response days for any measured daily maximum ambient temperature reading (as shown in Figure 30 below). Overall, energy savings at JAL properties is minimal and not clearly defined for any given ambient temperature condition. Apparent differences above 85 degrees are not statistically significant.

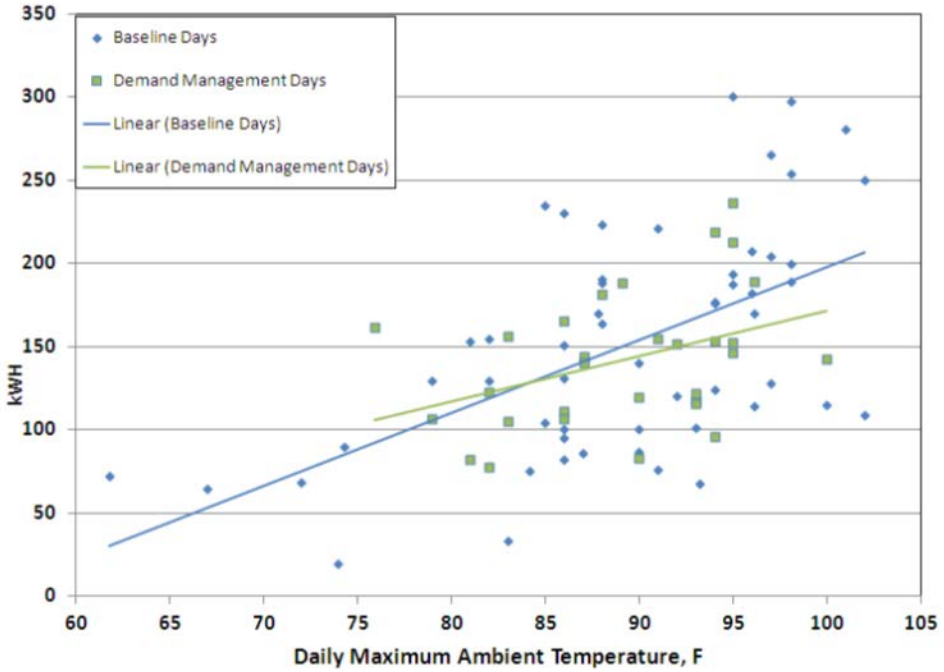

Figure 30. Daily Energy Use at JAL Properties

Statistical Significance of Energy Savings

An analysis of the statistical significance of the daily energy use versus ambient temperature for Baseline versus Demand Management operating modes was also investigated. The same analyses were run as previously described. Table 5 presents the results of the analysis. The regression P-Value for Emigh Hardware distinctly shows that the daily energy use for the AC units is statistically significantly different for baseline and demand management days and temperature dependent. JAL properties results were not statistically different as shown by the T-test.

Table 5. Statistical Significance of Daily kWh for Baseline Compared to DM modes by Site.

Site	R-Squared	N Observations	P-Value from Regression	P-Value from T-Test
Emigh Hardware	**0.77**	110	**<0.0001**	**0.010**
Gold's Gym Natomas	**0.74**	100	0.46	**0.016**
Gold's Gym Elk Grove	**0.75**	93	0.29	**0.004**
Maita Chevrolet	**0.85**	69	0.77	**0.041**
JAL Properties	0.29	85	0.36	0.415

Energy and Demand Savings

Table 6 below illustrates the annual energy savings for each of the analyzed sites. Savings is the reduction in annual energy use projected for baseline operation versus demand management operation of the AC units. Note that Demand Management mode also includes a control schedule that turns the units off during non-business hours, which the previous controls did not do. Savings were calculated using daily maximum temperatures from TMY weather and the regression lines developed in the previous set of charts. The annual cooling season was based on TMY weather data from April through October. Since the EnviroGrid controller can only limit the operation of the AC unit and not increase the operation, only positive savings can be calculated. There are savings tabulated from each site shown in absolute terms and normalized per square foot of conditioned space savings. Typical percent annual savings was also calculated and is presented as the last column in Table 6. Total site utility billing energy use for three years (2009-2011) was averaged to use as the base for the percent annual savings. Emigh Hardware had the highest annual energy savings while JAL Properties had the least amount of savings in absolute terms. Values highlighted in bold are statistically significant (greater than zero). When comparing savings in absolute terms to normalized terms, the descending order remained the same for most of the sites. In per square foot terms, Emigh Hardware still indicates the highest savings and JAL Properties indicates the least amount of savings.

Table 6. Annual Demand Management Mode Energy Savings by Site.

Site	Annual Energy Savings, kWh	Annual Energy Savings per square foot, kWh/sf	Percent Annual Savings
Emigh Hardware	**19,310**	**0.80**	**7.1%**
Gold's Gym Natomas	**5,961**	**0.14**	**0.6%**
Gold's Gym Elk Grove	**14,222**	**0.34**	**1.7%**
Maita Chevrolet	**9,608**	**0.38**	**1.0%**
JAL Properties	1,354	0.13	1.0%

A breakdown of average super peak demand savings is shown in Table 7 for a hypothetical 100 degree day for each site and control mode. The kW demand values listed in Table 7 are average demand over the three hour super peak period. Statistically significant savings values (greater than zero) are shown in bold. Only statistically significant values are included in the weighted averages. The far right column is a weighted average by baseline kW load for each result, except the baseline kW is a straight average. The JAL Properties site does not have a sufficient number of operating air conditioners for the system to provide effective savings. The air conditioning units that were operating at the time were in poor condition and could not fully realize the energy savings potential of the EnviroGrid controllers. In addition, some of the rooms at the JAL property were vacant during the program monitoring period. The combination of poor condition of the air conditioners and the vacant rooms lead to fewer EnviroGrid devices in use and may adversely affect the result at this site.

Table 7. Average Super Peak Period Demand and Savings by Site for a 100 °F Day

Condition	Emigh Hardware	Gold's Gym Natomas	Gold's Gym Elk Grove	Maita Chevrolet	JAL Properties	Weighted Average
Baseline kW	41.20	103.33	77.84	49.70	14.43	68.02
Number of AC Units	4	13	14	11	4	
Demand Management kW	32.51	98.98	72.74	50.31	12.18	77.48
Savings for Demand Management, kW	**8.69**	**4.35**	**5.10**	-0.61	2.26	5.42
Percent Savings	**21%**	**4%**	**7%**	-1%	16%	8%
Demand Response 10%, kW	27.39	84.84	73.21	45.30	12.87	65.59
Savings for Demand Response 10%, kW	**13.81**	**18.49**	**4.63**	**4.39**	1.57	10.72
Percent Savings	**34%**	**18%**	**6%**	**9%**	11%	15%
Demand Response 20%, kW	25.44	76.18	65.53	47.79	6.24	60.27
Savings for Demand Response 20%, kW	**15.76**	**27.14**	**12.31**	**1.91**	8.20	16.57
Percent Savings	**38%**	**26%**	**16%**	**4%**	57%	21%

Table 8 illustrates savings by site for all AC units for each period type based on a projected 100 °F day. Values highlighted in bold are statistically significant (greater than zero). The second to bottom row shows the weighted site averages by baseline kW load for each result. The bottom row shows the averages per AC unit for each result. Only statistically significant savings are included in the weighted site average. Overall, savings is increasing as expected for most sites; there are savings when comparing Baseline and DM days, DM and 10% DR days, and 10% DR and 20% days. Two of the sites, Maita Chevrolet and JAL properties do not show statistically significant savings for DM. Only JAL Properties shows no statistically significant savings between DM and 10% DR days, and DM and 20% DR days.

