OPEN AUTOMATED DEMAND RESPONSE FOR SMALL COMMERCIAL BUILDINGS

Sila Kiliccote
Mary Ann Piette
June Han Dudley
Lawrence Berkeley National Laboratory

Ed Koch
Dan Hennage
Akuacom

Acknowledgements

The work described in this report was funded by the Demand Response Research Center which is funded by the California Energy Commission (Energy Commission), Public Interest Energy Research (PIER) Program, under Work for Others Contract No.500-03-026, Am #1 and by the U.S. Department of Energy under Contract No. DE-AC02-05CH11231. Additional funding was provided by Southern California Edison Company through the Emerging Technologies Program. The authors are grateful for the extensive support from numerous individuals who assisted in this project:

Kristy Chew, Chris Scruton and Martha Brook (California Energy Commission)

California Institute for Energy and the Environment for their assistance with the contract.

Ron Hofmann and Roger Levy for their on going support.

Paul Mathew for his assistance with access to CEUS data and definitions.

Carlos Haid and Teren Abear (Southern California Edison)

Austen D'Lima (San Diego Gas and Electric Company)

Stephen Moss (San Francisco Community Power)

Gus Ezcurra, Tom Naylor and Mike Denny (Advanced Telemetry)

Table of Contents

1.0 Introduction 3
2.0 Goals and Objectives 5
3.0 Open Automated Demand Response Communications Infrastructure 6
4.0 Methodology 8
5.0 Results 15
5.1. Small Commercial Building Characterization 15
5.1.1. Heating Ventilation and Air Conditioning (HVAC) Systems 18
5.1.2. Lighting 19
5.1.3. End use load distribution 21
5.2. DR Technology Framework Development for Small Commercial Buildings 21
5.2.1. DR Signal Communication Means 24
5.2.2. IP Infrastructures 25
5.2.2.1. T-carrier 25
5.2.2.2. Digital Subscriber Lines (DSL) 25
5.2.2.3. Cable Internet 26
5.2.2.4. Integrated Service Digital Network (ISDN) 26
5.2.2.5. Satellite Internet 26
5.2.2.6. Optical Fiber to Building 26
5.2.2.7. Worldwide Inter-operability for Microwave Access (WiMAX) 27
5.2.2.8. Mobile Communications (Cellular) 27
5.2.2.9. Broadband over Power Lines (BPL) 27
5.2.2.10. Plain Old Telephone Service (POTS) 28
5.2.3. Radio Frequency (RF) Broadcast 28
5.2.3.1. Pager Networks 28
5.2.3.2. Datacasting 28
5.2.3.3. Radio Data System (RDS) 29
5.2.3.4. DirectBand 29
5.3. Small Commercial Customer Aggregation 31
5.4. Field Tests 33
5.4.1. Recruitment 33
5.4.2. Automated DR Events 34
6.0 Discussion and Conclusions 38
7.0 References 41
8.0 Glossary 43

Table of Figures

Figure 1. Generic Open Automated DR Interface Architecture 7
Figure 2. OpenADR architecture for the field tests 10
Figure 3. DRAS Operator Interface to Create DR Events. 12
Figure 4. DR Strategy Input Interface 13
Figure 5. Climate Regions Defined by CEUS 17
Figure 6. Light Source Distribution in Small Commercial Buildings (Source: EnergyIQ) 20
Figure 7. Ballast Types Used in Small Commercial Buildings (Source: EnergyIQ) 20
Figure 8. Lighting Controls in Small Commercial Buildings (Source: EnergyIQ) 21
Figure 9. DR Strategy in Load Controller 21
Figure 10. DR Strategy in EMCS 22
Figure 11. DR Strategy External to the Facility 22
Figure 13. Load Profile for Hesperia Site on November 7, 2008 36

Abstract

This report characterizes small commercial buildings by market segments, systems and end-uses; develops a framework for identifying demand response (DR) enabling technologies and communication means; and reports on the design and development of a low-cost OpenADR enabling technology that delivers demand reductions as a percentage of the total predicted building peak electric demand.

The results show that small offices, restaurants and retail buildings are the major contributors making up over one third of the small commercial peak demand. The majority of the small commercial buildings in California are located in southern inland areas and the central valley. Single-zone packaged units with manual and programmable thermostat controls make up the majority of heating ventilation and air conditioning (HVAC) systems for small commercial buildings with less than 200 kW peak electric demand. Fluorescent tubes with magnetic ballast and manual controls dominate this customer group's lighting systems. There are various ways, each with its pros and cons for a particular application, to communicate with these systems and three methods to enable automated DR in small commercial buildings using the Open Automated Demand Response (or OpenADR) communications infrastructure. Development of DR strategies must consider building characteristics, such as weather sensitivity and load variability, as well as system design (i.e. under-sizing, under-lighting, over-sizing, etc). Finally, field tests show that requesting demand reductions as a percentage of the total building predicted peak electric demand is feasible using the OpenADR infrastructure.

Keywords: open automated demand response, OpenADR, OpenADR, small commercial buildings, CEUS

Executive Summary

Small commercial buildings, those with less than 200 kW of peak demand, make up 20-25% of peak electric demand in California. We have identified small office buildings, restaurants and retail buildings as the major contributors making up over one third of the small commercial peak demand. A ten percent reduction in only these three types of facilities can yield overall peak demand reductions of up to 0.5% – 0.7% in California.

The goal of this project was to characterize small commercial buildings by market segments, systems and end-uses; to develop a framework for identifying DR enabling technologies and communication means; and to consider the feasibility of a low cost OpenADR enabling technology that delivers demand reductions as a percentage of the total predicted building electric peak demand.

The project has four key elements. First, California commercial end use survey (CEUS) was examined to understand the market segments, the regional concentration of small commercial buildings and the diversity of end-uses and controls. Second, a framework was developed for technologies that are compatible with the Open Automated Demand Response (or OpenADR) communication infrastructure for small commercial buildings. Third, we worked with five buildings that participated in manual DR with an aggregator to understand building characterization. Finally, a system that delivers demand reduction as a percentage of the whole-building peak electric demand was designed, developed and field tested in two quick-service restaurants in Southern California Edison's service territory.

The goal of the characterization of small commercial buildings was to identify opportunities and low hanging fruit for this customer group. Small office, restaurants and retail buildings are the major contributors making up over one third of the small commercial peak demand. A majority of the small commercial buildings are located in southern inland areas and the central valley. Single-zone packaged units with manual and programmable thermostat controls make up the majority of heating ventilation and air conditioning (HVAC) systems in this group of customers. Fluorescent tubes with magnetic ballasts and manual controls dominate this customer group's lighting systems.

The framework development provides a reference to small commercial building owners to evaluate their investment in various OpenADR enabling technologies. The small commercial building owner can use this framework to identify which method would work for his/her building and look for products that accommodate the selected method. Information on various means of DR signal communication is provided to assist small commercial building owners to select appropriate means of communication for their DR automation.

We worked with an aggregator and compiled data from five larger sites that participated in DR events in 2007, either manually or semi-automatically. The aggregator notifies the customers that a DR event is issued but has no information on the DR strategies or real-time meter data and is provided information on the portfolio's performance weeks after the events are dispatched. The deployment of advance metering infrastructure (AMI) will largely solve the existing information related issues. Meter data, when available, should be used to calculate load variability and weather sensitivity of buildings to better assess the DR potential in small commercial buildings.

Finally, the feasibility of using OpenADR to request demand reductions as a percentage of total predicted demand was demonstrated for Southern California Edison with field tests in two quick-service restaurants. The method to predict demand should be carefully chosen as there is no one baseline method that predicts peak demand for all facilities accurately. Building characteristics and building systems issues, such as design and controls, have to be considered when estimating how much and when demand reduction is available at each facility.

As a next step, first, we propose continuing field studies to characterize ownership, management and operational issues; to identify opportunities in small offices, restaurants and retail facilities especially for lighting systems; to consider the feasibility of using AMI infrastructure to deliver OpenADR signals to small commercial buildings; and to understand price-point requirements. Second, tools must be developed for small building owners to better understand their buildings' loads. Finally, a guide developed for small buildings owners to enable automation of DR can create awareness and facilitate deployment of enabling technologies.

1.0 Introduction

California requires about 53 GW of peak electric demand on the hottest summer day (CPUC FAQ). The commercial sector accounts for 35% percent of this peak demand. Large buildings or those with peak electric demand greater than 200 kW demand account for about 5 to 7 GW, or 10-15% percent of the summer peak demand, while small commercial buildings account for 10 to 12 GW, or 20 to 25% percent of the peak. This report develops and discusses a framework to deploy automated demand response (DR) for small commercial facilities as well as technologies and strategies to enable automated demand response. Enabling small commercial buildings to participate in automated DR programs and tariffs could substantially decrease summer peak demand.

Demand Response (DR) is a set of actions taken to reduce electric loads when contingencies, such as emergencies or congestion, threaten supply-demand balance, and/or market conditions occur that raise electric supply costs. DR programs and tariffs are designed to improve the reliability of the electric grid and to lower the use of electricity during peak times to reduce the total system costs. This effort builds on ongoing Demand Response Research Center (DRRC) research, development, demonstration and deployment activities related to Open Automated Demand Response (known as OpenADR). OpenADR is a set of standard, continuous, open communication signals and systems provided over the Internet to allow facilities to automate their demand response with no "human in the loop."

OpenADR has been proven in large commercial buildings because of the ability to use the Energy Management Control Systems (EMCS) to automate the DR control strategies. Although a detailed study of applicable technologies and installation of direct digital controls in small commercial buildings was undertaken by Southern California Edison in the past (Lockheed Martin Aspen 2006), this report begins to explore methods to deploy OpenADR in smaller commercial buildings that do not have centralized or sophisticated control systems and concentrates on how various technologies fit within the OpenADR enablement framework. Also, while the lack of an EMCS is a challenge, the lack of Internet connectivity is also an issue in small commercial buildings. Therefore this report compares various communication means to deliver OpenADR signals to small commercial buildings.

Finally, a new, standard Programmable Communicating Thermostat (PCT) designed for DR in residential buildings is also being tested in small commercial buildings (Herter 2008). Careful evaluation of control systems in small commercial facilities is needed to understand which type of cooling and ventilation technologies could work well with PCTs.

The structure of this report is as follows.

Section 2, Project Objectives, provides a discussion of the project objectives.

Section 3, Open Automated Demand Response Communication Infrastructure, describes the infrastructure currently being used for large commercial and industrial facilities to participate in fully automated demand response in California. The feasibility of the same infrastructure to be extended to small and medium commercial facilities is discussed in following sections.

Section 4, Methodology, outlines the project methodology covering the analysis of CEUS data, the framework for technology, evaluation of communication media, and analysis of SF Community Power data.

Section 5, Results, outlines small commercial facility characterization in California; presents the framework, technologies and communication media that can be used by small commercial facilities;

Section 6, Discussions and Recommendations, summarizes findings and next steps.

Appendices provide reporting on a parallel effort with San Francisco Community Power to understand the issues around small commercial facilities, baseline methods used for analysis, and a DR technology survey.

2.0 Goals and Objectives

The overall goal of this research is to better understand the opportunities for DR in small commercial buildings. The specific objectives of this research are:

1. To evaluate the summer whole-building electric load shapes, consider end-use load patterns, and understand the diversity and characteristics of small commercial buildings to understand the opportunities for DR.
2. To ascertain low-cost and effective ways to automate demand response (DR) for small commercial facilities that may lack effective communications and control infrastructure. The research concentrates on existing small commercial buildings, but also addresses new commercial buildings, which might benefit from the installation of newer technologies or infrastructure.
3. To evaluate the use of programmable communicating thermostats (PCT) in small commercial buildings and understand the market for the PCT beyond residential buildings. Additional questions include: 1) if a PCT is in a small commercial building, what modes of DR automation would be available for other end-uses such as commercial lighting, and 2) how might home automation network (HAN) technologies migrate into the small commercial sector.

3.0 Open Automated Demand Response Communications Infrastructure

This section provides an introduction into OpenADR. The Demand Response Research Center developed OpenADR to facilitate deployment of low-cost DR automation. OpenADR is a set of standard and open information exchange model to allow facilities to automate their demand response with no "human in the loop." OpenADR uses utility provided price, reliability, or event signals to automatically initiate customer pre-programmed energy management strategies. Key features of OpenADR include (Piette et al. 2007):

Signaling – OpenADR provides continuous, secure, reliable, two-way communication with end-use customers to allow end-use sites to be identified as listening and acknowledging receipt of DR signals.

Open Industry Standards - OpenADR consists of open, interoperable industry standard information exchange model designed to integrate with both common energy management and control systems and other end-use devices that can receive a dry contact relay or similar signals (such as Internet based eXtensible Markup Language).

Timing of Notification - Day ahead and day of signals are provided by OpenADR technologies and systems to facilitate a diverse set of end-use strategies such as building pre-cooling for "day ahead" notification, or near real-time communications to implement "day of" control strategies. Timing of a DR automation server (DRAS) communications must consider day-ahead events that include weekends and holidays

Most large commercial buildings with energy management and control systems (EMCS) and related lighting and other controls can be pre-programmed to initiate and manage electric demand response.

OpenADR architecture, as displayed in Figure 1, consists of two major elements built on open-interface standards model. First, a Demand Response Automation Server (DRAS) provides signals that notify electricity customers of DR events. Second, a DRAS client is at the customer's site to listen and provide automation signals to existing pre-programmed controls. There are two types of DRAS clients:

1. A Client and Logic with Integrated Relay (CLIR) or a simple client for legacy control systems.
2. A Web Services software or smart client for sophisticated control systems.

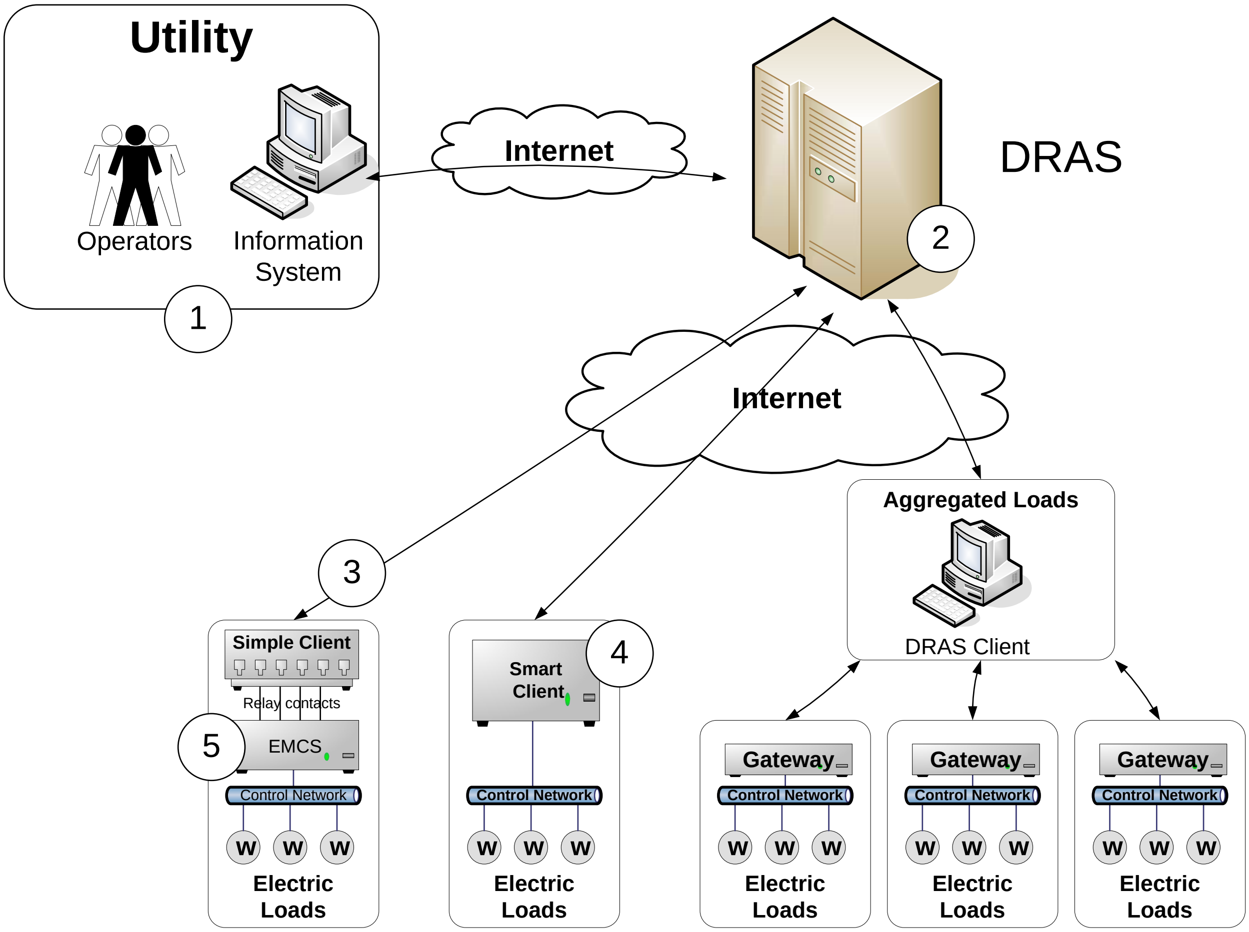


Figure 1. Generic Open Automated DR Interface Architecture

As shown in above figure, the steps involved in the OpenADR process during a DR event are:

1. The Utility or ISO defined DR event and price/mode signals are sent to the DRAS.
2. DR event and price services published on a DRAS.
3. DRAS Clients (CLIR or Web Service) request event data from the DRAS every minute.
4. Customized pre-programmed DR strategies determine action based on event price/mode.
5. Facility Energy Management Control System (EMCS) carries out load reduction based on DR event signals and strategies.

The EMCS allows for central control of heating, ventilation, and air conditioning systems.

4.0 Methodology

There are three major differences between small versus large commercial buildings with respect to the applicability of OpenADR:

1. Small buildings are generally not equipped with centralized energy management and control systems (EMCS). Furthermore, they lack on-site personnel and metering infrastructure to measure their demand and set up strategies for DR.

2. They have a wider variety of ownership models, energy management and related professional services. Very small commercial buildings are being operated like residential buildings where the owner, with limited information such as a utility bill, has to make decisions, and medium sized small commercial buildings are being operated more like their large counterparts.

3. They have more varied and limited availability of the Internet.

In addition, years of research on DR strategies for building systems in large commercial buildings resulted in an understanding of systems and strategies that are applicable to those systems (Motegi et al. 2006). There seems to be a lack of similar understanding of small commercial systems and technologies customers can utilize.

This study investigates the small commercial buildings landscape, its contribution to the peak electric load, end-uses, automation opportunities, means of delivering automation signals, categorizing technologies and finally presents a field study. The next step would be to understand various market segments, especially the top three that contribute to the peak electricity most and identifying best, common and poor practices in order to map technologies on structure and operations of small commercial buildings.

The methodology in this study involved four key elements.

1. *Analysis of the California Commercial End-Use Survey (CEUS) Data*

   CEUS is a comprehensive study of commercial building sector end-use energy use in California (Itron 2004). It captures detailed building systems data, building geometry, electricity and gas usage, envelope characteristics, building systems, operating schedules, and other commercial building characteristics. A random sample of about 2800 surveys was completed. Commercial buildings are weighted and aggregated to building segment results. For the commercial building analysis we used Energy-IQ which uses CEUS as its initial database. Peak electric load data are non-coincident and limited so, for this study we selected buildings under 25,000 ft^2. In addition, investor-owned utilities provided information on the number of accounts by peak load segments. The following summaries are prepared:

- Peak electric load distribution by market segment – The purpose of the analysis is to understand which market segments contribute more to the peak electric load. Market segments include small and large office, retail, restaurant, school, refrigerated and non-refrigerated warehouse, grocery, health care, lodging, colleges and a large uncategorized miscellaneous group. For each market segment, percent non-coincident peak electric load, total area of building and demand intensity is presented.

- Peak electric load distribution by location – The information on the concentration of small commercial buildings within California identifies the key areas where DR may be of value. Seven major areas within the database include southern inland, central valley, southern coast, central coast, desert, northern coast and mountains.
- Peak electric load distribution by utility – Number of accounts in various peak electric load categories are collected to understand how closely the data from the utilities matches with the CEUS data.
- Lighting system type and controls distribution – Initial starting point for developing DR strategies is understanding the type of systems and controls in small commercial buildings. These data is summarized to understand OpenADR potential for lighting systems in small commercial buildings.
- HVAC system type and distribution – These data is summarized to gain an understanding of OpenADR potential for HVAC systems in small commercial buildings.

2. Framework development for technologies compatible with automated demand response

For small commercial buildings, three basic models for implementing DR are identified:

- Shed strategy is implemented completely outside the facility. This is the model used for direct load control programs by utilities and aggregators.
- Shed strategy is implemented completely within the load controllers themselves, i.e. within the lighting or HVAC controls.
- Use of a centralized controller within the facility (EMCS lite) to program and control the shed strategies for the entire facility.

After identifying the three basic models, we collected information on the various communication media that may be used for delivering DR automation signals. In addition, we interviewed over 20 vendors whose products may be applicable to automation of DR in small commercial buildings. A summary of findings are outlined in the results section. Further details are included in the appendices.

3. Understanding small commercial building characterization issues

There are various ways that a small commercial facility can participate in DR tariffs and programs in California. OpenADR is a communication standard for machine-to-machine communication that allows the customer to participate directly with a utility's tariff or program. Some aggregators have contracts with utilities to bring in small commercial buildings to DR programs (Koch 2008). In both cases, where a customer participates in a program directly or through an aggregator, a metering infrastructure is required to measure the amount of demand reduction. While this is still a research issue now, we expect AMI initiative to solve metering issues for this group of customers. The remaining key issues with this group of customers is 1) understanding their load shapes by analyzing their load variability to determine if they are good DR candidates at all; and 2) the whole building demand's weather sensitivity by correlating hourly outside air temperature with hourly load. By analyzing SF Community Power's portfolio in 2007, we were able to understand some of these issues.

