## Title

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# Disclaimer

# Effects of Granular Control on Customers' Perspective and Behavior with Automated Demand Response Systems

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## ABSTRACT

Automated demand response (Auto-DR) is expected to close the loop between buildings and the grid by providing machine-to-machine communications to curtail loads without the need for human intervention. Hence, it can offer more reliable and repeatable demand response results to the grid than the manual approach and make demand response participation a hassle-free experience for customers. However, many building operators misunderstand Auto-DR and are afraid of losing control over their building operation. To ease the transition from manual to Auto-DR, we designed and implemented granular control of Auto-DR systems so that building operators could modify or opt out of individual load-shed strategies whenever they wanted.

This paper reports the research findings from this effort demonstrated through a field study in large commercial buildings located in New York City. We focused on (1) understanding how providing granular control affects building operators' perspective on Auto-DR, and (2) evaluating the usefulness of granular control by examining their interaction with the Auto-DR user interface during test events. Through trend log analysis, interviews, and surveys, we found that: (1) the opt-out capability during Auto-DR events can remove the feeling of being forced into load curtailments and increase their willingness to adopt Auto-DR; (2) being able to modify individual load-shed strategies allows flexible Auto-DR participation that meets the building's changing operational requirements; (3) a clear display of automation strategies helps building operators easily identify how Auto-DR is functioning and can build trust in Auto-DR systems.

## Introduction

Demand response (DR) – allowing customers to respond to reliability requests and market prices by changing electricity use from their normal consumption pattern – continues to be seen as an attractive means of demand-side management and a fundamental smart-grid application that links supply and demand. Large customers are often the first and most cost effective target for DR because they are major contributors to peak demand for electricity, and are equipped with centralized building management system (BMS) that automate control. With increased adoption of smart meters, standards-based building control networking, and building automation systems, an enormous opportunity lies ahead for medium and large customers to exercise their full DR potential.

Today, however, most adjustments to building controls and operations are done manually, making response to more frequent reliability events, hourly prices, or daily peak shaving impractical. Customers' ability to perform DR can significantly improve by enabling automated demand response (Auto-DR) [1]. By reducing the need for humans in the loop, Auto-DR can reduce the operational burden to provide real-time response and lower the costs associated with monitoring building consumption and responding load-shed requirements. Auto-DR can also help customers leverage the flexibility of their buildings by automating reaction to price and reliability signals. Therefore, Auto-DR can help make the grid more reliable while providing cost savings to energy consumers.

Although automation of demand responsive control strategies may provide financial benefits such as management of day-ahead hourly pricing and demand charge reduction, building owners and managers are often reluctant to adopt automation because they perceive it as relinquishing full control of their systems. Building management staff priorities are delivery of service and comfort for tenants, and, therefore, savings cannot be perceived to come at the cost of tenant satisfaction. This report outlines a study that offered equipment and zone level customizable automation strategies that enabled building managers to participate in a variety of demand management activities, while maintaining full control over all building level services.

The rest of the report is organized as follows. First, we provide background and objectives of the project, as well as an overview of DR programs in New York State's (NYS) wholesale electricity markets and discuss barriers to adoption in automated curtailment strategies. We then name project partners, and describe the participating buildings in the demonstration. We then describe general methods used for Auto-DR implementation and DR strategies developed for each participating building. Lastly, we summarize the key findings in and conclude with suggestions for future research opportunities in.

## Background

### Objectives

Starting in October 2011, the Demand Response Research Center (DRRC) at Lawrence Berkeley National Laboratory (LBNL) and New York State Energy Research and Development Authority (NYSERDA) conducted a demonstration project enabling Auto-DR in large commercial buildings located in New York City (NYC).

