Scaling Demand Response through Interoperability in Commercial Buildings

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Abstract

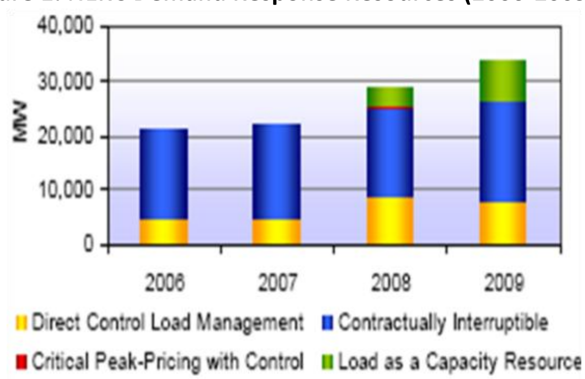
Roughly half of the peak demand in the United States comes from commercial buildings. In addition, the key decision-makers in the commercial sector are better informed and in control of larger load reductions than a homeowner. Yet, to date, most of the discussion and early activity surrounding the smart grid has focused on residential applications, with a majority of the funding being directed to advanced meters and utility-side technology.

This paper argues that commercial buildings will be central to a scaling up of demand response to levels that significantly reduce costs, mitigate environmental impacts, increase reliability and balance intermittent resources of an electric grid that is changing quickly. But "business as usual" will not be acceptable to building owners, who are requiring attractive financial returns, insisting on maintaining control of facility systems, and unwilling to add to the workload of already burdened operations staff. Technology in the building will be crucial to meeting all three criteria.

1. SCALING UP DEMAND RESPONSE THROUGH COMMERCIAL BUILDINGS

The North American Electric Reliability Corporation (NERC) estimates demand response resources today to be 32 GW, or about 4% of peak load in the U.S. and Canada.i As shown in Figure 1, most of this load is enrolled under two program mechanisms that have been in place for decades: direct load control (e.g. utilities can remotely cycle off residential air conditioners) and contractually interruptible tariffs (e.g. large load customers receive low rates in exchange for contracting to curtail load when requested by utility).

Figure 1: NERC Demand Response Resources (2006-2009)



Because neither of these approaches requires new technology or represents a new option to customers, it could be argued that they have reached saturation points and will not see considerable escalation in the future. An anecdotal example is the municipal utility in New Bern, North Carolina, where over 60% of residential customers are enrolled in a 20-year-old direct load control program.[ii]

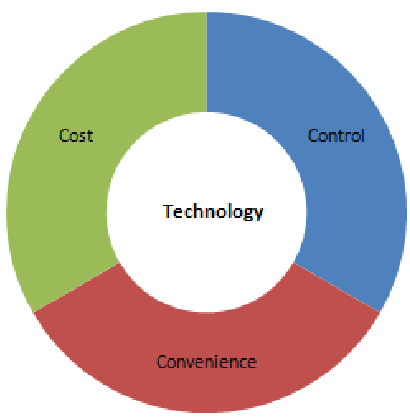
In contrast, the recent growth in the "Load as Capacity" category suggests the rise of a new paradigm for DR – one with the potential to scale up demand response to play a larger role in the electric system of the future. Within this category, participants bid into wholesale markets alongside conventional power plants. This type of demand response falls under the U.S. Department of Energy categorization of "incentive-based" DR, as opposed to "price-based" DR, the even more nascent but promising approach including real-time pricing and other dynamic pricing configurations.[iii]

Some incentive-based and price-based programs are in an early phase of market maturation, but hold great potential. Scaling up both types of programs will allow DR to reach its full potential for avoiding costs, increasing reliability and reducing the environmental impact of the electric system.. In the United States, this scaling will not be possible without the participation of the 4.8 million commercial buildings[iv] that contribute nearly half of peak demand today.[v]

> **Definition of Commercial Buildings:**
> "Commercial buildings include all buildings in which at least half of the floor space is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship."
> -US Energy Information Agency
> Source: www.eia.doe.gov/emeu/cbecs/

In order to attract significant commercial sector participation, demand response must continue to evolve. Programs must appeal to large buildings along three important dimensions: cost-effectiveness, control, and convenience. For each of these factors, technology in the building will play an enabling role.