Table 8. Average Super Peak Demand Savings for All AC Units and Period Types for a 100 °F Day

Site	# of AC Units	Baseline Load, kW	Average kW Savings, 4-7pm			Percent Savings, 4-7pm		
			DM	10% DR	20% DR	DM	10% DR	20% DR
Emigh Ace Hardware	4	41.20	**8.69**	**13.81**	**15.76**	**21%**	**34%**	**38%**
Gold's Gym Natomas	13	103.33	**4.35**	**18.49**	**27.14**	**4%**	**18%**	**26%**
Gold's Gym Elk Grove	14	77.84	**5.10**	**4.63**	**12.31**	**7%**	**6%**	**16%**
Maita Chevrolet	11	49.70	-0.61	**4.39**	**1.91**	-1%	**9%**	**4%**
JAL Properties	4	14.43	2.26	1.57	8.20	16%	11%	57%
Weighted Site Average		68.02	5.42	10.72	16.57	8%	15%	21%
Per AC Unit Average		6.48	0.52	1.02	1.58	8%	15%	21%

Table 9 illustrates 15-minute peak demand savings by site for all AC units for each period type based on a projected 100 °F day. Values highlighted in bold are statistically significant (greater than zero). The second to bottom row shows the weighted site averages by baseline kW load for each result. The bottom row shows the averages per AC unit for each result. Only statistically significant savings are included in the weighted site average. The peak 15-minute demand results are less consistent than the average super peak period demand results. However, there are savings when comparing Baseline and DM days, DM and 10% DR days, and 10% DR and 20% days. Fewer of the sites and period types show statistically significant savings than with the average period results.

Table 9. 15-Minute Peak Demand Savings for All AC Units and Period Types for a 100 °F Day

Site	# of AC Units	Baseline Load, kW	15-Minute kW Savings, 4-7pm			Percent Savings, 4-7pm		
			DM	10% DR	20% DR	DM	10% DR	20% DR
Emigh Ace Hardware	4	43.36	4.25	**8.19**	**11.55**	10%	**19%**	**27%**
Gold's Gym Natomas	13	107.95	-1.50	**1.51**	**27.60**	-1%	**1%**	**26%**
Gold's Gym Elk Grove	14	82.93	**0.72**	**-8.35**	**8.86**	**1%**	**-10%**	**11%**
Maita Chevrolet	11	57.43	-1.87	**4.77**	-4.18	-3%	**8%**	-7%
JAL Properties	4	19.20	3.14	-3.70	**8.27**	16%	-19%	**43%**
Weighted Site Average		**72.92**	**0.72**	**0.34**	**14.17**	**1%**	**2%**	**22%**
Per AC Unit Average		**6.94**	**0.05**	**0.03**	**1.62**	**1%**	**2%**	**22%**

Table 10 through Table 14 contain the peak 15-minute measured demands for each site across all AC units for each period type. The data is not extrapolated but is based on actual measurements for the given period types. The time and conditions of the peak are also provided. The peaks occurred during baseline periods for all of the sites, indicating that the EnviroGrid system would have reduced bills for all participants had it been deployed all days. SMUD's peak demand charge is based on the maximum 15-minute demand that has occurred during the past 12 months. Three of the five sites show a decreasing 15-minute peak demand with the progression of operating modes moving from Baseline to DM to 10% DR to 20% DR. Maita Chevrolet's peak demand on a 20% DR day is higher than the 10% DR day for an unknown reason. The JAL Property does not show the trend of decreasing 15-minute peak demand with the progression of period types. In addition, ambient temperature may have contributed to the 15-minute peak demand found in the tables below. This is especially true for the baseline day as most of the sites had a peak demand on June 21st which had a maximum temperature of 102 degrees during the peak period.

Table 10. Peak Measured Demands Across All AC Units for Each Period Type, Emigh Hardware

Period Type	15-Minute Peak Demand, kW	Ambient Temperature (F) when Peak Occurred	Maximum Temperature (F) for Peak Period	Time of Peak Occurrence
Baseline	40.73	101.0	102.0	6/21/2011 17:30
Demand Management	39.08	95.0	95.0	7/21/2011 16:15
Demand Response, 10%	36.37	88.8	99.5	9/22/2011 18:45
Demand Response, 20%	33.99	95.0	96.8	8/28/2011 18:00

Table 11. Peak Measured Demands Across All AC Units for Each Period Type, Gold's Gym Natomas

Period Type	15-Minute Peak Demand, kW	Ambient Temperature (F) when Peak Occurred	Maximum Temperature (F) for Peak Period	Time of Peak Occurrence
Baseline	125.59	101.0	102.0	6/21/2011 18:30
Demand Management	113.20	99.8	100.0	7/4/2011 16:45
Demand Response, 10%	106.87	93.0	96.0	7/28/2011 18:30
Demand Response, 20%	94.07	87.8	91.5	8/3/2011 18:00

Table 12. Peak Measured Demands Across All AC Units for Each Period Type, Gold's Gym Elk Grove

Period Type	15-Minute Peak Demand, kW	Ambient Temperature (F) when Peak Occurred	Maximum Temperature (F) for Peak Period	Time of Peak Occurrence
Baseline	92.03	102.0	102.0	6/21/2011 18:00
Demand Management	86.46	93.0	95.0	7/27/2011 19:00
Demand Response, 10%	85.91	98.6	99.5	9/22/2011 16:45
Demand Response, 20%	75.38	97.5	98.1	9/20/2011 17:30

Table 13. Peak Measured Demands Across All AC Units for Each Period Type, Maita Chevrolet

Period Type	15-Minute Peak Demand, kW	Ambient Temperature (F) when Peak Occurred	Maximum Temperature (F) for Peak Period	Time of Peak Occurrence
Baseline	61.00	96.0	96.0	8/23/2011 16:15
Demand Management	52.42	90.0	92.0	8/5/2011 17:00
Demand Response, 10%	49.86	96.0	96.0	7/28/2011 17:30
Demand Response, 20%	53.24	92.0	93.0	8/17/2011 17:30

Table 14. Peak Measured Demands Across All AC Units for Each Period Type, JAL Properties

Period Type	15-Minute Peak Demand, kW	Ambient Temperature (F) when Peak Occurred	Maximum Temperature (F) for Peak Period	Time of Peak Occurrence
Baseline	27.31	100.0	102.0	6/21/2011 16:15
Demand Management	17.43	94.5	95.0	7/27/2011 16:30
Demand Response, 10%	22.11	98.6	99.5	9/22/2011 16:45
Demand Response, 20%	18.59	84.9	90.5	7/29/2011 18:00

Number of Cycles Analysis

The EnviroGrid control strategy is to curtail a selected subset of air conditioning units out of the full population for a site at any given time. There is a concern that this will increase the number of cycles a compressor experiences beyond the number it will naturally experience and thus shorten it's operating life. This analysis was not part of the original study plan and compressor cycles were not directly monitored. Through analyzing 5 minute interval data from individual AC units, an algorithm was developed to determine if the demand changed more than a specified amount. Values above this threshold would indicate that compressor or motor loads had turned on or off. This algorithm is expected to catch at least 99% of the transitions. This would include a two stage AC unit when the operation changes from one compressor to two compressors; however, if both compressors turn off at the same time only one transition would be acknowledged.

