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Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

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Energy Environmental Technologies Division

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Executive Summary

Introduction

This report describes the results of the second season of research to develop and evaluate the performance of new Automated Demand Response (Auto-DR) hardware and software technology in large facilities. Demand Response (DR) is a set of time dependant activities that reduce or shift electricity use to improve electric grid reliability, manage electricity costs, and provide systems that encourage load shifting or shedding during times when the electric grid is near its capacity or electric prices are high. Demand Response is a subset of demand side management, which also includes energy efficiency and conservation. The overall goal of this research project was to support increased penetration of DR in large facilities through the use of automation and better understanding of DR technologies and strategies in large facilities. To achieve this goal, a set of field tests were designed and conducted. These tests examined the performance of Auto-DR systems that covered a diverse set of building systems, ownership and management structures, climate zones, weather patterns, and control and communication configurations.

Electric load shedding that is often part of a DR strategy can be achieved by modifying end-use loads. Examples of load shedding include reducing electric loads such as dimming or turning off non-critical lights, changing comfort thermostat set points, or turning off non-critical equipment. Levels of automation in DR can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as manually turning off or changing comfort set points at each equipment switch or controller. **Semi-Automated Demand Response** involves a pre-programmed load shedding strategy initiated by a person via 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 shedding strategies. We refer to this as **Auto-DR**. 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 the reduction in end-use services is not desirable.

Research Overview

The research described in this report was conducted in 2004 following the first year of tests in 2003. There were a number of specific objectives of the 2004 Auto-DR tests. One objective was to explore new control and communication systems; both gateway and relay technologies were tests. Another objective was to evaluate the size of the electric shedding potential of the 2003 Phase 1 buildings in warmer weather test events than our schedule permitted in 2003. These buildings participated in a warm weather 2004 “Retest”. A third objective was to evaluate how the test could be scaled up to allow more buildings to participate. A fourth objective was to better understand the range of electric shed strategies that are used in large facilities. These last two objectives were evaluated in a “Scaled Up” test. All of the 2004 tests were three hour shed events conducted at different times. The facility managers were unaware of the impending DR events.

The communication systems for the 2004 tests differed from the 2003 tests in that new methods of communication were used. During the 2003 test all of the sites had some sort of Web-based Energy Information System (EIS) and Energy Management and Control System (EMCS) with PC. During 2004, five of the 18 sites used an Internet relay that connected directly to the EMCS control panel. This new method allowed buildings with conventional control systems to participate in the test.

The test evaluation consisted of measuring the electric load sheds during each test event. A robust weather-normalized baseline model was developed for each building based on ten previous days of 15-minute whole-facility electric loads from the existing utility meters. Each shed event was evaluated with a common set of shed metrics. These metrics included include the average and maximum demand (power) savings for each hour of the three-hour test period (kW), the average and maximum demand (power) intensity shed for each hour (W/ft^2), and the average and maximum percent savings from the baseline for each hour (%). The shed savings for each building and the aggregated total across all test sites shed savings were estimated (kW).

Results

Participation – The project was successful in recruiting, configuring, and testing over 10 million ft^2 of facility floor area, with each site participating in at least one of the 2004 tests. The participants included 18 geographically distributed sites, covering 36 buildings. The participants include several office buildings, plus a supermarket, cafeteria, industrial process sites, university library, and a postal processing and distribution center. New technology was developed to explore and evaluate the capabilities of current controls and communications for Auto-DR with EMCS and XML. The project involved extensive outreach and recruitment efforts, and general publicity to audiences such as building engineers, utilities, property management companies, commissioning providers, and energy policy community. The Retests occurred on September 8th and 21st. The Scaled Up tests occurred on October 13th and November 5th. While each site participated in at least one test, there was no test where all of the sites worked as planned. The range of problems and issues that occurred during the preparation and execution of these tests illustrate the type of technical challenges that exist for future DR control and communication systems.

All but two of the Auto-DR test sites were in California. The Canadian and Wisconsin sites participated to better understand the XML technology and the electric price server. Although most of the sites were in California, some of the price clients and technology development sites were outside of California. Figure E-1 shows the geographic location of the pilot (test) sites along with the Web-based price clients, price server, and development sites.

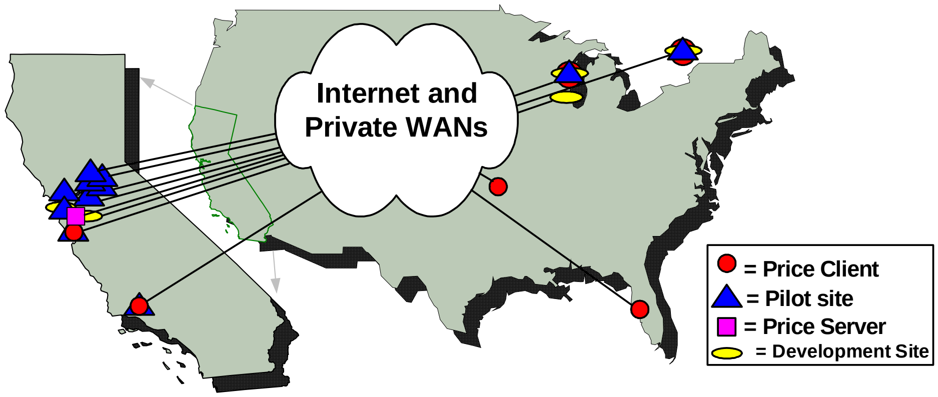

Figure E-1: Geographic Location of Pilot Sites and Related System Sites

Demand Savings – Results from the Retest of the five sites also evaluated in 2003 are as follows. The power reduction reached nearly 1 W/ft^2 for three of the five sites during the September 8th test, which was more successful in achieving large savings than the September 21st test. The largest individual savings were observed from strategies that used a cooling zone set point increase. Lighting, anti-sweat heaters, and other HVAC strategies were also pursued. The maximum aggregate savings over the three-hour shed was 1453 kW, or about 24% of the total aggregated demand for all five sites. There were negative savings at some of the sites during part of the shed, but each site achieved some savings during at least one of the shed hours. Negative savings can occur when the baseline model predicts the power should be less than the power observed during the particular shed hour. These demand intensities suggest there is significant demand reduction potential in large buildings and commercial facilities during warm weather. No occupant complaints were registered even with these large reductions in whole-building power. Figure E-2 shows the aggregated and individual load shapes of the five Retest buildings during the September 8th test. The baseline load shape is the sum of the individual baselines from each of the five sites. The individual buildings reduced between 5 to 30% of whole building power, with average power reduction of 11%, 24%, and 16% during the 3 hours of the test.

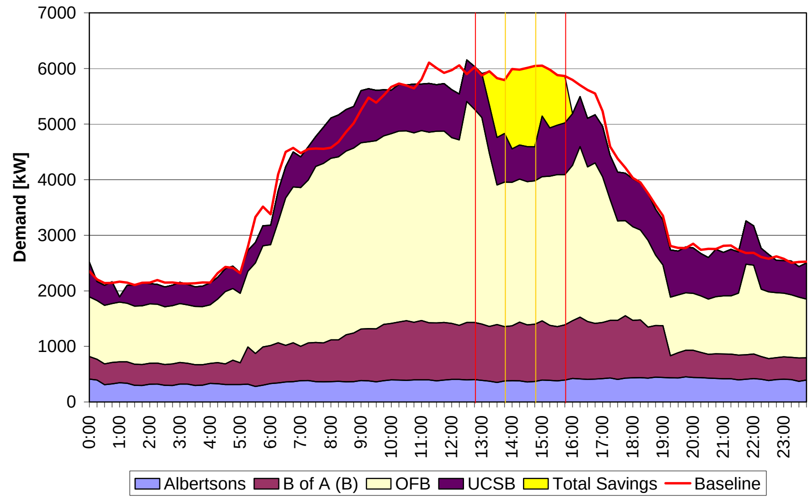

Figure E-2: Aggregated Demand Savings with a Maximum of 1453 kW Shed, Sept. 8th Retest

Results of the Scaled-Up test are as follows. Seventeen sites participated in the Scaled-Up test (one Retest site did not participate because a communication system was out of service following the Retest). Lighting, HVAC and a few other miscellaneous end-use load shed strategies were pursued. Figure E-3 shows the maximum 15-minute demand savings (kW) from 15 of the 18 sites that participated in the 2004 test events. Maximum savings from the Retest are also shown. Three of the 18 sites participated in the communications test only and not the demand savings analysis because of limited metering or being out of California.

On the November 5th test event the aggregated maximum savings among all 15 sites reached nearly 2.5 MW. Only 15 of the total 18 sites are included in this graph because the other three sites were involved in tests that involved the communication system only, and not measurement of the load shed. If all 15 sites reached their maximum shed simultaneously, a total of about 4 MW of demand response is available from these 15 sites that represent about 10 million ft^2 of floor area. Demand savings per site ranged from negative savings up to 1080 kW per site, with percent savings from zero to 42 %. Among the four test events, maximum savings per site were 0.01 to 1.81 W/ft^2, or 0.1 % to 56 % shed with an average from these 15 sites of 0.53 W/ft^2 and 14 %.

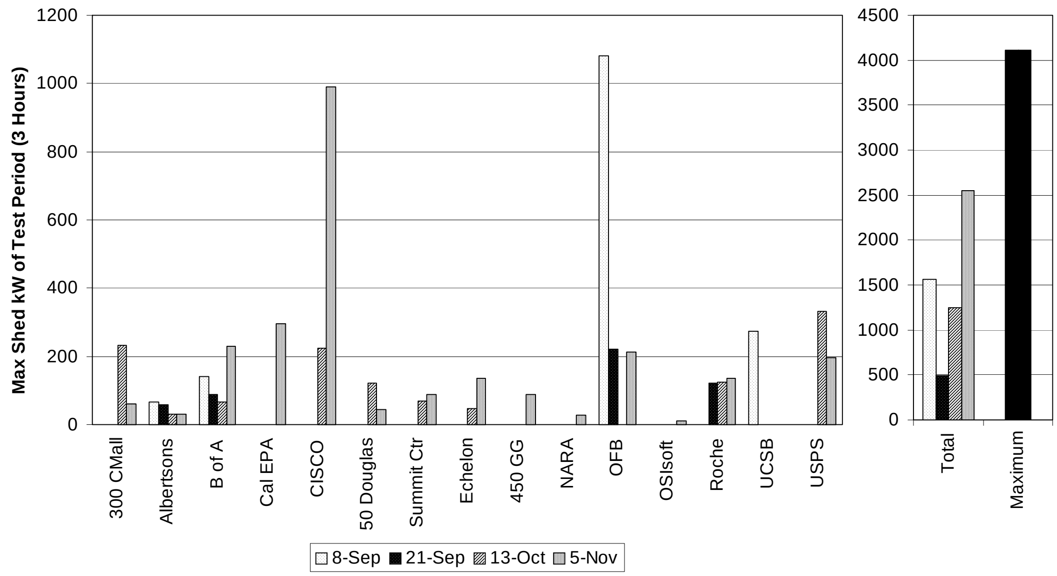

Figure E-3: Maximum Demand Savings for the September, October, and November Tests by Building, Total Aggregated Maximum Shed for Each Test, and Non-Coincident Maximum

This research has demonstrated that fully automated demand response systems are technically feasible for buildings with a wide range of control systems from highly sophisticated EMCS with telemetry communication to conventional EMCS. We demonstrated the features of Automated DR with EMCS and XML (eXtensible Markup Language). Both Internet gateways and Internet relays were tested. There are important pros and cons to these two systems. The Internet gateways are more sophisticated, having a greater set of functions. They are, however, more expensive as well. Further work is needed to continue to evaluate the shed strategies possible for a broad range of building systems, building type, and climatic conditions. Further research is also needed to determine the economics of such DR, evaluate reasonable scenarios for the frequency and duration of sheds, and possible occupant and tenant issues.

1. Introduction

1.1. Background

This report describes the results of the second year of research to develop and evaluate the performance of new Automated Demand Response (Auto-DR) hardware and software technology in large facilities. Demand Response (DR) is a set of activities that reduce or shift electricity use to improve electric grid reliability, manage electricity costs, and provide systems that encourage load shifting or shedding during times when the electric grid is near its capacity or electric prices are high. Demand response has been identified as an important element of the State of California's Energy Action Plan, which was developed by the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and Consumer Power and Conservation Financing Authority (CPA) (CEC et al., 2003). The CEC's 2003 Integrated Energy Policy Report also advocates DR (CEC, 2003). DR has been identified as a key national strategy to improve electricity markets and electric grid reliability (United States GAO, 2004).

Electric load shedding that is often part of a DR strategy can be achieved by modifying end-use loads. Examples of load shedding include reducing electric loads such as dimming or turning off non-critical lights, changing comfort thermostat set points, or turning off non-critical equipment. Levels of automation in DR can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as manually turning off or changing comfort set points at each equipment switch or controller. **Semi-Automated Demand Response** involves a pre-programmed load shedding strategy initiated by a person via 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 shedding strategies. We refer to this as **Auto-DR**. 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 the reduction in end-use services is not desirable.

This report provides a detailed discussion of the demand shedding strategies used at the test sites. In this study all of the DR strategies were instantaneous electric load sheds using automated controls. There was no pre-planned load shifting or pre-cooling because the sites were not given any early notification of the impending shed test. Unlike a day-ahead DR program, the sites could not pre-cool, pre-ventilate or prepare for the test (Xu et al, 2004). Industrial sites, if they had significant flexibility, could reschedule loads instantaneously, but this is not possible with most building HVAC or related loads. Thus, the responses evaluated in this research were all curtailment or electric load sheds.

The overall goal of this research project was to support increased penetration of DR in large facilities through the use of automation and better understanding of DR technologies and strategies in large facilities. To achieve this goal, we conducted a set of four field tests. These tests examined the performance of Auto-DR systems that covered a diverse set of building systems, ownership and management structures, climate zones, weather patterns, and control and communication configurations.

This report describes the results of the second year of research to develop and evaluate the performance of new Automated Demand Response (Auto-DR) hardware and software technology in large facilities. The tests took place from September through November 2004.

Review of Findings from the 2003 Tests

During 2003 LBNL conducted a two-week experiment to develop and test fully automated DR systems in large facilities. The study demonstrated a number of key issues that relate to Automated DR, and DR in general. The 2003 tests were conducted in November, during mild weather. Of the 5 MW under control among the 5 building, a shed of nearly 10% was achieved. One key finding was that fully automated DR is technically feasible with minor enhancements to current state-of-the-art technology. The enhancements involved custom software at each site programmed using the emerging technology standards "XML" and "Web services". Automation of DR is likely to foster greater participation in various DR markets by decreasing the time (and effort) needed to prepare for a DR event, increasing the number of times a facility may be willing to shed loads, and perhaps improving the size of the DR response.

The 2003 project involved extensive discussions and interactions with five large organizations and institutions. Overall we obtained excellent support and assistance in this research. The energy managers at these organizations believe that DR programs and tariffs will increase in importance and prominence, and new technology will help them participate in these programs. One key finding from the 2003 test was that new knowledge is needed to procure and operate technology and strategies for DR. DR is a complex concept. Facility operators need to understand DR economics, controls, communications, energy measurement techniques, and the relation between changes in operation and electric demand. Such understanding may involve numerous people at large facilities. Facility managers need good knowledge of controls, and current levels of outsourcing of control services complicate understanding of control strategies and system capabilities. Another key finding in the 2003 test was the wide support and interest in this research. Presentations of the results at ASHRAE and the XML Symposium, and elsewhere resulted in numerous control companies, software developers, and building owners expressing interest in participating in future tests.

This report is organized as follows. The remainder of this introductory section provides an overview of the project goals and objectives. The second section describes the project methodology, which includes the site recruitment, Auto-DR systems, and the DR overall evaluation techniques. The third section provides additional details on the Auto-DR system characteristics, the DR shed strategies, and the measurements at each site. The fourth section describes the results of the field tests, providing results on individual Auto-DR tests and examining the results of the tests by DR strategy. The fifth section is a discussion of particular issues such as controls and their relation to DR strategies, comparison of the 2003 and 2004 test results, and the relation between the DR control strategies and building commissioning. The final section is a summary and discussion of future research plans and outstanding issues. A series of appendices provide additional detail, as described and referenced in the report below. Appendix A includes the project outreach documents. Appendix B provides additional details on the site descriptions and demand shed strategies. Appendix C provides post-test interview notes. Appendix D is a case study of one of the complex HVAC Shed strategies. Appendix E lists acronyms and terminology.

1.2. Goals and Objectives

The overall goal of the 2004 project was to support increased penetration of DR in large facilities through the use of automation and better understanding of DR technologies and strategies in large facilities. To achieve this goal, field studies are needed that examine Auto-DR in a broader range of buildings and building systems, covering a range of attributes such as control system type, energy information system type, heating, ventilation, and air conditioning (HVAC) system type, lighting, and other building system, climate, ownership, and usage patterns.

There were a number of specific objectives of the 2004 Auto-DR tests. One objective was to evaluate the size of the electric shedding potential of the Phase 1 buildings in warmer weather. Another objective was to evaluate how the test could be scaled up to allow more buildings to participate. A third objective was to better understand the range of electric shed strategies that are used in large facilities and technical compatibility or feasibility of various control and EMCS technologies. This report reviews the results of these research questions. A future report will discuss the decision-making perspectives from the Auto-DR participants, which is also a subject of ongoing research.

2. Methodology

2.1. Project Overview and Site Recruitment

The basic concept of the project was to perform a series of tests of fully automated DR systems. The Retest, further described below, was a two-week test period with two DR event days. The Scaled-Up Test, also further described below, was a second two-week test period with two DR event days. The tests consisted of providing a single fictitious continuous electric price signal to each facility. The technology used for the communications is known as Extensible Markup Language (XML) with "Web services". Control and communications systems at each site were programmed to check the latest electricity price published by the price server and automatically act upon that signal. All of the facilities had Energy Information Systems (EIS) and Energy Management and Control Systems (EMCS) that were programmed to automatically begin shedding demand when the price rose from $0.10/kWh to $0.30/kWh (See Motegi et al, 2003, for a discussion of EIS and EMCS). The second stage price signal increased to $0.75/kWh. Figure 2-1 is an illustration of the price signal for a representative test day.

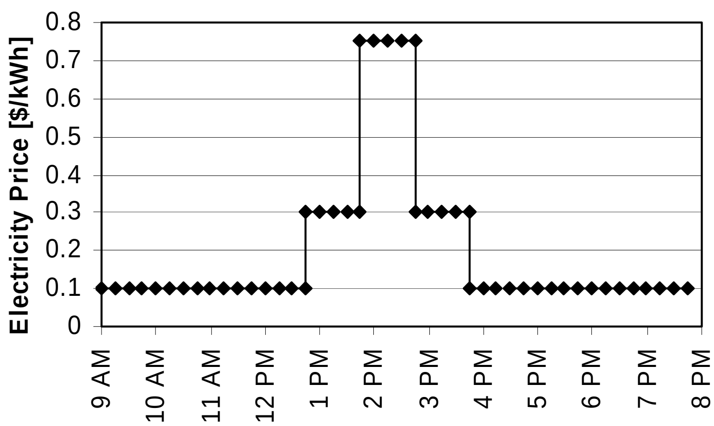

Figure 2-1: Electricity Price Test Signal

In the 2003 test, the price signal was published 15-minute ahead to provide participant sites 15 minutes of adjustment time. However, we found that all the participant sites responded within 1 minute from reception of the signal. This year, we used the same 15-minute-ahead signal, to reduce the effort needed to re-configure the system. Participant sites configured their systems to respond as soon as receiving the price signal change. To simulate the effect of instantaneous response, the time stamp was shifted 15 minutes in the subsequent data analysis[1].

[1] For example, to average the first $0.30/kWh price signal period (1pm – 2 pm), the data from 12:45 to 1:45 pm is used for analysis.

During the 2003 tests a set of site selection criteria were developed to identify sites for the Auto-DR tests. We recruited sites based on their characteristics related to the following criteria:

- **Facilities** – different types of commercial and light industrial
- **Energy Information System** (EIS) – multiple vendors
- **Energy Management Control System** (EMCS) – multiple vendors
- **Gateways** – multiple technologies
- **Ownership** – government, company owned, leased
- **End-Use Load Shedding Strategies** – lighting, HVAC, and other types of strategies

The criteria were described as "…the facilities selected for the 2003 Auto-DR test differed from most commercial buildings in California because each site had the capability to remotely monitor and control HVAC or lighting equipment over the Internet. Although these remote control and monitoring features, known collectively as telemetry, are becoming increasingly popular in newly installed EMCS, they are still uncommon within the installed base of commercial buildings in California. For this reason, the 2003 Auto-DR participating sites were a select group" (Piette et al, 2005). All of the 2003 test sites received CEC funds for advanced technologies known as Web-based Energy Information Systems. Each of the 2003 test sites had demonstrated some capability to shed that had been documented by a CEC evaluation contractor (Nexant, 2002). Additionally, in 2003 we looked for demonstrated DR capability and a willingness to share information on facility operation, facility characteristics and monitored data for time periods before and during the tests.

Retest

The first two-week test period, referred to as the "Retest", re-examined the 2003 test sites. The objectives of the Retest were 1) to demonstrate the same strategies in warmer weather, and 2) to determine how much effort was required for the sites once configured for the Auto-DR test in 2003 to be revised for the 2004 tests. In preparation for the Summer 2004 Retests, the 2003 test participants were contacted regarding the Summer 2004 plans. Each site was requested to participate in the Retest and the Scaled-up 2004 test. All five of the 2003 test sites agreed to participate in both of the 2004 Retest and the Scaled up test.

Scaled-Up Test

The second two-week test period we refer to as the "Scaled-up test". The objectives of the Scaled-up test were: 1) to demonstrate the Auto-DR in a greater number of building and facility systems, and 2) to overcome technical limitations of Auto-DR when applied to a larger set of buildings. Because the 2004 Auto-DR tests were intended to allow "typical" commercial buildings into the program, certain aspects of the Auto-DR communications architecture were altered to allow mainstream sites to participate. The detail of the new system architecture is described below. The criteria were relaxed to allow any large commercial building (over 200 kW service) with a conventional EMCS[2] to participate. The site recruitment effort was expanded to include wider variation of building types. The outreach process consisted of numerous strategies such as the following:

- Presentations at industry conferences and forums
- One-on-one discussions with retro-commissioning site contacts
- One-on-one discussions with control companies
- Technical Advisory Group outreach
- Outreach through professional industries - Automated Buildings Newsletter
- Outreach through Demand Response Research Center Web site – drrc.lbl.gov

Several of the sites that participated in the 2004 tests learned about the 2003 tests and contacted LBNL independently to express their interest in participating with the 2004 tests. LBNL worked with each site to explain the procedure for the Auto-DR tests using the documents provided in Appendix A.

The Retest sites were also informed about the Scaled-up test program. B of A, UCSB, and GSA all agreed to add additional buildings to the test. UCSB's showcase Bren Hall laboratory was identified for participation in the Scaled-up test, but the communications systems were not developed in time for the 2004 tests. (Bren Hall is one of the "greenest" laboratory buildings in the country, and one of only a small number of buildings in the United States to have received the U.S. Green Building Council's Platinum LEED accreditation, the highest level possible, in the Leadership in Energy and Environmental Design program (UCSB, 2005)). Albertsons and Roche did not add additional buildings due to staff and time limitations. Two additional B of A buildings and two additional GSA buildings were added to the Scaled-up test.

In order to evaluate each site the following information was collected. The site data collection documents are included in Appendix A.

- Site characteristics (size, type, location, HVAC systems, etc.);
- DR-Systems: software, firmware, and hardware, etc., installed at the site;
- Monitoring, control, and reporting attributes of the system;
- Level of automation, human expertise and experience with DR;
- DR-System and Energy Management capabilities and strategies used: How is the DR-system used to optimize energy performance, shed, or shift demand?

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[2] We refer to a "conventional EMCS" as an EMCS supported by a control panel interface or an EMCS with a PC workstation.

2.2. Test Preparation

Control and Communication System Configuration

All participants were responsible for reviewing and meeting the "Schedule for Demand Response Test Participants" of the "Automated Demand Response in Large Facilities Summer 2004 Scaled-Up Test Plan (Round 2)" (Appendix A). The basic design of the Retest was identical to the 2003 tests, but to occur during warmer weather. LBNL provided the participants with a fictitious XML electric price signal via the Internet that contained information to represent electricity prices. The participants agreed to work with their controls and DR system vendor and in-house staff to modify their system to be able receive or retrieve the XML signal, send back an acknowledgement, and initiate an automated shed. The Retest was scheduled to take place during a 2-week period in September 2004. Within a test day, the shed response was not requested for more than 3 hours. The Participant was able to override the test if needed.

The price signal was described in two documents "Automated Demand Response in Large Facilities Summer 2004 Scaled-Up Test Plan (Round 2)" and "Real Time Electricity Pricing Web Methods and XML Schema For Automated Demand Response Tests in Large Facilities" (both documents are in Appendix A). The baseline price for no action was $0.10/kWh. The first level of price increase was $0.30/kWh. The second level was $0.75/kWh. Triggers for the automated shed were based on those prices.

Data Collection

LBNL collected various types of data to evaluate the demand savings and changes in building systems and conditions. For all the participant sites, LBNL collected 15-minute interval whole building power data. A minimum of ten days of data prior to the two-week test period was collected to develop a baseline model. LBNL also collected HVAC, control, communications, energy, and other building time-series data, relevant to their shed strategies. Additional metering was added at 4 sites to support the analysis of the demand shedding strategies. These data were collected during the test period. Additional information about effectiveness of the shed strategies and issues that arose as a result of the tests were obtained by interviewing the responsible building engineer after the test was completed. Appendix C documents the raw data obtained from the post-test interviews.

2.3. Automated Demand Response System Description

This section provides an overview of the Auto-DR technologies. Both Internet gateways and Internet relays were used as the communication interface to the control systems at each building.

Internet Gateway

An Internet gateway is a device used in building telemetry systems to provide several functions. First, it physically connects two otherwise incompatible networks (i.e., networks with different protocols) and allows data to pass between them. Second, it provides *translation* and usually *abstraction* of messages passed between two networks. Third, it often provides other features such as *data logging,* and control and monitoring of input/output (I/O) points. Internet gateways typically connect the Internet communication protocol (TCP/IP) to the protocol of a given EMCS. This means that a different Internet gateway type is usually required to communicate with each different EMCS brand or product line. Internet gateways are not available for all EMCS. An Internet gateway can take several forms: 1) A PC with software and adapter cards that connect it to both the EMCS and the Internet. 2) An embedded device that has the network adapters and network connection software packaged in a dedicated embedded device that can be mounted in a panel.

During the recruitment phase of the 2004 project, it became apparent that many building managers were interested in participating in our study, but were unable to do so because their buildings and organizations lacked two key attributes: 1) an Internet Gateway (connects the EMCS to the Internet that enables telemetry) and 2) Computer programming skills that would enable them to create custom "Price Client" software. Overcoming these impediments can be daunting. The feasibility of adding an Internet gateway to a legacy EMCS varies depending on the EMCS manufacture, the protocol, the EMCS vintage and other factors. For many legacy systems, adding an Internet gateway (if possible) can cost between $5,000 and $15,000.

Even if a given site had an Internet gateway, with the architecture used in the 2003 Auto-DR tests, most typical commercial buildings could not participate due to their lack of in-house computer programming skills. Outsourcing this programming was generally not an option due to the unique skills required. Both XML/Web services programming skills and domain knowledge of the existing EMCS are required to create custom "Price Client" software. In addition, outsourcing the creation of the price client software could cost between $5,000 and $10,000.

To outfit typical commercial buildings using the communications architecture from the 2003 Auto-DR tests could cost between $10,000 and $25,000 for the necessary hardware and software. In addition, there is little consistency between buildings because different Internet gateways are required for each various EMCS protocols, many of which are proprietary and not interoperable with more open systems. Furthermore, Internet gateways may not be available for some EMCS.

Internet Relay

Rather than require all sites to have an Internet gateway, another connectivity option was provided for the 2004 tests. If desired, LBNL provided participating sites with a low-cost Internet relay. An Internet relay is a device with relay contacts that can be actuated remotely over a LAN, WAN or the Internet using Internet Protocols (IP). The Internet is based on a standard protocol (TCP/IP) and all EMCS can sense the state of relay contact closures (regardless of their particular EMCS protocol). Because of this, Internet relays can be used on virtually any commercial building that has a standard connection to the Internet (i.e., Internet connectivity directly to the EMCS is not required).

The Internet relay, which costs less than $200, was used to remotely signal five of the sites of the impending shed. Instead of converting XML messages to the native EMCS protocol, the Internet relay simply closes relay contacts, which were read as digital inputs by EMCS controllers. The in-house staff programmed the EMCS to shed loads based on the state of the Internet relay. Rather than require the sites to have in-house computer programmers, the price client software was developed and deployed by the programmers at the company that created the Price Server software, Infotility.

In the 2004 Auto-DR tests, both of the major impediments were overcome through a relatively minor modification to the system architecture. Figure 2-2 shows the communication sequence for each system type used in the Auto-DR tests. The four steps involved are:

1. LBNL defines the price versus time schedule and sends it to the price server.
2. The price is published on the server.
3. Polling clients request the latest price from the server every few minutes.
4. The Energy Management Control System (EMCS) initiates shed commands based on current price.

Some sites chose to create and deploy their own price client and logic software and used it to control their own Internet relays (as opposed to sites that used project "standard" Internet relays (which were Adam 6060s) controlled by Infotility price client and logic software). These sites hosted the price client and logic software wherever they desired and had the additional benefit of customizing the logic software, if desired.

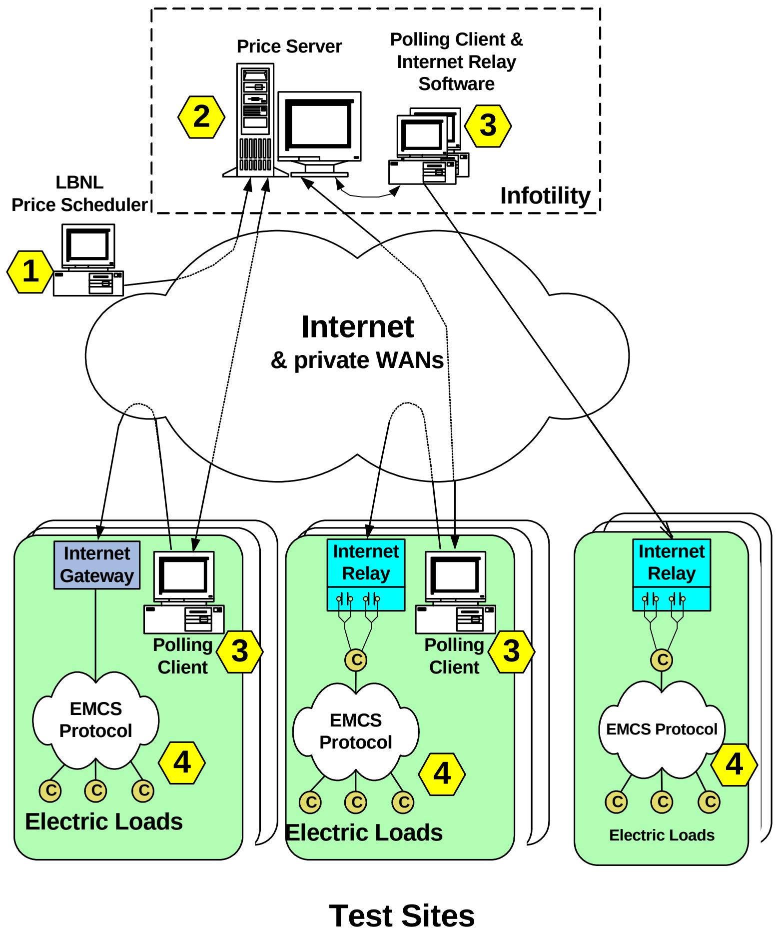


Figure 2-2: Auto-DR 2004 Sequence of Communication

The simplicity of the Internet relay architecture made it possible for many sites to participate in the 2004 Auto-DR tests that would not have been able to do so otherwise. Support for the original Internet gateway architecture used in the 2003 tests was continued in the 2004 tests. Seven of the new participants in the 2004 tests opted to use the more complex, yet more flexible Internet gateway architecture even though the Internet relay method was available. Several of the new sites were control and software companies experienced with software development (Echelon, Cisco, OSIsoft). Six of the new participants used the Internet relay.

The 2004 Auto-DR tests were conducted with the two options mentioned above. The procedures to follow for each option are described below.

Steps necessary for site facility staff to install an Internet gateway:

1) Determine if a compatible Internet gateway is available for the EMCS(s) in the facility of interest.
2) If available, contact an EMCS system vendor or integrator to purchase and/or configure the gateway.
3) Connect device to Internet with an RJ-45 Ethernet plug and assign a public static IP address to the device.
4) Hook up wires between the Internet gateway and the EMCS network bus.
5) Map the desired EMCS points into the gateways so as to allow control from the Internet.
6) Write and deploy price client and logic software.

Steps necessary for site facility staff to install an Internet relay:

1) Connect device to Internet with an RJ-45 Ethernet plug and assign a public static IP address to the device.
2) Hooks up wires between the Internet relay and two digital inputs on the EMCS.
3) Configures the EMCS to shed loads when Internet relay contact(s) close per the Table 2-1. The control strategy for Level 1 and Level 2 for each site is listed below in Table 3-4. Six contacts on each Internet relay allow up to 64 discrete shed levels to be sent, if desired (2^6=64).

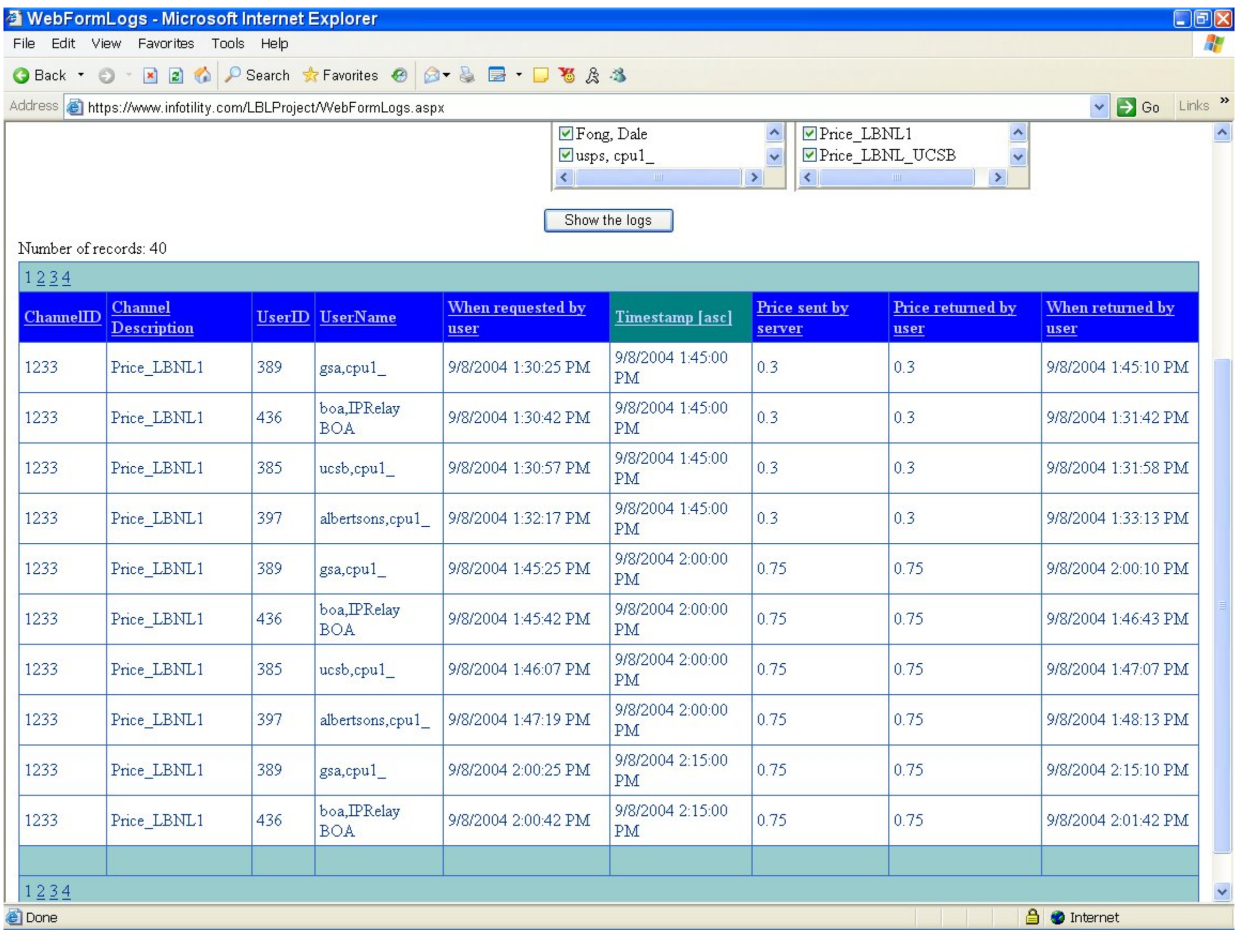
Table 2-1 Internet Relay Contact Closure Mapping for Demand Response

Contact #1 State	Contact #2 State	Shed Level	Fictional Price
OFF	OFF	Normal	$ 0.10/kWh
ON	OFF	Level 1	$ 0.30/kWh
ON	ON	Level 2	$ 0.75/kWh

The Auto-DR systems using the Internet gateways and those using Internet relays were both successful in conducting Auto-DR tests. The systems with Internet gateways tend to be more powerful and flexible due to their ability to enable two-way translation between EMCS and Internet protocols as well as other additional features such as data trending and logging. Systems with Internet relays, which are simpler, tend to be easier to integrate into existing buildings and easier for most building operators to understand.

LBNL Price Scheduler

LBNL price scheduler, a Web-based user interface for the price server, was developed by Infotility to schedule the test, observe server/client communications in real-time and create a historical log. To schedule the test LBNL personnel log into the site to setup the time and fictitious electric prices for an event. The electric prices are published to the price clients 15 minutes prior to the initial time of the price change. During and after the event LBNL is able to observe the two-way server/client communication log to ensure that the new price signals are received. Figure 2-3 shows a screenshot from the user interface showing the communication log. The log displays Channel ID, Channel description, User ID, User name, When requested by user, Time stamp, Price sent by server, Price returned by user, and When returned by user. The key feature of this tool is the return log from the user. The price server not only publishes price data, but also confirms which user could successfully receive the price signal. Both Internet gateway and Internet relay can return an acknowledgement response back to the price server. This acknowledgement is important for our evaluation of the communication system to verify receipt of information from each site.



ChannelID	Channel Description	UserID	UserName	When requested by user	Timestamp [asc]	Price sent by server	Price returned by user	When returned by user
1233	Price_LBNL1	389	gsa,cpu1_	9/8/2004 1:30:25 PM	9/8/2004 1:45:00 PM	0.3	0.3	9/8/2004 1:45:10 PM
1233	Price_LBNL1	436	boa,IPRelay BOA	9/8/2004 1:30:42 PM	9/8/2004 1:45:00 PM	0.3	0.3	9/8/2004 1:31:42 PM
1233	Price_LBNL1	385	ucsb,cpu1_	9/8/2004 1:30:57 PM	9/8/2004 1:45:00 PM	0.3	0.3	9/8/2004 1:31:58 PM
1233	Price_LBNL1	397	albertsons,cpu1_	9/8/2004 1:32:17 PM	9/8/2004 1:45:00 PM	0.3	0.3	9/8/2004 1:33:13 PM
1233	Price_LBNL1	389	gsa,cpu1_	9/8/2004 1:45:25 PM	9/8/2004 2:00:00 PM	0.75	0.75	9/8/2004 2:00:10 PM
1233	Price_LBNL1	436	boa,IPRelay BOA	9/8/2004 1:45:42 PM	9/8/2004 2:00:00 PM	0.75	0.75	9/8/2004 1:46:43 PM
1233	Price_LBNL1	385	ucsb,cpu1_	9/8/2004 1:46:07 PM	9/8/2004 2:00:00 PM	0.75	0.75	9/8/2004 1:47:07 PM
1233	Price_LBNL1	397	albertsons,cpu1_	9/8/2004 1:47:19 PM	9/8/2004 2:00:00 PM	0.75	0.75	9/8/2004 1:48:13 PM
1233	Price_LBNL1	389	gsa,cpu1_	9/8/2004 2:00:25 PM	9/8/2004 2:15:00 PM	0.75	0.75	9/8/2004 2:15:10 PM
1233	Price_LBNL1	436	boa,IPRelay BOA	9/8/2004 2:00:42 PM	9/8/2004 2:15:00 PM	0.75	0.75	9/8/2004 2:01:42 PM

Figure 2-3: Screenshot from Infotility Web Price Tool

2.4. Evaluation Techniques

Baseline Model

LBNL subtracted the actual metered electric consumption from the baseline consumption to derive the demand savings for each 15-minute period. The baseline consumption is an estimate of how much electricity would have been used without the demand shedding. In the 2003 test we developed the whole-building method and the component-level method to estimate baseline electricity consumption, and concluded that whole-building method provides reasonable estimates. Although the component-level method can be more accurate depending on the shed component and available measurement, it is time-consuming, requires additional measurements, and the methodologies may vary site by site.

