AUTOMATED CRITICAL PEAK PRICING FIELD TESTS:

2006 PROGRAM DESCRIPTION AND RESULTS

PIER INTERIM PROJECT REPORT

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California Energy Commission

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by binging environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

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For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

Table of Contents

List of Tables

List of Figures

Appendices

Abstract

In 2006 Lawrence Berkeley National Laboratory (LBNL) and the California Energy Commission, Public Interest Energy Research Program's Demand Response Research Center (DRRC) performed a technology evaluation for the Pacific Gas and Electric Company's (PG&E) Emerging Technologies Program. This report summarizes the design, deployment, and results from the 2006 Automated Critical Peak Pricing Program (Auto-CPP). The program was designed to evaluate the feasibility of deploying automation systems that allow customers to participate in critical peak pricing with a fully automated response. Prior to the beginning of the demand response season, LBNL recruited customers, configured sites, and tested communication and control systems. During the demand response season itself, LBNL oversaw operations, collected and analyzed building controls, load and occupant comfort data; provided peak-load reduction feedback to the customers and evaluated CPP economics for all of the participants. The program delivered an aggregated three-hour peak demand reduction of 1.2 megawatts on June 26, 2006 during a critical peak pricing event. During the severe heat wave of July 2006, all of the Auto-CPP sites continued to participate in demand response at a time when it was needed most. Full automation is technically feasible and provides value to critical peak pricing customers.

Keywords: Demand response, fully automated demand response, demand side management, peak demand reduction, PG&E Critical Peak Pricing Program (CPP), Demand Response Research Center (DRRC), Automated Critical Peak Pricing

Executive Summary

Introduction

In 2006 Lawrence Berkeley National Laboratory (LBNL) and the Demand Response Research Center (DRRC) performed a technology evaluation for the Pacific Gas and Electric Company (PG&E) Emerging Technologies Programs. This report summarizes the design, deployment, and results from the 2006 Automated Critical Peak Pricing Program (Auto-CPP). The program was designed to evaluate the feasibility of deploying automation systems that allow customers to participate in critical peak pricing with a fully automated response. The 2006 program was in operation during the entire six-month critical peak pricing period from May through October.

Method

The method for this field study included site recruitment, control strategy development, automation system deployment, and evaluation of sites' participation in actual CPP events through the summer of 2006. LBNL recruited sites in PG&E's territory in Northern California through contacts from PG&E account managers, conferences, and industry meetings. Each site contact signed a memorandum of understanding with LBNL that outlined the activities needed to participate in the Auto-CPP program. Each facility worked with LBNL to select and implement control strategies for demand response and developed automation system designs based on existing Internet connectivity and building control systems.

Once the automation systems were installed, LBNL conducted communications tests to ensure that the Demand Response Automation Server (DRAS) correctly provided and logged the continuous communications of the critical peak pricing signals with the energy management and control system for each site. LBNL also observed and evaluated demand response shed strategies to ensure proper commissioning of controls. The communication system allowed sites to receive day-ahead as well as day-of signals for pre-cooling, a demand response strategy used at a few sites.

Measurement of demand response was conducted using two different baseline models for estimating peak load savings. One was the critical peak pricing baseline model, which is based on the site electricity consumption from noon to 6 p.m. for the three days with highest consumption of the previous 10 non-weekend days; it is not normalized for weather. The second model, the LBNL-adjusted outside air temperature regression baseline model, is based on outside air temperature data and site electricity consumption from the previous 10 days, and it is adjusted using weather regressions from the 15-minute electric load data during each event day. These baseline models were used to evaluate the demand reduction during each demand response event for each site. The aggregated response from all sites for each event was also estimated using both baseline models. The evaluation research also included surveying the facility managers regarding any problems or issues that arose during the demand response events. Questions covered occupant comfort, controls issues, and other potential problems.

This 2006 Auto-CPP study included an assessment of the critical peak pricing economics for each site. This consisted of summing all of the credits on non- critical peak pricing days and subtracting the charges on critical peak pricing days. Estimates of the critical peak pricing economics without the demand response control strategies were also developed.

Results

- **Twenty-four facilities participated in the Auto-CPP program**. These facilities were a diverse set of building types, including office buildings, retail chain stores, schools, museums, laboratory buildings, a museum, and a bakery.
- **Thirteen sites participated in the majority of summer critical peak pricing events**. There were nine CPP events in Zone 1 and eleven in Zone 2 in 2006. Among the Auto-CPP sites, site responses to 125 events were fully automated and evaluated in this study. Their average peak demand reduction was 14 percent of the whole-facility load based on the three-hour high-price period. The average peak demand reduction was 87 kilowatts (kW) per facility, based on the outdoor air temperature regression baseline model. The savings using a critical peak pricing baseline without weather normalization were less than half of the savings using the outdoor air temperature regression baseline.
- The program delivered an aggregated three-hour peak demand reduction of 1.2 megawatts (MW) on June 26, 2006 during an actual critical peak pricing event.
- Even more potential was available as additional facilities came into the program in fall 2006. If all the sites that participated in 2006 provided their maximum six-hour peak demand reduction on the same day, the program could provide 1.7 MW of load reduction. If all sites provided the maximum three-hour peak demand reduction on the same day, the program could provide 2.0 MW.
- During the severe heat wave of July 2006, all of the Auto-CPP sites continued to participate in DR at a time when it was needed most. None of facilities opted out. Internal temperatures in the buildings did rise above normal conditions, with some increase in occupant complaints, but not to the point of disrupting activities in the buildings or causing facilities personnel to disable the automation.
- Full automation is technically feasible and provides value to critical peak pricing customers. One key aspect of the automation tests is that the facilities continue to participate after many years. Automation improves participation in demand response programs.

Recommendations and Future Directions

The 2006 Auto-CPP study showed that automating demand response is technically feasible. Planning for a scaled-up Automated Demand Response (Auto-DR) program for 2007, which includes other automated programs in addition to critical peak pricing, was initiated during 2006. Discussions have been underway with the three California investor-owned utilities to use a common Auto-DR infrastructure. The Demand Response Research Center will continue to support research to help understand the strengths and weaknesses of the current Auto-DR platforms and assist in identifying improvements. Specific examples of future research issues are listed below:

- **Explore Auto-DR for small commercial and large industrial sites.** One of the long-term strategies of automating demand response is to use customer relationships with current controls and communications technology vendors, informing and educating them on Auto-DR systems. Technically this project showed that most buildings with EMCS could participate in Auto-DR. Further work is needed to explore how to connect the Demand Response Automated Server with smaller buildings that do not have centralized energy management and control systems. Further work is also needed to evaluate the readiness of industrial process control systems for automation.

- **Develop common peak demand savings evaluation methods.** While the automation systems were shown to provide continuous, reliable communications of the demand response program signals, more work is needed to understand end-use control strategies. Perhaps the most critical need is to engage the engineering community and auditors who evaluate demand response strategies and estimate peak demand savings to develop common methods for savings calculations. While there are decades of experience with energy savings analysis methods and techniques, methods to estimate peak demand savings for short durations are relatively new. Such analysis methods are more complex than historical "bin" methods for energy efficiency analysis that simplify weather data into heating and cooling degree-days. Rather, new dynamic models are needed, based on knowledge of weather data, peak load shapes, and HVAC system and controls, combined in practical ways to provide simple, yet robust concepts for peak demand savings estimates.

- **Improve communication on the CPP tariff.** PG&E's critical peak pricing tariff is complex. The July 2006 heat storm resulted in one month with seven critical peak pricing events. This caused an average increase in commercial sector summer bills of 15 percent. Many of the participating sites were concerned with their high mid-summer utility bill following the heat wave. Improvements in communication by utilities with customers about bills are needed to explain the charges and credits each site is expected to collect for the entire summer if it enrolls in critical peak pricing.

- **Provide better information on the state benefits of demand response.** Demand response is a confusing term and demand response programs are confusing. More effort is needed to communicate the concepts of demand response. Automating DR may help improve the reliability of the resource, but there is a hurdle in marketing these programs because of limited understanding.

- **Consider alternative weather-adjusted baseline models.** The Auto-CPP project showed that the critical peak pricing baseline was lower than hot peak day loads prior to critical peak pricing events. When the critical peak pricing baseline is lower than the load shape, there are no estimated demand response savings. Weather-sensitive loads need weather-adjusted baseline models.

1.0. Project Background

California investor-owned utilities (IOUs) have been exploring the use of critical peak pricing (CPP) to help reduce peaks in customer end-use loads. CPP is a form of price-responsive Demand Response.[1] Recent experience has shown that customers have limited knowledge of how to operate their facilities to reduce their electricity costs under CPP (Quantum and Summit Blue, 2004). While the lack of knowledge about how to develop and implement demand response (DR) control strategies is a barrier to participation in DR programs like CPP, another barrier is the lack of automation of DR systems. Most DR activities are manual and require building operations staff to first receive emails, phone calls, and pager signals, and second, to act on these signals to execute DR strategies.

The various levels of DR automation can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as manually turning off or changing comfort setpoints at each equipment switch or controller. **Semi-Automated Demand Response** involves a pre-programmed demand response strategy initiated by a person via a centralized control system. **Fully-Automated Demand Response** does not involve human intervention, but is initiated at a home, building, or facility through receipt of an external communications signal. The receipt of the external signal initiates pre-programmed demand response strategies. The authors of this report refer to this as **Auto-DR** (Piette et al. 2005). One important concept in Auto-DR is that a homeowner or facility manager should be able to "opt out" or "override" a DR event if the event comes at time when a reduction in end-use services is not acceptable.

From the customer side, modifications to the site's electric load shape can be achieved by modifying end-use loads. Examples of demand response strategies include reducing electric loads by dimming or turning off non-critical lights, changing comfort thermostat setpoints, or turning off non-critical equipment. These demand response activities are triggered by specific actions set by the electricity service provider. Many electricity customers have suggested that automation will help them institutionalize their demand response. The alternative is manual demand response, when building staff receives a signal and manually reduces demand. LBNL research has found that many building energy management control systems (EMCS)[2] and related lighting and other controls can be pre-programmed to initiate and manage electric demand response.

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1. Demand Response (DR) is a set of time-dependent program activities and tariffs that seek to reduce electricity use or shift usage to another time period. DR provides control systems that encourage load shedding or load shifting during times when the electric grid is near its capacity or electricity prices are high. DR helps to manage building electricity costs and to improve electric grid reliability.

2. Energy Management and Control Systems are centralized controls, generally with personal computer interface, primarily for heating, ventilation, and air conditioning systems. These systems sometimes also provide lighting control, as well as control of fire and life-safety systems.

This Automated Critical Peak Pricing (Auto-CPP) project conducted in 2006 draws upon three years of previous research and demonstrations from previous projects in 2003, 2004, and 2005. The purpose of automated DR, of which Auto-CPP is one example, is to improve the responsiveness and participation of electricity customers in DR programs and to lower their overall costs. Automated DR involves systems that automatically reduce electric demand in facilities upon receipt of a signal denoting an electric grid emergency or a rise in the price of electricity. In Auto-CPP a communications signal provides notification of price variations that reflect the CPP tariff. The signal is published on a single web services server and is available on the Internet using the meta-language XML (Extensible Markup Language). Each of the participating facilities monitors this common price signal using web services client applications and automatically sheds site-specific electric loads when the price increases based on the PG&E Critical Peak Pricing Program. The system is designed to operate without human intervention during the DR period.

During 2003 and 2004, the Public Interest Energy Research (PIER)-funded Demand Response Research Center (DRRC) and LBNL conducted a series of tests of fully-automated electric demand response (Auto-DR) at 18 facilities (Piette et al., 2005a and 2005b). The overall average of the site-specific average coincident demand reductions was 10% for a variety of building types and facilities. Many electricity customers have suggested that automation will help them institutionalize their electric demand savings and improve their overall response and DR repeatability.

During 2005, DRRC and LBNL worked with PG&E to perform an initial series of tests to automate PG&E customers on CPP (Piette et al., 2006a and 2006b). This project showed that automating CPP showed promise to increase DR responsiveness and assist the sites in pre-programming DR strategies, allowing them to take place without a person in the loop.

This report focuses on and discusses the specific results of the Auto-CPP tests that DRRC and LBNL conducted during 2006. This series of new findings add to what was previously known about Auto-DR and Auto-CPP. These findings are informed by a full summer of Auto-CPP participation, CPP customer economics, and Auto-CPP events during a severe heat storm. Another new aspect of the 2006 program was the use of a third party organization, a DR Integration Services Company (DRISCO), to assist in the Auto-DR control and communications installations. The DRISCO was part of the technology transfer plan to move the technology from the research lab (LBNL) into the private sector.

The structure of this report is as follows. Section 2, Project Objectives, provides a summary of previous work and additional background followed by a discussion of the project objectives. Section 3, Methodology, outlines the project methodology covering the technology used for the automation plus the Auto-CPP program design and steps for participation. Section 3 also discusses the DRISCO role and introduces the DR control strategies and the evaluation methods used in the study. These include the peak demand baseline models, data collection methods, evaluation of effectiveness of automation, economic evaluation methods, and surveys. Section 4, Results, discusses the characteristics of the participants, automation systems used, DR control strategies, and the use and results of automation for each site on the fifteen CPP event days.

Section 4 also provides an overview of the aggregated and individual facility demand reductions. This section also provides the results of the economic analysis, with more detailed results in Appendix D. Section 5, Discussion, is a discussion of key findings relative to the project objectives and future directions of the Auto-CPP program. Section 6, Recommendations and Further Direction, presents recommendations and a discussion of next steps. Section 7, References, lists key references. Extensive appendices provide details on the DRISCO documents, CLIR and DRAS user guides, outreach and survey documents, site descriptions and details (program design, technology, facility characteristics), sites' DR strategies, peak demand reduction data, economic results, and post-event surveys.

2.0. Project Objectives

The objectives of this project were to:

- Demonstrate how an automated notification system for critical peak pricing can be used in large commercial facilities for demand response (DR). Evaluate the effectiveness of such a system. Determine how customers will respond to this form of automation for CPP.
- Evaluate what type of DR shifting and shedding strategies can be automated for CPP to provide effective DR.
- Evaluate CPP economics and the influence of various rate designs.
- Understand the costs and benefits of CPP from the building owners' perspective.
- Develop information systems for commercial customers, such as energy consumption feedback, audits, and economic analysis tools.
- Demonstrate integrated energy management using advanced controls for both energy efficiency and DR.
- Explore how automation of control strategies can increase participation rates and DR.
- Identify effective control and shedding strategies.
- Evaluate occupant and tenant response.

Comments on results for each of these objectives are provided in **Section 5, Discussion**.

3.0. Methodology

3.1. Technology

3.1.1. Control and Communication System Configuration

The 2006 Auto-CPP project used the technology developed in the 2005 Auto-CPP study with a number of additions as described below. All participants were responsible for reviewing and meeting LBNL's "2006 Automated Critical Peak Pricing Pilot Participation Requirements" (see Appendix C). The automated demand response client/server system created for this research uses the public Internet and private corporate and government intranets to communicate CPP event signals that initiate reductions in electric load in commercial buildings. The CPP signals are received by energy management and control systems, which perform pre-determined demand response strategies at the appropriate times. This section describes this system's technical details.

LBNL provided the participants one of two automation equipment options:

- web-service program source code, or
- Client and Logic with Integrated Relay (CLIR) Box (see Appendix B)

The participants agreed to work with their controls vendor or in-house staff to modify their systems to be able to retrieve the XML signal or receive a control signal, and initiate an automated demand response. In many cases the 2006 participants worked with the DRISCO.

Once the Auto-CPP system setup was completed, a test of the system was conducted. LBNL published an XML electricity price signal via the Internet that contained information to represent electricity prices for the CPP event days. This signal initiated the implementation of the facility's automated DR strategies. However, the participant was able to override the test and "opt out" if necessary.

The Demand Response Automation Server (DRAS) is at the heart of the controls and communications architecture for the Internet-based system used to enable Auto-DR in California. The DRAS was conceptualized and funded by California Energy Commission, Public Interest Energy Research (PIER), and Lawrence Berkeley National Laboratory (LBNL). The DRAS is managed by Akuacom[3] and provides a common signaling infrastructure for economic- and contingency-based demand response. The DRAS infrastructure allows each utility to communicate with energy service providers (ESCOs) and aggregators as well as customers in their territory. Since published open standards are used, ESCOs, aggregators and "trans-utility" statewide customers minimize their development effort through use of the common interface. Industry standards such as Extensive Mark-up Language (XML), Simple Object Access Protocol (SOAP) and web services are used.

