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SUMMARY OF THE 2006 AUTOMATED DEMAND RESPONSE PILOT

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ABSTRACT

This paper discusses the specific concept for, design of, and results from a pilot program to automate demand response with critical peak pricing. California utilities have been exploring the use of critical peak pricing (CPP) to help reduce peak day summer time electric loads. CPP is a form of price-responsive demand response. This Automated Critical Peak Pricing (Auto-CPP) project from 2006 draws upon three years of previous research and demonstrations from the years of 2003, 2004, and 2005. The purpose of automated demand response (DR) is to improve the responsiveness and participation of electricity customers in DR programs and lower overall costs to achieve DR. Auto-CPP is a form of automated demand response (Auto-DR).

INTRODUCTION

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

The various levels of DR automation can be defined as follows. **Manual Demand Response** involves a labor-intensive approach such as manually turning off or changing comfort set points at each equipment switch or controller. **Semi-Automated Demand Response** involves a pre-programmed demand response 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 demand response strategies. The authors 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 acceptable.

From the customer side, modifications to the site's electric load shape can be achieved by modifying end-use loads. Examples of demand response strategies include reducing electric loads by dimming or turning off non-critical lights, changing comfort thermostat set points, or turning off non-critical equipment. These demand response activities are triggered by specific actions set by the electricity service provider, such as dynamic pricing or demand bidding. Many electricity customers have suggested that automation will help them institutionalize their demand response. The alternative is manual demand response -- where building staff receives a signal and manually reduces demand. Lawrence Berkeley National Laboratory (LBNL) research has found that many building energy management and controls systems (EMCS[1]) and related lighting and other

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

controls can be pre-programmed to initiate and manage electric demand response.

This Automated Critical Peak Pricing (Auto-CPP) project from 2006 draws upon three years of previous research and demonstrations from the years of 2003, 2004, and 2005. The purpose of automated demand response (Auto-DR) is to improve the responsiveness and participation of electricity customers in DR programs and lower overall costs to achieve DR. Auto-CPP is a form of Auto-DR. Automated DR involves systems that automatically reduce electric demand in facilities upon receipt of an emergency signal or rise in the price of electricity. In Auto-CPP a communications signal provides notification of price variations that reflect the CPP tariff. The signal is published on a single server as a web service, available on the Internet using the meta-language XML (Extensible Markup Language). Each of the participating facilities monitors the common price-level signal using web service software client and automatically sheds site-specific electric loads when the price increases based on the Pacific Gas and Electric Company's (PG&E's) Critical Peak Pricing Program. The system is designed to operate without human intervention.

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

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

This paper focuses on the results of the Auto-CPP tests that LBNL and PG&E conducted during 2006. A series of new findings add to what was previously known about AutoDR and Auto-CPP. These include a full summer of Auto-CPP participation, CPP customer economics, and Auto-CPP events during a severe heat storm[2]. Another new aspect of the 2006 program was the use of a third party organization to assist in the Auto-DR control and communications installations done by a DR Integration Services Company (DRISCO). The DRISCO was part of the technology transfer plan to move the technology from the research lab (LBNL) into the private sector.

METHDOLOGY

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

Once the automation systems were installed, LBNL conducted communications tests to ensure that the communication system Internet server, known as the Demand Response Automation Server or DRAS, correctly provided and logged the continuous communication of CPP signals to each site. The pre-programmed DR (demand response) shed strategies were also observed and evaluated to ensure proper end-to-end functionality.

Measurement of demand response was conducted using two different baseline models. One was the CPP baseline model, which is based on the site electric consumption from noon to 6 p.m. for the three days of highest consumption of the previous ten non-weekend days; it is not normalized for weather. The second baseline, the LBNL adjusted Outside Air Temperature (OAT) regression baseline model, uses weather regressions from the fifteen-minute electric load data during each event day and is based on OAT data and electricity use from the previous ten

[2] See full report for a detailed discussion of these topics.

days. These baseline models were used to evaluate the demand reduction during each DR event for each site. The aggregated response (the sum of the individual responses for a given DR event) for each site was also estimated using both baseline models. The evaluation research also included surveying the facility managers regarding any problems or issues that arose during the events. Questions included comfort, controls issues, and other potential problems.