Previous research recommended a weather sensitive baseline model with adjustments for morning load variations (KEMA-XENERGY, 2003). We used an outside air temperature regression model with a scalar adjustment for the morning load. First, a whole building power baseline is estimated using a regression model that assumes whole building power is linearly correlated with outside air temperature (OAT). The OAT data were obtained from either an on-site weather station from the EMCS or EIS, or local weather stations from NOAA (National Oceanic & Atmospheric Administration). Input data are 15-minute interval whole building electric demand and 15-minute interval or hourly OAT. The model is computed as;

$$Li = ai + bi\ Ti$$

where Li is the predicted 15-minute interval electric demand of time i from the previous non-controlled working days. Depending on frequency of available weather data, Ti is the hourly or 15-minute interval OAT of time i. ai and bi are estimated parameters generated from a linear regression of the input data of 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). To develop the baseline electric loads for the demand sheds we selected 10 “non-shed” days. These 10 baseline days were non-weekend, non-holiday Monday through Friday workdays.

Secondly, the morning power load is used to adjust the regression model. The regression model is multiplied by average ratio between actual demand and the predicted demand from 9:00 am to noon. The adjusted load is computed as;

$$L'i = P\ Li$$

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

where Li is the adjusted load of time i, P is the calibration ratio, and Mi is the actual demand of time i. The hours from 9:00 am to 11:45 am are used to calculate P. Figure 2-4 shows an example of the whole-building baseline time-series chart on the September 8th test for theGSA Oakland Federal Building. The chart shows whole building power for the shed (the lower curve) and the whole-building baseline power predicted if the shed had not occurred. The vertical line at each baseline power data point is the standard error of the regression estimate. The vertical lines at each hour from 1 pm to 4 pm identify the time the the price signal was increased to trigger the demand shed.

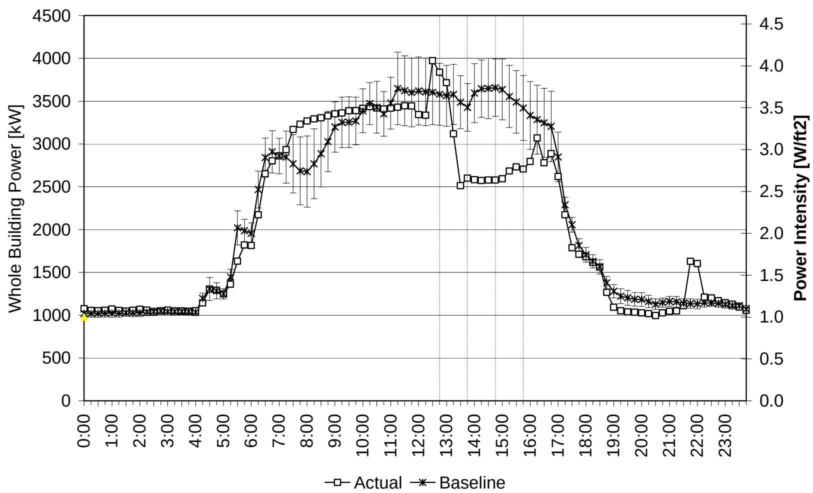


Figure 2-4: Whole-Building Baseline Time-Series Chart Example

In the development of the baseline model we considered an OAT regression model without a morning load shape adjustment and an average model with a morning load shape adjustment. Based on the analysis of multiple baselines using the 2004 Auto-DR test data, the OAT regression model with adjustment generally provided a better estimate than the model without the morning load shape adjustment. If the OAT is low in one morning and becomes higher in the afternoon, the model estimate of hourly demand is likely to be lower than actual.

The demand savings estimates are based on the baseline models described above. This estimation method may yield a negative demand savings if the baseline model predicts a baseline that is lower than the actual demand during a given 15-minute of hourly period. Negative savings are often seen after a shed period as part of a "rebound" or recovery peak in which the HVAC or cooling systems may try to bring the thermal zones back to normal conditions. This issue is further described below in Section 4.4.

The evaluation included deriving the electric load shed power reduction at each site, along with the reduction in whole-building power by percentage and the demand intensity (W/ft^2). The load shed power is calculated by subtracting the actual whole building power from its baseline demand. The load shed percentage savings is defined as the percentage of savings in whole building power. The demand-shed intensity (W/ft^2) is the load shed power (W) normalized by the building's conditioned floor area (square footage).

Milestones for Success

The evaluation also includes a detailed review of problems that may occur in the control and communication systems. The "system" from the price server to the end-use control strategy has the six milestones defined below:

- **Readiness**: The system was configured and ready to be tested by the research team.

- **Approval**: Organizational approval to perform demand responsive load control was granted.
- **Price Client/Price Server Communication**: The price client successfully obtained the correct electricity prices from the price server (Figure 2-2 between ⟨2⟩ and ⟨3⟩).

  Failures to pass this milestone were generally caused by the following faulty condition. The price server would sometimes get overloaded with requests from clients. When this condition occurred, it would send out faulty messages that contain no price values (also known as "null values"). When some price clients received null values, they failed to handle the error gracefully. This faulty condition caused communication between the client and the server to fail. The software for some other price clients was written so as to be more robust. These price clients ignored null values and other faults and continued to operate normally until valid data was restored.
- **Internet Gateway/Internet 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 2-2 between ⟨3⟩ and ⟨4⟩). Failures to pass this milestone were generally caused by 1) blockages of the Internet-based command signals due to firewalls, disconnection or network reconfiguration or 2) failures in the Internet gateway or Internet relay devices themselves.
- **Control of Equipment**: Target equipment was controlled as planned. Target equipment included HVAC equipment, lighting and other equipment that generate electric loads. Failures to pass this milestone were generally caused by HVAC equipment not responding to command signals over the EMCS network. An example of this type of failure occurred when an HVAC EMCS controller had been placed in manual operation (as opposed to automatic operation). In this case, control signals coming over the EMCS network were ignored.
- **Effectiveness**: To pass this milestone, the planned shed strategy must have been proven to effectively reduce electric demand. Effectiveness was tested by comparing the average power (kW) shed during the test to the average standard error of the regression model. The shed strategy was considered effective if in one or more hours of the three-hour test, the average power savings was larger than the hourly average of the standard error in the baseline model.

3. Auto-DR Systems Characterization and Measurement

3.1. Site Profiles

This section describes the 18 sites that participated in the Auto-DR tests during 2004. Table 3-1 lists the site name, location, type, and size of the five sites that participated in both the 2003 and the 2004 Retest. The peak electric demand from September 2004 is also shown for reference. The buildings include two office buildings, a supermarket, a library, a cafeteria, and an auditorium. The supermarket and the governmental office were standalone sites, though connected to multi-building remote monitoring and control systems from the large owners that managed dozens of geographically distributed sites. The other three sites were part of multi-building campuses. All the five sites were innovative sites that received advanced technology from the state during the 2001-2002 electricity crisis in California.

Table 3-1: Summary of Retest Sites

Site Name	Short Name	Location	Building Use	# of Bldg	Floor Space		Peak Load kW (Sept)
					Total	Conditioned	
Albertsons, Fruitville	**Albertsons**	Oakland	Supermarket	1	50,000	50,000	450
Bank of America Concord Data Center	**B of A**	Concord	Bank Office	1	200,000	176,000	1,120
GSA Ronald V. Dellums Oakland Federal Building	**OFB**	Oakland	Federal Office	1	1,105,000	978,000	4,100
Roche Palo Alto	**Roche**	Palo Alto	Cafeteria Auditorium	3	192,000	192,000	750
UC Santa Barbara Davidson Library	**UCSB**	Santa Barbara	Library	1	289,000	289,000	1,090
Total				7	1,836,000	1,685,000	7,510

* Only 1 of 4 buildings of B of A participated in the retest.

Table 3-2 lists the characteristics of the sites that participated in the two 2004 Scaled-up test. Over 10 million ft^2 of floor area was recruited for the 2004 tests that cover 18 individual sites and include 36 buildings. All but two of the Auto-DR test sites were in California. The Canadian and Wisconsin sites participated to better understand the XML technology. Although most of the sites were in California, some of the price clients and technology development sites were outside of California. Figure 3-1 shows the geographic location of the pilot sites along with the Web-based price clients, price server, and development sites. The largest site is Cisco, which consists of over 4 million ft^2 and 24 buildings. Most of the new sites were office buildings. Additional buildings include research laboratories and high technology buildings, one industrial facility that produces various commercial products from paper waste, a federal archive building, and a USPS mail distribution center.

Two sites were outside of California: Kadant in Green Bay, Wisconsin and CANMET research Center in Ottawa Canada. These sites participated to learn more about the communications technology. Because of the time zone difference for the site outside of California, the electric demand savings from these sites are not relevant or report in the analysis below. These sites were in e operations during the California peak periods. However, the evaluation of the communications is included. A third site, Monterey, is also only reported with respect to the evaluation of the communication connectivity and not the demand savings because the whole-building power data were not available at this building.

Table 3-2: Summary of Scaled-Up Sites

Site Name	Short Name	Location	Building Use	# of Bldg	Floor Space		Peak Load kW (Sept)
					Total	Conditioned	
300 Capitol Mall	**300 CMall**	Sacramento	Office	1	426,000	383,000	1,580
Albertsons, Fruitville	**Albertsons**	Oakland	Supermarket	1	50,000	50,000	450
Bank of America Concord Data Center	**B of A**	Concord	Bank office	3	616,000	708,000	5,380
Joe Serna Jr. Cal/EPA Headquarters Building	**Cal EPA**	Sacramento	Office	1	950,000	950,000	1,990
CANMET Energy Technology Centre - Varennes	**CETC**	Varennes (Quebec, Can)	Research Facility	1	45,000	18,000	240
Cisco Systems	**Cisco**	San Jose Milpitas	Office Tech Lab	24	4,466,000	4,466,000	27,860
Contra Costa County 50 Douglas	**50 Douglas**	Martinez	Office	1	90,000	90,000	500
Contra Costa County Summit Center	**Summit Ctr**	Martinez	Office	1	131,000	131,000	500
Echelon San Jose Headquarter	**Echelon**	San Jose	Office	1	75,000	75,000	410
GSA Phillip Burton San Francisco Federal Building	**450 GG**	San Francisco	Federal Office	1	1,424,000	1,424,000	2,130
GSA National Archives & Records Administration	**NARA**	San Bruno	Archive Storage	1	238,000	202,000	280
GSA Ronald V. Dellums Oakland Federal Building	**OFB**	Oakland	Federal Office	1	1,105,000	978,000	4,100
Kadant Grantek	**Kadant**	Green Bay (WI)	Material Process	1	100,000	0	1,440
Monterey Commerce Center	**Monterey**	Monterey	Commercial	1	170,000*	170,000*	N/A
OSIsoft	**OSIsoft**	San Leandro	Office	1	60,000	60,000	300
Roche Palo Alto	**Roche**	Palo Alto	Cafeteria Auditorium	3	192,000	192,000	750
UC Santa Barbara Davidson Library	**UCSB**	Santa Barbara	Library	1	289,000	289,000	1,090
US Postal Service, San Jose Process & Distribution Center	**USPS**	San Jose	Distribution Center	1	390,000	390,000	1,630
Total				36	10,647,000	10,406,000	50,630

* Monterey is not included in the total, because this site was used only for communication test.

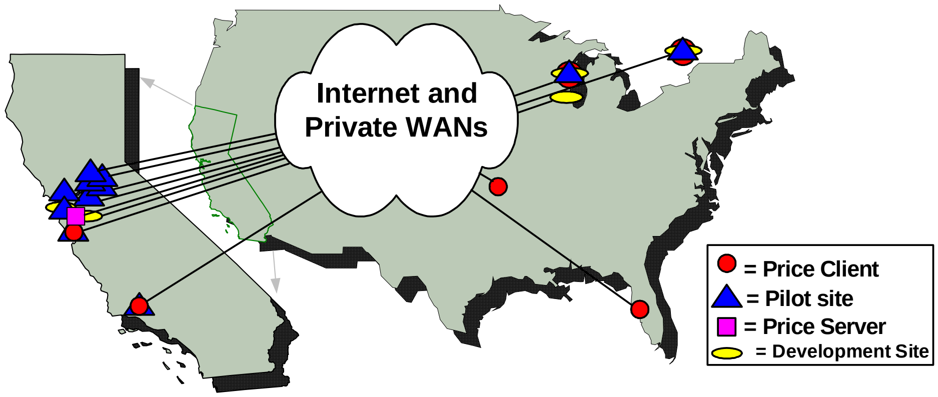


Figure 3-1: Geographic Location of Pilot Sites and Related System Sites

3.2. Auto-DR System Architecture

There are numerous examples of communication and control systems used in the test. See the previous report for a detailed discussion of sample systems (Piette et al, 2005). Some Auto-DR facilities hosted the polling client software on-site and others associated with geographically dispersed buildings hosted it at remote co-location sites. The geographic location of the computer that hosts the polling client is less important than the type of environment where it is hosted. Professional co-location hosting services or "co-los" offer highly secure environments for hosting computers and servers.

Table 3-3 summarizes the communication systems of each participant site. Nine sites used their own Internet gateway and created their own custom price polling client and logic software. Four sites used their own Internet relay and created their own custom price polling client and logic software. Five sites used an Internet relay provided by LBNL (ADAM6060) and allowed it to be controlled remotely by Infotility's price polling client and logic software.

Table 3-3: Summary of Site ADR2 Communication

Site	Gateway/ Relay	Device	Price Client Host	Price Client Host Location	Price Client Hosted at Co-Lo
300 CapMall	Relay	ADAM6060	Infotility	Fremont, CA	Yes
Albertsons	Relay	EPIM	Engage	Tampa, FL	Yes
B of A	Relay	ADAM6060	Infotility	Fremont, CA	Yes
Cal EPA	Relay	ADAM6060	Infotility	Fremont, CA	Yes
CETC	Gateway	Delta	CETC	Canada	No
Cisco	Gateway	Web CTRL	CISCO	San Jose, CA	No
50 Douglas	Relay	ADAM6060	Infotility	Fremont, CA	Yes
Summit Ctr	Relay	ADAM6060	Infotility	Fremont, CA	Yes
Echelon	Gateway	i.LON	Kenmark	San Francisco, CA	No
GSA 450GG	Gateway	Web CTRL	GSA (GEMnet)	San Francisco, CA	No
GSA NARA	Gateway	Web CTRL	GSA (GEMnet)	San Francisco, CA	No
GSA OFB	Relay	Alerton	GSA (GEMnet)	San Francisco, CA	No
Kadent	Gateway	eMinor	WPS Energy	Green Bay, WI	No
Monterey	Gateway	iLON	Kenmark	San Francisco, CA	No
OSIsoft	Gateway	Tridium	OSIsoft	Oakland, CA	No
Roche	Gateway	Tridium	Infotility/Yamas	Palo Alto, CA	No
UCSB	Relay		Itron	Santa Barbara, CA	No
USPS	Relay	Enflex	Chevron/Viron	Kansas City, KS	No

A few other system characteristics are important to mention. At both B of A and Cal EPA, new Internet connections were installed to ensure that the Internet Relay communications were separated from company's network to avoid network security risk. The other sites used existing Internet connections for the tests.

3.3. DR Shed Strategies

Since every facility is unique, so is each shed strategy. The sites were asked to develop two levels of shedding, one for $0.30/kWh, and a second for the $0.75/kWh signal. Table 3-4 shows the shed strategies for each site. Most of the sites pre-programmed their controls to reduce HVAC systems electric demand, while some focused on lighting. Several sites also worked with miscellaneous loads. The site operations staff developed the load-shed strategies on their own. LBNL documented the shed strategy and was available for discussion of technical issues if the site desired. Further discussion of these strategies is provided later in Section 5.1.

Table 3-4: Summary of each Site's Shed Strategy

Site Name	$0.30/kWh	$0.75/kWh
300 CMall	Chilled water temp 44 °F → 47 °F Annex building modify monitored average zone temp down by 1.5 °F Supply fan VFD* lock Fountain pump off Loading deck fan off Lobby lights off	Chilled water temp → 55 °F Annex building avg. zone temp down 3 °F
Albertsons	Overhead light 35% off	Anti-sweat door heater night-mode
B of A	Supply air temp reset 55 °F → 59 °F Duct static pressure 2.2 IWC → 1.8 IWC	Supply air temp reset → 59 °F Duct static pressure → 1.4 IWC
Cal EPA	Duct static pressure 1.0 IWC → 0.5 IWC	Turn off light where daylight is available
CETC	Unload chiller and cool with ice storage Two air handling units off Electric humidifier off	
Cisco	VAV zone setup 2 °F Computer Room AH setup 2 °F Boiler pump off & stairwell fan-coils off Sweep lighting where daylight is available. Stairwell, lobby, hallway lights off	
50 Douglas	Global zone setup 76 °F → 78 °F	Global zone setup → 80 °F
Summit Ctr	Global zone setup 76 °F → 78 °F	Global zone setup → 80 °F
Echelon	Zone set point increase Dim office lighting	2 of 3 Rooftop units off Lobby, common area light off Hallway light 33~50% off
450 GG	Global zone setup 72 °F → 74 °F Global zone setback 70 °F → 68 °F ***	Global zone setup → 78 °F Global zone setback → 66 °F
NARA	Global zone setup 75 °F → 76 °F Global zone setback 70 °F → 68 °F	Global zone setup → 78 °F Global zone setback → 66 °F
OFB	Global zone setup 72 °F → 76 °F Global zone setback 70 °F → 68 °F	Global zone setup → 78 °F Global zone setback → 66 °F
Kadant	Transfer pump off	
Monterey	Lobby lights 33% off	
OSIsoft	Global zone setup 72 °F → 76 °F Global zone setback 72 °F → 76 °F	Global zone setup → 78 °F Global zone setback 72 °F → 76 °F
Roche	Building-A2 supply fans off (50%)	Building-FS supply fans off (50%) Building-SS supply fans off (50%)
UCSB	Supply fan VFD 70% limit Economizer 100% open	Supply fan VFD 60% limit Duct static pressure reset 0.4 IWC (partial) Heating/cooling valve close
USPS	Chiller demand 75% limit	Chiller demand 50% limit

* VFD: Variable Frequency Drive, IWC = Inch Water Column
** Strategies chosen for $0.30/kWh level are continued in $0.75/kWh level (except for deeper increase or decrease of parameter set point chosen in $0.30/kWh level).
*** Zone temperature setup strategies produce reductions in cooling loads, at some sites the programming included setback strategies ensure that heating systems do not come on during zone setup events.

3.4. Site Measurement

Measurement techniques were developed to evaluate each 15-minute increment of the three-hour electric shed event. All the participant sites are required to have at least 15-

minute interval whole building power data. HVAC, control, communications, energy, and other building time series data are also collected to evaluate successfulness of the shed strategies. The following methods are used to collect the data.

Web-Based Energy Information System (EIS) – A Web-based EIS is a system to collect and archive energy and related data viewable via an Internet-based Web browser (Motegi et al, 2003). The data can usually be accessed in near real-time. The primary purpose of an EIS is to understand a building's energy usage characteristics and to improve energy management. Some EIS provide Web-based remote control capability if network communication between the EMCS and the Internet are already established. EIS software and XML client software can reside in the same server. Some sites have non-Web-based EIS, which tend to be data collection systems that use phone lines or other non-Internet based networked monitoring systems.

Energy Management and Control System (EMCS) – An EMCS is used to collect detailed HVAC trend logs. In some cases whole building and end-use power data were also collected through the EMCS. Trend logs were either emailed to LBNL, or LBNL visited the sites after the test to manually download the trend logs.

Sub-meter – Sub-metering was installed in a few cases where the EIS or EMCS trends were not available or insufficient for the analysis. LBNL or contractor staff visited the sites after the test to download the data.

While all of the sites had some form of EIS in the 2003 test, we selected a wider variety of facilities for the 2004 test. Table 3-5 shows types of measurements for each site. Within the 18 participant sites, 13 sites have some form of EIS including 11 sites with an EIS that is independent from the EMCS, and 5 sites with EIS connected to EMCS. 2 sites, 300 Capitol Mall and Roche, have an EIS that is not Web-based. 4 sites have only EMCS data collection. For the sites where there was no Web-based data archive, we asked the participants to email us the trend data after the test. For the 4 sites where EIS or EMCS data trends were insufficient, we installed sub-meter at critical components. For 6 of the sites, we used PG&E's InterAct[3] as the data collection tool for whole building power. At Albertsons and Kadant, a single EIS was used for data collection and analysis. These sites were relatively easy to evaluate because their strategies were simple and involved non-HVAC, or non-weather dependent systems. At the other 16 sites, significant re-configuration of the EMCS or EIS trending was required. B of A, Cisco, and Echelon have Web-based EMCS functionality though they don't have a classic EIS with electric data archived over the Web. Their EMCS trends were configured and the data were retrieved by email. The site engineers (either onsite or offsite) downloaded the data and emailed it to LBNL. Summaries of the measurement points for each site are listed in Appendix B.

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[3] EIS provided by PG&E and powered by Itron to archive/visualize 15-minutes electric interval meter data for each account. PG&E customers who have over 200 kW can access the data via a Web browser.

Table 3-5: Summary of Site Measurement

Site	Non-Web EIS	Web-based EIS independent from EMCS	Web-based EIS connected to EMCS	EMCS Trend	Submeter
300 CMall	✓			✓	
Albertsons		✓			
B of A		✓*		✓	✓
Cal EPA				✓	
CETC				✓	
Cisco				✓	
50 Douglas		✓*		✓	✓
Summit Ctr		✓*		✓	✓
Echelon				✓	
450 GG		✓*	✓		
NARA		✓*	✓		
OFB		✓*		✓	
Kadant		✓			
Monterey				✓	
OSIsoft			✓	✓	
Roche	✓		✓		
UCSB			✓	✓	
USPS		✓			✓

* InterAct

Outside air temperature (OAT) data for each site were retrieved from either the EMCS trends or from the local on-line NOAA (National Oceanic & Atmospheric Administration) weather data archive. One issue with EMCS trends is that they are often poorly calibrated unless the sensors have been carefully commissioned. The NOAA data can also be problematic in that the data source is usually the local airport, which is not always close to the site. Especially in Bay Area, the local climate varies significantly even within a city. Another issue is that the NOAA archive often has missing data.

4. Results

The Retest events occurred on September 8th and 21st. The Scaled-up test events occurred on October 13th and November 5th. All 18 sites successfully participated in at least one test. There was no test where all of the sites worked as planned. This section outlines the results of the tests, beginning with a review of the communications, and ending with a review of the electric demand shedding.

4.1. Retest Results

This section summarizes the results of the Retest (September 8th and 21st). The two-week Retest period began on September 8th and ended on September 21st. The maximum temperatures in Oakland on these two days were 90 °F and 79 °F respectively. The demand savings are presented along with the shed power for each hour (kW), shed percentage of whole-building load, and shed demand intensity (W/ft^2). Shed electric power reduction is calculated by subtracting the actual whole building power from its baseline demand. Shed percentage is defined as the percentage of savings in whole building power. Shed demand shed intensity is defined as the shed power normalized by the building conditioned floor area. Figure 4-1 and Figure 4-2 show the shape of electricity price signal of the two 3-hour tests.

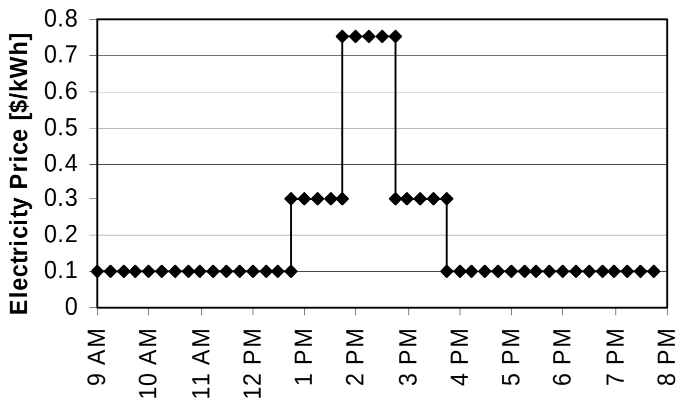


Figure 4-1: Electricity Price Signal, Sept. 8th

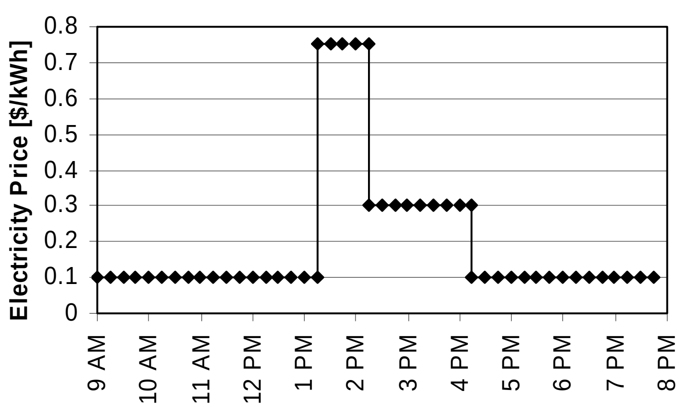


Figure 4-2: Electricity Price Signal, Sept. 21st

It is difficult to know if the shape had a significant influence on the savings because of variations in weather and other factors that influence the demand savings. The September 21st shape does bring on the 2nd level of shedding before the first level and may result in lower savings from rebound type operations.

Response Results

Table 4-1 and Table 4-2 summarize the results of the Retests. The tables show the success or failure in passing each milestone of the project described in Section 2.4. On September 8th test all the sites were ready and succeeded in the first test except Roche. Albertsons executed their anti-sweat door heater shed strategy, but the anti-sweat heater was already low-mode due to low humidity for both tests.

Table 4-1: Response Results of Sept. 8th

Site Name	Readiness	Approval	Server/Client Communication	Gateway/Relay Communication	Control of Equipment	Effectiveness
Albertsons						
B of A						
OFB						
Roche						
UCSB						

Succeeded Failed Not Applicable

On the September 21st test, UCSB failed because of a communication failure between the relay and the EMCS. The polling client successfully requested and returned the signal to the price server, but communication between the polling client and the gateway was blocked by network security reconfiguration between the tests. B of A did not show any identifiable shed because of complications with the shed strategy itself, which are discussed in Appendix D. Although OFB shed an average of 170 kW (7%) of the load, the “Effectiveness” “failed” because the standard error was large due to several irregular load shape days within the previous 10 days.

Table 4-2: Response Results of Sept. 21st

Site Name	Readiness	Approval	Server/Client Communication	Gateway/Relay Communication	Control of Equipment	Effectiveness
Albertsons						
B of A						
OFB						*1
Roche					*2	
UCSB						

*1: Standard error was too large due to several irregular load shape.
*2: Shed control partially didn't work.

Succeeded Failed Not Applicable

Demand Shed Results, September 8th

Figure 4-3 shows the aggregated electric load shape of all sites during the first Retest on September 8th. The power reduction on September 8th reached a maximum of 1453 kW during the maximum 15-minute period in the second hour of the shed. The maximum savings was 24% of the estimated baseline power of 6047 kW. The breakdown of the saving was 1080 kW savings from OFB, 48 kW from Albertsons, 104 kW from B of A, and 274 kW from UCSB. The average power saving during that middle hour was lower at 1416 kW, with an average of 650 kW and 926 kW during the 1st and 3rd hours of the 3-hour test. The outside temperatures reached 90 °F in Oakland on this test day, which was over 25 °F warmer than the 2003 tests, achieving the objective of conducting a Retest during warm weather. Further details on the weather sensitivity of shedding are discussed in Section 5.2.

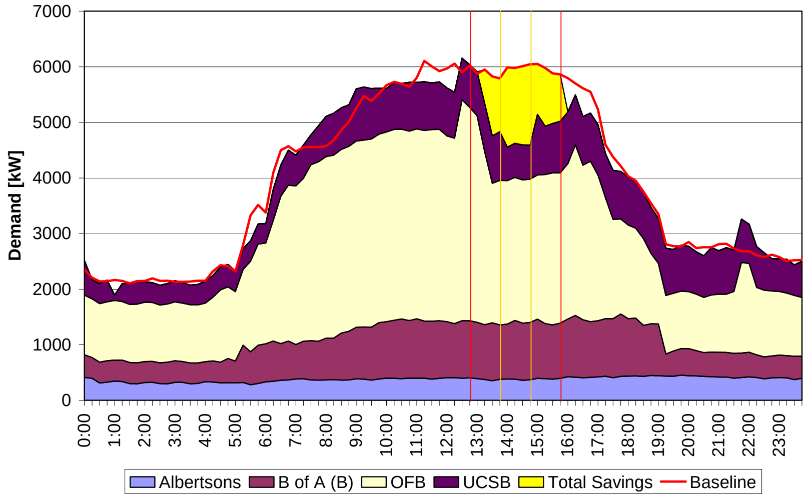


Figure 4-3: Aggregated Demand Savings, Sept. 8th

The following figures show the average power reductions from the test for each of the three hours. Figure 4-4 shows demand shed in absolute power (kW). Figure 4-5 shows the demand shed intensity (W/ft^2), and Figure 4-6 shows the demand shed in terms of the reduction in whole-building power (percentages). Minimum and maximum 15-minute average savings are shown for each hour. Because of demand shed rebounds and variable baselines, there were negatives savings in some of the 15-minute periods (such as UCSB during 3rd hour).

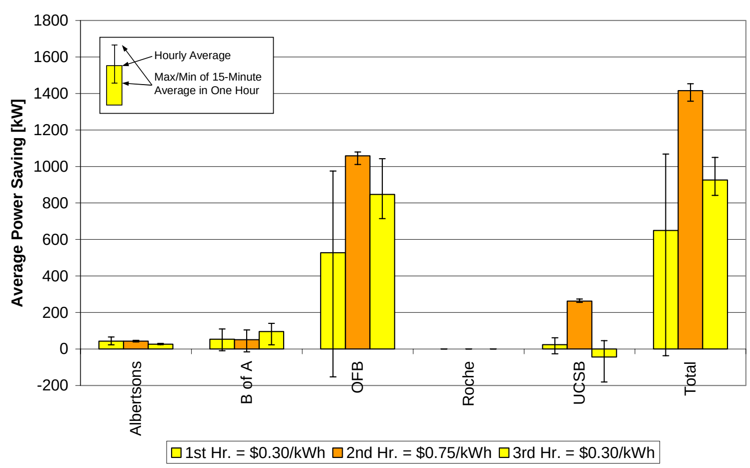


Figure 4-4: Average Power Saving kW by Shed Hour, Sept. 8th

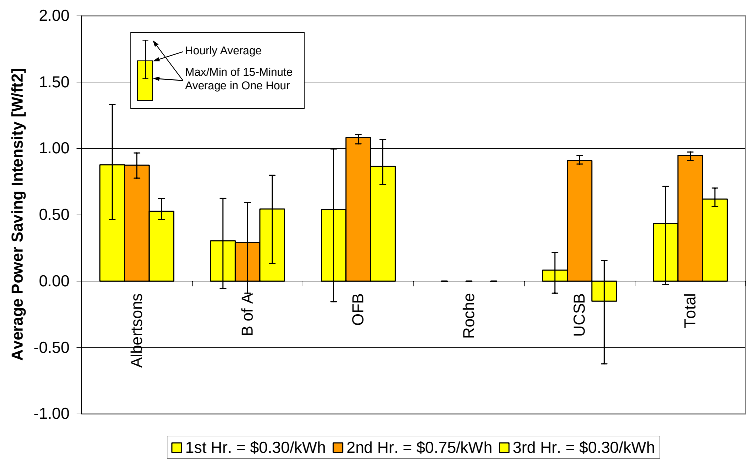


Figure 4-5: Average Power Saving Intensity by Shed Hour, Sept. 8th

It is remarkable that the power reduction reached nearly 1 W/ft^2 for three of the five sites during the September 8 test. These demand intensities suggested significant demand reduction potential in commercial facilities during warm weather. No complaints were registered in the post-event surveys even with these large reductions in whole-building power.

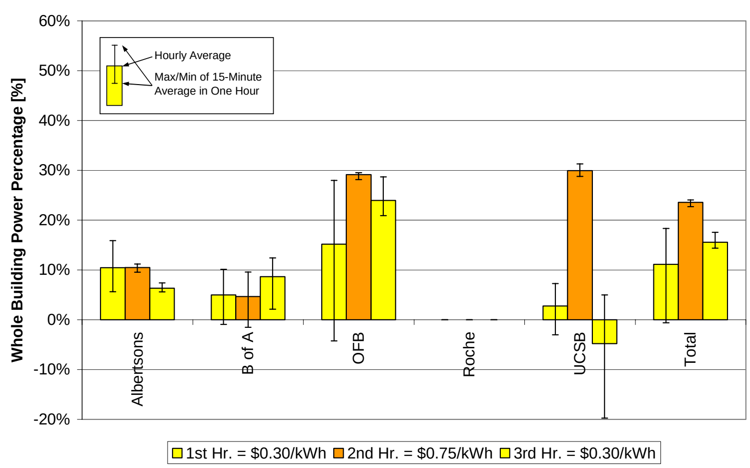


Figure 4-6: Average Power Saving Whole Building % by Shed Hour, Sept. 8th

Figure 4-6 shows that the buildings reduced 5 to 30% of whole building power, with average power reduction of 11%, 24%, and 16% during the 3 hours of the test. Table 4-3 shows hourly average and maximum of the demand saving, tabular view of Figure 4-4 through Figure 4-6.

Table 4-3 summarizes hourly average and maximum savings achieved on September 8th test. The table shows Total saving kW (sum of individual site demand sheds), Total whole-building power (WBP) % (percentage of sum of demand sheds in sum of baseline power), Average WBP% (average of WBP% at each site), Total W/ft^2 (sum of demand sheds divided by sum of square footages), and Average W/ft^2 (average of W/ft^2 at each site).

Table 4-3: Hourly Demand Saving, Sept. 8th

Unit	Site Name	Average			Max		
		1st Hr. = \$0.30/kWh	2nd Hr. = \$0.75/kWh	3rd Hr. = \$0.30/kWh	1st Hr. = \$0.30/kWh	2nd Hr. = \$0.75/kWh	3rd Hr. = \$0.30/kWh
Saving kW	**Albertsons**	44	44	26	67	48	31
	B of A	54	51	96	110	104	141
	OFB	528	1058	847	975	1080	1043
	UCSB	24	263	-44	62	274	46
	Total: Σ(ΔP)	**650**	**1416**	**926**	**1068**	**1453**	**1049**
WBP%	**Albertsons**	10%	10%	6%	16%	11%	7%
	B of A	5%	5%	9%	10%	10%	12%
	OFB	15%	29%	24%	28%	30%	29%
	UCSB	3%	30%	-5%	7%	31%	5%
	Total: Σ(ΔP)/Σ(BP)	**11%**	**24%**	**16%**	**18%**	**24%**	**18%**
	Average: Σ(ΔP/BP)/N	**8%**	**19%**	**9%**	**15%**	**20%**	**13%**
W/sqft	**Albertsons**	0.88	0.87	0.53	1.33	0.97	0.62
	B of A	0.30	0.29	0.54	0.62	0.59	0.80
	OFB	0.54	1.08	0.87	1.00	1.10	1.07
	UCSB	0.08	0.91	-0.15	0.22	0.95	0.16
	Total: Σ(ΔP)/Σ(A)	**0.44**	**0.95**	**0.62**	**0.72**	**0.97**	**0.70**
	Average: Σ(ΔP/A)/N	**0.45**	**0.79**	**0.45**	**0.79**	**0.90**	**0.66**

P = Power BP = Baseline Power ΔP = BP - P
N = # of site A = square footage (ft2)

Figure 4-7 shows the whole building power and baseline model of September 8th test for each site. The left scale shows whole building power (kW) and right scale shows whole building power intensity (W/ft^2). The right scale is identical at each site with a maximum of 10 W/ft^2 to allow comparisons of the demand intensity.

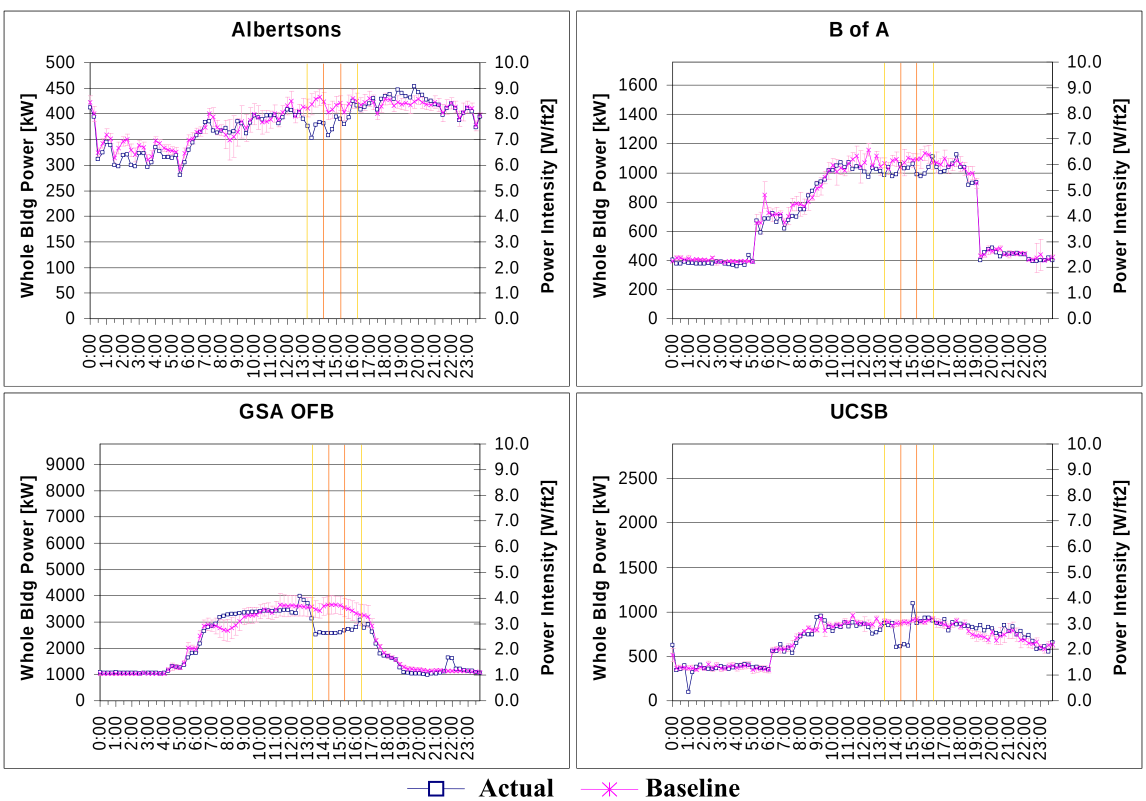


Figure 4-7: Whole Building Power and OAT Regression Model of Retest, Sept. 8th

Demand Shed Results, September 21st

Figure 4-8 shows the aggregated electric load shape of all five sites for the second Retest event on September 21st. Table 4-4 shows the demand savings from each site. During this test we programmed the price signal to rise from $0.10/kWh to $0.75/kWh without the $0.30/kWh period to see how quickly the system can provide maximum shed from normal operation. This may have reduced the size of the sheds. Another factor that caused the lower demand shed was that the weather was cooler on September 21st. The OAT reached a maximum of 79 °F in Oakland, 11 °F cooler than Sept 8. The maximum aggregated shed demand was 411 kW. These savings were 9% of whole building power and 0.29 W/ft^2.

