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Automated Demand Response Technologies and Demonstration in New York City using OpenADR

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Abstract

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 improvement that links supply and demand. Since October 2011, the Demand Response Research Center at Lawrence Berkeley National Laboratory and New York State Energy Research and Development Authority have conducted a demonstration project enabling Automated Demand Response (Auto-DR) in large commercial buildings located in New York City using Open Automated Demand Response (OpenADR) communication protocols. In particular, this project focuses on demonstrating how OpenADR can automate and simplify interactions between buildings and various stakeholders in New York State including the independent system operator, utilities, retail energy providers, and curtailment service providers. In this paper, we present methods to automate control strategies via building management systems to provide event-driven demand response, price response and demand management based on OpenADR signals. We also present cost control opportunities under day-ahead hourly pricing for large customers and Auto-DR control strategies developed for demonstration buildings. Lastly, we discuss the communication architecture and Auto-DR system designed for the demonstration project to automate price response and DR participation.

Keywords: commercial building, demand response, dynamic pricing, mandatory hourly pricing, OpenADR, Open Automated Demand Response, price response, smart grid

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Summary

Since October 2011, the Demand Response Research Center (DRRC) at Lawrence Berkeley National Laboratory (LBNL) and New York State Energy Research and Development Authority (NYSERDA) have conducted a demonstration project enabling automated demand response (Auto-DR) in large commercial buildings located in New York City (NYC) using Open Automated Demand Response (OpenADR). This interim report details the overall project concept, objective and progress. Currently, Auto-DR functionality has been commissioned at some demonstration sites and project's time line has all sites being commissioned, tested and operational over the summer and fall of 2013.

OpenADR is an open and interoperable communication standard that facilitates smart-grid information exchange among various entities such as utilities, system operators, aggregators, energy services providers, and end-users. These interactions are defined as client-server transactions via Internet using XML (eXtensible Markup Language) data models. OpenADR is different than other demand response application protocols, like Smart Energy Profile (SEP) intended for home-based device interactions over advanced metering infrastructure (AMI) based transport. OpenADR messages are used to communicate demand response (DR) requests, energy pricing and schedules from servers (e.g., utilities, system operators, energy suppliers, etc.) to subscribing clients at customer sites. As an open specification, OpenADR can simplify the implementation of multiple signaling systems and ease the adoption of building automation. As a machine-to-machine standard, OpenADR can interact with buildings and industrial control systems that are preprogrammed to take action based on DR or price signals in a fully automated fashion with no manual intervention. As a result, the demand-side resources can be used more frequently in smart grid transactions contributing to grid reliability and robustness.

New York State's (NYS'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 Service to the New York Independent System Operator (NYISO). OpenADR supports all of the common NYISO, utility, retail energy provider (REP) and curtailment service provider (CPS) interactions with commercial customers in NYS. Individually, these interactions are not complicated. However, as the number of interactions increases, the customer's burden to respond to multiple interactions also increases. OpenADR can simplify this process by standardizing how each will present its signals in a standards-based machine readable format and making it easier for more buildings to respond in ways for the benefit of a smarter gird in NYS.

The project focuses on following:

1) demonstrate how OpenADR can automate and simplify interactions between buildings and various stakeholders in NYS including the NYISO, utilities, REPs, and CSPs;
2) automate building control systems to provide event-driven demand response, price response, and demand management according to OpenADR signals; and
3) provide cost-saving solutions to large customers by actively managing day-ahead hourly prices and demand charges.

Event-Driven Demand Response

Using OpenADR, the NYISO or utilities could publish DR event notifications including the program type, date, time, and duration as well as target type (by load zone, geographic location, or program associations). Based on the DR event information published by the NYISO or utilities, a CSP can use OpenADR to communicate a DR event to all or selected groups of program participants. A participating building can subscribe to their CSP's OpenADR signal to receive DR event information. Upon the receipt of OpenADR signals, sites can respond automatically, manually, or a combination of both. If the response is automated, OpenADR signals would trigger pre-programmed control strategies via the facility's building management system (BMS). A BMS system could also guide facility operators to manually change operations and control set points.