4. Automated DR Field Tests

In order to put the strategies and technologies to test, two quick service restaurants were equipped with a relatively low cost technology that allows for multiple levels of demand shedding. The components of the system used for the pilot are shown in Figure 2. The facilities used for the pilot were two Taco Bells buildings located in San Juan Capistrano and Hesperia, CA. The components within the facilities were provided by Advanced Telemetry and customized for this pilot.

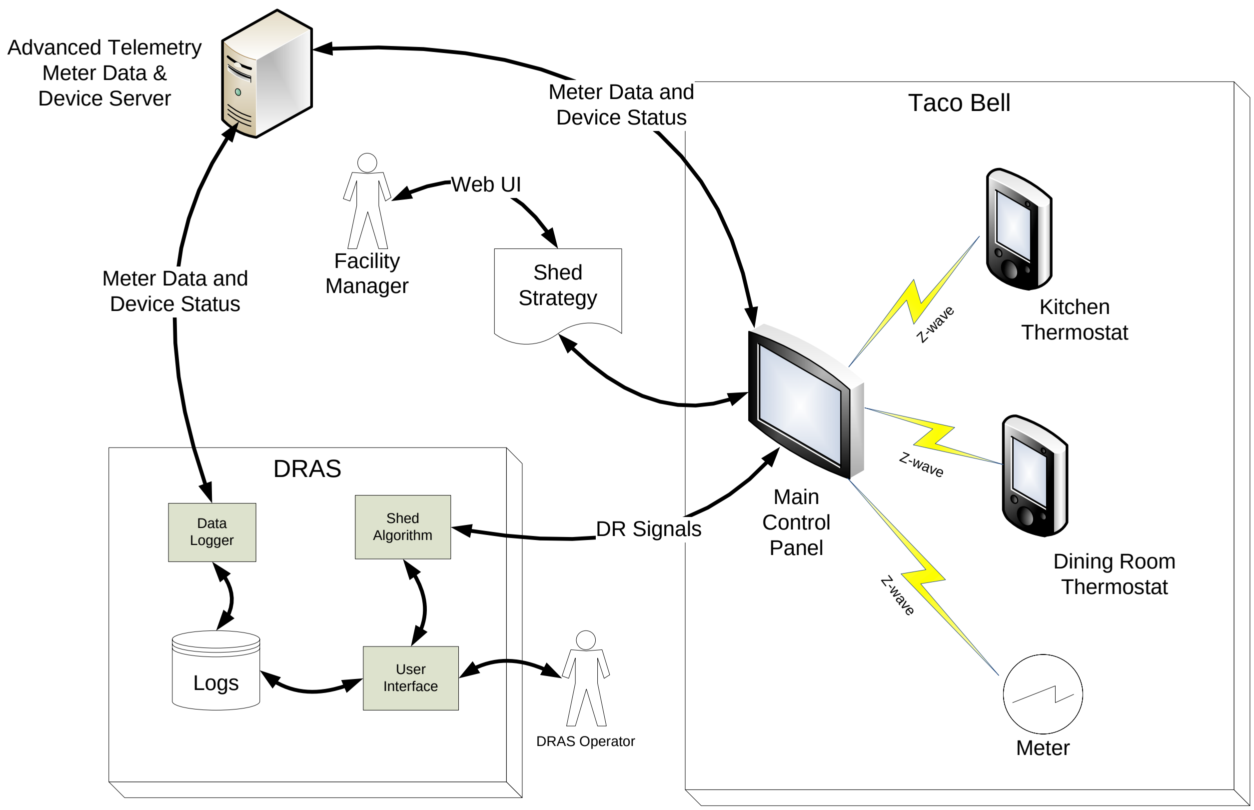


Figure 2. OpenADR architecture for the field tests

The components within the facilities consisted of the following:

- *Control panel* - This panel implemented the shed strategies for the facility and communicated with the other devices in the facility wirelessly over Z-wave.
- *Dining room and kitchen thermostats* – Typical installation for these facilities include two wireless thermostats: one located in the dining room area and the other in the kitchen area. These are programmable communicating thermostats (PCTs) that communicate with the control panel via Z-wave wireless communications.

- *Meter* - This provided whole building demand information in both real time and at 15 minute intervals. The customer owns these data and allows the third party to have access to it for on going maintenance.

As shown in Figure 2, there was also a separate server, owned by Advanced Telemetry, that specifically collected meter and device status information from each facility. Finally, a Demand Response Automation Server (DRAS) was responsible for managing the DR events and providing the DR signaling to the facilities. All the DR signaling used by the DRAS followed the OpenADR standards as documented in version R1 of the OpenADR proposed standard (Piette et al. 2008). All communications between the various servers and the facility was via the Internet and used a broadband connection in the facility.

There are two innovations worth mentioning with the field tests:

1. OpenADR signals were utilized to communicate directly with both facilities small scale EMCS (EMCS Lite) system.

2. A feedback loop was created and several baselines (Appendix D) were pre-calculated so that the utility could request a certain percentage of shed, using a pre-specified baseline, from each facility.

Information on the OpenADR signals can be obtained from http://openard.lbl.gov. The remaining of this section will concentrate on the DRAS operation for achieving a certain percent of demand reduction.

A DRAS was designed and developed to allow the DR events to be managed for each facility. It was designed to allow the operator to specify the amount of load to shed according to a percentage from some baseline. Two baseline methods, three highest within the last ten days (3/10) and 3/10 with morning adjustment were calculated. Calculations are explained in Appendix D. In addition, a third baseline using outside air temperature regression (OAT) was calculated after the events for analysis purposes. This baseline was not used during the events because real-time weather data, which was needed to develop real-time baseline, was not available at each facility.

To initiate a DR Event, the operator entered general DR event parameters such as event date, start time and end time and selected which baseline to use and the percentage from that baseline to shed. Figure 3 show the DRAS operator interface for creating DR events.

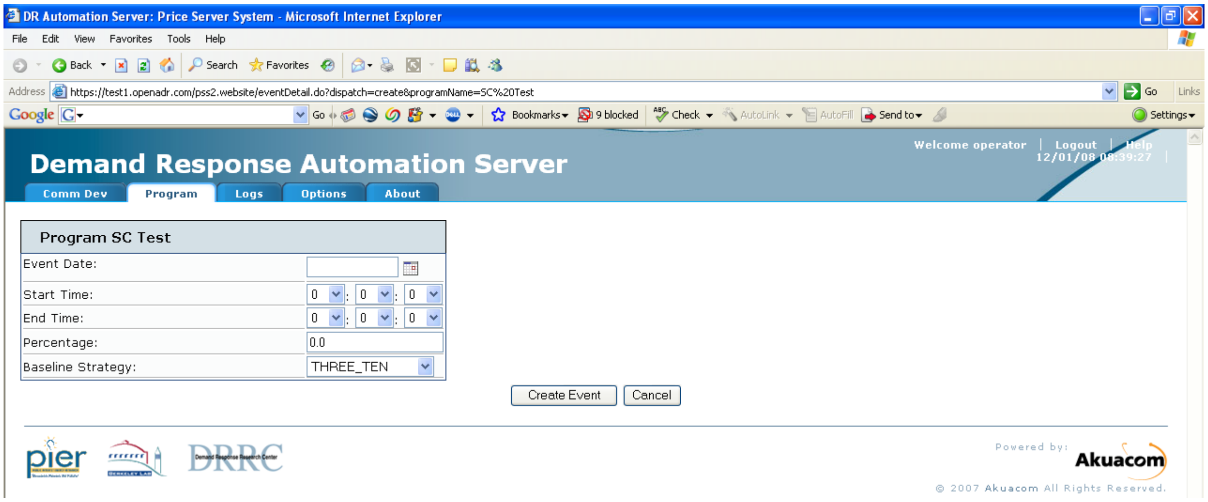


Figure 3. DRAS Operator Interface to Create DR Events.

The DR signals that were designed for this program consisted of 10 levels such that level 0 was considered normal and level 9 was considered the highest shed possible. The number of levels was chosen with a consideration for the level of granularity of controls requirement. Based on these levels, a shed strategy was assembled for each facility that consisted of correlating the device states in the facility with each of the levels. The only rule was that each successively higher level should result in a higher shed in the facility. Figure 4 is a screen capture of this interface. Although lighting sheds were initially part of the DR strategies and were programmed into the interface, final DR strategies only included the HVAC system.

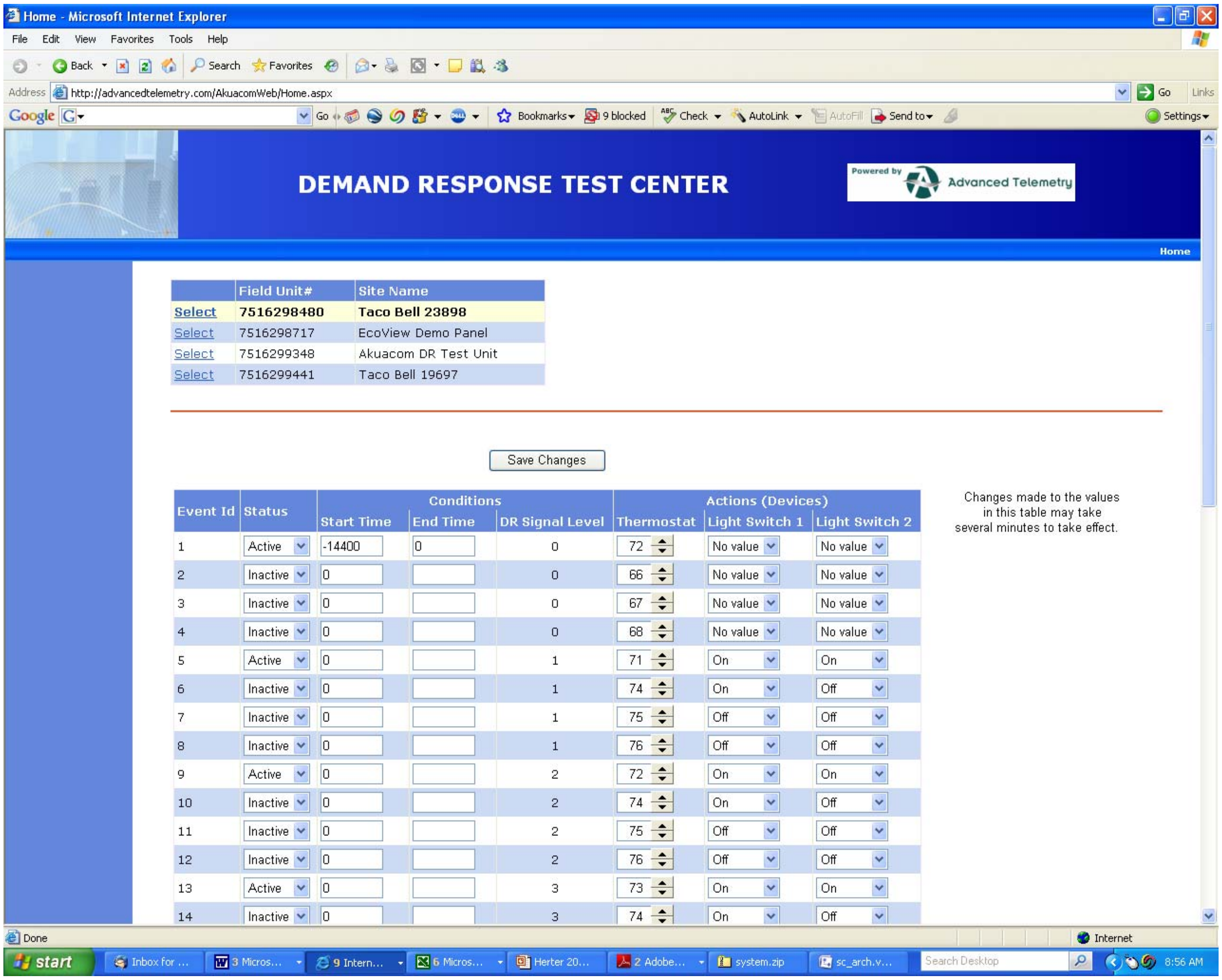


Figure 4. DR Strategy Input Interface

The shed strategy for each facility was programmed using a web based interface that consisted of filling out a table as shown in Figure 4. The table has rows that corresponding to shed levels and columns that correspond to the various device states. Time parameters were added that allowed for different device states for a particular shed level based upon when during the event the level occurs. In addition, there was the ability to input device states that should occur before the event occurs to support strategies such as pre-cooling.

Finally, the DRAS was designed to monitor the facilities response during the event and dynamically change the shed level sent to that facility if it was not shedding according to the percentage that was specified.

The basic process used with the DRAS consisted of the following:

1. Operator initiates an event and specifies the following: time and date for the event, baseline to use, the percentage to shed.
2. The DRAS notifies the facility of the pending event.

3. The event begins and DRAS sends an initial shed level to the facility.
4. The DRAS calculates the demand since the start of the event and compares it against the baseline.
5. If the facility is not shedding enough (based upon the percentage and baseline specified) then a higher shed level is sent to the facility.
6. If the facility is shedding more than required than a lower shed level is sent to the facility. (Effect of data latency to be examined)
7. Repeat steps 4 – 6 for the duration of the DR event.
8. End the event and return the facility to normal operations.

Since the meter data was being updated at 15 minute intervals the algorithm outlined in steps 4 – 6 above was being run at a frequency of every 15 minutes.

A total of six events were scheduled in October and November of 2008. The first two were test events scheduled to find and resolve bugs in the communication and algorithm development. Three were successfully completed at each facility. The last one was only completed in the Hesperia facility since there was a problem with the thermostats in San Juan Capistrano facility. The results from these tests are reported in Section 5.4 of this report.

5.0 Results

In this section, results from the four key elements of the study are presented. These are:

Small commercial facility characterization: California Commercial End-Use Survey (CEUS) and data collected from the investor-owned utilities are presented to characterize small commercial buildings, end uses and systems in California.

DR framework development for small commercial buildings: Three basic models and variations on these models are presented to address how small commercial buildings can participate in DR tariffs and programs through OpenADR signals.

Small Commercial customer aggregation: Collaboration with a small commercial facility aggregator to address issues related to the various types of customers is outlined.

Field Tests: Results from field tests are summarized.

5.1. Small Commercial Building Characterization

In this section, results from analysis of CEUS data and data shared by the utilities are presented. Analysis of these data is summarized in following categories:

- **Peak electric load distribution by market segment** – The purpose of the analysis is to understand which market segments contribute more to the peak electric load. Market segments include small and large office, retail, restaurant, school, refrigerated and non-refrigerated warehouse, grocery, health care, lodging, colleges and a large uncategorized miscellaneous group. For each market segment, percent non-coincident peak electric load, total area of building and demand intensity is presented.
- **Peak electric load distribution by location** – The information on the concentration of small commercial buildings within California identifies the key areas where DR may be of value. Seven major areas within the database include southern inland, central valley, southern coast, central coast, desert, northern coast and mountains.
- **Peak electric load distribution by utility** – Number of accounts in various peak electric load categories are collected to understand how closely the data from the utilities matches with the CEUS data.
- **Lighting system type and controls distribution** – Initial starting point for developing DR strategies is understanding the type of systems and controls in small commercial buildings. These data is summarized to understand OpenADR potential for lighting systems in small commercial buildings.
- **HVAC system type and distribution** – These data is summarized to gain an understanding of OpenADR potential for HVAC systems in small commercial buildings.

Table 1. Market Segmentation for Buildings Less Than 200 kW Peak Load (Source: CEUS)

Market Segment	% Peak Load n=96,872 kW	% Size n=27,965,216 sqft	Ave.W/sqft
Misc	25%	32%	2.6
Small Office	19%	12%	5.1
Retail	19%	18%	3.5
Restaurant	14%	5%	8.8
School	5%	6%	2.9
Warehouse	5%	14%	1.2
Grocery	4%	2%	6.6
Health Care	3%	3%	3.7
Lodging	3%	4%	2.2
Large Office	3%	3%	3.5
Refrigerated Warehouse	1%	1%	3.3
College	0%	0%	3.8

Table 1 shows the non-coincident peak load distribution of buildings less than 200 kW peak load for various market segments. It displays each segment by their contribution to the percent of total peak load, market segment percent contribution in terms of floor space and demand intensity for each market segment. Retail and small offices dominate the small commercial market in terms of their floor space and peak load followed by restaurants. Restaurants have the highest demand intensity followed by grocery stores and small offices. On the other end of the spectrum, warehouses tend to occupy 14% of the total floor space with relatively small contribution to the peak load due to their low demand intensity.

Table 2. Geographical Distribution and Peak Load Contribution of Small Commercial Buildings (Source: CEUS)

	% Peak Load	% Area	W/sqft
Southern Inland	32%	31%	3.5
Central Valley	26%	25%	3.5
Southern Coast	17%	18%	3.2
Central Coast	16%	19%	2.8
Desert	4%	3%	4.3
Northern Coast	3%	3%	3.6
Mountains	1%	1%	4.6

Table 2 displays the geographical distribution of small commercial buildings by percent of peak load, percent of floor space and by demand intensity. These data are important because it shows the geographical density of small commercial buildings in California. Small commercial buildings in southern inland and central valley contribute to more than half of the total peak load from all small commercial buildings followed by small commercial buildings in southern and central coasts. While the demand intensity of buildings in the desert and mountains tend to be higher, their contribution to the peak load is little because of their small number in these areas. Further analysis showed that both in southern inland areas and central valley the highest contributors to peak load are small offices, retail and restaurants. Moreover, more than half peak load contribution of each market segment comes from the two areas.

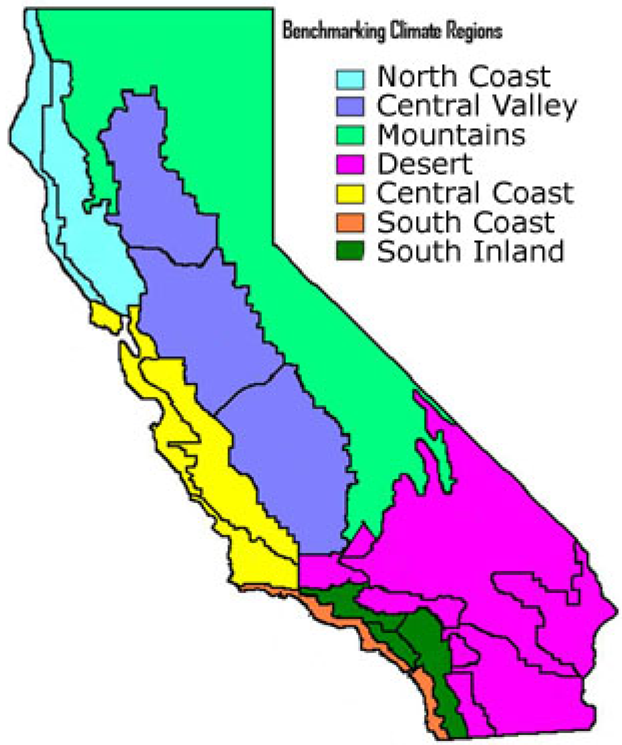


Figure 5. Climate Regions Defined by CEUS

The investor-owned utilities (IOUs) in California were asked to provide number of accounts in each peak load range as displayed in Table 3. The data gathered from CEUS and the IOUs is presented in Table 3. There is a slight difference in the percentage of less than 50 kW peak accounts but this may be due to IOUs servicing most but not all of California.

Table 3. Comparison of CUES Data with the Actual Percent of Accounts within Various Peak Demand Ranges in Three Investor-Owned Utility Territories in California (Source: Investor-Owned Utilities)

	kW Range					
	200>x>150	150>x>100	100>x>50	50>x>35	50>x>20	less than 20 kW
CEUS	1%	2%	5%	5%	17%	75%
SCE	1%	2%	4%	3%	8%	82%
PG&E	0%	1%	2%	1%	1%	96%
SDG&E	1%	1%	3%	2%	3%	90%

The next step in understanding applicability of Auto-DR to small commercial buildings requires characterization of the end-uses and controls that are commonly utilized in small commercial buildings. While CEUS does not have end-use and controls data sorted by peak load, it does provide data sorted by building size. For this study, CEUS data for buildings less than 25,000 ft^2 were considered.

5.1.1. Heating Ventilation and Air Conditioning (HVAC) Systems

On the HVAC side, ninety-nine percent of buildings in California less than 25,000 ft^2 have single zone systems. Further analysis showed that in this building size group, 65% of total tonnage is due to packaged single zone units while seventeen percent of total tonnage is due to air-source heat pumps (Table 4).

Table 4. Type of HVAC Systems by Count and Tonnage in Buildings Less Than 25,000ft²

Type	Total by Count n=1,101,320	% by Count	Total by Ton n=792,058	% by Ton
Single Zone	3456	0	4011	1
Packaged Single Zone	586532	53	511694	65
Split-System Single Zone	55541	5	54494	7
Packaged Terminal Unit	101014	9	19068	2
Unit Ventilator	62378	6	54962	7
Two-pipe Fan Coil	3955	0	3527	0
Four-pipe Fan Coil	1363	0	5763	1
Baseboard heater	50106	5	0	0
Air-source Heat Pump	231966	21	136542	17
Ground-Source Heat Pump	0	0	0	0
Water Loop Heat Pump	5009	0	1997	0

Dominance of packaged single zone units in small commercial customer group provides a starting point for DR strategy development. Typical HVAC DR strategies for packaged single zone units include:

- Global temperature adjustment (GTA)
- Compressor shut down
- Unit cycling
- Pre-cooling and/or night ventilation (free-cooling)

In previous research we defined *Global Temperature Adjustment* (GTA) as a DR strategy to allow commercial building operators to adjust the space temperature setpoints for an entire facility by one command from one location (Motegi et al. 2006). In the case of small commercial buildings with a single packaged unit and a single zone, this means setting up the temperature at the thermostat. However this becomes complicated when there are multiple packaged units because a way to network thermostats to provide the "global" or central temperature adjustment is required. This is also the case for large commercial facilities which are made up of small commercial type buildings.

Compressor shut down can be defined as turning off the compressor in a single compressor system for a short period time or turning off second stage of two stage compressor units. This requires either a small energy management control system (EMCS) or direct communication to the packaged unit system. When this strategy is used, ventilation requirements of buildings must not be compromised.

Unit cycling refers to shutting off a small number of units for a limited time if there are others that can continue servicing the facility. Again, ventilation requirements should not be compromised especially in retail buildings where out-gassing from merchandise may cause indoor air quality issues (Hotchi et al. 2006).