Another finding during the second retest is that the Albertson's anti-sweat door heater strategy didn't shed load because the anti-sweat door heater was already off. B of A's whole building power didn't show identifiable saving, as further described in Appendix D. Roche successfully shed load but encountered one difficulty in the strategy at one of the buildings (on $0.75/kWh level) where the shed control was accidentally left disconnected in the controls. OFB responded to the $0.75/kWh signal and increased its zone temperature set point. However, clear differences between $0.75/kWh and $0.30/kWh operation could not be identified. Further details are described in Appendix B.

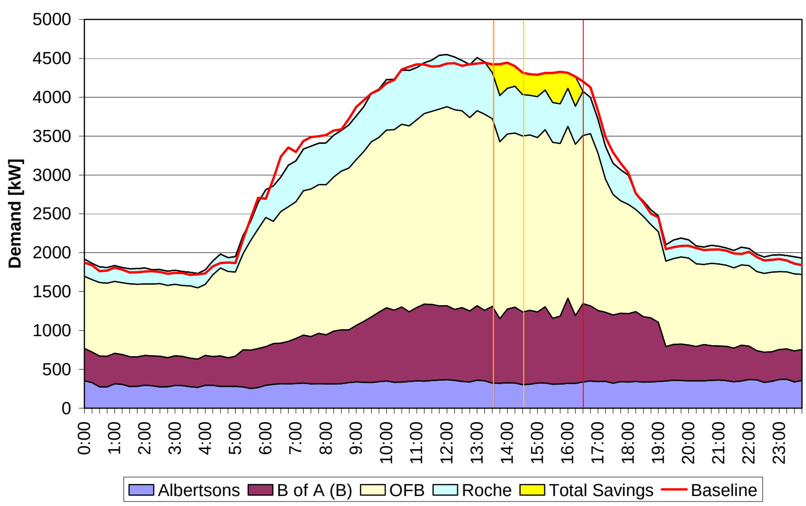


Figure 4-8: Aggregated Demand Savings, Sept. 21st

Table 4-4 summarizes hourly average and maximum of the demand saving.

Table 4-4: Hourly Demand Saving, Sept. 21st

Unit	Site Name	Average			Max		
		1st Hr. = $0.30/kWh	2nd Hr. = $0.75/kWh	3rd Hr. = $0.30/kWh	1st Hr. = $0.30/kWh	2nd Hr. = $0.75/kWh	3rd Hr. = $0.30/kWh
Saving kW	Albertsons	39	47	53	46	52	59
	B of A	-34	-40	6	67	0	89
	OFB	172	150	190	221	162	221
	Roche	99	108	94	108	120	101
	Total: Σ(ΔP)	**275**	**264**	**342**	**404**	**284**	**411**
WBP%	Albertsons	11%	13%	14%	12%	15%	16%
	B of A	-4%	-4%	1%	7%	0%	10%
	OFB	7%	6%	8%	9%	7%	9%
	Roche	14%	17%	16%	15%	19%	17%
	Total: Σ(ΔP)/Σ(BP)	**6%**	**6%**	**8%**	**9%**	**7%**	**9%**
	Average: Σ(ΔP/BP)/N	**7%**	**8%**	**10%**	**11%**	**10%**	**13%**
W/sqft	Albertsons	0.78	0.93	1.06	0.92	1.03	1.17
	B of A	-0.20	-0.23	0.03	0.38	0.00	0.51
	OFB	0.18	0.15	0.19	0.23	0.17	0.23
	Roche	0.51	0.56	0.49	0.56	0.63	0.52
	Total: Σ(ΔP)/Σ(A)	**0.20**	**0.19**	**0.25**	**0.29**	**0.20**	**0.29**
	Average: Σ(ΔP/A)/N	**0.32**	**0.35**	**0.44**	**0.52**	**0.46**	**0.61**

P = Power BP = Baseline Power ΔP = BP - P
N = # of site A = square footage (ft2)

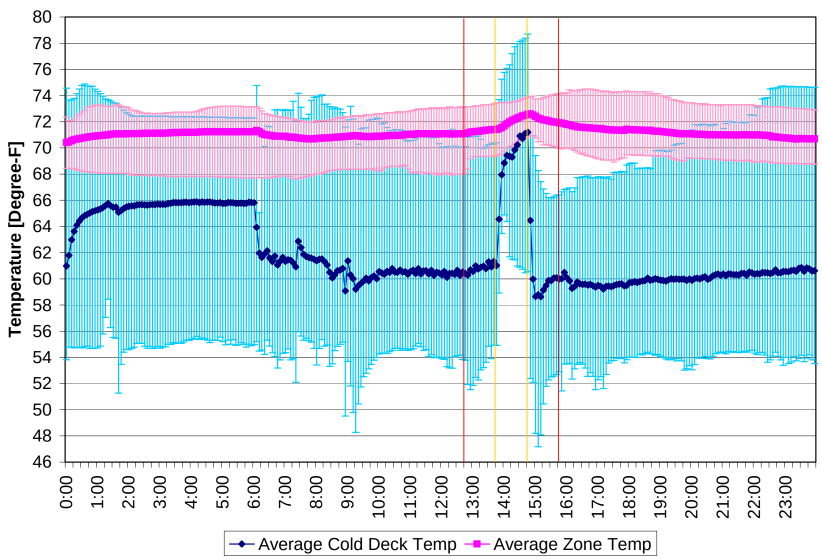
Operational Findings

This section provides some limited comments on the performance of the DR shed strategies. Additional details will be provided in a forthcoming report examining the DR shed strategies and the detailed HVAC and control data. Four of the five Retest sites employed HVAC shed control strategies. B of A is described in detail in the case study because of the challenges in working with the non-Direct Digital Control (DDC) systems (Appendix D).

One problem with some HVAC shed strategies is they may cause a "rebound peak" when the HVAC system returns to normal operation following a DR event. During this time the HVAC equipment may be more fully loaded than normal to recover from the shed conditions. In some cases this will not be a problem if the shed event ends during a time when evening occupancy schedules begin and the demands are lower than later afternoon peak demands. At the Oakland Federal Building (OFB) the controls programmer implemented a slow fan recovery strategy to mitigate the rebound peak. When the OFB building comes out of the shed from the global zone temperature setup, the supply fan variable frequency drive (VFD) speed is locked with a gradual diminishing of the VFD speed lock out limit for two hours. The term "global setup" refers to common control of all the thermal zones in a building.

On September 21st, OFB's slow recovery strategy succeeded in reducing and minimizing the demand rebound peak. A side effect of the strategy is that the VAV boxes went to 100% open due to the locked fan VFD, and caused a reduction of duct static pressure, which was observed in the EMCS pressure trend data. This condition likely caused reduced airflow to several VAV boxes and may have resulted in a temporary service reduction across the floors.

UCSB implemented both fan and cooling plant shed during the September 8th test and all the strategies worked as planned. Since the cooling power shed was more aggressive than the fan shed, approximately 85% of total shed kW was generated by cooling power shed. There was a high rebound spike right after the $0.75/kWh-level when the cooling valve opened. During both the September 8^{th} and 21^{st} tests, EMCS trend logs showed that changes zone temperatures over the sites were less than 4 °F. On September 8th, an interesting trend was identified at UCSB. The HVAC cold deck temperature increased from 58 °F to 71 °F on average, and to a maximum of 79 °F due to closing the cooling valve. However, the zone temperature increased only by 2 °F from 70 °F to 72 °F on average, and 74 °F at maximum. The thermal mass of the building probably slowed down the zone temperature increase. There were no complaints reported during these days. These findings are shown in Figure 4-9.



The chart shows maximum and minimum of zone temperature.

Figure 4-9: UCSB Cold Deck and Zone Temperature

On September 21st at OFB during the global zone temperature set up, the return air temperature increased only about 1 °F. The return temperature is a good measure of the average zone temperature because it is mixed return air from each zone. Temperatures in most zones did not show a significant increase, except several zones on the 16^{th} floor increased zone temperature 3 to 4 °F (up to 76 °F). One of the three zones of Roche increased zone temperature by 2 °F (up to 74 °F), and the other zones stayed within 1 °F of the pre-shed EMCS trend. According to the measured data at Roche, the carbon dioxide concentration increased from 440 ppm[4] to 490 ppm, which is low for office occupancy.

[4] ppm = parts per million.

4.2. Scaled-Up Test

This section summarizes the results of the Scaled-up test. The two-week period began on October 11th. The event days were October 13th and November 5th. The test period was extended for an additional week because of unseasonably cool weather. The maximum temperatures in Oakland on these two days were 86 °F and 62 °F respectively. The shape of electricity price signal was the same as September 8th (Figure 4-1) for both days.

Response Results

Table 4-5 summarizes results of the communication response of the first Scaled-up test on October 13th. A number of problems occurred during the October 13th test. Fifteen sites of the total 18 sites were ready for the test. Nine sites succeeded to successfully implement the test. Of these nine, two sites (B of A and Cisco) had such small sheds the baseline analysis found the results to be no effective. Examples of reasons that sites did not participate are as follows. Cal EPA opted-out due to administrative issues. Kadant failed due to an override, but would have had problems without the override due to a PLC programming bug. UCSB's communication problem had not been fixed since the last test. CETC and OSIsoft were also not ready for the test. At 300 Capitol Mall, periodic maintenance scheduled during the test interfered with the demand shed. The maintenance engineers disabled the demand response control during middle of the test. One issue of this test was that several polling clients received "null value" during the test. This was caused because the price server was busy when many polling clients requested the price, and some polling clients couldn't retrieve the price on time. While most sites ignored the null value, others had trouble with these null values. Cisco's communication handled the null values by resetting the operations back to normal conditions. However, because Cisco's polling client requested the price at one-minute intervals, Cisco's control went back to the shed mode as soon as it received a new price after the null value, causing a flip-flop pattern. GSA's computer hosting its price client crashed, possibly due to an unexpected value for the price signal received from the price server. This client crash resulted in failure of all 3 GSA sites during the October 13th test.

Table 4-5: Response Results of Oct. 13th

Site Name	Readiness	Approval	Server/Client Communication	Gateway/Relay Communication	Control of Equipment	Effectiveness
300 CMall					*1	
Albertsons						
B of A						
Cal EPA		*2				
CETC						
CISCO						
50 Douglas						
Summit Ctr						
Echelon						
450 GG						
NARA						
OFB						
Kadant					*3	
Monterey						
OSIsoft						
Roche					*4	
UCSB						
USPS						

*1: Unexpected chiller maintenance disabled the shed control during the test.
*2: Opt-out due to organizational approval issue.
*3: The site shed was overridden, PLC programming problem uncovered.
*4: Operator disabled the shed control right before end of shed period due to hot complaint.

Succeeded Failed Not Applicable

Table 4-6 summarizes the performance of the automated communication systems during the second Scaled-up test on November 5th. In preparation for the November 5th Scaled-up Tests, all 18 sites had completed the communications systems development and all were ready for the test. Thirteen of the 18 sites succeeded and 3 sites failed. San Francisco's 450 Golden Gate Federal building had trouble with the global temperature reset strategy, resulting in an increase in fan power and the heating systems came on. Kadant's communications systems worked as expected, but opted-out at middle of the test due to a busy production shift. UCSB's communication problems remained. Since the day was not particularly warm, most of the buildings had minimal cooling loads. Quite small electric demand sheds were identified at 300 Capitol Mall, NARA, and OSIsoft. At each of these sites the change of control states was confirmed demonstrating successful automated DR. CETC in Canada also successfully changed its control settings based on the Auto-DR systems, but no savings were identified because the test occurred after the building was closed.

Table 4-6: Response Results of Nov. 5th

Site Name	Readiness	Approval	Server/Client Communication	Gateway/Relay Communication	Control of Equipment	Effectiveness
300 CMall	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Failed
Albertsons	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
B of A	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Cal EPA	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
CETC	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Not Applicable
CISCO	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
50 Douglas	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Summit Ctr	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Echelon	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
450 GG	Succeeded	Succeeded	Succeeded	Succeeded	Failed *5	Not Applicable
NARA	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
OFB	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
Kadant	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded *6	Failed
Monterey	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Not Applicable
OSIsoft	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Failed
Roche	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded
UCSB	Succeeded	Succeeded	Succeeded	Failed	Not Applicable	Not Applicable
USPS	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded	Succeeded

*5: Target equipment responded wrong way due to inherent configuration problem.
*6: Opt-out after 30 minutes due to operation priority.

Succeeded / Failed / Not Applicable

Demand Shed Results, October 13th

Figure 4-10 shows the aggregated demand and demand savings of the first Scaled-up test on October 13th. Cisco is not included on this graphic because the full set of baseline and load shape data are not available[5]. Cisco is a 30 MW, 24 building site with 10 million ft^2, and it would dwarf the other sites if included in these graphics. Since CETC and Kadant are in different time zones, their demand-shed data are not relevant to this study. However, as discussed, the communications systems performed as expected at those sites. The Scaled up test results also exclude Monterey because it is also a “communications only” tests site and the whole building power data were not available.

The maximum aggregated shed was 817 kW. These savings were 8% of whole building power and 0.39 W/ft^2.

[5] Cisco trended the electricity and EMCS data in 1-minute resolution. Due to its limited data storage capacity, the data were only trended from late morning to late afternoon, and had to be downloaded daily.

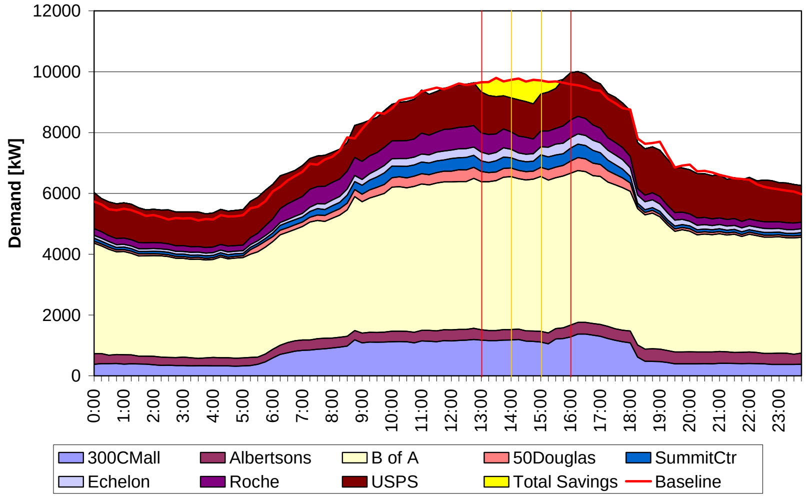


Figure 4-10: Aggregated Demand Savings, Oct. 13th

Figure 4-11 shows average power shed in absolute power from the October 13th test for each of the three hours. Some of the sites achieved significant savings. USPS achieved a maximum 333 kW of shed (23 % of WBP) or 0.85 W/ft^2 using their strategy of directly limiting the demand on the chiller. Fifty Douglas achieved a greater maximum demand savings of intensity of 1.34 W/ft^2 (31 % of WBP).

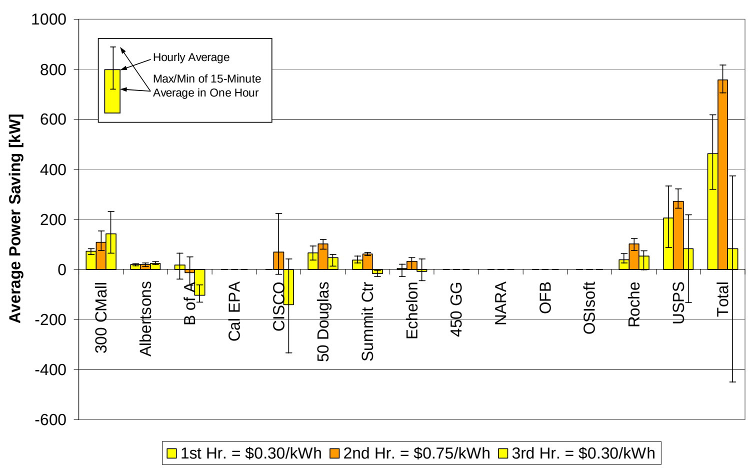


Figure 4-11: Average Power Saving kW by Shed Hour, Oct. 13th

Table 4-7 shows the hourly average and the maximum of the demand saving for each building. Cisco was eliminated from the table because their 1st hour data were not available. Cisco achieved a maximum of 223 kW shed in the 2nd hour, and total demand savings including Cisco was 817 kW.

Table 4-7: Hourly Demand Saving, Oct. 13th

Unit	Site Name	Average			Max		
		1st Hr. = \$0.30/kWh	2nd Hr. = \$0.75/kWh	3rd Hr. = \$0.30/kWh	1st Hr. = \$0.30/kWh	2nd Hr. = \$0.75/kWh	3rd Hr. = \$0.30/kWh
Saving kW	300 CMall	74	109	143	82	154	232
	Albertsons	20	19	25	23	26	30
	B of A	17	-12	-103	66	50	-61
	50 Douglas	66	102	47	93	120	60
	Summit Ctr	38	62	-16	54	68	-3
	Echelon	3	33	-8	21	47	42
	Roche	39	102	53	63	123	74
	USPS	205	272	83	333	321	219
	Total: Σ(ΔP)	**463**	**687**	**225**	**619**	**791**	**451**
WBP%	300 CMall	6%	9%	11%	7%	12%	18%
	Albertsons	5%	5%	7%	7%	7%	8%
	B of A	0%	0%	-2%	1%	1%	-1%
	50 Douglas	18%	27%	12%	25%	31%	17%
	Summit Ctr	10%	16%	-4%	14%	17%	-1%
	Echelon	1%	11%	-2%	7%	16%	14%
	Roche	6%	16%	9%	9%	20%	12%
	USPS	14%	19%	6%	23%	22%	15%
	Total: Σ(ΔP)/Σ(BP)	**5%**	**7%**	**2%**	**6%**	**8%**	**5%**
	Average: Σ(ΔP/BP)/N	**8%**	**13%**	**5%**	**12%**	**16%**	**10%**
W/sqft	300 CMall	0.19	0.28	0.37	0.21	0.40	0.61
	Albertsons	0.39	0.39	0.49	0.46	0.51	0.61
	B of A	0.02	-0.02	-0.15	0.09	0.07	-0.09
	50 Douglas	0.73	1.13	0.53	1.04	1.34	0.67
	Summit Ctr	0.29	0.47	-0.12	0.41	0.52	-0.03
	Echelon	0.04	0.44	-0.11	0.27	0.63	0.57
	Roche	0.20	0.53	0.28	0.33	0.64	0.39
	USPS	0.53	0.70	0.21	0.85	0.82	0.56
	Total: Σ(ΔP)/Σ(A)	**0.23**	**0.34**	**0.11**	**0.31**	**0.39**	**0.22**
	Average: Σ(ΔP/A)/N	**0.30**	**0.49**	**0.19**	**0.46**	**0.62**	**0.41**

P = Power BP = Baseline Power ΔP = BP - P
N = # of site A = square footage (ft2)

Demand Shed Results, November 5th

The November 5th test was the most successful in terms have having the largest number of sites (17 sites) and greatest facility area participation (10 million ft^2). Figure 4-12 shows the actual whole building power of all sites and aggregated demand savings of the second Scaled-up test on November 5th. The maximum aggregated shed demand was nearly 2 MW (1903 kW), as shown in Table 4-8. These savings were 5% of whole building power and 0.19 W/ft^2. CETC and Kadant were excluded from demand savings analysis because the sites were in a different time zone and the sheds occurred while they were in early evening operating modes. Monterey was excluded because the shed was a small lighting shed in a small building and whole-building meter were not available to verify the savings.

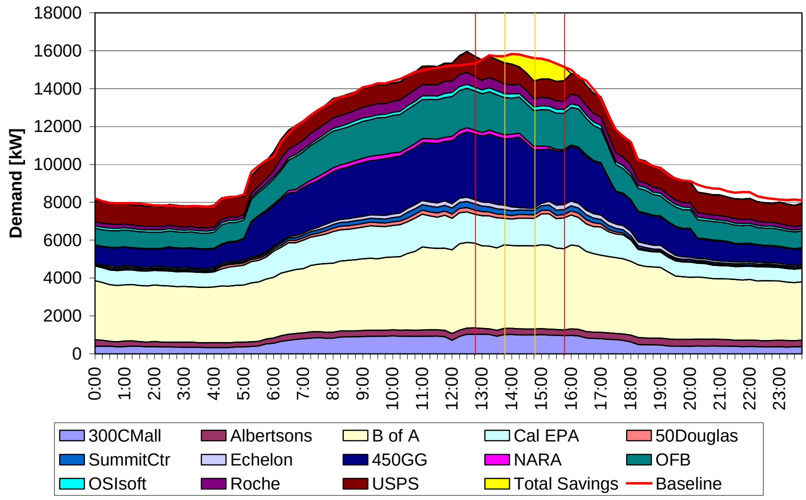


Figure 4-12: Aggregated Demand Savings, Nov. 5th

Figure 4-13 shows the average power shed for each of the three hours. Cisco achieved the maximum demand shed of nearly 1 MW (990 kW). 450 Golden Gate resulted in negative shed due to the control malfunction (described in Appendix B).

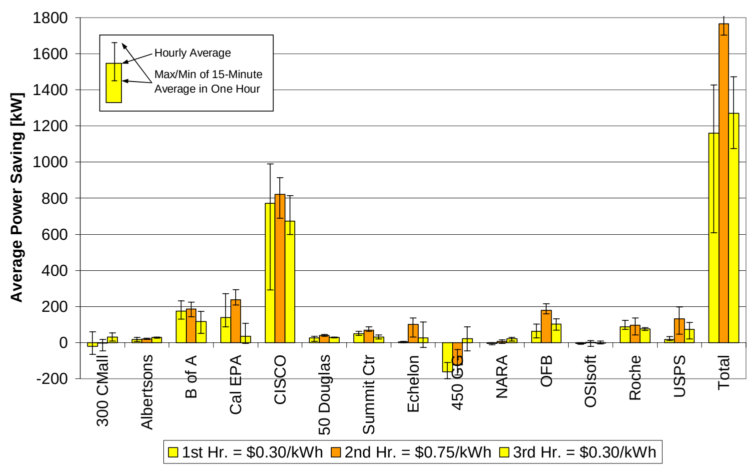


Figure 4-13: Average Power Saving by Shed Hour, Nov. 5th

Figure 4-14 shows the average power saving intensity of each price signal period. Cal EPA achieved a maximum 295 kW shed (17% of WBP). Echelon achieved a maximum savings intensity of 1.8 W/ft^2 (56 % of WBP). Echelon also had a wide range of shed kW because their rooftop unit shed was extreme (100% off). It required only a few minutes to reduce the load to the maximum shed. Echelon had a negative shed during the third hour of the test because of rebound peak when the rooftop unit turned back on.

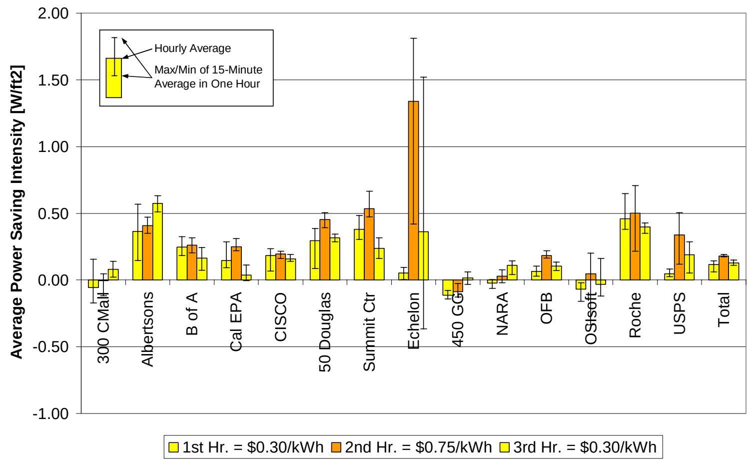


Figure 4-14: Average Power Saving Intensity by Shed Hour, Nov. 5th

Table 4-8 shows hourly average and maximum of the demand saving for each building. Figure 4-15 and Figure 4-16 show the whole building power and baseline model of November 5th test for each site.

Table 4-8: Hourly Demand Saving, Nov. 5th

Unit	Site Name	Average			Max		
		1st Hr. = $0.30/kWh	2nd Hr. = $0.75/kWh	3rd Hr. = $0.30/kWh	1st Hr. = $0.30/kWh	2nd Hr. = $0.75/kWh	3rd Hr. = $0.30/kWh
Saving kW	300 CMall	-21	-2	31	60	18	54
	Albertsons	18	20	29	28	24	32
	B of A	174	186	117	230	224	172
	Cal EPA	138	237	35	271	295	108
	CISCO	771	822	674	990	913	815
	50 Douglas	27	41	29	35	45	31
	Summit Ctr	50	70	31	63	87	41
	Echelon	4	100	27	7	136	114
	450 GG	-162	-124	22	-111	-38	87
	NARA	-5	6	23	1	15	29
	OFB	63	179	103	102	214	133
	OSIsoft	-4	3	-2	-1	12	10
	Roche	88	96	77	124	136	83
	USPS	18	132	74	33	196	111
	Total: Σ(ΔP)	**1160**	**1767**	**1270**	**1427**	**1903**	**1473**
WBP%	300 CMall	-2%	0%	3%	6%	2%	5%
	Albertsons	5%	6%	9%	9%	7%	10%
	B of A	4%	4%	3%	5%	5%	4%
	Cal EPA	8%	14%	2%	16%	17%	7%
	CISCO	3%	3%	3%	4%	3%	3%
	50 Douglas	12%	18%	13%	15%	19%	14%
	Summit Ctr	15%	22%	11%	19%	27%	14%
	Echelon	2%	42%	11%	3%	56%	48%
	450 GG	-10%	-8%	2%	-7%	-3%	6%
	NARA	-2%	3%	19%	0%	8%	28%
	OFB	3%	9%	5%	5%	10%	6%
	OSIsoft	-2%	1%	-1%	-1%	6%	5%
	Roche	14%	17%	15%	20%	22%	16%
	USPS	2%	12%	7%	3%	17%	10%
	Total: Σ(ΔP)/Σ(BP)	**3%**	**4%**	**3%**	**4%**	**5%**	**4%**
	Average: Σ(ΔP/BP)/N	**4%**	**10%**	**7%**	**7%**	**14%**	**13%**
W/sqft	300 CMall	-0.06	-0.01	0.08	0.16	0.05	0.14
	Albertsons	0.36	0.41	0.58	0.57	0.47	0.63
	B of A	0.25	0.26	0.16	0.32	0.32	0.24
	Cal EPA	0.15	0.25	0.04	0.29	0.31	0.11
	CISCO	0.18	0.19	0.16	0.23	0.22	0.19
	50 Douglas	0.29	0.45	0.32	0.39	0.51	0.34
	Summit Ctr	0.38	0.54	0.24	0.48	0.67	0.32
	Echelon	0.05	1.34	0.36	0.10	1.81	1.52
	450 GG	-0.11	-0.09	0.02	-0.08	-0.03	0.06
	NARA	-0.02	0.03	0.11	0.00	0.08	0.14
	OFB	0.06	0.18	0.11	0.10	0.22	0.14
	OSIsoft	-0.07	0.05	-0.03	-0.02	0.20	0.16
	Roche	0.46	0.50	0.40	0.65	0.71	0.43
	USPS	0.05	0.34	0.19	0.08	0.50	0.29
	Total: Σ(ΔP)/Σ(A)	**0.12**	**0.18**	**0.13**	**0.14**	**0.19**	**0.15**
	Average: Σ(ΔP/A)/N	**0.14**	**0.32**	**0.19**	**0.23**	**0.43**	**0.34**

P = Power BP = Baseline Power ΔP = BP - P
N = # of site A = square footage (ft2)

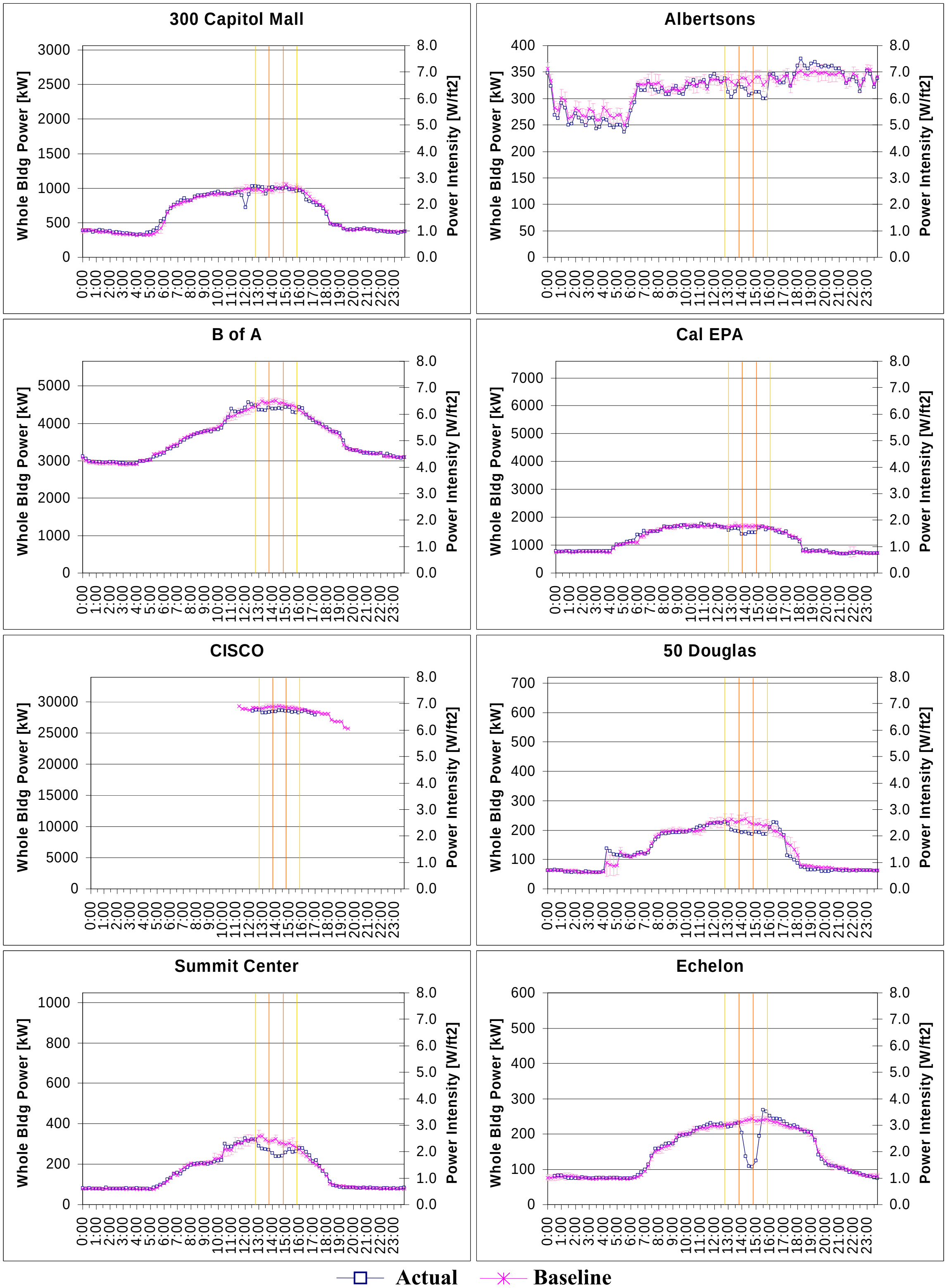


Figure 4-15: Whole Building Power and Baseline of Scaled-up Test, Nov. 5th (part 1)

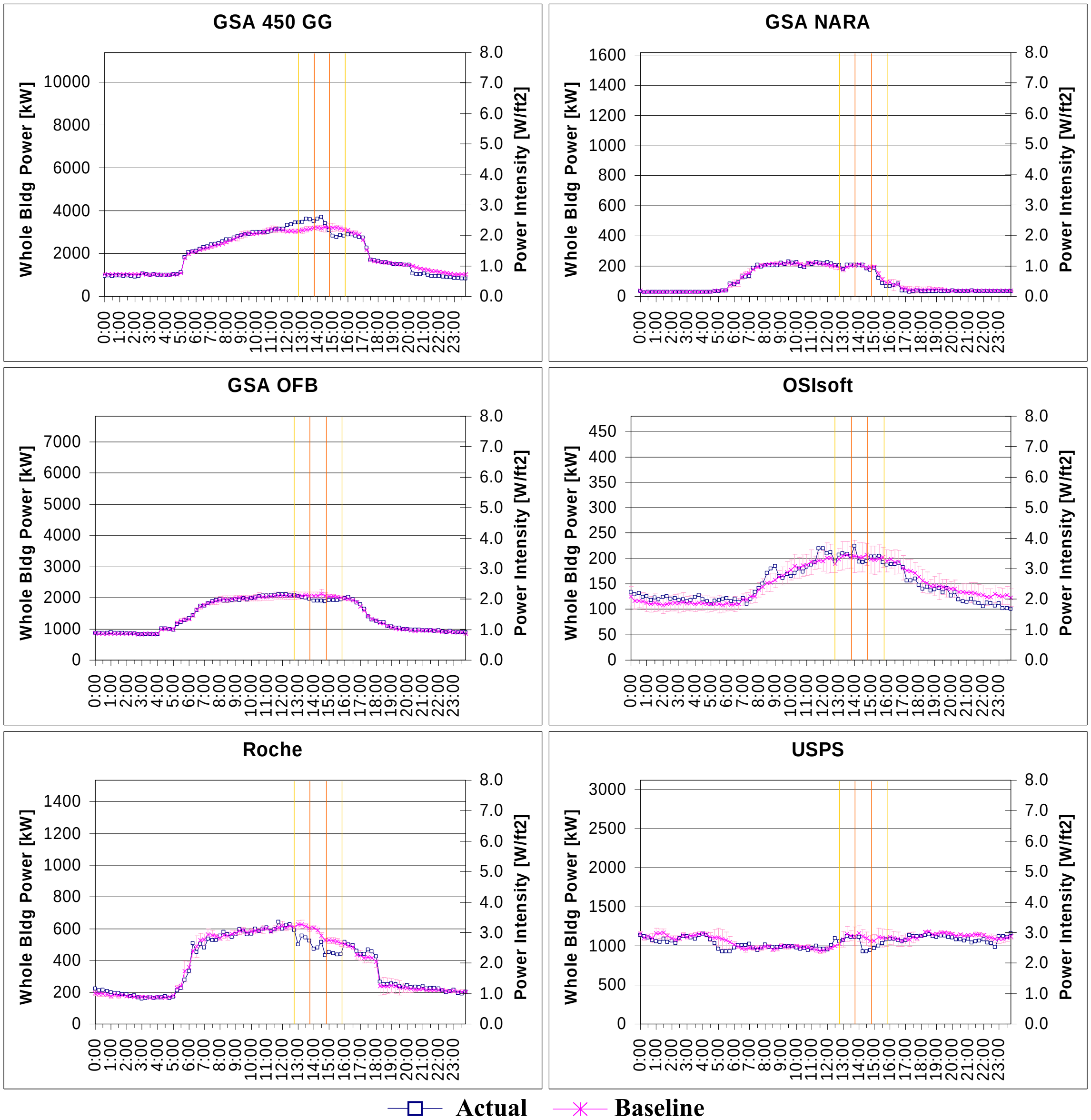


Figure 4-16: Whole Building Power and Baseline of Scaled-up Test, Nov. 5th (part 2)

Operational Findings

On the October 13th test at Echelon, the $0.30/kWh-level shed had virtually no effect, although the system worked as planned technically. In the second test at Echelon on November 5th, the shed at the $0.30/kWh-level had a greater effect, due to human factors described below. The effect at the $0.75/kWh-level was substantial in both tests at the Echelon site.

Under "normal" operation, each Echelon employee adjusts their own lighting level and temperature set point using a browser based user interface on their computer (see Appendix C for more detail). When the central system calls for a demand shed, known as "`Managed Load-Shed Mode`", it will do so only to the offices of occupants who have "opted-in" to allow this functionality. In addition, each occupant must define the lighting and temperature levels that will be allowed in their office when the central system enters

"`Managed Load-Shed Mode`". This approach offers each individual the opportunity to customize their own "tolerance" for possible reductions in services during rare shed events. Since awareness of the energy saver mode feature was low, few employees took the time to proactively enable it during the first test. After results of the first test were provided to Echelon, company spirit, personal responsibility or other human factors caused more employees to enable the `Managed Load-Shed Mode`. This resulted in a measurable difference in shed saving performance in the November 5th test.

Echelon had another issue during the November 5th test. While two of three rooftop units were disabled at $0.75/kWh, the last rooftop unit that was expected to run was accidentally already offline, which increased the shed to more than expected.

During the November 5th test at 450 Golden Gate, when the zone set point increased to unload the cooling systems, the VAV boxes unexpectedly initiated heating because the global zone set point control programming on the VAV box was not configured properly. By raising the space temperature set point, the system raised both cooling and heating set points, and some zones called for heating resulting in the increase in fan energy[6]. This resulted in negative demand savings. Many hot complaints were received from the 7th and other floors. The operator manually shut down the hot deck fans around 2:30 pm. To avoid this problem, boiler lock out strategy should be considered during the shed period, as well as commissioning of the VAV box control.

At Roche, during the October 13th test, the average zone temperature at Building A2 increased up to a maximum 76.3 °F (average zone temperature increase was less than 1 °F), and CO_2 concentration increased from 420 ppm to 500 ppm. Although the zone temperature was not unusual compared to the non-test days[7], the operator received a hot complaint and disabled the shed control fifteen minutes earlier than planned. Roche finally operated all the strategies successfully in the November 5th test without any trouble.

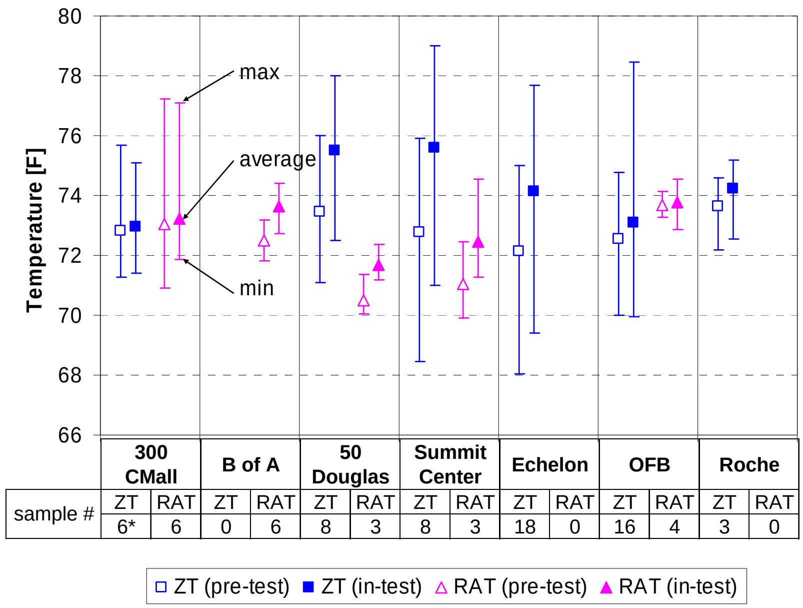
At Cisco on October 13th, the system dropped out of shed mode for one minute about two times per hour. This was caused by null values returned by the price server because it could not handle the volume of traffic on the server. Another problem was that the computer room air handler units did not change operation as planned due to a communication malfunction within the EMCS. By the second test on November 5th these problems had been corrected, and Cisco successfully shed 990 kW at maximum (See Appendix B and C for more detail).

We have conducted some preliminary analysis of the zone temperatures at seven sites to understand how much the interior conditions change. Figure 4-17 summarizes the average and maximum zone temperature and return air temperature increase for the sites where temperature measurements were available. 300 Capitol Mall, B of A, and Roche have trend data on both October 13th and November 5th. 50 Douglas, Summit Center, Echelon, and Oakland Federal Building have trend data only on November 5th. All the

[6] The solution taken to remedy the problem and beyond is described in Section 5.3.