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

The evaluation included quantifying the demand savings (kW) at each site, along with the savings in whole-building power by percentage, and the demand intensity (W/ft²). The demand savings percentage is defined as the percentage of savings in whole building power. The demand-savings intensity (W/ft²) is the saved demand normalized by the building's conditioned floor area. The demand savings was calculated by subtracting the actual whole building power from its calculated baseline demand.

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

As an example, Figure 1 shows the 2530 Arnold Street whole-building hourly electricity use during a CPP event on June 21st, 2006. The figure shows the actual whole building power plus the LBNL adjusted OAT regression baseline. The baseline is an estimate the whole-building power level if the demand response had not occurred. The vertical bands at noon, 3 p.m., and 6 p.m. indicate times of price changes.

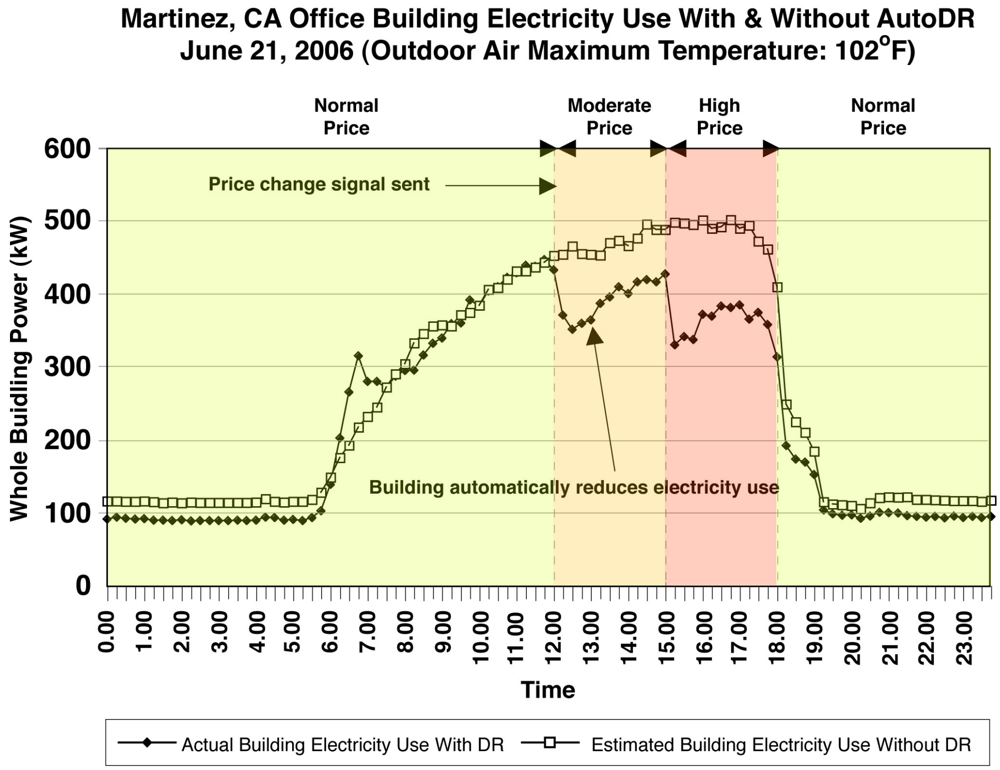

Figure 1. Example of Fully Automated Demand Shed at an Office Building

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

CONTROL AND COMMUNICATION SYSTEM CONFIGURATION

The 2006 Auto-CPP project used the technology developed in the 2005 Auto-CPP study with a number of additions as described in the discussion below. All participants were responsible for reviewing and meeting the "2006 Automated Critical Peak Pricing Pilot Participation Requirements" (see http://drrc.lbl.gov) California's automated demand response system uses the public Internet and private corporate and government Intranets or networks to communicate CPP event signals that initiate reductions in electric load in commercial buildings. The CPP signals are received by energy management and control systems, which perform pre-determined demand response strategies at the appropriate times.