The project focused on the following:

1. Demonstrating how the OpenADR standard can automate and simplify interactions between buildings and various stakeholders in NYS including the New York Independent System Operator (NYISO), utilities, retail energy providers (REPs), and curtailment service providers (CSPs);
2. Automating building control systems to provide event-driven demand response, price response, and demand management according to OpenADR signals;
3. Providing cost-saving solutions to large customers by actively managing day-ahead hourly prices and demand charges; and
4. Granting building management staff more granular control to remove any major piece of heating, ventilation, and air conditioning (HVAC) equipment out of load-shed sequences, or opt a building out in its entirety.

### Demand Response Programs Available to NYC Participants

New York State's market structure provides several mechanisms intended to encourage larger customers to reduce their impact on the grid. These include hourly prices for energy constraints; retail demand tariffs and utility DR programs for distribution system constraints; wholesale DR for capacity constraints; and even dispatchable DR for providing Ancillary Services to the New York Independent System Operator (NYISO).

The NYISO administers several DR market programs aligned to the following wholesale markets:

- Capacity (installed capacity);
- Energy (day-ahead balancing auctions); and
- Ancillary services (regulation, spinning reserve and non-spinning reserve).

In addition to the market-offered DR programs, utilities offer out-of-market DR programs to address their own transmission- and distribution-level constraints and emergencies. There are four generic forms of demand response present in New York State: 1) facility peak-shaving; 2) utility direct load control, 3) reliability DR programs (curtailment and distributed generation) and 4) dynamic pricing. In NYS, several incentive-based reliability programs are offered by the NYISO and utilities. Table 1 lists the name, service type, and trigger mechanism of all incentive-based curtailment programs currently available in NYC.

Table 1. Demand response curtailment programs in New York City

| Program Name | Operator | Service Type | Trigger |
|---|---|---|---|
| 1. Installed Capacity Special Case Resources (SCR) | NYISO | Capacity | Reliability |
| 2. Emergency Demand Response Program (EDRP) | NYISO | Energy | Reliability |
| 3. Commercial System Relief Program (CSRP) (aka Peak) | Con Edison | Out-of-market | Reliability |
| 4. Distribution Load Relief Program (DLRP) (aka Contingency) | Con Edison | Out-of-market | Reliability |
| 5. Demand Side Ancillary Services Program (DSASP) | NYISO | Energy, Reserve Regulation | Market bid/dispatch |
| 6. Day-Ahead Demand Response Program (DADRP) | NYISO | Energy, Reserve Regulation | Market bid/dispatch |

Customers are compensated for committing to reduce their electricity use during DR events by receiving seasonal reservation payments based on market prices and tariffs. Customers typically participate in curtailment programs through CSPs. CSPs manage a portfolio of DR resources and their response during DR events as well as aggregating smaller resources.

Dynamic pricing exists as an optional or mandatory utility tariff, or as a retail third-party energy supplier contract. Mandatory Hourly Price (MHP) rates communicate variations in wholesale prices that may induce changes in customers' energy consumption behavior due to the increase cost of energy. The MHP tariffs are charges independent of demand/deliver charges, or other tariffs.

## Barriers to Adoption of Automated Curtailment Strategies

Although utilities offer MHP as the default service to large customers, NYS's retail access policy allows customers to purchase their energy from any retail third party. Given various purchasing options and pricing structures offered as alternatives to the utility, MHP is not considered strictly 'mandatory'.

In practice it is widely understood that NYS customers for whom MHP may apply (those with roughly over 500kW demand) typically hedge against fluctuations in energy prices, and contract with a retail energy provider and choose energy pricing that is not dynamic. The form of retail supply contracts is not regulated and is often a flat-priced contract. Retail Energy Providers (REPs) represent their customers in the wholesale market as load serving entities for the purchase of forward capacity, forward and scheduled energy and ancillary services.