[7] Maximum zone temperatures of non-test days in October are between 1 pm to 4 pm are around 76 °F.

sites archived either zone temperature or return air temperatures. Among the sites that implemented HVAC shed strategies, average zone temperature increase at each site was 1.1 °F on October 13th and 1.4 °F on November 5th (maximum zone temperature increase was 4.4 °F on October 13th at 300 Capitol Mall and 5.6 °F on November 5th at Echelon)[8]. Average return air temperature increase at each site was less than 1.4 °F on October 13th and 0.8 °F on November 5th (maximum return air temperature increase was 2.3 °F on October 13th at 300 Capitol Mall and 2.1 °F on November 5th at Summit Center). There were no hot complaints except at Roche on October 13th.



The sample number shown is the number of measurement points.
300 Capitol Mall trended average zone temperature trend for each of 6 AHU zones.
(ZT= Zone Temperature; RAT= Return Air Temperature)

Figure 4-17: Zone and Return Air Temperature Changes, Nov. 5th

At the Oakland Federal Building, only limited zone temperature changes were identified except for a few zones on 16th floor where a large zone temperature increase was identified in the Retest. According to the operator, the 16th floor is the furthest from the supply fans. This floor tends to be warmer than the other floors when the duct static pressure is low. DR shed strategies may exacerbate or expose problems with HVAC design or configuration that do not lead to unacceptable performance in normal operation.

Cal EPA implemented both HVAC and lighting shed strategies for the November 5th test. The operator received many inquiry and complaint calls regarding lighting, but none for zone temperatures condition. Further details on these issues are provided in Section 4.4.

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[8] Zone temperature and return air temperature increase were calculated by delta T between hourly average temperature prior to the test (noon to 1 pm) and maximum temperature during the test (1 pm to 4 pm).

4.3. Summary of Four 2004 Tests

It is useful to examine the results from all 15 sites[9] among the four tests. Figure 4-18 shows the maximum 15-minute demand savings the 2004 test. The graph shows that the maximum demand sheds at each site range from 12 kW to over about 1 MW. On the November 5th test event the aggregated maximum savings among the 14 sites that successfully executed the shed control reached nearly 2 MW. If all 15 sites reached their maximum shed simultaneously, a total of about 4 MW of demand response is available from these 15 sites that represent about 10 million ft^2 of floor area. The summary of the data in Figure 4-18 is shown in absolute power to show the size of building sheds that are available from this type of a commercial building sample. Results could also be shown in power density (W/ ft^2), but the absolute shed power is useful for future DR resource planning.

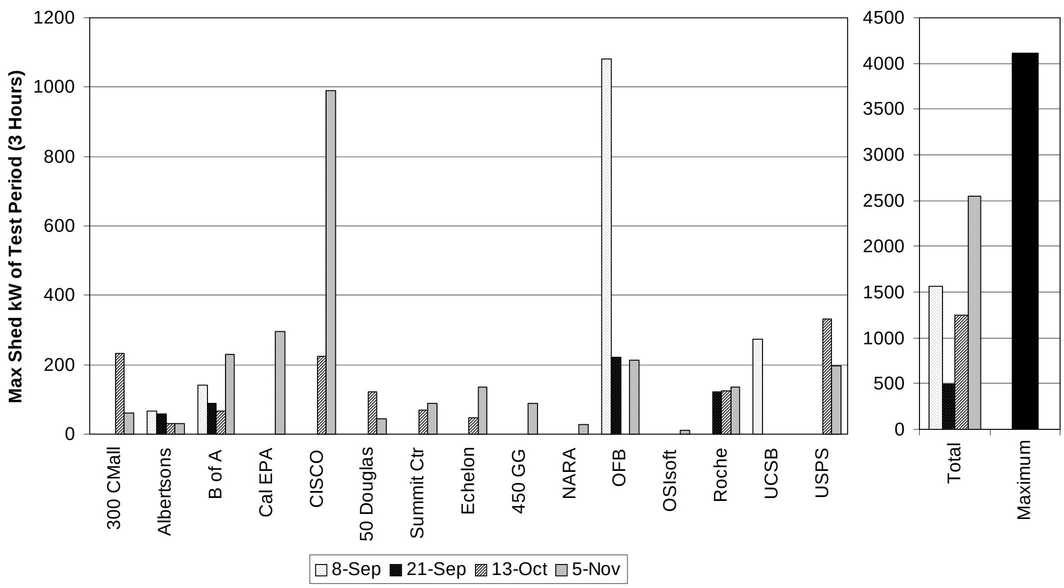

Figure 4-18: Maximum Demand Savings for the Retest and Scaled-Up Tests by Building, Total Aggregated Maximum Shed for Each Test, and Non-Coincident Maximum

4.4. Shed Strategies Analysis

Shed Strategies by Building Control Attributes

The shed strategy methods used by the various sites can be categorized into five HVAC and two lighting shed types. An obvious observation is that the type and effectiveness of building's shed strategy can be dependent on the building control attributes that are available. Table 4-9 is an initial framework for analyzing the needed building control capabilities for specific shed strategy categories. For each shed type, the needed building control attribute is identified with a check mark.

[9] Excluding CETC, Kadant and Monterey due to the reason mentioned in Section 3.1.

Table 4-9: Examples of Building Control Attributes and Shed Strategies

	Shed Strategy Types	Building Control Attributes: EMCS Zone Temp. Control	EMCS Equip. Control	Variable Frequency Drives	Central Lighting Control
HVAC	Thermostat Setup/Setback	✓	✓		
	Cooling Limit		✓		
	Duct Static Setback		✓		
	Fan Speed Limit		✓	✓	
	Equip. Lock-out		✓		
Lighting	Reduce Common Area Lighting				✓
	Reduce Private Office Lighting				✓
Misc. Equip.	Equip. Lock-out		✓		

Table 4-9 is a simple framework to describe the building control capabilities a building needs to participate in automated DR events. Another method that could be used in a building audit is to use a decision tree as depicted in Figure 5-1 in Section 5 below. This process helps the building operations staff explore the capabilities of their building controls in a systematic sequence.

Demand Savings by Strategy and End Use

The results of this study provide some indication that significant demand savings can be achieved with a variety of control strategies. Figure 4-19 shows maximum demand savings intensity categorized by shed strategy for the November 5, 2004 Scaled-up test. While most of the results above were derived from whole-building electric data, the savings for the lighting sheds are based on end-use metering at the three sites shown (Albertsons, Cal EPA, and Echelon). Three sites also have end-use metered HVAC electricity use (OFB, Cal EPA and Echelon). We calculated the savings for the HVAC shed strategies shown in Figure 4-19 using the baseline regression model with the HVAC end-use data. By contrast, 50 Douglas, Summit Center, B of A, Roche and USPS had only whole building power measurement, but only used a single strategy. Therefore attributing the savings to the HVAC strategy is straightforward. Albertsons, Cal EPA and Echelon did overhead lighting shed. Albertsons and Echelon have lighting end-use measurements and Cal EPA can estimate lighting plus receptacle power by subtracting HVAC power from whole building power.

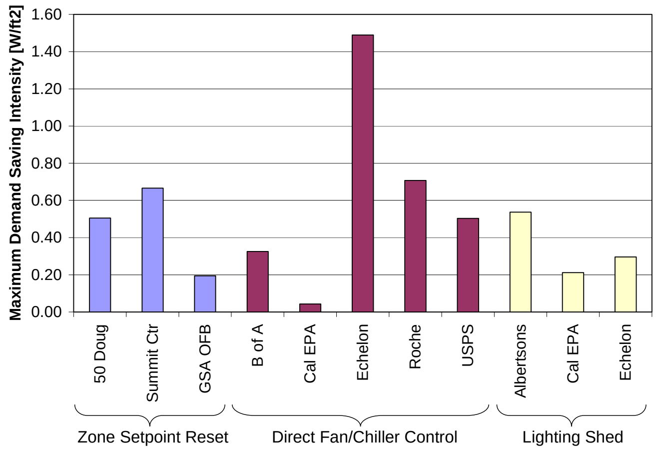

Figure 4-19: Demand Saving Intensity (W/ft^2) by Shed Strategy

Summary of Results by Strategies

This section summarizes findings and recommendation for each shed strategy. One finding from the post-test interviews was that occupants were sensitive to stepped control of electrical lighting circuits. This problem is not surprising and well known in the lighting control field. Major steps in lighting control are noticeable. Dimming systems, however, have been shown to be less intrusive. It is also notable that the HVAC service interruptions had a minimal impact on complaints.

Global Zone Setup/Setback

The global zone setup/setback strategy performed well at each of the 7 sites where it was successfully implemented. There were no occupant complaints from these sites. It is important to remember that there could have been some discomfort even though there were no complaints. This issue will be pursued in future research. For variable air volume (VAV) systems, this strategy is the most desirable since it eliminates any possible fan penalty discussed in the Cooling Limit section below. A drawback of this strategy is that it is likely to have a rebound peak, which described separately in later section.

As one of global zone setup/setback strategies, Echelon used an innovative technique for their strategy. Echelon reprogrammed the control strategy from Table 3-4 prior to the second Scaled-up test on November 5th. The price signal information was converted into percentage ratio, so that the system can have more flexible control (e.g., linearly correlate the zone temperature setup with the price signal). Appendix C describes the strategy in more detail. This feature is an example of an advanced strategy that could not be executed with a simple Internet relay.

Cooling Limits

If the building doesn't have zone level set point control, one way to reduce the power load from the cooling plant is to limit the cooling systems. One technique to limit the cooling is to set-up chilled water supply or supply air temperatures. Unfortunately, in many building systems the zones will still call for cooling. For example, if the airside system is a VAV system, a warmer supply air temperature will cause the VAV boxes to open to provide more air to the zones. This typically results in increasing the fan power consumption that may offset the savings from the cooling plant.

This strategy was used at B of A throughout their four tests. B of A increased supply air temperature by 4 °F. Many control iterations were tried in an effort to minimize the fan power. A cooling limit can be developed in combination with a fan limit, but it is difficult and this “open loop” control may have unknown affects within the zones. Locking a VFD can provide some fan limiting. This strategy, however, may result in losing control within the zones. A detailed analysis of the B of A strategies is provided in Appendix D.

As with the other examples, 300 Capitol Mall increased chilled water temperature by 11 °F with VFD speed lock, and UCSB fully closed the cooling valve which supplies chilled water from the central plant. Both sites shed their demand well, but also set high rebound peaks.

Fan Power Limits

In cases where direct limits to cooling are not feasible, limiting air distribution loads may be possible. Fan electrical demand can be shed by reducing the fan air flow or reducing the duct static pressure.. One Fan flow and demand can be controlled with VFDs or inlet guide vanes.. UCSB employed this strategy, limiting the fan VFD to 60%. If reducing the volumetric flow of air is not, duct static set point reset can be considered.

The potential for reducing fan power may be lower than the potential to reduce cooling power because minimum ventilation standards may be required during shed operations. Limiting air flow and fan power may reduce cooling loads, though the risk of system balance problems or discomfort should be considered. Careful consideration is needed to evaluate zone and cooling plant control.

HVAC Equipment Lock-Outs

If the building system doesn’t have zone level DDC, direct control of HVAC components is often considered. However, as with the cooling and fan limiting, these strategies can cause unforeseen system interactions that may increase loads on other components or cause system unbalances and discomfort. Careful consideration of shed strategies is required. Moreover, the risk of rebound peaks can be more pronounced with the simple turning off and on of equipment.

Rebound Peak/Slow Recovery Strategy

One unfortunate finding in the execution of global zone setup/setback and cooling/fan limit control is that there can be a noticeable rebound peak following the end of the shed at several sites. Some of the rebound peaks were larger than the daily maximum load established in the baseline. Such problems occurred at 300 Capitol Mall, 50 Douglas, Summit Center, Echelon and UCSB.

The implementation of a slow recovery strategy to normal operation is important for the mitigation of rebound effects. Control engineers at the Oakland Federal Building implemented a slow recovery strategy that successfully mitigated the rebound peak. While OFB controlled VFD speed for their slow recovery strategy (see Section 4.1), the other control parameters can be used for the strategy. Slowly reverting to the original zone set point would be ideal for the zone temperature reset strategy[10]. Another method to mitigate rebound peak is to extend the shed mode until the end of occupancy schedule. This method may be used if the DR event continues until 5 pm or later.

Lighting Shed

Lighting as an end-use is not a weather sensitive load and can therefore provide a consistent demand saving regardless of weather. More research is needed to understand building occupant perception of different electric demand shedding strategies. One critical issue with stepped lighting controls is that occupants tend to be more aware of large changes in lighting levels compared to the changes in HVAC shed. We learned about some employees at Albertsons who had questions about the lighting shed, and the store manager was afraid that some customers might misunderstand and think the store is closing. At the Cal EPA, the shed strategy included both HVAC duct static pressure set point change and a lighting reduction. About 50 occupants called the property manager's office when the perimeter lights were turned off. Most were simple "Why did the lights go out?" inquiries. Most people were satisfied when they were reminded about the DR test, but about 15% of the occupants remained unhappy and their calls were logged as complaints. Advanced notice to the employees and some soft of notification during the shed may help reduce confusion or misunderstanding.

Research is underway to develop low-cost dimmable, fluorescent lighting systems that are suited for easy retrofit into existing commercial buildings and demonstrate the benefits to the lighting community (AEC, 2005). Slowly adjusting dimmable ballasts have been shown to reduce occupant awareness while providing significant reductions in lighting power.

Miscellaneous Equipment Shed

Another strategy is to turn off miscellaneous equipment. Some sites turned off some non-critical component during the shed. Albertsons shed anti-sweat heaters on the freezers. 300 Capitol Mall turned off the exterior fountain pumps. Kadant programmed to shed transfer pumps that can be shutdown for short period of time.

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[10] LBNL conducted a simulation study to compare various recovery strategies in a study on pre-cooling research (Xu, et.al. 2004).

5. Discussion

This section provides a discussion of three additional research issues. The first section includes a review of how to identify HVAC control strategies using flow charts to characterize system capabilities. The second section review how the building sheds for buildings tested in both 2003 and 2004 compare. The final section discusses DR and building commissioning.

5.1. HVAC Controls and DR Strategies

As in 2003, in the 2004 Auto-DR tests, building owners and facility managers made the final decisions about which shed strategies to employ. One objective of our research is to understand which strategies are most appropriate for various building systems. In a few cases LBNL assisted with the decision-making process using knowledge gained from the 2003 tests. After observing and assisting building managers in selecting their shed strategies for many different types of buildings, mechanical systems and controls, some decision making patterns started to emerge. Figure 5-1 shows a decision tree for selecting HVAC shed strategies for commercial buildings. This graphic is a preliminary framework to support identification of control characteristics and DR strategies. Once a given building owner or manager expresses desire to evaluate demand response strategies and has authorization to do so, technical attributes of the building and appropriate shed strategies can be evaluated. Key strategies are as follows:

1. **Global zone setup/setback.** This strategy has proven to be an effective and minimally disruptive technique for achieving HVAC demand response. The other strategies should be considered if a given building either does not have zone level DDC EMCS controls or else the VAV controllers could not be easily programmed to offset zone set points globally.

The following HVAC shed strategies can be effective although they are potentially more disruptive than the aforementioned global zone temperature set point setup.

2. **Cooling limit.** This strategy can be implemented by reducing the maximum capacity of the chiller, direct expansion (DX) fan systems or cooling coils. Increased chilled water temperature set point, increased cold deck supply air temperature set point, DX compressor limiting and chilled water coil valve limiting are all methods of implementing this strategy. Cooling reduction can be used on constant volume or variable volume systems. On VAV systems, care must be taken to avoid an automatic increase in air volume and energy to make up for higher air temperatures. Unwanted air volume increases can be prevented by limiting a variable frequency drive (VFD) speed of supply fans to a value equal to or less than its speed prior to the demand response event.
3. **Fan speed or volume limit.** This strategy can be used on any fan with a VFD or inlet guide vanes to reduce energy use during a demand response event.
4. **Duct static pressure reset.** This strategy is relevant to most variable air volume (VAV) systems.

5. **HVAC Equipment lockouts.** In this method, a fan, pump, chiller or compressor is shut off or disabled during the demand response event. If none of strategies from 1 to 4 are possible or practical for a given site, this strategy may be used. This method is potentially more disruptive than all of the aforementioned methods. This method can be accomplished with or without an EMCS. To disable equipment directly without the use of an EMCS, the start/stop circuit of the equipment can be hardwired through the contact(s) of an Internet relay or similar device. Shed strategies described above can vary substantially in the degree to which they adversely affect the comfort of the occupants based on cooling load in building, air system balancing, solar load and other factors.

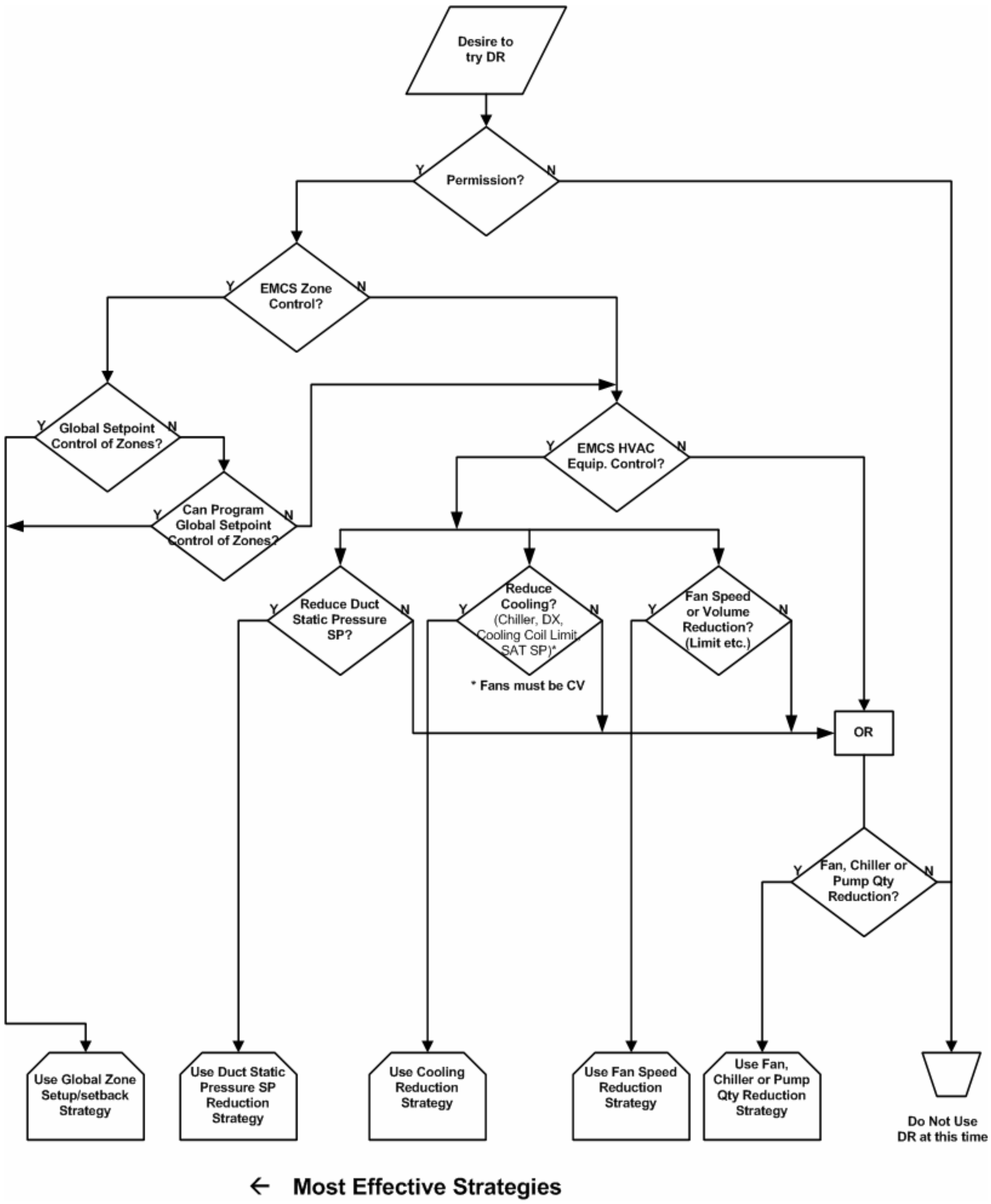

Figure 5-1: Demand Response Using HVAC in Commercial Buildings Sample Shed Strategy Decision Tree

5.2. Comparison of 2003 and 2004 Test Results

One objective of this project was to evaluate the performance of the buildings tested in 2003 again in 2004 during warmer weather. With two tests in 2003 and four tests in 2004, there were a total of six tests during the past two years. Figure 5-2 shows the maximum demand savings versus outside air temperature for 18 test events. The data for this graphic are shown in Table 5-1. Albertsons succeeded in shedding electric loads in all 6 tests. OFB succeeded in 4 tests (November 19th 2003, September 8th and 21st, November 5th 2004 test. Roche succeeded in 5 tests (missed September 8th 2004 test). UCSB succeeded in two 2003 tests, and the September 8th 2004 test. B of A was excluded from this analysis because their control system, shed strategies, and building size have been modified significantly between 2003 and 2004.

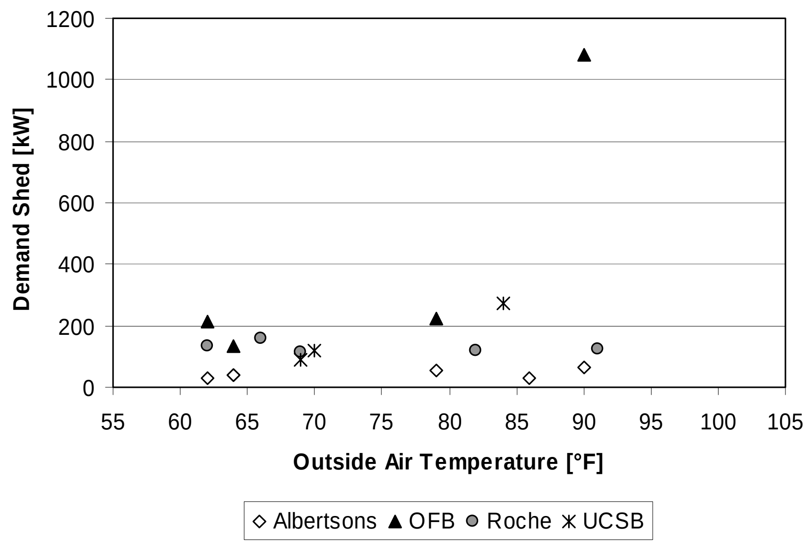

Figure 5-2: OAT vs Demand Savings

Table 5-1: OAT vs Demand Savings

	Albertsons		OFB		Roche		UCSB	
	Max OAT [°F]	Max Shed [kW]	Max OAT [°F]	Max Shed [kW]	Max OAT [°F]	Max Shed [kW]	Max OAT [°F]	Max Shed [kW]
11/12/03	64	39	64		69	115	69	92
11/19/03	64	41	64	133	66	159	70	117
09/08/04	90	67	90	1080	91		84	274
09/21/04	79	55	79	221	82	120	79	
10/13/04	86	30	86		91	123	71	
11/05/04	62	32	62	214	62	136	64	

The strategies that Albertsons and Roche implemented were weather-independent and mostly constant power equipment sheds. It is not clear, however, why Albertsons achieved the maximum savings on the hottest day. Their demand sheds are expected to be the same for each test. OFB and UCSB's shed strategies are weather-sensitive. Figure 5-3 shows the correlation between OAT and WBP with demand savings of OFB including 2003 test and 2004 test. Power requirements for this building greatly increase with outdoor temperatures. Demand reduction is also greater at higher OAT.

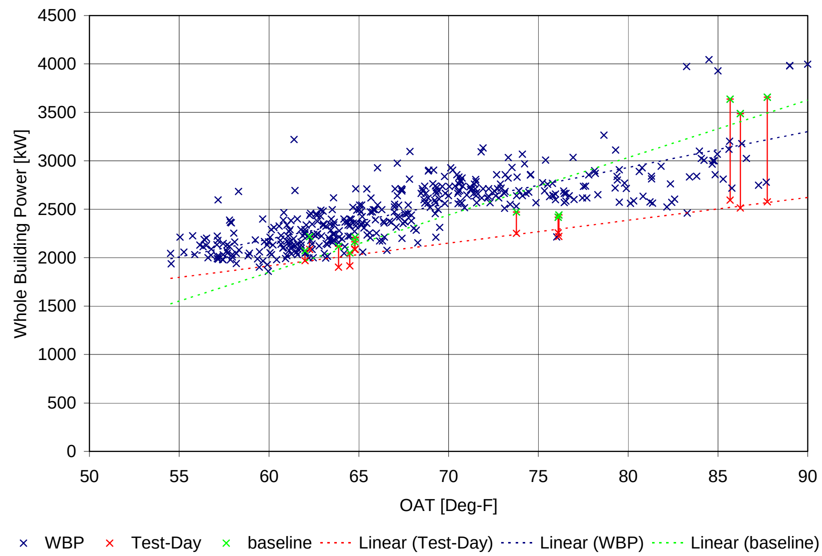

Figure 5-3: Whole-building hourly demand versus OAT and Demand Sheds for OFB

The UCSB library also increases demand savings with higher OAT. Ideally as more information on such sheds is available for different weather conditions one could predict the shed savings based on previous results. It is surprising the savings at OFB for the September 13th event were low (221 kW) compared with the large savings on September 8th (1.1 MW). It is also notable that the demand shed at UCSB for 2004 in 84 °F weather at 274 kW was double the savings from the 2003 test (117 kW) during 70 °F weather. These results demonstrate the strong weather sensitivity of HVAC shed strategies.

5.3. DR and Commissioning

All of the operational problems encountered could be addressed with traditional commissioning approaches. For example, there is a need for careful design-intent documents to outline the concept behind a load-shed strategy. Functional tests are needed to define the conditions for a load-shed test, methods to conduct the test, and evaluation concepts to determine if the test was successful. Since many HVAC load-shedding strategies are weather dependent, new evaluation techniques are needed to understand how a load shedding strategy behaves in different weather. Further work in this area is needed to support the growing number of buildings that will participate in future DR programs.

One specific example of how DR can help in system commissioning is the case study of B of A. In many buildings it is common to find the duct static set point has been set higher than optimal. Since determining the correct duct static setting can be a time consuming process and involve an intensive airside test and balance assessment, many operators use high static pressure settings that results in greater fan energy use. When implementing a demand shed strategy for fan systems at B of A, high static pressure settings had been identified as wasting energy during normal operations. The shed called for a 0.8″ duct static pressure reduction. After the test, the building engineer learned that two of the three buildings tested (Buildings B & C) could have at least a 10% duct static pressure set point reduction during normal operation.

Another example is the case study of GSA's 450 Golden Gate Building. This site employed a global set point setup/setback strategy, but the VAV controllers had a problem in that the strategy setup both cooling and heating (see Section 4.2). After reviewing the code for both the VAV and AHUs, the facility engineers corrected the problem by increasing the cooling set point for the DR strategy. The strategy also brings the VAV boxes to their minimum airflow setting, providing both cooling and direct fan power saving. GSA is developing a duct static pressure reset strategy that uses feedback from the zone controllers to drive the duct static pressure. This strategy will increase the tolerance for zones that are low in air flow, and drive the duct static pressure set point down to further reduce fan power. The facility engineers will test these sequences to reduce energy consumption during both normal operation and during a DR event. The VAV program has been tested and the duct pressure reset in the AHU program is being developed for participation in 2005 DR programs.

6. Summary and Future Research

This research has demonstrated that fully automated demand response systems are technically feasible for buildings with wide range of control systems from highly sophisticated EMCS with telemetry communication to conventional EMCS. We demonstrated the features of Automated DR with EMCS and XML. Both Internet gateways and Internet relays were tested. There are important pros and cons to these two systems. The Internet gateways are more sophisticated, having a greater set of functions. They are, however, more expensive as well.

Eighteen facilities were successfully recruited and fully participated in the tests. This sample includes a variety of building types, but office buildings dominated the sample. A total of 35 buildings participated in the tests representing 10 million ft^2. Each site participated in at least one test. Demand savings ranged from negative savings up to 1080 kW per site. Among all sites over 4 MW of aggregated non-coincident shedding was demonstrated. The buildings reduced their electric demand from zero to a maximum of 42%. There was positive savings at each site during at least one 15-minute period. Average demand savings were 0.3 W/ft^2 and 8 % of the facility load.

Five of the sites that participated in the 2004 tests also had participated in a similar test in 2003. The demand reduction among the sites whose loads were not weather sensitive was similar in both years' test. However, with a specific objective of evaluating the weather sensitivity of the DR strategies, the two buildings with weather sensitive loads shed at least twice as much during the hot weather tests of 2004.

A broad range of strategies was demonstrated including HVAC, lighting, and other equipments to produce sheds and examined control capabilities, sequence of operations, and results of the shed.

Future Research

This report has summarized key findings in evaluating the initial electric load shed data from the 2004 Auto-DR tests. Additional work that will be conducted based on this data set is as follows. First, LBNL will evaluate the prevalence of EMCS with telemetry system and EIS in existing commercial buildings in California and their readiness for Web services and XML price signal interaction employed in the Auto-DR tests or similar signal interactions. One basic question is what percent of the commercial sector buildings in California could be reached with the methods used in this project. The methods to be considered in this evaluation include research of characteristics in existing buildings using questionnaires or other methods, the existing and new Commercial End-Use Survey, industry surveys, and other such sources. The analysis will address the minimum technical requirement to implement Auto-DR, and recommended technology solutions and associated costs for various building types (e.g., an Internet relay along with necessary software templates may be a recommended solution for buildings without Web telemetry to EMCS). This analysis will also include a systematic review of controls and communications in existing buildings from large to small commercial buildings. The prevalence of control types, such as EMCS, DDC, and pneumatic, and availability of internet based telemetry systems to support automated DR control systems in buildings will be explored for various market segments.

A second area of future work is to conduct further analysis of the demand response control strategies including but not limited to the strategies employed at the 18 sites that participated in 2004 Auto-DR tests. A number of different HVAC, lighting and the other equipment shed strategies with a wide range of control systems have demonstrated in the 2004 tests. This analysis will address advantages and disadvantages of different DR control strategies and decision making procedure to develop optimal DR strategies for a given control system and building type.

A final element of future work is to review results from the interviews with all 18 sites to discuss their motivations for and experience with the Automated DR tests. LBNL will explore methods to allow for improved knowledge transfer for DR practices. One possible outcome is the development of a peer-to-peer discussion forum that allows building operators, engineers, and energy managers to share their experience with DR shed strategies and technologies.

Further research is also needed to determine the economics of manual and automated DR, evaluate reasonable scenarios for the frequency and duration of sheds, and possible occupant and tenant issues.

7. References

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Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

Appendix A
Outreach Documents

September 7, 2005

Table of Contents

Memorandum of Understanding (Retest)

Project Participant Memorandum of Understanding

Between

Environmental Energy Technologies Division,

Lawrence Berkeley National Laboratory (LBNL)

And

Participant Company Name

Test Participants for Demand Responsive Technology Demonstration

Purpose: The purpose of this document is to describe the plans for the upcoming project and establish the roles of each party in its implementation. This is not a legally binding document.

Introduction: LBNL is conducting a research project for the California Energy Commission to test automated Demand Response (DR) technologies in commercial buildings. Detailed information about the planned project is included in the LBNL document titled, "Automated Demand Response in Large Facilities Summer 2004 Scaled-Up Test Plan", dated June 30, 2004.

Responsibilities

LBNL agrees to:

- Promptly respond to general comments, questions and concerns of the participants including those about controls, communications and shed strategies.
- Develop a measurement strategy for each demand shed and provide technical support as required for the tests.
- Schedule the price signal as outlined in the Scaled-Up Test Plan.

Participant agrees to:

- Select appropriate shed strategies and implement them in a manner appropriate for their site.
- Provide information to LBNL about the facilities, control systems, shed strategies, energy consumption patterns, and performance measurement systems.
- Participate in the Scaled-up test as described in the test plan.
- Collaborate with LBNL as necessary to implement and perform the tests.

- If changes in circumstances cause the participant to drop out of the test, inform LBNL of these changes.

Collection of Information on Demand Response System

LBNL will collect and compile the following types of information, including but not limited to:

- Site characteristics (size, type, location, HVAC systems, etc.)
- Characteristics of controls, communications and monitoring systems installed at the site.
- HVAC, control, communications, energy, and other building time series data during the test to evaluate the shed.
- Strategies for aforementioned equipment during normal and shed modes.

The Participant agrees to provide the above information to LBNL and allow it to be published in a public report from LBNL to the CEC. Upon Participant's advance request, LBNL will provide a copy of the report to Participant prior to making such report public.

In addition to this MOU document, I have read the document describing the Auto-DR test titled, "**Automated Demand Response in Large Facilities Summer 2004 Scaled-Up Test Plan**", dated June 30, 2004.

This memorandum of understanding applies to the following sites:

____

Site Name, Address

____

Site Name, Address

____

Site Name, Address

Terms of Agreement

LBNL is in no way responsible for any issues that arise at the building facility as a result of the tests. This memorandum is intended to memorialize the understanding of LBNL and Participant in the research of automated DR in buildings. The parties agree that this memorandum is not intended to be legally binding and that if the parties desire to create specific, legally-binding obligations, such binding obligations shall only arise under a separate written agreement signed by duly authorized representatives of both parties.

Signed:

Mary Ann Piette

Staff Scientist, and Deputy Group Leader

Lawrence Berkeley National Laboratory

______________________________ ______________

Signature: Date:

Name of Owner Representative ______________________________

Title ______________________________

Company Name ______________________________

______________________________ ______________

Signature: Date:

Attachments (Reference Documents)

- Automated Demand Response in Large Facilities Summer 2004 Scaled-Up Test Plan – June 30, 2004

Memorandum of Understanding (New Sites)

Project Participant Memorandum of Understanding

Between

Environmental Energy Technologies Division,

Lawrence Berkeley National Laboratory (LBNL)

and

Participant Company Name

Demand Responsive Technology Demonstration

June 9, 2004

Introduction

LBNL has developed a research project for the California Energy Commission to test automated Demand Response (DR) technologies in buildings. This Memorandum of Understanding (MOU) provides a brief description of the objectives of the DR project, what LBNL plans to undertake and what is expected of the Participant.

Project Objectives

The objectives of this research project are:

- to improve understanding of the status of automated demand responsive building systems, particularly the levels of automation in best practices
- to quantify demand-savings potential of automated demand responsive systems
- to identify technology gaps and priorities to improve future systems
- to understand key features of the market for DR systems and decision making perspectives about the adoption of DR technology
- to develop and test an automated signal to initiate demand response events

Some new objectives

- How to scale-up in enterprise-wide
- Emergency based test
- Cost to implement Auto-DR on various types of buildings (with or without existing enterprise telemetry)

- To evaluate and compare effectiveness of different shed strategies.
- Business logic
- To standardize Auto-DR system installation/configuration and M&V methodologies.

Collection of Information on DR System

LBNL has selected Name of the Site, Street Address of the Demonstration Site (City, CA) to participate in the DR Demonstration project because of the State-Of-the-Art building control technology at the site. LBNL will collect and compile the following type of information to include but is not limited to:

- Site characteristics (size, type, location, HVAC systems, etc.)
- DR-Systems: software, firmware, and hardware, etc., installed at the site.
- Monitoring, control, and reporting attributes of the system
- Level of automation, human expertise and experience required
- DR-System and Energy Management capabilities and strategies used: How is the DR-system used to optimize energy performance, shed, or shift demand?
- Document first costs for technologies that facilitates the automated demand-response, including capital and installation costs
- Estimate operating costs, including maintenance and support costs: How does the DR enabling technology change operating costs?
- Determine peak demand and energy savings: How does the DR technology increase flexibility of the facility and therefore increase savings in energy expenditures?

The "Automated Demand Response Test Site Questionnaire" dated June X, 2004 is to be completed and returned to Dave Watson (dswatson@lbl.gov) by July X, 2004. Owner/operators will coordinate this effort with their Energy Information System suppliers. Dave Watson is available at 510 486 5562.

The Participant agrees to provide the above information to LBNL. Much of the information will be included in a public report from LBNL to the CEC. Upon Participant's advance request, LBNL will provide a copy of the report to Participant prior to making such report public.

Demand Response Test

All participants are responsible for reviewing and meeting the attached "Time Schedule for Demand Response Test Participants" dated June X, 2004.

During August 2004 LBNL will send the Participant an XML signal via the Internet that contains information to represent electricity prices.

The Participant will work with their controls and DR system vendor and in house staff to modify their system to be able receive or retrieve the XML signal, send back an acknowledgement, and initiate an automated shed. The tests will take place during a 2 week period in August 2004. The automated response will not be requested during more than two working days. These days may be non-consecutive. Within a test day, response will not be requested for more than 3 hours. The Participant will be able to override the test if need be. However, LBNL would like to verify that the shed was fully automated with no operator intervention.

Further definition of the price signal is provided in two documents "Price Signal for the Automated Demand Responses Tests" (dated June 26, 2003) and "RT Pricing Web Methods and XML Schema" (dated August 4, 2003), which are attached. The baseline price for no action will be $0.10/kWh. The first level of price increase will be to $0.30/kWh. The second level will be $0.75/kWh. Triggers for the automated shed should be based on those prices.

LBNL plans to compile HVAC, control, communications, energy, and other building time series data during the test to evaluate the shed. The development of this information to evaluate the success of the automated shedding will require additional collaboration between LBNL, the building owner/operator, and the EIS provider. Time for this collaboration effort should be anticipated. LBNL plans to report on the results of the shed in a report to the CEC. Results from the participant will be compared with results from other sites as well.

Terms of Agreement

LBNL is in no way responsible for any issues that arise at the building facility as a result of the tests. LBNL understands that due to circumstances that cannot be predicted, the Participant may not be able to complete their participation in the project. LBNL would like to be informed of such a decision at least one month in advance of the test.

This memorandum is intended to memorialize the understanding of LBNL and Participant in the research of automated DR in buildings. The parties agree that this memorandum is not intended to be legally binding and that if the parties desire to create specific, legally-binding obligations, such binding obligations shall only arise under a separate written agreement signed by duly authorized representatives of both parties.

Signed:

Mary Ann Piette

Staff Scientist, and Deputy Group Leader

Lawrence Berkeley National Laboratory

____ ____________________

Signature: Date:

Name of Owner Representative

Title

Company Name

____ ____________________

Signature: Date:

Attachments (Reference Documents)

- Automated Demand Response Test Site Questionnaire - Updated August 5, 2003
- Time Schedule for Demand Response Test Participants - Updated August 5, 2003
- Price Signal for the Automated Demand Responses Tests – Dated June 26, 2003
- RT Pricing Web Methods and XML Schema – Updated August 4, 2003

LBNL Automated Demand Response 2004
Site Questionnaire

LBNL Interviewer	
Date Interviewed	

1. Contact Information

Name	
Company	
E-mail	
Phone	
Fax	
Contact's address	

2. Site Information

Name of the site		
Primary services or Products of the site		
Does the site consist of multiple buildings or single building?	☐ Multiple buildings → # of buildings ☐ ☐ Single building	
Location (address)		
Year constructed		
Floor space	Total	
	Conditioned	
# of floors		
Occupancy schedule	Weekday	
	Non-Weekday	
Utility company		
Facility management type	☐ Company-owned ☐ Outsourced	

3. Energy

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

4. HVAC system

5. EMCS, Control

Control system type		
Control system is viewable at,	☐ Web-browser ☐ Off-site ☐ On-site ☐ Never	
Currently trending EMCS data?	☐ Yes ☐ No If No, is it capable to trend data? ☐ Yes ☐ No Data point collected or requested to collect:	
	Trend interval	

6. Lighting system

Lighting control	☐ Yes ☐ No If yes, type of control:

7. EIS and EMCS (data monitoring and collection)

Utility provided EIS	☐ Yes ☐ No If yes, utility/vendor:
Other EIS installed	☐ Yes ☐ No If yes, vendor:
Data points collected	
Trend interval (minutes)	
Is the data accessible from third party (LBNL)?	☐ Yes ☐ No If yes, please provide URL and password.