Price Response

The NYISO could publish wholesale (i.e. Day-ahead Locational Based Marginal Price) prices in OpenADR protocol. Utilities and REPs can receive price signals from the NYISO and determine their rates (minus adjustments) to reflect the wholesale market variations. End-users who respond to dynamic pricing can pull the OpenADR price information from a utility, a REP or the ISO via their OpenADR client and manage energy consumption accordingly. The buildings could dynamically control and optimize loads to minimize costs according to the day-ahead price variations. If the buildings do not have the ability to process the dynamic price information and make decisions about how to respond to that information, the OpenADR server can generate simple operation mode (*Normal*, *Moderate*, *High*, or *Special*) for the buildings based on the price information. The buildings can then trigger pre-programmed control strategies based on the simple operation mode.

Demand Management

In NYS, customers pay delivery charges that are largely based on the maximum demand of each billing cycle to reflect the cost of the distribution infrastructure. Typically, the delivery charges for large customers are more expensive in summer than winter and additional charges apply during peak hours. Therefore, it is important that the customers manage their maximum demand in order to reduce electricity bills. The OpenADR server can assist the building's peak load management by monitoring electric demand in real time and automate peak load reduction if the demand is nearing a preset threshold.

Auto-DR Demonstration in NYC

Four buildings were recruited for the demonstration project. Preferences were given to the buildings that represented the typical construction of large commercial buildings in NYC. All demonstration buildings previously participated in one or more incentive-based DR programs through CSPs. Prior to this project, the load reduction at these buildings was provided through manual control of HVAC, lighting, and other systems.

OpenADR Communication Architecture

Currently in NYS, wholesale day-ahead hourly prices are published in a downloadable spreadsheet format at the NYISO website and are made available from some utility websites. Today, DR event notifications are propagated via email and phone by the NYISO and CSPs. Since the NYISO, Consolidated Edison (Con Edison), and CSPs did not publish price or DR signals using the OpenADR protocol, the project team used a centralized server to mimic the transfer of these signals from these entities to the facilities using OpenADR data models. Con Edison's customers who are subject to the default Mandatory Hourly Pricing (MHP) tariff are billed under Rider M for their electricity supply. Under this rider, the cost of energy is roughly calculated based on the customer's actual hourly energy usage multiplied by the NYISO's day-ahead zonal locational based marginal price (DA LBMP). This does not account for miscellaneous charges like taxes and adjustments which do not vary hourly. To generate a standards-based machine readable pricing signals, the project's OpenADR server scrapes DA LBMP published on the NYISO's website and converts the data into OpenADR data models for each day.

For this project, DR event notifications undergo a similar conversion to machine-readable OpenADR protocol. If a CSP sends DR test/event notifications to the customer via email, the OpenADR server would receive the same email and convert the message into OpenADR signals. The customer's building automation is equipped with OpenADR client software that reads both the OpenADR signals for daily prices, day-ahead DR event notifications, and day-of DR notifications. The facility's BMS activates respective pre-programmed control strategies. The OpenADR server also collects electric meter data for monitoring purposes. All information exchange is accomplished through a secure Internet connection with 128-bit Secure Sockets Layer encryption.

Building Auto-DR System Design and Configuration

A site's Auto-DR system design and configuration depends heavily on the capabilities of existing building control systems and protocols. It is common for large commercial buildings to have several systems and devices (i.e., HVAC, lighting, electric, security, etc.) used for building operation. A centralized BMS integrates individual control systems/devices to provide greater controllability and efficiency to building managers. Installing a centralized BMS can be a seamless process if all systems/devices use an open building automation communication protocol (i.e. BacNet, Modbus, Lonworks, etc.), which facilitates interoperability between different vendors' systems. Open building automation communication protocols are a vendor-neutral standard used within a facility supporting all building systems and devices equally. (OpenADR, on the other hand, is a smart grid data protocol developed to facilitate interoperable exchange of information relating to electricity market information, transactions, etc.) The use of an open building automation communication protocol is advantageous for Auto-DR when multiple systems/devices need to respond to the same OpenADR signals. Three of the four demonstration sites' BMS use BACnet as the building automation communication protocol and one building uses a proprietary protocol.