As of 2011, only 15% of the MHP-eligible customers were enrolled in MHP and the rest (85%) were retail access customers [2]. Anecdotally, it is thought that flat price contracts are a compelling reason for customer to contract with a REP. The problem with this trend is that, by nature, flat price retail contracts hedge against price fluctuations and therefore do a poor job of reflecting wholesale near-term market prices (day-ahead, hour-ahead and real-time). Flat price contracts are also more expensive due to the inherent risk premium of offering a less variable rate [3]. When retail prices are not tied to wholesale market variations, they can distort supply-demand balances and "increase the level of peak demand by underpricing" electricity and can also "discourage increased demand during off-peak hours by overpricing it" [4]. The net effect is inefficiency and added costs in the near term energy markets. NYS customers are allowed to pay a premium for the security of a flat rate, but the premium does not cover the added costs to other customers having to absorb higher energy prices. Though retail products with dynamic prices indexed to the near-term wholesale energy prices exist, there is no method for making day-ahead prices broadly available.

A recent report by KEMA identified the primary barriers to the adoption of dynamic pricing (in the form of day-ahead Mandatory Hourly Prices) and indexed retail contracts as insufficient resources to monitor hourly prices and inflexible labor schedule [2]. This is not surprising since most customers rely on manually adjusting their systems and operations to provide DR. Providing DR manually is a labor-intensive process. If customers do not have the capability to monitor daily or hourly price variations and manage their loads in an automated way, they are likely to choose a more conventional rate such as a flat rate. It should be noted that customers often prefer stable energy prices for budgeting purposes.

Moreover, customers have not yet found a compelling business case to migrate to MHP or choose indexed retail products. Many customers presume that the cost of monitoring and automation outweighs the potential savings. Even if the savings exist under day-ahead hourly prices, they are not as obvious and repeatable as the DR payments, because the savings are embedded in the total electricity bill. Therefore, in order to increase the adoption of MHP and dynamic-price retail contracts, we not only need to make the prices broadly available but also automate customers' price response, and communicate the differences between flat rate and dynamic rate structures.

## Project Participants

### Project Team

For this project, Auto-DR implementation was accomplished through the teamwork of LBNL and industry partners including Honeywell Building Solutions (HBS) and Akuacom. HBS provided site enablement and equipment installation. Akuacom provided the OpenADR server and signals. LBNL developed technical specifications such as Graphical User Interfaces and Auto-DR control strategies, analyzed load-shed impact, and managed the overall project.

### Site Descriptions

Four buildings were recruited for the demonstration project, all of which had previously participated in one or more incentive-based DR programs through their respective CSPs. Prior to this project, DR at these buildings was handled through manual control of heating, ventilation, air conditioning, lighting, and other systems. Some also provided manual peak load management. Because DR was manually performed, however, building managers only acted on hot days or during DR event days. Prior to this study, building managers did not perform any price response due to the frequency of manual intervention required, and the nature of their fixed price contracts. The customer's participation in this project was driven by the motivation to automate DR, and evaluate cost savings opportunities available through alternative energy procurement strategies, demand charge management, and increased DR program participation. Figure 1 shows the location of the four demonstration sites.

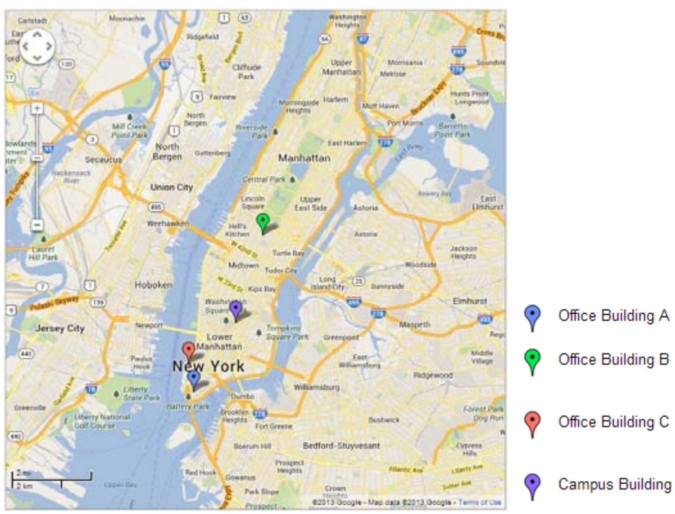


Figure 1. Demonstration Site Location. *Source*: Google Map.