The number of cycles per AC unit per hour was tabulated for 5 degree temperature bins for each of the operating modes. The data were combined with typical meteorological year (TMY) temperatures to determine the expected number of equipment cycles that would occur for a cooling season running from April through October. Table 15 contains the expected number of annual equipment cycles for baseline and DM operating modes. The number of cycles per year for DM mode versus Baseline mode ranged from 93% to 150%. The weighted average (by number of AC units) only showed a one percent increase in the number of annual cycles from 4,529 to 4,587. This should have a minimal impact on the equipment life expectancy. One theory for the reason that the number of cycles per year is not higher is that in DM mode the units are not allowed to operate during hours the business is closed when the units otherwise may operate for a minimal amount of time but none the less still cycle. The DR 10% and DR 20% modes can only be active for a maximum combined total of 48 hours per year and so would have a minimal impact on the annual operating cycles and were not included in the annual analysis.

Table 15. Equipment On/Off Cycles per AC Unit per Year for Baseline and DM Operating Modes.

Site	Number of AC Units Used	Baseline Cycles/Unit/Yr	Demand Management Cycles/Unit/Yr	DM Cycles as a % of Baseline
Emigh Hardware	4	2,254	3,384	150%
Gold's Gym Natomas	13	3,349	3,376	101%
Gold's Gym Elk Grove	14	4,425	4,125	93%
Maita Chevrolet	11	7,777	7,868	101%
JAL Properties	4	2,076	2,319	112%
Weighted Average		4,529	4,587	101%

As part of the equipment cycle analysis, the cycles per unit per hour were binned in 5 degree increments. Charts in Figure 31 to Figure 35 show the cycles for each operating mode versus ambient temperature.

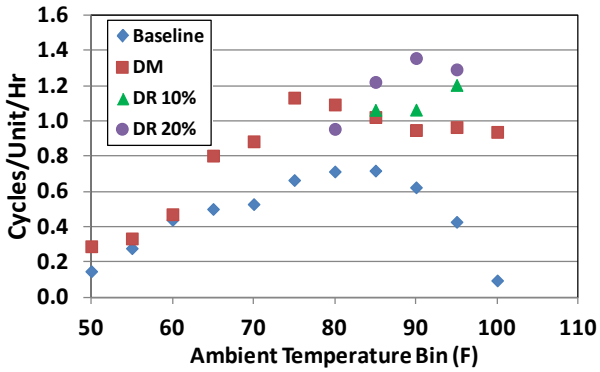

Figure 31. Equipment Cycles per Unit per Hour versus Temperature at Emigh Hardware

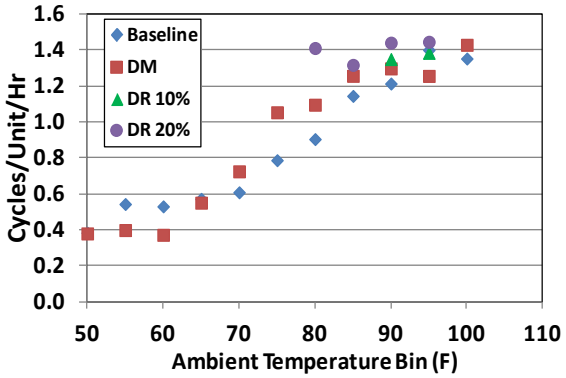

Figure 32. Equipment Cycles per Unit per Hour versus Temperature at Gold's Gym Natomas

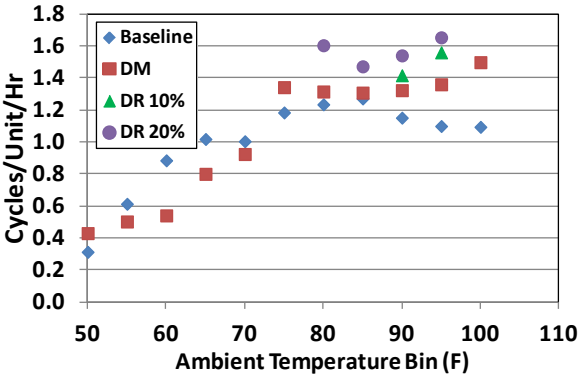

Figure 33. Equipment Cycles per Unit per Hour versus Temperature at Gold's Gym Elk Grove

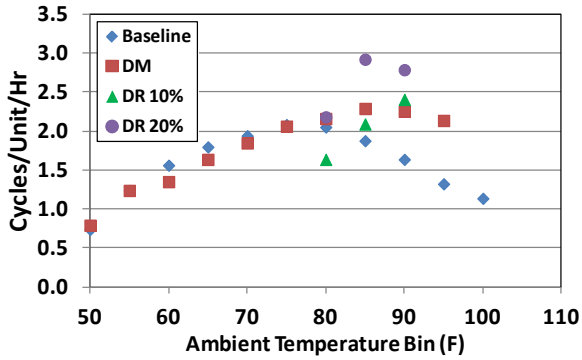

Figure 34. Equipment Cycles per Unit per Hour versus Temperature at Maita Chevrolet

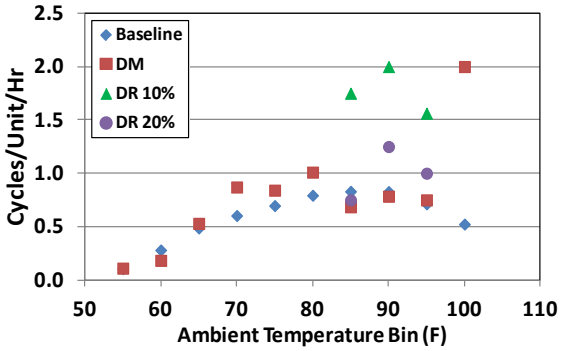

Figure 35. Equipment Cycles per Unit per Hour versus Temperature at JAL Properties

In addition to the equipment cycle analysis, an analysis of AC unit load fraction was conducted. The average load fraction for each of the AC units was calculated and an average per site load fraction was developed based on 5 degree temperature bins for each operating mode. The unit full load profile versus ambient temperature was developed by using the maximum measured inputs (demand) to the unit during the monitoring period. The average load fraction was calculated as the average demand divided by the maximum measured demand. The average load fractions for the five sites are provided in *Figure 36* to Figure 40. The load fraction increases with temperature. For some sites the load fraction at high ambient temperatures is less for the DM mode than the Baseline mode. However since these are averages, only reduction for the DR modes would be expected.