3. http://www.akuacom.com/

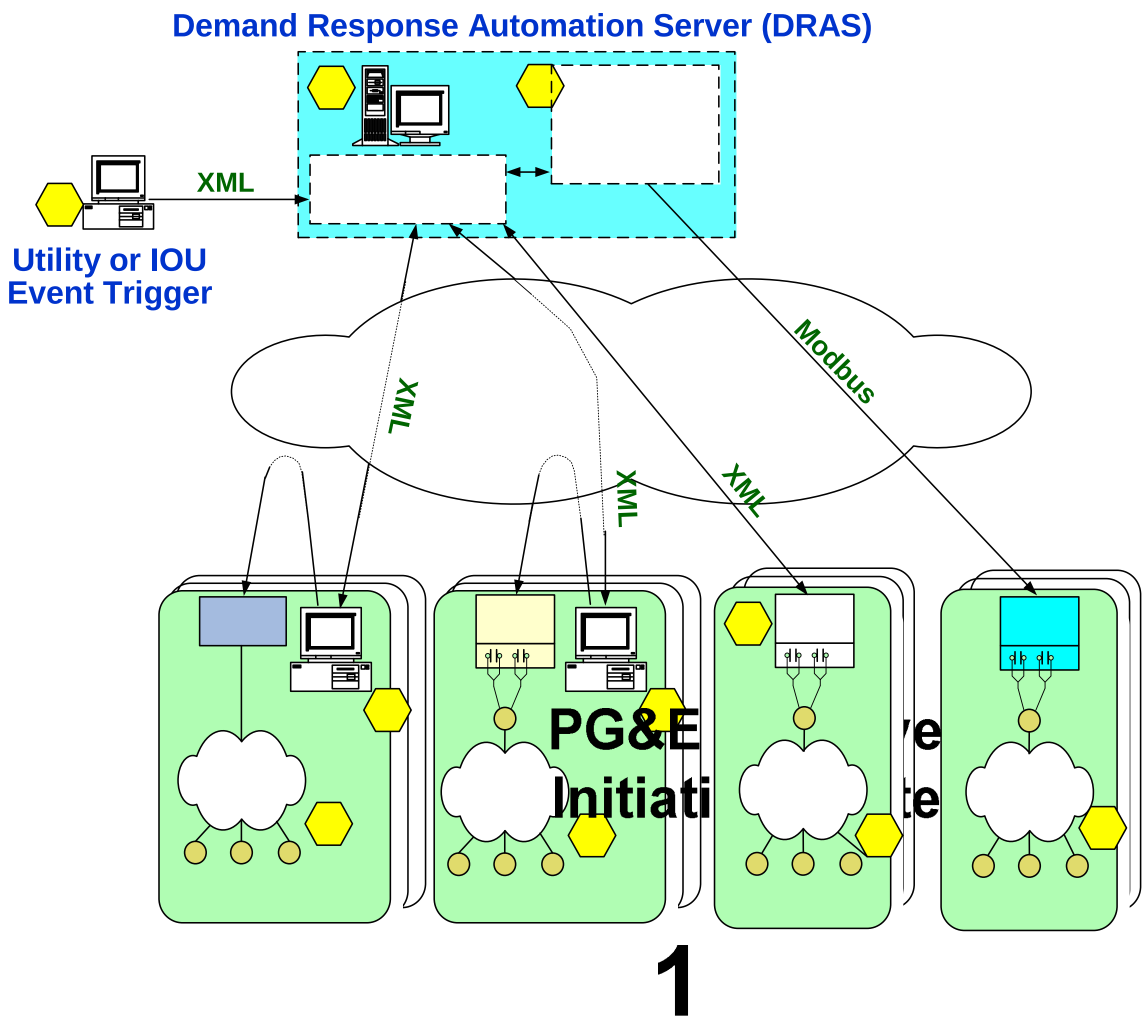

Figure 1. Auto-CPP control and communication system architecture

Figure 1 shows the Auto-CPP control and communication system architecture with four example site types. When the utility triggers a CPP event, an XML message is sent to the DRAS indicating the event date. The DRAS creates an event notification table visible to all users and publishes an event-pending signal so that all the polling clients at participating sites receive this notification information. On the day of the event, at 12 p.m., 3 p.m., and 6 p.m., the DRAS publishes the new price signals.

3.1.2. Automated Demand Response System Description

The DRAS can be used to initiate electric load sheds through virtually any control system as well as via devices that control loads directly. Care has been taken to minimize the effort required by control software developers who wish to interface their systems to the DRAS. LBNL has provided example files and descriptions to software developers. These files are designed to enable software developers to create software clients to communicate with the DRAS. The purpose of such software is to connect the DRAS to other systems as desired. The client software polls the DRAS to determine the timing and magnitude of demand response events. Generic software source code is provided as an example. Each user creates logic to shed electric loads based on DR signals and connectivity to each system based on the requirements of their site.

DRAS version 1.0 was designed and used as a research tool in 2003 and 2004. Version 2.0 was a pilot production tool designed and used as the automation "engine" of PG&E's Auto-CPP program in 2005. Version 2 was built to meet the high standards required for financial transactions using Internet technology. The version 2 server successfully met PG&E's requirements for the 2005 tests including:

1. Flexibility. The system was customized to interface with PG&E's existing CPP processes and Itron[4]'s InterActII™[5] system.
2. High availability/reliability. The system was on-line and available for every PG&E-initiated Auto-CPP event. In 2006 it proved to exceed 99.99% availability.
3. Scalability. Tests show that the 2.0 framework was more than adequate for the size of the 2005 pilot. Scalability testing indicates that the current system could support approximately 3000 "sites" with an end-to-end latency, starting with the initial notification and ending with the observance of sheds averaging less than ½ second.
4. Security. The basic server architecture was designed to be secure enough to allow LBNL to conduct further tests with utilities and other organizations in a manner that meets current industry standards for financially-binding transactions. It is of utmost importance that Auto-DR tests are secure. A security breech could become a major public relations and/or system reliability setback to the utility industry.

Version 3.0 of the DRAS added multiple user levels and collaborative work flow features as described below.

3.1.3. The DR Automation Server (DRAS) Version 3.0

To reach the next level of progress in Automated Demand Response research, it was necessary to add features and enhancements to the DRAS. The enhanced DR Automation Server 2006 (version 3.0) supported the Auto-CPP program with PG&E and a small number of tests with San Diego Gas and Electric (SDG&E) in the summer of 2006. All tests were production pilots with financial implications to the participating utilities and their customers.

The overall Auto-DR project for 2006 had several major themes. These themes, along with technical lessons learned from previous years, drove many of the features and other enhancements of the DRAS version 3.0:

- Process turnover. Researchers at LBNL further defined and documented DR processes and turned over more tasks to others (utilities and other 3rd parties such as the DRISCO).

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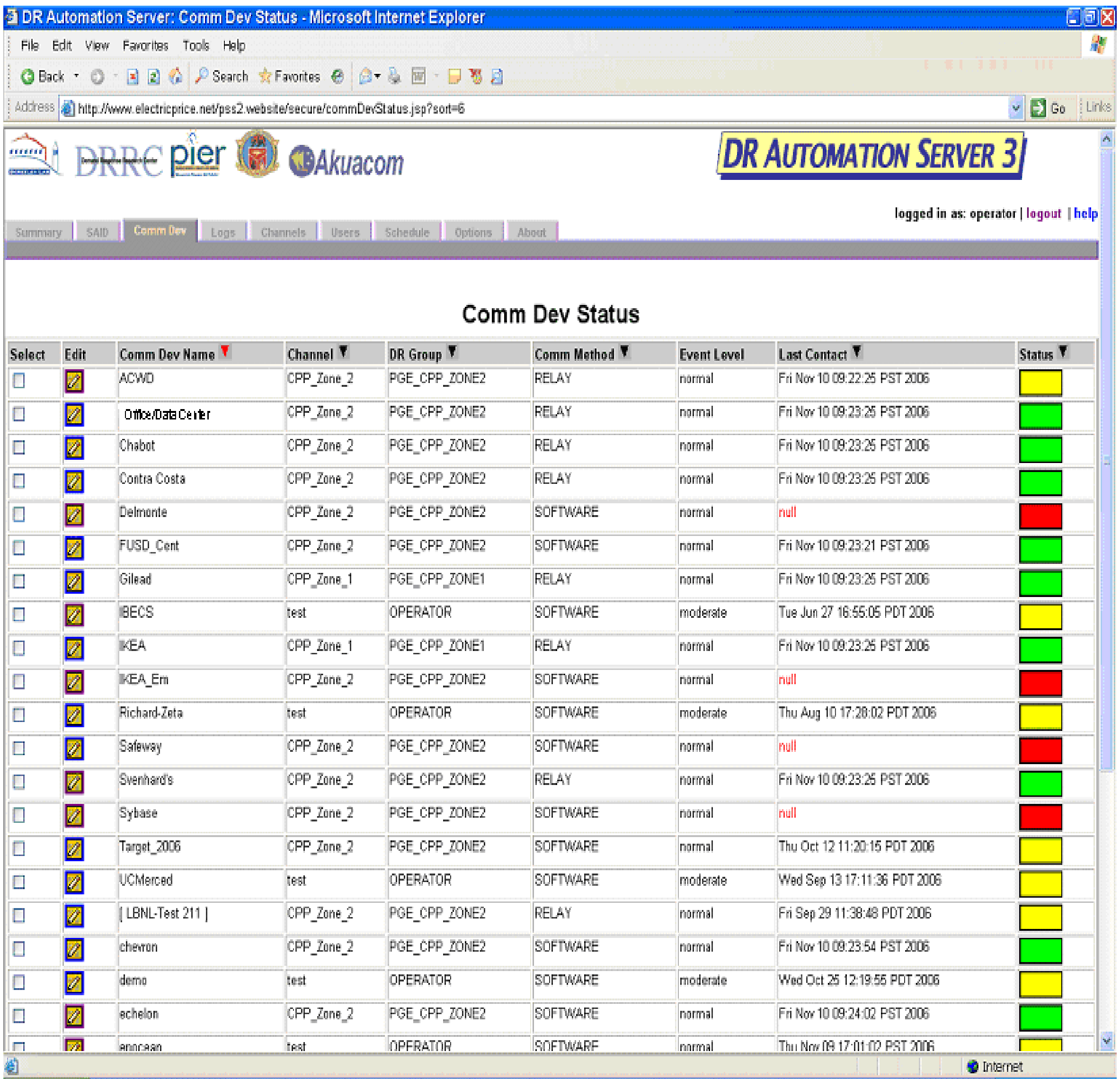
4. http://www.itron.com/

5. http://www.pge.com/biz/demand_response/interactII/index.html

- Provision of secure, reliable, customized interfaces to multiple utility partners.
- Sharing of real-time, system-level, non-sensitive load, and DR information with the California Energy Commission, researchers, and other parties.
- Continued enhancements in performance and usability.
- Cost optimization.

Figure 2 shows an example of the DRAS 3.0 Internet interface. The communication device tab (Comm Dev) shows the name of the device, program, zone, type of communication device, and current communication status.



Select	Edit	Comm Dev Name	Channel	DR Group	Comm Method	Event Level	Last Contact	Status
		ACWD	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Nov 10 09:22:25 PST 2006	
		Office/Data Center	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		Chabot	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		Contra Costa	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		Delmonte	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	null	
		FUSD_Cent	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	Fri Nov 10 09:23:21 PST 2006	
		Gilead	CPP_Zone_1	PGE_CPP_ZONE1	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		IBECS	test	OPERATOR	SOFTWARE	moderate	Tue Jun 27 16:55:05 PDT 2006	
		IKEA	CPP_Zone_1	PGE_CPP_ZONE1	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		IKEA_Em	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	null	
		Richard-Zeta	test	OPERATOR	SOFTWARE	moderate	Thu Aug 10 17:28:02 PDT 2006	
		Safeway	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	null	
		Svenhard's	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Nov 10 09:23:25 PST 2006	
		Sybase	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	null	
		Target_2006	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	Thu Oct 12 11:20:15 PDT 2006	
		UCMerced	test	OPERATOR	SOFTWARE	moderate	Wed Sep 13 17:11:36 PDT 2006	
		[LBNL-Test 211]	CPP_Zone_2	PGE_CPP_ZONE2	RELAY	normal	Fri Sep 29 11:38:48 PDT 2006	
		chevron	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	Fri Nov 10 09:23:54 PST 2006	
		demo	test	OPERATOR	SOFTWARE	moderate	Wed Oct 25 12:19:55 PDT 2006	
		echelon	CPP_Zone_2	PGE_CPP_ZONE2	SOFTWARE	normal	Fri Nov 10 09:24:02 PST 2006	
		[illegible]	test	OPERATOR	SOFTWARE	normal	Thu Nov 09 17:01:02 PST 2006	

Figure 2. Demand Response Automation Server web interface

The aforementioned overall project themes and lessons learned from previous years drove the need for the following categories of enhancements to the DRAS version 3.0 for 2006:

- Support for multiple additional operator types (e.g., operators from different utilities).
- Enhanced design and manufacturing process for hardware interface devices to each participating site with the production of the Client and Logic with Integrated Relay (CLIR) Box.[6]
- Enhanced reliability and reduced maintenance requirements.
- Continued attention to security and scalability.

LBNL gathered extensive feedback from utilities for the creation of new features for the DRAS in 2006. Requirements based on existing utility processes were implemented.

3.2. Auto-CPP Program Design

3.2.1. Program Requirements for Participation

The basic requirements to participate in Auto-CPP were as follows:

- Participate in PG&E's voluntary Critical Peak Pricing program.
- Use an energy management control system (EMCS), energy information system (EIS), or similar end-use device with a hard contact relay.
- Have interval meter connected to PG&E's InterActII™[7] energy use information system.
- Provide access to the Internet (connections from offices at the site). Having a web-enabled EMCS or EIS was preferred but not required.
- Select DR control strategies. Global zone temperature setpoint setup/setback, lighting reductions, or shutting off other non-critical loads are examples of such strategies. Each site's facilities staff considered these and other strategies that were best suited to their facility.
- Program or hardwire EMCS to curtail loads based on relay contact or XML signal. Simple program changes were to be conducted by staff or contractor.

In preparation for CPP days, the participating sites worked with LBNL on the following tasks:

1. **Sign Memorandum of Understanding (MOU).** The MOU is for mutual communication purposes. It allows the project team to ensure that each site understands the LBNL

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6. A CLIR Box is an Internet gateway device designed, built, and provided to PG&E customers (where needed) to accept Auto-CPP event signals and transmit them to the customer's EMCS for this project.

7. Energy Information System (EIS) is provided by PG&E and powered by Itron to archive/visualize 15-minute electric interval meter data for each account. PG&E customers who have over 200 kW installed can access the data via a web browser.

agreement for collaboration, and ensures the payment of the Participation award (see Appendix C).

2. **Provide General Site Data.** LBNL requests energy use information about each site including facility size, use, HVAC equipment type, etc.
3. **Define Electric Data Collection Methods.** Most commercial sites have local databases that archive data from electric meters through PG&E InterAct™, EMCS or EIS. The MOU describes allowing access to data by LBNL project staff and the project DRISCO (if applicable).
4. **Define Shed Strategies.** Successful strategies that were used in the 2003, 2004 and 2005 tests included global temperature adjustment, duct static pressure decrease, variable frequency drive (VFD) limit, cooling valve limit, and reductions in lighting usage. The project team encouraged facilities management staff to design innovative shed strategies that were appropriate for their own site.
5. **Establish Connectivity.** Each site had to be outfitted to receive the LBNL-generated price signals (or the associated operational mode signals) with one of the three following methods:
   - Client and Logic with Integrated Relay Box (CLIR Box)
   - Internet to EMCS or EIS Gateway - If the site already had a gateway that connected the EMCS/EIS to the Internet then this method could be used. If the site could currently view its EMCS data using an Internet browser then such a gateway was likely installed. Additional information can be found at http://drrc.lbl.gov/pubs/Connectivity.pdf.
   - ADAM Relay8 - LBNL supported the sites that continued to participate in 2006 that had installed ADAM Relays in 2005.
6. **Program Shed Strategies into EMCS.** Once a method of receiving the price signal was established, the EMCS could be programmed to facilitate the desired sheds upon a rise in price.
7. **Receive Price Signal.** During the CPP period (May 1st - October 31st), each participating site and LBNL received CPP notifications from PG&E. LBNL relayed PG&E's signal to participants to initiate shed events. During each shed event, each participating site automatically shed predetermined electric loads.

   To receive notification of a CPP event, customers needed to have access to the Internet and an e-mail address. In addition, all customers needed to have an alphanumeric pager that was capable of receiving a text message sent via the Internet. PG&E notifies its customers by 3:00 p.m. on a day-ahead basis when a CPP day is to occur the next business day. A CPP event may be called only Monday through Friday, excluding holidays. CPP event days are ordinarily determined based on day-ahead maximum

8. A relay with Modbus Internet control available from Advantech, http://www.advantech.com/products/

temperature forecasts at specific locations within each of two designated PG&E zones. The two zones are Zone 1 (San Francisco and San Mateo Counties) and Zone 2 (all other areas PG&E serves). Figure 3 shows the price signal on a hypothetical CPP event day where between noon and 3 p.m. the customers are subject to moderate prices and between 3 p.m. and 6 p.m. to high prices. The figure also shows the normal Time of Use (TOU) prices.

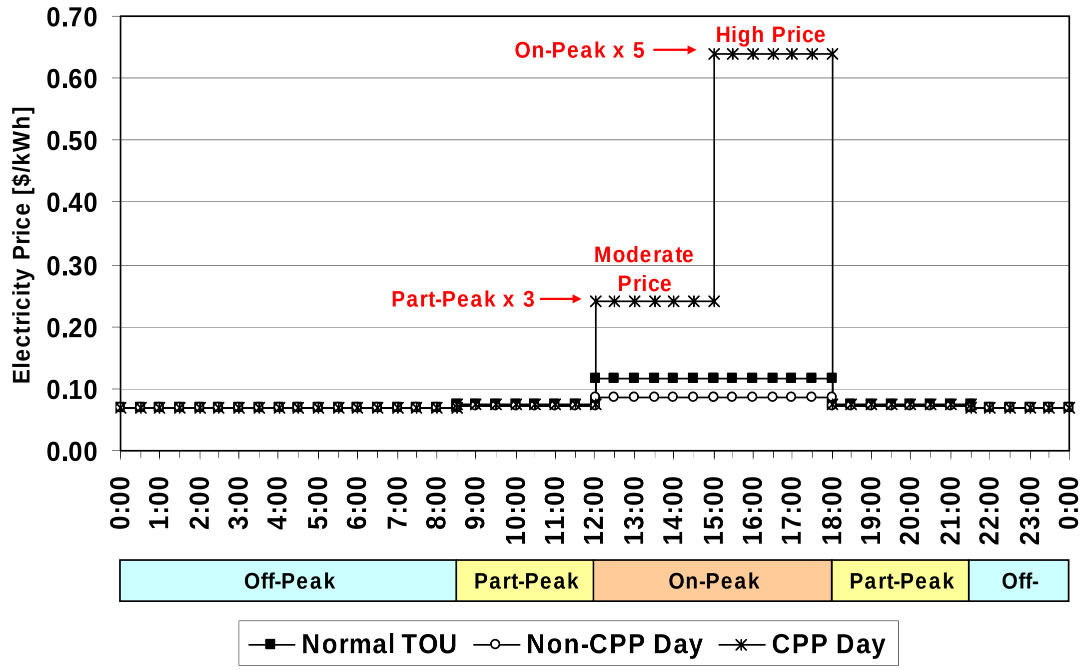

Figure 3. PG&E Critical Peak Pricing program tariff structure

8. **Document the Shed.** LBNL collected whole-building/facility electricity consumption data for each site in the pilot study. When available, LBNL also collected detailed data from an EMCS or other end-use meters to help understand the dynamics of the shed strategies.