Figure 2: Major Factors Driving Commercial Participation in Demand Response Programs



Technology, already a critical part of modern energy management, will be central to demand response participation in commercial buildings. It provides a means of instantaneous information and communication, quick and automated load shed, and built-in measurement systems. Displays and dashboards can empower building operators with demand response notifications, information and ultimate control over participation. Communication systems can provide a direct link between the grid and the energy-consuming equipment. Smart meters and building management software can model, monitor and measure energy use. At every step of the process, from receiving notification to verifying the results, technology provides commercial building operators with an easy, cost-effective demand response opportunity that allows them to maintain control with limited time commitment.

2. COMMERCIAL BUILDINGS REQUIRE COST-EFFECTIVE OPPORTUNITIES

The chief concern for building owners considering demand response is the economics. In a recent global survey of decision makers in commercial buildings, 97% identified cost savings as having a "very significant" influence on energy efficiency decisions.[vi] The bottom line likewise influences decisions to alter energy use patterns in response to signals from the grid.

In order to reach scale through commercial buildings, DR must provide a compelling business case. The basic financial calculation for demand response is identical to that used in all business decisions: a comparison costs and benefits.

The degree to which the benefits overcome the costs is the basis for the decision to participate, typically represented by a metric like Return on Investment (ROI), Internal Rate of Return (IRR) or simple payback. Thus, the trigger for participating in demand response depends on whether a threshold of cost effectiveness is met (e.g. simple payback less than 3 years).

2.1. Costs

For most of the common DR programs in existence today, the upfront cost to the customer is zero (implementation is typically either a direct control technology owned and installed by the utility or executed manually), and the ongoing costs vary widely.[1] The complexity of commercial buildings today makes manually participating in an event very costly, requiring staff time to implement load reductions (shutting down equipment, switching off circuit breakers). In addition, the capacity for error in manually executing load reductions can lead to even greater costs, such as facility operation problems or unexpected losses in productivity. By investing in technology to automate the response to signals from the grid, the building owner is able to minimize the ongoing cost of participation. Like investments in energy efficient technology, the automated demand response

1 This figure can vary widely. In the case of energy-consuming equipment that is switched off remotely (Direct Load Control), there is negligible cost to the customer. On the other hand, a building that must dispatch operations staff to switch off lights or alter settings on equipment could see very high costs of participation.

analysis becomes a question of initial cost versus payback over time.

Although automating demand response means lower costs on an ongoing basis, it requires more investment of both time and money at the beginning. In addition to the purchase, installation and commissioning of the information and control technology, the building ownership must invest in design and engineering to identify specific strategies for reducing load shed. Investing in equipment will typically stimulate a more careful and deliberate upfront articulation of DR logic and policies than would be performed under manual participation.

Leveraging existing tools to manage response to DR events can reduce the up-front costs. For example, building management systems can be programmed to receive DR signals and automate load shed responses accordingly. The cost of automation can be reduced to (1) internet connectivity, (2) "middleware" that can listen to, interpret and relay signals from the grid, and (3) the programming of existing systems to respond. Most modern control systems allow building operators to pre-program load-reducing operations; advanced controls can help integrate DR into a broader energy management optimization strategy.

Pilot programs carried out by Lawrence Berkeley National Laboratory in the last several years have followed this approach in order to implement fully automated demand response solutions in large buildings, the majority of which were already outfitted with energy management control systems. In Northern California, typical costs of automation for large facilities (>200 kW) were found to be between $3,000 and $5,000 per building.[vii] A separate pilot in the Pacific Northwest found similar costs, with an average cost of $4,000.[viii] These figures show that the cost of automating demand response could be relatively small in comparison to the energy efficiency investments typical of large buildings, which range from tens of thousands to millions of dollars. However, the pilot programs provide a limited sample, and one that is biased toward buildings with control systems already in place.

2.2. Benefits

At a system level, demand response provides significant financial benefits. Pike Research estimates that the total financial incentives paid for demand response in the U.S. will grow from $1.4 billion in 2010 to over $8 billion in 2020.[ix] A portion of this benefit will be passed on to participants as either incentives or bill savings. As technology makes the building more autonomous and less reliant on third-part service providers, a higher proportion of the value created by the load reductions will flow to the building owner. In this way, automating technology increases the financial upside of participation in demand response programs. This shift will be an important factor in scaling up DR resources in the commercial sector.