Auto-DR Equipment Installation and Programming

Each demonstration building had a vendor-specific BMS, namely Honeywell's Enterprise Buildings Integrator, Automated Logic Corporation's WebCTRL®, Schneider Electric's Andover Continuum, and Johnson Control Inc.'s Legacy respectively. Honeywell provided the overall system design and equipment installations for the project. Programming of the Auto-DR control strategies was done by subcontractors who can program in each vendor's software. Most of the control strategies were HVAC-related, such as set-point changes and fan speed reduction. We proposed lighting strategies for two buildings in addition to the HVAC strategies. However, the lighting system was not integrated into the BMS prior to the project and additions would increase costs and further delay the project.

Conclusions and Next Steps

In this report, we provided progress updates on project by presenting customer bill control opportunities, Auto-DR implementation methods, and DR control strategies for the project's demonstration buildings. The demonstration buildings were automated to provide event-driven demand response, price response, and demand management according to OpenADR signals. Control strategies were designed to curtail customer's load as per day-ahead hourly prices and demand charges as well as DR events. HVAC control strategies were often the first to be automated because they were effective at lowering demand and they could be easily controlled through the facility's BMS. The strategies involving starting chillers during non-operational hours (i.e., precooling) could not be automated because they require a site engineer to be present by the NYC Fire Code. The implementation of Auto-DR system in demonstration buildings heavily depended on the existing control systems and communication protocols. The building systems that used an open building automation communication protocol were easier to automate than the ones used proprietary protocols because the open protocols could speak to multiple systems/devices manufactured by different vendors to activate control strategies according to OpenADR signals.

To this point, we concluded that 1) OpenADR can support the price and DR interactions defined by the deregulated and restructured market in NYS; 2) price response to day-ahead hourly pricing can be made easier through Auto-DR; and 3) Auto-DR helps customer's DR participation by eliminating human labor and costs to provide DR and making it a repeatable and error-free process.

Auto DR enablement and commissioning at all sites were completed in early summer 2013. The DR testing has taken place throughout the summer and fall of 2013.

1 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 improvement 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 they are equipped with centralized building management system (BMS). With increased adoption of interval 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. However, today most adjustments to building controls and operations are done manually, making responding to more frequent reliability events, hourly price response and 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 cost associated with monitoring and responding. It also helps customers leverage the flexibility of their buildings by automating responses to price and reliability signals. Therefore, Auto-DR can help make the grid more sustainable and cost-effective.

Since October 2011, the Demand Response Research Center (DRRC) at LBNL and New York State Energy Research and Development Authority (NYSERDA) have conducted a demonstration project enabling automated demand response (Auto-DR) in large commercial buildings located in New York City (NYC) using OpenADR. New York State's (NYS'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 Service to the New York Independent System Operator (NYISO).

The project focuses on following:

1) demonstrate how OpenADR can automate and simplify interactions between buildings and various stakeholders in NYS including the NYISO, utilities, retail energy providers (REPs), and curtailment service providers (CSPs);
2) automate building control systems to provide event-driven demand response, price response, and demand management according to OpenADR signals; and
3) provide cost-saving solutions to large customers by actively managing day-ahead hourly prices and demand charges.

The rest of the report is organized as follows. In Chapter 2, we provide an overview of DR programs in NYS's wholesale electricity markets and discuss cost control opportunities under day-ahead hourly pricing. In Chapter 3, we explain some of the key concepts of OpenADR specifications and describe how OpenADR can assist smart-grid interactions between the stakeholders in NYS. In Chapter 4, we describe general methods used for Auto-DR implementation in large commercial buildings in NYC. In Chapter 5, we describe the specific demonstration buildings and DR strategies developed for each participating building. Lastly, we summarize the key findings in Chapter 6 and suggest future research opportunities in Chapter 7.

2 Background

Prior to the project implementation, the DRRC commissioned an overview study of the wholesale and retail electricity markets in NYS; the types of DR programs; retail pricing structures; and Mandatory Hourly Pricing (MHP) [2, 3]. In this chapter, we summarize the findings from this study and discuss cost control opportunities under the day-ahead hourly pricing. The demonstration sites for this project are in Manhattan and therefore in Con Edison's service territory.

2.1 Demand Response Forms Currently Present in New York State

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).