LBNL provided the participants one of two automation communication equipment options that serve as "client-interface" to the automation server in a "publish and subscribe" service oriented architecture (SOA). The two communication clients are:

- A DRAS software client for sites with Internet control connectivity which is typically based on an Internet backbone,
- A DRAS communicating CLIR (Client and Logic with Integrated Relay) Box that incorporates hardware and software client for systems not currently using Internet based controls.

The participants agreed to work with their controls vendor or in-house staff to modify their systems to be able to retrieve the price-level signal or receive a control signal using web services, and initiate an automated demand response. In many cases the 2006 participants worked with a specially trained DR Integration Services Company (DRISCO).

Once the Auto-CPP system setup was completed, LBNL published an electric price signal web service via the Internet that contained information to represent electricity prices for the CPP event days. The Participant was able to override the test and "opt out" if necessary.

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

3 Web services (WS) a set of modular applications that are self-describing and self-contained that can be easily integrated with other Web services to create objects and processes. WS are built using open Internet standards, thus enabling systems to be constructed and integrated with applications on any platform and programming language.

Simple Object Access Protocol (SOAP) – SOAP is a form of Remote Procedure Call (RPC) that uses Internet protocol, HTTP as its base transport and XML as means to encode requests and responses for accessing services, objects, data, and systems/servers that are independent of platforms.

Extensible Markup Language (XML) – XML is a open and flexible data communication format to enable data and format sharing between varied systems, Internet, Intranet, and other areas, thus enabling cross-platform data-sharing and system integration.

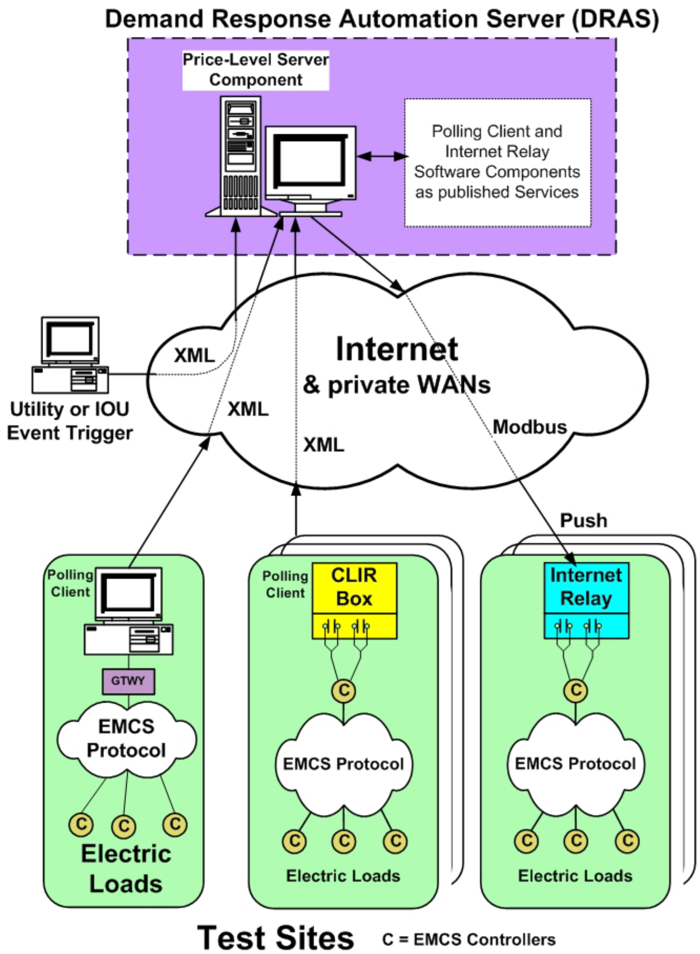

Figure 2. Auto-CPP Communication System Architecture

Figure 2 shows the Auto-CPP control and communication system architecture. The lower systems under the Internet cloud show the two communication methods mentioned above, along with previous relay and configurations used in previous year tests. The CLIR box is preferred to the previous relay technologies because of improved Internet security features and ease of installation on most Internet local area networks. When the utility triggers a CPP event, an XML message is sent to the DRAS indicating the event date. DRAS creates an event notification table visible to all users and publishes an event-pending signal so that all the polling clients at participating sites receive this notification information.