Returning to the (limited) available empirical data, the PG&E pilot project reported an average savings in energy bills (customers were enrolled in a critical peak pricing program) of $1,776 per summer and a median simple payback period of 2.25 years.[x] Within this pilot setting, automation of demand response falls well within most building owner's criteria for acceptable payback periods, found on average in a recent global survey to be 3.1 years.[xi]

The cost-benefit calculation is the most important factor for commercial buildings considering demand response. With automating technology, ongoing costs are dramatically reduced, leaving a small upfront cost that is offset by monetizing the value created by load reductions. The potential result is increased participation from commercial buildings and large scale demand response resources.

3. BUILDING OPERATORS IN CONTROL

While residential customers may be comfortable with programs that remotely control load reductions within their buildings, any demand response program targeting the commercial sector must allow for flexibility and control at the facility-level to attract significant participation.

Approaches with long histories and more extensive market share, such as direct load control (DLC) and interruptible tariffs for large industrial customers, typically require the customer to forfeit control to the program administrator. For many commercial buildings, the need to support and control business processes and the central mission of the organization will incline owners toward a more autonomous model. Facility managers are reluctant to reduce cooling loads if doing so would decrease occupant productivity. Because conditions and criteria are constantly changing, commercial buildings need to stay flexible by retaining control over their equipment.

This requirement to control their participation in demand response events can be illustrated in the form of an entire spectrum of demand response programmatic approaches. Figure 3 presents a "spectrum" of demand response program options, ranging from complete central control to complete autonomous control. All types of demand response mechanisms, from price-based to incentive-based programs in both wholesale and retail power markets, can be categorized in terms of the division of control between building operators and program administrators. Customers can choose to enroll in one or more programs by contracting with utilities, independent system operators, or third-party curtailment service providers (for a related discussion on control in demand response program architectures, see Koch and Piette).[xii] It is important to note that customers must enroll in these programs; they are not mandatory.

Figure 3: The Spectrum of Demand Response Control

	Central Control			Autonomous Control
	• Direct Load Control	• Interruptible Tariff • CSP Capacity Programs • Emergency Programs	• Critical Peak Pricing • CSP Energy Programs • Voluntary Demand Bidding	• Real Time Pricing • Direct Bids into Wholesale Markets
"Call Events"	Administrator	Administrator	Administrator	Customer
"Opt in/out"	Administrator	Administrator	Customer	Customer
"Flip Switch"	Administrator	Customer	Customer	Customer

	Administrator Utility , Independent System Operator, or Curtailment Service Provider	**Customer** Residential, commercial or industrial entity with potential to deliver peak kW reductions
"Call Events"	Administrator determines time and duration of requested reductions.	Customer decides when to trigger action in response to price signals from the grid.
"Opt In/Out"	Administrator contractually requires reductions each time they are needed.	Customer is free to participate in specific DR events or do nothing.
"Flip Switch"	Administrator directly switches off equipment within a customer's facility.	Customer takes actions to reduce load during events.

Under any demand response program, there is a distribution of ownership of the tasks of calling curtailment events, determining whether or not the site will respond, and physically triggering the load reduction. The various levels of control displayed on the spectrum differ in their allocation of these tasks. On the left of the spectrum, a direct load control program allows the administrator to call the event and trigger curtailment in specific equipment without any involvement from the customer. On the other extreme, a pure real time price allows the customer to "call events" by choosing the appropriate responses to pre-identified price thresholds, then manage the tradeoff between energy costs and other business objectives.

It is important to point out that each extreme on the spectrum has benefits, and each demand response configuration is likely to attract a particular market segment. From a utility or grid operator perspective, central control is appealing because it allows the administrator to simply "push a button" and be assured of the resulting decrease in load.[2] While this model allows the utility to retain control of DR events and responses, it does not necessarily lead to dependable reductions because many customers may have already reduced their loads. Because all of the risk and expenditures in such a configuration fall on the implementer of the program, it is logical that they also retain most of the resulting benefits. This approach has found most success among customers willing to turn over control of their equipment, such as a homeowner.

In contrast, the autonomous control approach places the full share of both risk and reward on the participant, who must optimize electricity use for cost under each event or on an hourly basis. This flexibility is attractive to building owners with occupant comfort and productivity as the top priority. In addition, autonomous approaches remove utilities' and administrators' fine-grain control on the system, but there is debate over whether or not these programs are less predictable. Portfolio and risk management over all participating customers, for example, can effectively mitigate the uncertainty of individual participants. Day-ahead DR bidding or registration can also reduce uncertainty, allowing the utility to plan for the combined effect registered buildings will have on the overall demand curve. These programs, however, must achieve scale in order to be reliable in resource planning.