8. Connectivity – Connecting the EMCS to the Internet

a. Does the site have Internet connectivity for tenants (i.e. can they surf the Web?).	☐ Yes	☐ No
b. Is EMCS data viewable through a Web browser on site?	☐ Yes	☐ No
c. Is EMCS data viewable through a Web browser off site?	☐ Yes	☐ No
d. If 9c above is Yes, is a Web programmer available to install a Web services/XML client (template provided)?	☐ Yes	☐ No
e. If (9a = Yes) and (9c or 9d = No), can you provide a public IP address? A pre-configured IP relay will be shipped to your site.	☐ Yes	☐ No

9. DR Plan

Have you done any type of demand shed before?	☐ Yes ☐ No If yes, describe the shed control strategy.
Do you have any shed control ideas?	
How much kW do you think you can shed? [kW]	
Are you participating in a program now?	

Time Schedule for Demand Response Test Participants

Phase-2 Fully Automated Demand Response Test for Phase-1 Participants (Dated – June 9, 2004)

Date	Party	Activities
June 18	All	Agreement on re-test
June 30	EIS Vendor Infotility	Confirmation of connectivity
July 1 ~ July 31	All	DR test conducted (same shed), randomly for X days during this period.
July 16	Owner EIS Vendor	Completion of shed strategies for "more shed".
July 16	LBNL	Completion of measurement and verification plan for "more shed".
August 1 ~ August 31	All	DR test conducted (more shed)
September	LBNL	Data analysis

Phase-2 Fully Automated Demand Response Test for Scaled-up Test (Dated – June 25, 2004)

Date	Party	Activities
Early July	LBNL	Send documents to owners by E-mail.
Early July	LBNL Owner	Call to owners. Conduct site interview and have them fax the MOU with signature.
Early July	Owner	Receive MOU.
Early July	LBNL	Sent back the MOU with signature.
Late July	Owner EIS Vendor	Select the buildings.
Late July	LBNL	Complete of measurement and verification plan.
August	LBNL EIS Vendor	Get EIS access. Download sample data.
August	EIS Vendor Infotility	Confirm connectivity.
September	All	DR test conducted, randomly for X days during this period.
October	LBNL	Data analysis

MEMO: Price Signal for the Automated Demand Response Tests

FROM: Osman Sezgen and Mary Ann Piette

Lawrence Berkeley National Laboratory

TO: Participating Facilities

DATE: June 26, 2003

This memo provides an overview of the price signals for the automated Demand Response (DR) test.

The automated DR tests will be initiated by an electricity price signal sent from Infotility using "push" architecture. [Push architecture will be used if the technology used by the EMS can support it or can integrate it. If not, "pull" architecture will be used--the EMS queries a server that returns the real time price.] The profile of the price-signal will be determined and controlled by the Lawrence Berkeley National Laboratory as further described below.

We request that each site acknowledges the receipt of the price data as further described below. Following receipt of the signal we request that your system automatically initiates your load shedding response when the price signal moves to a level above standard time-of-use pricing. We will discuss this with you.

The signal itself will be simple and the profile of the electric prices will be designed to cause minimal inconvenience to the facilities that are participating in the DR test.

Description of the Price-Signal (Hardware/Software Point of View)

The price signal will be broadcasted every 15 minutes (approximately on the hour, and every fifteen minutes after the hour). The price broadcasted will be in effect in about 15 minutes. (The facility will have at least 15 minutes of advance notice before the price changes.) Every signal will have two time stamps: (1) the time that it is broadcasted, and (2) the time that it will be in effect. The time that the signal is broadcasted may be slightly earlier than the 15-minute notice period but the times of effectiveness of prices will be on discrete times (on the hour and every fifteen minutes after the hour). The time that it will be in effect is a 15 min ending time.

The communications systems at the facility will need to be programmed to accept the electric price signals from Infotility and send an acknowledgement signal back. This acknowledgement signal should include the full information about the original signal including the time stamps.

The facility will need to provide an IP address to Infotility. This address is going to be used as the target for the price information. To be able to receive price information pushed by Infotility, there are 2 options:

1. “Push” architecture: The EMS of the facility will have to integrate a “connector” that communicates with the Infotility servers in real time (“Push” architecture).
2. “Pull” architecture: actually, the “pull” architecture includes both “push” and “pull” technologies: an application from Infotility would be installed on a computer on the LAN of the facility. Infotility’s servers would push real time pricing to this application. The EMS of the facility would pull the real time prices from this application.

Description of the Price-Signal (Operations Point of View)

Although the signal is designed to change every fifteen minutes, the actual signal will be constrained to make it less onerous to the participating facilities. The objectives are:

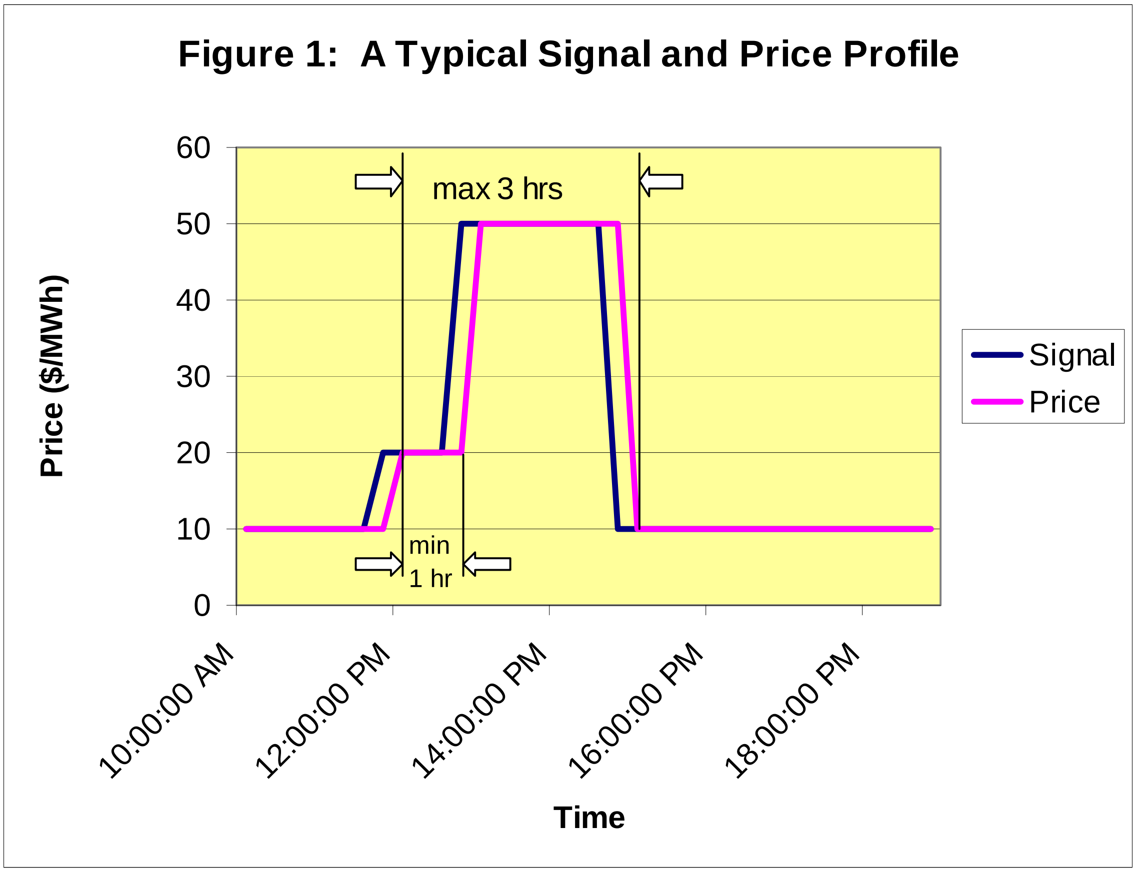
- Give some predictability on the frequency side (frequency of price changes)
- Give some predictability on the price side (level of prices)
- Give some predictability on the duration of the high prices

The shape of the signal will be such that:

- When the price level changes, the level will stay the same for at least one full hour.
- There will be three levels of price: normal (10 cents/kWh), medium (30cents/kWh) and high (75 cents/kWh), the facility operator can preprogram response actions for each level.
- The duration of price changes to higher than normal will not exceed 3 hours (thus shorter than CPP) and prices will move above normal only once during one day (once prices move, the facility can be sure that it will be back to normal within 3 hours and will not move again for the day).
- Signals may change prices between the hours 12pm to 7pm (weekdays). The latest signal that may change prices will be for 6pm and will change the price effective between 6pm to 7 pm.
- The tests will take place within 2 weeks and we will not change prices during more than two working days within this period. Thus, we want all of the communication systems to be ready for the test at the same time. The test is intended to take place at all 6 sites in real time.

For example, as shown in Figure 1 if we would like to change the price to a medium level at 12pm, we will send a signal by 11:45 am. Once we set the price for 12pm, we will not change it until 1pm. If we want to change the price at 1 pm (to high or normal), we will send another signal by 12:45 pm. If we change the price to medium at 12pm and high at 1pm, we can only hold the prices above normal until 3 pm. If we set the price to medium at 12pm and set it back to normal at 1pm, we will not change the price level again until possibly the next weekday.

Finally, the facility will be able to opt out within the 15-minute notice period just before a higher price comes into effect. (Between the time the signal is sent and the time when the price is in effect the facility can inform us and opt out of the test.)



RT Pricing: Web Methods and XML Schema

Author: Nicolas Kardas (Infotility) with additions from Mary Ann Piette (LBNL)

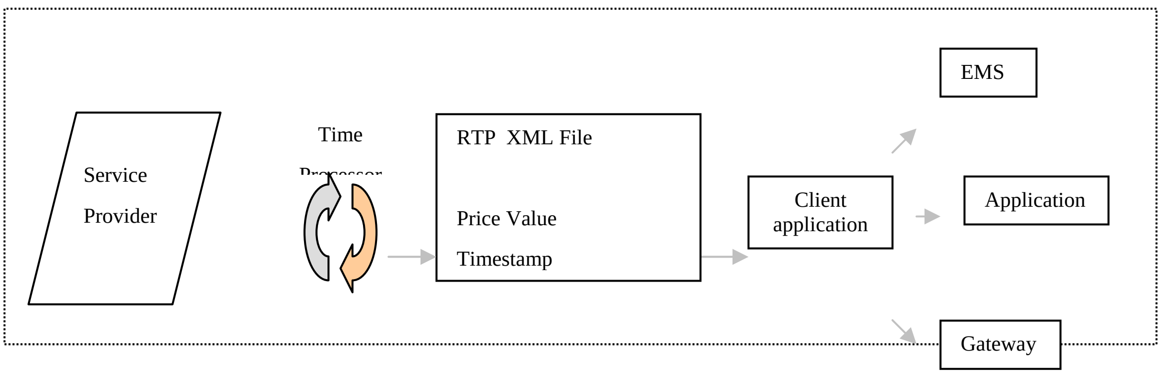
Date: June 14th, 2004

1. Introduction:

Infotility will deliver an electricity price stream to the facilities in the automated demand response research project developed by Lawrence Berkeley National Laboratory. The client applications connected to the LAN at the user's site can receive the electricity price stream through a variety of methods. The client application may direct the price stream directly to an Energy Management Control System (EMCS), an electric meter, an Energy Information System (EIS) gateway device, IP relay or any a software application. These options are shown in Figure 1.

Note: a client application may not be needed: the EMCS/EIS can directly call the web services.

Figure 1. Real-time Pricing Delivery Service Example



In order to get access to the prices, the End-users regularly call a Web service that returns the prices. This would be done automatically by the client application or the EMCS/EIS. The prices are formatted using the XML RT Pricing schema (see below). EMS/EIS may already have connectors available to call Web services methods.

2. The server will check that the price are successfully received by the participants EIS

In order to give to the project team visibility regarding which participants get the price, when they get it and if they get it right, the servers logs each web service transaction between the server and the participant EIS and checks that the prices are received correctly by the participants EIS.

To be able to perform this check, when a participant EIS calls a web service to get a new price, it has to pass, as a parameter, the value of the last price it received from the server and the timestamp of this price. The server will log this data and will check that the price received by the participant EIS is the same as the one that was returned by the server.

If a participant EIS has not called the web service for more than x minutes or if the price was not successfully received by the participant, an Email alert will be sent to the participant and the project team.

3. Web methods to call to get Real Time Prices

They are 2 steps to get a real time price from Infotility's servers:

- Step 1: Login to the system
- Step 2: Call a Web method to get the real time prices

Web method to login

The signature of the Web method is the following:

```
public DataSetClientWSReturns Sessions_Login (
      string strEMail,
      string strPassword,
      ref string strWho,
      ref bool bLoggedIn,
      ref int iUserID)
```

This method must be called only once when the application starts. The Email and Password are passed to uniquely identify the user in the system. The method returns 3 parameters:

- strWho: it is a unique key that identifies the session that has been created for the user in the system. This parameter is returned by the server. This parameter has to be passed in each web method call to get the price data.
- bLoggedIn: it is equal to true if the login has been successful on the server
- iUserID: the userID of the user in the system.

Web method to retrieve Real Time Prices

```
public DataSetClientData GetNextPrice(
      int iReqUserID,
      string strWho,
      ref bool bSessionTimeOut,
      string strReqChannelIDList,
      string DateTimeLastCall,
      float ValueLastCall)
```

To call this web method, the client application must pass the following parameters:

- `iReqUserID`: set it to the userID parameter returned by the Web method Sessions_Login
- `strWho:` set it to the strWho parameter returned by the Web method Sessions_Login
- `strReqChannelIDList:` Identifier of the price channel to retrieve (you will get this identifier from Infotility)
- `DateTimeLastCall:` The timestamp of the price that was returned by this web method the last time it was called. It corresponds to the Date_Time field of the DataSetClientData.xsd dataset returned by the server. The format of this parameter is a string: "mm/dd/yyyy hh:mm:ss"
- `ValueLastCall:` The value of the price that was returned by the web service method the last time this web method was called.

This Web method returns a parameter (boolean): `bSessionTimeOut.` This will be always false because the session duration will not be limited for the users of this project.

The Web method returns the price data in a dataset based on the RTPricing XML schema described below.

Other web methods

- ```
  public_ DataSetClientWSReturns LogoutOnServer(
                      int iReqUserID,
                      string strWho,
                      ref bool bLoggedOut)
  ```

  This method is used to logout. It is not required to use it because when the user logs in, the existing sessions are automatically cleared.

- `DateTime GetSystemClock ()`
  This method the current UTC time on the server

4. RT Pricing XML Schema

The RTPricing XML schema is defined by the following schema (DataSetClientData.xsd):

```
<?xml version="1.0" encoding="utf-8"?>

<xs:schema
xmlns:mstns="http://tempuri.org/DataSetClientHistDataStr.xsd"
xmlns:msdata="urn:schemas-microsoft-com:xml-msdata"
xmlns="http://tempuri.org/DataSetClientHistDataStr.xsd"
attributeFormDefault="qualified" elementFormDefault="qualified"
targetNamespace="http://tempuri.org/DataSetClientHistDataStr.xsd"
id="DataSetClientHistDataStr"
xmlns:xs="http://www.w3.org/2001/XMLSchema">

  <xs:element msdata:IsDataSet="true" name="DataSetClientHistDataStr">

    <xs:complexType>

      <xs:choice maxOccurs="unbounded">
```
```