Table 5. Controls for Single Zone Packaged Air Units (Source: CEUS)

Type	Total by Count	% by Count	Total by Ton	% by Ton
Manual	609736	61.26	338609	47.52
Always on cons temp	29527	2.97	28352	3.98
Time clock	59925	6.02	62324	8.75
EMS	16628	1.67	29127	4.09
Programmable Tstat	279473	28.08	254093	35.66

In order to implement the DR strategies outlined above, the next step is to understand the kind of controls that are being used in small commercial buildings. Table 5 displays the type of controls in buildings less than 25,000 ft^2. Energy management and control systems (EMCS) is by far the most preferred way to implement DR strategies in buildings because they allow for pre-programming strategies and either manually or automatically call the strategies when a DR event is dispatched. Unfortunately, the penetration rate of these systems into small commercial buildings is low because they are expensive. Most of the buildings have manual control. Manual control is adjusting thermostat setting manually. Programmable thermostats are the second widely used controls with a penetration rate of 28%.

5.1.2. Lighting

Electrical lighting in buildings is responsible for 30 – 33% of the commercial sector peak load (Rubinstein et al.2006). Lighting may provide opportunities in small commercial buildings as well. CEUS data shows that fluorescent lamps dominate small commercial buildings with 76% penetration followed by 11% penetration of incandescent light sources. Ballast types in small commercial buildings are magnetic ballasts, electronic ballasts and high efficiency magnetic ballasts, 41%, 31% and 27%, respectively. There is little penetration of advanced electronic ballasts in small commercial buildings.

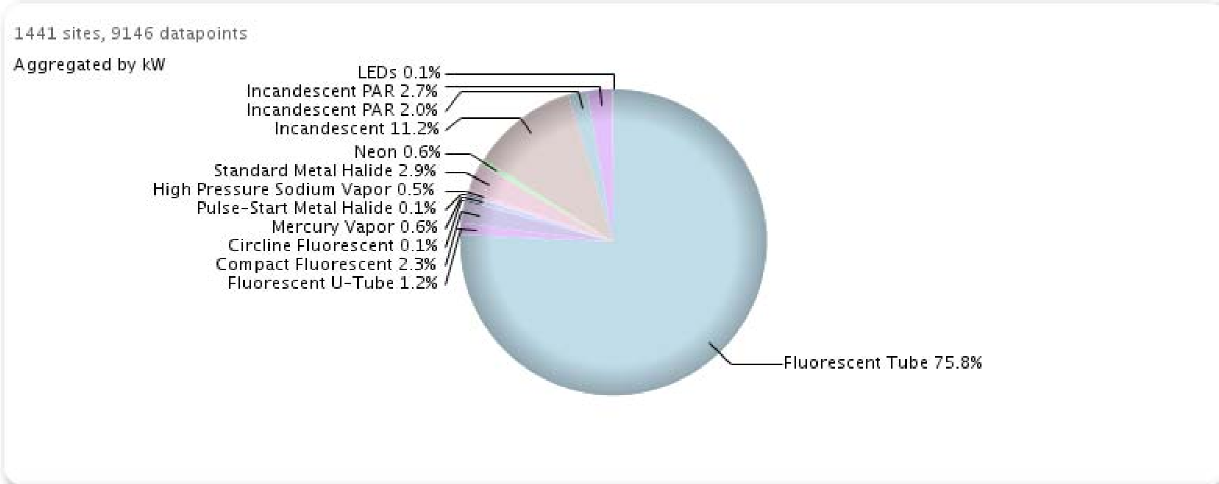


Figure 6. Light Source Distribution in Small Commercial Buildings (Source: EnergyIQ)

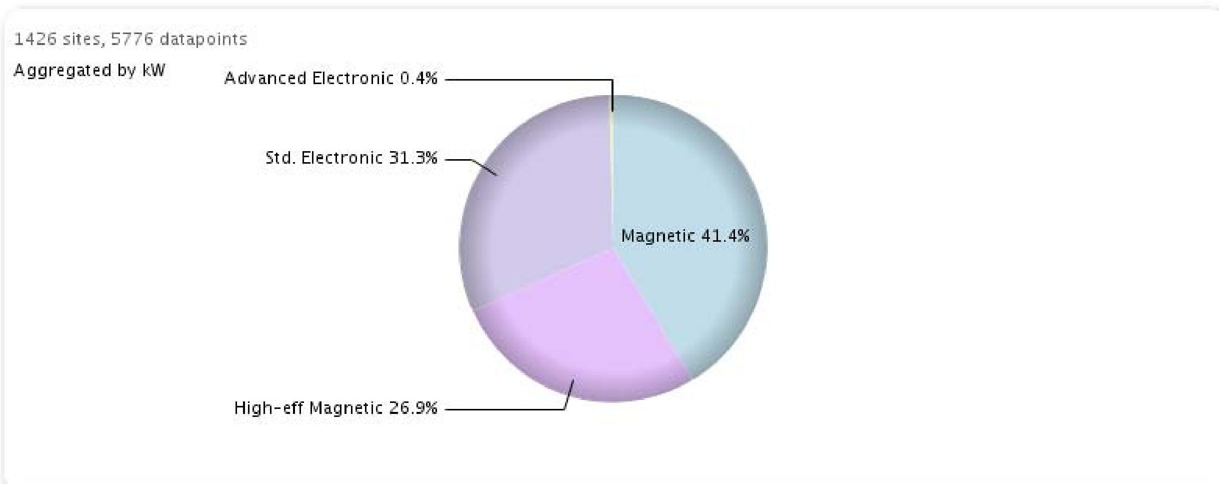


Figure 7. Ballast Types Used in Small Commercial Buildings (Source: EnergyIQ)

Centralized control systems allow for easy implementation of DR automation. CEUS data show that 93% of small commercial buildings have only manual control over lighting systems and that only about 2 % have EMCS.

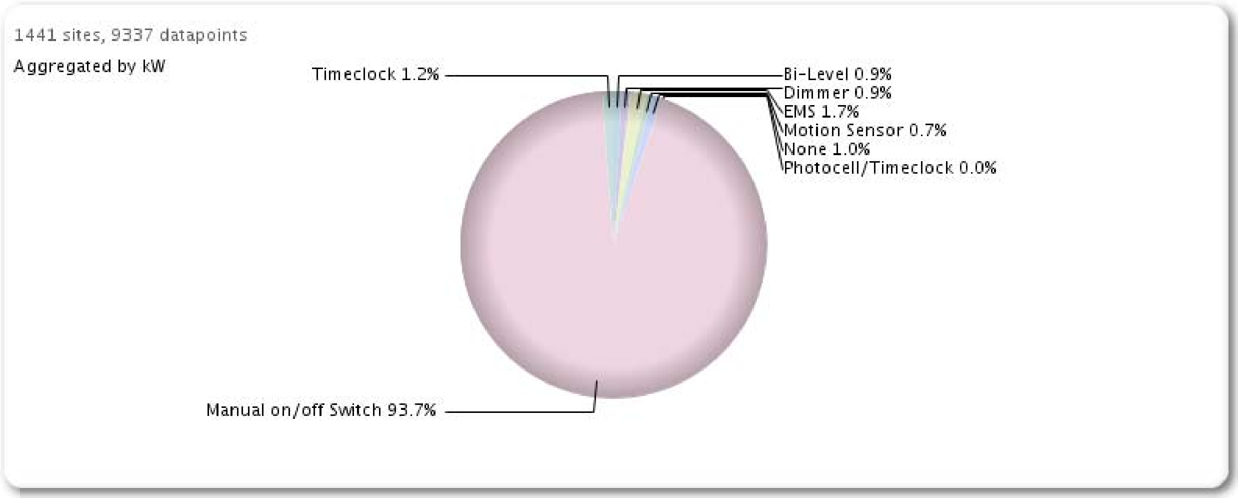


Figure 8. Lighting Controls in Small Commercial Buildings (Source: EnergyIQ)

5.1.3. End use load distribution

HVAC and lighting systems make up more than half of the peak load in large commercial buildings in California. In small commercial building market segments, other end uses such as refrigeration may also contribute largely to the peak load. It is extremely important to understand how much each end use contributes to the total peak load because for any demand reduction to be visible and measurable, reduction has to be outside of the standard deviation of the whole building peak load. Experience in large commercial buildings of various types indicates that reduction has to be between 5 to 10% reduction in peak demand to be visible.

5.2. DR Technology Framework Development for Small Commercial Buildings

For small commercial buildings, three basic models for implementing DR are identified:

1. Shed strategy is implemented completely within the load controllers themselves, i.e. within the lighting or HVAC controls (see Figure 9).

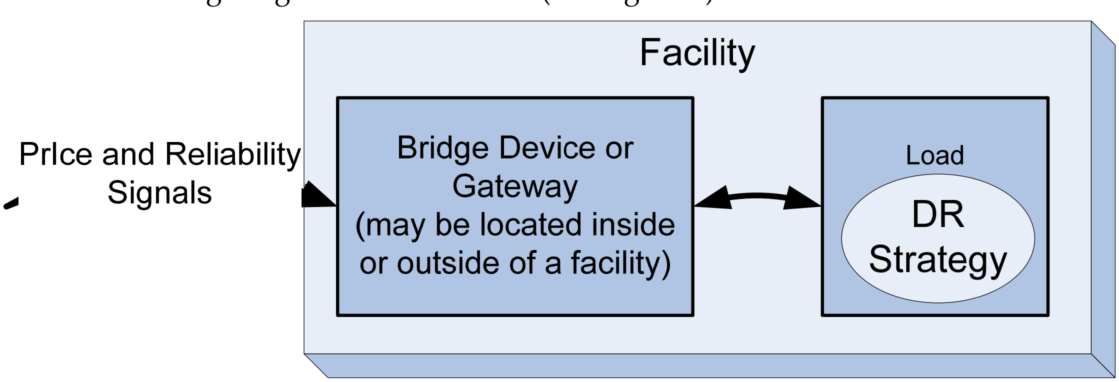


Figure 9. DR Strategy in Load Controller

2. Use of a centralized controller within the facility (EMCS lite) to program and control the shed strategies for the entire facility (see Figure 10).

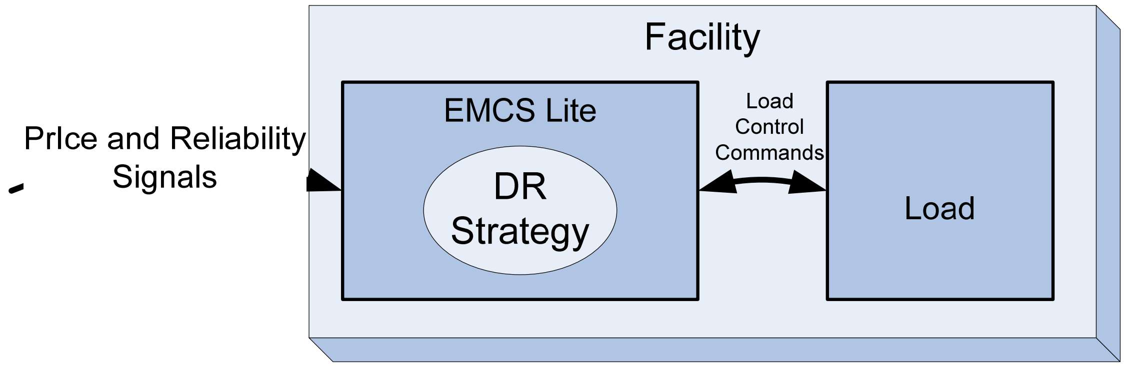


Figure 10. DR Strategy in EMCS

3. Shed strategy is implemented completely outside the facility. This is the model used for direct load control programs by utilities and managing load reductions for customer groups by aggregators (see Figure 11).

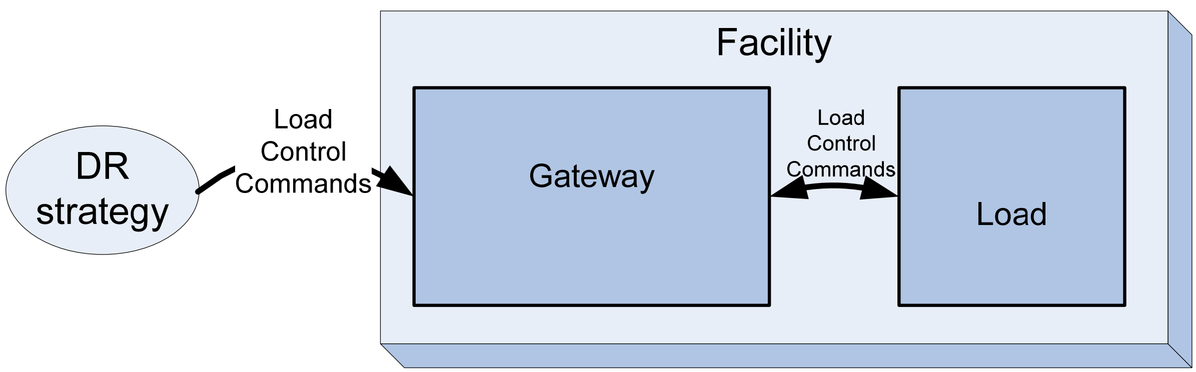


Figure 11. DR Strategy External to the Facility

The difference among the three models is the location where the price signals (DR signals) are converted into DR strategies (controls signals or commands). There are variations in implementation for each of the three models that make up the framework for technology evaluation. This section describes each model, implementation variations and describes the pros and cons of each implementation. At its core, there is a DR automation server that publishes prices and reliability signals. At each facility, there are software or hardware clients that poll the information and bring it into the buildings. There are three types of clients: *smart, simple and bridge*. A *smart client* is any hardware or software client that can take the entire information model, parse and use it to call the necessary programs and strategies to activate DR strategies. A *simple client* is any hardware or software client that listens to a portion of the information model where the information is presented in simpler (or mapped) manner. A *bridge client* translates OpenADR information into device-specific and/or communication-specific information. The bridge client is conceived to be used to send information via broadcast to thermostats and to allow third-party entities (e.g., aggregators) to map information to proprietary networks.

Figures 9, 10 and 11 show that the nature of the signals sent to the facility is related to where the DR strategy is implemented. In cases where the DR strategy is in an EMCS lite device or in the load controllers, a DR signal containing business level information (i.e. prices or shed levels) may be sent to the facility. In the case where the DR strategy is implemented outside of the facility, load control commands are sent. For the purposes of this report, the first two methods are considered equivalent since they both involve the same type of DR signal being sent to the facility.

In the first model (Figure 9), standalone communicating load controllers contain the DR strategy, which is implemented at the facility, and are able to receive OpenADR signals. This method may or may not require a bridge client that requires some level of configuration to distribute messages. If a bridge client is not required, then it requires enough intelligence at the standalone load controllers to accept DR event information from the DRAS. An example of a device that fits in with this framework is a programmable communicating thermostat (PCT). In this model, each load controller has to be pre-programmed. While the DR strategy implemented at the standalone load controllers grant increase granularity of controls, it is difficult if not impossible, to implement system wide shed strategies unless they are centralized. In 2006, Lawrence Berkeley National Laboratory (LBNL) collaborated with two Whole Foods Market stores and installed client logic with integrated relay (CLIR) boxes to control lighting in the buildings. One installation issue was the spacing of loads. When the loads to be controlled are further away from each other, the installation may require more than one client device for each facility thus possibly increasing the cost of implementation.

In the second model (Figure 10), EMCS Lite provides centralization of controls. It is defined as a type of EMCS controller that is designed specifically for the type of loads and logic that are used for DR applications in small commercial buildings. Thus, by definition it should be easy to program and not necessarily rely on a computer to display a user interface and pre-program control strategies. It should also be able to receive standard DR event information such as OpenADR signals. The existence of an EMCS Lite at a small commercial building enables the customer to design and implement shed strategies for their own buildings thus being able to make decisions about the site's control strategies including opting out of an event. Many large commercial buildings are equipped with more sophisticated EMCSs where the EMCS is able to host a smart client to poll DR signals. For the small commercial Auto-DR pilot with Southern California Edison (SCE), LBNL and Akuacom partnered with Advanced Telemetry to experiment with their OpenADR ready EMCS Lite device. Another advantage with partnering with Advanced Telemetry was to work with them to recruit from their customer pool for the pilot project.

For the last model (Figure 11), where the DR strategy is completely implemented outside of the facility, the facility does not receive any price or reliability signals, just control and set point signals. Signal conversion from prices to DR strategies takes place somewhere between when utility sends the price signals and the site receives commands. One way to do this is that *all* site specific DR strategies are implemented in an external server. This requires that the external server have generic device models, a description of inputs and outputs, for each load controller. Depending upon the DR strategy it may require that certain state, or systems status, information from the facility to be fed back into the external server. In the case of retail or fast food chains, a cookie cutter approach may simplify DR strategy implementation and lower the cost of installations. While this model allows for minimum installations at each site, the price paid for such a system is that control of a facility is relinquished to an external server and DR strategy decisions are no longer made at each site and that opting out of an event may be problematic. This is a model closely followed by aggregators participating in DR programs in California. However, instead of using open communications with the end use, they send command and control signals out to the facilities that participate in DR programs.

Table 6 categorizes the products of some of the companies LBNL surveyed into three basic Auto-DR models outlined above. A detailed analysis is presented in Appendix A.

Table 6. Sample of Products That Support Different Models

End Use	EMCS/EMCS Lite	DR Strategy at Load	Remote DR Strategy
HVAC	Advanced Telemetry, Alerton, Automated Logic, Echelon, Green Box, Loytec, Teletrol	Novar, Tendril, Universal Devices, Carrier, Golden Power, Lennox, Lightstat, Proliphix, RCS, White Rogers	Canon, PowerMand, Site Controls
Lighting	Universal, Lumenergi	Adura, Echoflex	Adura

5.2.1. DR Signal Communication Means

For any small commercial facility to participate in automated DR, it needs to receive price and reliability signals over a communication media. For large commercial and industrial facilities that participated in Auto-DR programs in California, their local area network (LAN) or digital subscriber lines (DSL) has been utilized. However, not every small commercial facility may have a LAN or dedicated DSL lines. Therefore, this section outlines other media that may be used to communicate DR signals to small commercial customers and compares the various choices.

In general the following are the desired characteristics of any communications means for the purposes of automated DR.

- Reliable
- Two way
- Secure
- Reasonable latency. This requirement depends upon the type of DR program that is being implemented. For most types of DR keeping the latency less than a minute is adequate, but there may be requirements of seconds if doing DR for the purposes of grid reliability.
- Support for open and widely adopted protocols such as Internet Protocol

- Cost effective to design into automation equipment. This means that the equipment should be cheap enough to keep the overall equipment manufacturing cost down and it should be simple enough to keep the development costs within reason.
- Cost effective to operate. This means that there should not be high operational costs associated with using the communications means.

5.2.2. IP Infrastructures

Communications infrastructures that support Internet Protocol (IP) communications and can utilize the Internet as the main means for communicating are as follows:

- T-Carrier
- Digital Subscriber Lines (DSL)
- Cable Internet
- Integrated Service Digital Network (ISDN)
- Satellite
- Optical Fiber to Building
- WiMAX
- Mobile Cellular
- Broadband Power Line
- Plain Old Telephone Service (POTS)

5.2.2.1. T-carrier

Many buildings have dedicated T-carrier connections. This includes T1 connection which has a 1.544 Mbit/s line rate. T-carrier connections are typically dedicated cables to the facility with a monthly service charge of a few hundred dollars per month. Because of this cost, they are not appropriate for DR only applications in small commercial buildings. If there is an existing T1 connection into a facility, which is highly unlikely in small commercial buildings, it can be leveraged for the purposes of DR. With the advent of faster and cheaper DSL and Cable broadband connections T1 is becoming less prevalent.

Devices receiving DR signals over this medium will typically utilize an Ethernet connection to the facility LAN or T1 router.

5.2.2.2. Digital Subscriber Lines (DSL)

This is a class of broadband service that is offered by the telephone companies. DSL is generally cheaper than a T1 connection and has become a more viable broadband connection. Monthly service charges for business are approximately $50 - $250 depending upon the nature of the service. Since DSL utilizes existing phone lines into the facility it is relatively inexpensive to initiate service. The monthly service charge may be too high to be dedicated to DR, but if there is an existing DSL service it can be utilized for DR.

Devices receiving DR signals over this medium will typically utilize an Ethernet connection to the facility LAN or DSL router.

5.2.2.3. *Cable Internet*

This is a class of service that is offered by the cable television service providers. Cable Internet originated with television service providers and has traditionally been a residential service. Recently it has been growing in popularity among businesses due to its higher throughput and lower cost compared to DSL and T1. Typically Cable Internet has higher installation costs over DSL due to the fact that cables need to be installed. The monthly cost is comparable to DSL and probably would not be appropriate for a dedicated DR communications infrastructure, but if it existed for other purposes, could easily be utilized for DR.

Devices receiving DR signals over this medium will typically utilize an Ethernet connection the facility LAN or Cable Modem/Router.

5.2.2.4. *Integrated Service Digital Network (ISDN)*

This is a data service provided by telephone companies. Although it still exists, in general this is an obsolete means of communications and has been replaced by DSL services. Devices receiving DR signals over this medium would typically use Ethernet connect to an ISDN router.

5.2.2.5. *Satellite Internet*

This is a form of broadband connection in which the downstream connectivity is via a satellite transmission and the upstream is typically via terrestrial land line such as a simple phone connection. This is typically used in residential applications where it is either difficult to get DSL or cable service. In some cases it is used where the customers already have existing satellite television service. This type of connection is rarely used in businesses and would not be appropriate for a dedicated DR communications channel due to its relatively high cost.

Devices receiving DR signals over this medium would typically use Ethernet connect to a router.

5.2.2.6. *Optical Fiber to Building*

Optical fiber communications are an integral part of the backbone of most communications networks in use today. This is due to its high bandwidth and cost effectiveness in terms of the amount of data that can be transferred compared to the cost of the infrastructure. This section specifically addresses the use case where fiber is run to the building itself as opposed to just being part of the backbone.