3.2.2. Changes from the 2005 Study

With the communication infrastructure proven to work in 2005, the 2006 Auto-CPP study concentrated on recruiting different types of sites (including buildings in hot climates and industrial facilities), further developing the DR Automation Server (DRAS), and commercializing the pilot study. PG&E and LBNL planned the 2006 study to transition into a fully-automated DR program in 2007. The 2006 efforts included:

- Identifying new and different types of customers, such as sites in hot climates, manufacturing and other industrial facilities, and high-impact customers such as retail stores.

- Working with PG&E's Technology Incentives (TI) program to cover the cost of automation and to find ways to use TI funds to provide customer incentives to participate in Auto-DR programs.
- Developing the DRAS further and adding new features, such as making it accessible to multiple users with variable authorization levels, and providing web access for each customer's facility to allow control depending on moderate- and high-price periods.
- Developing the DR Integration Systems Company (DRISCO) concept by defining tasks and qualifications as well as finding a company to build capabilities.
- Conducting an economic analysis of the customers' costs and savings based on an entire year of CPP participation.

3.2.3. Recruitment Process

This section outlines the key steps used to select, educate, promote, and enroll pilot program participants. Methods used to inform potential customers about the Auto-DR program included:

- PG&E program mailings
- Discussions with customer account managers
- Outreach at meetings and conferences
- Contact with controls companies
- Contact with existing CPP and DBP (Demand Bidding Program) customers from PG&E participants list
- Audit programs
- Retro-commissioning activities
- Professional society outreach

LBNL presented plans and concepts for the research at numerous conferences and meetings. These meetings included:

- Pacific Energy Center (PEC) seminar: "Manual and Automated Demand Response and Critical Peak Pricing Strategies" (May 16, 2006, San Francisco)
- National Town Hall Meeting on DR (June 26 & 27, 2006, Berkeley)
- National Conference on Building Commissioning (May 2006, San Francisco)
- American Council for Energy Efficient Economy Summer Study on Energy Efficiency in Buildings (August 2006, Pacific Grove)
- California Energy Commission meetings
- Building Automation 2006 Conference (September 2006, San Diego)
- Pacific Industrial and Business Association Meeting (October 2006, Palo Alto)
- Silicon Valley Leadership Group Energy Forum (October 2006, Sunnyvale)

The individual steps for site recruitment in 2006 were similar to the previous year and are summarized in Appendix C. However, 2006 recruitment efforts concentrated on sites in hot climates and industrial facilities. First, PG&E provided LBNL with the most current CPP participant list. This list was sorted by region and by maximum load. Second, sites that were contacted the previous year and/or sites known to have no automation were omitted from the list. Last, sites that might be interested in DR automation were identified after phone conversations with their account managers; they were then approached about participating. All the account managers were provided with materials explaining the Auto-CPP study. Sites interested in learning more were presented with findings from the previous year's study and a summary of benefits and incentives available for participants through conference calls, online presentations, and site visits.

The recruitment goal of 20-40 participants was not met primarily because of the time-consuming nature of the PG&E TI application process, and also due to the late start of the project and the vacation schedules of decision-makers during the summer months. However, a sufficient number of participants were recruited to allow a meaningful study.

3.2.4. Demand Response System Integrator

The 2006 Auto-CPP program developed and contracted with a third party company to assist with the project. This DR Integration Services Company, or DRISCO, was an engineering and controls firm selected to assist in the coordination of fieldwork to automate demand response at each facility. As automated DR and CPP scaled up and moved toward broader adoption by electric utilities and other private sector organizations, LBNL defined and assigned tasks formerly undertaken by LBNL to the third-party DRISCO. The DRISCO provided technical assistance to commercial building managers in their efforts to participate in the Auto-CPP program.

LBNL produced on-line and printed materials that minimized the need for site visits by PG&E, LBNL, or the DRISCO. However, half of the new sites typically required site visits to assist in the installation. Ideally, in the future, the connectivity systems will be simple enough for existing staff to configure, since some of the sites may be as far north as Humboldt County and as far south as Santa Barbara County.

LBNL identified the selection criteria and task activities for the DRISCO (see Appendix A). C&C Building Automation[9] was the firm selected as the DRISCO. The tasks that the DRISCO undertook are included in Appendix A.

3.2.5. DR Control Strategies

The key contacts at each customer site were asked to develop two levels of demand response, one for the moderate-price period, and a second for the high-price period. This was recommended because responding to a six-hour event can be difficult using one strategy, especially an HVAC strategy. Section 4.2.3 further discusses this approach. Most of the sites

9. http://www.ccbac.com/

programmed their EMCS to reduce HVAC system electric loads, while some included lighting sheds. In general, the site staff made their own decisions regarding which DR control strategies to employ. LBNL and the DRISCO consulted with sites as needed to determine available DR strategy options.

LBNL developed a guide, *Introduction to Commercial Building Control Strategies and Techniques for Demand Response*, for DR control strategy installation based on case studies from previous Auto-DR research activities and other researchers to facilitate understanding of DR strategy installation among facility managers, building owners, controls contractors, and DR auditors (Motegi et al., 2007).

One challenge of the 2006 Auto-CPP pilot was to streamline the DR strategy installation process and define a feasible business model without the assistance of a researcher. During the 2006 pilot, LBNL prepared materials and work flowcharts to transfer the technical coordination work to third party companies (see Appendix A). Another challenge of this pilot was to utilize incentives provided by the utilities to cover the cost of DR automation equipment installation. The following steps describe the procedure used to develop the TI application for Auto-DR control strategies; these activities should be supervised by a "Technical Coordinator[10] (TC)" or DRISCO. The procedure includes planning, installation, and implementation, and is designed to maximize demand savings while minimizing service level changes and impacts to occupants.

1. **Initial site inspection.** At the beginning of DR strategy planning, the TC collects all the necessary information on the site. These data include building type, floor area, HVAC and lighting system profiles, EMCS profiles, and historical electricity demand data.
2. **DR strategy sequence of operation.** Together the TC, facility managers, controls contractors, and other key personnel evaluate DR strategies to determine system capabilities, potential impact to occupants, potential demand savings, and other relevant factors. Each DR strategy needs to be evaluated and a detailed control sequence developed so that the controls contractors can understand exactly what is needed for EMCS programming and additional hardware installation.
3. **Demand savings potential estimation.** The TC makes a preliminary estimate of demand savings potential to estimate the benefits of participating in the DR program and to justify the project cost. While the estimation of demand savings from lighting DR strategies can be relatively simple, the demand savings from HVAC DR strategies are complicated by weather and other factors.
4. **Performance monitoring plan.** Along with the DR strategy sequence of operation, EMCS data collection methods should be developed by the facility management team for monitoring purposes. EMCS trend data are helpful to evaluate the execution of DR strategies.

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10. Technical Coordinator (TC) is a term proposed for use in the 2007 Auto-DR Program. Appendix A outlines the roles and responsibilities of the TC.

5. **Proof-of-concept manual test.** It is recommended that the facility management team perform a manual DR strategy test. The TC should supervise the test and analyze the trend data after the test. If the demand savings from the DR strategies are weather-dependent, such a test should preferably be conducted on a warm day that can represent a DR event day (at least 85°F or higher). If operational problems or complaints occur even though the sequence of operation is successful, the strategies should be reconsidered. The test results should be compared with the preliminary demand savings potential estimate. If there is difficulty conducting both a demand savings estimate and a manual test, at least one should be performed (manual test is preferred). Obstacles to manual testing include seasonal weather conditions, concerns about distracting occupants without a real DR situation, and lack of sophisticated controls (e.g., hundreds of zone setpoints that cannot be changed simultaneously without automation).
6. **DR strategy proposal.** Based on the DR strategy sequence of operation developed in the previous step, the controls contractor develops a project proposal for the client.
7. **DR strategy installation.** When the facility manager accepts the project proposal, the controls contractor starts the EMCS programming and hardware installation as specified in the proposal.
8. **Post-installation test.** When the DR strategy installation is completed, the facility manager tests the strategies to 1) confirm that the strategies work correctly as specified in the sequence of operation and 2) verify the demand savings potential as estimated in the calculation and the pre-installation test. Confirmation of correct operation is critical, and may be done on a cool day with a shorter duration than actual DR events. EMCS trend data should be collected during the test. After the test, the TC should check the EMCS data, especially for the modified parameters, to see if the controls change occurred as planned. If it did not occur, the EMCS programming should be revised.
9. **Measurement and verification.** The TC should continue measurement and verification (M&V) efforts during the actual curtailment. If the post-installation test was conducted before the hot summer season, the reduction in service can be larger and the demand savings can be widely different during the real curtailment than in the test. The DR operation should be carefully reviewed, especially until the first or second curtailment is completed. The facility manager should modify the strategies to maximize demand savings while minimizing impact to occupants.

Completing all the steps above may take several months or more, depending on the effort required for coordinating the process among facility managers, controls contractors, and upper management decision-makers. It is important to prepare DR strategies well in advance of the peak summer season.

3.3. Evaluation

3.3.1. Peak Demand Baseline Models

Adjusted outside air temperature (OAT) regression model baseline

LBNL has developed several baseline models (e.g., OAT regression, morning adjustment, outside air temperature regression with morning adjustment) to estimate the demand savings from the DR strategies. For this study, the electricity consumption data for each site were collected from InterAct™. The actual metered electricity consumption was subtracted from the baseline-modeled consumption to derive an estimate of demand savings for each 15-minute period. Previous research recommended a weather-sensitive baseline model with adjustments for morning load variations (KEMA-XENERGY, 2003). Therefore, the LBNL adjusted OAT regression baseline model uses outside air temperature regression with a scalar adjustment for the morning load.

To develop the baseline electric loads for the demand savings, LBNL selected 10 "non-demand response" days. These 10 baseline days were non-weekend, non-holiday Monday through Friday work days.

In LBNL's 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). The source of the OAT data is described in the following section. Input data 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 morning power load is used to adjust the regression model. The regression model is shifted up by the average difference between the actual demand and the predicted demand of the three-hour period immediately prior to the shed control. The adjusted load is computed as:

$$L'i = Li + P$$

$$P = Average\ (Li - Mi)$$

where *Li* is the adjusted load for time *i*, *P* is the calibration ratio, and *Mi* is the actual demand for time *i*. The three hours immediately prior to the shed control are used to calculate *P*.

The demand savings estimates for most of the buildings and Auto-CPP event days were based on this OAT regression baseline model with morning load shape adjustment. However, the pre-cooling sites used the OAT regression model without the morning load shape adjustment because morning adjustment for pre-cooling sites overestimates the afternoon loads.

If the model predicts a lower baseline than the actual demand at any given 15-minute period, it indicates negative demand savings. Negative demand savings are often found after a DR period as part of a "rebound" or recovery peak in which the HVAC system tries to bring the thermal zones back to normal conditions.

The evaluation included quantifying the demand savings (kW) at each site, calculated by subtracting the actual whole building power from its calculated baseline demand. It also included calculating the demand savings percentage, defined as the percentage of savings of whole building power, and estimating the demand-savings intensity (W/ft^2) as the saved demand normalized by the building's conditioned floor area.

CPP baseline

PG&E uses a CPP baseline for its CPP event evaluation. The CPP baseline is the average hourly load shape of the three highest consumption days in the last 10 work days (excluding holidays). The baseline algorithm considers the site electric consumption from noon to 6 p.m. when selecting the highest three days. CPP event days are excluded from the 10 reference days. The CPP baseline may be lower than the actual demand if the site's demand is weather-sensitive, since a CPP day typically occurs on a day with higher outside temperatures. If the previous 10 working days were cooler than the CPP day, the baseline tends to be lower. Since the CPP tariff is based on price per kWh, the baseline calculation does not have any financial impact.

PG&E also develops their Demand Bidding Program (DBP) baseline using a similar procedure. The DBP baseline uses the site electric consumption from noon to 8 p.m. to select the highest three days from the last 10 work days.

For commercial buildings, the CPP baseline typically shows a lower estimate than the LBNL adjusted OAT regression baseline on CPP days. Generally, in northern California climates, high OAT days occur several days in row right after moderate OAT days. The CPP baseline can only use moderate OAT days from the previous 10 days and may underestimate the electric demand of high OAT days if the building demand is weather-sensitive.

As an example, Figure 4 shows the 2530 Arnold Street whole-building baseline time-series chart of the CPP event on June 21st, 2006. The chart shows the actual whole building power plus the LBNL adjusted OAT regression baseline and the CPP baseline. Recall that these baselines estimate what the whole-building power would be if the demand response had not occurred. The vertical line at each baseline power data point is the standard error of the regression estimate. The vertical lines at noon, 3 p.m., and 6 p.m. indicate times of price changes.

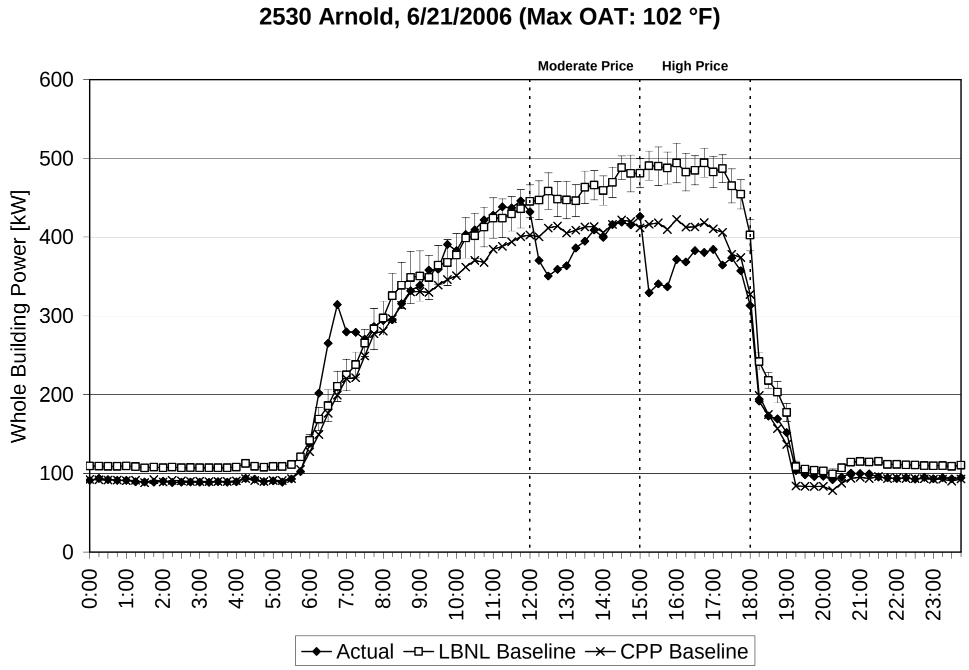

Figure 4. Example of OAT regression and CPP baselines and actual building data

3.3.2. Data Collection

LBNL collected data to evaluate the demand savings and changes in building systems and conditions. For all participating sites, LBNL collected whole building 15-minute-interval power data. A minimum of 10 days of data prior to each CPP event was required to develop a baseline model. LBNL also collected HVAC, controls, communications, energy, and other building-related time-series data relevant to each DR strategy. Section 4.2.2 describes the data collection methods. Additional information about the effectiveness of the DR strategies and issues that arose from the DR implementation was obtained by interviewing the responsible building engineer after each Auto-CPP event. Appendix H documents the raw data obtained from the post-event surveys.

Outside air temperature (OAT) data

LBNL gathered OAT data for each site to develop the OAT regression baseline model. The following data sources were used:

- **NOAA (National Oceanic & Atmospheric Administration)**: InterAct™ has a real-time subscription for NOAA hourly local temperature and dew point data. Most of these data are from weather stations at nearby airports. While useful when the weather stations are near the site being evaluated, the online weather data archives can be problematic when the weather stations are not close to the site. This is especially true in the San Francisco Bay Area, where microclimates vary significantly – even within a single city. Hence, LBNL used other sources to supplement the NOAA data.

- **CIMIS (California Irrigation Management Information System)**: CIMIS provides hourly weather data via website (http://www.cimis.water.ca.gov). Currently CIMIS has approximately 200 weather stations in California.
- **Building weather station**: Some buildings have an on-site weather station and the weather data may be monitored by the building's EMCS. This can be the most accurate data source if the sensors are properly calibrated. However, the data must be carefully examined, as many weather stations were poorly commissioned. Also, correction must be done where the OAT temperature data is the outside air intake temperature at an AHU rather than the true OAT. At one site, the 50 Douglas building, PowerLight (the solar electric system provider)[11] provides 15-minute interval on-site weather data via the Internet collected at a weather station on the building rooftop.

3.3.3. Participation Success

Each Auto-CPP event was reviewed for problems that might have occurred in the control and communication systems. Six milestones had to be met – from the DRAS to the end-use control strategy – for the system to work properly. (The participation record of each site is summarized in Table 7 in Section 4.3.1.)