2 The effectiveness of a DLC program depends on the state of the equipment before the event is called. For example, a utility that switches off air conditioners would not see a decrease in demand if all the air conditioners were already switched off. However, implementing direct control at scale (e.g. many air conditioners) can increase the reliability of the load reduction.

Commercial customers are beginning to see the benefits of autonomous control and the markets are changing as a result.[xiii] But the lack of resources at most facilities to actively manage electric load has created a market for demand response services, characterized by firms known as curtailment service providers (CSP's). Working with one of these service providers, a customer can give up some degree of control and a portion of the financial benefits in exchange for added convenience. As technology in buildings leads to more convenient and cost-effective demand response, building operators will also have the ability to maintain direct control over their participation.

4. CONVENIENCE IS CRUCIAL FOR BUSY OPERATIONS STAFF

Even when the economics are attractive and the program mechanism provides the building operator ample control, demand response will not be practical if it places large burdens on operations staff. In many cases, facility departments are already pressed for time to maintain existing equipment, practice preventative maintenance, and cater to the changing needs of building occupants. Adding an extensive set of tasks associated with ongoing demand response participation is simply not an option.

Designing a DR program that effectively balances control and convenience for DR participants can be challenging. Here again, technology can help. Communications, control and metering technology allow building owners to predetermine their strategy for demand response participation, pre-program logic and actions into building automation systems, and allow the facility to execute this strategy "on autopilot." This approach allows operations staff to maintain control over their systems at all times because they create the response strategy that works for their building, revise it over time, and always retain the capability to "opt out" of an event and return all systems to normal operation (although—depending on the program under which they are enrolled—their contract could include penalties for non-performance). Automated systems also enable advanced performance measurement and verification with more accurate and consistent energy consumption and curtailment data. Along with the added ease of participation, automation technology can assure quality and consistency compared to a scenario in which human operators perform the load reduction tasks.

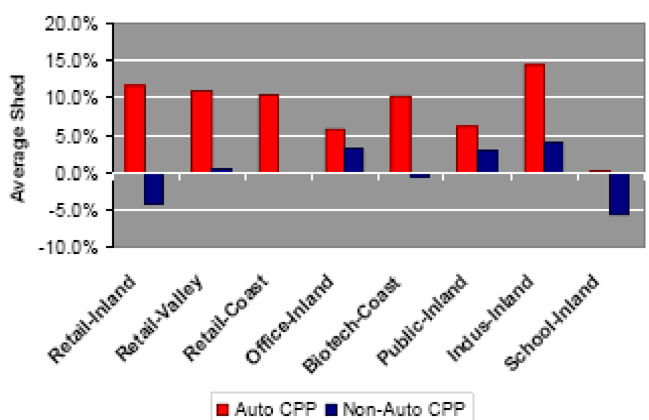
One example of technology providing greater convenience for commercial building operators is Integrated Demand Response (IDR). The subject of a recently awarded research grant from the U.S. Department of Energy, this technology will exchange price and demand signals with the utility, calculate curtailed load, and generate load profile forecasts while maintaining a consistent level of comfort within the building.[xiv]

Empirical evidence confirms the theory that technology can make DR participation convenient and therefore attainable for commercial buildings. Two pilot studies of sites with dynamic electricity pricing have shown that commercial and industrial facilities equipped with automation deliver higher average load reductions than those without:

A large and comprehensive study on dynamic pricing in California showed that large commercial and industrial customers with automation technology reduced demand by an average of 10%, compared to 5% for sites without such technology.[xv]

An Automated Demand Response pilot in PG&E found that commercial and industrial sites with automation responded to a Critical Peak Price (CPP) with greater magnitude and consistency than those without automation. As shown in Figure 4, this trend held across several building types and climate regions.[xvi] Even though customers were enrolled in the same program (CPP), it should be noted that operators at the automated facilities made a deliberate choice to curtail load, representing a selection bias in these results.

Figure 4: Load reduction from automated and non-automated facilities



In complex commercial buildings, the convenience afforded by technology will be an important enabler for widespread acceptance of demand response. If participation adds prohibitive cost or workload, buildings simply will not participate.