Table 2 below summarizes the business type, floor space, peak demand, energy supplier, and DR program enrollments for each participant. All of the sites purchased electricity from a retail energy provider through retail access.

Table 2. Demonstration site summaries

| Facility | Peak Load (kW) | Floor Area ($ft^2$) | Peak Load Intensity ($W/ft^2$) | Load Factor | Annual Consumption (kWh) | Electricity Supplier | Demand Response Program Enrollment | Building Management System |
|---|---|---|---|---|---|---|---|---|
| Office Building A | 6,190 | 1,400,000 | 4.4 | 0.51 | 27,612,000 | NYPA | NYISO SCR & EDRP | Johnson Metasys |
| Office Building B | 3940 | 1,700,000 | 2.3 | 0.52 | 8,717,000 | Direct Energy | NYISO SCR & EDRP<br>ConEd DLRP & CSRP | Delta Controls |
| Office Building C | 4640 | 1,400,000 | 3.3 | N/A | 24,782,000 | NYPA | NYISO SCR<br>Con Ed DLRP | Honeywell |
| Campus Building | 600 | 122,000 | 4.9 | 0.39 | 2,150,000 | NYPA | NYISO SCR & EDRP | Automated Logic |

# Methodology

## Auto-DR System

Prior to automation capabilities installed through this project, all sites performed manual demand response, and did not have the capability to respond to machine-readable price signals. For the project, each site was outfitted with an OpenADR client using a common gateway system (JACE® Java Application Control Engine) to receive the integrated LBNL/Akuacom generated price signals. Upon receipt, the gateway converted price and operation mode signals into BACnet® messages and relayed to the Open Plant Controller (CPO) to activate pre-programmed control strategies via the site's BMS, as shown in Figure 2 below.

Building managers were able to modify pre-programmed control strategies by deselecting individual control strategies via the CPO's graphical user interface (Figure 3). They could also opt out of Auto-DR by switching the system button from 'On' to 'Off' via the CPO. The opt-out can be pre-scheduled via Akuacom's DRAS client interface to address the site's special needs.

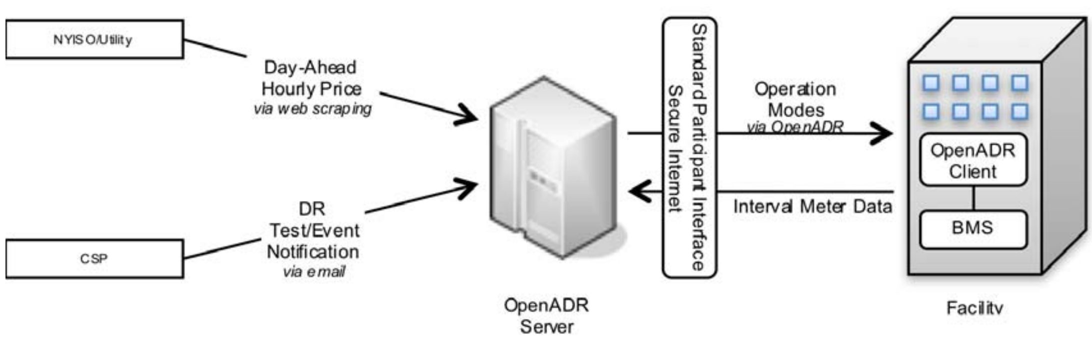


Figure 2 System architecture showing the DR signals, DR automation service, interface, facility client and automation systems.