RESULTS

Twenty-four sites participated in the Auto-CPP pilot during 2006. Fourteen sites were continuing sites from the 2005 demonstration, and 10 sites were new in 2006. Table 1 lists the site name, location, CPP zone, building use, floor space, and peak electric demand in summer 2006. The table shows the CPP Zone 1 and 2 used in 2006 because PG&E had their service territory divided into two geographical zones. (The program in 2007 has only one zone) The participant buildings include 12 office buildings, seven retail stores, two schools, an electronics manufacturer, a museum, a bakery, and a detention facility. Some office buildings contain laboratories or data centers.

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Table 1. Summary of Auto-CPP Site Characteristics

Short Name	Location	CPP Zone	Building Use	# of Bldg	Floor Space		Peak Load kW
					Total	Conditioned	
ACWD	Fremont	2	Office, lab	1	51,200	51,200	348
Office/Data Center	Concord	2	Office, data center	4	616,000	708,000	5712
Chabot	Oakland	2	Museum	2	86,000	86,000	336
2530 Arnold	Martinez	2	Office	1	131,000	131,000	536
50 Douglas	Martinez	2	Office	1	90,000	90,000	459
MDF	Martinez	2	Detention Facility	1	172,300	172,300	561
Echelon	San Jose	2	Hi-tech office	1	75,000	75,000	523
Centerville	Fremont	2	Junior Highschool	1	0	0	332
Irvington	Fremont	2	Highschool	1	186,000	186,000	446
Gilead 300	Foster City	1	Office	1	83,000	83,000	288
Gilead 342	Foster City	1	Office, Lab	1	32,000	32,000	495
Gilead 357	Foster City	1	Office, Lab	1	33,000	33,000	662
IKEA EPaloAlto	East Palo Alto	1	Furniture retail	1	300,000	300,000	1191
IKEA Emeryville	Emeryville	2	Furniture retail	1	274,000	274,000	1466
Oracle Rocklin	Rocklin	2	Office	2	100,000	100,000	808
Solectron	Milpitas	2	Office, Manufacture	9	499,206	499,206	4655
Svenhard's	0	0	Bakery	1	101,000	101,000	696
Sybase	Pleasanton	0	Hi-tech office	2	425,000	425,000	1995
Target Hayward	Hayward	2	Retail	1	130,000	130,000	449
Target Antioch	Antioch	0	Retail	1	140,686	140,686	572
Target Bakersfield	Bakersfield	0	Retail	1	143,941	143,941	645
				34	3,384,706	3,476,706	21,958

Thirteen sites participated in the majority of summer CPP events. The other sites were not ready for the summer 2006 CPP program but were part of the technology incentive program that has prepared them for the 2007 AutoDR program. Among the Auto-CPP sites, 125 events were fully automated and evaluated in this study. Their average peak demand reduction was 14% of the whole-facility load based on the three-hour high-price period. The average peak demand reduction was 87 kW per facility, based on the weather-normalized baseline model. The savings using a CPP-baseline without weather normalization were less than half these levels.