Additionally, 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 NYS: 1) facility peak-shaving; 2) utility direct load control, 3) reliability DR programs (curtailment and distributed generation) and 4) dynamic pricing. Direct load control in NYS is a Con Edison program specific to small customers and is therefore not examined in this project, but this project will examine Auto-DR as a means of facilitating the other three. 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 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. Day-Ahead Demand Response Program (DADRP)	NYISO	Energy, Reserve and 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 respectively. 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 communicates variations in wholesale prices that may induce changes in customers' energy consumption behavior in addition to the utility tariff components such as demand/delivery charges which are not dynamic but also may induce peak shaving. Dynamic pricing exists as an optional or mandatory utility tariff, or retail third-party energy supplier contract. In NYS, MHP is the default utility service tariff for electricity for large commercial and industrial customers which indexes energy supply to wholesale market prices[1].

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[1] MHP was mandated as part of the decision made by the State of New York Public Service Commission in 2005 [4].

2.2 Barriers to Hourly Price Response in NYS

Although utilities offer MHP as the default service to large customers, NYS's retail access policy allow customers to purchase their energy from any retail third party supplier with various pricing structure as an alternative to the utility so MHP is not strictly 'mandatory'. In practice it is widely understood that NYS customers for whom MHP may apply (roughly over 500kW demand) typically contract with a REP and choose energy pricing that is not dynamic. The form of these retail supply contracts are not regulated and often are flat-price contracts. REPs represent their customers in the wholesale market as load serving entities (LSEs) for the purchase of forward capacity, forward and scheduled energy and ancillary services. This structure is intended to equitably allocate wholesale costs to customers and provide sufficient forward signals to the capacity and energy markets.

As of 2011, only 15% of the MHP-eligible customers were enrolled in MHP and the rest (85%) were retail access customers [5]. Anecdotally, it is thought that flat price contracts are compelling for customer to contract with a REP. The problem of this trend is that 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 more expensive due to the inherent risk premium of offering a less variable rate [6]. When retail prices are not tied to wholesale market variations, they can "inefficiently increase the level of peak demand by underpricing" electricity and can also "discourage increased demand during off-peak hours by overpricing it" [9]. 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 (LBMPs). Thought 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.

The recent report by KEMA identified the primary barriers to the adoption of MHP and indexed retail contracts as insufficient resources to monitor hourly prices and inflexible labor schedule [5]. 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 stay with 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 a function of the market and 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. Moreover, potential savings and ways to achieve it should be clearly communicated to customers.

2.3 Cost Control Opportunities

Day-Ahead Hourly Price Management

Customers' electricity bills are made up of a number of different charges but they can be generalized into three large categories: supply, delivery, and miscellaneous charges. MHP is used to calculate the supply portion of electricity bills for large commercial customers unless the customer purchases electricity from a retail energy supplier. Con Edison's customers who are subject to the default MHP tariff are billed under Rider M for their electricity supply. Under this rider, the cost of energy is calculated based on the customer's actual hourly energy usage multiplied by the NYISO's day-ahead zonal locational based marginal price (DA LBMP) [7]. The price variation in DA LBMP is perceived by customers to be wide and unpredictable. Although a market is inherently unpredictable, our analysis over a year ending August 2012 revealed a different story: 1) DA LBMP stayed within a narrow range most of the time and 2) spikes in DA LBMP were concentrated on cooling and heating dominated hours. Following figures support our findings. Figure 1 displays the price duration curves of DA LBMP for Zone J: NYC between September 2011 and August 2012 [8].

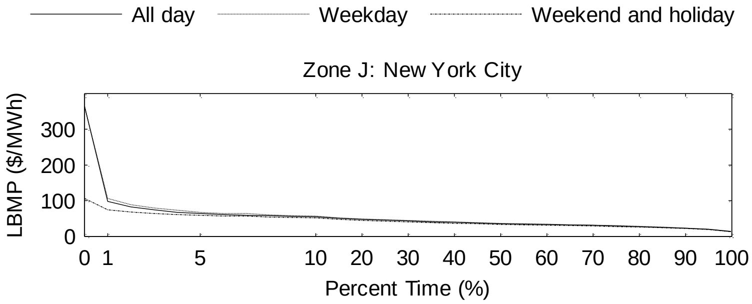

Figure 1. Price duration curves: New York City LBMP from Sept 2011 to Aug 2012

DA LBMP did not vary significantly between weekdays and weekend/holiday. The price mostly stayed below $100 per MWh. Deviation from that was only seen during the top one percent of the hours where the price increased up to $363 per MWh. When plotted against the time of day, as shown in Figure 2, it was clear that the prices corresponding to the top one percent of the hours were concentrated around cooling season (summer afternoon) and heating season (winter morning and evening).