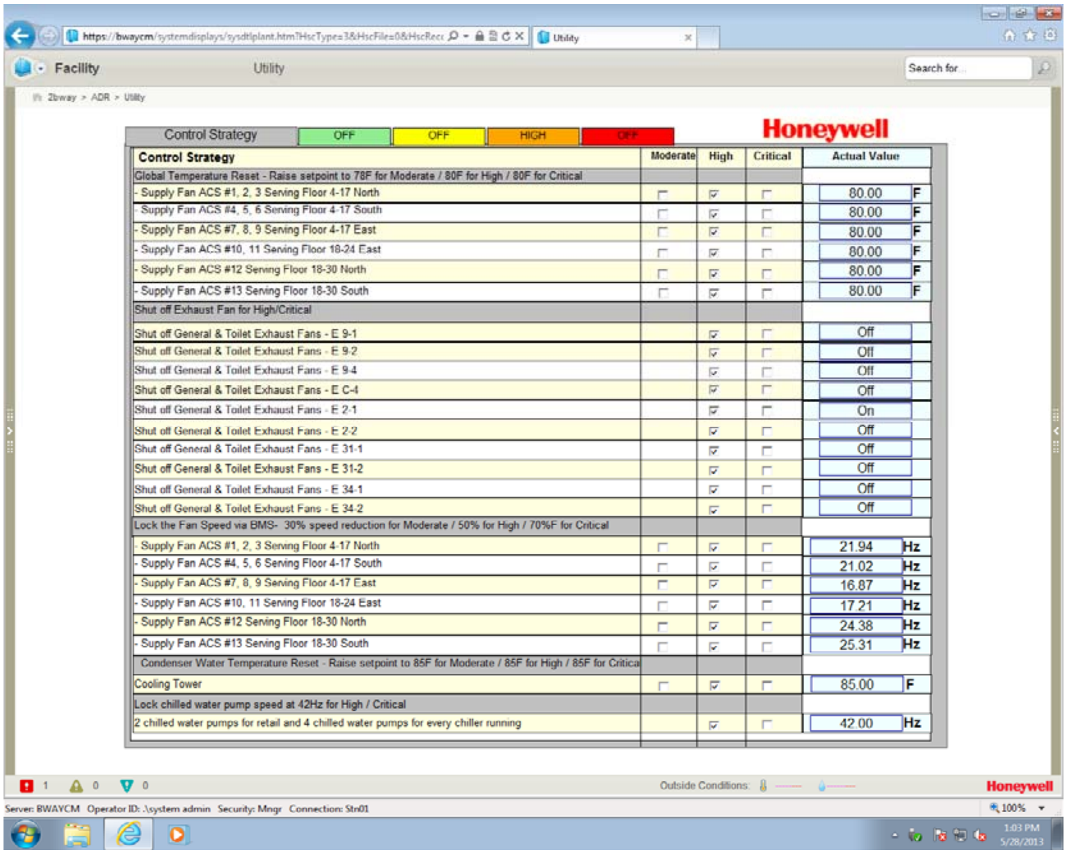


Figure 3. A screenshot of the Open Plant Controller used for communication and control of pre-programmed load-shed sequences, and specific equipment enrolled in each sequence. Users could use check-boxes to opt out specific pieces of equipment.

## Control Strategies

Based on the existing control strategies previously used for DR events, LBNL developed shed strategies that were appropriate for each site. Only the strategies that could be automated were chosen and grouped into three levels of shed response: Moderate, High, and Critical. Pre-cooling was considered as a load shifting strategy but could not be automated due to the NYC Fire Code requirements to have a licensed engineer on site for chiller start. To minimize possible post-DR rebound peak electric demand, the equipment was returned to the normal operation in a controlled and sequential manner.

Table 3 shows the shed strategies for all four participating sites. All automated control strategies were related to HVAC control due to the easy integration with the existing BMS. Centralized lighting control was not available through the existing BMS in these sites. Due to the increased cost and potential for project delays, the project team decided not to automate lighting control for this demonstration.