```
        <xs:element name="HistData">
          <xs:complexType>
            <xs:sequence>
              <xs:element msdata:ReadOnly="true"
msdata:AutoIncrement="true" name="DataID" type="xs:decimal" />
              <xs:element name="ChannelID" type="xs:decimal" />
              <xs:element name="Date_Time" type="xs:string" />
              <xs:element minOccurs="0" name="DataValue"
type="xs:float" />
              <xs:element minOccurs="0" name="Status" type="xs:short"
/>
              <xs:element minOccurs="0" name="When_Created"
type="xs:string" />
              <xs:element minOccurs="0" name="Prev_Created"
type="xs:string" />
            </xs:sequence>
          </xs:complexType>
        </xs:element>
      </xs:choice>
    </xs:complexType>
    <xs:unique msdata:PrimaryKey="true" name="Constraint1">
      <xs:selector xpath=".//mstns:HistData" />
      <xs:field xpath="mstns:DataID" />
    </xs:unique>
  </xs:element>
</xs:schema>
```

There are 6 elements:

- ChannelID: the ChannelID of the price
- Date_Time: it is the timestamp of the price. The format of this element is string: “mm/dd/yyyy hh:mm:ss”
- DataValue: it is a float number that contains the price value
- Status: It is a number that describes the DataValue. It is set to 1 for the prices of this project.
- When_Created: it is the date and time when this price value was received on the Infotility servers. The format of this element is string: “mm/dd/yyyy hh:mm:ss”
- Prev_Created: Not used for these prices

Bandwidth Requirements: Depending on the frequency of the RTP price delivery, the bandwidth requirements may vary; however, the data transfer rates are expected to remain low.

5. Server URL

The URL of the server wsdl is:

http://webservice01.infotility.com/lblwebsrv072803/servicelbl.asmx?wsdl

Note: Infotility is currently implementing https on this server. Https will be activated before 8/xx/04. You will get an Email when it is ready. The new URL will be:

https://webservice01.infotility.com/lblwebsrv072803/servicelbl.asmx?wsdl

Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

Appendix B
Site Description & Demand Shed Details

September 7, 2005

Table of Contents

300 Capitol Mall Building

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Large Office	SMUD	Private/Property Management	Office Tenants	Sacramento, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
Supermarket Store	383,200	18 floor class A office tower managed by a national property management company. There is an 3 floor annex facility (~30,000 ft^2) directly north of the tower.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
VAV with perimeter reheat Annex: Qty 1 Boxcar unit with four 25 ton compressors stages	6 AHUs with economizers	Qty 2, 398 ton Electric Chillers	Qty 2, 7.0Mbtu Natural Gas Boilers

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Johnson Metasys for fan, cooling, heating plant & lighting	No	EnerLink interval metering for whole building electric, chiller plant & mechanical risers.	Qty 2 15 HP pumps and one 5 HP pump run the water fountain

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP Relay	Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Fan speed locks in concert with chilled cooling water temperature (CCWT) setup; Turn off shipping dock exhaust fan; turn off lobby lights; modify zone temperature average reading on boxcar unit control; turn off water fountain pumps

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
CCWT setpoint	44 °F	47 °F	47 °F
Lobby Lights, Shipping Exhaust Fan, Water Fountain Pumps	ON	OFF	OFF
Temp offset to the zone temp. average control point for the Boxcar unit.	0 °F	0 °F	4 °F

Shed Results:

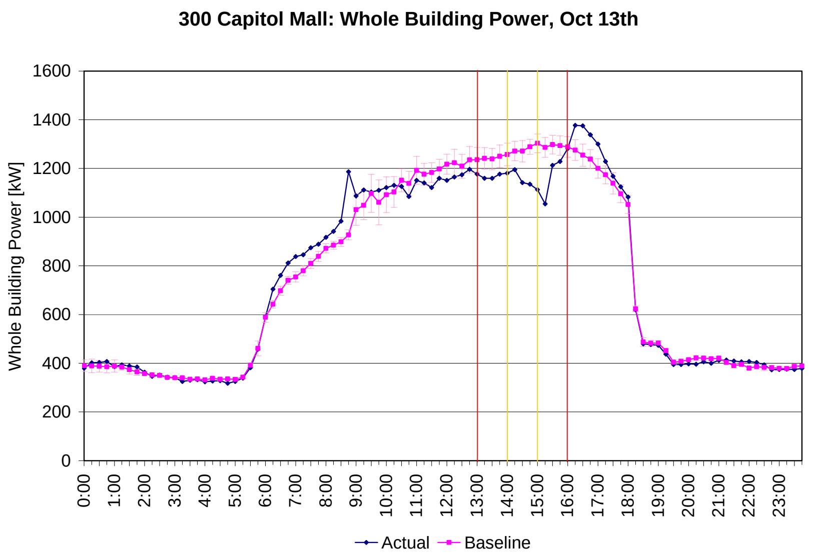
Carrier conducted an un-scheduled maintenance on the chillers during time of test on October 13th. This caused some strange patterns in the chiller trends. The maintenance did not interrupt chiller service to the building.

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh	232	108	0.61	0.28	18%	8%
	$0.75/kWh	154	109	0.40	0.28	12%	9%
Nov 5th	$0.30/kWh	60	5	0.16	0.01	6%	0%
	$0.75/kWh	18	-2	0.05	-0.01	2%	0%

Result Details (Oct 13)

Operations staff were not aware of the test until the front desk security called about the lights going off. There was no other occupant feedback or complaints during the test.

The chief engineer is quite happy with what they set up and he plans to install an "initiate now" button on his system so they can start the shed strategies manually when ever deemed necessary.



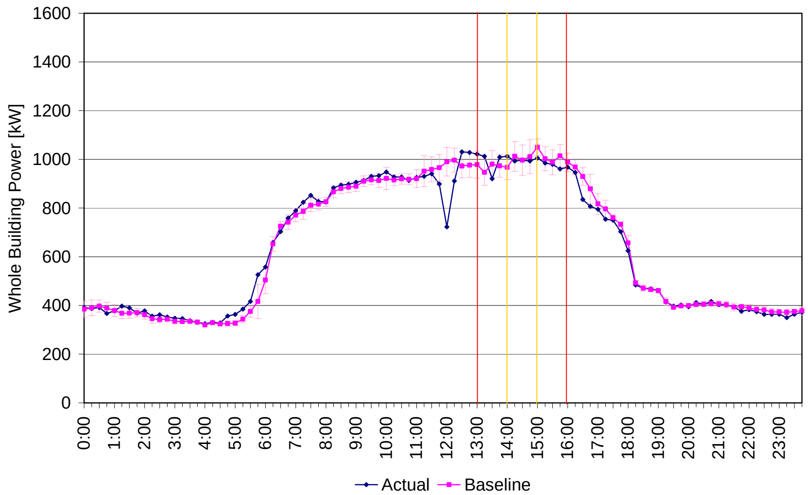
Result Details (Nov 5)

Again, the operations staff was not sure the test had started until the front lobby lights went off.

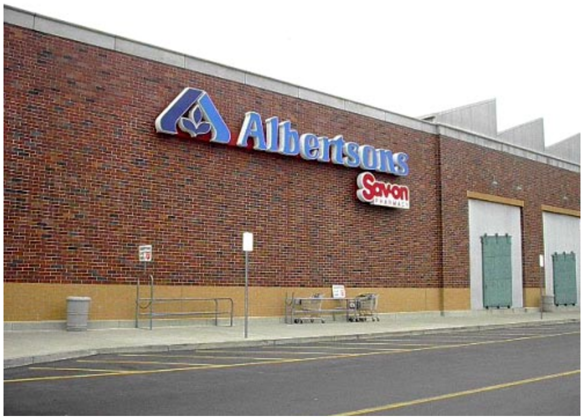
The chief engineer checked the system settings and noticed that the chilled water temp change did take but did not hold. That was likely because the cooling load was so low, and the increased water temperature caused the chillers to cycle off. It appears there was not any room to play with this set point due to weather conditions.

He also notice that the Annex space temperatures were getting warm He confirmed that the Boxcars units were out of mechanical cooling and in free cooling mode. The strategy of fooling the system to think the average zone return temperature was cooler that actual did succeed in cycling off compressor stages.

300 Capitol Mall: Whole Building Power, Nov 5



Albertsons Supermarket – Fruitvale



Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Supermarket	PG&E	Public Corporation	Employees, Customers	Oakland, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
Supermarket Store	50,000	Store hours, 6 am to 12 am seven days a week. Plug and refrigeration power density is approximately 8.0 W/ft^2.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
N/A	N/A	N/A	N/A

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
N/A	N/A	Engage EPIM™ - IP I/O Device capable of measuring electric data and remote monitoring over the Albertsons' enterprise network. Remote control capabilities as well. A Web server that displays achieved data is hosted by eLutions at a co-location site in Tampa Bay, Florida.	Albertsons' WAN and the Internet was used to transmit energy data and Auto-DR commands.

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Sept 8th & 21st (Retest) Oct 13th & Nov 5th (Scaled-up Tests)	Not needed.

Shed Strategies Used:

	$0.30/kWh	$0.75/kWh
Shed Descrip.	Dim overhead lighting by 35%	Turn off the anti-sweat door heaters

Shed Results:

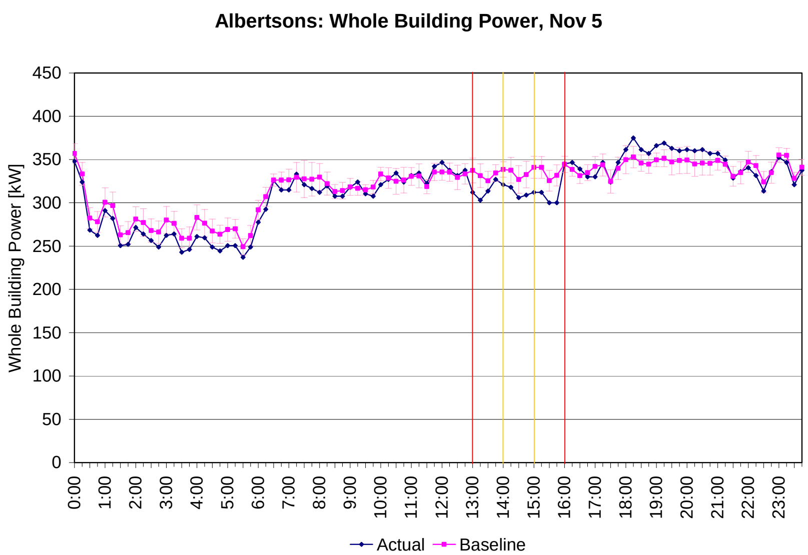
The lighting shed is weather-independent, resulting in a constant 26.5 kW reduction. The anti-sweat door heaters were off on all the test days, probably due to dry weather, so there are no additional reductions at the $0.75/kWh price stage.

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Sept 8th	$0.30/kWh	67	35	1.33	0.70	16%	8%
	$0.75/kWh	48	44	0.97	0.87	11%	10%
Sept 21st	$0.30/kWh	59	50	1.17	1.00	16%	14%
	$0.75/kWh	46	39	0.92	0.78	12%	11%
Oct 13th	$0.30/kWh	30	22	0.61	0.44	8%	6%
	$0.75/kWh	26	19	0.51	0.39	7%	5%
Nov 5th	$0.30/kWh	32	23	0.63	0.47	10%	7%
	$0.75/kWh	24	20	0.47	0.41	7%	6%

(Against the fact that the demand saving is weather-independent, the saving estimates were calculated by whole building regression model method to analyze all test site in consistent format.)

Result Details

The light level in the store decreased from approximately 160 lx to 110 lx (30% decrease) at corner and side, and decreased from 120 lx to 70 lx (40% decrease) at center of the store. According to the store manager, some employees and customers noticed the change and asked for the reason, though they were not complaints.



Bank of America – Concord Data Center, Buildings A, B & C

See Appendix D Case Studies – HVAC Shed Strategy and Effectiveness.

Joe Serna Jr. Cal/EPA Headquarters Building

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Large Office	SMUD	Government	State Employees	Sacramento, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
25 Floors	930,000	The Cal-EPA building ranked highest among 87 participants currently in the LEED-EB program, which applies the council's rating system to buildings already built when the standards were developed in 2000.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Single Duct VAV with perimeter electric reheat	Qty 52 Air Handlers 104 variable speed fans	Qty 3: 300 (w/VSD), 800, 1200 Ton Chillers Qty 3, Primary CV Pumps Qty 3, Secondary VSD Pumps	Qty 2, 3.5 & 4.0 MBtu Boilers Qty 2, Primary CV Pumps Qty 2, Secondary VSD Pumps

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Johnson Metasys for fan, cooling & heating plant	Yes	None available	Network security for the IP Relay connection is administered remotely from Philadelphia, PA.

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP Relay	Nov 5th (Scaled-up Test)	None

Shed Strategies Used: Duct Static Pressure Reduction & Reduce Hallway Lighting

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Static setpoint	1.0”	0.5”	0.5”
Hallway lights	All On	All on	Reduced to Emergency Lights only

Shed Results:

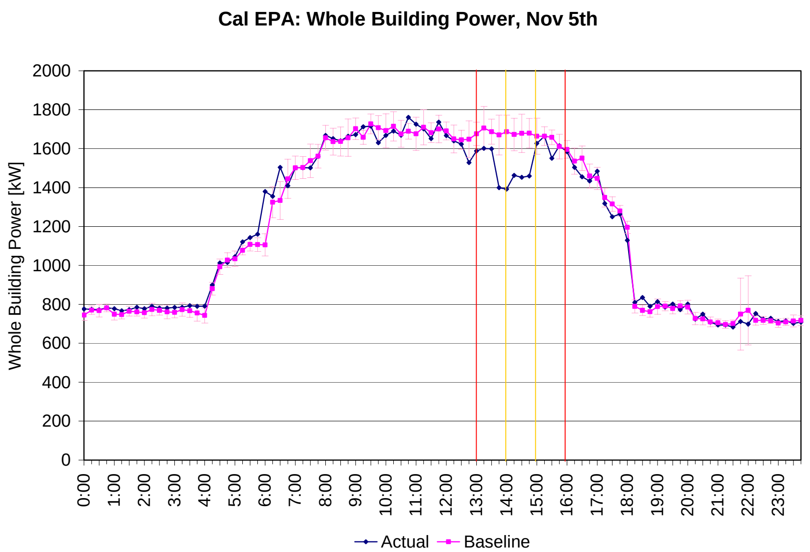
The site was not ready for the Oct 13th test. The major constraint regarding preparation was distributing a Test Participation memo to all the building tenants. Since the IP Relay preparations were only completed 1 day prior to the first test, the distribution of a tenant memo could not occur with enough advance notice.

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Nov 5th	$0.30/kWh	271	87	0.46	0.15	16%	5%
	$0.75/kWh	295	237	0.50	0.40	17%	14%

Result Details (Nov 5)

The responsible building engineer had an alarm set up for the HVAC part of shed, so he knew when the test began. However, the tenants didn't know until the hall lights went off. Even after the lighting shed, occupants didn't complain about comfort.

There was one occupant that complained after the test memo. Rather that risk a work disruption for that person, the local zone was exempted from the test. This was a very small percentage of the building floor area.



CANMET Energy Technologies Centre – Varennes

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Energy R&D center	Hydro-Quebec			Varennes (Quebec, Canada)

Campus or Building Description	Gross Floor Area (ft^2)	Details
Single building	4189 m.ca	heat cool:1700m.ca, heat only:2489 m.ca

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
	12 supply fans, 6 return fans. 75 kW / 75 hp. 60, 000 CFM. VFD.	Chiller: 2, 70 tons each constant volume and a iced bank of 70t equivalent. DDC, incorporate peak load management	

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Bacnet and V2 delta propriety protocol	Yes, 60 zones		

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
EMCS Gateway	N/A	None

Shed Strategies Used:

Single level shed:

- Unload electric humidifier
- Stop AHU M4 and M31 (15 kW)

Shed Results:

October 13th: The server communication was not ready.

November 5th: The test started at 4 pm EST. Electric humidifier and AHU M4 and M31 were already turned off at this time. No shed occurred due to this strategy.

Cisco Systems

Site Summary

Facility	**Utility**	**Ownership Type**	**Type of Tenants**	**Location**
Office, Hi-tech laboratory	PG&E	Company owned	Company employees	San Jose, CA Milpitas, CA

Campus or Building Description	**Gross Floor Area (ft^2)**	**Details**
23 buildings	4354,000 ft2	Gross area 4241,000 ft2 was used for saving analysis because kW trend was not available at one building.

HVAC System Summary

Air Distribution Type	**Air Handler Unit & Fan Count**	**Cooling Plant**	**Heating Plant**
	4 sets of supply fans (75~100 hp) and return fans (25~30 hp) for each building.	2~3 chiller units (400~650 tons) for each building. Total 24600 tons.	

HVAC Control System	**DDC Zone Control**	**EIS Capabilities/Services**	**Other Details**
Altron	Yes		

Auto Demand Shed Summary

Auto Demand Participation Method	**2004 Test Participation**	**Slow Recovery Strategy**
EMCS Gateway	None	None

Shed Strategies Used:

Single level shed during the 3-hour period.

- VAV setpoint 2F increase
- Computer Room AH setpoint 2F increase
- Boiler pump turn off
- Stairwell fan-coils turn off
- Sweep daylight
- Stairwell, lobby, Hallway light turn off

Shed Results:

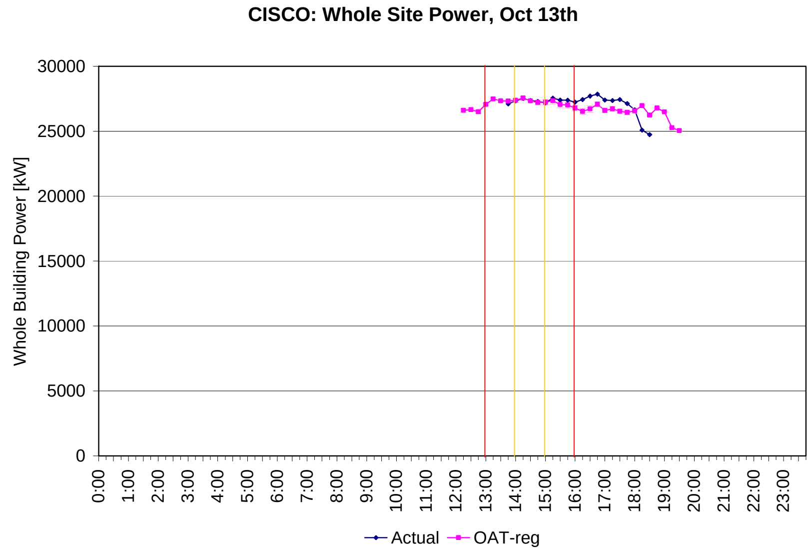
Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh	223	-127	0.05	-0.03	1%	0%
	$0.75/kWh	42	-4	0.01	0.00	0%	0%
Nov 5th	$0.30/kWh	903	709	0.21	0.17	3%	2%
	$0.75/kWh	831	694	0.20	0.16	3%	2%

Result Detail (Oct 13)

The shed controls worked as planned with the following exceptions;

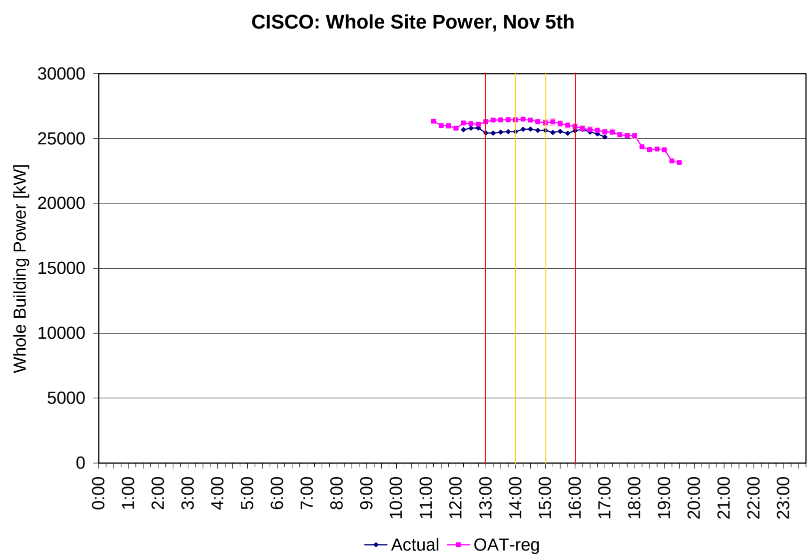
i) The Computer room AHUs (CA), qty. > 200, did not shed as planned. This is due to the fact that their controllers did not "hear" the global shed command that was sent across the ALC network. The other AHUs, the VAV terminal boxes and the chiller plant all received the message and shed according to plan.

ii) About two times per hour, the system dropped out of shed mode for one minute. This was later determined to be caused by null values returned by the Price server. Although these drop-outs shouldn't affect energy savings of the shed much, if any, it is not proper to change setpoints and other parameters so frequently. In addition, each time that this happened our pagers received the message "Leaving LBNL shed level 1" then one minute later, "Entering LBNL shed level 1.



Result Detail (Nov 5)

Shed control worked as planned. The site achieved maximum 903 kW of shed.



Contra Costa County – 50 Douglas Building

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Small Office	PG&E	Government	County Employees	Martinez, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
3 Floors	90,782	This building has a building integrated photovoltaic (PV) array with a maximum power rating of 100kW. The array is connected on the customer side of the meter.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Single Duct VAV with perimeter reheat	3 roof top package units with DX cooling. Qty 2 at 75 Tons & one at 90 Tons	75 Ton units have 4 equal compressor stages 90 Ton unit has 6 equal compressor stages	Each RTU has direct fired natural gas heaters

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Alerton Controls using BACtalk, operating on local workstations.	Yes	InterAct interval metering and online PV sub metering provided by PowerLight Corp.	Custom alarm reports were created to document each price change and temperature setting change

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP Relay	Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Global Thermostat Setpoint Adjustment

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	76 F	78 F	80 F

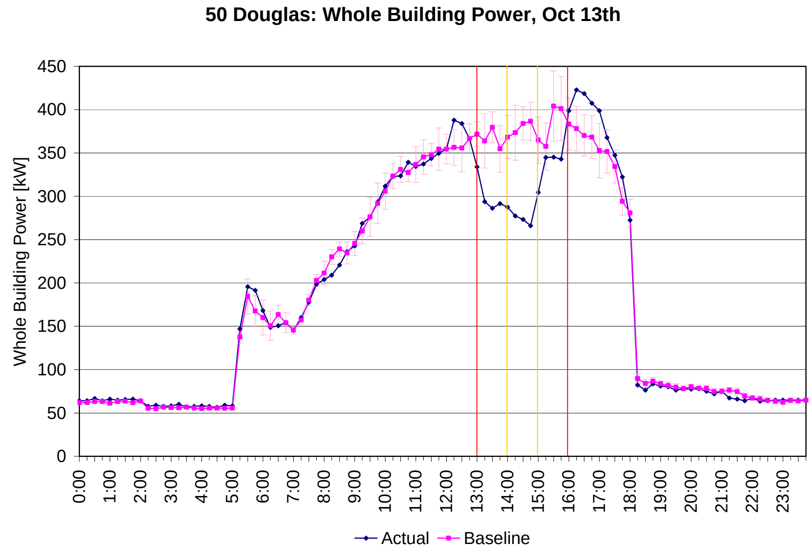
Shed Results:

This building and the other Contra Costa County building (Summit Center) responded very well to the thermostat setup strategy. However, both buildings experienced large demand rebounds after the test measures were released.

Date	**Price**	**kW**		**W/ft^2**		**WBP%**	
		Max	**Ave**	**Max**	**Ave**	**Max**	**Ave**
Oct 13th	$0.30/kWh	93	57	1.04	0.63	25%	15%
	$0.75/kWh	120	102	1.34	1.13	31%	27%
Nov 5th	$0.30/kWh	35	28	0.39	0.31	15%	12%
	$0.75/kWh	45	41	0.51	0.45	19%	18%

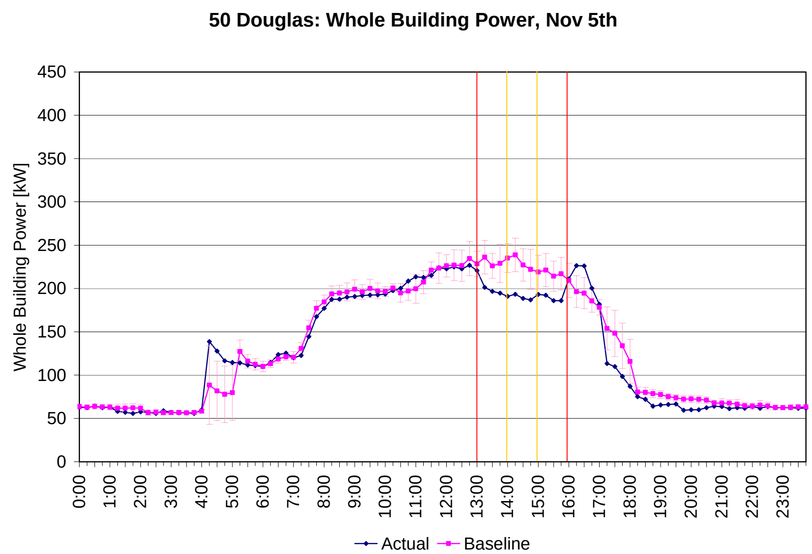
Result Details (Oct 13)

No complaint calls were reported. The chief engineer set up local alarms for each price change, so once he logged into the local EMCS computers, he could see each price change time stamped alarms. Prior to this, he did not know the test had started.



Result Details (Nov 5)

Again, no complaint calls were reported. The chief engineer again didn't know that the test had started until he looked at the alarm log.



Contra Costa County – Summit Center (2530 Arnold)

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Small Office	PG&E	Government	County Employees	Martinez, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
3 Floors	100,000	

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Single Duct VAV with perimeter reheat	4 roof top package units with DX cooling, 60 Tons each	Each 60 Ton units have 8 equal compressor stages	Separate direct fired natural gas roof top package

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Alerton Controls using BACtalk, operating on local workstations.	Yes	InterAct interval metering and online PV sub metering provided by PowerLight Corp.	Custom alarm reports were created to document each price change and temperature setting change

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP Relay	Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Global Thermostat Setpoint Adjustment

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	76 F	78 F	80 F

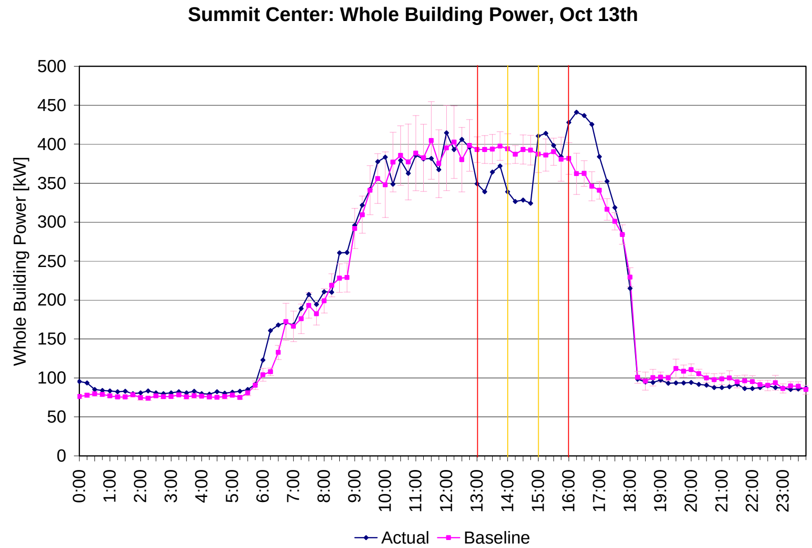
Shed Results:

This building and the other Contra Costa County building (50Douglas) responded very well to the thermostat setup strategy. However, both buildings experienced large demand rebounds after the test measures were released.

Date	Price	kW		W/ft²		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh	54	11	0.41	0.09	14%	3%
	$0.75/kWh	68	62	0.52	0.47	17%	16%
Nov 5th	$0.30/kWh	63	41	0.48	0.31	19%	13%
	$0.75/kWh	87	70	0.67	0.54	27%	22%

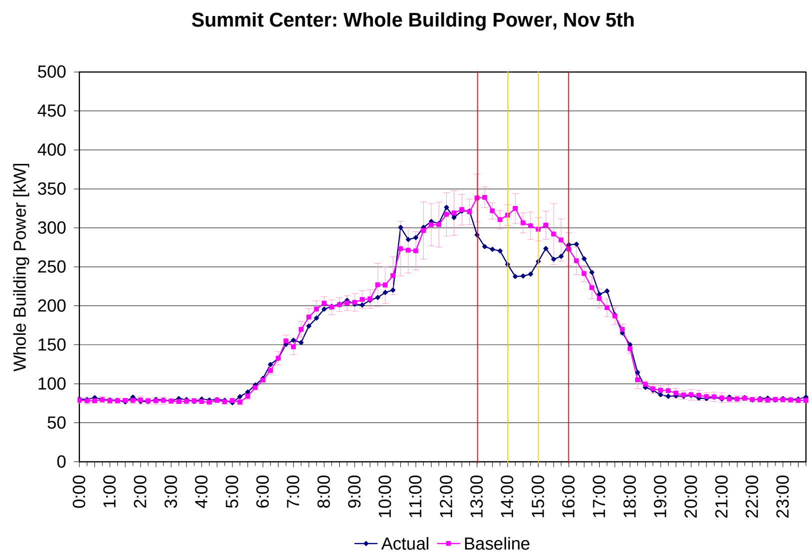
Result Details (Oct 13)

No complaint calls were reported. The chief engineer set up local alarms for each price change, so once he logged into the local EMCS computers, he could see each price change time stamped alarms. Prior to this, he did not know the test had started.



Result Details (Nov 5)

Again, no complaint calls were reported. The chief engineer again didn't know that the test had started until he looked at the alarm log.



Echelon – San Jose Headquarter

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Office, technology lab	PG&E	Company owned	Company employee	San Jose, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
3 Floors	75,000 ft^2	Echelon San Jose Headquarter was built as a company's technology showcase.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
	Total 4,800 tons of package units with VFD. One unit per floor.		

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
All the package units and VAV are controlled with LonWorks.	Yes		The office spaces are equipped lighting with dimmable ballast.

Each office zone has energy-saving mode. The energy-saving mode includes lighting level and zone temperature setpoint control, which can be customized by occupants of the zones. Occupants can customize it with web-based user interface. Lighting can be customized at each zone. One VAV box serves for 2 or 3 zones, and energy-saving mode takes votes for the zone temperature setpoint. There are approximately 60 energy-saving mode zones and 20 VAV boxes per floor.

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Energy-saving mode (dim lighting, increase setpoint), package unit turn-off, and Lightings at hallway (no daylight access) reduction.

Oct 13th

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Energy saving mode	Off	On (dim lighting, increase setpoint)	On (dim lighting, increase setpoint)
Package unit	All on	All on	2 of 3 units off.

Nov 5th

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Energy saving mode	Off	On	On
Package unit	All on	All on	All 3 units off.
Hallway lighting	All on	All on	33~50% off

Shed Results:

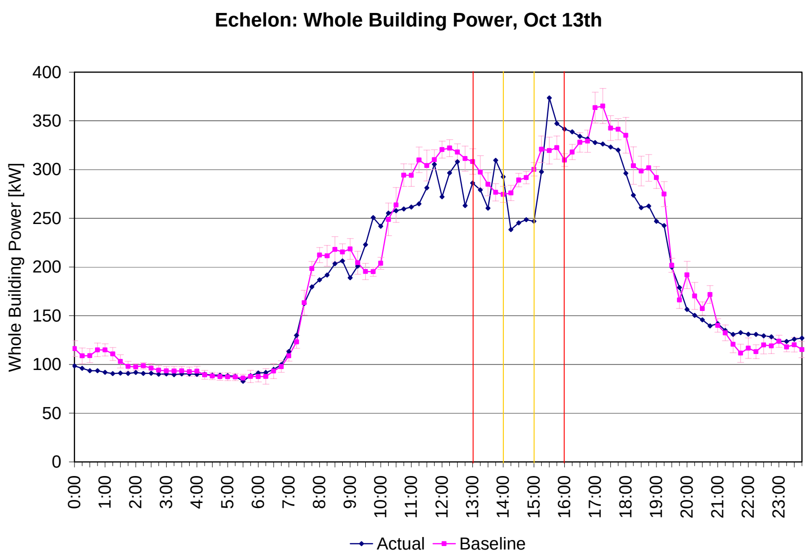
Date	Price	kW		W/ft²		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh	42	-2	0.57	-0.03	14%	-1%
	$0.75/kWh	47	33	0.63	0.44	16%	11%
Nov 5th	$0.30/kWh	114	16	1.52	0.21	48%	7%
	$0.75/kWh	136	100	1.81	1.34	56%	42%

Result Details (Oct 13)

Technically, the system worked as planned. However, the $0.30/kWh-level shed had virtually no effect for the following reason: Prior to the test, an email was sent out to all building occupants that asked them to log onto their own personal office control Web page and 1) enable remote shed capability 2) Set parameters for their offices including a) raise cooling setpoint b) dim overhead lights. Virtually none of the building occupants took these steps, so there was no noticeable shed at this level.

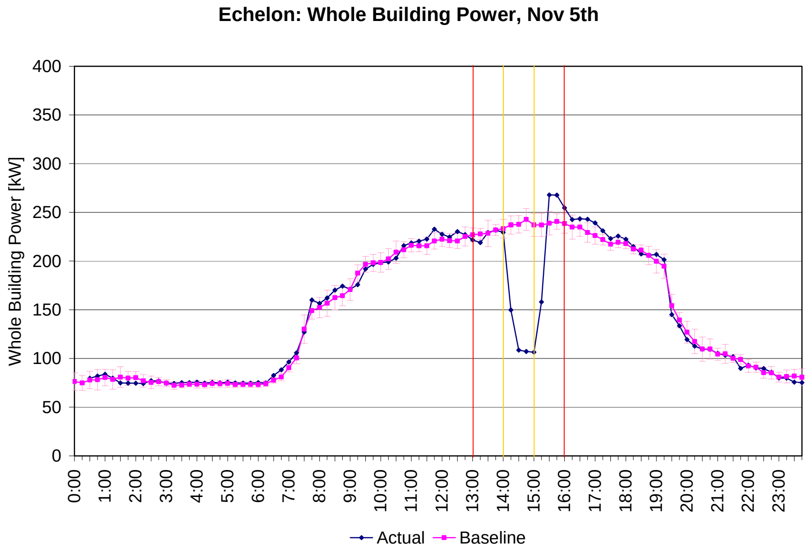
At $0.75/kWh-level, two out of the three package units were shut off completely. However, it took approx 10 minutes for the package units to shed the electricity load after receiving the signal, although the static pressure dropped down immediately after the signal. The recovery was also slow, too.

Zone temperature was increased 1.5 F in average (73.0 F to 74.5 F). The maximum zone temperature during the shed was 77.7 F at the end of $0.75/kWh-level.



Result Details (Nov 5)

Energy-saving mode at $0.30/kWh-level showed no shed effect as last time. At $0.75/kWh-level, all three package units were turned off. Shed kW was 124 kW (94% of total HVAC) in maximum. Zone temperature increase was 2 F in average (72 F to 74 F), and maximum zone temperature was 77.7 F. Lighting power also showed maximum 23 kW shed (31% of total lighting).



Echelon: Whole Building Power, Nov 5th
Whole Building Power [kW]
400
350
300
250
200
150
100
50
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Actual
Baseline

GSA – Phillip Burton San Francisco Federal Building

Site Summary

Facility	**Utility**	**Ownership Type**	**Type of Tenants**	**Location**
Government, large office building	PG&E	US Federal GSA	Federal employees	San Francisco, CA

Campus or Building Description	**Gross Floor Area (ft^2)**	**Details**
22 floors (20 floors tenant occupied)	1,420,000 ft^2 (1,200,000 ft^2 conditioned)	The building is the site of a major demonstration site of the BACnet communication protocol. Tenants include IRS, FBI, and courtrooms.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Dual duct system. Fully DDC VAV boxes.	8 air-handlers, VFD at supply and return fans (partially constant volume). 5 multi-zone systems. Courtrooms are air-conditioned by 13 package units.	3 water-cooled chillers 2 air-cooled chillers 6 cooling towers	3 steam boilers

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
BACnet	Yes	InterAct	

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Global setpoint setup/setback. 15 to 20th floors (courtrooms) are excluded.

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	72 ~ 74 F	76 F	78 F

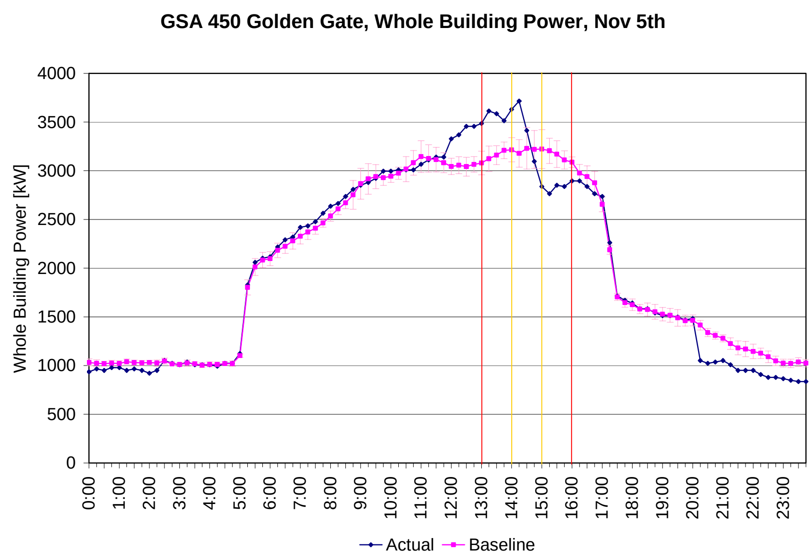
Shed Results:

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh						
	$0.75/kWh						
Nov 5th	$0.30/kWh	440	-26	0.31	-0.02	14%	-1%
	$0.75/kWh	123	-253	0.09	-0.18	4%	-8%

During the November 5th test at 450 Golden Gate, when the zone setpoint increased to unload the cooling systems, the VAV boxes unexpectedly initiated heating. The reason for this was that the global zone setpoint control programming on the VAV box was not setup properly. By raising the space temperature setpoint, the system raised both cooling and heating setpoint, and the cold deck desired airflow CFM was overridden to 50% of the max CFM. As a result both the hot and cold decks lost pressure resulting in the increase in fan energy. This resulted in negative demand savings. Many hot complaints were received from the 7th and other floors. The operator manually shut down the hot deck fans around 2:30 pm.

After reviewing the code for both the VAV and the AHU, the facility engineers corrected the problems with the global zone setpoint control by increasing only the cooling setpoint on a command for demand reduction. This strategy brings all the VAV boxes to their minimum airflow settings, and contributes to fan power saving.

The facility engineers stepped beyond the original DR plan. They are working on the duct pressure reset strategy which uses feedback from the zone controllers to drive a duct static pressure setpoint. This strategy will increase the tolerance for zones that are starved of air and drive the static pressure setpoint down to further reduce fan power. The facility engineers will test these sequences of operation and reduce energy consumption of the building during normal operation and when a DR event is called. The VAV program has been tested and is working as desired, and the duct pressure reset in the AHU program is being developed to be in time for the demand response season.



GSA – National Archive & Records Administration

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Historical document archive	PG&E	Government		San Bruno, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
Single building	1,300,000 ft2	Less than 5% of space are conditioned.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Full zone control	15 AHU (SF/RF set) 10~40 hp VFD (3 of them)	Water cool chillers: 30 tons x2 2 hp pumps 50 tons Rooftop unit, 5 hp	

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Envision	Yes	PG&E InterAct (monthly update)	

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy

Shed Strategies Used: Global zone setpoint increase

Archives, preservation lab, and offices will be exempt from the test, though they will take most area of the building.

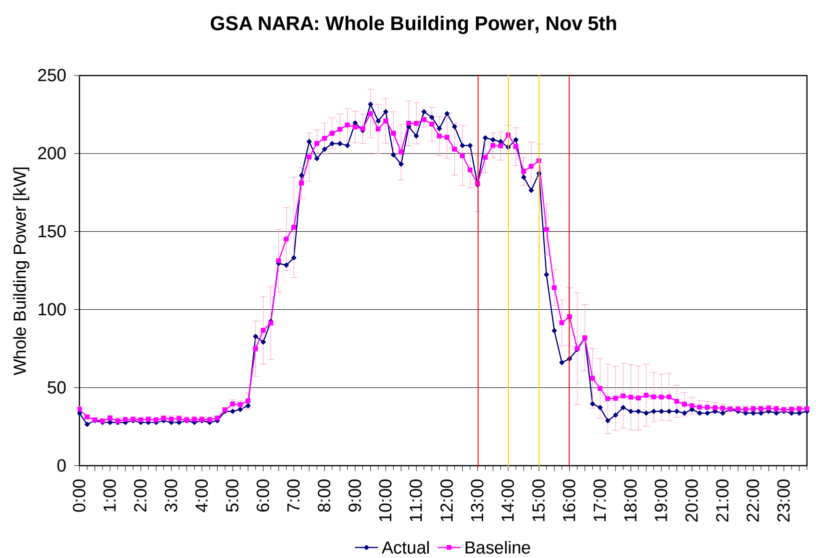
	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	74 F	76 F	78 F

Shed Results:

Date	**Price**	**kW**		**W/ft^2**		**WBP%**	
		Max	**Ave**	**Max**	**Ave**	**Max**	**Ave**
Oct 13th	$0.30/kWh						
	$0.75/kWh						
Nov 5th	$0.30/kWh	29	9	0.14	0.04	28%	8%
	$0.75/kWh	15	6	0.08	0.03	8%	3%

Detail Results (Nov 5)

Since the building doesn't have much internal heat gain, it doesn't have much cooling load during the shoulder seasons. The chief operator mentioned the cooling system was not operated. There might not be affected by the shed strategy at all.



GSA – Roland V. Dellums Oakland Federal Building

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Large Office	PG&E	Government	Federal Employees	Oakland, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
Twin towers	1.1 million	971,000 ft^2 of office space, a 7,200 ft^2 computer center, and a 36,000 ft^2 parking garage. EnergyStar award in 2000.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
Perimeter: Dual Duct VAV with reheat Core: Single Duct VAV without reheat	11 AHUs 22 variable speed fans 47 smaller CV fans	3 Qty, 980 Ton Chillers 2 Qty, 450 Ton Chillers	2 Qty, 10,500 MBH Boilers 2 Qty, 20 HP Circ. Pumps

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Johnson Metasys for fan, cooling & heating plant	Yes	InterAct interval metering	Some Alerton BACnet devices used for ADR communications

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Sept 8th & 21st (Retest) Oct 13th & Nov 5th (Scaled-up Tests)	Gradually diminishing VFD limit on fans for 2 hours after test.

Shed Strategies Used: Global Thermostat Setpoint Adjustment

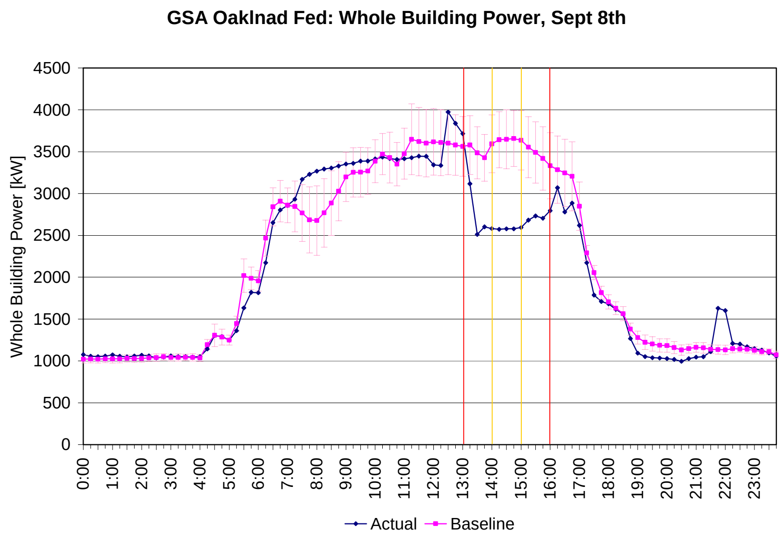
	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	72 ~ 74 F	76 F	78 F
Heating setpoint	70 ~ 72 F	68 F	66 F

Shed Results:

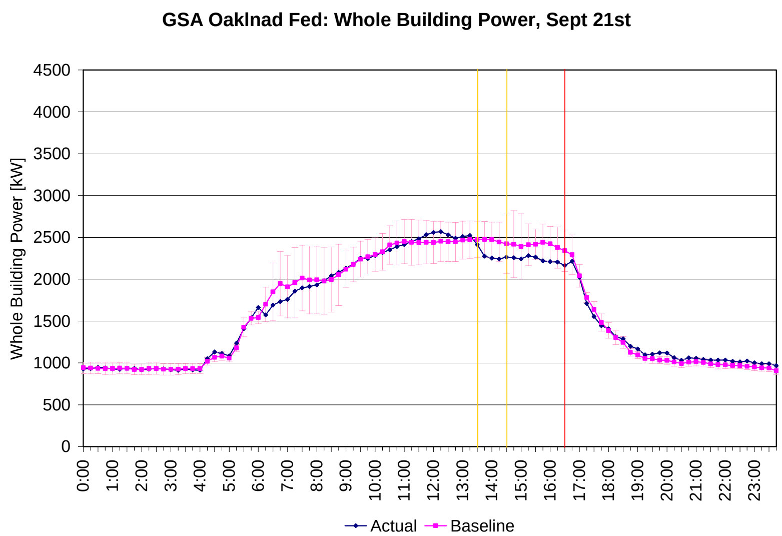
Date	Price	kW		W/ft2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Sept 8th	$0.30/kWh	1043	687	1.07	0.70	29%	20%
	$0.75/kWh	1080	1058	1.10	1.08	30%	29%
Sept 21st	$0.30/kWh	221	170	0.23	0.17	9%	7%
	$0.75/kWh	221	172	0.23	0.18	9%	7%
Oct 13th	$0.30/kWh						
	$0.75/kWh						
Nov 5th	$0.30/kWh	133	83	0.14	0.09	6%	4%
	$0.75/kWh	214	179	0.22	0.18	10%	9%

Result Details

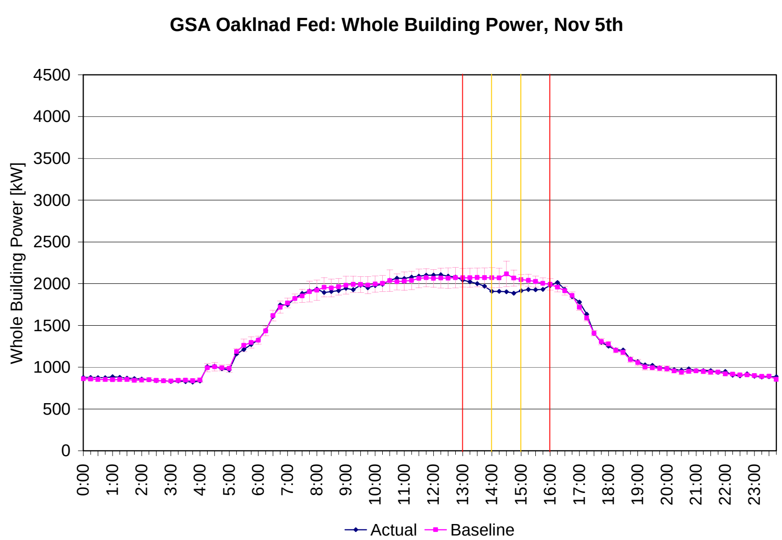
The slow recovery strategy succeeded in reducing the demand rebound peak. However, post-test the VAV boxes did go to 100% open causing a reduction of duct static pressure. This condition likely caused many VAV boxes to starve and may have resulted in temporary pressure imbalance across the floors.



GSA Oaklnad Fed: Whole Building Power, Sept 8th
Whole Building Power [kW]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Actual
Baseline



GSA Oaklnad Fed: Whole Building Power, Sept 21st
Whole Building Power [kW]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Actual
Baseline



GSA Oaklnad Fed: Whole Building Power, Nov 5th
Whole Building Power [kW]
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Actual
Baseline

Kadant Grantek

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Industrial/agricultural material process	WPS			Green Bay, WI

Campus or Building Description	Gross Floor Area (ft^2)	Details
Single building	100,000 sqft	3 acre plant space

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
		No AC, 4,000 office space with HVAC	only heating

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
N/A	N/A	Yes (provided by WPS)	Process line: Allen-Bradley, DDC control

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
EMCS Gateway	Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: 2 motors, 100HP and 75HP. Constant volume.

Shed "transfer operation" that pumps the finished product by differential pressure from storage tank to silo used for loading trains. The motors are controlled by Allen-Bradley PLC.

Shed Results:

October 13th: The shed did not occur, because an operator override was in place. A PLC programming error was discovered during analysis of the results.

November 5th: The plant opted out from the shed after 30 minutes because the process was busy and the plant couldn't afford to stop the pump operation. During the first 30 minutes of the test, the plant shed 43.7 KWH.

Monterey Commerce Center

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Commercial space	PG&E	Lease		Monterey, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
3 buildings	170,000	

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
VAV with pneumatic control	4 Rooftop units Constant Volume		

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Time clock	None		

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
EMCS Gateway	N/A	None

Shed Strategies Used: Common area light partly off

This site was used to demonstrate the capability to control multiple remote sites.

OSIsoft

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Office	PG&E	Leased, but maintained by the company	Company employees, city employees (1st floor)	Oakland, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
3 Floors	60,000 ft^2	The building has just finished major HVAC system retrofit before the test.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
	Two 60-ton rooftop units, and one 30-ton unit with 4 cycle control.		

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
VAV system is full DDC after the retrofit. Zone control is equipped with Distech system. HVAC system control is totalized by Tridium system with LonWorks protocol.	Yes		

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Global setpoint increase/decrease.

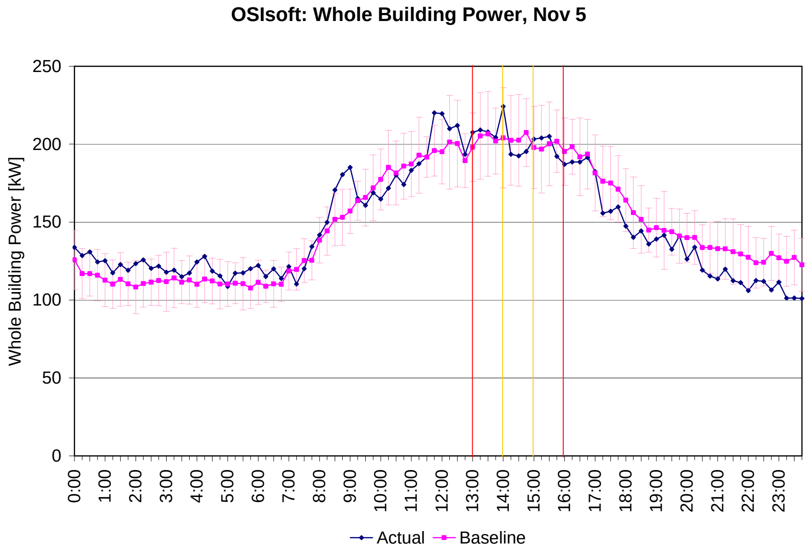
	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Cooling setpoint	72 ± 2.5 F	76 F	
Heating setpoint	70 ± 2.5 F	68 F	

Shed Results:

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh						
	$0.75/kWh						
Nov 5th	$0.30/kWh	10	-3	0.16	-0.05	5%	-2%
	$0.75/kWh	12	3	0.20	0.05	6%	1%

Tridium system had some problem from 12:30 until 2:00 pm, and shed control couldn't be initiated. The system came back at 2:00 pm. Cooling setpoint was increased 4 F at each zone setpoint temperature. Zone temperature at each location slightly increased (at most 2 F) over the shed period.

Apparently there was no out of the ordinary complaints from our buildings tenants regarding comfort issues during the time of the test. Nor was there any negative effects from the load shedding.


OSIsoft: Whole Building Power, Nov 5
Whole Building Power [kW]
250
200
150
100
50
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Actual
Baseline

Roche Palo Alto

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Pharmaceutical research facility	City of Palo Alto Utility	Large-owner-occupied research campus	Laboratory staff	Palo Alto, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
Conference room, cafeteria, and facility service office	192,000 ft^2	Roche Palo Alto Campus, situated in the Stanford Research Park, consists of 17 buildings with a total area of 760,000 square feet. These buildings are administrative buildings and pharmaceutical laboratories. The peak load for the campus is 15MW.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
	Constant volume fans	Chilled water is supplied by central plant located outside of the buildings.	

Cooling power is not measured for the saving analysis, though the shed strategy contributes to central plant demand shed.

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Tridium system			

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Sept 8th & Sept 21st (Retest), Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Energy-saving mode (dim lighting, increase setpoint), package unit turn-off, and Lightings at hallway (no daylight access) reduction.

Oct 13th

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Supply fans at the conference building	All on	Half off	Half off
Supply fans and return fan at cafeteria building	All on	All on	Half off
Air at facility service building	All on	All on	1 off

Shed Results:

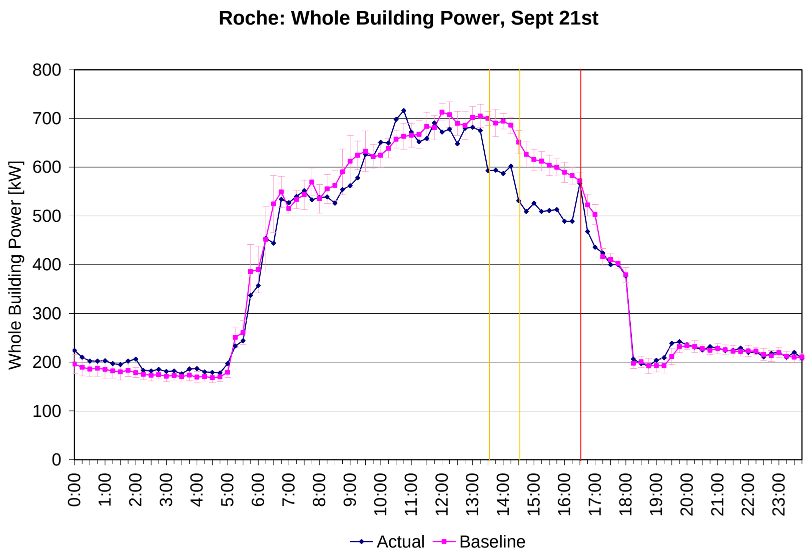
Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Sept 8th	$0.30/kWh						
	$0.75/kWh						
Sept 21st	$0.30/kWh	120	101	0.63	0.52	19%	16%
	$0.75/kWh	108	99	0.56	0.51	15%	14%
Oct 13th	$0.30/kWh	74	46	0.39	0.24	12%	7%
	$0.75/kWh	123	102	0.64	0.53	20%	16%
Nov 5th	$0.30/kWh	124	82	0.65	0.43	20%	14%
	$0.75/kWh	136	96	0.71	0.50	22%	17%

Result Details (Sep 8)

Connection was not ready.

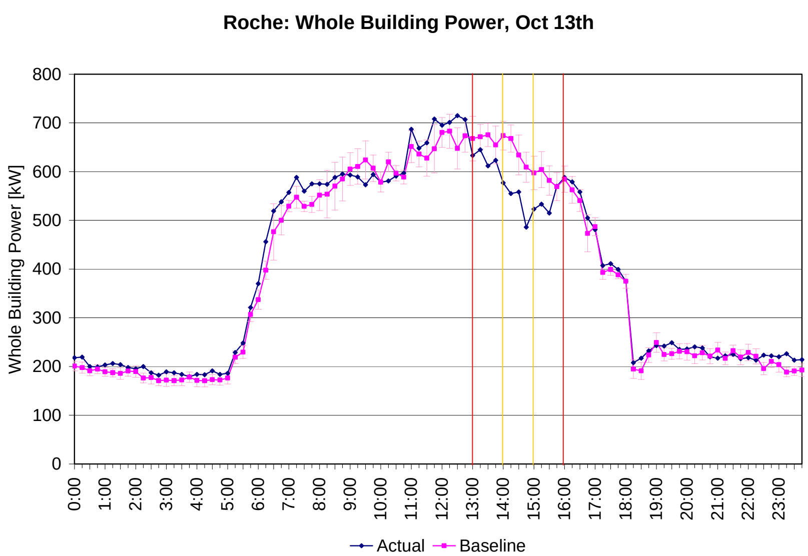
Result Details (Sep 21)

$0.75/kWh signal was received, but the cafeteria fans were not disabled. The air handler at the facility service building was not operated this day.



Result Details (Oct 13)

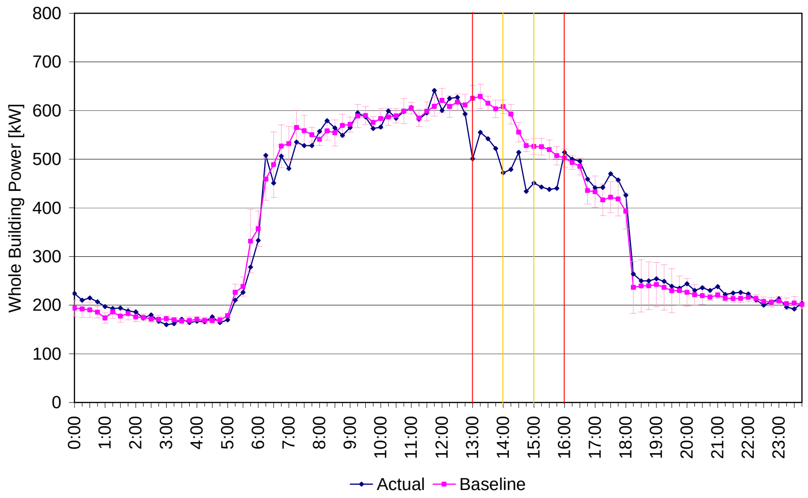
There was complaint call from the conference facility after 3 pm (during $0.30/kWh period), and the operator overrode the DR control. The fans started on 3:30 pm, 15 minutes earlier than planned.



Result Details (Nov 5)

Everything worked well as it planned.

Roche: Whole Building Power, Nov 5th



University of California, Santa Barbara – Davidson Library

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
University campus library	Direct access (APS) and PG&E in Santa Barbara	Large owner occupied campus	Student, library staff	Santa Barbara, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
8 Floors	289,000 ft^2	The library consists of three adjacent buildings, II, III, and IV. The library was chosen because it houses a large amount of books, which has a substantial thermal mass effect. Considering the thermal mass effect, the interior temperature change is slow, and it is easier to maintain the occupants' comfort during the tests.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
		Virtual central plant	

The library is connected to the virtual central plant which the chilled water loop that runs through the campus links multiple buildings and allows any single chiller to supply to all the buildings when the demand is low.

HVAC Control System	**DDC Zone Control**	**EIS Capabilities/Services**	**Other Details**
Johnson Metasys	Yes		

A Johnson Metasys proprietary protocol EMCS is used to control the HVAC systems on the UC Santa Barbara campus. Two versions of the Johnson protocol are used: "N2" communications between I/O controllers within each building and the much faster "N1" which communicates between buildings over the campus intranet.

The facilities department has its own enterprise subnet, separate from UCSB campus network. This subnet includes Johnson gateways (TCP/IP to N1) and several computers used by the facilities department staff. The polling client and business logic software was installed on the existing SiE server which also resides on the facilities department subnet. An IP relay was added for the Auto-DR test.

Auto Demand Shed Summary

Auto Demand Participation Method	**2004 Test Participation**	**Slow Recovery Strategy**
IP/EMCS Gateway	Sep 8th & Sept 21st (Retest), Oct 13th & Nov 5th (Scaled-up Tests)	None

Shed Strategies Used: Supply fan VFD limit, Static pressure reset, heating and cooling valve shutdown, economizer open 100% (to maintain ventilation rate).

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Supply fan VFD limit	Controlled	70% (where applicable)	60% (where applicable)
Static pressure reset			0.4 IWC (at selected 2 supply fans)
heating and cooling valve position	Controlled	Controlled	0%
Economizer open	Controlled	100%	100%

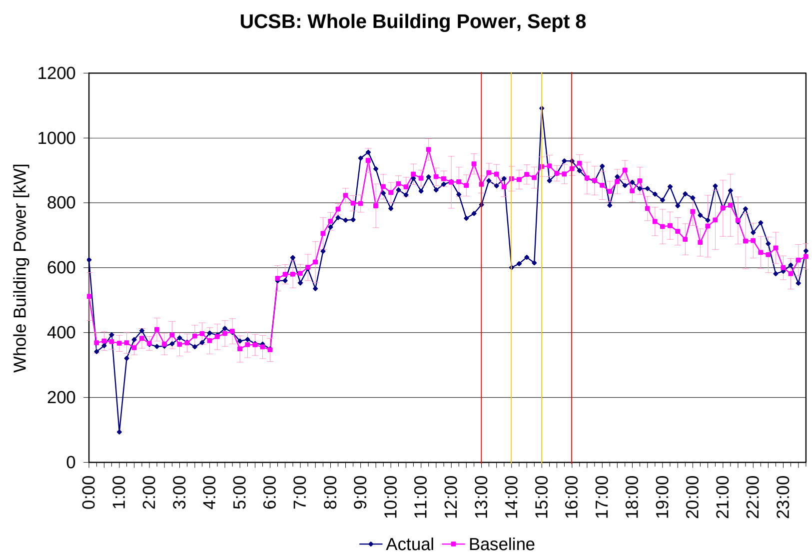
Shed Results:

Date	Price	kW		W/ft²		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Sept 8th	$0.30/kWh	62	-10	0.22	-0.03	7%	-1%
	$0.75/kWh	274	263	0.95	0.91	31%	30%
Sept 21st	$0.30/kWh						
	$0.75/kWh						
Oct 13th	$0.30/kWh						
	$0.75/kWh						
Nov 5th	$0.30/kWh						
	$0.75/kWh						

The strategies worked as planned, though the $0.30/kWh-level shed was too small to be identified in the whole building saving analysis. There was a high rebound spike right after the $0.75/kWh-level. It was over 200 kW increase against the baseline. (Note: This spike was larger than cooling power load increase and fan power didn't show any significant rebound spike. Reliability of the original data has to be confirmed)

During the test, cold deck temperature increased from 58 F to 71 F in Average (increased to 79 F at maximum) due to cooling valve shutdown. However, zone temperature increased from 70 F to 72 F in average (74 F at maximum). This might be caused by the thermal mass effect.

There was a communication failure after the first test, and it was not fixed for the last three tests.



United States Postal Service – San Jose Process & Distribution Center

Site Summary

Facility	Utility	Ownership Type	Type of Tenants	Location
Post service process and distribution center	PG&E	Government owned	Post service staff	San Jose, CA

Campus or Building Description	Gross Floor Area (ft^2)	Details
	390,000 ft^2	Processing and distribution of mailing. 24 hour operation.

HVAC System Summary

Air Distribution Type	Air Handler Unit & Fan Count	Cooling Plant	Heating Plant
	Constant volume Package DX Units: 17.5 tons (210 MBH), 5.0 tons (60 MBH)	Chillers: 364 tons x2, Constant volume CW Pumps: 20 HP x3, Constant volume CHW Pumps: 30 HP x3, Constant volume CHW booster pump: 10 HP x1, Constant volume Cooling tower: 2 motors in each unit (40 HP/10 HP)	

HVAC Control System	DDC Zone Control	EIS Capabilities/Services	Other Details
Star System	No.		

Auto Demand Shed Summary

Auto Demand Participation Method	2004 Test Participation	Slow Recovery Strategy
IP/EMCS Gateway	Oct 13th & Nov 5th (Scaled-up Tests)	None

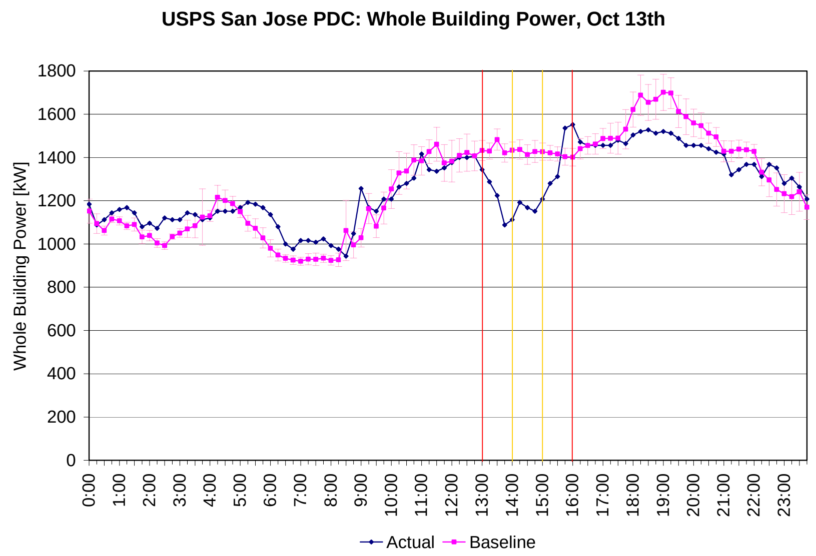
Shed Strategies Used: Control devise is installed at electric distribution panel, and limit power at the panel level (Chiller doesn't have VFD).

	Normal ($0.10/kWh)	**$0.30/kWh**	**$0.75/kWh**
Package unit	100%	75%	50%

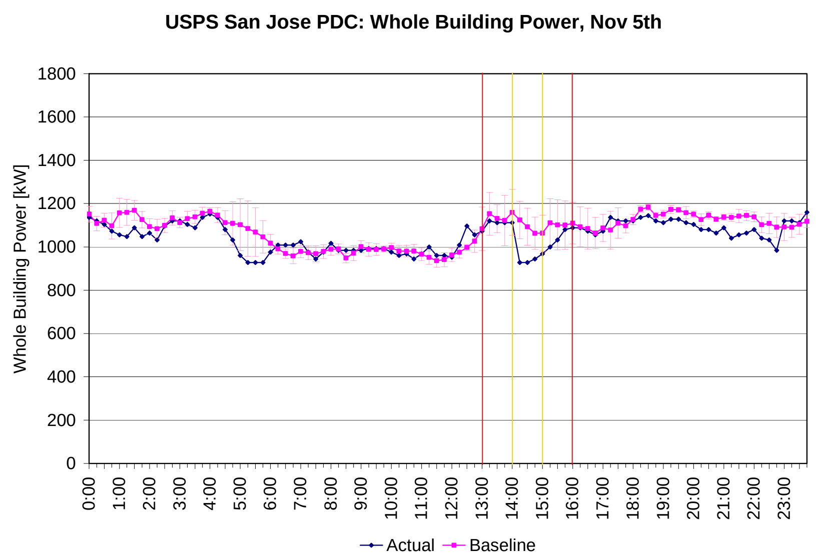
Shed Results:

Date	Price	kW		W/ft^2		WBP%	
		Max	Ave	Max	Ave	Max	Ave
Oct 13th	$0.30/kWh	333	144	0.85	0.37	23%	10%
	$0.75/kWh	321	272	0.82	0.70	22%	19%
Nov 5th	$0.30/kWh	111	46	0.29	0.12	10%	4%
	$0.75/kWh	196	132	0.50	0.34	17%	12%

Result Details (Oct 13)



Result Details (Nov 5)



Data Collection Summary

Site	Type	Name, Vendor	Data Points	Data Freq.	# of Points	Web Access
300 CapMall	EIS	Enerlink	Main power Mechanical power, Chiller power	15 min	5	No
	EMCS	JCI Metasys	AHU (SAT, RAT, VFD, Economizer) Zone temp, Fountain pump status	15 min	40	No
Albertsons	EIS	EP Web	Main power, Overhead light power Anti-sweat heater power, OAT	15 min	4	Yes
B of A	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EMCS	Tracer Summit	AHU (SAT, MAT, RAT, airflow, DSP, Economizer, SF-VFD, RF-VFD, OAT)	15 min	66	Yes*
	Sub-meter		Building B power Building B fan MCC power	15 min	2	No
Cal EPA	EMCS		Main power, Mechanical power Chiller (power, tons), Pump power AHU (SAT, RAT, VFD, DSP, damper) Zone (Temp, setpoint, airflow) OAT, OA humidity	15 min	131	No
CTEC	EMCS		Main power, Chiller power AHU (SF status, SAT, SA/RA humidity) Zone (temp, setpoint)	10 min	22	No
CISCO	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EMCS		Main power kVA Chiller (power, tons, flow, temp) , CT (VFD) Pump (VFD, status), Boiler pump status AHU (SAT, RAT, SF-VFD, RF-VFD, DSP, airflow, damper) Computer AH (temp, setpoint, valve) Zone (temp, setpoint, airflow) OAT, OA humidity	5 min	1248	Yes*
50 Douglas	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EIS		PV generation	15 min	1	Yes
	EMCS		Rooftop (SAT, RAT, DSP, damper, VFD) Zone (temp, setpoint, damper), OAT	15 min	42	No
Summit Ctr	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EMCS		Rooftop (SAT, RAT, DSP, damper, VFD, airflow), Zone (temp, setpoint, damper), OAT	15 min	49	No
Echelon	Meter	WattNode	Main power, Receptacle power Rooftop power	15 min	9	Yes*
	EMCS		Rooftop (SAT, DSP, airflow, occupancy) Zone (Temp, airflow, DSP, occupancy), OAT		155	Yes*

Site	Type	Name, Vendor	Data Points	Data Freq.	# of Points	Web Access
GSA 450 GG	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EIS	GEMnet				Yes
GSA NARA	EIS	InterAct	Main power, OAT	15 min	2	Yes
	EIS	GEMnet				Yes
GSA OFB	EIS	InterAct	Main power, Mechanical power Central plant power, Light+Recep power OAT	15 min	6	Yes
	EMCS	JCI Metasys	Main power, Mechanical power Central plant power, Lighting+Recep power Chiller (amps, tons, temp, flow, pressure) Pump (status, VFD), CT status AHU (CDT, HDT, MAT, RAT, DSP, airflow, VFD, valve), Zone (temp, flow) OAT, OA humidity	15 min	298	No
Kadent	EIS	WPS	Main power, Shedable load LBNL price signal	15 min	3	Yes
Monterey	EMCS		Common area light amps	15 min	1	Yes*