1. **Readiness:** The system was configured and ready to be tested by the research team.
2. **Approval:** The customer approved demand responsive load control. If approval was not granted, the site opts out from the event (designated "Opt out" in later analysis).
3. Price client to DR automation server communication: The price client successfully obtained the correct electricity prices from the DRAS (Figure 1 between ⟨2⟩ and ⟨3⟩). Failure to pass this milestone was generally caused by the price client server being down or overloaded.
4. **Internet gateway or relay communication:** The communication was successful between the computer containing the price client and associated logic software and the Internet gateway or Internet relay located at each site (Figure 1 between ⟨3⟩ and ⟨4⟩). Failure to pass this milestone was generally caused by: a) blockages of the Internet-based command signals due to firewalls, disconnection or network reconfiguration or b) failures in the Internet gateway or Internet relay devices.
5. **Control of equipment:** Target equipment was controlled as planned. Target equipment included HVAC equipment, lighting, and other equipment. Failure to pass this milestone was generally caused by: a) HVAC equipment not responding to command signals over the EMCS network or b) the relay being physically disconnected from the control panel.
6. **Effectiveness:** To pass this milestone, the planned demand response strategy must have been proven to effectively reduce electric demand. Effectiveness was tested by comparing the average power (kW) savings during the test to the average standard error

11. http://www.powerlight.com/

of the regression model. The demand response strategy was considered effective if in either or both of the moderate-price or the high-price periods the average power savings over the 3-hour period were larger than the standard errors in the baseline model.

3.3.4. Economic Analyses and Surveys

The 2006 Auto-CPP study provided a new opportunity to evaluate CPP economics since 13 Auto-CPP sites participated in a full CPP season. Analysis of the electricity bills revealed the following:

- **CPP charges** occurred during moderate-and high-price periods on a CPP event day. When there were many CPP events in one billing period, CPP charges tended to be high for that billing period.
- **CPP credits** were collected by the facilities on non-CPP days for their kWh usage. In billing periods with high number of CPP events, CPP credits tended to be lower because there were not as many days to collect credits.
- **Demand charges** are the costs associated with maintaining sufficient electrical distribution facilities at all times to meet each customer's highest demand for energy. LBNL checked that none of the sites incurred demand charges during the DR recovery period.

The utility bills were analyzed to extract the following information:

- **Overall change in energy costs** during the CPP season. This change compared the credits earned on non-CPP days with the charges accrued on CPP days. This information determined if the customers saved money under CPP.
- **Estimated change in energy costs without DR**. This information represented the potential May through October electricity costs during the CPP season without the DR shed strategies. LBNL estimated whether customer costs would have increased or decreased.
- **Impact of seven CPP days in one monthly billing period**. The heat storm of 2006 caused the CPP events to be grouped in one billing period. LBNL evaluated the percentage change in the monthly costs to examine how large an impact the CPP tariff had on monthly cost variation.

Section 4 presents results of the economic analyses. LBNL developed a survey for acquiring facility characteristic data to evaluate whether a site was a good candidate for Auto-DR. This “Site Survey” is further described below. A second survey, the “Post-Event Survey,” was used to evaluate any problems, comfort issues, or other information the sites wanted to report. A third survey, the “Cost of Automation Survey,” was used for sites that did not go through the TI process. The Site Survey and Post-Event Survey forms are found in Appendix C and the

Post-Event Survey results are presented in Appendix H. All of these surveys are available at LBNL's DR download website.[12]

Site Survey

This detailed survey collected the following information from each site that participated in the pilot study. Key data collection fields included:

- Site contact information
- Building information
- Electric demand levels
- HVAC system specifications
- Cooling and heating plant equipment
- Domestic hot water system specifications
- Lighting system information
- Process and other equipment loads

Post-Event Survey

After each CPP event, each site was reminded to fill out the post-event survey. This survey collected the perceptions of the facility operator about the automated CPP day. Questions asked were:

- Was the operator on-site and watching the event?
- Did s/he notice a change?
- Were there any operational issues?
- Did the occupants notice any difference?
- Were there any complaints?

Table 1 shows the sites and the surveys they completed. "No Zone 1" means the event took place in Zone 2 and not Zone 1. "Not Ready" means that the site's automation was not completed prior to the event.

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12. Site Survey: http://www.surveymonkey.com/s.asp?u=868801590056
Cost of Automation Survey: Available at http://www.surveymonkey.com/s.asp?u=790671962171
Post-Event Survey: Available at http://www.surveymonkey.com/s.asp?u=446391966685

Table 1. Post-event surveys

	21-Jun	22-Jun	23-Jun	26-Jun	17-Jul	18-Jul	20-Jul	21-Jul	24-Jul	25-Jul	26-Jul
ACWD	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	
Office/Data Center	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Chabot	Done	Done	Done	Done	Done	Done	Done	Done	N/A	N/A	Done
50 Douglas	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
2530 Arnold	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
MDF	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done	Done
Echelon	Done	Done	Done	Done	Done	Done	Done	Done	Done		
Irvington					Done	Done	Done	Done	Done	Done	Done
Gilead 300	No Zone 1	No Zone 1	Done	No Zone 1			No Zone 1			No Zone 1	No Zone 1
Gilead 342	No Zone 1	No Zone 1	Done	No Zone 1			No Zone 1			No Zone 1	No Zone 1
Gilead 357	No Zone 1	No Zone 1	Done	No Zone 1			No Zone 1			No Zone 1	No Zone 1
IKEA Palo Alto	No Zone 1	No Zone 1	Done	No Zone 1	Done	Done	No Zone 1	Done	Done	No Zone 1	No Zone 1
Oracke Rocklin											
Solectron	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready
Svenhard's	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready	Not ready
Target Hayward	Done	Done									

	9-Aug	31-Aug	1-Sep	22-Sep
ACWD	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Office/Data Center	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Chabot	No Zone 2	No Zone 2	No Zone 2	No Zone 2
50 Douglas	No Zone 2	No Zone 2	No Zone 2	No Zone 2
2530 Arnold	No Zone 2	No Zone 2	No Zone 2	No Zone 2
MDF	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Echelon	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Irvington	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Gilead 300	Done			
Gilead 342	Done			
Gilead 357	Done			
IKEA Palo Alto	Done	Done	Done	Done
Oracke Rocklin	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Solectron	Not ready	Not ready	Not ready	Not ready
Svenhard's	Not ready	Not ready	Not ready	Not ready
Target Hayward	No Zone 2	No Zone 2	No Zone 2	No Zone 2
USPS	Not ready	Not ready	Not ready	Not ready

Cost of Automation Survey

The purpose of this survey was to collect data to estimate the total cost of automating the DR shed strategies selected by each site. Breakdowns of costs by key categories such as hourly labor and total completion time were collected for hardware installation, software programming, EMCS programming and EMCS trend setup. No new data were added in 2006, but some results from the 2005 Cost of Automation survey are presented in Section 4.

Initial costs required for the Auto-CPP setup were collected and compared against the demand savings. For participant sites that continued Auto-CPP from previous years, the costs required for the initial setup in the previous year were collected. Table 2 shows these costs broken down by category. Many of the early participant sites set up their Auto-DR using their own labor or under their existing control contracts. Therefore, it was hard to capture their exact initial setup costs.

From the data collected through this survey, the cost of automation was estimated to be $3,000 to $5,000 for each site.

During the 2006 demonstration LBNL began applying for and using PG&E's DR Technology Incentive (TI) applications to recover the Auto-CPP setup costs. The TI application requires a detailed cost estimate. The initial cost data for the new Auto-CPP sites that went through the TI process are summarized in section 4.5, Table 14.

Table 2. Auto-DR Cost Categories

Costs Category	Persons in Charge	Description/Notes
EMCS programming	Controls contractors or in-house personnel	EMCS programming to set up DR control strategies
EMCS trend setup	Controls contractors or in-house personnel	Setup data trending for EMCS.
Software client programming	Software programmers or in-house personnel	Only for software client sites
Hardware procurement	Control contractors or in-house personnel	Additional hardware purchase including CLIR box
Hardware installation	Control contractors or in-house personnel	Relay, CLIR box, or other hardware installation and additional wiring work
Project administration	Facility managers	Facility managers' time for meetings and coordination

4.0. Results

This section outlines the key results from the 2006 Auto-CPP tests. The discussion contains a review of participant characteristics, summary of demand savings, cost analysis results, and discussion of the baselines.

4.1. Site Profiles

This section describes the 24 sites that participated in the Auto-CPP pilot during 2006. Fourteen sites were continuing sites from the 2005 demonstration and 10 sites were new in 2006. Table 3 lists the site name, location, CPP zone, building use, floor space, and peak electric demand in summer 2006. The participant buildings include 12 office buildings, seven retail stores, two schools, an electronics manufacturer, a museum, a bakery, and a detention facility. Some office buildings contain laboratories or data centers.

Table 3. Summary of Site Information

Site Name	Short Name	Location	CPP Zone	Building Use	# of Bldg	Floor Space		Peak Load kW
						Total	Conditioned	
Alameda County Wat	**ACWD**	Fremont	2	Office, lab	1	51,200	51,200	348
Bank of America, Con	**Office/Data Center**	Concord	2	Office, data center	4	616,000	708,000	5712
Chabot Space and Sci	**Chabot**	Oakland	2	Museum	2	86,000	86,000	336
Contra Costa County,	**2530 Arnold**	Martinez	2	Office	1	131,000	131,000	536
Contra Costa County,	**50 Douglas**	Martinez	2	Office	1	90,000	90,000	459
	MDF	Martinez	2	Detention Facility	1	172,300	172,300	561
Echelon, San Jose Hea	**Echelon**	San Jose	2	Hi-tech office	1	75,000	75,000	523
Fremont Unified Scho	**Centerville**	Fremont	2	Junior High school	1	NA	NA	332
Fremont Unified Scho	**Irvington**	Fremont	2	High school	1	186,000	186,000	446
Gilead Science, 300 La	**Gilead 300**	Foster City	1	Office	1	83,000	83,000	288
Gilead Science, 342 La	**Gilead 342**	Foster City	1	Office, Lab	1	32,000	32,000	495
Gilead Science, 357 La	**Gilead 357**	Foster City	1	Office, Lab	1	33,000	33,000	662
IKEA, East Palo Alto	**IKEA EPaloAlto**	East Palo Alto	1	Furniture retail	1	300,000	300,000	1191
IKEA, Emeryville	**IKEA Emeryville**	Emeryville	2	Furniture retail	1	274,000	274,000	1466
Oracle Corporation, R	**Oracle Rocklin**	Rocklin	2	Office	2	100,000	100,000	808
Solectron, Corporate	**Solectron**	Milpitas	2	Office, Manufacture	9	499,206	499,206	4655
Svenhard's Swedish B	**Svenhard's**	Oakland	2	Bakery	1	101,000	101,000	696
Sybase, Corporate He	**Sybase**	Pleasanton	2	Hi-tech office	2	425,000	425,000	1995
Target, Hayward Stor	**Target Hayward**	Hayward	2	Retail	1	130,000	130,000	449
Target, Antioch Store	**Target Antioch**	Antioch	2	Retail	1	140,686	140,686	572
Target, Bakersfield St	**Target Bakersfield**	Bakersfield	2	Retail	1	143,941	143,941	645
Total					34	3,384,706	3,476,706	21,958

Of the 24 sites, 10 sites (Centerville, IKEA Emeryville and West Sacramento, Safeway Stockton, Sybase, Svenhard's, Sybase, Target Antioch and Bakersfield, and Walmart Fresno) did not participate in the 2006 Auto-CPP events due to late completion of their system setup. Irvington was excluded from the demand savings analysis because the school was on summer vacation and the HVAC system was not active on the CPP event days even though the automation was fully functional.

4.2. Auto-CPP System Profiles

4.2.1. Auto-CPP Communications

Table 4 summarizes the connectivity options used by the sites. Of the 24 participant sites, five sites chose to program their own polling software client. Echelon and Target Hayward had been utilizing the software client since 2005 and used the same client in 2006 without any modification. The new Target sites (Antioch and Bakersfield) shared a newly-developed software client for their 2006 participation. Although all three Target sites were controlled remotely from a central location, separate software clients were required because the control systems were different at Hayward from those at the other two sites. Walmart also used a software client in their network control system.

Eight sites used CLIR boxes to communicate with the DRAS. Two sites (Irvington and Oracle Rocklin) had been the initial demonstration sites of the CLIR box at the end of the 2005 demonstration. The remaining six sites were new participants in 2006 and installed CLIR boxes on site.

Eleven sites used an Internet relay to communicate with the DRAS. Of the 11 sites, nine were continuing participants from 2005. Gilead used one relay to control all three buildings. Previously Contra Costa County Buildings (2530 Arnold and 50 Douglas) had individual relays at two sites; in 2006 the network control system was upgraded and both sites were remotely controlled from one relay. MDF newly participated in 2006 and hooked up directly to the remote control system. Although they made modifications in their controls communication system, MDF preferred to use an Internet relay because they were accustomed to using the device and they had a sophisticated firewall system to eliminate risk. Svenhard's also chose the Internet relay option because they had to install the communication device directly on their pan washer, which was located in a hot and humid environment; LBNL was concerned that the CLIR box might not be suitable to such an environment. Svenhard's also had no problem using Internet relay since they had a sophisticated firewall system.

Based on the communication technology adopted by the sites, the price client locations were then distributed. While some were on-site, some were at a central management facility outside of California, and some were located in the co-location facility ("Co-Lo" in the table) where the DRAS resides.

Table 4. Auto-CPP Communication Profiles by Site

Site	Communication Method	Device	Price Client Host	Price Client Host Location	Price Client Hosted at Co-Lo
ACWD	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
Office/Data Center	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
Chabot	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
2530 Arnold	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
50 Douglas	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Echelon	Software client	i.LON	Kenmark	San Francisco, CA	No
Centerville	CLIR	CLIR	CLIR	Fremont, CA	No
Irvington	CLIR	CLIR	CLIR	DRAS Co-Lo	Yes
Gilead 300	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Gilead 342	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
Gilead 357	Relay w/WAN	ADAM6060	DRAS	DRAS Co-Lo	Yes
IKEA EPaloAlto	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
IKEA Emeryville	CLIR	CLIR	DRAS	DRAS Co-Lo	Yes
Oracle Rocklin	CLIR	CLIR	CLIR	Rocklin, CA	No
Safeway Stockton	CLIR	CLIR	CLIR	Onsite	No
Solectron	CLIR	CLIR	CLIR	Milpitas, CA	No
Svenhard's	Relay at site	ADAM6060	DRAS	DRAS Co-Lo	Yes
Target Hayward	Software client	Canon Technologies	Target	Minesota	Yes
Target Antioch	Software client	Automated Logic	Target	Minesota	Yes
Target Bakersfield	Software client	Automated Logic	Target	Minesota	Yes
Walmart	Software client	EnergyICT	EnergyICT	Belgium	No

4.2.2. Site Data Collection

Table 5 lists the OAT data source used for each Auto-CPP participant site to develop the adjusted OAT regression baseline. The majority of the participant sites used NOAA data, while three sites used CIMIS data due to lack of nearby NOAA weather station locations. The distance between the location of the building and the weather station is listed in Table 5 to indicate how representative the data source was for the facility. All facilities were within 15 miles of a weather station. The 50 Douglas and MDF sites used OAT data measured at weather stations installed on site by their photovoltaic system vendor for more accuracy.

EMCS data were collected and analyzed at ACWD, Echelon, Gilead, IKEA East Palo Alto and Target Hayward. Detailed analysis of the EMCS data is presented in Appendix D.

Table 5. Outside Air Temperature Source by Site

Site	City	OAT Data Source	Weather Station Location	Distance from Weather Station
ACWD	Fremont	NOAA	Hayward Airport	15 miles
Office/Data Center	Concord	NOAA	Buchanan Field	2 miles
Chabot	Oakland	CIMIS	Oakland Foothills	2 miles
2530 Arnold	Martinez	NOAA	Buchanan Field	1 miles
50 Douglas	Martinez	PowerLight	50 Douglas (Martinez)	0 miles
MDF	Martinez	PowerLight	MDF (Martinez)	0 miles
Echelon	San Jose	NOAA	San Jose Airport	3 miles
Centreville	Fremont	NOAA	Hayward Airport	9 miles
Irvington	Fremont	NOAA	Hayward Airport	15 miles
Gilead 300	Foster City	NOAA	San Francisco Airport	6 miles
Gilead 342	Foster City	NOAA	San Francisco Airport	6 miles
Gilead 357	Foster City	NOAA	San Francisco Airport	6 miles
IKEA EPaloAlto	East Palo Alto	NOAA	Palo Alto Airport	1 miles
IKEA Emeryville	Emeryville	NOAA	Metro Oakland Airport	6 miles
IKEA West Sac.	West Sacramento	NOAA	Sacramento Airport	8 miles
Oracle Rocklin	Rocklin	CIMIS	Fair Oaks	10 miles
Safeway Stockton	Stockton	NOAA	Stockton Metro Airport	6 miles
Solectron	Milpitas	NOAA	San Jose Airport	4 miles
Svenhard's	Oakland	NOAA	Oakland Metro Airport	7 miles
Sybase	Dublin	CIMIS	Pleasanton	1 miles
Target Antioch	Antioch	NOAA	Buchanan Field	8 miles
Target Bakersfield	Bakersfield	NOAA	Meadow Field	4 miles
Target Hayward	Hayward	NOAA	Hayward Airport	5 miles
Walmart Fresno	Fresno	NOAA	Fresno Airport	2 miles

4.2.3. DR Strategies at Each Site

Table 6 lists the demand response control strategies by major categories (HVAC, lighting, and other) for each building. Nineteen of the 24 buildings used a global temperature adjustment strategy. Throughout previous studies, global temperature adjustment was found to be effective and one of the least disruptive strategies. In general, DR strategies that curtail demand for both air distribution and cooling components produce higher demand savings than strategies that curtail only air distribution (Motegi et al., 2007). (For an explanation of the strategies listed in Table 6, see that report.)

Six buildings implemented lighting control strategies. Most other buildings were unable to control lighting due to lack of interface between the lighting control panel and the EMCS. Four buildings (Chabot, Centerville, Irvington, and Svenhard's) used demand-shifting strategies. Chabot, Centerville, and Irvington chose pre-cooling. Comments on these sites are as follows:

- **Chabot Space and Science Museum** had highly irregular load profiles that complicated the baseline development and the demand savings analysis for the pre-cooling strategies (Xu et al., 2006).
- **Centerville High School** completed the Auto-CPP controls setup after the 2006 CPP season, so it did not have results for this study.