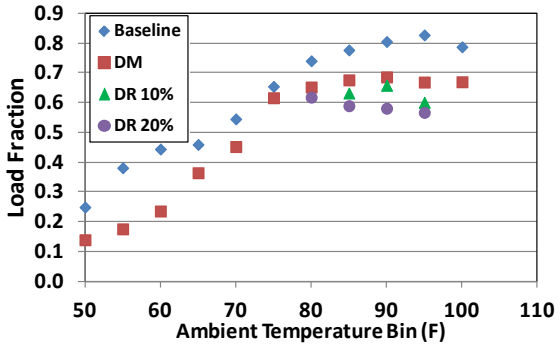

Figure 36. AC Unit Load Fraction versus Temperature at Emigh Hardware

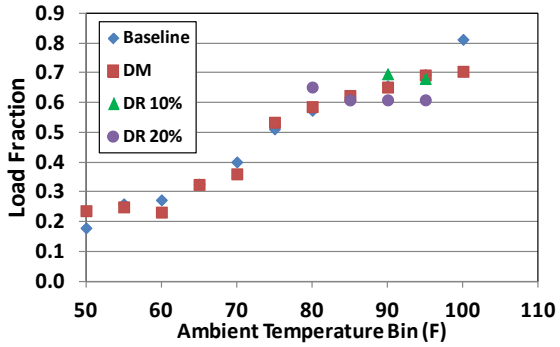

Figure 37. AC Unit Load Fraction versus Temperature at Gold's Gym Natomas

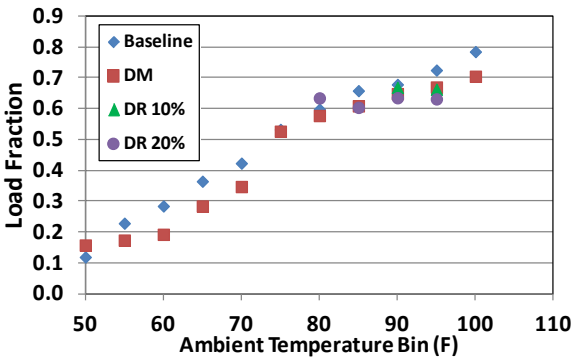

Figure 38. AC Unit Load Fraction versus Temperature at Gold's Gym Elk Grove

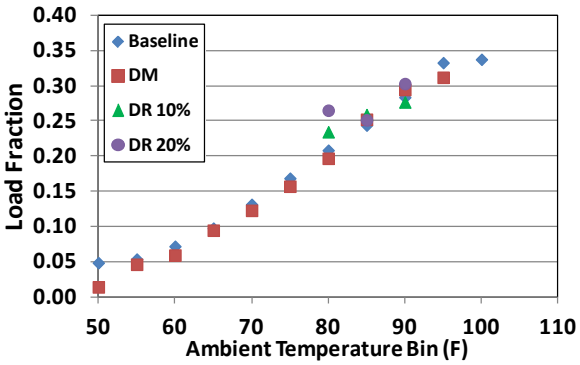

Figure 39. AC Unit Load Fraction versus Temperature at Maita Chevrolet

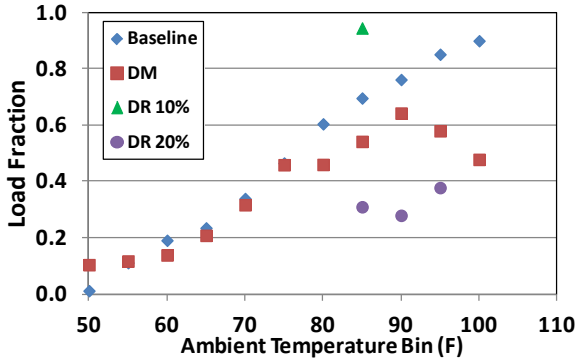

Figure 40. AC Unit Load Fraction versus Temperature at JAL Properties

Comparison of ADM and REGEN Recorded Data

The EnviroGrid system has the capability to record power use in snapshots. Figure 41 shows a comparison of REGEN's data to the power data collected by ADM. It showed a good correlation of the tested sites. The following chart shows the comparison of power measurements at Gold's Gym Elk Grove. REGEN's values are generally conservative for every day type and could be used for analysis. When the difference between period types is taken into account the error would be even less. Although caution should be taken when using a vendor's self reported data, if several points are verified they can be used to validate the rest of the data. Using the vendor's equipment to collect power data could save on monitoring costs.

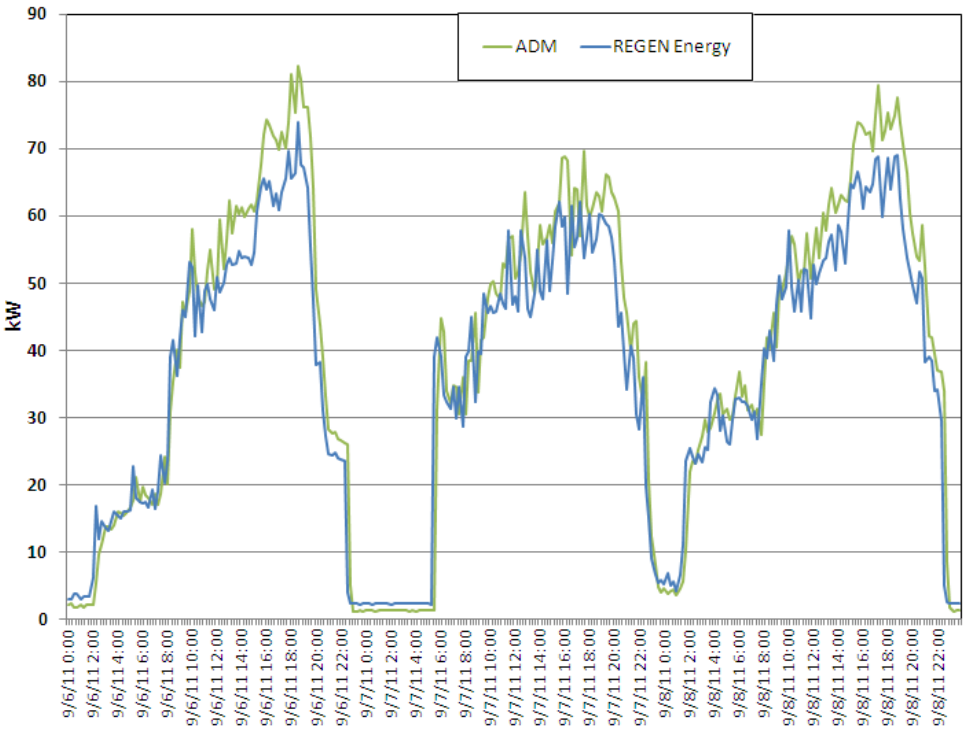

Figure 41.Gold's Gym Elk Grove Power Measurement Comparison

Additional analysis was conducted to compare the power measurements made by the EnviroGrid system versus the power measurements made by ADM using Enernet K-20 power meter recorders. Demands for all active AC units at a site were totaled for the comparison. Table 16 compares the top 10% of the demand records made by both power measurements. The weighted average (by number of AC units) shows the REGEN power measurements are 93% of the ADM power measurements. This would translate into a 7% lower demand savings using REGEN's data. In other words, REGEN would have a conservative estimate of savings. Only one site showed the REGEN data overestimating the demand and that was due to the measurements of only one of the four AC units at the site. There is no data that suggests the relationships to power measurements are different when the units are operated in different control modes by the EnviroGrid controllers.