5. CONCLUSIONS AND RECOMMENDATIONS

The three factors for effective scaling of demand response in commercial buildings—cost, control and convenience—are all highly interconnected, but clear tradeoffs exist among them. Convenient solutions (e.g. Direct Load Control) might be unacceptable to building operators, while increased control at the facility level might raise costs of ongoing participation.

Technology, particularly at the building level, provides an important link to making DR attractive from cost, convenience and control perspectives, empowering building owners to achieve significant peak load reductions on their own terms. Several factors will enable and accelerate the scaling up of demand response among large buildings:

Emphasis on the Commercial Sector:

In order to increase DR program participation in a cost-effective manner, prioritizing market segments is important. Commercial buildings are an enormous resource for demand response; yet most of the dialogue in the smart grid community centers on the residential sector and a majority of government funding has been directed to meters and utility-side technologies.[xvii] Commercial buildings, particularly large buildings equipped with facility management personnel and building management systems, represent low hanging fruit for DR growth. As a result, commercial buildings should be a central part of any plans to increase demand response capacity and realize the benefits of a smart grid.

Open standards supporting demand response.

Both technical and business process standards provide stable foundations for increasing the number of buildings that participate in demand response programs. Technical standards "enhance interoperability and communications between system operators, DR resources and systems that support them."[xviii] One of the leading open standards is OpenADR,[xix] which defines the signaling of price and emergency events between the grid and the building. By communicating via an open standard, DR program administrators lower the barriers to entry. In addition, standards that concern business processes, such as measurement and verification, also will be vital for building owners and operators to accurately and consistently measure load shed, and for utilities to compensate them accordingly. If standards are not uniform, commercial companies with facilities across diverse geographies may opt out of DR programs due to the complexity. As stakeholders work together to develop and implement open standards, the commercial building sector will be able to respond at scale.

Supportive market structures:

Recent work in some wholesale and retail markets has placed demand response resources on a more equal footing with electricity supply. While these efforts are a move toward more efficient, dynamic market structures, there is still a significant gap. Commercial buildings will not be able to realize the full benefit of actively managing loads in response to grid conditions without a truly dynamic price of electricity. Largely under the jurisdiction of state regulators in the U.S., dynamic pricing is a crucial companion to the technology innovation for a "smart grid." Similarly, commercial buildings should have the ability to participate directly in wholesale energy markets, which will lead to more dynamic and responsive wholesale power markets.

Technology Incentives:

In the near term, uncertainty about the technology and financial benefits of demand response make building owners reluctant to invest in automation. To the extent that innovative utility programs and government incentives can reduce the initial cost to the customer, more data will be accumulated and fully automated demand response will gain momentum towards widespread commercial adoption. Recent research shows that facilities implementing DR programs become more aware of potential energy savings opportunities and are more inclined to implement energy efficiency measures, and building controls systems can serve to both maximize energy efficiency projects and manage DR events. This could justify the use of ratepayer energy efficiency funds for automation technology.[xx]

Customer Education:

As DR programs evolve to more effectively incent participation from commercial buildings, education and outreach will be necessary for widespread enrollment of these customers. Many building operators are unaware of the economic opportunities associated with DR participation, and most of them lack knowledge on required technologies, communication devices, and overall expectations of programs. LBNL's demonstration project in Seattle, for example, required extensive recruitment and education initiatives to get each customer comfortable with the idea of DR.[xxi]

Biography

Kelly Smith supports energy and sustainability efforts across the global Building Efficiency business of Johnson Controls. As part of the Institute for Building Efficiency, he conducts original research and collaborates with leading thinkers on how the built environment can become more efficient and sustainable. His areas of interest include managing greenhouse gas emissions across large portfolios, integration of energy efficiency, renewable energy and demand response and the role of technology and information in optimizing buildings. In addition to his work with the Institute, Kelly provides research and analysis for strategy, business development, and new product design efforts at Johnson Controls.

Prior to joining Johnson Controls, Kelly provided consulting services in the fields of energy efficiency and demand response. He has contributed to several key papers analyzing the potential for meeting electricity challenges with solutions on the customer side of the meter, and has assisted utilities across the United States in developing programs to reduce energy use and peak demand among their customers.

Kelly received an MS in Nuclear Science from Massachusetts Institute of Technology and a BS in Physics from Brigham Young University.

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