OSIsoft	EIS/ EMCS	Pi Server/ Tridium	Main power VAV (clg/htg setpoint, damper, airflow) Zone Temp, OAT, OA humidity	1 sec	164	Yes
Roche	EIS/ EMCS	RTET/ Tridium	Fan status Zone (temp, CO2)	15 min		Yes
	EIS	PML Pegasys	Main power	15 min	3	No
UCSB	EIS	EEM Suite	Main power, Gas Chiller (power, tons, temp) Fan power-amps	15 min	16	Yes
	EMCS	JCI Metasys	Chiller (power, tons) AHU (Cold/hot deck temp, RAT, DSP, VFD, clg/htg valve, economizer, fan power-amps) Zone temp	5 min	163	No
USPS	EIS	UtilityVision	Main power	15 min	1	Yes
	Sub-meter		Chiller (power, water temp, flow)	15 min	5	No

Main power = whole building power, Mechanical power = chiller, fans, pumps
DSP = duct static pressure
* Web-access is limited because of security issues.

Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

Appendix C
Post-Test Interviews

September 7, 2005

Table of Contents

300 Capital Mall

October 13th

Date of test: 10/13/04	Interviewee: Ken Van Duyn (Chief Engineer)
Interview date: 10/14/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	No
	How did you know?	They were not aware until security called about lights going off.
Physical Response	Did the response strategy work as planned?	Yes, but there was some trouble.
	If not, reason of failure	Carrier was conducting un-scheduled maintenance on chillers. This will cause some strange patterns in the chiller trends. However, it did not interrupt chiller service to the building.
Implications of Test	Were there any operational issues compromised the building services?	None.
	Were tenants of customers aware?	No
	Any complaints or comfort issues?	No
Other Comments	Ken said he was not present when the test occurred, so he was disappointed that he didn't see it first hand. *Well the test couldn't have been more screwed up, I'm so disappointed. Our office barely got the letters out, the chiller mechanic was here and had the chillers in manual operation with start and stops and the BAS didn't page out or print out as I thought. I would like to initiate another test on Friday for nothing else but to do it accurate and follow our procedures. Sorry for the confusion, but I would like to kill Carrier for showing up unannounced without me being here to stop them.* **Additional Notes:** Upon hearing that there will be another full test next week, he doesn't feel they need to try one again this Friday. He was concerned that next weeks test would not include a the stage 2 price. He is happy with what they set up and he plans to install an "initiate now" button on his system so they can start the shed strategies manually when ever deemed necessary. Norman and Ken discussed the idea of reducing Static Setpoint as well on the next test, probably the same 0.4" steps that was used at B of A yesterday. He said this is very easy to add to the programming.	

November 5th

Date of test: 11/05/04	Interviewee: Ken Van Duyn
Interview date: 11/11/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Note really
	How did you know?	After seeing the lobby lights were off, he went to control work station to confirm the shed strategies were on
Physical Response	Did the response strategy work as planned?	Yes, by observing chilled water temp went up a bit on the trend log.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	When he checked the system settings, he noticed that the chilled water temp change did take but did not hold. That was likely because the cooling load was so low, and setting up the water temperature was causing the chillers to want to cycle off. It appears there was not any room to play with this set point due to weather conditions.
	Were tenants of customers aware?	No
	Any complaints or comfort issues?	No
Other Comments	He did notice that the Annex space temperatures were getting a little warm, so it looks like it worked well. He confirmed that the Boxcars units were out of mechanical cooling and in free cooling mode. The strategy of fooling the system to think the average zone return temperature was cooler that actual did succeed in cycling off the compressors.	

Albertsons

September 8th

Date of test: 09/08/04	Interviewee: Patrick McBride	
Interview date: 09/10/04	Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Observing the light went off.
Physical Response	Did the response strategy work as planned?	Yes, by observing the light.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	Not sure that it "compromised" the service. However, it was obviously darker than usual.
	Were tenants of customers aware?	Yes.
	Any complaints or comfort issues?	No.
Other Comments		

September 21st

Date of test: 09/21/04	Interviewee: Patrick McBride	
Interview date: 09/25/04	Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Observing the light went off.
Physical Response	Did the response strategy work as planned?	Yes, by observing the light. He didn't notice any change in anti-sweat door heaters.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	Yes. Patrick was asked several times by employees why the light was off.
	Any complaints or comfort issues?	No.
Other Comments		

October 13th

Same as above.

November 5th

Unable to interview because the interviewee was too busy.

Bank of America

September 8th

Date of test: 09/08/04	Interviewee: Bill Young
Interview date: 09/--/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Yes
	How did you know?	The logging report
Physical Response	Did the response strategy work as planned?	Yes, by observing Bldg B AH1 Logging Report.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	It was transparent.
	Were tenants of customers aware?	None that we are aware of. Occupants were not warned of the upcoming test. Only the building operations people.
	Any complaints or comfort issues?	None so far.
Other Comments	None.	

September 21st

Date of test: 09/08/04	Interviewee: Bill Young
Interview date: 09/27/04	Interviewer: Naoya Motegi

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	An operator found changes at the monitor.
Physical Response	Did the response strategy work as planned?	Yes, by looking at the EMCS monitoring.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	No.	

October 13th

Date of test: 10/13/04	Interviewee: Hank Blank
Interview date: 10/13/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Hank was actually programming on the system, had just finished on A Bldg, then noticed that the test had just started. Also they have set up a Static Pressure alarm at 1.4" and immediately after Stage 2, static went to 1.3" for a bit, so the alarm went off.
Physical Response	Did the response strategy work as planned?	Yes, by observing zones temperatures were drifting up on the EMCS trends.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	A few rooms on the corner of A Bldg, South West corner, temps got into 80's. But no one complained.
	Were tenants of customers aware?	None noticed.
	Any complaints or comfort issues?	None reported.
Other Comments	The new duct static setpoint reduction strategy, as documented in the email correspondence below, still did not produce significant reductions. However this time Hank did see significant temperature changes in many zones. Hank feels the static setpoint reduction might not be aggressive enough for Bldgs B and C. He has learned from this test that he can probably reduce static setpoint in B and C to 2.0" (from 2.2") for normal operation without affecting service. Bldg A on the other hand has under sized fans and the static setpoint reduction cause airflow problems in some areas of the upper floors. As a next iteration to the shed strategy, Hank and agreed to try and reintroduce the VFD fan lock at the same time as the static setpoint reduction. Since the PID control can only modulate the system static, for the static setpoint reduction, by modulating fan speed – we can not reduce static setpoint and lock VFD at the same time. However, Hank says it only takes a couple minutes for the system to achieve steady state from a static setpoint change so he proposed add a 5 minute "Wait" that locks the VFDs after the system has adjusted to the new static setpoint. Since this can only be done at the beginning of the test window, he proposes we eliminate the two step static adjustment and implement the full 0.8" reduction at the beginning of the test window. I've summarized the final iteration of the shed strategy below. In my opinion, this combination of SAT setup, VFD lock and static setpoint - especially during stage 2 - is plenty aggressive at this point.	

	Summary of proposed new strategy: → Level Zero = normal operation → Level One = Reduce duct static pressure setpoint 0.8" w.c. below normal. Increase SAT setpoint by 4 deg.F. After 5 minutes the programmed sequence locks supply fan VFDs at current fan speeds. → Level Two = Maintain the same reduced duct static pressure setpoint of 0.8" w.c. below normal. Increase SAT setpoint another 4 deg.F to a total of 8 deg.F. above normal (this price will last 1 hour maximum).

November 5th

Date of test: 11/05/04	Interviewee: Hank Blank
Interview date: 11/10/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	They had some duct static alarms came in, so they knew the test started.
Physical Response	Did the response strategy work as planned?	Yes, it appears to have, though have not looked at the trends yet to confirm.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	None. He checked the next morning and every thing was in order. "It ran perfect."
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	After the second test (the first ADR Scaled Up Test) he did find some errors in the programming, that resulted in incorrect operation post test. When the test ended, the system did not restore the 2.3" duct static due to the programming error. He did not notice the condition until the next morning and promptly corrected it. Hank, "This was a good exercise. I learned a lot about my building and how to program the system in ways that I had never thought about before!"	

Cal EPA

October 13th

Date of test: 10/13/04	Interviewee: Scott ----, Theresa Parsley
Interview date: 10/20/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	N/A
	How did you know?	
Physical Response	Did the response strategy work as planned?	No.
	If not, reason of failure	Opt out
Implications of Test	Were there any operational issues compromised the building services?	N/A
	Were tenants of customers aware?	N/A
	Any complaints or comfort issues?	N/A
Other Comments	The Chief Engineer and the Facility Manager ordered the internet relay disconnected once she saw the notice for test this week. She doesn't have a problem with the HVAC shed strategies at stage 1 shed, because the occupants will probably not notice. However the lighting shed of stage 2 will cause occupant complaints. Since it is a short week they did not send out the notice to tenants, removing the chance to participate.	

November 5th (Interview to Chief Operator)

Date of test: 11/05/04	Interviewee: Bob Young
Interview date: 11/11/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Bob had an alarm set up for the HVAC part. Then when the lights went off, they had all the occupants knew. They got occupants feedback such as "Hey the lights when out", but they reminded them about the test.
Physical Response	Did the response strategy work as planned?	Yes, he knows it implemented correctly, because when the alarm triggered he spot checked zones to make sure the settings were modified correct.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	None. "It was essentially invisible from an operations point of view. Everything went as planned"

	Were tenants of customers aware?	None noticed the HVAC changes. None even complained about the HVAC after the lighting shed started. There was one occupant that complained after the test memo. Rather that risk a work disruption for that person, the local zone was exempted from the test. This was a very small percentage of the building floor area.
	Any complaints or comfort issues?	
Other Comments	This site was not ready for the Scaled Up Test. The major constraint regarding preparation was distributing a Test Participation memo to all the building tenants. Since the technical preparations were delayed, only being completed 1 day prior to the first test, the distribution of the memo could not occur with enough advance notice. This situation has brought up an interesting side bar discussion regarding the relations between a facility management and highly a unionized tenant population, with regard to demand response program participation. The California EPA management has a Standard Operating Procedure (SOP) that clearly governs the facility management to tenant relations, in order to minimize work interruption liabilities. In the case of our test, the SOP came into play. Moreover the SOP would come into play again in the case of actual participation in future demand response programs and tariffs. There will be a small section in the final on this topic, with regard to impact this might cause for other similar public institutions and their potential participation in ADR.	

November 5th (Interview to Property Manager)

Date of test: 11/05/04	Interviewee: Andrew Rhoades
Interview date: 01/26/05	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	No, he didn't know until the lighting shed started. All of the occupant complaint calls, HVAC or other, are routed through Andrew's office.
	How did you know?	Once lighting shed started, his office received many occupant calls.
Physical Response	Did the response strategy work as planned?	After the test, Bob Young reported to him that the test executed correctly.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	

	Were tenants of customers aware?	Once the Stage 2 shed started, his office was flooded with occupant telephone calls. Typical feedback was, "Hey my lights when out?!" Thomas Properties reminded them about the ADR test and most were satisfied with that. There were 40 to 50 calls over the hour duration of the lighting shed.
	Any complaints or comfort issues?	Approx 10 to 15% were complaints the remaining were inquiries. They did not receive any complaint calls about the temperature or HVAC.
Other Comments	Based on this result, in the future would they include lighting in the shed? Andrew says it depends how critical the demand shed is. If it was an emergency (i.e., 2001), then they would. For a first wave shed, they wouldn't shed lighting. If a way to notify tenants of the critical nature of the shed while it is occurring were available, they could use it more readily.	

Cal EPA, Tenant Notice

From: Parsley, Theresa
10/25/04 11:41AM

The California Energy Commission and Lawrence Berkeley Lab (LBL) are studying the ability of large facilities to reduce electricity demand temporarily through implementation and testing of an Automated Demand Response (Auto-DR) systems. Auto-DR is being evaluated in terms to its potential to flatten the load shape of the electrical grid on peak days to help avoid the black outs that occurred in California in 2001. We have been invited to participate in this study at the Cal/EPA Headquarters Building.

The overall goal of this research is to test control strategies that could automatically reduce electrical demand in facilities throughout California. Upon receipt of an emergency signal or rise in the price of electricity, each participating facility will monitor via the web, a fictional variable common signal that will automatically shed site specific electrical loads. The system is designed to operate without human intervention during the test period.

The object of this study is to evaluate a broad range of facility demand response strategies. Evaluate the state of controls and communications technology at large facilities. Evaluate the costs and characteristics of such technologies. The test window is from October 27th through November 8th. LBL plans to have one 3 hour triggered event during that time. The test time period is from 12:00 Noon from to 6:00 pm. We have agreed to participate.

WHAT THIS MEANS TO US:

When the Cal-EPA Building receives the Auto-DR signal, it will trigger the first step in demand load shedding by automatically adjusting chilled water and air temperature set points for two hours. This should not be perceptible to staff, and will not affect ventilation rates.

In the third hour of the test, the facility non-emergency lighting will be reduced, for one hour only. Engineering staff have already reviewed areas that do not receive natural light (interior offices and conference rooms, for example), and have programmed them to keep the lights on during this test.

THINGS TO KEEP IN MIND:

We will only have one test period during this study, of 3 hours in duration. We will not be notified in advance of the upcoming test - it will be entirely random. Engineers have reviewed the study for impact on our staff, and have taken steps to ensure your comfort and ability to continue to operate during the test. However, if you are in an area that is affected adversely please do not hesitate to contact Property Management at 916.551.1449 to report the problem. They will respond quickly to identify and rectify the problem.

Thanks for your continued support as we are involved in these important energy management issues.

An employee response:

Ms. Parsley,
I make an effort to save as much energy as possible, but when my air is effected, I draw the line. I have Asthma and a problem with breathing. This experimentation may not effect the general population of CalEPA, but it most likely will result in my inability to breathe well. In the past when the air has been off, I definitely feel the difference, and it is very uncomfortable. If this lasts for 3 hours, I will have to go home. This act infringes on my right to breathe freely and easily, and also on my right to work in a nonthreatening work environment.

CETC

November 5th

<table>
<tr><td>Date of test: 11/05/04</td><td colspan="2">Interviewee: Robert Cantave</td></tr>
<tr><td>Interview date: 11/11/04</td><td colspan="2">Interviewer: Norman Bourassa</td></tr>
<tr><td rowspan="2">Awareness</td><td>Were you aware the price changed during the test?</td><td>Yes.</td></tr>
<tr><td>How did you know?</td><td>Robert noticed the price signal change at his computer.
Daniel noticed the test period in the HVAC trends the next day. (Because he was not present during the test).</td></tr>
<tr><td rowspan="2">Physical Response</td><td>Did the response strategy work as planned?</td><td>Yes. They know from the trend logs.</td></tr>
<tr><td>If not, reason of failure</td><td></td></tr>
<tr><td rowspan="3">Implications of Test</td><td>Were there any operational issues compromised the building services?</td><td>No.</td></tr>
<tr><td>Were tenants of customers aware?</td><td>No.</td></tr>
<tr><td>Any complaints or comfort issues?</td><td>No.</td></tr>
<tr><td>Other Comments</td><td colspan="2">The first test did not work for them, because they didn’t notice that they had to respond with the price signal.
Note: The test occurred at 4 pm Montreal time. But the AHU units are normally scheduled to minimum at this time, so measuring an impact at 4pm on Friday will be difficult because the occupant (and conditioning load) was very small at this time of the day.

Robert is writing a summary of the programming and implementation procedure they conducted. Daniel will share that with us as soon as it’s complete.

They view this test as very successful. They were not surprised and were confident that it would succeed. Implementation was easy for them, since they have extensive experience doing this kind of programming on building automation systems.

Daniel mentioned the test to a Hydro Quebec representative, who was very interested and they may collaborate with similar concepts in Quebec.</td></tr>
</table>

Cisco Systems

October 13th

Date of test: 10/13/04	Interviewee: David Liembrock
Interview date: 10/20/04	Interviewer: David Watson

Awareness	Were you aware the price changed during the test?	Yes
	How did you know?	Pager software was written for this test. There was the pager alert with text message while we were in a meeting. Toward end of test, we observed the shed behavior on the HMI.
Physical Response	Did the response strategy work as planned?	Yes, with the following exceptions:
	If not, reason of failure	i) The Computer room AHUs (CA), qty. > 200, did not shed as planned. This is due to the fact that their controllers did not "hear" the global shed command that was sent across the ALC network. The other AHUs, the VAV terminal boxes and the chiller plant all received the message and shed according to plan. ii) About two times per hour, the system dropped out of shed mode for one minute. This was later determined to be caused by null values returned by the Price server. Although these drop-outs shouldn't affect energy savings of the shed much, if any, it is not proper to change setpoints and other parameters so frequently. In addition, each time that this happened our pagers received the message "Leaving LBNL shed level 1" then one minute later, "Entering LBNL shed level 1.
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	Not to my knowledge
	Any complaints or comfort issues?	No complaints due to shed. Occupants use a Web based comfort and maintenance tool.
Other Comments	The problem with the lack of shed from the computer AHUs has already been corrected. It is not known if it was an ALC bug or had another cause.	

	The price client software was revised to ignore null and zero values. Note: since the code was written in Java, Java automatically converted the nulls to zero values. That is why the business logic responded by putting the system back into normal mode. However, I collected packets off of the "wire" coming directly from Infotility using a packet sniffer. These files show that null values were being returned by the Infotility server. There are several people at Cisco who are interested in this project. They are working to consider and promote the development and use of Cisco products in the building controls area. (DW Note: I sent David the final report from the 2003 Auto-DR tests. He will forward to interested parties within Cisco). We discussed the possibility of a meeting to discuss LBNL and Cisco visions of AutoDR technology.

Contra Costa County (50 Douglas and Summit Center)

October 13th

Date of test: 10/13/04	Interviewee: David Nyberg
Interview date: 10/13/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	He set up local alarms for each price change, so once Dave logged into the local EMCS computers, he could see each price change time stamped alarms. He then knew that the test had started. Prior to this he did not know the test had started.
Physical Response	Did the response strategy work as planned?	Yes, by logging into the local computers to confirm operation.
	If not, reason of failure	

Implications of Test	Were there any operational issues compromised the building services?	No. No complaint call was reported.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.

Other Comments	Separate Discussion with Andy Green – He thinks he can see the shed results in the InterAct data during the test. His guess is around 175 kW to 200 kW reduction.

November 5th

Date of test: 11/05/04	Interviewee: David Nyberg
Interview date: 11/15/04	Interviewer: Norman Bourassa

Awareness	Were you aware the price changed during the test?	No, He wasn't working that day.
	How did you know?	He set up local alarms for each price change, and he checked in the following Monday.
Physical Response	Did the response strategy work as planned?	Yes, with following exception;
	If not, reason of failure	At 50 Douglas Stage 1 and Stage 2 were triggered "off" at the same time stamp (4:48:13 pm) in his alarm log. His BTI clock is 1 hour forward at 50 Douglas. Dave just discovered that during this interview.

Implications of Test	Were there any operational issues compromised the building services?	No. No complaint call was reported.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.

Other Comments	

Echelon

October 13th

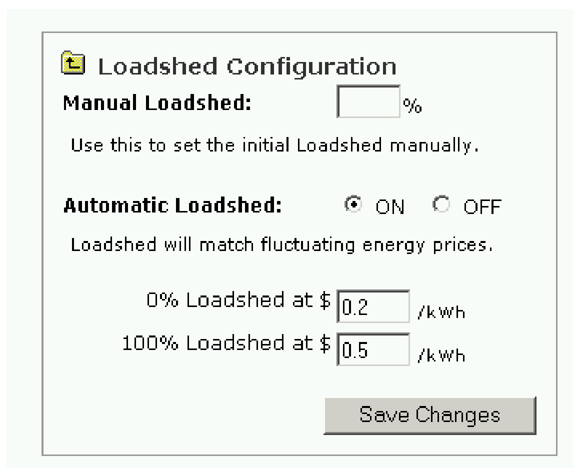
Date of test: 10/13/04	Interviewee: Richard Hair
Interview date: 10/20/04	Interviewer: David Watson

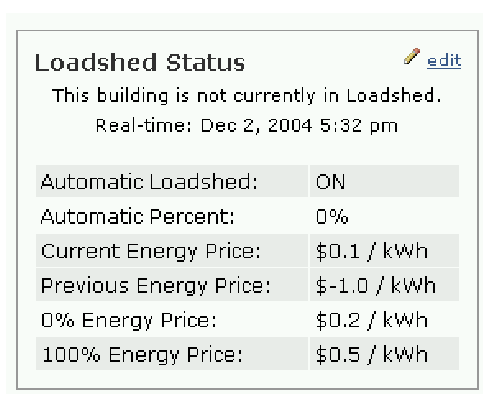
Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Watching the screen and just finishing programming. Also Lights in my office dim upon shed. It was slightly warmer in my office and some parts of the building.
Physical Response	Did the response strategy work as planned?	Technically, the system worked as planned.
	If not, reason of failure	However, the level 1 (medium) shed had virtually no effect for the following reason: Prior to the test, an email was sent out to all building occupants that asked them to log onto their own personal office control Web page and 1) enable remote shed capability 2) Set parameters for their offices including a) raise cooling setpoint b) dim overhead lights. Virtually none of the building occupants took these steps, so there may be no noticeable shed at Level 1. At level 2 (high), two out of the three package rooftop AHUs were shut off completely (they all feed a common supply air shaft).
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	Not in my knowledge.
	Any complaints or comfort issues?	No.
Other Comments	Will try to get approval to change occupant defaults for each personal office control Web page so than 1) remote shed capability is enabled 2) a) raise cooling setpoint offset several degrees b) dim overhead lights. Null values returned from the server were noticed, but did not effect my price client software.	

November 5th

Date of test: 11/05/04	Interviewee: Richard Hair
Interview date: 11/05/04	Interviewer: David Watson

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Boss called and said lights were out in hallways.
Physical Response	Did the response strategy work as planned?	Yes.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	1. RTU3 offline on failure created deeper shed than normal 2. Medium shed = building lighting 3. Full shed = RTU's off plus building lighting off 4. The central server collects price and converts it to a load shed percentage that is configurable per site:	





loadshed command sent to iLON100 as percentage
Percentage converted via type translator to four switches (LEV_Desc):
Full = 100%
High = 99 – 66
Medium = 65 – 33
Low = 32 – 1
These outputs are connected to inputs specifically configured as energy saving inputs or over-ride off commands (RTU)

The Kenmark BOC also supports regionally based pricing servers. Each site on the BOC is a sub-domain (site1.kenmarkboc.com, site2.kenmarkboc.com) Each site is configured using the above loadshed box with a linear percentage point between the 0% price and 100%price. Each site is pre-configured to look for records in the database associated with its regional pricing server:

Table ENERGYPRICES in database BOC

Rows 1 to 25 of 151 →

	timestamp	source	price
☐	20040830232550	LBLDEMO	0.4
☐	20040830232440	LBLDEMO	0.25
☐	20040830232604	LBLDEMO	0.5
☐	20040830232503	LBLDEMO	0.35
☐	20040831010614	LBLDEMO	0.1
☐	20040901000320	LBLDEMO	0.8
☐	20040901000336	LBLDEMO	0.6
☐	20041026065302	LBLDEMO	-1
☐	20040915204809	LBLDEMO	0.35
☐	20040915205816	LBTEST	0.25
☐	20040915210033	LBTEST	0.1
☐	20040915210704	LBLDEMO	0.1
☐	[illegible]	[illegible]	[illegible]

the “source” could be any pricing server source e.g. “Texas_Utility” as a source could server Texas client sites. A utility could push data into the BOC Energy Prices database for efficiency. The BOC would then handle the site-specific access issues.

GSA (450 GG, NARA, OFB)

October 13th

Date of test: 10/13/04	Interviewee: Stephen May
Interview date: 10/20/04	Interviewer: David S. Watson

Awareness	Were you aware the price changed during the test?	
	How did you know?	
Physical Response	Did the response strategy work as planned?	No.
	If not, reason of failure	Steve May noticed that price client software was having intermittent problems starting about Oct. 8 (note: This is the time when multiple sites all started listening to channel 1233). When the GSA price client software received erroneous data from the Infotility server, it caused the client to fail. This in turn caused the sheds to fail.
Implications of Test	Were there any operational issues compromised the building services?	
	Were tenants of customers aware?	
	Any complaints or comfort issues?	
Other Comments	In addition, Stephen was unavailable to monitor and correct the behavior of the client software on the day of the shed (10/13/04) because of unexpected circumstances. When he returned to work late that afternoon, he said that he observed problems related to the server errors. It was his belief that the shed did not occur that day at GSA.	

November 5th

Date of test: 10/13/04	Interviewee: Stephen May
Interview date: 10/20/04	Interviewer: David S. Watson

Awareness	Were you aware the price changed during the test?	Not at first, but then noticed it about one hour into it by observing changes in certain GEMnet database fields. At that time, the building manager, Julius, called me to discuss. He had already talked to the facilities maintenance contractors, Innovity, who were aware of the shed, but were unable to help correct problems that occurred.
	How did you know?	
Physical Response	Did the response strategy work as planned?	All GEMnet communications worked as planned with one exception. There were operational problems that occurred at 450 GG due to EMCS programming issues. The one minor problem that occurred in GEMnet was that the Auto-DR client/ business logic and associated software was that it did not shift out daylight savings time to PST. Even a manual correction by S.May returned to the wrong time by the software. S.May suggests considering adding a client location field to the XML schema so that the server could return the local time to each client. There were no recorded null values or error code values (-1) returned by the Infotility server within the last two weeks. Such an error would be logged. To the best of Steve's knowledge, the EMCS sheds worked as planned at GSA Oakland and NARA.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	
	Were tenants of customers aware?	
	Any complaints or comfort issues?	
Other Comments		

GSA 450 Golden Gate

November 5th

Date of test: 11/05/04		Interviewee: Louis Coughenour	
Interview date: 11/09/04		Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	Yes.	
	How did you know?	Complaint call.	
Physical Response	Did the response strategy work as planned?	No.	
	If not, reason of failure	When zone setpoint increased, the VAV boxes turned into heating mode. Then hot air dampers opened, hot deck static pressure went down, and hot deck fan VFD speeded up.	
Implications of Test	Were there any operational issues compromised the building services?	Caused many hot complaints and increased the hot deck fan power.	
	Were tenants of customers aware?	Yes.	
	Any complaints or comfort issues?	Many hot complaints from 7th and other floors.	
Other Comments	Louis suggested either to increase the deadband (currently +/- 1F) or to disable boiler operation along with zone setpoint increase, to avoid this problem.		

GSA NARA

November 5th

Date of test: 11/05/04		Interviewee: Kam Chiu	
Interview date: 11/09/04		Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	No.	
	How did you know?		
Physical Response	Did the response strategy work as planned?	Not sure.	
	If not, reason of failure	Since the building doesn't have either cooling or heating load during this time of period, no operational changes would happen due to the shed strategy.	
Implications of Test	Were there any operational issues compromised the building services?	Not at all.	
	Were tenants of customers aware?	No.	
	Any complaints or comfort issues?	No.	
Other			

Comments	

GSA Oakland Federal Building

September 8th

Date of test: 09/08/04	Interviewee: Bill Goodner	
Interview date: 09/09/04	Interviewer: David S. Watson	
Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Phone call from Stephen May and e-mail alert. It was noticeably warmer in my office and some parts of the building.
Physical Response	Did the response strategy work as planned?	Though I did not view the EMCS extensively during the test, it is my belief that the system worked as planned. Zone temperature setpoints were set-up.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	Not to my knowledge.
	Any complaints or comfort issues?	No.
Other Comments	This is the second time we've participated in the Auto-DR tests and we still didn't have any complaints.	

November 5th

Date of test: 11/05/04	Interviewee: Bill Goodner	
Interview date: 11/10/04	Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Control panel located at facility management office has a signal lamp which is connected to panel relay.
Physical Response	Did the response strategy work as planned?	Probably yes.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	Bill called GSA tenants to notify the test when he noticed the lamp. But not for all the tenants. Bill was wondering why we didn't notify before the test this time. I explained him the concept of the "blind" test, and told him that we have never pre-informed of the test. He might misunderstand since we sent out the 2-week window start notification mostly on the day of the test. Currently the AHU is running under low static pressure to seek	

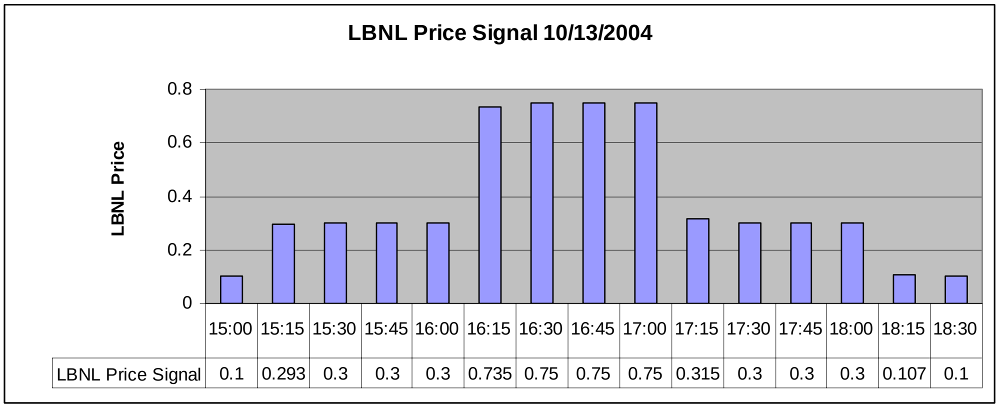
	energy saving opportunities. Since the static pressure setting change was done during the 2-week test period, we should be careful to develop the baseline.

Kadant Grantek

October 13th

Date of test: 10/13/04	Explanation: Jay Nick, WPS Energy Services
e-mail date: 10/18/04	e-mail to: Dave Watson

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Price signal is sent to WPS via eMiner at the end of every 15 minute interval. Customer has it displayed on their HMI
Physical Response	Did the response strategy work as planned?	No.
	If not, reason of failure	PLC programming error
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	Kadant found 2 things when looking into the test results. First, the PLC was programmed with an "equal to" block for the price (=0.30) instead of a "greater than or equal to" block. That has been fixed. Second, they allowed the operator to override the signal and think that might have happened (which is why there was no reduction in the total plant load). They are not sure since the test occurred on their second shift and they did not have a chance to talk with the operator about it. Our eMiner product worked well and was not impacted by the problems at Infotility. We read the price every minute and discard errors, so we always managed to get the price for the next interval. I am happy with how our product performed. The correct price signal was always successfully passed to the PLC network. We have no control over the PLC programming and probably should have done more testing, but did not want to be too disruptive to our volunteer customer.	

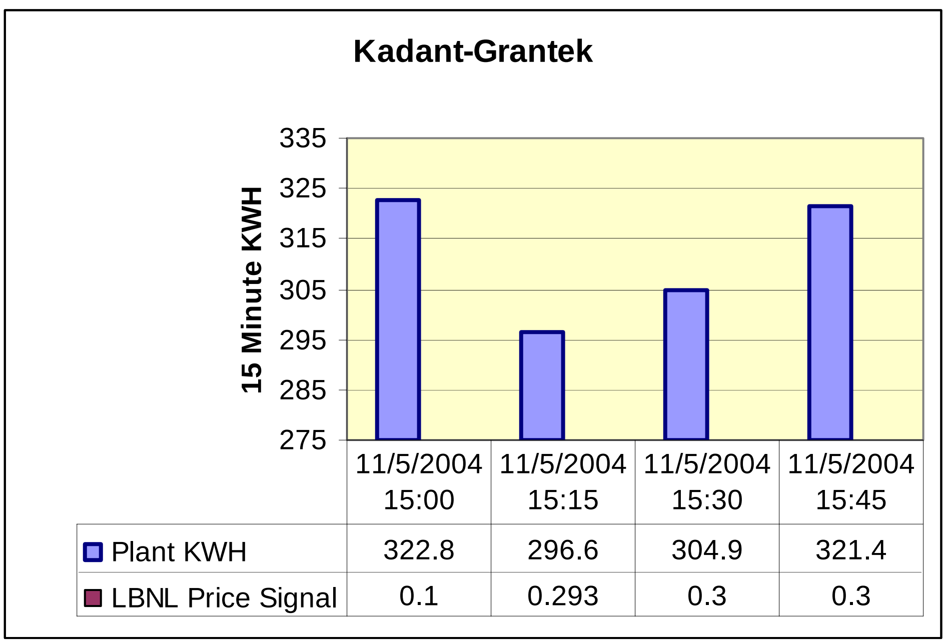


	15:00	15:15	15:30	15:45	16:00	16:15	16:30	16:45	17:00	17:15	17:30	17:45	18:00	18:15	18:30
LBNL Price Signal	0.1	0.293	0.3	0.3	0.3	0.735	0.75	0.75	0.75	0.315	0.3	0.3	0.3	0.107	0.1

November 5th

Date of test: 11/05/04	Explanation: Jay Nick, WPS Energy Services
e-mail date: 11/05/04	e-mail to: Dave Watson

Awareness	Were you aware the price changed during the test?	Yes.
	How did you know?	Price signal is sent to WPS via eMiner at the end of every 15 minute interval. Customer has it displayed on their HMI
Physical Response	Did the response strategy work as planned?	Yes and No. The process shut down and stayed down for 2 15-minute intervals
	If not, reason of failure	Operator override
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	Kadant recently received several large orders that they have to fill and as a result cannot afford to shut down their transfer operation because they have to get the product out. I had asked Kadant that, if there was an interruption, would they leave it down for at least 1 15-minute interval. They agreed to keep it down for an interval, but then they would override the price signal due to their business requirements. From the data we have received, they shut down for about 30 minutes before starting back up. Kadant was running at about 322 KWH every 15 minutes or 1288 KW. During the first 15 minute interval they shed 26.2 KWH or 104.8 KW. For the 2 intervals, the total KWH shed amounted to 43.7 KWH	



OSIsoft

November 5th

Date of test: 11/05/04	Interviewee: Mike Kennedy
Interview date: 11/--/04	Interviewer: Naoya Motegi

Awareness	Were you aware the price changed during the test?	No.
	How did you know?	
Physical Response	Did the response strategy work as planned?	Yes. Trend log shows Stage-1 Alert during the test duration. Also the cooling setpoint changed from 72 F to 76 F for Stage-1. There was only single stage shed. Actual zone temperature increase could be observed in the trend log, too.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No.
	Were tenants of customers aware?	No.
	Any complaints or comfort issues?	No.
Other Comments	Tridium system had some problem from 12:30 until 2:00 pm, and shed control couldn't be initiated. The system came back at 2:00 pm. There was gas leak problem on same day from 5 pm to 10 pm. It was nothing to do with the DR test, just by accident. Apparently we had no out of the ordinary complaints from our buildings tenants regarding comfort issues during the time of the test. Nor did we have any negative effects from the load shedding. I am also supposed to meet with one of our engineers later this week to write down some of our thoughts about the test and our experiences with processes similar to the load shedding.	

Roche

Interview Date: 12/02/04
Interviewee: Jeff Stamp
Interviewer: Naoya Motegi

September 21st
$0.75/kWh signal was received, but Building FS and SS fans didn't respond the signal. Jeff doesn't know why. Jeff didn't change anything on these controls, but it was fixed by the next test. There was no complaint call reported.

The polling client server (on-site, different from Tridium server) was forced to log off several times. Jeff noticed when he checked the server status in the morning, as he does everyday. He logged in again each time.

October 13th
$0.30/kWh signal stopped at 3:35 PM, 10 minutes earlier than it supposed to. Jeff got a complaint call from A2 Building occupants, and disabled the DR control. A2 Building holds conferences once in a while, and requires more cooling than usual on this occasion.

He was little confused of the test duration among different buildings, and was thinking shed control at A2 should end by 3 PM. So he assumed that DR control was longer than usual.

November 5th
Everything worked well as it planned. There was no complaint call reported.

UCSB

September 8th

Date of test: 09/08/04	Interviewee: Jim Dewey	
Interview date: 09/10/04	Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	Not at all. Jim was not aware of the test was conducted until LBL called him.
	How did you know?	
Physical Response	Did the response strategy work as planned?	Jim didn't even know the test was conducted, but he checked the EIS during this interview and found that strategy might have worked.
	If not, reason of failure	
Implications of Test	Were there any operational issues compromised the building services?	No. But the whole building power spiked up at the end of the test.
	Were tenants of customers aware?	No indication.
	Any complaints or comfort issues?	There was no service call or complaint call logged.
Other Comments		

September 21st

Date of test: 09/08/04	Interviewee: Jim Dewey	
Interview date: 09/10/04	Interviewer: Naoya Motegi	
Awareness	Were you aware the price changed during the test?	No.
	How did you know?	
Physical Response	Did the response strategy work as planned?	No.
	If not, reason of failure	IT group might disconnect the signal communication. Jim has to discuss with them to find out why it didn't work. Jim didn't change any setting himself since the last test in September 8th.
Implications of Test	Were there any operational issues compromised the building services?	
	Were tenants of customers aware?	
	Any complaints or comfort issues?	
Other Comments		

October 13th

Date of test: 10/13/04		Interviewee: Jim Dewey, Dale Fong
Interview date: 10/20/04		Interviewer: David S. Watson
Awareness	Were you aware the price changed during the test?	No.
	How did you know?	
Physical Response	Did the response strategy work as planned?	No.
	If not, reason of failure	The device that we control speaks Modbus protocol over TCP/IP on one-side with relays that feed Johnson Dis on the other. Dale Fong reported to Jim Dewey that their software has been unable to contact that device via its IP address.
Implications of Test	Were there any operational issues compromised the building services?	
	Were tenants of customers aware?	
	Any complaints or comfort issues?	
Other Comments	Jim Dewey reset the Modbus device, and it seems to be working.	

USPS

October 13th

Interviewee: John Samuelson
Interviewer: Naoya Motegi

- John didn’t notice the change of operation.
- There was no complaint call or occupants awareness reported.

November 5th

Interviewee: John Samuelson
Interviewer: Naoya Motegi

- John didn’t notice the change of operation.
- There was no complaint call or occupants awareness reported.

Comment from Chevron Energy Service

By Bruce Dickinson