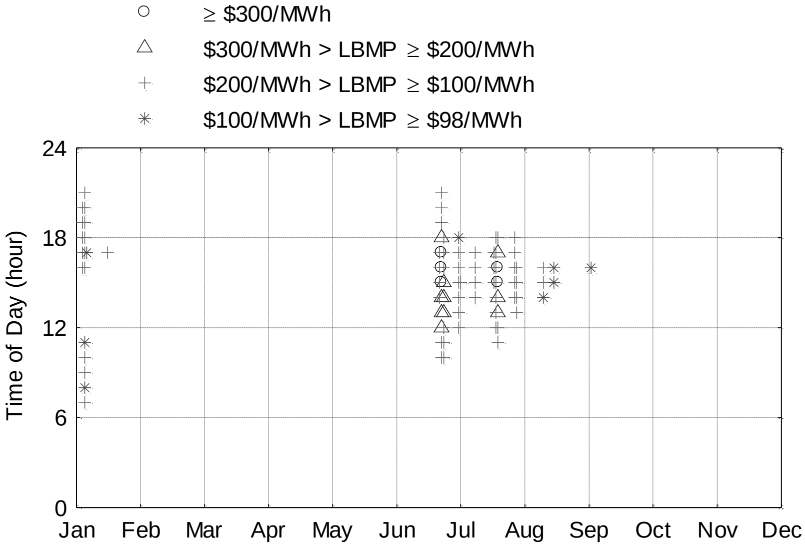

Figure 2. Distribution of New York City LBMP over month and time-of-day during the top 1% of the time between Sept 2011 and Aug 2012

Therefore, controlling loads during the top one percent of the time, over the period we analyzed, would have helped customers reduce their electricity bills were they on MHP. The same would be true for retail customers whose electricity prices were tied to wholesale market variations. Moreover, reductions in demand during peak hours by large customers can increase the efficiency of markets and reduce generating costs in the long run [9, 10].

Demand Management

In addition to supply charges, large customers under Con Edison's Service Classification 9 (SC-9) or those with a retail energy supplier pay delivery charges to utilities for the delivery of electricity [11]. Table 2 shows the table of Con Edison's delivery charges under SC-9, Rate II – Time-of-Day applied to customers whose monthly maximum demand exceeds 1,500 kW.

Table 2. Con Edison SC-9 - General Large, Rate II - Time-of-Day Delivery Charges[2]

Component of Delivery Charges	Charges/Units
Demand Delivery Charges	
Summer, all days, all hours	$16.62 / kW-max demand
Summer, weekday, 8am-6pm (additive)	$8.28 / kW-max demand
Summer, weekday, 8am-10pm (additive)	$15.49 / kW-max demand
Winter, all days, all hours	$5.33 / kW-max demand
Winter, weekday, 8am-10pm (additive)	$11.42 / kW-max demand
Energy Delivery Charges	
All months, all days, all hours	0.82¢ / kWh
Other Charges	
Metering Services	$/month
Reactive Power Demand Charge	$/kVar
Additional Delivery Charges and Adjustments	varies

The delivery charges have two main components: demand delivery and energy delivery. The demand delivery charges have a tiered pricing structure calculated based on the maximum demand of each billing cycle. The demand delivery charge is more expensive in summer than winter and additional charges apply during peak hours. Hence, customers need to reduce energy demand during expensive periods in order to save electricity bills. The energy delivery charge is a flat fee charged based on the total consumption of the billing cycle; therefore, customers are not penalized for one-time peak demand for this charge. Additional charges such as metering, reactive power, and payment processing fees are applied to include the cost of the distribution infrastructure that the utility must maintain.