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

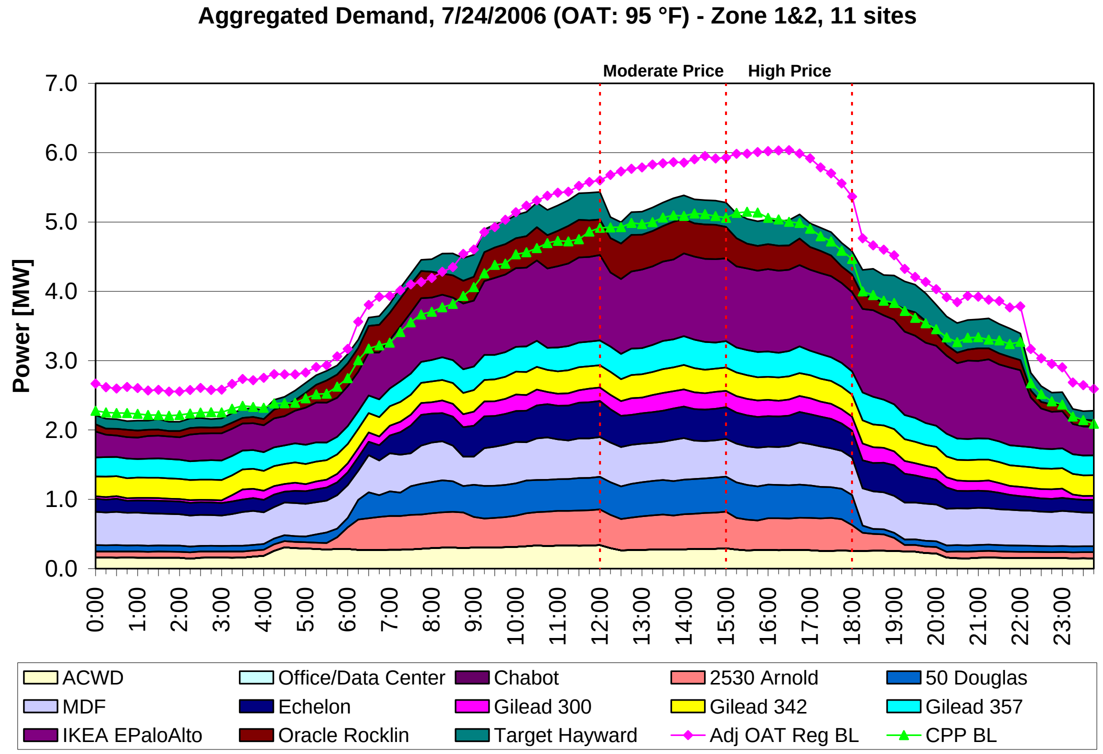

Figure 3. Aggregated Demand Savings, July 24th, 2006

Table 2. Summary of Demand Savings, July 24th, 2006

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

Additional key results are as follows:

- **During the severe heat wave of July 2006, all of the Auto-CPP sites continued to participate in DR at a time when it was needed most.** Internal temperatures in the buildings did rise above normal conditions, with some increase in occupant complaints, but not to the point of disrupting activities in the buildings or causing the facilities personnel to disable the automation.
- **Eleven of the thirteen sites with a full CPP season saved money under Auto-CPP.** CPP provides credits for energy costs on non-CPP days and charges on CPP days. The credits were larger than the costs for nearly all of the sites.

Full automation is technically feasible and provides value to CPP customers. One key aspect of the automation tests is that the facilities continue to participate after many years. The theory of this pilot program is that automation improves participation in demand response. This question will be explored over time in future research.

One additional result of this multi-year research program is the development of a DR strategies guide. The guide provides a review of DR strategies for common configurations of HVAC and lighting, and control systems (Motegi et al, 2007). The guide is designed for use by utility personnel, building operators, and consulting engineers to assist in DR strategy development and testing. It is applicable to both manual and automated strategies.

RECOMMENDATIONS AND FUTURE DIRECTIONS

The 2006 Auto-CPP study showed that automating demand response is technically feasible using an open architecture that allows for multiple building control system to be linked to common systems. Planning for a scaled-up Auto-DR program for 2007 was initiated during 2006. The Demand Response Research Center (DRRC) will continue to support research to help understand the strengths and weaknesses of the current Auto-DR platforms and assist in identifying improvements. Specific examples of future research issues are listed below:

- **Explore Auto-DR for Small Commercial and Large Industrial Sites -** One of the long-term strategies of automating DR is to utilize customer relationships with current controls and communications technology vendors, informing and educating them on Auto-DR systems. Technically this project showed that most buildings with EMCS can participate in Auto-DR. Further work is needed to explore how to connect the DRAS with smaller buildings that do not have centralized EMCS. Further work is also needed to evaluate the readiness of industrial process control systems for automation.

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

- **Provide Better Information on the State Benefits of DR –** Demand response is a confusing term and DR programs are confusing. More effort is needed to communicate the concepts of

DR. Automating DR may help improve the reliability of the resource, but there is a hurdle in marketing these programs because of limited understanding.

- **Consider Alternative Baseline Models** – The Auto-CPP project showed that the CPP baseline was lower than hot peak day loads prior to CPP events. Weather-sensitive loads need weather-adjusted baseline models. Further research on this issue is underway.

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