The market penetration of optical fiber to the building is small and varies widely by country. Most analysts agree that it represents the future of data connection to the building due to its high bandwidth capabilities. There are businesses today that have fiber installed and this number will increase over time. Due to the relatively high cost of installing fiber this would not be an appropriate means of communication dedicated to DR, but if it did exist it could easily be used for DR applications.

Devices receiving DR signals over this medium would typically use Ethernet to connect to a router.

5.2.2.7. *Worldwide Inter-operability for Microwave Access (WiMAX)*

WiMAX is a wireless technology that is quickly gaining acceptance for data communications.

Since it is a wireless network, the cost of building out the infrastructure is relatively low. In addition the wireless service providers view this as a means to compete with DSL and Cable broadband providers. The current market penetration of WiMAX is still relatively low, but increasing fast. The monthly service charges for WiMAX are comparable to DSL and Cable and as such means that it probably is not appropriate to be dedicated for DR, but if it already exists in the facility it can easily be shared for DR applications.

Devices receiving DR signals over this medium would typically use Ethernet connect to a router, but if the prices of WiMAX continue to drop and approach the levels of WiFi it may be possible to embed the WiMAX network interface directly in the device.

5.2.2.8. *Mobile Communications (Cellular)*

Mobile communications covers a wide range of technologies, networks, protocols and service providers. Although the technologies primarily exist to support wireless voice services they have evolved over the years to also support mobile wireless data services as well. Table 7 summarizes a wide range of communication means for DR.

Cellular mobile communications are not appropriate and rarely used to bridge LANs within buildings to the Internet. They are typically used to provide connectivity to specific devices such as cell phones and other handheld devices. Therefore, if a DR device were to use these technologies, the connections would most likely be dedicated to the device. This means that all the deployment and monthly costs will be dedicated entirely to DR. In addition, embedding cellular technology into a device is somewhat more costly and difficult than other communications interfaces. For these reasons cellular wireless is not an appropriate means of communications for DR.

5.2.2.9. *Broadband over Power Lines (BPL)*

Broadband over Power Lines is a service that utilizes existing power lines to offer communications services.

Electrical power is transmitted over high voltage transmission lines, distributed over medium voltage, and used inside buildings at lower voltages. Power line communications can be applied at each stage. Most PLC technologies limit themselves to one set of wires (for example, premises wiring), but some can cross between two levels (for example, both the distribution network and premises wiring).

BPL services have met with some resistance due to concerns about interference with existing wireless systems and are not widely offered today. Nonetheless, it is a service that offers some promise for providing the communications infrastructure for AMI systems.

Devices receiving DR signals over this medium would typically use Ethernet to connect to a router.

5.2.2.10. *Plain Old Telephone Service (POTS)*

POTS refers to the existing land line based telephone network. Although wireless voice services are starting to supplant POTS, it still remains the most widely available communications network in existence. Because of its widespread deployment and relatively inexpensive cost, POTS remains a potential candidate for providing communications for purposes of DR. The main problem with POTS is that it is not an always on connection and therefore, the DR signals can not be polled from the DR signal server. This means that the DR signal must be pushed to the facility, thus requiring a dedicated POTS line. This will increase the costs of using POTS since there will be a monthly service cost associated with any POTS service. These charges can be relatively low, but they may still be too much for a DR program for small commercial buildings.

DR devices that utilize POTS will most likely have an analog modem embedded in the device. This is a relatively low cost and mature technology.

5.2.3. Radio Frequency (RF) Broadcast

This section describes a number of RF based infrastructures that are not IP based, but may be used for the purposes of DR signaling.

5.2.3.1. *Pager Networks*

Paging networks are relatively inexpensive and easy to deploy. Some pager networks are two way while others are only one way.

There has been some use of pager networks for DR programs, especially for those that are doing some type of direct load control as in the case of base interruptible programs. In general pager networks suffer from the following drawbacks:

Most pager networks only support one way communications they are not appropriate if it is necessary to receive some sort of feedback from the facility. The amount of information that may be transmitted via the paging network is somewhat limited. Due to latencies in the network it may not be reasonable to send individual messages to a large number of DR participants. Some sort of broadcasting mechanism will have to be employed. The latency of receiving messages in a pager network can be somewhat high. There may be monthly service charges associated with the network if it is provided by a third party service provider.

DR devices that will receive DR signals via the Pager network will most likely embed the RF interface to the pager network directly into the device. This is relatively inexpensive.

5.2.3.2. *Datacasting*

Datacasting is a generic term that refers to the broadcasting of data using RF and typically refers to using existing broadcast channels such as TV or FM radio. Datacasting networks that utilize FM radio broadcasts are more commonly used for a wide range of applications that can benefit from low bandwidth one way communications. This section further discusses two such Datacasting networks – RDS and Directband.

5.2.3.3. *Radio Data System (RDS)*

RDS is a type of datacast network that utilizes existing FM broadcast channels for communications. It is used for a wide range of applications such as radio programming, traffic, advertising, weather, etc., where low bandwidth, small messages can be broadcast to a wide range of devices. RDS holds promise as a communications means for DR signals because it utilizes existing FM broadcast infrastructure and is low cost to embed into devices. It is one of the proposed communications means in the California Programmable Communicating Thermostat initiative. RDS has the following drawbacks:

RDS only supports one way communications and is not appropriate if it is necessary to receive some sort of feedback from the facility. The amount of information that may be transmitted via RDS is somewhat limited. It is not feasible to target individual facilities with RDS broadcast messages and therefore DR signals must be sent in a broadcast fashion to a large number of facilities.

DR devices that will receive DR signals via the RDS will embed the RDS RF interface directly into the device. This can be done at a low cost.

5.2.3.4. *DirectBand*

DirectBand is a North American wireless datacast network owned and operated by Microsoft. It uses FM radio broadcasts in over 100 cities to constantly transmit data to a variety of devices, including portable GPS devices, wristwatches and home weather stations.

DirectBand is similar to RDS in terms of its functionality and as such has similar advantages and disadvantages with the exception that it is proprietary to Microsoft.

Below is a summary of each means of communication described in this section.

Table 7. Summary of Communication Means for DR

Type	Must be dedicated to DR devices	Two Way	Installation costs	Monthly costs	Costs to implement in devices
T-carrier	No	Yes	High if dedicated	High if dedicated	Low (Ethernet)
DSL	No	Yes	Medium if dedicated	Medium if dedicated	Low (Ethernet)
Cable	No	Yes	Medium if dedicated	Medium if dedicated	Low (Ethernet)
ISDN	No	Yes	Medium if dedicated	Medium if dedicated	Low (Ethernet)
Fiber	No	Yes	High if dedicated	High if dedicated	Low (Ethernet)
Satellite	No	Maybe	High if dedicated	Medium if dedicated	Low (Ethernet)
WiMax	No	Yes	Medium if dedicated	Medium if dedicated	Low (Ethernet)
Mobile	Yes	Yes	Low	Medium	High
POTS	No	Yes	Low	Medium	Low if not dedicated
BPL	No	Yes	Medium if dedicated	Medium if dedicated	Low (Ethernet)
Paging	Yes	Both	Low	Medium	Medium
RDS	Yes	No	None	None	Low
Direct Band	Yes	No	None	None	Low

5.3. Small Commercial Customer Aggregation

In order to understand some of the small commercial customer demand reduction measurement issues, we partnered with SF Community Power to analyze their portfolios' participation in the capacity bidding program with PG&E in 2007. The goal of the study was to:

- understand the DR performance of SF Power's Capacity Bidding Program (CBP) participation in 2007,
- investigate issues related to baseline
- examine DR strategies related to each individual building, and
- improve the DR performance of the sites.

Appendix B includes the detailed analysis of the data which does not include DR strategies and performance improvements as SF Community Power did not collect DR strategy data from the participants and LBNL did not have access to the sites. However, a site questionnaire was jointly developed to collect information on the sites, DR strategies and automation opportunities Appendix C

SF Power is an aggregator of 26 facilities with 41 service account IDs (SAID) on PG&E's Capacity Bidding Program (CBP) in 2007. CBP is a voluntary DR program that offers aggregators and customers capacity payments and demand reduction incentives for reducing energy consumption when requested by PG&E. The program season for CBP is May 1 through October 31 and the events are called between 11 a.m. to 7 p.m. CBP provides participants day-ahead and day-of options and three products which are 1-4 hour, 2-6 hour and 4-8 hour.
SF Power has three portfolios which participate in five CBP DR events in 2007 at different times and durations based on their contracts. In this section, we discuss the evaluation of five large facilities by characterizing their loads by their weather sensitivity and load variability. Also, we calculate three different baselines to quantify their manual participation in to the CBP portfolios.

Rank order correlation (ROC) calculation results, which correlate hourly weather and demand for each facilities, and variability (VAR) calculation results, which quantify load variability of facilities, are presented in Table 8. For ROCs higher than 0.7, the facilities are marked highly weather sensitive. For VARs higher than 0.15, the facilities are marked highly variable (Coughlin 2008). For both calculations, the hourly results are averaged over noon to 8 pm period.

Table 8. Weather Sensitivity and Load Variability of the Five Facilities

Site	ROC	Weather Sensitivity	VAR	Load Variability
Site A	0.007	Low	0.157	High
Site B	0.219	Low	0.080	Low
Site C	0.495	Low	0.131	Low
Site D	0.513	Low	0.151	High
Site E	0.753	High	0.177	High

Three baseline methods used to measure demand reduction are outlined in Appendix D. For weather sensitive facilities with low load variability, outside air temperature regression baseline with morning adjustment (OAT with MA) is recommended. For highly variable loads, none of the baselines predict demand for DR events with high accuracy. Table 9 displays the average, minimum and maximum shed amounts for each of the facilities for all of the CBP days they participated using the three baseline methods. A positive number indicates reduction and a negative number indicates and increase in demand as compared with the baseline. Unfortunately, no DR strategy information is available as it was not being collected from the participating sites.

Table 9. Evaluation of the DR Sheds for the Five Facilities Using Three Baseline Methods

	Ave. with 3/10		Ave. with 3/10 with MA		Ave. with OAT with MA	
	kW	%	kW	%	kW	%
Site A	12	2%	2	0%	-16	-2%
Site B	23	6%	6	2%	7	2%
Site C	13	6%	6	3%	-3	-1%
Site D	-30	-2%	1	0%	-16	-1%
Site E	25	4%	11	2%	34	5%

The results of the analysis are summarized below:

- *Weather sensitivity and load variability calculations are necessary in predicting loads.* While baselines with morning adjustment work better for weather sensitive buildings, load variability in buildings effect how much load reduction is available from facilities. Baseline models do not work well for facilities with highly variable loads.
- *Information on DR strategies is important.* Information about DR strategies and technologies at these facilities is limited. In order to understand demand reduction opportunities, we need to collect information on the strategies and EMCS operations. Traditionally, Auto-DR participants have been reducing whole building power by 10-15%, which is higher than the average demand reduction from the five facilities.

5.4. Field Tests

5.4.1. Recruitment

Site selection criteria were developed by LBNL to assist SCE in their recruitment (Appendix F). Despite SCE's efforts, only two Taco Bell sites, located in San Juan Capistrano and Hesperia, were recruited into the pilot program. Both sites were brought into the pilot by Advanced Telemetry building on their existing relationship with this customer. LBNL visited San Juan Capistrano site and conducted an interview with Advance Telemetry's director of field operations. The results of the interview yielded the following:

- *Both buildings are comparable.* LBNL requested that the pilots sites fit two main criteria: 1) matching in size and 2) different climates. San Juan Capistrano and Hesperia sites are 2,200 ft^2 and 2,150 ft^2, respectively. While San Juan Capistrano site is fourteen years old, Hesperia site is only 2 years old.
- *The HVAC equipment is undersized*. In the San Juan Capistrano site, the set points for dining room and kitchen area are 74ºF and 76ºF, respectively. On really hot days, the HVAC system can not keep these temperatures. This information was not available from the Hesperia site prior to the tests.
- *Lighting will not be included in DR strategies.* Initial calculations showed that only about 2.5 kW of the peak 40 kW in the San Juan Capistrano store is due to lighting. A lighting shed of 1 kW, which is more than one third of the site, would not be visible in the whole building profile. This information convinced the team not to go through with lighting sheds.
- *Trend logs are available to confirm automated events take place.* Advanced Telemetry system logs readings from two sensors, located in the kitchen and dining room areas, and space temperature setpoints. In addition, the system has real-time power monitoring capability used to iterate DR strategies to achieve the required shed levels.

Noting the above mentioned issues, in the absence of other candidates for the pilot, Advanced Telemetry installed an updated system that communicates with the DR automation server using the OpenADR standard communication infrastructure. The overall architecture is displayed in Figure 2.

Table 10 displays the results from weather sensitivity and load variability calculations for the two filed test sites. While both sites are not weather sensitive, San Juan Capistrano has variable loads during the DR event periods.

Table 10. Weather Sensitivity and Load Variability of the Field Tested Sites

Site	Weather Sensitivity		Load Variability	
San Juan Capistrano	Low	0.34	High	0.18
Hesperia	Low	0.56	Low	0.12

5.4.2. Automated DR Events

Installation of the OpenADR enabling technologies and initial communications tests were completed in mid October. A total of six events were called and each event lasted for two hours. The first two events were communications and control test events where bugs in the system were identified and resolved. Table 11 summarizes the test events and DR strategies at each site for each event. October 16th and 17th were the communications and controls test events and the rest were actual test events. The first test event, which was planned for two hours, had to be stopped at one hour and fifteen minutes into the event because there were complaints from the sites that the space was too hot. Although the setpoint was adjusted to 78ºF, the indoor temperature had reached 79ºF at the time of the complaints. Therefore, the upper limit for temperature setpoint was determined to be 77ºF for the remaining events. The tests were repeated the following day with pre-cooling each site one hour before the event. San Juan Capistrano site's setpoint was adjusted 4ºF while Hesperia site's setpoint was adjusted 2ºF during the two hour test period. Results and all the load profiles from all the events are reported in Appendix E.

Table 11. Summary of Test Events and DR Strategies

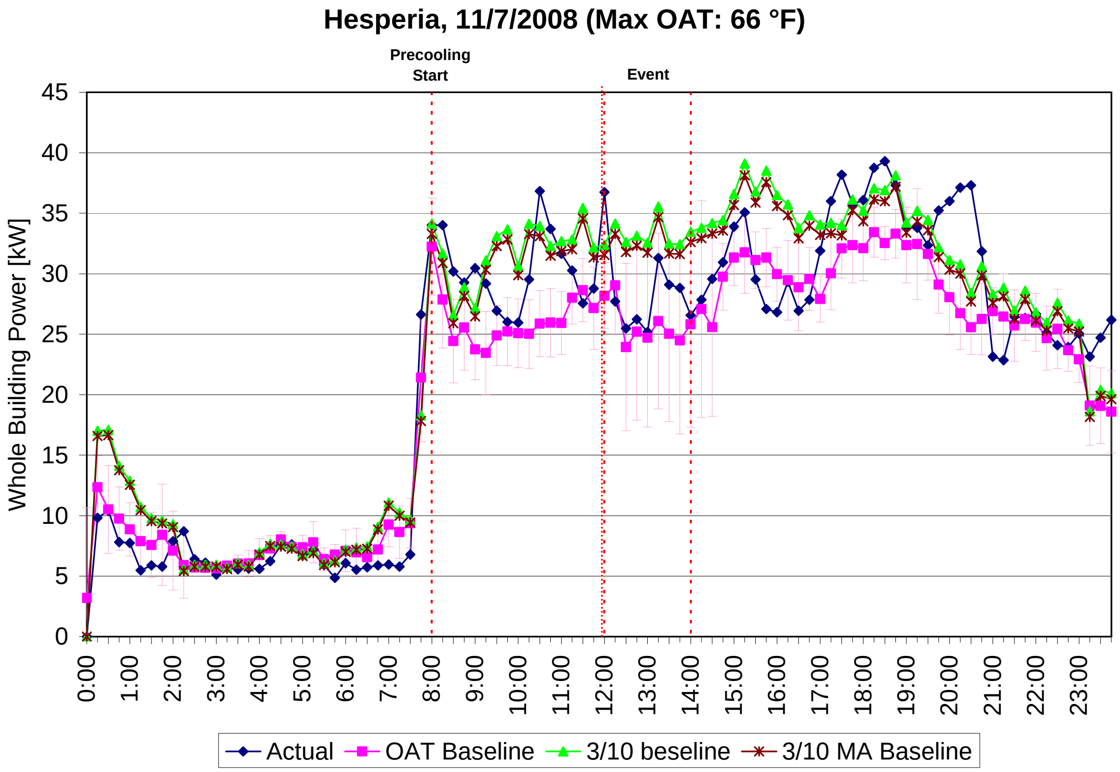
Site	Test Date	Precooling	Start time	End Time	DR strategy
San Juan Capistrano	10/16/2008	1-2pm	2pm	3:15pm	Pre-cool at 72Deg starting at 1 pm and set up temp . 76F from 2-2:50, 77F from 2:50-3, 78F from 3-3:15, event canceled at 3:15
Hesperia	10/16/2008	No	2pm	3:15pm	76F from 2-2:50, 77F from 2:50-3, 78F from 3-3:15, event canceld at 3:15
San Juan Capistrano	10/17/2008	1-2 pm	2pm	4pm	Pre-cool starting at 1 pm and set up temp at 70Deg. 1-74, 2-75, 3-76, 4-77
Hesperia	10/17/2008	1-2 pm	2pm	4pm	precool starting at 1 pm and set up temp at 70Deg 1-76, 2-76, 3-77, 4-77
San Juan Capistrano	10/22/2008	2-3pm	3pm	5pm	Pre-cool at 70F starting at 2pm. 3-5pm 10% Shed from 3/10 MA baseline
Hesperia	10/22/2008	2-3pm	3pm	5pm	Pre-cool at 70F starting at 2pm. 3-5pm 10% Shed from 3/10 MA baseline
San Juan Capistrano	10/24/2008	11am-noon	noon	2pm	Pre-cool at 70F starting at 11am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	10/24/2008	11am-noon	noon	2pm	Pre-cool at 70F starting at 11am. Noon to 2pm, 10% Shed from 3/10 baseline
San Juan Capistrano	11/7/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	11/7/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	11/14/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 19% Shed from 3/10 baseline

After the initial controls and communication tests, four DR events were dispatched as summarized above. The first test took place on October 22, from 3 pm to 5 pm, with an hour long pre-cooling at 70ºF followed by a request to shed 10% from the 3/10 with morning adjustment baseline. With only one hour of pre-cooling, of the four zones in two facilities, only one zone reached the setpoint target before the event started (Table 12). Therefore, one-hour pre-cooling is proven to be too short for these sites. For the next event, the event period is moved to noon to 2 pm with one hour pre-cooling starting at 11am and with a request to shed 10%. Because the pre-cooling period was now within the morning adjustment period, 3/10 baseline was used for percent load reduction calculations. October 24th was the warmest day the tests were conducted. While San Juan Capistrano site still could not reach the pre-cooling target temperature, Hesperia kitchen and dining zones reached 72ºF and 71ºF, respectively. For the next two events, pre-cooling period was extended to bring down the temperatures in all of the zones. DRLAT, a building simulation tool was used to refine the strategy. While, extending pre-cooling period did not have an effect on the kitchen zones, temperature in San Juan Capistrano's dining area was reduced to 72ºF. The system over achieved its goal in Hesperia on November 7th because impact of a strategy is only visible after 15 minutes when the meter collects and sends these data back into the server. On November 14th, Hesperia site was the only site tested because of the thermostat problems in San Juan Capistrano. Thermostat manufacturer had to be contacted after the Advanced Telemetry system identified that there was a problem with the thermostat.

Table 12. Summary of Sheds and Indoor Conditions During DR Events

Site	Date	Baseline	Shed requested	Shed achieved	Pre-cool Kitchen Temp (DegF)	Precool Dining Temp (DegF)	Max Kitchen Temp (DegF)	Max Dining Temp (DegF)	Max OAT (DegF)
SJC	22-Oct	3/10_MA	10%	8%	75	74	80	78	78
SJC	24-Oct	3/10	10%	7%	74	74	79	78	100
SJC	7-Nov	3/10	10%	7%	76	72	79	78	79
Hesperia	22-Oct	3/10_MA	10%	13%	73	70	78	78	78
Hesperia	24-Oct	3/10	10%	11%	72	71	78	77	82
Hesperia	7-Nov	3/10	10%	17%	75	70	80	77	66
Hesperia	14-Nov	3/10	19%	18%	74	71	77	78	70

Outside air temperatures for each facility were collected by a logger installed in a shaded area right outside of the facility. The data collected from the logger at San Juan Capistrano does not match the archived weather data that was available on the Internet for the first two test days, 92 DegF and 85 DegF, respectively. The weather data for the third test date was not available on-line.



Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Nov-07	3/10	12:00-2:00	7	6	3.43	2.68	23%	17%
	3/10 MA		7	5	3.06	2.29	21%	15%
	OAT		1	-2	0.62	-0.94	5%	-8%

Figure 12. Load Profile for Hesperia Site on November 7, 2008

Figure 12 displays the demand profile of the Hesperia site on November 7th. All three baselines are calculated and displayed with the actual whole building demand. There is a large variation between the 3/10 baselines and OAT temperature baseline. If the OAT baseline were chosen to base the demand reduction on that day, the building might not have reached its target. Also, demand profile of the site matches with its schedule where the dining room closes at 10 pm and the kitchen continues to serve customers until 1 am. While dining area loads are driven with occupancy and tend to fluctuate, kitchen loads are driven by internal cooking, heating and refrigeration loads.

Additional analysis, using the data collected after the end of the event period, showed that both facilities are not weather sensitive and their loads are not variable. This additional information confirms that 3/10 baseline is an appropriate baseline for these facilities.

The results of the field tests are summarized below:

- *Requesting and receiving demand reduction as a percentage of whole building demand from a pre-specified baseline is feasible.* The field tests show that requesting a percentage reduction from the whole building peak demand can be achieved. However, it depends on understanding 1) which baseline to use; 2) where the reductions come from; and 3) limit of shed including how deep and how long.