- **Irvington High School** had no DR results because it was closed for summer vacation during the CPP event days.
- **Svenhard's Bakery** disabled an oven-pan washer during the CPP highest price period and washed the pans after the event was over. This type of industrial process demand shifting can be applied to various non-critical industrial processes by shifting certain activities without affecting the entire process. Svenhard's completed the Auto-CPP controls setup after the last CPP day in Zone 2 and were unable to participate in Auto-CPP events in 2006.

Table 6. Summary of Demand Response Strategies

		HVAC												Light			Other equipment					
	Building use	Global temp. adjustment	Duct static pres. Increase	SAT Increase	Fan VFD limit	CHW temp. Increase	Fan qty. reduction	Pre-cooling	Cooling valve limit	Chiller demand limit	Chiller qty. reduction	Slow recovery	Extended shed period	Turn off lights	Dimmable ballasts	Bi-level switching	Anti-sweat heater shed	Fountain pump off	Non-critical process shed	Elevator cycling	Shut off cold storage	Wwater pump peak shift
ACWD	Office, lab	X	X	X		X			X				X									
Office/Data Center	Office, data center		X	X	X	X			X													
Chabot	Museum	X						X														
2530 Arnold	Office	X										X										
50 Douglas	Office	X										X										
MDF	Detention facility	X																				
Echelon	Hi-tech office	X	X	X			X							X	X							
Gilead 300	Office			X																		
Gilead 342	Office, Lab	X		X																		
Gilead 357	Office, Lab	X		X																		
Irvington	High school	X						X														
Centerville	Junior High school	X						X														
IKEA Emeryville	Furniture retail	X																				
IKEA EPaloAlto	Furniture retail	X																				
Oracle Rocklin	Office	X	X																			
Safeway Stockton	Supermarket															X						
Solectron	Office, Manufacture	X												X								
Sybase	Hi-tech office													X								
Svenhard's	Bakery																		X			
Target Antioch	Retail	X					X															
Target Bakersfield	Retail	X					X															
Target Hayward	Retail	X					X									X						

SAT: Supply Air Temperature, VFD: Variable Frequency Drive, CHW: Chilled Water

4.3. Automation of Events

This project successfully demonstrated that automated DR is technically feasible with existing technology and that buildings can provide significant levels of automated DR within existing CPP programs. This section discusses the key results from the buildings that participated in the Auto-CPP pilot program. Starting with a summary overview of each site's participation in the Auto-CPP process and events, summary results for representative CPP events are discussed. See Appendix D for further information and detailed event results for each site.

4.3.1. Participation Summary

The CPP program period started on May 1st and continued until October 31st 2006, and could call a maximum of 12 CPP events per zone for the year. Nine events were called in Zone 1 and 11 events were called in Zone 2. Table 7 lists the Auto-CPP event dates and summarizes each site's participation success level (succeeded, not ready, opt out, failed, not visible, or no data) for each event. The participation success milestones used are outlined in the evaluation method in Section 3.3.3 and the terms above are defined below the table. The average maximum OAT is also listed for each day, calculated as:

Average Max OAT = $\left(\sum_{i=1}^{i=N} T\right) / N$, where

T = Max OAT at site, N = # of participating sites

This OAT value is different from Zone 2's average OAT, which PG&E calculates and uses to trigger a CPP event.

Five events were called simultaneously for both Zone 1 and Zone 2 during the 2006 CPP program period.

Note that nine sites (Centerville, IKEA Emeryville and West Sacramento, Safeway Stockton, Solectron, Sybase, Target Antioch and Bakersfield, and Walmart Fresno) were not included in the demand savings analysis due to their late completion of the Auto-CPP setup. Of these, Centerville, Svenhard's, and Target Antioch and Bakersfield completed their Auto-CPP system setup before the end of the CPP period, and a mock CPP event was conducted for these four sites on October 20th. The results from this mock test are described in Appendix D. Office/Data Center was not included in the demand savings analysis of July 17th, July 21st, and July 24th due to missing data from InterAct™.

Table 7. Summary of Event Participation

Event Date	Jun-21	Jun-22	Jun-23	Jun-26	Jul-17	Jul-18	Jul-20	Jul-21
Max of Average OAT	97 °F	100 °F	88 °F	87 °F	0 °F	0 °F	0 °F	0 °F
ACWD	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Office/Data Center	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Chabot	Not visible	Not visible	Not visible	Closed	Closed	Closed	Succeeded	Succeeded
2530 Arnold	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
50 Douglas	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
MDF	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Echelon	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Irvington	Closed	Closed	Closed	Closed	Closed	Closed	Closed	Closed
Gilead 300	No Zone 1	No Zone 1	Succeeded	No Zone 1	Succeeded	Succeeded	No Zone 1	Succeeded
Gilead 342	No Zone 1	No Zone 1	Succeeded	No Zone 1	Succeeded	Succeeded	No Zone 1	Succeeded
Gilead 357	No Zone 1	No Zone 1	Succeeded	No Zone 1	Succeeded	Succeeded	No Zone 1	Succeeded
IKEA EPaloAlto	No Zone 1	No Zone 1	Succeeded	No Zone 1	Succeeded	Succeeded	No Zone 1	Succeeded
Oracle Rocklin	Succeeded	Succeeded	Succeeded	Not visible	Succeeded	Succeeded	Succeeded	Succeeded
Target Hayward	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Svenhard's	Manual	Manual	Not ready	Manual	Not ready	Not ready	Not ready	Not ready

Event Date	Jul-24	Jul-25	Jul-26	Aug-09	Aug-31	Sep-01	Sep-22
Max of Average OAT	0 °F	0 °F	0 °F	0 °F	0 °F	0 °F	0 °F
ACWD	Succeeded	Succeeded	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Office/Data Center	Succeeded	Succeeded	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Chabot	Closed	Closed	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
2530 Arnold	Succeeded	Succeeded	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
50 Douglas	Succeeded	Succeeded	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
MDF	Succeeded	Succeeded	Succeeded	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Echelon	Succeeded	Succeeded	0	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Irvington	Closed	Closed	0	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Gilead 300	Succeeded	No Zone 1	No Zone 1	0	0	0	0
Gilead 342	Succeeded	No Zone 1	No Zone 1	0	0	0	0
Gilead 357	Succeeded	No Zone 1	No Zone 1	0	0	0	0
IKEA EPaloAlto	Succeeded	No Zone 1	No Zone 1	0	0	0	0
Oracle Rocklin	Succeeded	Succeeded	0	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Target Hayward	Succeeded	Succeeded	0	No Zone 2	No Zone 2	No Zone 2	No Zone 2
Svenhard's	Not ready	Not ready	0	No Zone 2	No Zone 2	No Zone 2	No Zone 2

Succeeded:	The shed control was operated successfully.
Not ready:	The Auto-CPP system was not completed before the start of CPP period (Milestone #1).
Opt out:	The site decided to opt out although the system was ready (#2).
Failed (1):	Communication failure between ADRS and price client (#3).
Failed (2):	Communication failure between the price client and relay device (#4).
Failed (3):	Communication failure between the relay device and control panel, or other control malfunction (#5).
Not visible:	The shed kW was too small to identify (#6).
No data:	Participation in the event was confirmed, but whole building power data are missing on InterAct II.

4.4. Demand Savings

This section describes the results of the demand reduction achieved in the 2006 Auto-CPP program. Throughout this report the demand savings were based on LBNL's adjusted OAT regression baseline model unless otherwise noted. Savings estimates based on the CPP baseline are also shown. This section begins with a review of the aggregated demand response results of five CPP events. This is followed by a summary of the individual demand savings at each site for all CPP events.

4.4.1. Aggregated Results by Event

This section discusses five of the fifteen 2006 CPP event days (June 23rd, June 26th, July 17th, July 18th, and July 24th). These provide examples that compare results for the OAT regression and CPP baselines at different outside air temperatures. Results for all other CPP events are presented in Appendix F.

June 23, 2006

The average maximum OAT on June 23rd was 84°F (71°F for Zone 1 and 89°F for Zone 2). Figure 5 shows the aggregated demand savings for 13 sites. The three-hour demand savings during the high-price period (3 p.m. to 6 p.m.) was 960 kW (10% of aggregated demand). This section focuses on the high-price period results because some of the sites responded only in this second three-hour period. In those cases the CPP and LBNL's Adjusted OAT regression baseline were nearly identical. This occurred because of the relatively mild weather on this date; there was a dramatic change in the later examples. Note also that the shape of the shed was clear, with two levels of demand response clearly identified among the 13 sites. The first level shows the shed from noon to 3 p.m. The second level shows larger savings in the 3 p.m. to 6 p.m. period.

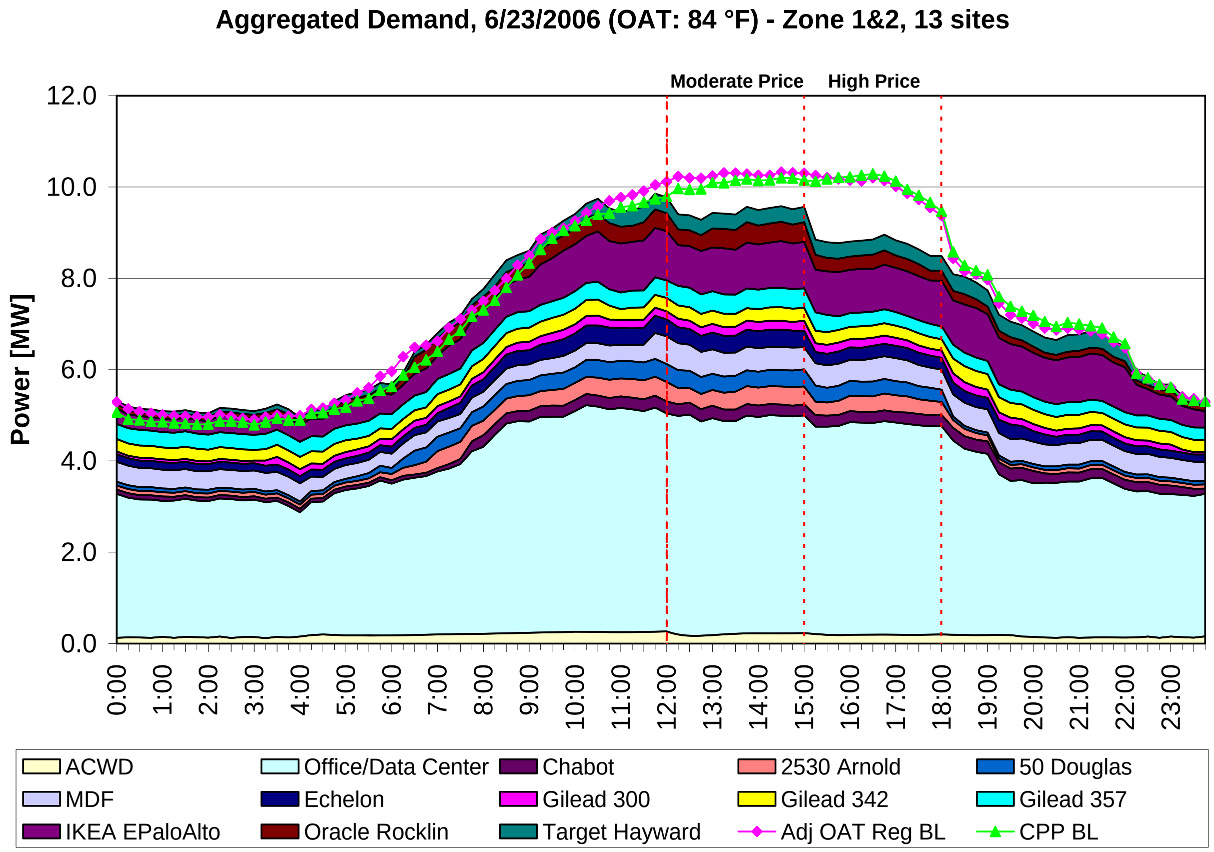

Figure 5. Aggregated demand savings, June 23, 2006

The 13 sites delivered 748 kW (7% of aggregated demand) during the moderate-price period and 1172 kW (12%) during the high-price period. The largest savings were provided by the Office/Data Center site, which reduced electric loads by 388 kW during the high-price period. Five sites provided over 100 kW each. One site (Chabot) had negative savings during both periods, which was related to the complex baseline at this museum. The average demand reduction at the sites was 0.6 W/ft² during the high-price period. Table 8 shows demand savings from each site during the event on June 23rd. The results were calculated as:

- Individual site results
  - $Avg\ kW\ saved\ per\ event = \dfrac{\sum_{h=DR.start.time}^{h=DR.end.time}(Baseline.demand - Actual.demand)}{DR.event.duration}$
  - $Avg\%\ saved\ per\ event = \dfrac{\sum_{h=DR.start.time}^{h=DR.end.time}(Baseline.demand - Actual.demand)}{\sum_{h=DR.start.time}^{h=DR.end.time} Baseline.demand}$
  - *AvgW/ft² saved per event = Avg kW saved per event / Building area*
- Aggregated results

- *Aggregated avg kW saved per event* = $\sum_{i=1}^{i=N} AvgkW.saved.per.event$

  (N = number of sites)

- *Aggregated avg% saved per event* = $\dfrac{\sum_{i=1}^{i=N}(Baseline.kW - Actual.kW)}{\sum_{i=1}^{i=N} Baseline.kW}$

- *Aggregated avg W/ft² saved per event* = $\dfrac{\sum_{i=1}^{i=N} AvgkW.saved.per.event}{\sum_{i=1}^{i=N} Building.area}$

Table 8. Summary of Demand Savings, June 23, 2006

	Average kW		Average %		Average W/ft²	
	Moderate	High	Moderate	High	Moderate	High
ACWD	77	95	27%	33%	1.51	1.85
Chabot	-36	-43	-17%	-22%	-0.42	-0.50
2530 Arnold	78	113	17%	25%	0.59	0.86
50 Douglas	59	92	14%	23%	0.66	1.02
MDF	-75	1	-17%	0%	-0.44	0.01
Echelon	29	118	7%	31%	0.38	1.57
Gilead 300	19	16	9%	8%	0.23	0.19
Gilead 342	62	77	18%	22%	1.94	2.39
Gilead 357	-14	44	-3%	12%	-0.42	1.32
IKEA EPaloAlto	137	120	12%	11%	0.46	0.40
Oracle Rocklin	23	101	5%	26%	0.23	1.01
Target Hayward	53	52	13%	13%	0.41	0.40
Office/Data Center	337	388	7%	8%	0.48	0.55
Aggregated	748	1172	7%	12%	0.38	0.59

June 26, 2006

During the June 26th event, the OAT regression baseline was well above the CPP baseline, as it was in the next three events as well. During this day, the average maximum OAT was 89°F for Zone 2. Figure 6 shows the aggregated demand savings for eight sites. The three-hour demand savings during the high-price period (3 p.m. to 6 p.m.) was 1281 kW (16% of aggregated demand). The CPP baseline was under the actual load prior to the noon hour, which shows again the problem of using a non-weather adjusted baseline. The shed patterns in this event show an initial drop, with some rebound in the first three hours, and a second drop at 3 p.m. with another rebound, though staying well below the 3 p.m. baseline demand. Table 9 shows the average demand savings and demand savings intensity (W/ft²) for the moderate- and high-price periods.

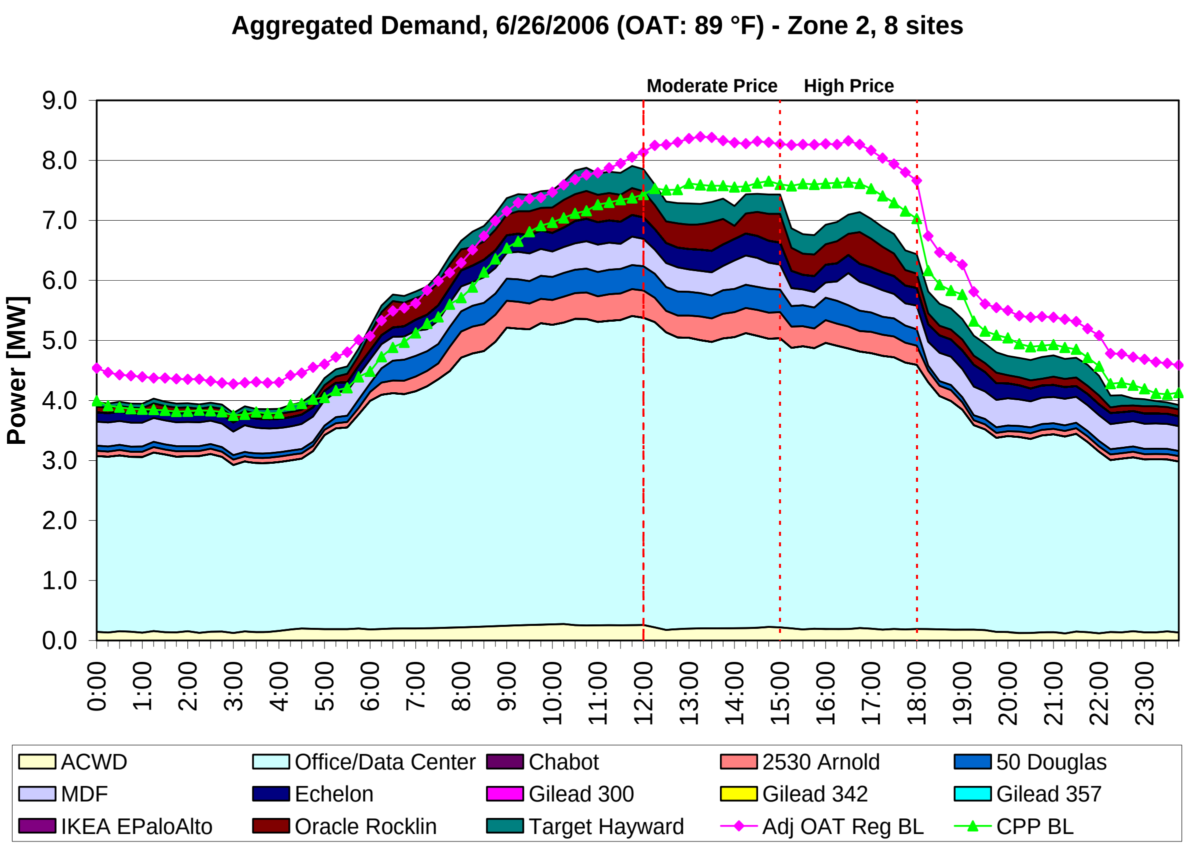

Figure 6. Aggregated demand savings, June 26, 2006

Table 9. Summary of demand savings, June 26, 2006

	Average kW		Average %		Average W/ft²	
	Moderate	**High**	**Moderate**	**High**	**Moderate**	**High**
ACWD	78	91	28%	32%	1.53	1.78
2530 Arnold	102	140	20%	29%	0.78	1.07
50 Douglas	57	94	13%	22%	0.63	1.04
MDF	90	155	17%	30%	0.52	0.90
Echelon	-2	80	0%	22%	-0.02	1.07
Oracle Rocklin	85	60	17%	14%	0.85	0.60
Target Hayward	59	56	15%	15%	0.45	0.43
Office/Data Center	478	604	9%	12%	0.67	0.85
Aggregated	946	1281	11%	16%	0.65	0.88

July 17, 2006

The average maximum outside air temperature on July 17th was 95°F (84°F for Zone 1 and 100°F for Zone 2). Figure 7 shows the aggregated demand profile of the 11 participating sites. The average demand savings during the high-price period (3 p.m. to 6 p.m.) was 1051 kW (19% of aggregated demand). This graph is different from the previous two because the data for the Office/Data Center, the largest site, were missing on this date. The CPP baseline was under the load prior to the noon hour (as it was for June 26th); therefore using the CPP baseline would show zero savings during the first three hours of this event. Table 10 shows the average demand savings, percent savings, and demand savings intensity (W/ft²) for the moderate- and high-price periods.