Table 16. Average of Top 10% of Records Comparing ADM to REGEN Demand Measurements.

Site	Number of AC Units Used	ADM Average Measured Demand (kW)	REGEN Average Measured Demand (kW)	REGEN kW as a % of ADM kW
Emigh Hardware	4	38.0	51.3	135%
Gold's Gym Natomas	13	86.1	75.4	88%
Gold's Gym Elk Grove	14	66.3	61.8	93%
Maita Chevrolet	11	49.1	45.2	92%
JAL Properties	4	22.6	19.2	85%
Weighted Site Average		61.5	57.1	93%

As part of the analysis, scatter charts were produced showing the total AC demand measured by REGEN versus the demand measured by ADM. Figure 42 to Figure 46 show the relationship between the two datasets. Four of the five sites show a very linear relationship. Emigh hardware shows a bimodal relationship depending on whether the one AC unit registering higher on the REGEN data than the ADM data was on or not. This was the only exception.

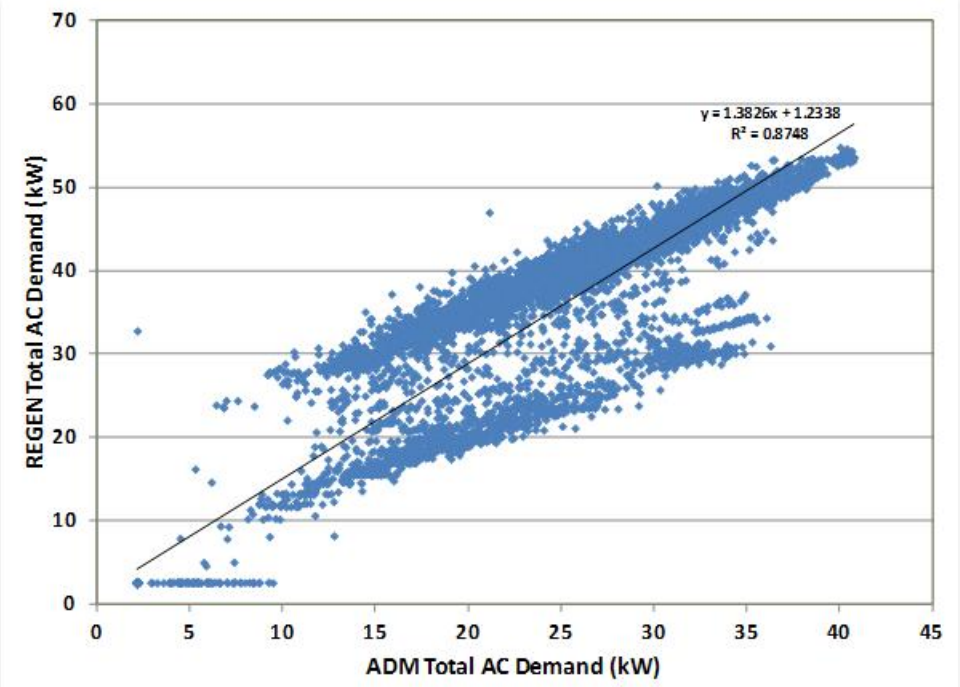

Figure 42. Emigh Hardware Comparison of REGEN to ADM Demand Measurements.

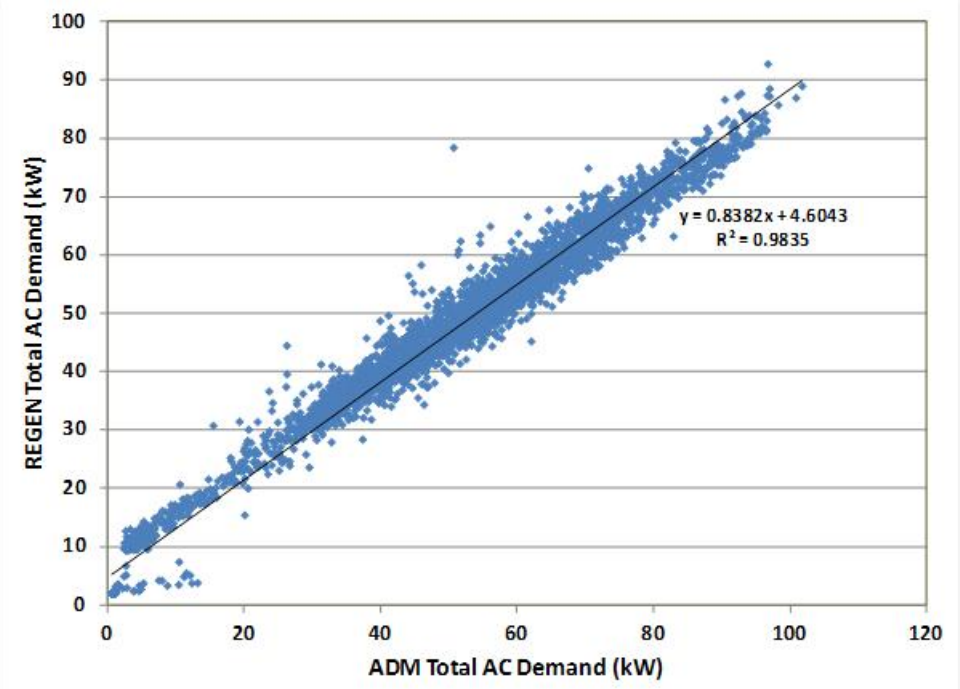

Figure 43. Gold's Gym Natomas Comparison of REGEN to ADM Demand Measurements.