- *Demand reduction in undersized systems is difficult.* Increasing temperature setpoints to reduce demand from compressors and fans does not yield savings if the systems are still running at their maximum capacity to maintain the new setpoints. In the field tests, extending the pre-cooling period seems to help in reducing space temperatures to the target setpoint levels.
- *Total cost of the system (two wireless thermostats, two wireless sensors and a control panel) including its development and installation is $3,345.* With an average of 3-4W of reduction for each site, the demonstration cost for kW is between $1,115 and $835. Note that these are demonstration unit costs and costs are expected to be lower for commercial products produced in higher quantities.
- *Pre-cooling for a longer period of time for these two facilities is more effective*. The goal of pre-cooling is to cool the mass in buildings so as to use this thermal capacity when the temperature setpoints are increased. While one-hour pre-cooling only cools the air (and even that not effectively), the extended pre-cooling period cools the exposed masses and yields more sustainable demand reduction.

6.0 Discussion and Conclusions

This report has discussed the research efforts by the Demand Response Research Center (DRRC) to characterize small commercial buildings in California, to develop a framework for automated DR technologies for this customer group and described building related issues. It has also described the collaboration between DRRC, Southern California Edison (SCE), Akuacom and Advance Telemetry for the field studies where DR sheds were requested as a percentage of total buildings' peak demand.

Small commercial buildings make up 20 to 25 percent of peak electric demand in California. Small offices, restaurants and retail buildings are the major contributors making up over one third of the small commercial peak demand. A ten percent reduction in only these three types of buildings can yield up to 0.5 to 0.7 percent of peak demand in California. However, there are several barriers to small commercial buildings' participation into automated DR programs:

1. Small buildings are generally not equipped with centralized energy management and control systems (EMCS). Furthermore, they lack on-site personnel and metering infrastructure to measure their demand and set up strategies for DR.
2. They have a wider variety of ownership models, energy management and related professional services. Very small commercial buildings are being operated like residential buildings where the owner, with limited information such as a utility bill, has to make decisions, and medium sized small commercial buildings are being operated more like their large counterparts.
3. They have more varied and limited use of the Internet.

The goal of the characterization (Section 5.1) of small commercial buildings is to identify opportunities and low hanging fruit for this customer group. Small offices, restaurants and retail buildings are the major contributors making up over one third of the small commercial peak demand. Majority of the small commercial buildings are located in southern inland areas and central valley. Single zone packaged units with manual and programmable thermostat controls make up the majority of heating ventilation and air conditioning (HVAC) systems in this group of customers. Fluorescent tubes with magnetic ballast and manual controls dominate this customer group's lighting systems.

The framework development is presented in section 5.2 as a reference to small commercial building owners to evaluate their investment in various OpenADR enabling technologies. The small commercial building owner can use this framework to identify which method would work for his/her building and look for products that accommodate the selected method. Information on various DR signal communication means is provided to assist small commercial building owners to select appropriate communication means for their DR automation.

We worked with an aggregator and compiled data from five larger sites that participated in DR events in 2007 either manually or semi-automatically. The aggregator notifies the customers that a DR event is issued but has no information on the DR strategies or real-time meter data and is provided information on the portfolio's performance weeks after the events are dispatched. The deployment of advance metering infrastructure (AMI) will largely solve the existing information related issues. Meter data, when available, should be used to calculate load variability and weather sensitivity of buildings to better assess the DR potential in small commercial buildings.

Finally, feasibility of using OpenADR to request demand reductions as a percentage of total predicted demand was demonstrated with field tests in two quick service restaurants. The method to predict demand should be carefully chosen as there is no one baseline method that predicts peak demand for all facilities accurately. Building characteristics and building systems issues, such as design and controls, have to be considered when estimating how much and when demand reduction is available at each facility.

Summary of conclusions is as follows:

- There are control technologies and communication means that enable OpenADR. Therefore lack of technology is not the barrier but lack of awareness of options and cost for the small commercial buildings are barriers.
- Opportunities for reducing peak load in small commercial facilities are;
    - Small commercial buildings with interval meters – need a way to measure what is being reduced.
    - Single owner with multiple small commercial buildings provide one entry point to many buildings. Restaurant and retail chains are good examples.
    - Global Temperature Adjustment (GTA) which is a DR strategy widely used in large commercial buildings, is also a good DR strategy for small commercial buildings.
    - Lighting is an end use that has potential and buildings with bi-level switching are good candidates.
- Small commercial buildings with more than one zone for lighting and HVAC require centralization of their systems unless the DR strategy is located in the load controllers. In the absence of centralized systems, the number of clients connected to the server will increase drastically possibly introducing scalability issues to the two-way communication (with meter feedback) requirements.

As a next step of this project, we propose the following:

- Developing tools for small building owners to better understand their buildings' loads and to better manage them.
- Continue field studies to characterize ownership, management and operational issues; to identify opportunities in small office, restaurants and retail facilities; to consider the feasibility of using AMI infrastructure to deliver OpenADR signals to small commercial

buildings; to consider lighting as a potential end use for OpenADR; and to understand price point requirements.

- A guide to small buildings owners to enable automation of DR.

7.0 References

CPUC FAQ
http://www.cpuc.ca.gov/cfaqs/howhighiscaliforniaselectricitydemandandwheredoesthepowercomefrom.htm

Motegi, N., M.A. Piette, D.Watson, S., Kiliccote, P. Xu,. Introduction to Commercial Building Control Strategies and Techniques for Demand Response. LBNL Report 59975. May 2007. Available at drrc.lbl.gov.

Piette, M.A., O. Sezgen, D.S. Watson, N. Motegi, and C. Shockman. 2005a. Development and Evaluation of Fully Automated Demand Response in Large Facilities. Lawrence Berkeley National Laboratory CEC-500-2005-013. LBNL-55085. Berkeley CA, January.

Piette, M.A., D.S. Watson, N. Motegi, N. Bourassa, and C. Shockman. 2005b. Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities. Lawrence Berkeley National Laboratory. CEC-500-03-026. LBNL-58178. Berkeley CA, September. Available at drrc.lbl.gov.

Piette, M. A., D. Watson, N. Motegi, S. Kiliccote, P. Xu (Lawrence Berkeley National Laboratory). Automated Critical Peak Pricing Field Tests: Program Description and Results. Report to the Pacific Gas and Electric Company Emerging Technologies Program and California Institute for Energy and the Environment. LBNL-59351. April 2006.

Itron. California Commercial End-Use Survey. Consultant Report to California Energy Commission. CEC 400-2006-005. March 2006

Koch, E., Piette, M.A., Scenarios for Consuming Standardized Automated Demand Response Signals. Presented at the Grid Interop Forum, Atlanta, GA, November 11-13, 2008.

Lockheed Martin Aspen. Demand Response Enabling Technologies for Small-Medium Businesses – A technical report prepared in conjunction with the 2005 California Statewide Pricing Pilot. April 12, 2006

Piette, M.A., G. Ghatikar, S. Kiliccote, E. Koch, D. Hennage, and P. Palensky. Open Automated Demand Response Communication Standards: Public Review Draft 2008-R1. LBNL number forthcoming. May 2008.

Hotchi, T., AT. Hodgson and W.J. Fisk. Indoor Air Quality Impacts of a Peak Load Shedding Strategy for a Large Retail Building. Lawrence Berkeley National Laboratory. DRRC Report. LBNL-59293. January 2006

Rubinstein, F.M., and S. Kiliccote. Demand Responsive Lighting: A Scoping Study. Lawrence Berkeley National Laboratory. DRRC Report. LBNL-62226. January 2007

Coughlin, K., M. A. Piette, C. Goldman and S. Kiliccote. Estimating Demand Response Load Impacts: Evaluation of Baseline Load Models for Non-Residential Building in California. Demand Response Research Center, Lawrence Berkeley National Laboratory. LBNL-63728. January 2008.

Piette, M.A., D.Watson, N. Motegi, and S., Kiliccote. Automated Critical Peak Pricing Field Tests: 2006 Pilot Program Description and Results. LBNL Report 62218. May 2007.

Piette, M.A., S., Kiliccote and G., Ghatikar. Design and Implementation of an Open, Interoperable Automated Demand Response Infrastructure. Grid Interop Forum. November 2007.

ANSI/ASHRAE Standard 135-2004 – BACnet® – A Data Communication Protocol for Building Automation and Control Networks. Atlanta, Georgia. 2004.

Title 24 - California's Energy Efficiency Standards for Residential and Non-residential Buildings. (CEC-40002005-006-CMF) April 1, 2005.

8.0 Glossary

CLIR	Client and Logic with Integrated Relay
DNS	Domain Name Server
DR	Demand Response
DRAS	Demand Response Automation Server
DRRC	Demand Response Research Center
EMCS	Energy Management and Control Systems
EPRI	Electric Power Research Institute
HVAC	Heating, Ventilation and Air Conditioning
LBNL	Lawrence Berkley National Laboratory
NIST	National Institute of Standards and Technologies
OAT	Outside Air Temperature
OpenADR	Open, Non-Proprietary Automated Demand Response
PG&E	Pacific Gas and Electric Company
POTS	Plain Old Telephone Systems
ROC	Rank Order Correlation
SCE	Southern California Edison
SDG&E	San Diego Gas and Electric Company
SOA	Service Oriented Architecture
SSL	Secure Socket Layer
TA/TI	Technical Audit /Technology Incentives
VPN	Virtual Private Network
XML	eXtensible Mark-up Language

Appendix A: Technology Review

1.0 Load Controls for Small Commercial Applications

The following gives a breakdown of a variety of existing products that may be appropriate for small commercial DR. Each product is categorized by the following:

- Centralized Gateways/Controllers – these are devices that can be used to act as a centralized EMCS system in the facility or to bridge communications with other devices in the facility.
- HVAC – these are controllers that are used to control HVAC systems and include thermostats.
- Lighting – these are controllers that may be used to control lighting.
- Miscellaneous – these are controller that may be used to control a variety of miscellaneous loads.

For each product the following set of information is given

Model	The name or model number of the product
Vendor	The vendor of the product
Load Type	The type of load being controlled, i.e. HVAC, lighting, etc.
Type of control	The type of control being applied to the load
Feedback/Status	Whether the product is capable of providing feedback or status of the load it is controlling
References	A reference to more information
Availability	The availability of the product
Cost	The approximate cost of the product
Comms Interfaces	The communications interfaces on the product
Standards	Any standards that the product supports
Integrate with local EMCS	Whether the product can be integrated or used with a local EMCS system
Communicate to remote servers	Whether the product can communicate with remote servers to receive DR related information or commands. In some cases this amounts to direct load control and in others the DR signal may be business level logic (i.e. prices or shed levels) and not load control commands.

Implement Shed Logic	Whether the product can implement some form of shed logic itself.
User Programmability	Whether there is a means to support programmability by a user to respond to DR signals
Notes	General comments and notes

1.1. Gateways/Controllers

Within the facility a there may exist a centralized controller or gateway that may be used for the following:

- Receive DR Signals from Utility/ISO
- Implement the shed logic necessary to translate information in the DR Signals to load control commands
- Interface to the load controllers within the facility and send them commands
- Provide a centralized location for the facility managers to program their shed logic

Advanced Telemetry

Model	EcoView
Vendor	Advanced Telemetry
Load Type	HVAC and Lighting
Type of control	EMCS
Feedback/Status	Yes, both usage and device status
References	http://www.advancedtelemetry.com/
Availability	In production
Cost	$1000 - $1500 for typical system
Comms Interfaces	Ethernet, Z-wave, Zigbee
Standards	OpenADR
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes, via web site
Notes	The Advanced Telemetry panel allows the system to both perform energy management and DR functions. System supports centralized and remote control of HVAC (via communicating PCT), whole facility metering and lighting control. Currently involved in pilot projects in CA and support OpenADR standard.

Alerton

This product is probably not appropriate for small commercial

Model	BCMweb
Vendor	Syserco
Load Type	HVAC
Type of control	EMCS
Feedback/Status	No
References	http://www.alerton.com/
Availability	Available
Cost	Depends on the system
Comms Interfaces	Ethernet, BACnet
Standards	BACnet (Alerton BACtalk)
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes
Notes	This system is used in schools with distributed loads. The system does offer wireless communication both for controllers and Internet communications.

Automated Logic

Model	ME and SE Line
Vendor	ALC
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.automatedlogic.com/
Availability	In production
Cost	
Comms Interfaces	Depends on model, Ethernet, EIA-485, ARCNET, MS/TP
Standards	BACnet
Integrate with local EMCS	Yes
Communicate with	Yes, sometimes via a router or gateway provided by ALC

remote servers	
Implement Shed Logic	Yes
User Programmability	Yes, including graphical tools for programming logic
Notes	ALC has a number of controllers that may be appropriate for small commercial applications in their SE, ME and ZN lines. The controllers are programmable and can be used to interface to a wide range of different types of equipment. The ALC equipment can be used to put together a complete solution that includes both HVAC and lighting control.

Cannon (COOPER) Power Systems)

Cannon & Honeywell together for smart thermostat.

Cannon has virtual EMS system - http://www.cannontech.com/products/drvirtualems.asp

Cannon has software suite for supporting DR - http://www.cannontech.com/products/softwareapplications.asp

Model	Load Response Center
Vendor	Cannon
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.cannontech.com/products/drvirtualems.asp http://www.cannontech.com/products/softwareapplications.asp
Availability	In use by many utilities
Cost	
Comms Interfaces	Ethernet
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes, but logic is implemented remotely
User Programmability	Yes, but logic is implemented remotely
Notes	A software suite specifically targeted towards DR that is intended to be used with 3rd party vendors such as Honeywell. Mostly a remote web based application that is

	deployed by the Utilities. Shed logic is implemented on the server side and can be used for both DLC and user programmability.

Echelon

Model	iLON smartserver
Vendor	Echelon
Load Type	EMCS
Type of control	Act as EMCS with a wide variety of LonWorks based devices
Feedback/Status	yes
References	http://www.echelon.com/products/cis/smartserver/default.htm
Availability	In production
Cost	
Comms Interface	LonWorks, ethernet
Standards	EIA 709.X
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Local Shed Logic	Yes
User Programmability	Yes
Notes	Programmable gateway/controller that can be used for LonWorks networks. Supports interfacing to a wide range of LonWorks based devices and load controllers. Can be user programmed for a variety of functions. Have demonstrated compatibility with OpenADR.

Green Box

Unclear what equipment they interface with in the facilities, but seem to support Zigbee.

Model	Greenbox
Vendor	Greenbox
Load Type	EMCS programming front end
Type of control	Programming front end, and web based display of facility state
Feedback/Status	Yes
References	http://www.getgreenbox.com/

	http://www.getgreenbox.com/company/for-utilities/
Availability	In trials
Cost	
Comms Interfaces	IP based SW suite
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes as a programming front end
User Programmability	Yes
Notes	Web based software suite that is targeted towards residential. It is primarily targeted towards providing a GUI that allows customers to view their energy usage, but may be used as a programming front end for programming thermostats for DR applications.

Loytec

Model	LINX-110
Vendor	Loytec
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.loytec.com/index.php?option=com_content&task=view&id=43&Itemid=17
Availability	In production
Cost	
Comms Interfaces	LonWorks, Ethernet, modbus, BACnet
Standards	EIA 709.X, 852, IEC 61131-3, EN14908, RS232
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes
Notes	A gateway/EMCS device that provides a high degree of programmability and interfaces to a wide range of devices that may be used for DR applications.

Novar

Model	OPUS
Vendor	Novar
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.novar.com/ http://www.novar.com/default.asp?action=category&ID=56
Availability	In production
Cost	
Comms Interfaces	Ethenet, RS-232, RS-485
Standards	
Integrate with local EMCS	Yes
Communicate with	Yes

remote servers	
Implement Shed Logic	Yes
User Programmability	Yes
Notes	The OPUS line is designed for mult-site installations, but can be used for single sites that need remote connectivity. It includes a line of controllers and some HVAC control equipment such as thermostats. The OPUS line is based on Tridium's Niagra and JACE products.

PowerMand

Model	DreamWatts
Vendor	PowerMand
Load Type	Web Based Monitoring and control via a gateway
Type of control	EMCS
Feedback/Status	Yes
References	http://www.powermand.com/corp/index.jsp http://www.smartgridnews.com/artman/publish/industry/PowerMand_Pioneers_New_Approach_to_Demand_Response.html
Availability	In trials
Cost	
Comms Interfaces	Ethernet, Zigbee
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Remotely on server
User Programmability	unknown
Notes	Build products targeted towards demand response for residential and small commercial. Has created a web based product that is used in conjunction with a gateway to communicate with devices in the facility via Zigbee. The gateway is a communications facilitator and not a controller. Control and interfacing to the devices are via web based interfaces. Mostly sell to Utilities and aggregators.

Teletrol

Model	eBuilding Network Controller http://www.teletrol.com/products/ebuilding/network_contr

	oller.shtml
Vendor	Teletrol
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.teletrol.com/
Availability	In production
Cost	
Comms Interfaces	Ethernet, BACnet, MS/TP, RS-485
Standards	BACnet
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes, via graphical interface
Notes	Specifically used for commercial building management functions and interfaces to a wide range of devices for control purposes. Has a large number of models to suite exact needs.

Tendril

Model	TREE line of products
Vendor	Tendril
Load Type	EMCS, suite of products for residential
Type of control	EMCS
Feedback/Status	Yes
References	http://www.tendrilinc.com/ http://www.tendrilinc.com/consumers/products/
Availability	In production
Cost	
Comms Interfaces	Ethernet, Zigbee
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes

User Programmability	Yes, via web based portal
Notes	Tendril makes a suite of low cost products that are targeted towards residential energy management including gateways, controllers, thermostats, and displays. Currently developing compatibility with OpenADR standard.

Tridium

Model	JACE (variety of models, JACE-200 probably most appropriate for small commercial)
Vendor	Tridium
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Yes
References	http://www.tridium.com/ http://www.tridium.com/cs/products_/_services/jace
Availability	In production and OEM'd to a number of manufactures
Cost	$300 - $1500 depending upon options
Comms Interfaces	Etnernet, RS-232, RS-485, LonWorks, BACnet, MODBus
Standards	LonWorks, BACnet, MODBus, OBix
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes
Notes	The JACE platform interfaces to a wide range of devices through its numerous interface options and Niagra framework. It is specifically designed for Internet enabled applications and provides a high degree of programmability.

Universal Devices

Model	ISY-99i Series
Vendor	Universal Devices
Load Type	EMCS
Type of control	EMCS
Feedback/Status	Unknown
References	http://www.universal-devices.com/

Availability	In production
Cost	$299 - $369
Comms Interfaces	INSTEON, X10, UPB (under development), ZWave (under development)
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes
Notes	A residential control device that is intended to allow users to interface to and control a wide range of devices. Has a programming interface that may be adapted for DR applications.

1.1 HVAC

There are many aspects and components of a HVAC system that can be controlled. Because of wide variations between different manufacturers and between different facilities in terms of what type of equipment is installed it is difficult to specify a consistent and prototypical approach to controlling individual subsystems and components of an HVAC system that is appropriate for DR. One possible exception to this the direct cycling of HVAC compressors which is sometimes done for the purposes of DR.

For the purposes of this report the control mechanism for the HVAC is considered to be some sort of mechanism that is specifically designed to control the HVAC system as a whole. These can be classified into the following two categories.

Programmable Communicating Thermostats (PCT) – These are thermostats which have the ability to communicate and receive commands and DR signals. The control of the HVAC equipment is done via the thermostat controls which typically means modifying temperature set points and modes of operation.
HVAC control units. These are controllers that are specifically designed for the control of all operations of an HVAC unit as it pertains to the facility. It provides finer grain control over various subsystems of the HVAC than does a thermostat, but controls those subsystems within the context of the overall operation of the HVAC.

Automated Logic

Model	Various models in ZN zone control line
Vendor	ALC
Load Type	HVAC
Type of control	Zone controllers
Feedback/Status	Yes
References	http://www.automatedlogic.com/ http://www.automatedlogic.com/alcInternet.nsf/webview/products_ZN220?OpenDocument
Availability	In production
Cost	
Comms Interfaces	ARCNET, MS/TP
Standards	BACnet
Integrate with local EMCS	Yes
Communicate with remote servers	Yes via gateways or EMCS systems
Implement Shed Logic	Yes

User Programmability	Yes
Notes	ALC manufactures a wide range of zone controllers that are highly programmable and can be used for a wide range of HVAC applications. They can be interfaced to a wide range of devices and HVAC subsystems.

Carrier

Model	ComfortChoice Demand Management Solution
Vendor	Carrier
Load Type	HVAC
Type of control	PCT - Temperature setback or compressor duty cycle
Feedback/Status	DR state, temperature settings, HVAC operational states
References	http://www.comfortchoice.carrier.com/generic/0,2804,CLI1_DIV17_ETI777,00.html http://www.comfortchoice.carrier.com/Files/Comfort_Choice/Global/US-en/FirstEnergy_Selects_Carrier-final_article.doc
Availability	Currently used in DR pilots since 2001. Many 10K's units installed
Cost	
Comms Interface	Two way pager
Standards	ReFlex-50 wireless protocol
Integrate with local EMCS	unclear
Communicate with remote servers	Yes, direct load control
Implement Shed Logic	limited
User Programmability	YES via website
Notes	A sophisticated programmable thermostat with two way communications to allow direct changing of the set point and reporting of HVAC status and settings.

Golden Power

Model	Thermostat
Vendor	Golden Power
Load Type	HVAC
Type of control	PCT
Feedback/Status	Yes
References	

Availability	In production
Cost	$89 in 100K quantities
Comms Interfaces	Zigbee, RDS, ZWave
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes via RDS
Implement Shed Logic	Yes, limited to HVACs
User Programmability	limited
Notes	A protocol independent PCT that is designed to both receive broadcast information via RDS and to integrate with EMCS systems via a variety of wireless connections.

Honeywell

Honeywell has many products in various price ranges. Authors recommend checking with the company.

Lennox

Model	L Connection Network series of products
Vendor	Lennox
Load Type	HVAC
Type of control	Various including thermostat, rooftop unit, centralized controller
Feedback/Status	Yes
References	http://www.lennox.com/ http://www.lennoxcommercial.com/products/list_controls.asp
Availability	In production
Cost	
Comms Interfaces	Ethernet, L Connection network
Standards	Moving toward BACnet
Integrate with local EMCS	Yes
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes

Notes	The L Connection Network manages HVAC, zoning and building operations from a single point of control. It is compatible with all Lennox HVAC equipment, as well as electro-mechanically controlled third-party equipment. Can be used for managing and controlling lighting systems as well.