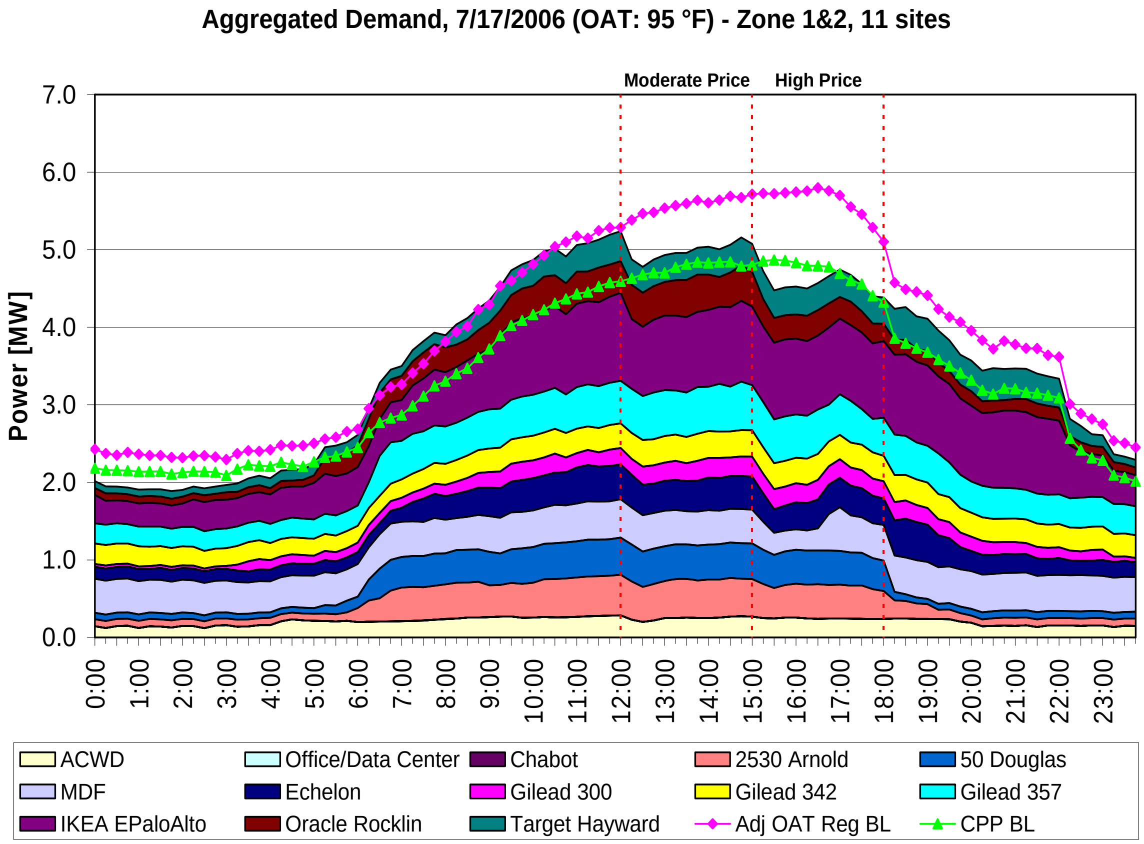

Figure 7. Aggregated demand savings, July 17, 2006

Table 10. Summary of demand savings, July 17, 2006

	Average kW		Average %		Average W/ft²	
	Moderate	**High**	**Moderate**	**High**	**Moderate**	**High**
ACWD	58	95	19%	28%	1.14	1.85
2530 Arnold	48	105	9%	20%	0.37	0.80
50 Douglas	22	51	5%	10%	0.25	0.56
MDF	86	186	16%	33%	0.50	1.08
Echelon	81	124	17%	26%	1.08	1.65
Gilead 300	13	14	5%	5%	0.16	0.16
Gilead 342	5	38	1%	10%	0.14	1.18
Gilead 357	30	86	5%	14%	0.92	2.59
IKEA EPaloAlto	184	175	16%	15%	0.61	0.58
Oracle Rocklin	9	103	2%	25%	0.09	1.03
Target Hayward	68	76	16%	18%	0.52	0.58
Aggregated	604	1051	11%	19%	0.50	0.88

July 18, 2006

The average maximum OAT on July 18th was 90°F (84°F for Zone 1 and 93°F for Zone 2). Figure 8 shows the aggregated demand profile of the 12 sites. Table 11 shows the aggregated demand savings for the 12 sites. The average demand savings during the high-price period (3 p.m. to 6 p.m.) was 961 kW (9% of aggregated demand).

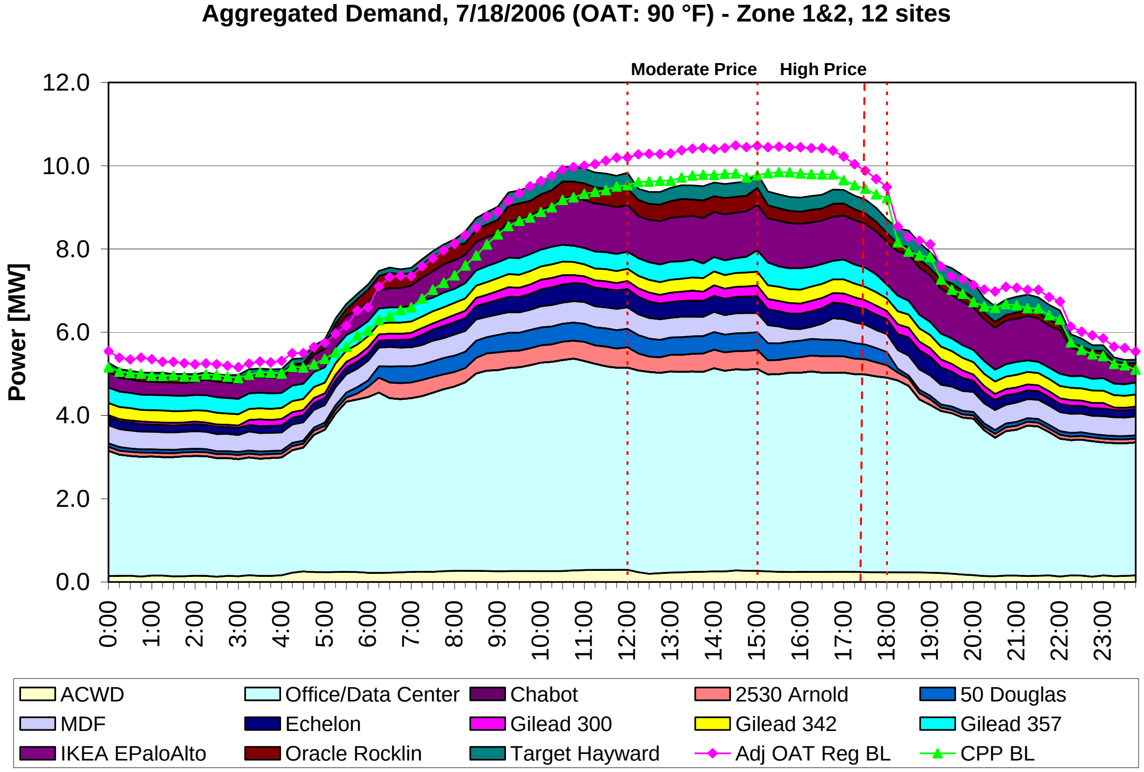

Figure 8. Aggregated demand savings, July 18, 2006

Table 11. Summary of demand savings, July 18, 2006

	Average kW		Average %		Average W/ft²	
	Moderate	**High**	**Moderate**	**High**	**Moderate**	**High**
ACWD	58	79	19%	24%	1.12	1.54
2530 Arnold	62	101	13%	22%	0.47	0.77
50 Douglas	29	49	6%	11%	0.32	0.54
MDF	69	149	12%	27%	0.40	0.87
Echelon	47	72	11%	16%	0.62	0.97
Gilead 300	30	14	12%	6%	0.36	0.17
Gilead 342	29	27	8%	8%	0.91	0.86
Gilead 357	94	-5	19%	-1%	2.84	-0.15
IKEA EPaloAlto	74	90	6%	8%	0.25	0.30
Oracle Rocklin	46	110	10%	28%	0.46	1.10
Target Hayward	85	74	21%	18%	0.65	0.57
Office/Data Center	228	201	5%	4%	0.32	0.28
Aggregated	849	961	8%	9%	0.45	0.50

July 24, 2006

July 24th was one of the hottest days of the July heat wave with the statewide system at peak conditions. The average maximum OAT on July 24th was 95°F (83°F for Zone 1 and 103°F for Zone 2). Figure 9 shows the aggregated demand profile of the 13 sites. Again the CPP baseline was under the aggregated load during nearly the entire event. This would suggest there was no demand response occurring, yet from evaluating the results for the individual buildings it is apparent that there were large sheds occurring. Table 12 shows the aggregated demand savings for the 13 sites. The average demand savings during the high-price period (3 p.m. to 6 p.m.) was 917 kW (16% of aggregated demand). Again the Office/Data Center, the largest site, was not included because of data issues. Had the DR events not occurred the aggregated load for these buildings would have been around 6 MW.

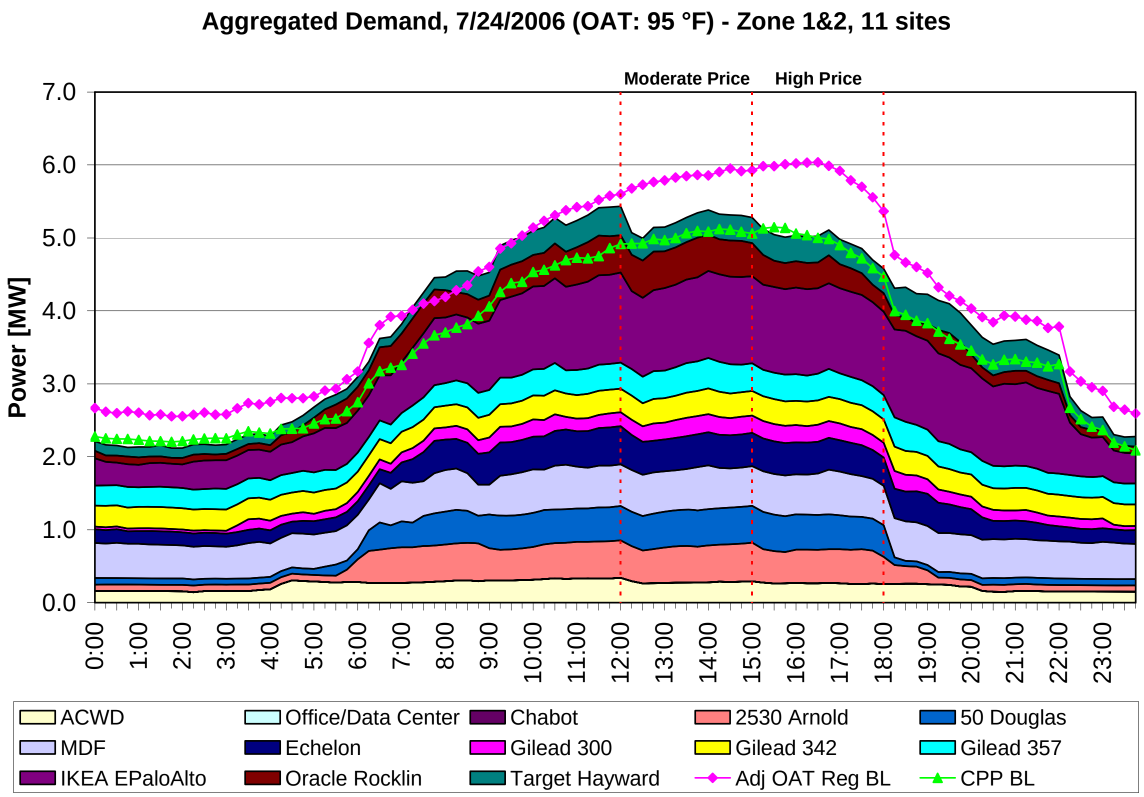

Figure 9. Aggregated demand savings, July 24, 2006

Table 12. Summary of demand savings, July 24, 2006

	Average kW		Average %		Average W/ft²	
	Moderate	High	Moderate	High	Moderate	High
ACWD	87	133	24%	33%	1.70	2.60
2530 Arnold	56	99	10%	18%	0.43	0.76
50 Douglas	16	57	3%	11%	0.18	0.64
MDF	72	127	11%	18%	0.42	0.73
Echelon	51	84	10%	16%	0.68	1.12
Gilead 300	20	14	8%	6%	0.24	0.16
Gilead 342	12	21	3%	6%	0.37	0.66
Gilead 357	77	35	16%	8%	2.33	1.06
IKEA EPaloAlto	82	93	7%	7%	0.27	0.31
Oracle Rocklin	33	151	6%	31%	0.33	1.51
Target Hayward	98	102	23%	23%	0.75	0.79
Aggregated	605	917	10%	16%	0.51	0.77

4.4.2. Summary of Demand Savings

Table 13 shows a summary of demand savings results of each of the 13 participant sites for all CPP events (for an average of six hours from noon to 6 p.m.). The aggregated total shed for all sites for each event is also shown with estimates using both the OAT regression and the CPP baseline models.[13] In this table, the average of the aggregated demand savings across the total number of events is defined as:

- *Avg aggregated kW saved =* $\sum_{i=1}^{i=n}(Aggregated.avgkW.saved.per.event)/n$

  (n = number of event days)
- Avg aggregated % saved =

  $$\frac{\sum_{i=1}^{i=n}(Aggregated.baseline.kW - Aggregated.actual.kW)}{\sum_{i=1}^{i=n}Aggregated.baseline.kW}$$

If all the sites had provided their maximum six-hour peak demand reduction on the same day, the program could have provided 1.7 MW of load savings. If all sites had provided the maximum three-hour peak demand reduction on the same day, the program could have provided 2.0 MW of savings.

13. Svenhard's is not included in the analysis, since it completed the Auto-CPP control setup after the last CPP day in Zone 2 and was unable to participate in Auto-CPP events in 2006.