Table 2. Automated control strategies for demonstration sites

| Facility | Operation Mode | Global temperature adjustment | Precooling | Supply fan speed reduction | Exhaust fan quantity reduction | Chilled water temperature increase | Chilled water pump speed reduction | Shutting off chilled water pumps | Chiller quantity reduction | Condenser water temperature increase | Shutting off condenser water pumps | Slow recovery | Sequential equipment recovery | Extended DR control Period | Turning off lighting in auxiliary space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Office Building A | Critical | x | x | x | x | x | x | x | x | x | x | x | x | x | P* |
| | High | x | x | x | x | x | x | | | x | x | x | x | x | |
| | Moderate | x | | x | | x | | | | x | x | x | x | x | |
| Office Building B | Critical | | | x | x | | x | | | x | | x | x | x | |
| | High | | | x | x | | x | | | x | | x | x | x | |
| | Moderate | | | x | | | x | | | x | | x | x | x | |
| Office Building C | Critical | | | x | x | | | x | | | | x | x | x | |
| | High | | | x | x | | | x | | | | x | x | X | |
| | Moderate | | | | x | | | x | | | | x | x | x | |
| Campus Building | Critical | x | x | x | x | | | | | | x | x | x | x | P* |
| | High | x | x | x | x | | | | | | x | x | x | x | P* |
| | Moderate | x | | x | | | | | | | x | x | x | x | P* |

## Results

### Price Responsive Load Management Tests

Over the course of the 2013 summer and fall seasons, the project team ran a total of 16 test events that were triggered by day-ahead hourly location based marginal price signals (LBMP). During the test periods for each building, LBNL researchers set price thresholds that generated a combination of Moderate and/or High operation modes for the next day's operation. The DRAS web interface processed both LBMP and price thresholds, and then triggered any combination of the operation sequences. The server also observed server/client communications in real-time, and created a historical log. Load shed was captured through whole-building interval metering, building automation systems, and Akuacom's demand response automation server.

Figure 4 below summarizes occurrences of both whole-building and system level opt-outs of load-shed events. The data collected over the course of the test period highlight the fact that although all participating sites were concerned with both whole-building and individual system opt-out capabilities, only 2 of the 4 buildings used the functionality to opt out. Furthermore, it was observed that although all building owners requested the feature of individual system opt-out control, only 1 building owner actually made use of it.

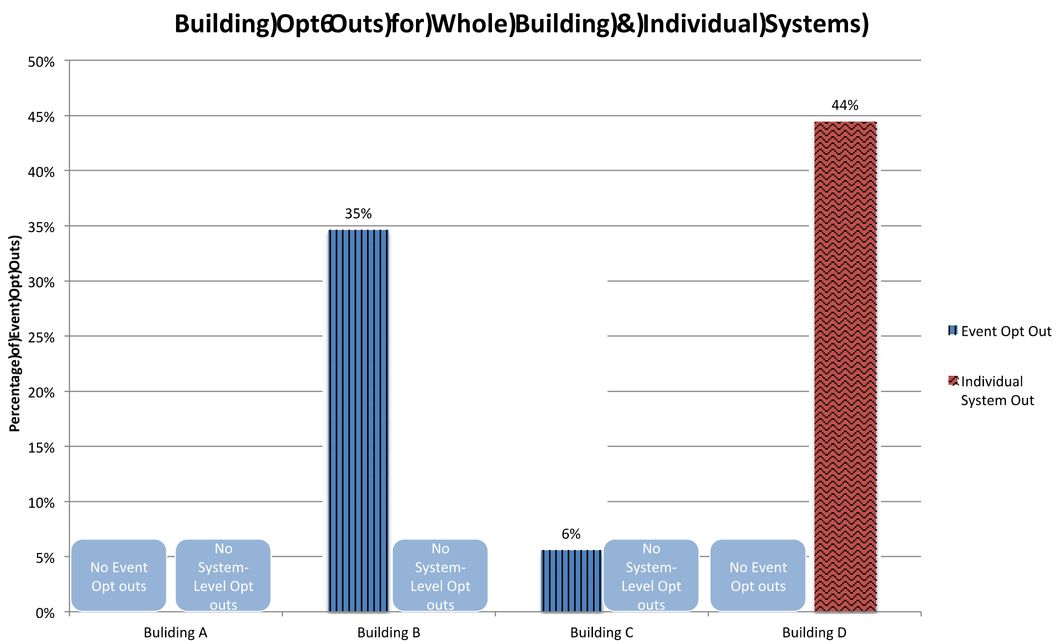


Figure 4. Occurrences of building opt-outs from load-shed events.