LIGHTSTAT

Model	RTPstat
Vendor	LIGHTSTAT
Load Type	HVAC with optional auxiliary load controls
Type of control	PCT - Temperature setback or complete duty cycle
Feedback/Status	none
References	http://www.lightstat.com/products/utility.asp
Availability	Currently in use
Cost	
Comms Interface	930 MHz pager
Standards	
Integrate with local EMCS	No
Communicate with remote servers	Yes
Implement Shed Logic	limited
User Programmability	Yes via Internet
Notes	Lightstat's RTPstat Internet-programmable thermostat incorporates a flexible set of built-in load control commands that allow the utility to reduce heating and air conditioning power consumption during peak times. Cycle heating or cooling, offset the temperature setpoint, or turn off the A/C entirely. For control of other large residential loads such as pool pumps and water heaters, Lightstat offers the Virtual Gateway programmable load control module. Up to two modules per customer can be cycled or interrupted to provide additional load reduction.

Novar

Model	LOGIC ONE
Vendor	Novar

Load Type	HVAC, miscellaneous electrical loads
Type of control	Varied, PCT, unit controllers, load controllers
Feedback/Status	Yes
References	http://www.novar.com/ http://www.novar.com/default.asp?action=category&ID=16 http://www.novar.com/default.asp?action=category&ID=36
Availability	In production
Cost	
Comms Interfaces	RS-485, Ethernet, POTS modem, MODBUS, USB,
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Yes, via Envoi interface panel
Implement Shed Logic	Yes
User Programmability	Yes
Notes	The LOGIC ONE is a complete line of networked controllers that include EMCS, HVAC, lighting and miscellaneous loads. The HVAC control includes both thermostats and unit controllers. The HVAC equipment may be controlled and accessed via a variety of devices including the Envoi, Lingo, and Savvy controllers/gateways. The Lingo is probably most appropriate for small commercial applications.

Proliphix

Model	NT PRO and Thermal Management Series
Vendor	Proliphix
Load Type	HVAC
Type of control	PCT
Feedback/Status	Yes
References	http://www.proliphix.com/ http://www.proliphix.com/NT-Pro.aspx
Availability	In production
Cost	$399 - $499
Comms Interfaces	Ethernet
Standards	

Integrate with local EMCS	possibly
Communicate with remote servers	Yes
Implement Shed Logic	Limited
User Programmability	Limited, may be adapted to provide more
Notes	Develops and manufactures inexpensive Internet-enabled thermostats for use in the residential and light commercial industries. Most Proliphix thermostats are used for energy management by multi-tenant property or corporate facilities managers, hospitality administrators, retail franchise owners, as well as electric utility energy curtailment initiatives. The thermostats employ an embedded web server which serves up a graphical interface (GUI).

Residential Control Systems (RCS)

Model	Numerous thermostats
Vendor	RCS
Load Type	HVAC
Type of control	PCT
Feedback/Status	
References	http://www.resconsys.com/
Availability	In production
Cost	
Comms Interfaces	X10, RS-485, UPB, ZWave, LonWorks, RDS
Standards	
Integrate with local EMCS	Yes
Communicate with remote servers	Thermostats - Yes via RDS Control Panel - Yes
Implement Shed Logic	Yes, limited in the PCT
User Programmability	Yes, limited in the PCT
Notes	RCS makes a line of communicating thermostats that can communicate via a variety of different protocols.

	Mostly targeted towards residential and light commercial systems. Can also interface with a number of different EMCS systems. RCS also makes a control panel that has a touch screen and can be used as an EMCS and adapted for DR applications (see Advanced Telemetry). Their PCT is also being used for pilot DR programs in CA.

White Rogers

Model	
Vendor	
Load Type	HVAC
Type of control	PCT
Feedback/Status	No
References	
Availability	Available
Cost	
Comms Interfaces	RDS
Standards	
Integrate with local EMCS	No
Communicate with remote servers	Yes
Implement Shed Logic	Yes
User Programmability	Yes
Notes	This is a stand alone programmable communicating thermostat where the client is at a radio station and devices listen to the DR signals over radio lines using RDS

1.2 Lighting

Lighting Type	Type of Control	OpenADR ready system availability*
Incandescent - over 15% of small commercial buildings	On-off Dimming	Available** Available**
Fluorescent – over 80% of small commercial buildings	On-off	Available**
	On-off with bi-level switching	Available since Title24 requires such wiring.
	Step-level dimming	Although some of the other systems can be used to enable step-level dimming, the authors do not have any field experience with such systems.
	Dimming	Available**

*The lighting controls for small commercial buildings are similar to residential lighting controls.
** Although the systems are available, lighting controls that enable OpenADR is limited.

1.3 Miscellaneous

These categories of controllers are used to control a miscellaneous collection of loads that do not fall into the Lighting or HVAC category.

Cannon Technologies

Model	LCR-5000
Vendor	Cannon Technologies
Load Type	Miscellaneous
Type of control	Multiple independent relays
Feedback/Status	?
References	http://www.cannontech.com/products/drdirectcontrol.asp
Availability	Numerous pilots and DR programs
Cost	
Comms Interface	900 MHz FLEX Paging (dual provider for extra reliability)
Standards	
Integrate with Local EMCS	unclear
Communicate with remote servers	Yes
Implement Shed Logic	Limited
User Programmability	Yes via web page
Notes	Part of a suite of products from Cannon for supporting DR programs, mostly in the area of DLC.

Others in this category include aggregator technologies currently being used in California. For more information, contact aggregators.

Appendix B: SF Community Power Data Analysis

The purpose of this study is to:

- understand the DR performance of SF Power's Capacity Bidding Program (CBP) participation in 2007,
- investigate issues related to baseline
- examine DR strategies related to each individual building, and
- improve the DR performance of the sites.

[This report is outlines the phase 1 of this work where the performance of SF Power's three portfolios are evaluated and five individual sites are analyzed in detail. Phase 2 will go into understanding the strategies at these sites and phase 3 will consider automation solutions]

1.0 Introduction

As a solution of temporary electric supply shortage, demand response (DR) has been identified as a key demand side management area to reduce rotating electrical outages and improve electric grid reliability. As a major provider of electricity and natural gas in California, PG&E offers a number of DR programs. Among them, the Capacity Bidding Program (CBP) is a voluntary DR program that offers aggregators and customers capacity payments and demand reduction incentives for reducing energy consumption when requested by PG&E. The program season for CBP is May 1 through October 31 and the events are called between 11 a.m. to 7 p.m. CBP provides participants day-ahead and day-of options and three products which are 1-4 hour, 2-6 hour and 4-8 hour.

SF Power is an aggregator of 26 facilities with 41 service account IDs (SAID) on CBP. SF Power has three portfolios which participate in five CBP DR events in 2007 at different times and durations based on their contracts. The dates and hours of participation for each portfolio are shown in Table 1.

This report outlines the available data for each portfolio, presents the analysis of five sites that have extensive data and the performance of each portfolio. Final section includes a discussion of next steps.

Table 13. Summary of 2007 capacity bidding program participation for SF Power

Portfolio	Event Date	MW	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19
SFCP_PGE3_DA_1-4_BUL	8/31/2007	0.084			1	1	1	1		
SFCP_PGE3_DA_4-8_BUL	8/31/2007	0.209			1	1	1	1	1	
SFCP_PGE3_DA_4-8_DAL_(CNE)	8/31/2007	0.075			1	1	1	1	1	
SFCP_PGE3_DA_1-4_BUL	8/30/2007	0.084			1	1	1	1		
SFCP_PGE3_DA_4-8_BUL	8/30/2007	0.209			1	1	1	1	1	
SFCP_PGE3_DA_4-8_DAL_(CNE)	8/30/2007	0.075			1	1	1	1	1	
SFCP_PGE3_DA_1-4_BUL	8/29/2007	0.084				1	1	1	1	
SFCP_PGE3_DA_4-8_BUL	8/29/2007	0.209			1	1	1	1	1	
SFCP_PGE3_DA_4-8_DAL_(CNE)	8/29/2007	0.075			1	1	1	1	1	
SFCP_PGE3_DA_1-4_BUL	7/5/2007	0.03					1	1	1	1
SFCP_PGE3_DA_4-8_BUL	7/5/2007	0.113					1	1	1	1
SFCP_PGE3_DA_4-8_DAL_(CNE)	7/5/2007	0.115					1	1	1	1
SFCP_PGE3_DA_1-4_BUL	7/3/2007	0.03				1	1	1	1	
SFCP_PGE3_DA_4-8_BUL	7/3/2007	0.113				1	1	1	1	
SFCP_PGE3_DA_4-8_DAL_(CNE)	7/3/2007	0.115				1	1	1	1	

2.0 Methodology

In 2007, SF Power participated in PG&E's Capacity Bidding Program with three portfolios. Three portfolios are:

- SFCP_PGE3_DA_1-4_BUL (Portfolio 1) participated in Capacity Bidding Event Days for four hours between noon and 7pm with one account in July and five accounts in August and September.
- SFCP_PGE3_DA_4-8_BUL (Portfolio 2) participated in Capacity Bidding Event Days for minimum of four hours between noon and 7pm with eleven accounts in July and 28 accounts in August and September.
- SFCP_PGE3_DA_4-8_DAL_(CNE) (Portfolio 3) participated in Capacity Bidding Event Days for minimum of four hours between noon and 7pm with two accounts in July, August and September.

The analysis is divided into three phases:
Phase 1: Data gathering, portfolio analysis and weather sensitivity and load variability analysis for facilities which have historical data available.
Phase 2: Site and DR strategy information gathering from each site.
Phase 3: Assessment of feasibility of automating demand response strategies.

This report summarizes the phase 1 effort and will be expanded to include information from phases 2 and 3 when they become available.

2.1. Baselines

Three baseline models are calculated in for the portfolio analysis and the analysis of the five large sites. CBP baseline is also called 3/10 baseline which is the hourly average based on the three highest energy usage days with the highest total kilowatt hour usages during the program hours of the immediate past ten days excluding weekends, holidays and other DR days. It is used by utilities in California to calculate demand reduction. 3/10 Baseline with morning adjustment (3/10_MA) model is adjusting the 3/10 baseline by a morning adjustment multiplier (r_a) to each hour. The factor r_a is defined as the ratio of the actual to the predicted load in the two hours prior to the event period shown in Equation 1. However, the data at the hour end at 12 (HE12) and HE13 were used in this project because of the difficulty of obtaining the data at the prior two hours before the event period start, and no portfolio bid earlier than 14:00 during the five events in 2007. Adjusted OAT-regression (OAT_MA) baseline model uses weather regression model with morning adjustment. The weather regression model is estimating the hourly load by the outside air temperature (OAT) linear regression based on the past ten uncurtailed business days. In this model, the load $L_{p,h}$ can be calculated by equation 2. The morning adjustment methodology is the same as the 3/10_MA model.

$r_a = (L_{a,10}+L_{a,11})/(L_{p,10}+L_{p,11})$……………………………………………………………………………1

where, r_a is the morning adjustment factor

$L_{a,10}$, $L_{a,11}$ are the actual load at the hour end at 10:00am (HE10), 11:00am (HE11), respectively

$L_{p,10}$, $L_{p,11}$ are the predicted load by 3/10 baseline at the hour end at 10:00am (HE10), 11:00am (HE11), respectively

$L_{p,h} = a_h+b_h*T_h$ ………………………………………………………………………………..2

Where, $L_{p,h}$ is the predicted load at the hour *h*

a_h, b_h are the linear constants at the hour *h* which can be calculated by the ten pair of past actual load and OAT data

T_h is the OAT at the hour *h*

3.0 Data Analysis

3.1. Three Portfolios in Capacity Bidding Program

The data for the portfolio analysis are gathered from APX which facilitated the capacity bidding program for all the IOUs in California. The meter numbers and obtained data range in three portfolios of SF Power from June to September 2007 are shown in Table 2. For each portfolio, two baselines are calculated: 3/10 baseline and 3/10_MA baseline. The site P27692 participated in a different portfolio in 2007.

Table 14 Meter numbers in 3 portfolios of SF Power from July to September 2007

	July	August	September	Data Range
SFCP_PGE3_DA_1-4_BUL	7884R5	7884R5	7884R5	6/18/2007-9/28/2007
		35P421	35P421	7/17/2007-9/28/2007
		83P385	83P385	7/17/2007-9/28/2007
		P27692	P27692	7/17/2007-8/31/2007
		P95868	P95868	7/17/2007-9/28/2007
SFCP_PGE3_DA_4-8_BUL	46T755	46T755	46T755	6/18/2007-9/28/2007
	56M088	56M088	56M088	6/18/2007-9/28/2007
	56T502	56T502	56T502	6/18/2007-9/28/2007
	5P3101	5P3101	5P3101	6/18/2007-8/31/2007
	5P3377	5P3377	5P3377	6/18/2007-9/28/2007
	5P5512	5P5512	5P5512	6/18/2007-8/31/2007
	7932R5	7932R5	7932R5	6/18/2007-9/28/2007
	83P505	83P505	83P505	6/18/2007-9/28/2007
	P27692			6/18/2007-7/31/2007
	P30706	P30706	P30706	6/18/2007-8/31/2007
	P95906	P95906	P95906	6/18/2007-8/31/2007
		14M866	14M866	7/17/2007-9/13/2007
		18P063	18P063	7/17/2007-9/28/2007
		2P2890	2P2890	8/1/2007-9/28/2007
		57P589	57P589	7/17/2007-9/28/2007
		5P3376	5P3376	7/17/2007-9/28/2007
		7P2210	7P2210	7/17/2007-9/28/2007
		7P2211	7P2211	7/17/2007-9/28/2007
		83P399	83P399	7/17/2007-9/28/2007
		9M4668	9M4668	7/17/2007-9/28/2007
		P29330	P29330	7/17/2007-9/28/2007
		P29565	P29565	7/17/2007-9/28/2007
		P30784	P30784	7/17/2007-9/28/2007
		P31016	P31016	7/17/2007-9/13/2007
		P94941	P94941	7/17/2007-9/6/2007
		P95367	P95367	7/17/2007-9/28/2007
		P95925	P95925	7/17/2007-8/31/2007
		P95926	P95926	7/17/2007-9/11/2007
		P95965	P95965	7/17/2007-9/28/2007
SFCP_PGE3_DA_4-8_DAL_(CNE)	2623R5	2623R5	2623R5	6/18/2007-9/28/2007
	2P2825	2P2825	2P2825	6/18/2007-9/28/2007

3.2. Demand Reduction Evaluation

3.2.1. Portfolio 1 (SFCP_PGE3_DA_1-4_BUL)

Portfolio 1 had only one participant in July. Therefore, the baseline for Portfolio 1 in July is the same as 7884R5's individual baseline. The number of participants in this portfolio increased to five in August. In August, 7884R5 still predominated the baseline because it is the absolute large load in this portfolio. Table 3 shows the demand contribution of site 7884R5 to Portfolio 1 on CBP event days. Table 4 shows the coincident baseline day No. of the portfolio and individual site in August. In addition, the portfolio's three highest average electricity consumption days are the same as 7884R5's. None of the other sites' all three highest average consumption days match the portfolio's selected three highest days. Table 5 through 7 show the demand savings based on 3/10 baseline and 3/10_MA baseline during CBP events in 2007. 3/10_MA seems to consistently lower the demand reduction calculations suggesting that morning loads for the portfolio are lower that the baseline on the day of the CBP events. Table 5 shows the portfolio 1 aggregated whole building power for each event day in July and August. Columns in the table show the period with hour ending (HE) marks for each hour. Table 6 is the whole building power for meter number 7884R5. Tables 5 and 6 are very close suggesting once again the largest load dominates demand reduction in this portfolio. Although other participants significantly reduce their loads (Table 7), their reductions are a small portion of the entire portfolio.

Table 15 the WBP contribution of Facility 7884R5 to the Portfolio 1 on CBP event days

	HE12	HE14	HE15	HE16	HE17	HE18	HE13	HE19
7/3/2007	100%	100%	100%	100%	100%	100%	100%	100%
7/5/2007	100%	100%	100%	100%	100%	100%	100%	100%
8/29/2007	97%	96%	97%	97%	97%	95%	95%	88%
8/30/2007	95%	96%	96%	97%	96%	95%	94%	89%
8/31/2007	97%	96%	96%	96%	96%	95%	93%	88%

Table 16 Coincident baseline day No. of Portfolio 1 and single site in August

Site	Max_Load (kW)	Coincident Baseline day No.
7884R5	677.1	3
P27692	10.11	2
P95868	33.01	2
35P421	3.23	2
83P385	3.73	0

Table 17 Demand savings WBP% of Portfolio 1

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				12.0%	11.8%	14.0%	21.2%		14.7%
	7/5					0.8%	1.1%	9.9%	1.1%	3.2%
	8/29				1.9%	0.2%	-2.1%	-9.9%		-2.5%
	8/30			2.1%	0.2%	-0.8%	-3.1%			-0.4%
	8/31			13.6%	11.8%	11.2%	8.4%			11.3%
3/10_MA Baseline	7/3				2.4%	2.2%	4.6%	12.6%		5.5%
	7/5					-3.6%	-3.3%	6.0%	-3.2%	-1.0%
	8/29				2.5%	0.8%	-1.5%	-9.2%		-1.9%
	8/30			3.6%	1.7%	0.6%	-1.6%			1.1%
	8/31			0.6%	-1.4%	-2.2%	-5.3%			-2.1%

Table 18 Demand Savings WBP% of Facility 7884R5

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				12.0%	11.8%	14.0%	21.2%		14.7%
	7/5					0.8%	1.1%	9.9%	1.1%	3.2%
	8/29				-0.7%	-2.0%	-2.8%	-11.4%		-4.2%
	8/30			0.4%	-1.9%	-2.7%	-3.3%			-1.9%
	8/31			12.2%	10.5%	9.9%	8.0%			10.2%
3/10_MA Baseline	7/3				2.4%	2.2%	4.6%	12.6%		5.5%
	7/5					-3.6%	-3.3%	6.0%	-3.2%	-1.0%
	8/29				2.3%	1.1%	0.3%	-8.0%		-1.1%
	8/30			2.8%	0.6%	-0.2%	-0.8%			0.6%
	8/31			0.9%	-1.0%	-1.7%	-3.9%			-1.4%

Table 19 Demand Savings WBP% of other Facilities

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	8/29				48%	38%	11%	10%		27%
	8/30			32%	37%	32%	0%			25%
	8/31			37%	35%	33%	16%			30%
3/10_MA Baseline	8/29				10%	-6%	-53%	-54%		-26%
	8/30			20%	25%	20%	-18%			11%
	8/31			-6%	-9%	-13%	-42%			-18%

3.2.2. Portfolio 2 (SFCP_PGE3_DA_4-8_BUL)

Eleven accounts were in Portfolio 2 in July. In August and September, the total number of accounts in portfolio 2 was 28. There is a wide variety of collectable data ranges. Five large facilities over 200kW participated in Portfolio 2. The coincident baseline day No. of Portfolio 2 and single site in table 8 shows that in July, two of the five large facilities have two coincident baseline days while three of them have only one or none coincident baseline day to the whole portfolio. In August, one of the five large facilities has the same baseline days as the whole portfolio, three of them have two coincident baseline days, and only one has one coincident baseline day to the portfolio (table 9). The effect of them cause that no site could dominate the portfolio demand. In July, 6/21, 6/25 and 7/2 were chosen as 3/10 baseline days for portfolio 2. None of the sites had the same dates for three highest days selection. In August four out of 28 had matching three dates with the portfolio highest days. This issue and how it affects portfolio performance will be further analyzed.

Table 10 shows the demand reduction of portfolio 2. Based on 3/10 baseline, Portfolio 2 had average demand reduction from 0.1% to 7.9% on event days. However, based on 3/10_MA baseline, negative demand reduction were observed on 7/5 and 8/30.

Table 20 Coincident baseline day No. of Portfolio 2 and single site in July

Site	Max_Load (kW)	Coincident Baseline day No.
P27692	9.12	1
56T502	694.80	2
P30706	375.12	2
5P3101	27.20	2
5P3377	113.00	2
5P5512	19.32	1
P95906	61.71	2
7932R5	398.20	1
83P505	6.13	1
46T755	444.30	1
56M088	361.08	0

Table 21 Coincident baseline day No. of Portfolio 2 and single site in August

Site	Max_Load (kW)	Coincident Baseline day No.
P30706	392.28	3
7932R5	425.4	2
P94941	91.1	2
2P2890	82.1	2
57P589	34.96	3
56M088	364.04	2
46T755	467.7	2
P95906	61.94	2
P95965	53.97	3
P31016	76.02	2
P29565	26.24	2
P30784	57.05	2
P95367	36.43	3
18P063	57.17	2
P29330	45.34	1
5P3376	28.67	1
5P5512	20.31	1
56T502	727.8	1
5P3101	28.17	1
83P505	6.14	1
83P399	4.8	2
P95926	135.65	1
7P2211	67.81	1
P95925	9.25	0
14M866	7.78	0
7P2210	8.49	1
5P3377	110.66	0
9M4668	6.4	0

Table 22 Demand savings WBP% of Portfolio 2

	Event Day	HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				5.7%	8.0%	8.8%	6.4%		7.2%
	7/5					1.7%	3.0%	3.2%	3.8%	3.0%
	8/29			-1.3%	0.8%	-0.1%	0.4%	0.8%		0.1%
	8/30			1.9%	1.4%	0.1%	0.6%	-1.7%		0.5%
	8/31			5.3%	6.5%	6.9%	6.2%	4.4%		5.9%
3/10_MA Baseline	7/3				1.1%	3.5%	4.4%	1.9%		2.7%
	7/5					-3.7%	-2.3%	-2.1%	-1.5%	-2.4%
	8/29			2.0%	4.0%	3.2%	3.6%	4.0%		3.4%
	8/30			1.0%	0.5%	-0.8%	-0.3%	-2.6%		-0.5%
	8/31			2.2%	3.4%	3.9%	3.1%	1.3%		2.8%

3.2.3. Portfolio 3 (SFCP_PGE3_DA_4-8_DAL_(CNE))

Portfolio 3 includes two large facilities July through September. Hourly load data during program hours for both facilities are available. The hourly load of 2P2825 is twice larger than 2623R5. Analysis shows that while before 8/21 there is significant reduction after 5 pm, after 8/21, the load shape is flatter and reduction is reduced. The demand profile analysis of 2P2825 showed that the loads are relatively constant between 11:00am-20:00pm on the same day but highly variable from day to day June through September.