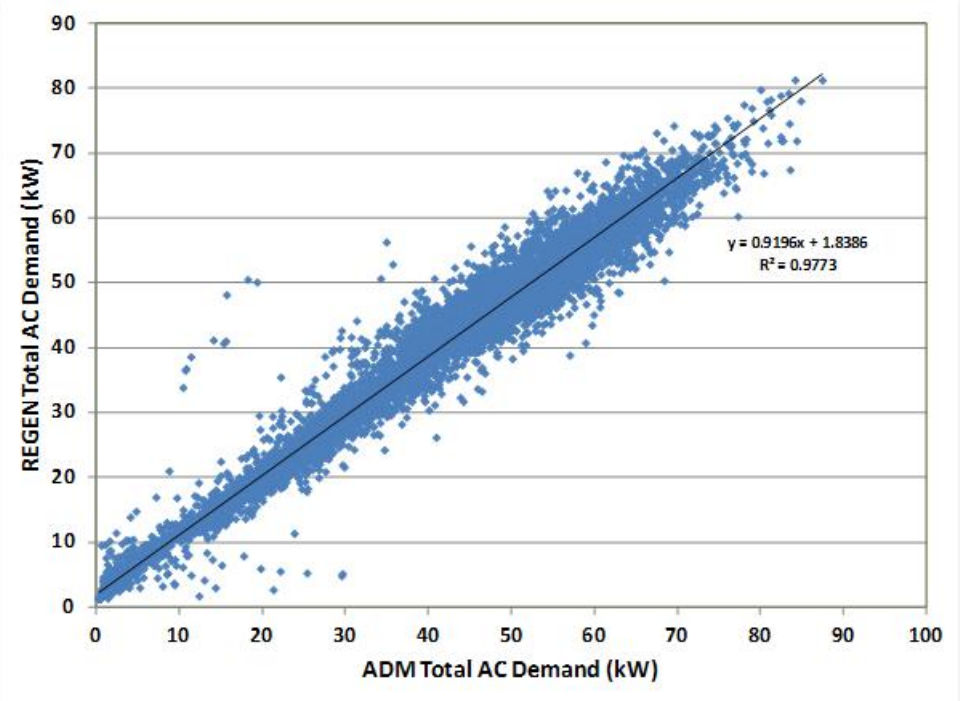

Figure 44. Gold's Gym Elk Grove Comparison of REGEN to ADM Demand Measurements.

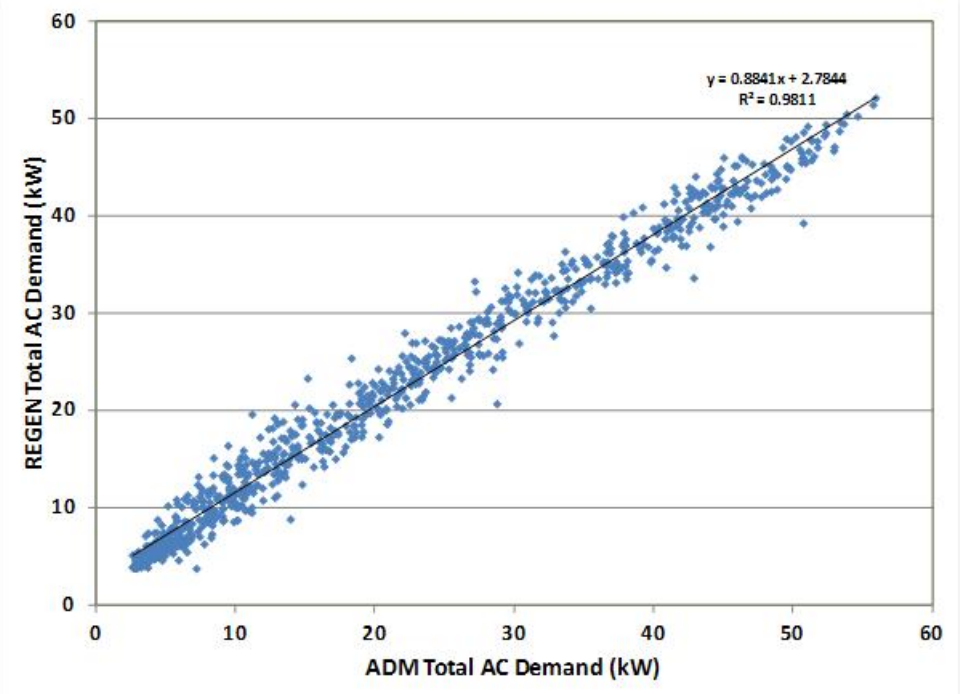

Figure 45. Maita Chevrolet Comparison of REGEN to ADM Demand Measurements.

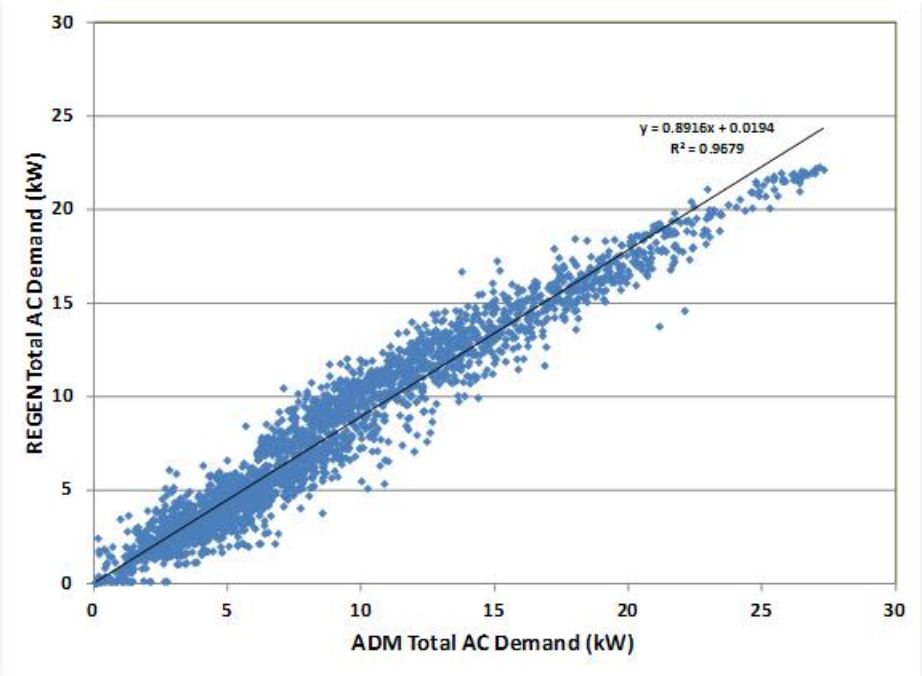

Figure 46. JAL Properties Comparison of REGEN to ADM Demand Measurements.

Figure 47 and Figure 48 chart the measurements of individual AC units. They show some characteristics that are different between the two sets of measurements. The snapshot readings of the REGEN data manifest themselves in horizontal bands on these two charts. The bands are modes of operation of the AC unit with various sets of fans and compressors on, whereas the ADM data is averaged over the entire 5 minute interval where there can be more than one mode of operation.