## Customer Feedback

Following the completion of load-shed test events, the project team conducted a series of interviews with each of the participating sites. Feedback was relatively homogenous in the praise of simplicity of opt-out control, as well the requirement of allowing operator overrides when necessary. The following list summarizes lessons learned from the participant interviews.

- Overcoming fear of discomfort is critical to adoption of automated load-shed strategies. Although not always used, granular control allays fears of discomfort and backlash from occupants or tenants.
- Portfolio managers have to offer building level management staff granular control beyond low, medium, and high. Intricacies of occupancy, staffing, and user requirements demand controls at the zonal or equipment level.
- Building or portfolio managers don't consider DR automation strategies as opportunities to take advantage of MHP or demand management savings. This is due to a combination of operator training and inadequate technology.
- As diversity in space usage and schedule increases, so does the granular control requirement. Changes in occupancy schedules can change tolerance to service interruption, thus easily configurable control is required.
- Building managers tended to prefer automatic enrollment with options to ‘opt-out’ as opposed to ‘opt-in’ controls.
- On larger campuses, building engineers often travel between buildings, so a web-accessible portal for opt-out control is important.

- Cost savings can be viewed as equally important as energy savings, but priority can depend on institutional mandates.
- Automation capabilities compatible with Auto-DR should be considered in portfolio design guidelines, and owner requirements documents.
- There are often bandwidth limitations on legacy control systems, and requiring frequent data trending or other communication may slow control systems.

## Conclusions and Recommendations

This project focused on demonstrating how OpenADR can automate and simplify interactions between buildings and various stakeholders. It also demonstrated that granting building management staff more visibility and granular control of specific systems could allay fears of lapses in service or loss of control.

The findings from this project reaffirm the notion that though many building operators misunderstand Auto-DR and are reluctant to give up control of building operations, enabling equipment-specific or zone-level control for opt-out or offering modified load-shed strategies increases willingness to participate in load-shed events. Furthermore, the team observed that understanding the cost savings and demand management benefits and broader potential of automated demand management strategies beyond basic Demand Response programs, led portfolio managers to consider incorporation of automation capabilities into portfolio design guidelines.

The demonstrations and findings of this project show clear benefits of automation technology and participation in DR programs. There are, however, barriers that must be overcome before grid-responsive automation is widely adopted. Building managers are often weary of computing and data transfer requirements slowing down antiquated legacy control systems networks, and future research will address latency and communication bandwidth requirements. Furthermore, though some building managers may already understand the value of automation, their reluctance to adopt is not driven by misunderstanding of Auto-DR technology, rather by the high costs of programming legacy proprietary controls platforms.

Although applications of load-shed strategies are clear for Demand Response programs, automated load control capability is also valuable in increasing adoption of variable priced energy contracts. The team found that most building owners shied away from variable priced and indexed retail contracts in favor of fixed price supply, to hedge against price fluctuations, and to maintain more certainty in energy expenditure forecasts. Through our project, we demonstrated that automated price response enabled customers to actively respond to price fluctuations in day-ahead indexed markets. This active response and management both removed the burden of manually monitoring hourly prices, and provided a safeguard against spiking demand and consequent high costs. This level of demand and expenditure control can serve as a critical tool in increasing adoption of dynamically priced retail contracts, and thus increasing economic efficiency of retail energy markets.

Demand response interfaces need to be simple but transparent and convey the fact that automation does not mean losing control of a facility. There is a research need in this area to understand and evaluate how to provide enough information for decision making but also enough automation to simplify taking action without confusing or deterring facility operators.

## Acknowledgements

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