3/10 baselines for each individual facility and the entire portfolio were calculated. Two of the three baseline days of Portfolio 3 for event days 7/3 and 7/5 coincide with two of the three highest energy usage days of 2P2825, and one of them fell into the three highest energy usage days of 2623R5. For the event days in August, all the three baseline days for Portfolio 3 are coincident with the three highest energy usage days of 2P2825, and two of them fell into the three highest energy usage days of 2623R5(TABLE 10). Due to the bigger load, 2P2825 has bigger effect on Portfolio 3 than 2623R5 does.

The 3/10 baselines in July are shown in figure 3. 2623R5 and 2P2825 show the 3/10 baselines if the facilities are not aggregated. The aggregated 3/10 baseline is a simple aggregation of the two individual 3/10 baselines above. The portfolio baseline is the 3/10 baseline of the whole portfolio which is slightly lower than aggregated 3/10 baseline. The same trending is found in August in Figure 4. The differences between aggregated 3/10 baseline and portfolio baseline in August are smaller than those in July. That's because more coincident baseline days are included in August.

The demand reduction of the whole portfolio, site 2623R5 and 2P2825 are shown in table 11 to 13. Here, the data of HE12 and HE13 were used for morning adjustment.

Table 23 Coincident baseline day No. of Portfolio 3 and single site in July and August

Month	Site	Max_Load (kW)	Coincident Baseline day No.
July	2P2825	1274	2
	2623R5	630	1
August	2P2825	1172	3
	2623R5	642	2

Table 24. Percent demand savings WBP of Portfolio 3

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				-2%	1%	2%	1%		0.4%
	7/5					2%	-5%	4%	4%	1.2%
	8/29			-7%	-5%	-10%	-7%	-9%		-7.7%
	8/30			-6%	-5%	-7%	-4%	-6%		-5.7%
	8/31			2%	4%	3%	7%	6%		4.6%
3/10_MA Baseline	7/3				-9%	-6%	-5%	-5%		-6.2%
	7/5					0%	1%	1%	1%	0.7%
	8/29			-1%	1%	-4%	-1%	-2%		-1.4%
	8/30			-2%	-1%	-3%	0%	-2%		-1.5%
	8/31			0%	3%	1%	5%	5%		2.8%

Table 25. Percent demand savings WBP of Site 2623R5

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				-10%	-9%	3%	5%		-2.6%
	7/5					-6%	3%	5%	4%	1.5%
	8/29			-1%	1%	-2%	-3%	-3%		-1.5%
	8/30			0%	0%	-1%	1%	0%		-0.1%
	8/31			6%	7%	8%	11%	12%		8.8%
3/10_MA Baseline	7/3				-5%	-4%	8%	10%		2.3%
	7/5					-7%	6%	8%	7%	3.6%
	8/29			2%	4%	1%	0%	0%		1.3%
	8/30			2%	1%	1%	3%	1%		1.6%
	8/31			-1%	0%	2%	4%	6%		2.1%

Table 26. Percent demand savings WBP of Site 2P2825

		HE12	HE13	HE14	HE15	HE16	HE17	HE18	HE19	Average
3/10 Baseline	7/3				1%	5%	1%	0%		1.8%
	7/5					5%	-8%	4%	4%	1.1%
	8/29			-11%	-9%	-14%	-9%	-12%		-11.0%
	8/30			-10%	-8%	-11%	-6%	-9%		-8.7%
	8/31			0%	3%	0%	5%	3%		2.3%
3/10_MA Baseline	7/3				-12%	-7%	-12%	-13%		-10.9%
	7/5					3%	-1%	-3%	-1%	-0.6%
	8/29			-3%	-1%	-6%	-1%	-3%		-2.7%
	8/30			-4%	-2%	-5%	-1%	-3%		-3.1%
	8/31			1%	4%	1%	6%	4%		3.2%

3.3. Analysis of five large sites with historical data

In addition to the portfolio analysis, five accounts, which have historical data available through PG&E's InterAct system, have been analyzed for their weather sensitivity and load variability. In order to understand the weather sensitivity of these sites, nearest weather station is selected and the hourly weather data is downloaded (section 2.1).

Once the data are obtained, weather sensitivity of five sites was calculated using Rank Order Correlation (ROC) as well as Pearson Moment Correlation Coefficient (PMCC). After a brief description of the baselines which were used to evaluate the demand reduction, section 3.3 concentrates on the demand reduction using different baselines for each portfolio. Section 3.4 concentrates on the variation of load reduction for the five sites with extensive data. Section 4 outlines a final discussion and next steps.

3.3.1. *Weather data*

The weather data is obtained from the nearest weather station for each facility. The weather data is formatted to show hourly outside air temperature (OAT). Table 14 shows the weather station for each of the five sites.

Table 27 Proximity of Weather Stations

Customer	Weather Station	WS ID	Distance to WS
Site A	Oakland Foothills	CI149	0.8 mile
Site B	CW6328 San Francisco	SFOC1	2.3 mile
Site C	San Fran Sewage Treatment Plant	CQ147	2 mile
Site D	W6CQZ-10 Alameda	AS562	1.5 mile
Site E	CW6328 San Francisco	SFOC1	2.3 mile

3.3.2. *Weather Sensitivity Analysis (5 facilities)*

In this project, the Rank Order Correlation Coefficient (ROC) r_s and Pearson Moment Correlation Coefficient (MCC) r are used for identifying the weather sensitivity of each facility. ROC is used to measure the ordinal data correlation. And the MCC is used to measure the direct correlation of demand data and OAT.

Figure 3 and 4 show the results of ROC and MCC respectively. Swig is identified to be the only weather sensitive facility because its ROC is above 0.7 during the normal operation period. The r_s and r for Sites A, B, C and D are lower than 0.7 which means they are not weather sensitive.

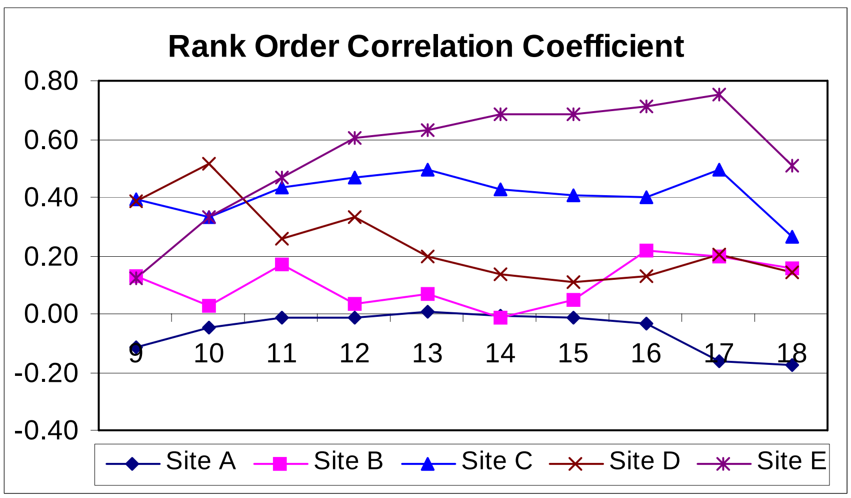


Figure 13 Hourly Rank Order Correlation Coefficient of facilities

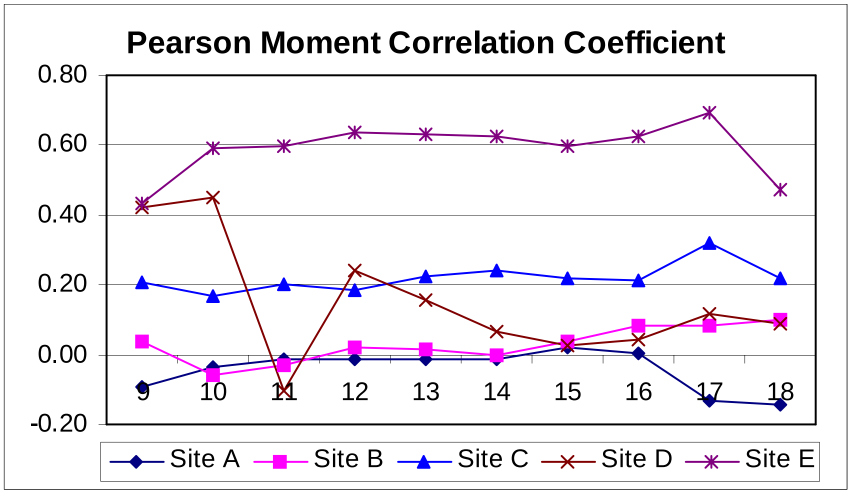


Figure 14 Hourly Moment Correlation Coefficient of facilities

3.3.3. Variation in demand reduction

Variation in demand reduction is studied for five sites using 3/10, 3/10_MA and OAT_MA baselines. Figure 5 to 7 show the average, minimum and maximum demand reduction for each site with each baseline. Based on the 3/10 baseline, four out of five facilities had positive average demand reductions. Based on 3/10_MA baseline, all of the five facilities had positive average demand reductions; however, the average demand reductions are smaller. Based on OAT_MA baseline, three of the five facilities show negative demand reductions. Baseline development greatly affects demand reduction measurement. Therefore, selecting an appropriate baseline is very important. Site C is the least variable site. Site D is the most variable site.

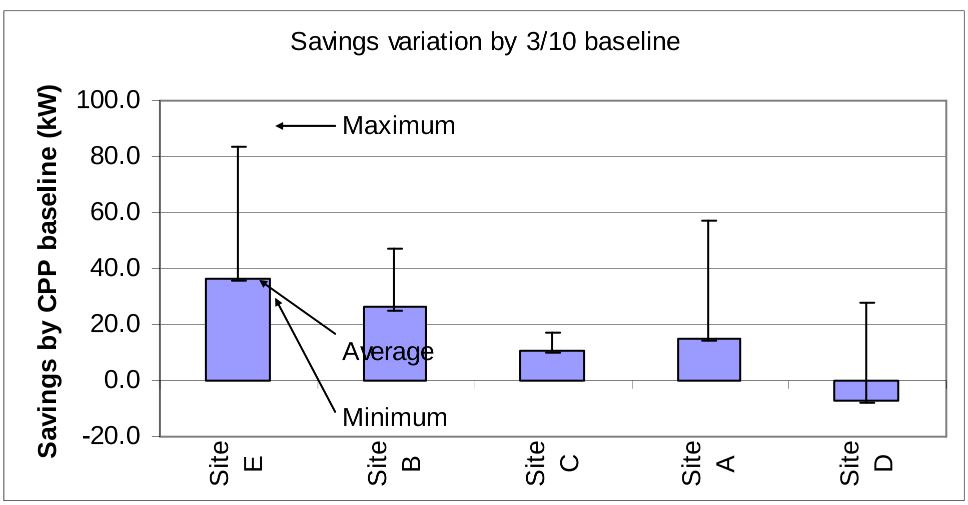


Figure 15 Average, Minimum and Maximum Demand Reduction Based on 3/10 Baseline

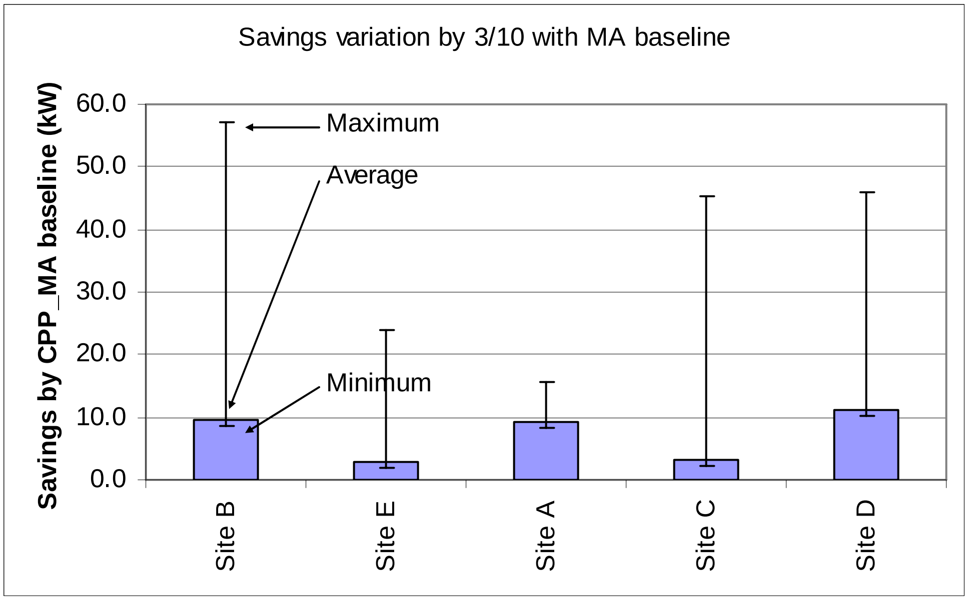


Figure 16 Average, Minimum and Maximum Demand Reduction Based on 3/10_MA Baseline

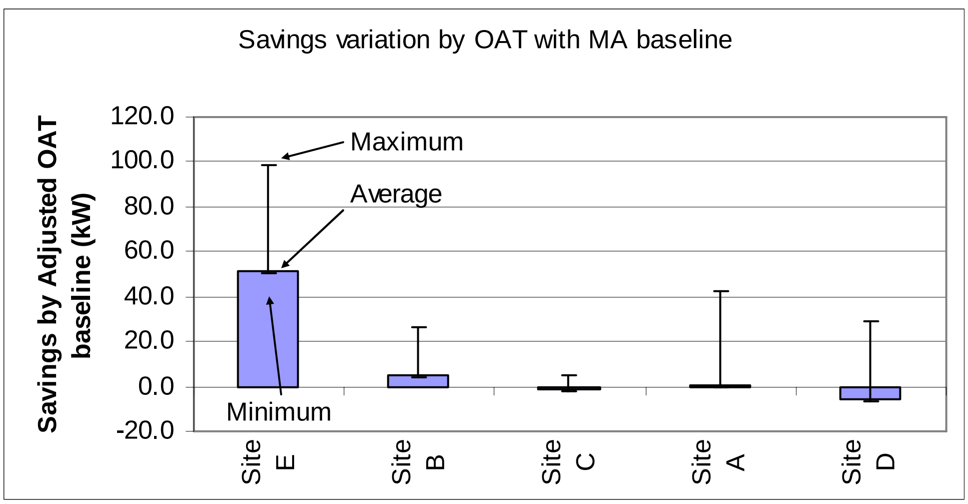


Figure 17 Average, Minimum and Maximum Demand Reduction Based on OAT_MA Baseline

4.0 Discussion

In this report, we analyzed the portfolio performance, and how the individual facility affects the portfolio. Because of insufficient outside air temperature data, 3/10 baseline, 3/10_MA baseline were calculated for each portfolio. Then, weather sensitivity and demand reduction variation analysis were conducted on five large facilities. Only one site was identified to be a weather sensitive facility. Other four facilities' loads had very small correlation with the OAT.

The study was conducted without any information about the buildings, DR control strategies or automation opportunities. A next step to this study to make it more complete would be to collect this information and match it with the performance to better characterize individual buildings' performance.

Appendix C: Small Commercial Site Survey

1. Contact Information

Name	
Company	
E-mail	
Phone	
Fax	
Contact's address	

2. Site Information

Facility Type (e.g. small office, restaurant, etc)		
Does the site house multiple or a single tenant?	☐ Multiple tenants → # of tenants [ ] ☐ Single tenant	
Location (address)		
Year constructed		
General building description (e.g. number of floors, construction material, wood frame or masonry, single or double paned windows)		
Floor space (ft^2)	Total	
	Conditioned	

Occupancy schedule	Weekday	
	Non-Weekday	

Facility management type	☐ Self ☐ Landlord

3. Energy

Peak load [kW]		
Connected load [kW]		
Approximate breakdown of summer peak period [in %]	Lighting	
	HVAC	
	Appliances, misc.	
	Process line	

4. HVAC system

Air Distribution Type

Choose one from below:

Single duct	Constant volume	Single zone	☐
		Multiple-zone reheat	☐
		Bypass VAV	☐
	Variable air volume (VAV)	Throttling	☐
		Fan-powered	☐
		Reheat	☐
		Induction	☐
		Variable diffusers	☐
Dual duct	Constant volume		☐
	VAV		☐
	Dual conduit		☐

Direct digital control (DDC) at zone level control

☐ Yes ☐ No

Global setpoint control capability

☐ Yes ☐ No

Zone temperature setpoint

Cooling	°F
Heating	°F

<table>
<tr><td rowspan="3">Cooling Plant</td><td>Choose one from below:
<table>
<tr><td rowspan="6">Central cooling</td><td rowspan="2">Centrifugal chiller</td><td>Constant volume</td><td>☐</td></tr>
<tr><td>Variable frequency drive (VFD)</td><td>☐</td></tr>
<tr><td rowspan="2">Absorption chiller</td><td>Constant volume</td><td>☐</td></tr>
<tr><td>Variable frequency drive (VFD)</td><td>☐</td></tr>
<tr><td rowspan="2">Other chiller (describe): ____</td><td>Constant volume</td><td>☐</td></tr>
<tr><td>Variable frequency drive (VFD)</td><td>☐</td></tr>
<tr><td rowspan="2">Decentralized cooling</td><td rowspan="2">Package unit</td><td>Constant volume</td><td>☐</td></tr>
<tr><td>Variable frequency drive (VFD)</td><td>☐</td></tr>
</table></td></tr>
<tr><td>Number and size (tons, kW) of equipments:</td></tr>
<tr><td>Direct digital control (DDC)?
☐ Yes ☐ No</td></tr>
<tr><td rowspan="3">Air Handling Unit</td><td>Choose one from below:
<table>
<tr><td>Constant volume</td><td>☐</td></tr>
<tr><td>Variable speed drive (VSD)</td><td>☐</td></tr>
</table></td></tr>
<tr><td>Number and size (horse power, kW, CFM) of equipments:</td></tr>
<tr><td>Direct digital control (DDC)?
☐ Yes ☐ No</td></tr>
</table>

5. Lighting System

<table>
<tr><td>Zone control</td><td>Choose one from below:
<table>
<tr><td>Single zone control</td><td>☐</td></tr>
<tr><td>Multi-zone control</td><td>☐</td></tr>
</table></td></tr>
<tr><td>Control type</td><td>Check all applicable:
<table>
<tr><td>Single circuit control for a zone</td><td>☐</td></tr>
<tr><td>Multiple circuit control for a zone</td><td>☐</td></tr>
<tr><td>Bi-level switching</td><td>☐</td></tr>
<tr><td>Dimmable ballast</td><td>☐</td></tr>
</table></td></tr>
</table>

General description of types of lamps and fixtures (e.g., CFLs, T-12s, T-8s, High Intensity Discharge)	
Centralized control	*Centralized lighting control?* ☐ Yes ☐ No
	Is the lighting control integrated into EMCS? ☐ Yes ☐ No

6. Energy Management and Control System

EMCS vendor	
What protocol is used?	
Remote monitoring/ control capability	Control systems are viewable/controllable via (Check all applicable):

	Viewable	Controllable
Web-browser	☐	☐
Off-site	☐	☐
On-site	☐	☐
Never	☐	☐

Data collection at EMCS	Does the EMCS have capability to trend logs? ☐ Yes ☐ No	
	If yes, data point collected:	
	Trend interval (minute)	

7. Energy Information System (data monitoring and collection)

Utility provided EIS	Do you have access to a web-based electricity data archive and visualization system? ☐ Yes ☐ No	
Other EIS installed	Do you have web-based Energy Information System? ☐ Yes ☐ No	
	If yes, vendor:	
	Data points collected:	
	Trend interval (minute)	
	Is the data accessible from third party (LBNL)? ☐ Yes ☐ No	

8. Connectivity – Connecting the EMCS to the Internet

(a) Does the site have Internet connectivity for tenants? (i.e., can they surf the Web?)	☐ Yes ☐ No
(b) Is EMCS data viewable through a Web browser on site?	

9. Shed Plan

When called upon on Energy Alert days how do you reduce your load?	
Is your building able keep the temperature set points on hot summer days?	☐ Yes ☐ No
Do you have any shed control ideas?	
How much kW do you think you can shed? [kW]	

Appendix D: Baseline Calculations

There are three baseline models considered for the small commercial buildings study:

1. Adjusted outside air temperature (OAT_MA) regression baseline model,
2. Adjusted 3/10 baseline model (3/10_MA), and
3. 3/10 baseline model.

The goal of this document is to describe three baseline models and outline the calculation methods so that these baselines can be developed and demand reduction feedback is provided using the various baselines.

Adjusted outside air temperature (OAT_MA) regression baseline model

LBNL has developed several baseline models to estimate the demand savings from the DR strategies. For this study, OAT baseline had to be calculated after the events because there was not a real-time outside air temperature reading that could be used to generate a dynamic baseline. Electricity consumption data for each site is collected from the current transducers that are installed as a part of the Advanced Telemetry installation. The actual metered electricity consumption is subtracted from the baseline-modeled consumption to derive an estimate of demand savings for each 15-minute period. Recent research recommends a weather-sensitive baseline model with adjustments for morning load variations (Coughlin , 2008). Weather data is obtained from the temperature sensors that are installed at each site. Being cautious about potential gaming by the customers, utilities in California offered to use a four-hour adjustment as opposed to a two-hour adjustment period. Therefore, all the morning adjusted baseline models use a morning adjustment multiplier that is calculated over four hours before the DR event starts.