Table 13. Summary of Six-hour Average Demand Savings by Each Site

Avg, 6hr		6/21	6/22	6/23	6/26	7/17	7/18	7/20	7/21	7/24	7/25	7/26	8/9	8/31	9/1	9/22	Avg
OAT	Zone1			73°F		85°F	84°F		84°F	85°F			88°F	77°F	70°F	77°F	
	Zone2	97°F	100°F	90°F	90°F	101°F	94°F	94°F	97°F	103°F	101°F	89°F					
ACWD	kW	83	112	86	85	77	68	63	74	110	93	101					86
	%	26%	30%	30%	30%	24%	22%	21%	23%	29%	27%	33%					27%
Office/Data Center	kW	310	152	363	541		214	259			264	251					294
	%	6%	3%	7%	10%		4%	5%			5%	5%					6%
Chabot	kW	37	29	-39				6	-30			-43					-7
	%	14%	11%	-19%				3%	-11%			-21%					-4%
2530 Arnold	kW	100	83	95	121	76	81	74	71	78	80	76					85
	%	21%	17%	21%	24%	14%	17%	16%	15%	14%	15%	17%					17%
50 Douglas	kW	37	48	75	75	36	39	41	69	37	78	35					52
	%	9%	11%	18%	17%	8%	9%	10%	15%	7%	15%	8%					11%
MDF	kW	104	72	-37	122	136	109	92	113	99	116	77					91
	%	20%	13%	-8%	24%	25%	20%	17%	18%	15%	18%	13%					16%
Echelon	kW	75	69	73	39	102	59	56	67	68	93	66					70
	%	18%	16%	19%	11%	21%	14%	13%	15%	13%	19%	16%					16%
Gilead 300	kW			17		13	22		6	17			-8	4	31	39	16
	%			9%		5%	9%		3%	7%			-3%	2%	15%	14%	7%
Gilead 342	kW			69		21	28		2	16			-1	33	93	69	37
	%			20%		6%	8%		0%	5%			0%	10%	28%	18%	10%
Gilead 357	kW			15		58	44		19	56			-28	1	61	31	29
	%			4%		9%	9%		4%	13%			-6%	0%	15%	8%	6%
IKEA EPaloAlto	kW			128		180	82		91	88			-3	-17	2	97	72
	%			12%		16%	7%		8%	7%			0%	-2%	0%	10%	6%
Oracle Rocklin	kW	43	40	62	73	56	78	53	21	92	21	54					54
	%	12%	11%	15%	16%	13%	19%	13%	5%	18%	5%	12%					13%
Target Hayward	kW	55	67	52	57	72	79	62	75	100	78	75					70
	%	13%	15%	14%	15%	17%	20%	16%	18%	23%	19%	20%					17%
Aggregated (LBNL BL)	**kW**	**844**	**672**	**960**	**1114**	**828**	**905**	**705**	**578**	**761**	**822**	**691**	**-41**	**20**	**188**	**236**	**619**
	%	**10%**	**8%**	**10%**	**14%**	**15%**	**9%**	**9%**	**10%**	**13%**	**9%**	**8%**	**-2%**	**1%**	**9%**	**11%**	**10%**
Aggregated (CPP BL)	**kW**	**411**	**200**	**964**	**420**	**-35**	**307**	**510**	**208**	**-116**	**-118**	**478**	**-175**	**-4**	**178**	**232**	**231**
	%	**5%**	**3%**	**10%**	**6%**	**-1%**	**3%**	**6%**	**4%**	**-2%**	**-2%**	**6%**	**-8%**	**0%**	**9%**	**11%**	**4%**

Figure 10 shows the average demand savings of each site for the CPP high-price period (3 p.m. to 6 p.m.) for all the CPP events. The savings are shown for both the LBNL (OAT regression) and CPP baselines. The sum of the average demand savings from each site divided by the sample size yields an estimate that on average the program provided 1133 kW per site. The greatest average demand response was from the Office/Data Center site with 294 kW on average, which represented a reduction of 7% using the OAT model.

The maximum, minimum, and standard deviation of the demand reduction are also shown in Figure 10 for each site. For most sites the variation in demand reduction among the events was within 20% of the mean, showing good repeatability and predictability.

For several sites the standard deviation was more than 30% of the mean (or average). The variation in the Chabot savings was related to complexities with the baseline because the hours of use and schedules at this museum were highly irregular. The strategy at the IKEA appeared to be overridden and the variation in the savings may be related to this. IKEA did not show any demand savings during three of the nine events for zone 1. LBNL checked the DRAS communication logs and conducted a communications test when the controls vendor was on-site to evaluate if there was a problem with the automation systems. The results confirmed that the site had received the pricing signal. The controls vendor conducted additional tests and found that the temperature appeared to have been manually reset to the lower cooling setpoint during these events. The facility engineer did not recall changing the setpoints back to their original setting. He also did not record this information in the post-event surveys.

Unfortunately, detailed EMCS logs were not available to better determine why the DR strategy had been overridden for 3 of the 9 events.

The average aggregated savings was 745 kW (12%) for an average 8.5 participant sites per event. The average of site average savings is defined as:

- Average of site savings kW = $\sum_{i=1}^{i=N} \left(\sum_{i=1}^{i=n} Average.kW \Big/ n \right)$
- Average of site savings % = $\dfrac{Average.of\ .site.average.saving.kW}{\sum_{i=1}^{i=N} \left[\sum_{i=1}^{i=n} (Average.baseline.kW) \Big/ n \right]}$

where N = number of participant sites and

n = number of event days.

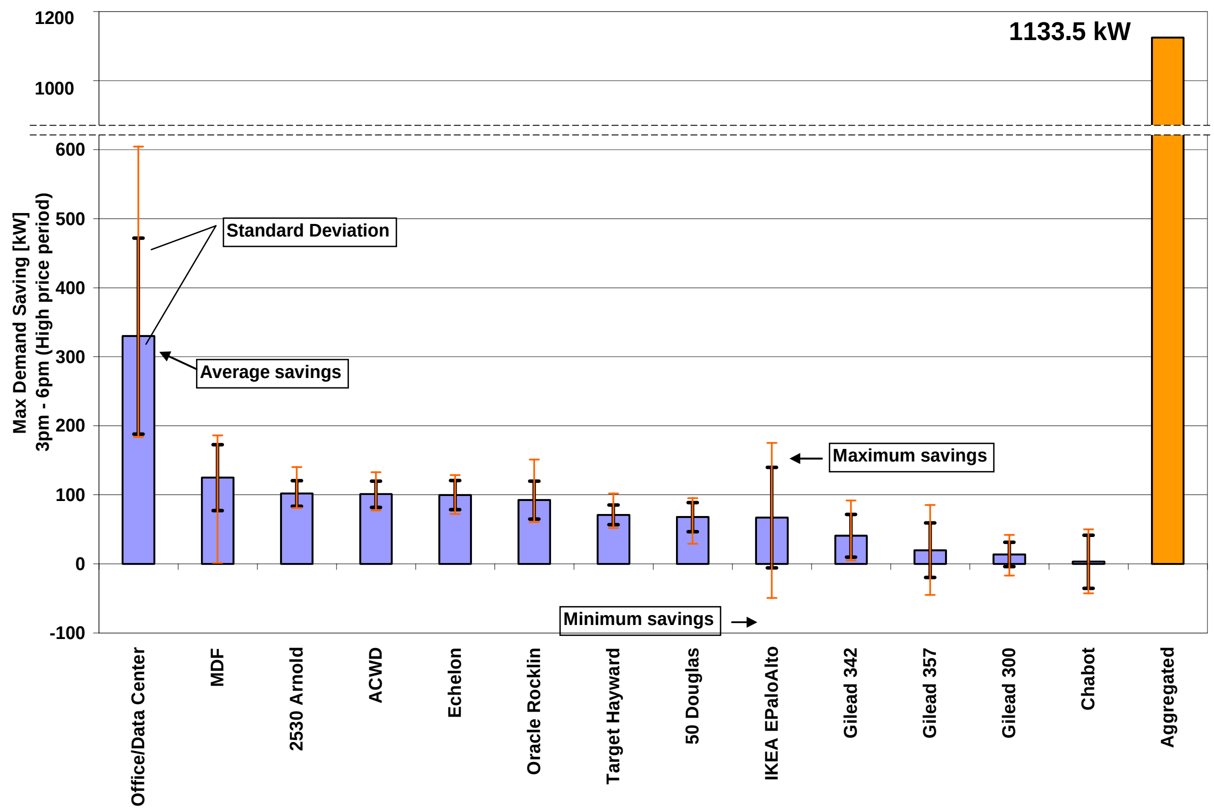

Figure 10. Average, maximum, minimum, and standard deviation of demand savings

4.4.3. Comparison of OAT Regression and CPP Baselines

One key finding from the 2006 study is that the CPP baseline provided much lower demand savings estimates than the weather-normalized OAT regression baseline developed by LBNL. Figure 11 compares the average OAT regression baseline savings with the CPP baseline savings. This graph shows average demand reduction for the full 6-hour period, while Figure 10 above shows the high-price period savings. In comparing the OAT and CPP models, the project team reviewed the results for the largest site, the Office/Data Center. Figure 11 shows that the average peak demand reduction for the Office/Data Center building was 294 kW using the OAT regression baseline model and was only 105 kW using the CPP baseline model. On average, for all 13 sites the CPP baseline savings for the full six hours were 15 kW, while the average OAT regression baseline savings were 48 kW. The aggregated six-hour averages were 201 kW with the CPP baseline and 619 kW with the OAT regression baseline, a factor of three difference.

The two baseline models can be evaluated by determining how well they predict whole-facility loads on non-CPP days. Additional work is needed to quantify the "goodness of fit" for the two models. In general, since the facilities in this study were weather-sensitive, the weather-normalized (OAT regression) baseline model was a better predictor of load shape than the non-weather sensitive (CPP) baseline model.

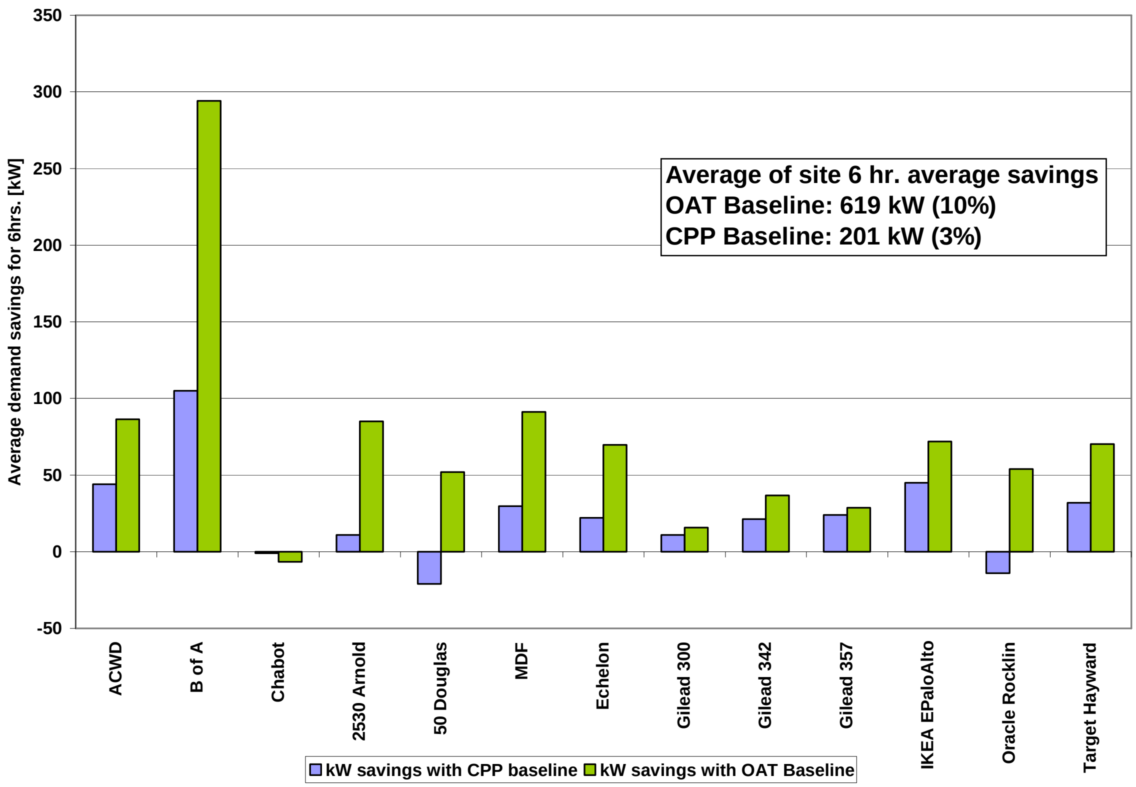

Figure 11. Average demand savings for OAT and CPP baselines

4.5. Economic Analysis

This section discusses the economics of Auto-CPP, including tariff analysis and automation setup costs.

4.5.1. CPP Tariff Analysis

Change in electricity costs under Auto-CPP

After analyzing the electricity bills for the sites that participated in the full summer of CPP events, LBNL found that 11 of the 13 sites saved money in 2006. In other words, their CPP credits they accrued were larger than the CPP charges. While the savings were small, they did show a positive return, making the time and effort worthwhile to participate in Auto-CPP for most sites. One of the larger sites saved over $7,000; these savings, however, accounted for less than 1 cent/ft^2-year ($0.01/$ft^2$ -yr). Two sites had very small increased costs under Auto-CPP ($40 and about $600). The average reduction in costs for the 13 sites was $1,700, which was on average 0.8% of their costs over the 6-month period. Two sites saved $0.10/$ft^2$-yr and one site saved $0.05/$ft^2$-yr. All other sites saved less than $0.01/$ft^2$-yr. The average savings was $0.02/$ft^2$-yr.

CPP cost without any DR action

Another way to evaluate the site economics is to estimate what the CPP tariff implications would have been if the sites had not shed any load with their DR strategies. These estimates were derived by estimating the CPP credits and charges if each site had not participated in DR events. The credits were the same because these happened on non-DR days. The charges were calculated using the baseline model to estimate how many more kW each site would have used on CPP days. This evaluation was done with both the LBNL OAT regression baseline and the CPP baseline models. The calculations showed that only two out of 13 sites would have lost money if they had made no changes during DR events. These losses were less than $350 for each site.

New demand charges due to DR event rebound

While it is important to reduce demand during the CPP period, it is also important to bring equipment back to operation slowly so as to avoid introducing a new rebound peak. In the 125 site-events (the sum of the sites times the number of events in which they participated), three different sites hit new monthly peaks during the 6 to 8 p.m. window after a CPP event. The sites were made aware of the rebound problems and were offered solutions after their post-event analysis. This analysis was done by careful review of the date and time of the summer demand charges.

Impact of multiple CPP days in one billing period

During the CPP period, the facility managers did not have access to the entire CPP period economic data to analyze the total financial impacts of their participation. Their monthly utility bills were their only feedback regarding the financial impact for the program. With the heat wave hitting northern California in the second half of July, many sites that received a bill with seven CPP events were confused by high utility bills despite their efforts to reduce peak demand. The uneven distribution of the CPP events resulted in unexpectedly high utility bills for that month. On average, among the seven sites with seven events in one month, the average bill increased 15%; one facility saw an increase of 26%. Many of the participating sites were concerned with these high utility bills following the heat wave. Improvements in communication with customers about high bills were needed to help explain the charges and credits each site collected for the entire summer.

4.5.2. Automation Setup Cost Analysis

LBNL collected information on the cost to install the automation systems and configure the control systems. Table 14 summarizes the range of costs reported for EMCS programming and Auto-CPP communication system installation and configuration. The setup cost also included the cost of the CLIR box ($1,500/box) for eight sites. The table shows costs for the 13 sites that participated in the entire CPP period.

The table also shows the total cost per demand savings ($/kW) for comparison to the utility's technical incentives, whose maximum allowance is based on potential demand savings (kW). In December 2006 PG&E began to provide a Technical Incentive (TI) of $100/kW for DR-enabling technologies. In the 2006 Auto-CPP demonstration, the average cost per demand savings was $52, which would be within the allowance of the new incentive.

The table also shows simple payback time based on the savings from Auto-CPP to provide a ballpark assessment of the economics independent of TI for DR customers. The average payback period among the sites in the table was four years.

Table 14. Summary of costs for Auto-CPP implementation

Site	6hr. average kW reduction (CPP baseline)	Average % reduction (CPP baseline)	6hr. Average kW reduction (OAT baseline)	CPP credits - CPP charges	Initial Cost	Payback (yrs)
2530 Arnold	11	3%	85	$241	$3,500	2.4
50 Douglas*	-21	-6%	52	-$576		
MDF*	30	7%	91	$1,769		
ACWD*	44	16%	86	$1,513	$13,324	8.8
B of A	105	2%	294	$7,370	$2,900	0.4
Chabot	-1	-1%	-7	-$39	$6,010	N/A
Echelon*	22	6%	70	$2,213	$3,620	1.6
Gilead 300	11	5%	16	$1,303	$4,500	0.6
Gilead 342	21	6%	37	$3,191		
Gilead 357	24	4%	29	$3,565		
IKEA EPaloAlto*	45	4%	72	$364	$6,360	17.4
Oracle Rocklin*	-14	-4%	54	$613	$1,875	3.1
Target Hayward	32	9%	70	$1,565	$3,312	2.1

*Indicates estimation of unavailable bills for at least one billing period.

For the participant sites that continued Auto-CPP from previous years, the costs required for the initial setup in the previous year were collected. Many of the early participant sites configured their Auto-DR setup using their own labor or under existing controls contracts. Therefore it was hard to capture the exact initial setup costs. Of the sites in Table 14, Offices B, C1, C2, D and F, Detention Center, and Retail A2 set up the system with their own labor or within existing contracts with their controls contractors. Offices A and E, Museum, Labs A1 and A2 and Retail B1 used their controls contractors and the costs were gathered from the controls contractor's proposals.

4.6. Facility Operators' Response to DR Events

After each event, LBNL asked the sites to fill out an online survey to collect information on the facility manager's perceptions regarding the conditions in the building during the DR events. The goal was to collect information on any operational issues that might have stemmed from the DR strategies or the automation systems. In some of the sites, the building operators shared the link to the survey with their managers so that LBNL could record their perceptions as well. Table 15 summarizes their responses. In some of the sites the building operators assembled a distribution list of all or part of the occupants to inform them about a coming CPP event. Only two sites reported operational issues and more than half of the sites did not report any comfort issues.

Table 15. Summary of Occupant Responses

Site	Was the operator on site?	Was the operator watching the event?	Did the occupants know?	Operational issues?	Comfort issues?
ACWD	Yes	Sometimes	Yes	No	Some*
B of A	Yes	No	No	Some*****	Some**
Chabot	Yes	Yes	Yes	No	Yes***
2530 Arnold	No	No	No	No	No****
50 Douglas	No	No	No	No	No
MDF	No	No	No	No	No
Echelon	Yes	Yes	No	No	No
Gilead 300	Yes	Sometimes	Yes	No	No
Gilead 342	Yes	Sometimes	Yes	No	No
Gilead 357	Yes	Sometimes	Yes	No	No
IKEA EPaloAlto	Sometimes	Sometimes	No	No	No
Oracle Rocklin	Yes	Sometimes	No	Yes	Yes
Target Hayward	No	Sometimes	No	No	No

* Some complaints of high temperatures

** Some comfort concerns

*** Too cold - precooling strategy not working properly

**** Occupants realized it was getting warmer in the afternoon but no complaints

***** Realized the limitations of the control system

5.0. Discussion

The following section contains observations from the study and connects them to the overall context of DR and energy-efficiency efforts in California.

5.1. Approach to Auto-DR

The 2006 Auto-CPP program showed that fully automated demand response is technically feasible and the costs to automate DR appear to be viable.