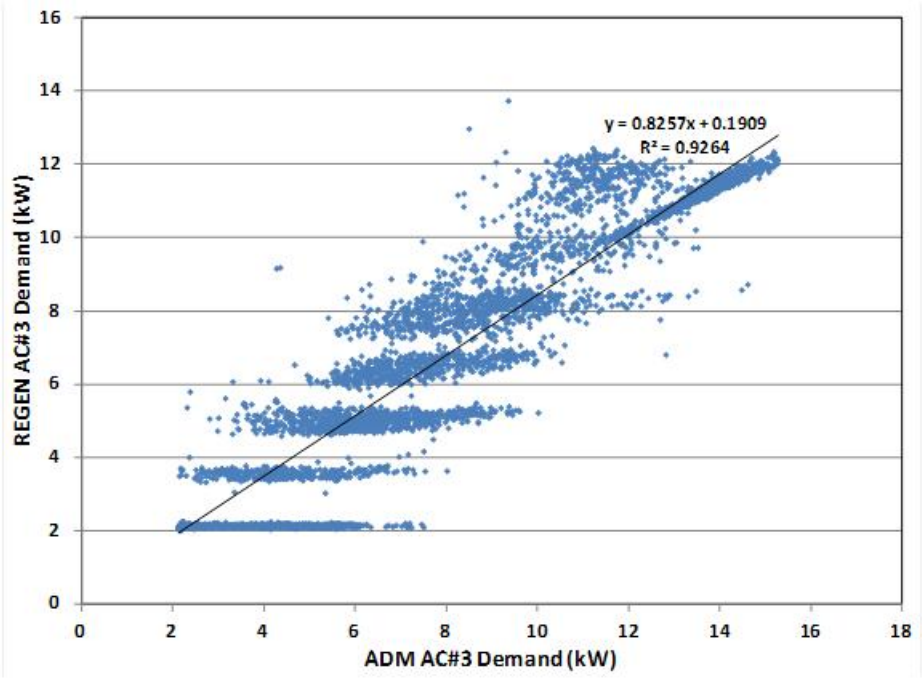

Figure 47. AC#2 at Emigh Hardware Comparison of REGEN to ADM Demand Measurements.

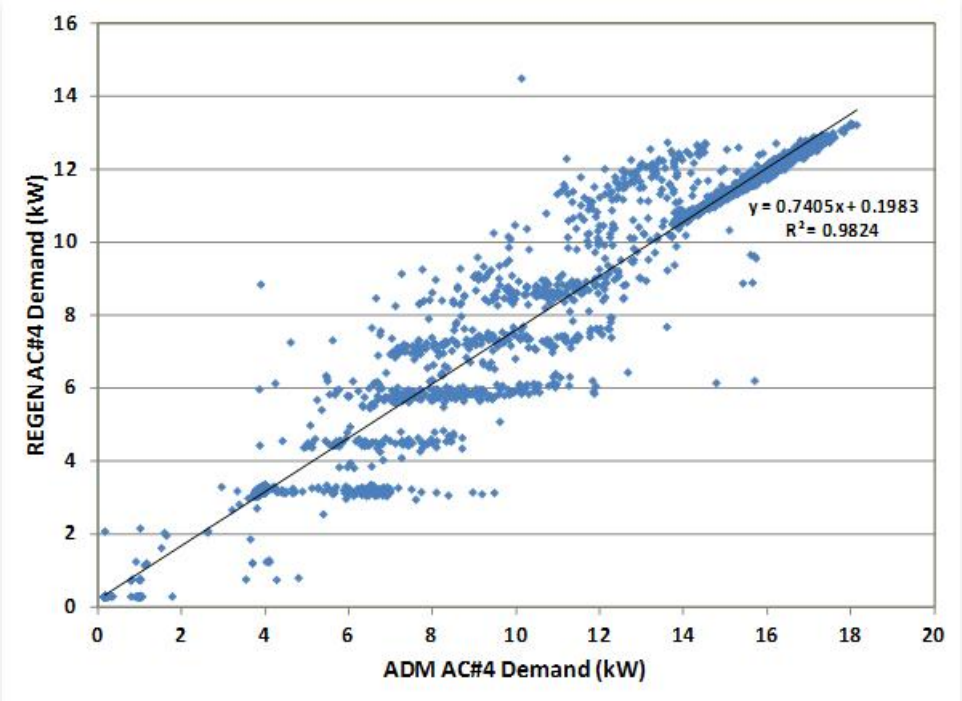

Figure 48. AC#4 at Gold's Gym Natomas Comparison of REGEN to ADM Demand Measurements.

The Survey

Managers and employees at the five air conditioning monitored sites were called and surveyed about the temperature and comfort levels in the buildings. Surveys were conducted the day after specified baseline or different test day types. The survey also includes results from the prior report completed in 2009 for two of the sites, Maita Chevrolet and JAL Properties. Managers were asked a couple extra questions regarding complaints from other employees and the temperature conditions.

Six managers and nine other employees were surveyed a total of 66 times. Table 17 through Table 21 illustrate the responses to the survey questions.

Table 17. Responses to Baseline Day: How comfortable are you with the temperature today *at work?*

	1) Definitely too cold or 2) A bit chilly		3) Just right / OK		4) A bit warm		5) Definitely too hot		Total	
Business	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Emigh Hardware	0	0%	1	5%	0	0%	0	0%	1	5%
Gold's Gym Natomas	0	0%	1	5%	0	0%	0	0%	1	5%
Gold's Gym Elk Grove	0	0%	2	10%	1	5%	0	0%	3	14%
Maita Chevrolet	0	0%	3	14%	1	5%	1	5%	5	24%
JAL Properties	0	0%	9	43%	1	5%	1	5%	11	52%
Total	0	0%	16	**76%**	3	**14%**	2	**10%**	21	100%

Table 18. Responses to DM event: How comfortable were you with the temperature *between 4-7 PM?*

	1) Definitely too cold or 2) A bit chilly		3) Just right / OK		4) A bit warm		5) Definitely too hot		Total	
Business	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Emigh Hardware	0	0%	1	5%	0	0%	0	0%	1	5%
Gold's Gym Natomas	0	0%	1	5%	0	0%	0	0%	1	5%
Gold's Gym Elk Grove	0	0%	5	25%	1	5%	0	0%	6	30%
Maita Chevrolet	0	0%	5	25%	2	10%	2	10%	9	45%
JAL Properties	0	0%	3	15%	0	0%	0	0%	3	15%
Total	0	0%	15	**75%**	3	**15%**	2	**10%**	20	100%

Table 19. Responses to DR1 event: How comfortable were you with the temperature *between 4-7 PM?*

	1) Definitely too cold or 2) A bit chilly		3) Just right / OK		4) A bit warm		5) Definitely too hot		Total	
Business	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Emigh Hardware	0	0%	2	4%	1	2%	0	0%	3	5%
Gold's Gym Natomas	0	0%	1	2%	0	0%	0	0%	1	2%
Gold's Gym Elk Grove	0	0%	5	9%	1	2%	0	0%	6	11%
Maita Chevrolet	0	0%	9	16%	3	5%	12	22%	24	44%
JAL Properties	0	0%	11	20%	8	15%	2	4%	21	38%
Total	0	0%	28	**51%**	13	**24%**	14	**25%**	55	100%

Table 20. Responses to DR2 event: How comfortable were you with the temperature *between 4-7 PM?*

	1) Definitely too cold or 2) A bit chilly		3) Just right / OK		4) A bit warm		5) Definitely too hot		Total	
Business	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**	**Count**	**%**
Emigh Hardware	0	0%	2	15%	0	0%	0	0%	2	15%
Gold's Gym Natomas	0	0%	1	8%	0	0%	0	0%	1	8%
Gold's Gym Elk Grove	0	0%	2	15%	0	0%	0	0%	2	15%
Maita Chevrolet	0	0%	3	23%	1	8%	0	0%	4	31%
JAL Properties	0	0%	3	23%	1	8%	0	0%	4	31%
Total	0	0%	11	**85%**	2	**15%**	0	0%	13	100%