To develop the baseline electric loads for the demand savings, ten "non-demand response" days are selected. These 10 baseline days are non-weekend, non-holiday Monday through Friday work days. In the OAT_MA model, first the whole building power baseline is estimated using a regression model that assumes that whole building power is linearly correlated with OAT (Motegi et al. 2004). Input data for this baseline development are 15-minute interval whole building electric demand and 15-minute interval or hourly OAT. The baseline is computed as:

$$Li = ai + bi\ Ti$$

where *Li* is the predicted 15-minute interval electric demand for time *i* from the previous non-CPP work days. Depending on the frequency of the available weather data, *Ti* is the hourly or 15-minute interval OAT at time *i*. *ai* and *bi* are estimated parameters generated within the model from a linear regression of the demand data for time *i*. Individual regression equations are developed for each 15-minute interval, resulting in 96 regressions for the entire day (24 hours/day, with four 15-minute periods per hour; *i* is from 0:00 to 23:45).

Second, the actual morning load is used to adjust the regression model. The regression model is shifted up (or down) by a multiplier that is the ratio of the actual load to the predicted load four hours prior to the event start time. The adjusted load is computed as:

$L'i = P\ Li$

$P = [\ M(t-4) + M(t-3) + M(t-2) + M(t-1)\ ] / [\ L(t-4) + L(t-3) + L(t-2) + L(t-1)]$

where *L'i* is the adjusted load for time *i*, *P* is the multiplier, and *t* is the DR event start time, *M* is the actual load of the facility and *L* is the predicted load. For example, if the event starts at noon, the actual load for hour ending at 9, 10, 11 and 12 are considered.

3/10 Baseline Model

The 3/10 baseline model is the average hourly load shape of the three highest consumption days during the DR period in the last 10 business days excluding holidays, weekends and DR event days. The baseline algorithm considers the site electric consumption during the DR period when selecting the highest three days. The 3/10 baseline may be lower than the actual demand if the site's demand is weather-sensitive. Rank Order Correlation between weather temperature and whole building loads is used to calculate weather sensitivity of buildings (Coughlin, 2008)

Morning Adjusted 3/10 (3/10_MA) Baseline Model

The same morning adjustment factor (*P*) calculated to adjust the OAT regression baseline model in the previous sections is used to calculate 3/10_MA where the adjustment factor is multiplied with each entry.

Appendix E: Results of the Field Tests

Building Use	Restaurant
Industry Classification	N/A
City	San Juan Capistrano, CA
Gross Floor Area	2,200 ft²
Conditioned Area	2,200 ft²
# of Buildings, floor	1-building, 1-floor
Peak Load kW	10 kW
Peak W/ft²	4.55 W/ft²
Tenant Type	N/A
Facility Management	Advanced Telemetry
Weekday Schedule	6:30 am - 10 pm dining room 6:30 am - 1 am kitchen
Non-weekday Schedule	6:30 am - 10 pm dining room 6:30 am - 1 am kitchen
Building Details	None

HVAC System Summary

Air Distribution Type	N/A
Air Handler Unit	2 RTUs - 7.5 tons and 12 tons
HVAC Control System	Advanced Telemetry
DDC Zone Control	No

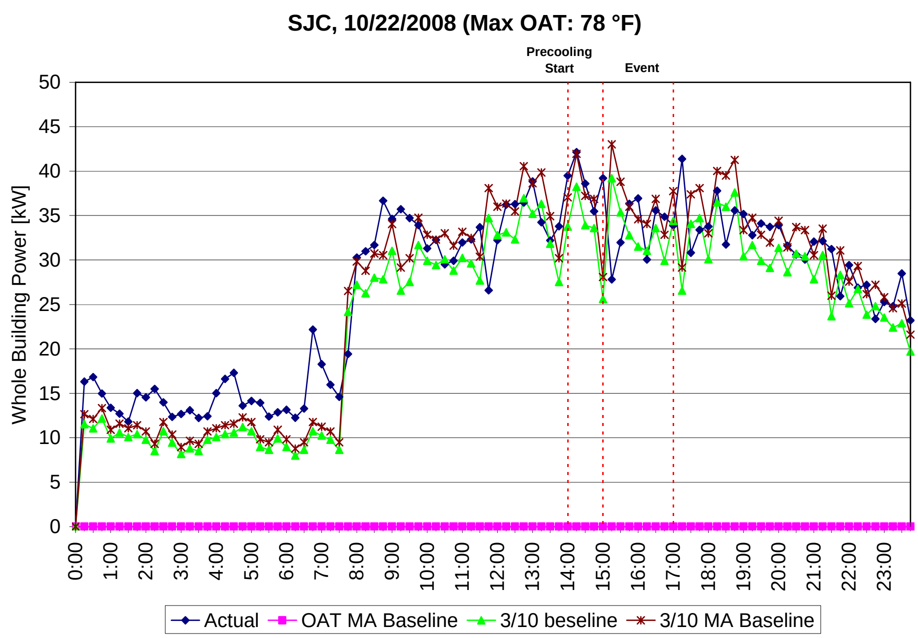
Data Trending

DDC Zone Control	EMCS Trends=yes Submeter=yes
Data Trending Detail	kitchen temp, dining room temp and kitchen and dining room thermostat set points

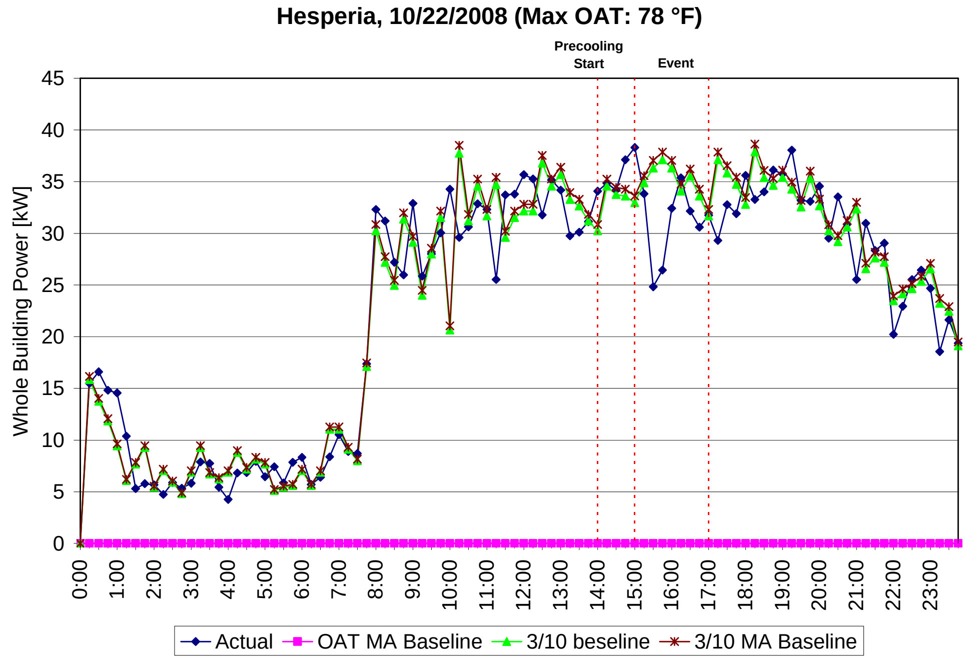
A total of four tests events were dispatched. A summary of the events and strategies are displayed below. This section displays the load profiles for each event day for each facility followed by a summary table that shows the average load shed with the three baselines.

Site	Test Date	Precooling	Start time	End Time	DR strategy
San Juan Capistrano	10/16/2008	1-2pm	2pm	3:15pm	Pre-cool at 72Deg starting at 1 pm and set up temp . 76F from 2-2:50, 77F from 2:50-3, 78F from 3-3:15, event canceled at 3:15
Hesperia	10/16/2008	No	2pm	3:15pm	76F from 2-2:50, 77F from 2:50-3, 78F from 3-3:15, event canceld at 3:15
San Juan Capistrano	10/17/2008	1-2 pm	2pm	4pm	Pre-cool starting at 1 pm and set up temp at 70Deg. 1-74, 2-75, 3-76, 4-77
Hesperia	10/17/2008	1-2 pm	2pm	4pm	precool starting at 1 pm and set up temp at 70Deg 1-76, 2-76, 3-77, 4-77
San Juan Capistrano	10/22/2008	2-3pm	3pm	5pm	Pre-cool at 70F starting at 2pm. 3-5pm 10% Shed from 3/10 MA baseline
Hesperia	10/22/2008	2-3pm	3pm	5pm	Pre-cool at 70F starting at 2pm. 3-5pm 10% Shed from 3/10 MA baseline
San Juan Capistrano	10/24/2008	11am-noon	11am	2pm	Pre-cool at 70F starting at 11am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	10/24/2008	11am-noon	noon	2pm	Pre-cool at 70F starting at 11am. Noon to 2pm, 10% Shed from 3/10 baseline
San Juan Capistrano	11/7/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	11/7/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 10% Shed from 3/10 baseline
Hesperia	11/14/2008	8am-noon	noon	2pm	Pre-cool at 70F starting at 8am. Noon to 2pm, 19% Shed from 3/10 baseline

October 22, 2008

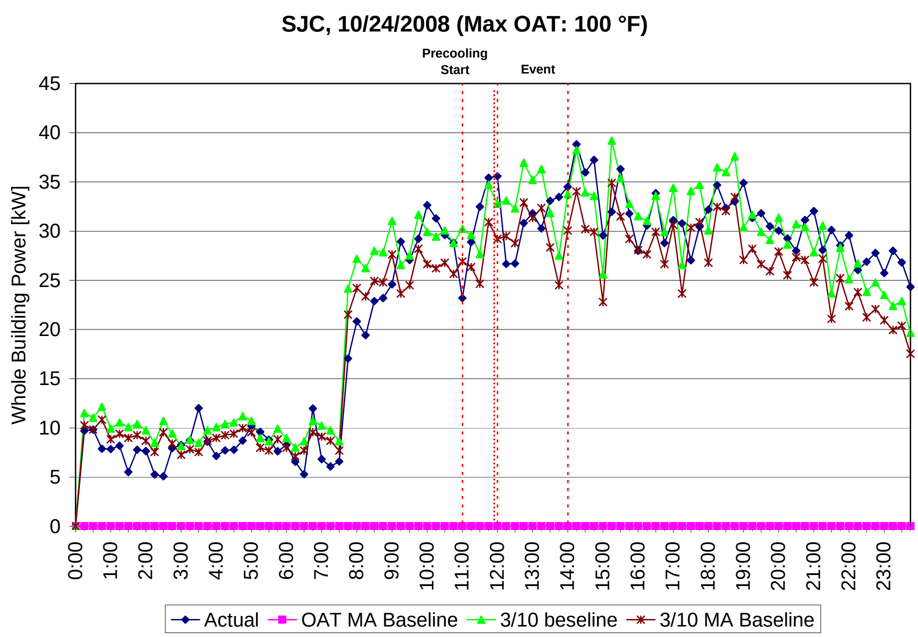


Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Oct-22	3/10	3:00-5:00	11	0	5.18	0.02	29%	-1%
	3/10 MA		15	3	6.91	1.50	35%	8%
	OAT MA		-	-	-	-	-	-

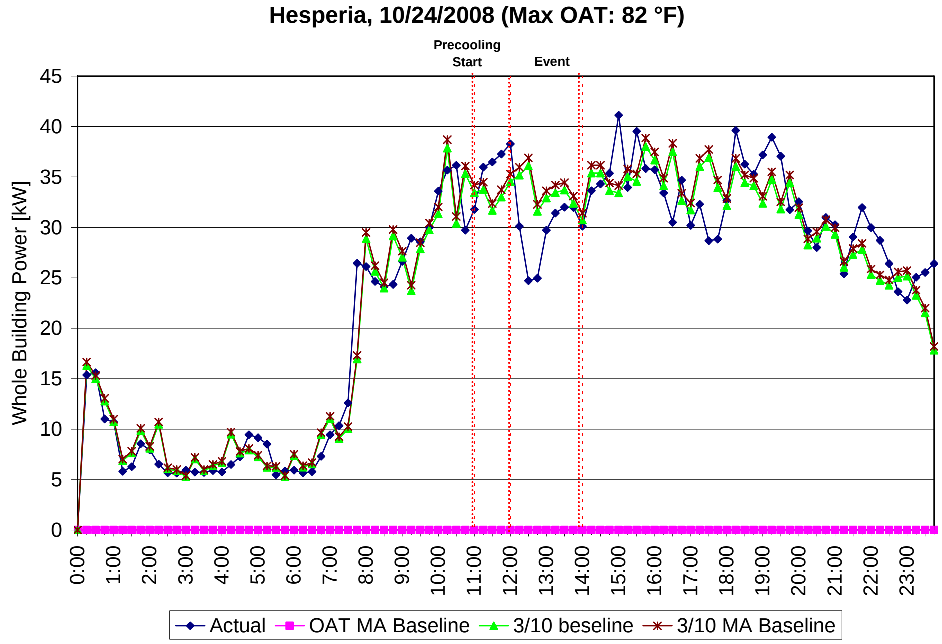


Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Oct-22	3/10	3:00-5:00	11	4	5.34	1.87	32%	11%
	3/10 MA		12	5	5.68	2.19	33%	13%
	OAT MA		-	-	-	-	-	-

October 24, 2008

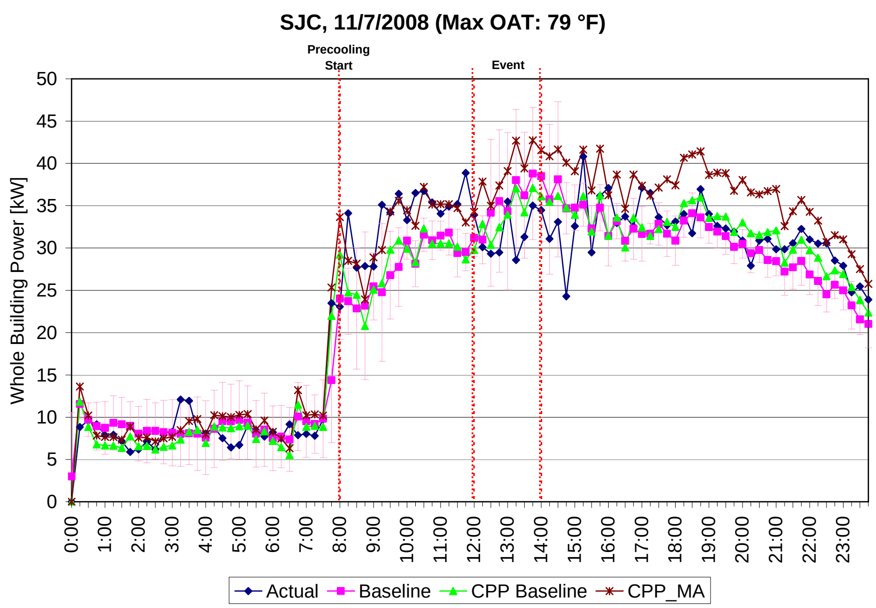


Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Oct-24	3/10	12:00-2:00	6	2	2.94	1.12	20%	7%
	3/10 MA		3	-1	1.29	-0.54	10%	-5%
	OAT MA		-	-	-	-	-	-

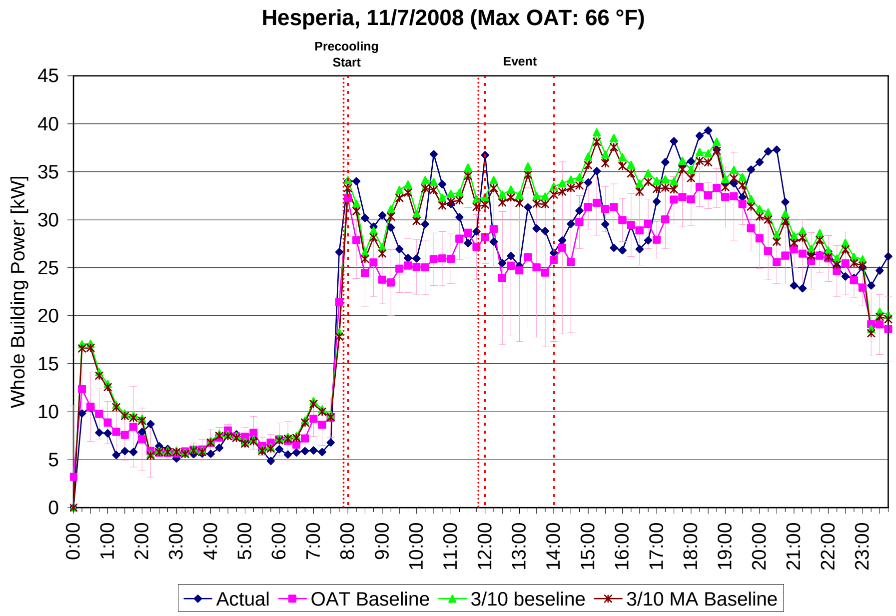


Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Oct-24	3/10	12:00-2:00	11	4	5.30	1.80	32%	11%
	3/10 MA		12	5	5.67	2.14	33%	13%
	OAT MA		-	-	-	-	-	-

November 7, 2008

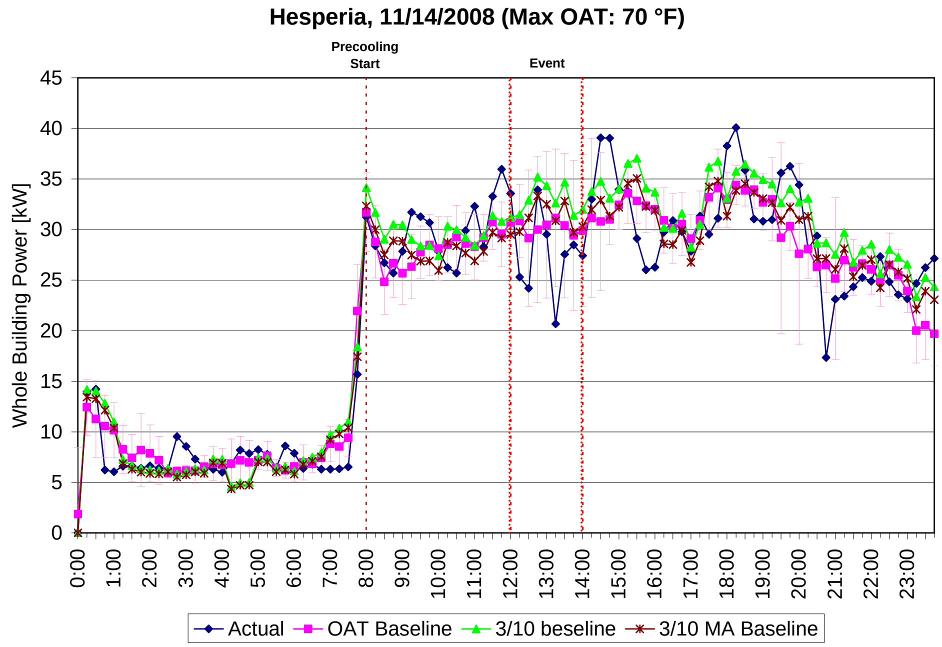


Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Nov-07	3/10	12:00-2:00	8	3	3.85	1.15	23%	7%
	3/10_MA		14	8	6.42	3.52	33%	19%
	OAT		14	8	6.42	3.52	33%	19%



Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Nov-07	**3/10**	12:00-2:00	7	6	3.43	2.68	23%	17%
	3/10 MA		7	5	3.06	2.29	21%	15%
	OAT		1	-2	0.62	-0.94	5%	-8%

November 14, 2008



Date	Baseline	Event Time	kW		W/ft²		WBP%	
			Max	Ave	Max	Ave	Max	Ave
Nov-14	3/10	12:00-2:00	12	6	5.56	2.76	37%	18%
	3/10 MA		10	4	4.75	1.94	33%	13%
	OAT		10	3	4.87	1.41	34%	10%

Appendix F: Site Selection Criteria for the Small Commercial Study

This document outlines the selection criteria for the small commercial building study with SCE. The criteria are divided into two categories: 1) minimum requirements, and 2) additional requests. Sites varying in technologies are preferred.

Minimum requirements:

1. **Type of Facility:**

Lockheed Martin Aspen study (April 12, 2006) commissioned by SCE states that the small commercial building segment of the market is dominated by retail facilities and offices. These type of facilities tend to have low load variability so it will be easier to predict and asses demand reductions and understand the repeatability aspects of demand savings. We suggest the following types of facilities:

Retail (with and without refrigeration requirements)

Office

2. **Ownership**:

One-off, Chain or small chain dictates whether they have a service contract with a vendor or not. Prefer to have sites that do not have service contracts with other vendors. County is easier than multi-tenant facilities.

3. **Size:**

While the 10 to 35 kW segment technologies are very similar to residential technologies, 150 kW to 200 kW segment tend to have technologies similar to large commercial segment so we suggest recruiting facilities whose loads are between 35 and 150 kW.

4. **HVAC System:**

Most facilities in the small commercial group tend to have packaged air-cooled HVAC systems. We suggest recruiting sites with Variable Air Volume packaged units instead of Constant Air Volume units as these systems allow for better controllability. Units may have single or double compressors. In addition, multi-zone units propose another level of complexity with which we'd like to experiment. Some important questions to be answered are:

Does the thermostat need 24V power?

Does the site have a service contract with a company?

5. **Lighting System:**

The minimum requirement for the lighting system is that it has some level of bi-level switching at the panel or at the switch leg as mandated by Title 24.

6. **Loads and occupancy schedule:**

This study is going to explore strategies for HVAC, lighting and refrigeration systems but will attempt to identify and control other loads found in the facilities.

7. **IP Connection**: Sites with some sort of always on connection (cable, DSL, T1, etc) to the Internet.
8. **Other:**

In general, we are looking for sites with low variability of hourly loads whose HVAC systems are not undersized.

Additional Requests (nice to have):

Facilities: Mixed type of facilities that combine several different uses (Office facilities with a restaurant, automobile dealer with servicing department, etc.), hotel, healthcare, restaurants or any type of facility we have not yet experimented with.
Lighting: Dimmable ballasts
Metering: Sites with interval metering so that we can have historical data and experiment with tying into the kyz output of the meter to provide feedback.

	Minimum	**Additional**
Facility Type	Retail (w/ refrigeration) Retail (w/out refrigeration) Office	Multi-type Hotel Healthcare Restaurant
Size	>35 kW <150 kW	
HVAC	Packaged units Single and multi zone NOT undersized	
Lighting	Bi-Level Switching at Panel	Dimmable Ballasts
Loads	Low variability	
Metering	N/A	Interval Metering with historical data
Other		