<u>*Sample Case*</u>

A sample breakdown of customer's electricity bills is shown in Figure 3 and Figure 4. Figure 3 was developed based on the actual monthly electricity bills in 2011 collected from one of our demonstration buildings that purchased electricity from and is billed by the New York Power Authority (NYPA). NYPA applies Time-of-Day (TOD) rates to calculate the supply portion of electricity bills. Using the customer's interval meter data from 2011, we created shadow bills as if this customer had taken service and had been billed by Con Edison in 2011 under the MHP tariff (SC-9 with Rider M) shown in Figure 4. The numbers are shown in percentage where 100% represents the total annual electricity cost in 2011. The charges are grouped by seasons and the type of charges.

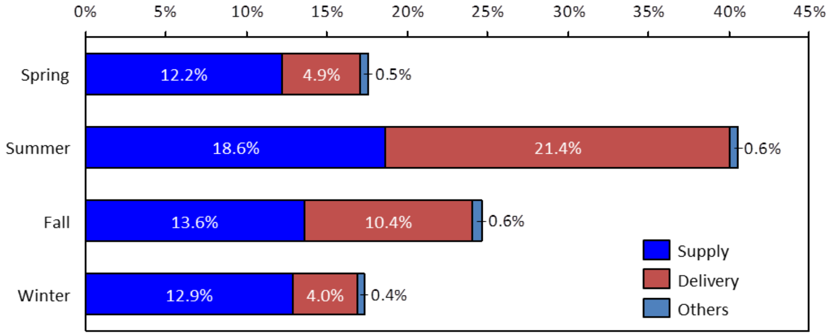

Figure 3. NYPA: actual electricity bill breakdown for a sample office building in 2011[3]

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[2] effective as of 04/01/2012, available at http://www.coned.com/documents/elecPSC10/SCs.pdf

[3] Spring includes March, April, and May. Summer includes June, July, and August. Fall includes September, October, and November. Winter includes December, January, and February.

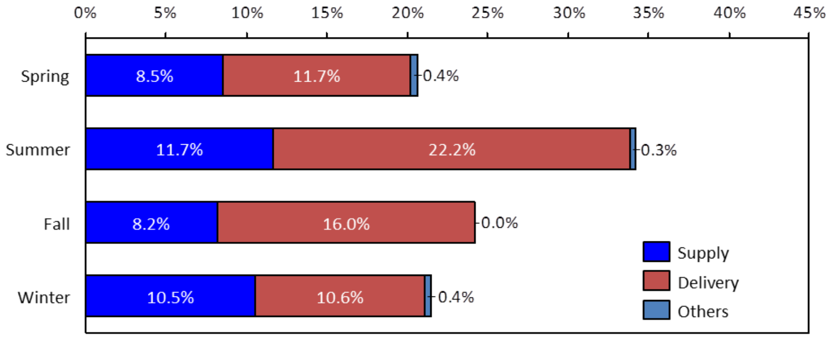

Figure 4. Con Edison: predicted electricity bill breakdown for a sample office building in 2011

Some of the key observations are summarized below.

- Despite of the concerns of being subject to hourly price variations for energy supply, the biggest share of the customer's annual electricity cost was delivery (60.6%), not supply (38.9%) over the one-year period we analyzed. Delivery consistently outweighed supply in all four seasons under the Con Edison's MHP scenario.
- In the case of NYPA, most of the delivery charges came from summer months, representing about 20% of the total annual electricity cost. Under NYPA, the customer paid more for supply (57.3%) than delivery (40.7%) for this year.
- Supply cost can be controlled by optimizing energy usage according to price variations and delivery cost can be controlled by managing peak demand during expensive periods.
- OpenADR can help customers reduce their energy bills by automating price response and peak shaving.

It is worth noting that all of our demonstration buildings purchase electricity from a retail access supplier with a flat rate and are not on Con Edison's MHP tariff, though the one building taking their supply from NYPA was on a time-of-day rate. For the purpose of the project, we assumed that the demonstration buildings purchased electricity under Con Edison's MHP tariff and therefore exposed all of their consumption to the day-ahead hourly price variation of MHP.