```
The price signal came in two stages.  I do not have the specifics
available now, but my recollection was that the 1st stage only brought
the chillers down to 75% of "full input demand limit" -- so if the
chillers were only loaded to 82%, the 1st stage drop in kW will be
barely noticeable on the main meter.  With the submetering we have
installed, the actual chiller performance for the two units will be
clear.

The test was to last for 3 hours, or until about 5pm.  We did attempt
to have a lag in the "de-curtailment" control steps, but I still notice
a small overshooting in the demand between 4:45pm and 5:15pm as the
system came back to full capacity and attempted to get the chilled
water temp reduced to setpoint.
```

Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

Appendix D

Case Studies – HVAC Shed Strategy and Effectiveness

September 7, 2005

Bank of America – Concord Data Center

Site Description

The Bank of America Concord Center is a campus of four buildings (buildings A, B, C and D). The fourth, Building D, house a large data center (1 floor), offices and the campus HVAC central plant. Table 1 lists each building's floor count and total area.

Table 1: Bank of America - Building Floor Areas

Building Height	Gross Floor Area (ft^2)
A - 13 floors	A: 288,000 ft^2
B - 9 floors	B: 200,000 ft^2
C - 4 floors	C: 220,000 ft^2
D - 6 floors	D:

Space conditioning is handled by a Variable Air Volume (VAV) air distribution system, served by a chilled water and hot water central plant located in Building D. Table 2 provides a quick summary of the campus HVAC systems.

Table 2: HVAC System Summary

Air Distribution Type	**Large Air Handler Units & Fan Count**	**Cooling Plant**	**Heating Plant**
Single Duct VAV with perimeter reheat	8 AHUs 36 Fans with Variable Frequency Drives (VFD)	Qty 5, 750 Ton & Qty 1, 300 Ton Electric Centrifugal Chillers	Qty 3, 4.0 MBtu Natural Gas Boilers
HVAC Control System	**DDC Zone Control**	**EIS Capabilities or Services**	
Tracer Summit, BACnet over IP based system with extensive electric metering.	No	EIS and WAN connectivity through a WebGen polling client server located in Andover, MA	

The whole campus electrical demand peaks at approximately 4,500 kW in the summer. Winter peak deceases to about 4,000 kW. During a spot check of the campus electrical meters on January 6th, 2005, the electrical demand was distributed across each building as listed in Table 3.

Table 3: Campus Electrical Demand by Building

Building	Meter read from Jan 6th, 2005.
A	860 kW *
B	898 kW
C	870 kW
D	1,395 kW *
Total	4,025 kW

* Building A sub meter does not include any of the main HVAC air distribution fans. They are fed from the emergency power circuit (for smoke evacuation reasons) and metered on the Building D sub meter.

Auto Demand Shed Strategy

The Bank of American site participated in the 2003 test and all four 2004 ADR tests. From the beginning, the operators have had difficulty finding a shed strategy that produced a measurable demand reduction on the whole campus meter.

The 2003 test and the Sept. 8th, 2004 test were conducted on only Building B. The remaining 2004 tests (Sept. 21st, Oct. 13th and Nov. 5th) tests were conducted on Buildings A, B and C. In 2004, the Sept. 8th and 21st tests used the same shed strategy. On Oct 13th and Nov 5th, the ENCS programming improvements were implemented.

While the demand reductions at the whole campus level remained low, the Nov. 5th programming iteration did produce detectable reductions at the campus meter. Unfortunately, the Nov. 5th test occurred during mild weather conditions.

Table 4 through Table 6 summarize the shed strategies used in the four 2004 tests.

Table 4: Shed Programming - Sep. 8 and 21Tests

Initiate Order	Normal ($0.10/kWh)	$0.30/kWh	$0.75/kWh
Supply Fan Speed Mode	VFD (VAV system)	Lock Speed at last pre-test value	Keep same speed lock
SAT setpoint	55 F	57 F	59 F

Table 5: Shed Programming - Oct 13th - Static Pressure Setback

Initiate Order	Normal ($0.10/kWh)	$0.30/kWh	$0.75/kWh
Static setpoint	2.2”	1.8”	1.4”
SAT setpoint	55 F	57 F	59 F

Table 6: Shed Programming - Nov 5th - Static Pressure Set Down &VFD Lock

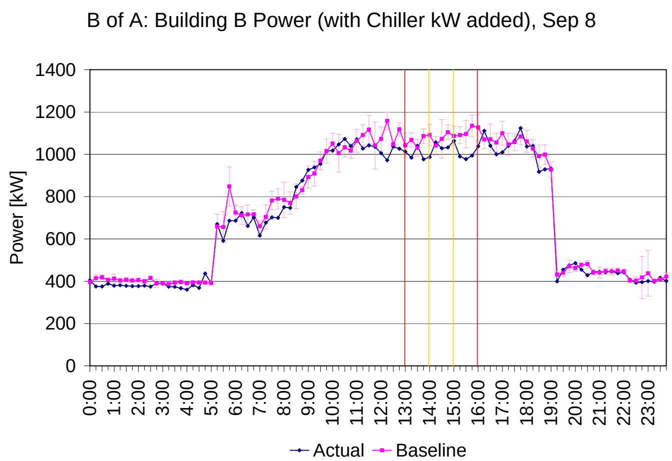
Initiate Order	Normal ($0.10/kWh)	$0.30/kWh	$0.75/kWh
Static setpoint	2.2”	1.4”	1.4”
Supply Fan Speed Mode	VFD (VAV system)	Wait 3 minutes then lock fan speed after new static has taken	Keep same fan speed lock
SAT setpoint	55 F	57 F	59 F

The EMCS does not have zone level thermostat control. As a result, the operators chose to implement a Cooling Limit shed strategy using a supply air temperature (SAT) setpoint set-up. The air systems at this site are Variable Air Volume (VAV). VAV systems condition a zone by modulating the flow rate of constant temperature air into the zone. When a SAT set-up method is used on a VAV system, the increased air temperature during the shed will cause the control loop to call for more air, meaning increase the fan speed. The control loop does this by opening dampers in the VAV boxes as the zone call for more cooling. For the purposes of this Cooling Limit demand shed discussion, we will refer to this interactive effect as the VAV Fan Penalty.

At the Concord Data Center, the staff tried to remove the VAV Fan Penalty, locking the VFD fans immediately prior to raising the SAT.

<u>Findings – Sept. 8th Test</u>

The Whole Campus and Building B electrical demand are graphed in Figure 1. Both graphs show an inconclusive demand reduction. Additionally, the sub meters on the chiller plant do not show a convincing demand shed (Figure 2).



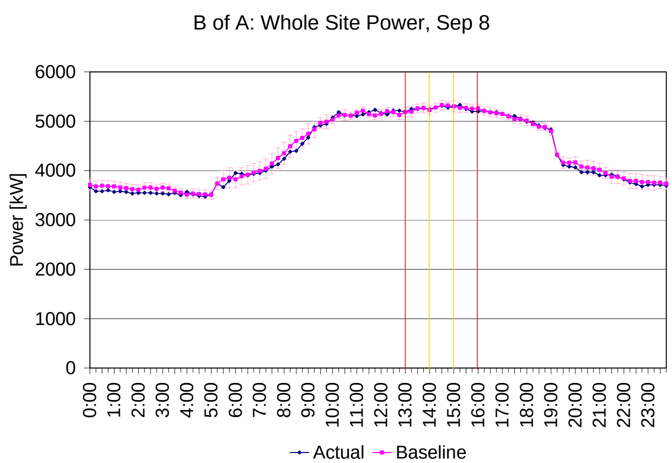


Figure 1: Sept. 8 – kW Reduction Graphs

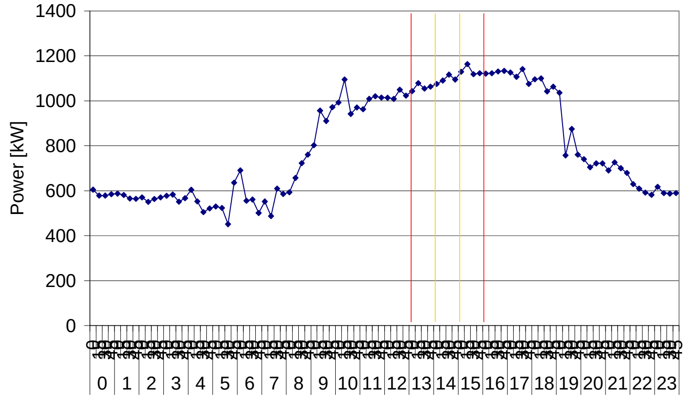


Figure 2: Average Chiller Plant Power (kW)

However, other EMCS data logs show some success. Figure 3 graphs the average kW at the Motor Control Centers (MCC) serving the Building B fans. An approximate 25 kW reduction is apparent during the last hour of the test. Also of note is the equally large rebound immediately after the test.

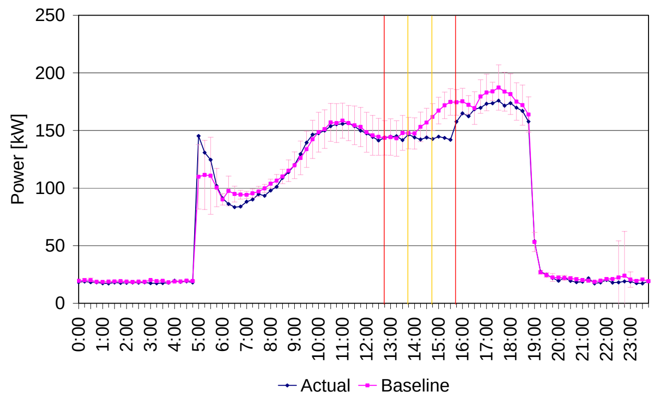


Figure 3: Sept. 8 - Building B Motor Control Center (MCC) kW Trend Data

As indicated in Figure 4, the supply fan VFD speed locked successfully at approximately 84% for the duration of the test. However, the supply airflow did not remain constant, starting at approximately 38,000 cfm and slowly increasing about 4,000 cfm over the duration of the test. Again, rebounds are apparent in both fan speed and air flow immediately after the test.

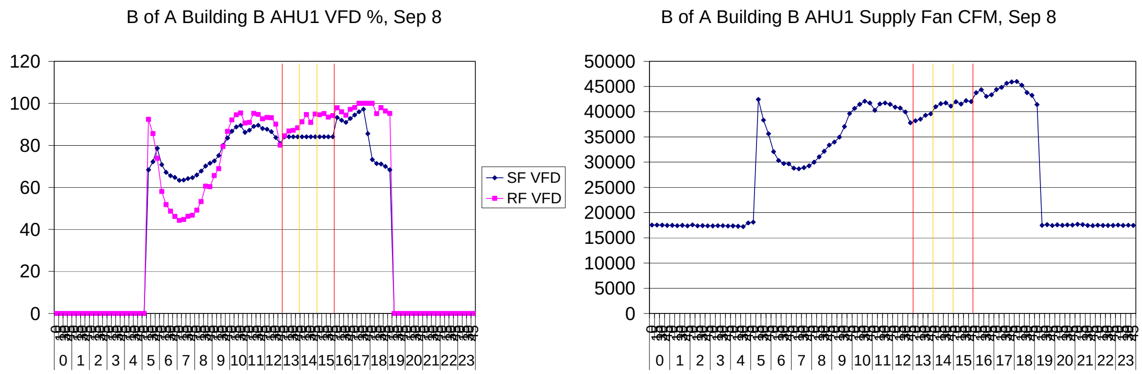


Figure 4: Sept. 8 - Building B EMCS Trend Graph

Findings – Sept. 21st Test

The test of Sept. 21st used the same shed strategy, but it was expanded to buildings A and C as well as building B. Once again, the shed did not produce enough demand savings to show at the whole campus power meter. The trend data in Figure 5 shows that the same basic systems response in Building B as those recorded on Sept. 8th. Unfortunately, some EMCS programming errors affected Buildings A and C causing failure.

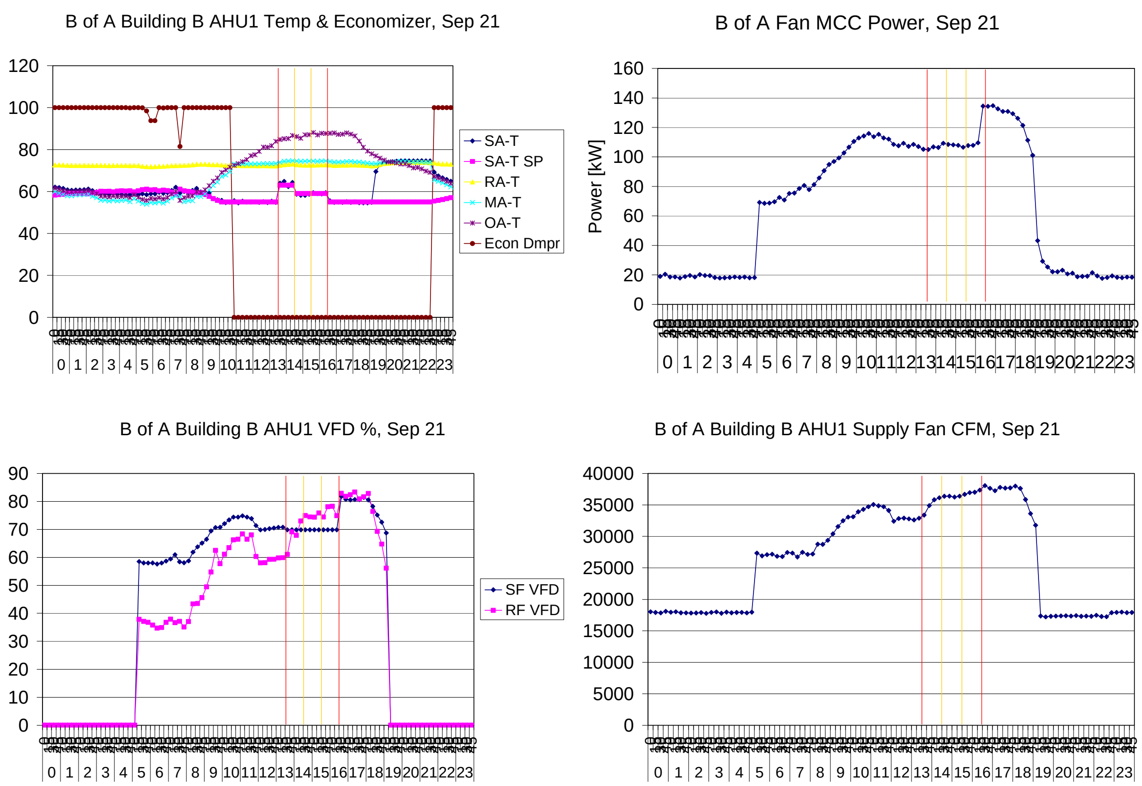


Figure 5: Sept. 21 - Building B EMCS Trend Graphs

Findings – Oct. 13th Test

In continued effort to find a strategy that provides more fan savings, the test was modified and a duct static pressure setpoint reduction was implemented. One of the primary reasons for abandoning the VFD lock method was the open loop effect it created on the control system. Once again, the whole campus savings were very small and the VAV Fan Penalty was not sufficiently removed.

Findings – Nov. 5th Test

Prior to the final test, very much discussion centered on the control interruptions that the VFD lock introduced into the control system. Limiting the VAV Fan Penalty with a static pressure setpoint reduction did not open the control loop, but the operators felt the static pressure reduction was not aggressive enough on its own.

The final solution was to try both. At the beginning of the test both the SAT temperature set-up and the static pressure setpoint reduction were initiated together. After the VAV system used the VFDs to adjust to the new static pressure setpoint (approx. 3 minutes), the shed programming then lock the VFDs at their new value for the remainder of the test.

Analysis of the EMCS data for Building B shows that the shed strategy didn't implement as planned. First of all, the outside temperature was very mild as seen in the upper left graph of Figure 6, which shows the economizer was on for the duration of the test. The VFD graph (lower left) shows that the VFD speed locks probably did not initiate.

Despite these indications of failure at Building B, the whole campus meter shows an estimated demand shed approaching 200 kW (Figure 7).

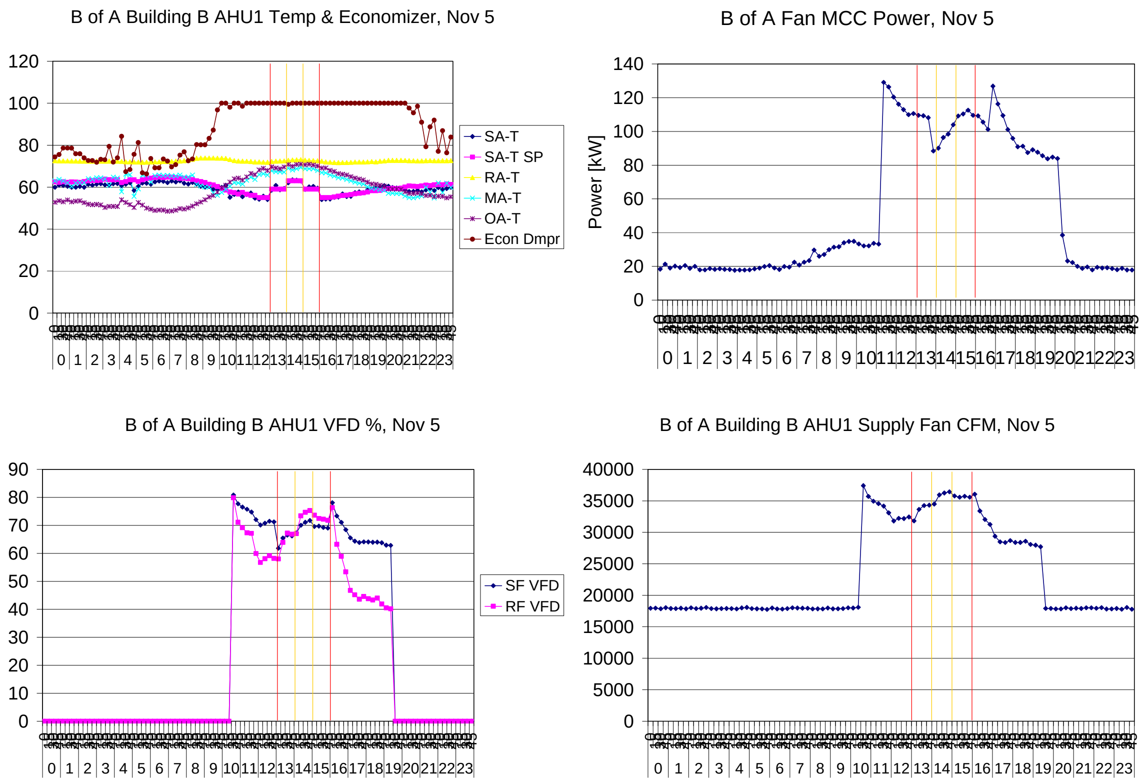


Figure 6: Nov. 5 - Building B EMCS Trend Graphs

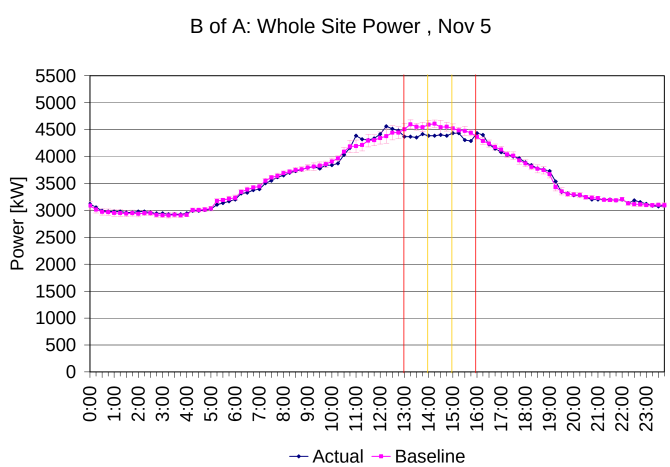


Figure 7: Nov. 5 – kW Reduction Graph

Final Analysis

Upon further analysis the increase in airflow, despite the VFD lock, is to be expected. With warmer supply air, the system responds by opening the VAV boxes (reduces total duct static pressure) to deliver more air. Since the locked VFD can't compensate by increasing speed, fan affinity laws will cause the fans to increase flow anyway by riding the fan performance curve. Figure 8 depicts this effect with point #1 on the curve moving in direction "a" to location #2 on the curve. As total duct static pressure lowers across a constant volume fan, the airflow increase causes the performance point to move in the "a" direction. Conversely, a rising static pressure causes movement in the "b" direction. Similarly, the performance point on the fan power curve moves in the "a" and "b" directions.[1]

As resistance drop with opening VAV dampers, the fans will continue to ride along the curve until the system has either met the duct static setpoint or flow reaches maximum and the VAV boxes, now 100% open, become starved for air. If the VAV boxes attain this condition, the actual associated fan consumption is indeterminate unless we know the exact fan power curve, which is specific to each fan, drive and motor combination. The power curve shape in Figure 8 is conceptual; merely showing that at some point the power might peak and in some conditions a very low static and high air flow condition can actually represent a power saving condition.

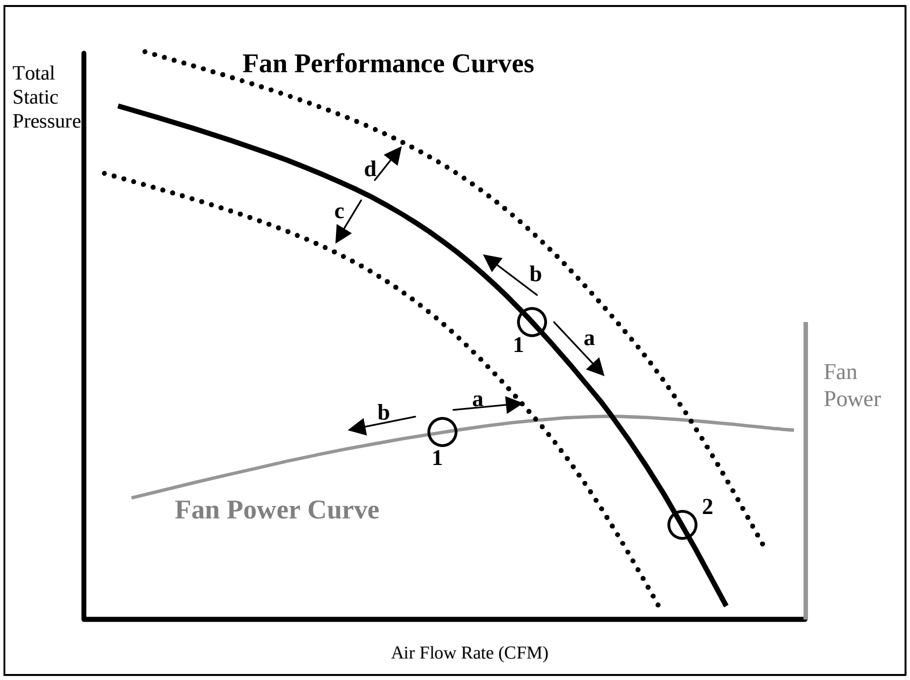


Figure 8: Fan Performance & Power Curves

This can explain the apparent conflict between the power and airflow data in Figure 3 and Figure 4. Since the airflow data from Sept. 8th doesn't show the airflow topping off, it is likely that the VAV boxes did not fully open during the test.

After consideration of this analysis, a better strategy to counter the VAV Fan Penalty would be to use only a static pressure reduction and let the VFDs do their job. In this case, as static pressure reduces the VFDs will adjust the fan to a new optimal fan performance curve. This is depicted by the dashed curves in directions "c" and "d" in Figure 8. Keeping the VFD operation online with a setback duct static pressure during the Cooling Limit shed will allow the VAV fans to remain in a closed loop operating condition. Additionally, the resulting fan power savings will be more predictable.

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[1] 2004 ASHRAE Handbook – HVAC Systems and Equipment, Fan Laws, Figure 3, Page 18.4

Findings from the 2004 Fully Automated Demand Response Tests in Large Facilities

Appendix E
Acronyms and Terminology

September 7, 2005

Acronyms and Terminology

AHU – Air Handling Unit

Auto-DR - Automated Demand Response

Business Logic – In the Auto-DR tests, the business logic determines EMCS actions based on price and business rules.

Client (computer) - The client part of a client-server architecture. Typically, a client is an application that runs on a personal computer or workstation and relies on a server to perform some operations. For example, an e-mail client is an application that enables you to send and receive e-mail. In the Auto-DR tests the clients at each site polled the server to get current pricing information

Co-lo - See Co-Location

Co-Location - A server, usually a Web server, that is located at a dedicated facility designed with resources which include a secured cage or cabinet, regulated power, dedicated Internet connection, security and support. These co-location facilities offer the customer a secure place to physically house their hardware and equipment as opposed to locating it in their offices or warehouse where the potential for fire, theft or vandalism is much greater. Most co-location facilities offer high-security, including cameras, fire detection and extinguishing devices, multiple connection feeds, filtered power, backup power generators and other items to ensure high-availability which is mandatory for all Web-based, virtual businesses. Co-location sites are being erected at various points around the world to provide services to the rapidly expanding Web hosting and e-commerce marketplace. The term co-location is also known as co-lo.

Control network – A network of controllers, data gathering panels and other devices that measure values from sensors and send commands to actuators. Control networks have been designed and optimized for the requirements of these systems including low installed cost and small communication packet sizes. Historically, many control networks have been based on RS-485 communications using proprietary protocols. Increasingly open protocols are being used including BACnet and LonTalk over RS-485 and Internet Protocols (IP). Control networks are generally separate from enterprise networks.

Data logging - The process by which I/O points are logged into a database.

Digital outputs (DO) – In an I/O controller, digital outputs are used to command equipment ON or OFF. Physically, a digital output consists of an automatically controlled relay contact. Constant volume fans and pumps and lights can be commanded ON or OFF with a digital output (see I/O controller).

DMZ - Short for demilitarized zone, a computer or small subnetwork that sits between a trusted internal network, such as a corporate private LAN, and an untrusted external network, such as the public Internet. Typically, the DMZ contains devices accessible to Internet traffic, such as Web servers… The term comes from military use, meaning a buffer area between two enemies.

DR - Demand Response

EIS - Energy Information System - An EIS is a system to collect and archive energy and related data. The primary purpose of an EIS is to understand a building's energy usage characteristics and to improve energy management. Some EIS provide Web-based remote control capability if network communication between the EMCS and the Internet are already established. EIS software and XML client software can reside in the same server. Some sites have non-Web-based EIS, which tend to be data collection systems that use phone lines or other non-Internet based networked monitoring systems.

Embedded (devices) – Special purpose computers with the following attributes:

1) Targeted functionality with little, if any, flexibility for the user to add different programs or customize the device.
2) User interfaces usually limited to allow targeted functionality only. May include small LCD screens, LEDs, buttons switches and knobs. QWERTY keyboards and Cathode Ray Tube display screens are generally not included.
3) Memory is usually cost optimized for the targeted functionality. Read only memory (ROM) and Flash memory chips are usually used in lieu of spinning hard discs.
4) Form factor is specially designed for the targeted functionality. Examples of embedded devices include Internet routers, automotive engine computers and cell phones.

EMCS - Energy Management and Control System

Enterprise - A business organization. In the computer industry, the term is often used to describe any large organization that utilizes computers. An intranet, for example, is a good example of an enterprise computing system.

Ethernet - A local-area network (LAN) architecture developed by Xerox Corporation in cooperation with DEC and Intel in 1976. Ethernet uses a bus or star topology and supports data transfer rates of 10 Mbps. The Ethernet specification served as the basis for the IEEE 802.3 standard, which specifies the physical and lower software layers. Ethernet uses the CSMA/CD access method to handle simultaneous demands. It is one of the most widely implemented LAN standards. A newer version of Ethernet, called 100Base-T (or Fast Ethernet), supports data transfer rates of 100 Mbps. And the newest version, Gigabit Ethernet supports data rates of 1 gigabit (1,000 megabits) per second.

Firewall - A system designed to prevent unauthorized access to or from a private network. Firewalls can be implemented in both hardware and software, or a combination of both. Firewalls are frequently used to prevent unauthorized Internet users from accessing private networks connected to the Internet, especially intranets. All messages entering or leaving the intranet pass through the firewall, which examines each message and blocks those that do not meet the specified security criteria. There are several types of firewall techniques:

1) Packet filter: Looks at each packet entering or leaving the network and accepts or rejects it based on user-defined rules. Packet filtering is fairly effective and transparent to users, but it is difficult to configure. In addition, it is susceptible to IP spoofing.
2) Application gateway: Applies security mechanisms to specific applications, such as FTP and Telnet servers. This is very effective, but can impose a performance degradation.
3) Circuit-level gateway: Applies security mechanisms when a TCP or UDP connection is established. Once the connection has been made, packets can flow between the hosts without further checking.
4) Proxy server: Intercepts all messages entering and leaving the network. The proxy server effectively hides the true network addresses.

In practice, many firewalls use two or more of these techniques in concert. A firewall is considered a first line of defense in protecting private information. For greater security, data can be encrypted.

Gateway - Gateways used in building telemetry systems provide several functions. First, they connect two otherwise incompatible networks (i.e., networks with different protocols) and allow communications between them. Second, they provide *translation* and usually *abstraction* of messages passed between two networks. Third, they often provide other features such as *data logging*, and control and monitoring of I/O points.

Generation – In electronics, computer equipment and software, the term "generation" is used to describe a major upgrade for which previous versions may or may not be compatible.

High Availability – Used to quantify the "uptime" for computer servers and systems. High availability is a requirement for operation of mission critical systems. High availability systems are often described in terms of the number of "nines" of availability (i.e., four 9s or 99.99% means less than one hour of unscheduled downtime per year).

HTTP - Short for HyperText Transfer Protocol, the underlying protocol used by the World Wide Web. HTTP defines how messages are formatted and transmitted, and what actions Web servers and browsers should take in response to various commands. For example, when you enter a URL in your browser, this actually sends an HTTP command to the Web server directing it to fetch and transmit the requested Web page. Webopedia 2004

HVAC - Heating, Ventilation, and Air Conditioning

I/O – Abbreviation for Input/Output. Commonly used in the controls industry. Refers to inputs such as sensors and outputs such as actuators (see abstraction, point mapping and translation).

I/O controller – A device that measures inputs values from sensors and commands outputs such as temperature control valves, usually to maintain a defined setpoint.

Internet - A global network connecting millions of computers. More than 100 countries are linked into exchanges of data, news and opinions.
Unlike online services, which are centrally controlled, the Internet is decentralized by design. Each Internet computer, called a *host*, is independent. Its operators can choose which Internet services to use and which local services to make available to the global Internet community. Remarkably, this anarchy by design works exceedingly well.
There are a variety of ways to access the Internet. Most online services, such as America Online, offer access to some Internet services. It is also possible to gain access through a commercial Internet Service Provider (ISP).

Intranet - A network based on TCP/IP protocols (an internet) belonging to an organization, usually a corporation, accessible only by the organization's members, employees, or others with authorization. An intranet's Web sites look and act just like any other Web sites, but the *firewall* surrounding an intranet fends off unauthorized access. Like the Internet itself, intranets are used to share information.

IP I/O device - A device that measures inputs (e.g., electric meter data) and controls outputs (e.g., relays) that can be measured and actuated remotely over a LAN, WAN or Internet using Internet Protocols (IP).

IP relay - A device with a relay or relays that can be actuated remotely over a LAN, WAN or Internet using Internet Protocols (IP).

ISO - Independent System Operator

IT - Short for Information Technology, and pronounced as separate letters, the broad subject concerned with all aspects of managing and processing information, especially within a large organization or company. Because computers are central to information management, computer departments within companies and universities are often called IT departments. Some companies refer to this department as IS (Information Services) or MIS (Management Information Services).

LAN - A computer network that spans a relatively small area. Most LANs are confined to a single building or group of buildings. Most LANs connect workstations and personal computers. Each node (individual computer) in a LAN has its own CPU with which it executes programs, but it also is able to access data and devices anywhere on the LAN. This means that many users can share expensive devices, such as laser printers, as well as data. Users can also use the LAN to communicate with each other such as by sending e-mail. There are many different types of LANs Ethernets being the most common for PCs. Webopedia 2004.

LonTalk – An open communications protocol used in building control systems and other industries. Publicly published under EIA-709.1, the Electronic Industries Alliance (EIA) Control Network Protocol Specification. Products that communicate using LonTalk are available from hundreds of companies.

LonWorks – A line of product offerings available from Echelon Corporation. LonWorks products use LonTalk protocol for communications (see LonTalk).

Machine-to-Machine (M2M) - Machine to Machine (M2M) is a term used to describe the technologies that enable computers, embedded processors, smart sensors, actuators and mobile devices to communicate with one another, take measurements and make decisions - often without human intervention.

MCC - Motor Control Center

Modem – A hardware device that allows computers to communicate with one another over the public switched telephone network (PSTN).

NOC - Short for network operations center, the physical space from which a typically large telecommunications network is managed, monitored and supervised. The NOC coordinates network troubles, provides problem management and router configuration services, manages network changes, allocates and manages domain names and IP addresses, monitors routers, switches, hubs and UPS systems that keep the network operating smoothly, manages the distribution and updating of software and coordinates with affiliated networks. NOCs also provide network accessibility to users connecting to the network from outside of the physical office space or campus.

Onboard – Refers to electronic components that are mounted on the main printed circuit board as opposed to components that are mounted remotely and connected via wires.

Open protocol – A communications protocol that is used to communicate between devices of any compliant manufacturer or organization. Open protocols are published in a public forum for use by all interested parties (see Proprietary protocol).

Point mapping – The process by which I/O points are mapped to another system or protocol (see abstraction, I/O and translation).

Poll - A method by which one computer gets information from another.

Polling Client – In the Auto-DR tests, it is the software that polls the server to get price.

Price Server – In the Auto-DR tests, it is the common source of current price info.

Proprietary protocol – A communications protocol that is used to communicate between devices of one manufacturer or organization while effectively disallowing all other devices to exist on the same network. Proprietary protocols are not published in a public forum (see Open protocol).

Protocol (data communication): A data communication protocol is a set of rules governing the exchange of data over a computer network.

Pull architecture - In a client-server architecture the client "pulls" information from the server by polling (see poll).

Real-time – In real-time control and monitoring systems, data is measured, displayed and controlled at a rate fast enough that the system latencies are negligible compared with the process at hand. Acceptable latency can vary substantially based on the type of process (e.g., from 1 millisecond to several minutes).

Server - (computer) Servers are often dedicated, meaning that they perform no other tasks besides their server tasks. On multiprocessing operating systems, however, a single computer can execute several programs at once. A server in this case could refer to the program that is managing resources rather than the entire computer. In the 2003 Auto-DR tests, pricing information was "served" from a Web services server hosted by Infotility Inc.

Setpoint – The target value for which an I/O controller attempts to maintain. Setpoint values (e.g., temperature, pressure etc.) are maintained through adjustments of the final control elements (e.g., temperature control valves, dampers etc.).

Systems Integrator – A type of business that designs, installs and configures computer and control systems usually using components and software from multiple vendors.

TCP/IP - (Transmission Control Protocol / Internet Protocol) - Internet Protocol specifies the format of packets, and the addressing scheme. Most networks combine IP with a higher-level protocol called Transmission Control Protocol (TCP), which establishes a virtual connection between a destination and a source.

Telemetry - A communications process that enables monitoring and/or control of remote or inaccessible sensors and/or actuators. Telemetry often uses radio frequency signals or Internet technologies for communications

Translation - The process by which I/O points are translated to another system or protocol. Translation changes messages in one protocol to the same messages in another (see abstraction, I/O and point mapping).

VAV – Variable Air Volume

VFD – Variable Frequency Drive

WAN (Wide Area Network) A computer network that spans a relatively large geographical area. Typically, a WAN consists of two or more local-area networks (LANs). The largest WAN in existence is the Internet, which is open to the public. Private and corporate WANs use dedicated leased lines or other means of assuring that the network is only available to authorized users of the organization.

WBP – Whole Building Power

Web Services - The infrastructure of the Auto-DR System is based on a set of technologies known as Web Services. Web Services have emerged as an important new type of application used in creating distributed computing solutions across the Internet. Properly designed Web services are completely independent of computer platform (i.e. Microsoft, Linux, Unix, Mac etc.). Web pages are for people to view information on the Internet. Web services are for computers to share information on the Internet. Since human intervention is not required, this technology is sometimes referred to as "Machine-to-Machine" or "M2M". XML is often used to enable Web services. M2M is a superset of technologies that includes some XML/Web services based systems (see XML, Machine to Machine).

XML - Extensible Markup Language, is a `meta-language' —a language for describing other languages —that allows design of customized markup languages for different types of documents on the Web (Flynn, 2003). It allows designers to create their own customized tags, enabling the definition, transmission, validation, and interpretation of data between applications and between organizations.