Table 21. Respondents who were "a bit warm"

Demo Site	Baseline Work Hours	DM Event 4-7 pm	DR 10% Event 4-7 pm	DR 20% Event 4-7 pm
Emigh Hardware	0	0	1	0
Gold's Gym Natomas	0	0	0	0
Gold's Gym Elk Grove	1	1	1	0
Maita Chevrolet	1	2	3	1
JAL Properties	1	0	8	1
Total Warm	**3**	**3**	**13**	**2**
Total Respondents	**21**	**20**	**55**	**13**
% Warm	**14%**	**15%**	**24%**	**15%**

Survey respondents answered that the comfort level was either just right, a bit warm in every scenario, or definitely too hot at the interviewed sites. There were no responses of individuals feeling too cold or a bit chilly. From the Baseline to the 10% Demand Response event, the percent of people that felt the temperature was a bit warm went from 14% to 24%. However, when comparing the Baseline day with the Demand Management or 20% Demand Response Days, the results indicate that there was no significant difference in comfort level. The percentage of individuals who felt that the temperature was just right or OK from the Baseline Days, Demand Management Days, and Demand Response Days ranged from 51% to 85%. However, when the 10% Demand Response day was not counted, the range is smaller with percentages that range from 75% and 85%. One other question was asked to the interviewees regarding whether job performance was impacted from the DR event days.

In addition to the questions reported in the previous set of tables, a question asked if their comfort level was affected. Only one person felt that the DR day affected their comfort level, but the individual's job performance was not negatively affected.

Observations

One criterion that should be part of further implementation of the technology would be to ensure that the AC Units are in proper working order prior to controller installation. Start up problems that are site specific need to be addressed as they arise. As more implementation increases, these problems can be anticipated and avoided by proper selection of sites and implementation of the controllers. Some problems may be averted by taking into account special needs of certain zones or avoiding some zone rather than trying to control all the AC units.

Some take-back will occur when customers at these sites operate fans to keep themselves cool. These fans are very hard to measure since they are distributed throughout the facilities often located under desks where they are out of sight. Some of the people surveyed normally left work between 5 p.m. and 6 p.m. and were not at work during the entire DR event.

Discussion

REGEN Energy has refined their understanding of how air conditioning units operate with the algorithms of their EnviroGrid controllers. During this process they are devising ways to address identified issues. These issues are described in this section.

The unit controllers monitor the demand of the AC unit they control and store the peak demand to share with the swarm or group of controllers. A few instances have been identified by REGEN Energy where a controller over-reports the demand capacity of the unit it controls. By over-reporting the kW to the swarm, the algorithm to balance the loads is fed wrong information and the resulting allocation of units designated to operate during a cycle may not optimize smoothing out the loads. To address the issue, REGEN Energy is updating the controller determination of peak through multiple readings rather than on a single reading. New units now make measurements every 30 seconds for five minutes, discard the minimum and maximum readings and average the remaining readings. The result is compared to the stored peak demand for the unit and if it is larger than the stored value, the stored value is replaced by the new average measurement.

The current EnviroGrid devices are able to control the compressors of the individual AC units. The upcoming EnviroGrid devices will be able to control the fans as well. By controlling the fans, warmer air will not be blown into the room when the air compressor is shut off. As a result, the conditioned space will return to the ambient temperature much slower after cycling off, leading to less air conditioning use and more energy savings.

Historically the EnviroGrid controllers operate on a 15-minute decision cycle. If by chance a unit is not allowed to operate two consecutive cycles, the temperature in the zone may deviate from an acceptable range in the 30 minutes of non operation. The reallocation cycle times are now being reduced to 10-minute decision cycles to allow for more dynamic operation of unit operation while still managing demand. In addition, the EnviroGrid controller power measurements are being improved to take snapshot readings every 30 seconds for five minutes, throw out the highest and lowest reading and average the remaining eight values to report as the unit demand for the five minute period.

REGEN Energy is working to improve the feedback of the system to confirm that units are in fact not operating when they are not supposed to operate. A problem could arise if an AC service technician disconnects all or part of the controller on a unit. Control units provide call for cooling, measured kW and peak kW information to the swarm. The measured kW has been stored as a value available on the web interface. The swarm will now monitor to confirm units are turning off as requested and report alarms if units are not responding.

The startup procedures of a new installation include an initial period where the units are not controlled but are just monitored to determine the natural duty cycle for each unit. After a week or so the duty cycles are manually coded into the controllers via the web portal. REGEN Energy is developing programming that provides the controllers with the ability to monitor the duty cycles of the AC units. This adaptive duty cycle functionality termed by REGEN Energy as "LiveHive™" will also optimize demand by dynamically adjusting the DM and DR duty cycles themselves, rather than the allowable operating times, more effectively addressing changing load

conditions inside the building during DM mode, and capturing the full benefit of load reduction during DR modes.

Another startup procedure is that the installers will fill out a worksheet for each AC unit they plan on installing a controller. Besides nameplate information of the AC units, they will also note any maintenance or service issues that should be attended to before a controller is installed.

Last year REGEN Energy implemented a new feature on the web portal. It allows a user to schedule DR events in advance. This is a very valuable feature. The entire system is OpenADR capable, allowing for completely automated DR activity by being tied directly to utility DR servers.

Conclusions

The continuous power monitoring showed that the EnviroGrid controllers cycled most AC units off at some time during DR events. This shows that the technology is successful in its claim to provide DR control remotely. The EnviroGrid controllers cycled most AC units off at some time during DM Periods. This should translate into reduced demand charges for GS rate customers. SMUD's peak demand is based on a yearly 15-minute maximum peak value rather than a 15-minute monthly peak. The DM mode impact on the customer's yearly peak was calculated for each site and was found to show substantial kilowatt hour savings. The reason for the expected energy savings is that on Demand Management days the EnviroGrid controllers are scheduled to curtail AC use during non-business hours. The savings are derived from optimized schedule of operation and not demand management during business hours. REGEN's power measurements are generally conservative and do not inflate savings estimates.

No individuals were highly dissatisfied with temperatures maintained during DM and DR events, however they did feel that their work environment was a bit warm. No employees reported that their work performances were affected. Those indicating discomfort based on temperature felt that the effects were minor. However, the survey did not distinguish among employees. Because the higher level employees have more pull in the decisions of programs implemented at the facilities, their opinions will have more weight if this technology is implemented in a full-scale demand response program.

Deployment of this technology would be most compatible in facilities with slow thermal response time such as big box department stores, large open retail stores, large open offices, cold storage warehouses, and grocery stores. Sites with more AC units have more options to control the demand to reduce peak loads. It is suggested that sites should have at least six AC units and preferably more. The minimum number of AC units would need to be increased if they are various sizes rather than similarly sized. Demand savings to the customer may be limited to the demand of the smallest unit when it is cycled off if there are too few units to cycle. If the utility had a program with only a few participants, it would reduce the utility's average demand over the entire period. If the utility had a program with many participants, it would reduce the utility's demand over all of the intervals of the peak period.