The program went beyond the 2005 Auto-CPP demonstration in several important ways. The technology performed successfully for a full summer period without technical problems. Customers appeared to be comfortable and accepting of the automation. The project team continued to see that the HVAC DR strategies were reliable and robust, with a primary emphasis on global temperature adjustment (GTA). GTA provided a two-stage strategy that met a six-hour demand response program. Many other DR strategies were automated including other HVAC strategies, lighting strategies, and some process modifications.

5.2. Information Systems and Feedback to Participants

The 2006 Auto-CPP program was successful in providing adequate information to the participants about what to expect regarding automation of the DR program. During the course of the project, LBNL developed online tools to collect cost, comfort, and building systems data. A set of materials developed and refined in 2005 and 2006 was developed to explain the program and how the automation functions. LBNL developed a bi-weekly email newsletter to keep the participants informed about the number of events that had occurred and the number of events pending.

LBNL also emailed the participants graphs and data showing their achieved peak demand reduction. This appeared to be important feedback to the participants to help confirm the value of their actions and level of savings they achieved.

The participants, however, had many questions about how much peak demand they shed, how their CPP economics worked, and whether their participation in the program made a difference. One building operator requested to receive feedback on the impact of CPP participants on the overall relief of the grid. Better information about the regional and statewide benefits of DR is needed to help promote the program. The increase in monthly utility bills during the heat wave was a major concern for some of the sites. A predictive tool that outlines the number of CPP events called as well as CPP credit days and predicted credits could help eliminate these concerns.

5.3. Linking DR and Energy Efficiency

DR programs will be more successful in the long run if they can be linked to energy efficiency programs. DR can fit into a demand side management (DSM) framework as shown in Figure 12. DR capabilities in buildings are dependant on controls. Ideally a candidate building would have good dynamic control capability, energy-efficient equipment, good commissioning, and good feedback linking operating conditions and strategies to energy costs. More of these attributes are needed in buildings to improve both DR capabilities and daily energy efficiency practices.

	Efficiency and Conservation (Daily)	Peak Load Management (Daily)	Demand Response (Dynamic Event Driven)
Motivation	- Environmental Protection - Utility Bill Savings	- TOU Savings - Peak Demand Charge Savings - Grid Protection	**- Economic - Reliability - Emergency - Grid Protection**
Design	- Efficient Shell, Equipment & Systems	Low Power Design	**Dynamic Control Capability***
Operations	- Integrated System Operations	Demand - Limiting Shifting	**Demand - Limiting Shifting Shedding**
Initiation	Local	Local	**Remote**

* required for DR

Figure 12. Demand side management framework

Figure 13 shows a conceptual diagram of how technologies and strategies can be used to maximize the value of energy efficiency, load management, and demand response (Kiliccote et al., 2006). From an operational perspective, a building's EMCS is the main component that can implement and verify capabilities in these three DSM areas.

As an example, during the summer of 2006, LBNL began working with nine buildings in the Milpitas campus of Solectron. Solectron's first request was to help them understand their bill and map which buildings and addresses corresponded to the service agreement identification numbers in InterActII™. Second was the development of a data collection system. None of the nine buildings' HVAC systems on the Milpitas campus were being monitored through the EMCS. Therefore no operational data were collected or stored. Hence, it was difficult for the building operators to estimate the DR potential of the buildings. If an energy-efficiency upgrade was to take place, its effectiveness had to be measured and validated. The same data collection and storage capability that would be used for measuring the effectiveness of the energy-efficiency upgrade would be used to evaluate and refine the control strategies for DR.

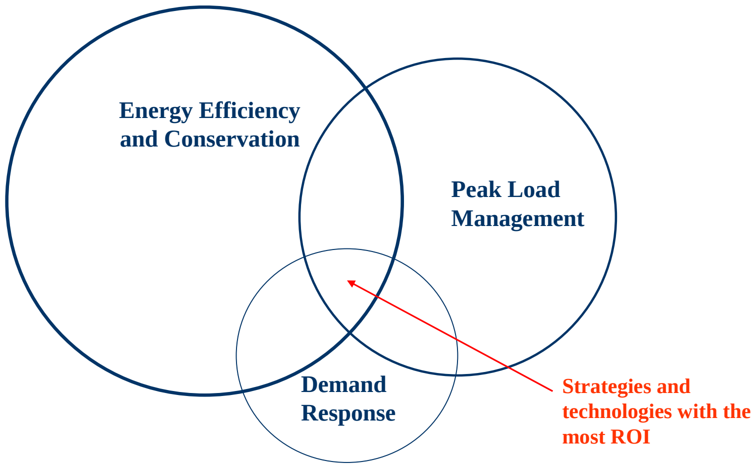

Figure 13. Linking energy efficiency, load management, and DR

In response, funding from Silicon Valley Leadership Group's (SVLG) energy efficiency program and LBNL's support for Solectron's investment in data collection and storage systems will enable better analysis of their facilities' data, result in more efficient use of their facilities, provide them with operational flexibility, and provide means to measure energy use and savings, load management, and DR effectiveness.

However, LBNL has some concerns about these nine buildings because, according to the former building engineer, the HVAC system was sized to handle a maximum outside air temperature of 85ºF. If CPP days are hotter than 85ºF the HVAC system is undersized and overloaded. In such a case a DR strategy that involves temperature setup may provide reduced demand savings when outside temperatures are high because the chiller may continue to run to try to meet loads on moderate days (with temperatures in the high 80s).

5.4. Acceptability of Auto-DR

One key factor in the success of Auto-DR is to understand how acceptable it is to participants. Since Auto-DR is automated, it occurs as a transparent activity, and often when occupants are asked about their experiences they have limited opinions. LBNL collected anecdotal information from the Auto-CPP sites through a "request for quotes." Since most of the sites had an EMCS, the responses showed that the operators in Auto-CPP sites do not differentiate between semi-automated and fully automated DR strategies. Post-event surveys showed that many of the second-year (2006) participants did not watch the events. Also, since the automation and communications technology performed without problems, the conclusion is that the automation was effective and acceptable, although there were some complaints, as discussed below.

Another aspect of acceptability is whether there were problems from the control strategies that form the basis of the demand response. In 2006, 125 site-events took place with the majority of them on hot days. In addition, in July seven CPP events were called on 10 consecutive business days. After each event (or set of events if they were back-to-back) LBNL collected information from the sites about occupant complaints and comfort. The post-event surveys did register some increase in the complaints during the heat wave of July 2006. These complaints occurred mostly in office buildings. There were no complaints in the retail stores. One of the key findings for the heat wave is that none of the Auto-CPP sites opted out during the events that occurred three or four days in a week.

Concerns about high temperatures concentrated mainly in four of the seven office buildings. To help employees cope with the heat, one company called the CPP days "Hawaiian shirt days" and relaxed dress codes for the employees. At this site, the operator observed that on consecutive CPP days, the occupants manually adjusted their thermostats to a lower setting prior to the event start time to pre-cool their spaces. Another company realized that the west-facing corner offices were much hotter than the other areas in the building and changed its DR programming to exclude corner offices with double sun exposure. Other sites thought they might consider pre-cooling, but no implementation had been done in 2006.

LBNL conducted analysis of EMCS data at several of the sites to understand how warm interior spaces got during the heat wave. Indoor temperatures reached 78°F in one retail store, but there were no complaints registered regarding these temperatures. The same retail store, despite including lighting sheds the previous year, excluded lighting from their DR strategies in 2006 and used it as a "last resort strategy" that could be deployed when the grid was seriously constrained and the utilities contacted them.

Feedback on the acceptability of lighting sheds shows that results vary depending on the type of facility and their tasks. For retail stores, there were concerns that lighting sheds might potentially reduce sales. In 2005, feedback from the staff in Target was that lighting sheds were noticeable and undesirable. In 2006, feedback from Sybase (in process but not yet automated) suggested that on back-to-back CPP days occupants in the facility preferred to have their lights on; they cancelled the lighting shed after the first couple of CPP days. In Echelon, during the first CPP event the occupants were not notified and one employee strongly insisted on information for subsequent events.

5.5. Auto-DR Plans for 2007

LBNL is working with PG&E to implement a larger-scale automated demand response program for summer 2007 in accordance with the requirements outlined by the California Public Utilities Commission (CPUC). Those specifications call for the implementation of an automated demand response (Auto-DR) program funded through PG&E's existing TA/TI (technical audit/technical incentive) program. The goal of the program is to achieve a 15 MW peak load reduction averaged over all DR event days with a baseline comprised of three of the previous 10 days as approved by the CPUC. The DR events are to be initiated through PG&E's existing price-based demand response programs. There are currently two programs that fit this definition – the Critical Peak Pricing (CPP) and Demand Bidding (DBP) programs.

During the early stages of this implementation effort, a detailed plan will be developed that will define how the Auto-DR load reductions will be achieved vis-à-vis these two programs (e.g., the types of customers to be targeted, the anticipated loads to be shed from these customer segments, etc.). Figure 14 illustrates the Auto-DR technology development and commercialization strategy. During the 2006 Auto-CPP project, LBNL managed the majority of the activities for Auto-DR with a fraction of the work done by private sector subcontractors and consultants. The 2007 Auto-DR PG&E program is designed to scale up and disseminate the technology beyond LBNL project management. Over time the goal of this effort is to develop incentives for Auto-DR providers to install and configure communication systems that automate current and future DR programs.

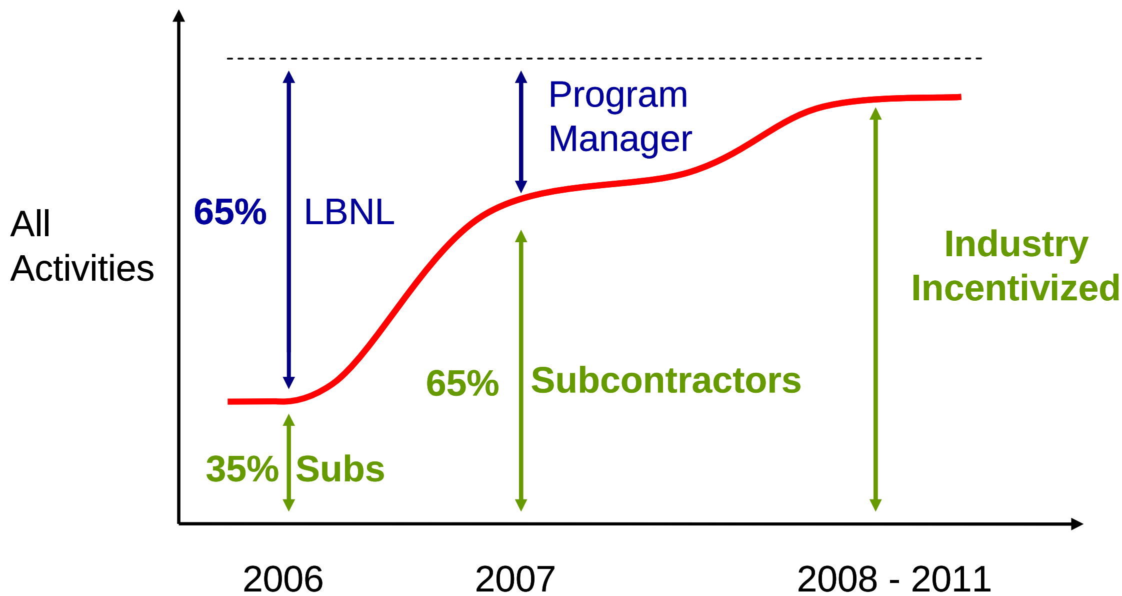

Figure 14. Auto-DR commercialization strategy

6.0. Recommendations and Future Directions

This section outlines some of the technical challenges for 2007 and beyond.

One goal of scaling up the Auto-DR infrastructure is to ensure that all of the IOUs use a common set of automation technologies to allow energy customers a common connectivity platform throughout California. Each IOU is offering at least one Auto-DR program for 2007, but continuous coordination and common concepts are needed to facilitate that both the energy customers and the vendor community offer common technology and program offerings. The DRRC will continue to support research to help understand the strengths and weaknesses of the current Auto-DR platforms and assist in identifying improvements. Specific examples of future research issues are listed below:

- **Explore Auto-DR for small commercial and large industrial sites.** One of the long-term strategies of automating DR is to strengthen relationships with the current controls and communications technology vendors to inform and educate them on the Auto-DR systems. Technically, this project showed that most buildings with EMCS can participate in Auto-DR. Further work is needed to explore how to connect the DRAS with smaller buildings that do not have centralized EMCS. For example, LBNL has not connected the DRAS or CLIR box directly to an HVAC system comprised of packaged rooftop units. Further work is also needed to evaluate the readiness of industrial process control systems for automation.
- **Develop common peak demand savings estimation methods.** While automation systems have been shown to provide continuous, reliable communication of DR program signals, more work is needed to understand end-use control strategies. Perhaps the most critical need is to engage the engineering community and auditors who evaluate DR strategies and estimate peak demand savings to develop common methods for savings calculations. While there are decades of experience with energy savings analysis methods and techniques, methods to estimate peak demand savings for short durations are new. Such analysis methods are more complex than historical "bin" methods for energy efficiency analysis that simplify weather data into heating and cooling degree-day bins. Rather, new dynamic models are needed, based on knowledge of weather data, peak load shapes, and HVAC system and controls knowledge, combined in practical ways to provide simple yet robust methods for peak demand savings estimates.
- **Improve communication on the CPP tariff.** PG&E's CPP tariff is complex. The July 2006 heat storm, with seven CPP events, caused an average increase of 15% in participants' summer utility bills. Many of the participating sites were notably concerned with the high mid-summer utility bill following the heat wave. Improved utility communication with customers about the tariff and their bills is needed to explain the charges and credits each site collects for the entire summer. A predictive tool that calculates predicted CPP charges and credits based on the number of CPP events could help eliminate these concerns.

- **Provide better information about state benefits of DR.** Demand response is a confusing term with confusing programs. More effort is needed to communicate the concepts of DR and how it benefits the state electricity system. Automating DR may help improve the reliability of the resource, but there is a hurdle in marketing these programs because of limited customer understanding.

- C**onsider alternative weather-adjusted baseline models.** The Auto-CPP project showed that the CPP baseline was lower than hot peak day loads prior to CPP events. When the CPP baselines are lower than the load shape, there are no estimated DR savings. Weather sensitive loads need weather-adjusted baseline models.

- **Develop new DR tariffs and economic evaluation tools.** New tools are needed to help customers understand how their load shape and DR strategies affect their monthly electricity costs. There is a PIER tool under development for this purpose. Further work is needed to disseminate this tool, evaluate user feedback, and improve economic analyses. Furthermore, the CPP tariff itself offers minimal economic incentives for the DR shed level that many sites can offer. To attract more DR participants, new tariff designs need to be explored.

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Glossary

ADAM Relay – an Internet relay used to communicate with some of the sites in 2004 and 2005 studies

AHU – Air Handling Unit

Auto-CPP – Automated Critical Peak Pricing demand response program

CEC – California Energy Commission

CIMIS - California Irrigation Management Information System

CLIR Box – Client and Logic Internet Relay – an Internet gateway device designed, built, and provided to PG&E customers (where needed) to accept Auto-CPP event signals and transmit them to the customer's EMCS for this project

Co-Lo – Co-location facility where the DRAS resides

CPP – California's Critical Peak Pricing Program as mandated by the CPUC

CPUC – California Public Utility Commission

DBP – Demand Bidding Program

DR – **Demand Response**, strategies and programs to facilitate load shedding during peak system demand periods

DRAS - DR Automation Server, an Internet-based communications server and database system that produces a computer-readable, electricity price signal on a Web services server, using the meta-language XML (Extensible Markup Language)

DRISCO - Demand Response Integration Services Company, an engineering and controls firm that provides assistance to end users to automate demand response at their facilities

DRRC – Demand Response Research Center, a technology center at LBNL funded primarily by the California Energy Commission's PIER Program

DSM – Demand-Side Management

EIS – Energy Information System

ESCO – Energy Services Company

EMCS – Energy Management and Control System

GTA – Global Temperature Adjustment

HVAC – Heating Ventilating and Air Conditioning

IOU – Investor-Owned Utility

IT – Information Technology

LBNL – Lawrence Berkeley National Laboratory, performs work for the University of California on this research project contract

LAN – Local Area Network

M&V – Measurement and Verification

Modbus - a serial communications protocol for programmable logic controllers (PLCs)

MOU – Memorandum of Understanding

NOAA - National Oceanic & Atmospheric Administration

OAS – Otherwise Applicable Service

OAT – Outside Air Temperature

PEC – Pacific Energy Center (PG&E)

PG&E – Pacific Gas and Electric Company

PG&E Communication Staff – PG&E Corporate and Customer Energy Management Division staff who manage messages to PG&E Account Service Managers and PG&E customers and partners

PG&E CPP Customer – a customer of PG&E Company who is under agreement to the terms and conditions of the CPP Demand Response Program

PG&E Account Manager – PG&E's Account Service Managers who manage energy solutions for major PG&E commercial and industrial customers

PG&E DR Managers – DR program managers within PG&E's Demand Response Program

PG&E Integrated Audits – Analyses of energy conservation and demand reduction opportunities conducted for PG&E major commercial and industrial customers under PG&E's Integrated Audits Program

PG&E's InterAct™ System - an Internet-based action-oriented energy management software application offered to business customers of Pacific Gas and Electric Company who participate in PG&E's Demand Response and Real-Time Metering Programs

PG&E Program Manager – PG&E staff who manage technology incentive and information programs

PIER – The California Energy Commission's Public Interest Energy Research Program

SDG&E – San Diego Gas and Electric Company

SOAP – Simple Object Access Protocol

SVLG – Silicon Valley Leadership Group

Technical Coordinator (TC) – A company that understands building controls and information technology issues and can assists customers in the automation of their DR strategies

TA – Technical Audit

TI – Technology Incentives

TOU – Time of Use

URL - Uniform Resource Locator

VFD – Variable Frequency Drive

XML – Extensible Markup Language