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ABSTRACT

For decades, policymakers and program designers have gone on the assumption that large customers, particularly industrial facilities, are the best candidates for real-time pricing (RTP). This assumption is based partly on practical considerations (large customers can provide potentially large load reductions) but also on the premise that businesses focused on production cost minimization are most likely to participate and respond to opportunities for bill savings. Yet few studies have examined the actual price response of large industrial and commercial customers in a disaggregated fashion, nor have factors such as the impacts of demand response (DR) enabling technologies, simultaneous emergency DR program participation and price response barriers been fully elucidated.

This second-phase case study of Niagara Mohawk Power Corporation (NMPC)'s large customer RTP tariff addresses these information needs. The results demonstrate the extreme diversity of large customers' response to hourly varying prices. While two-thirds exhibit some price response, about 20% of customers provide 75-80% of the aggregate load reductions. Manufacturing customers are most price-responsive as a group, followed by government/education customers, while other sectors are largely unresponsive. However, individual customer response varies widely. Currently, enabling technologies do not appear to enhance hourly price response; customers report using them for other purposes. The New York Independent System Operator (NYISO)'s emergency DR programs enhance price response, in part by signaling to customers that day-ahead prices are high. In sum, large customers do currently provide moderate price response, but there is significant room for improvement through targeted programs that help customers develop and implement automated load-response strategies.

Introduction

Since the inception of real-time pricing (RTP) tariffs, policymakers and program designers have assumed that large customers, particularly industrial facilities, are the best candidates for these tariffs. This assumption is based partly on practical considerations (large customers can provide potentially large load reductions) but also on the premise that businesses focused on production cost minimization are most likely to participate and respond to opportunities for bill savings. Yet, although several studies have examined the actual price response of large industrial and commercial customers (Boisvert et al. 2003; Braithwait & O'Shealy 2001; Goldman et al. 2004a; Herriges et al. 1993; Schwarz et al. 2002; Zarnikau 1990), there have been limited attempts to disaggregate results, and the impacts of such factors as demand response (DR) enabling technologies, simultaneous emergency DR program participation and barriers to price response have not been fully elucidated. Furthermore, previous studies examined response to RTP

offered as optional service tariffs at vertically integrated utilities.¹ In light of increasing interest by policymakers in default-service RTP in regions with organized wholesale markets and varying degrees of retail choice, disaggregated information on customer adaptation and response strategies, in such contexts, are needed to understand the DR potential of default-service pricing initiatives and to identify customer market segments that would most benefit from policies designed to enhance their price response potential.

We address these information needs with results from the second phase of a case study of Niagara Mohawk Power Corporation (NMPC)'s large customer RTP tariff, adopted as the default service for the "SC-3A" class of customers with peak demand greater than 2 megawatts (MW) in 1998. The 149 affected SC-3A customers range in peak demand from 2 MW to over 20 MW and include manufacturers (32%), government/education facilities (30%), commercial and retail businesses (11%), and health care (11%) and public works (16%) facilities.

The first phase of this research (Goldman et al. 2004b) examined SC-3A customers' price response, aggregating results by three business sectors: industrial, commercial and government/education. In addition, detailed customer surveys and interviews provided qualitative information on how these customers responded to default-service hourly day-ahead hourly pricing. The second phase of this study was undertaken to follow up on questions that remained unanswered (Goldman et al. 2005). It involved a second, shorter customer survey designed to obtain targeted information from a wider base of respondents; intensive follow-up with customers provided an excellent response rate of 57%. In addition, a more flexible demand model was used to estimate individual price elasticities for each customer, enabling a more disaggregated analysis of the results.² In this phase, two additional years of hourly price and load data were available, expanding the study period to five summers (2000-2004).

We begin this article with background on the RTP tariff and other options available to SC-3A customers during the study period, including other electric commodity supply options from NMPC and the competitive retail market, financial hedge products, DR-enabling technologies and emergency DR programs offered by the New York Independent System Operator (NY-ISO). We also provide data on the uptake of these options. Next, we discuss how customers respond, based on their survey responses, focusing on their load response strategies, the impact of enabling technologies and barriers they have encountered in responding to day-ahead hourly prices. Quantitative estimates of SC-3A customers' price response are then discussed, demonstrating the large variation in individual customer price response that underlies aggregate results. Based on model results and survey research, we discuss the primary factors driving SC-3A customers' price response: business sector, the influence of NYISO emergency DR programs, and the presence of price-response "champions".

Electricity Pricing, Products and Services

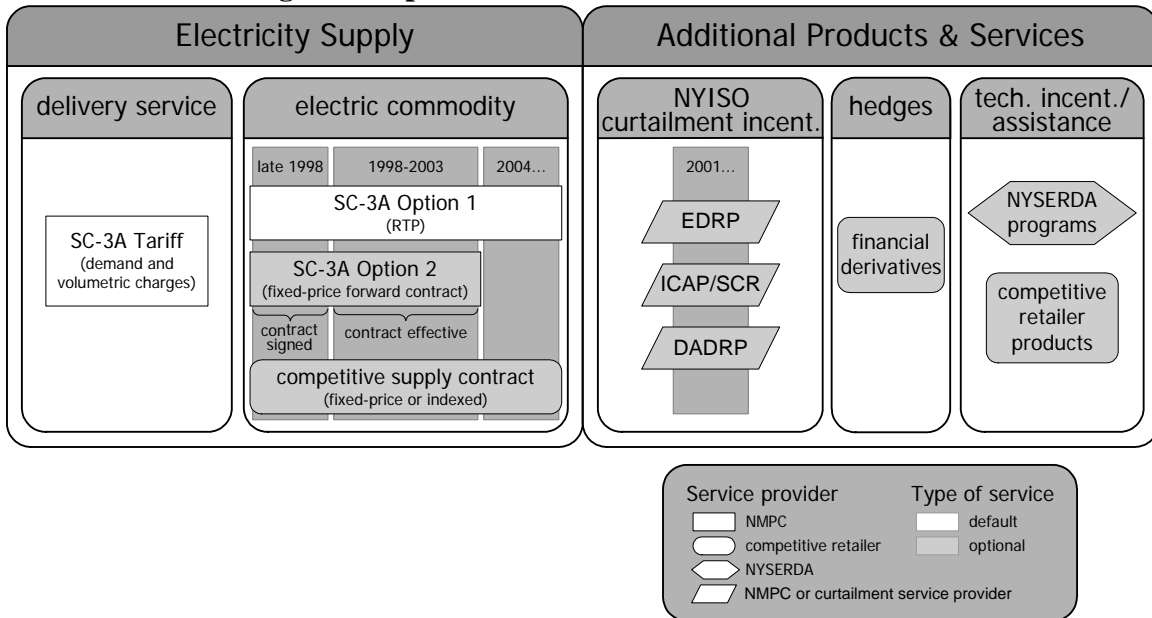
SC-3A customers could choose from a variety of electricity supply options and related products and services during the study period (see Figure 1). These choices, their uptake by SC-

¹ Goldman et al. (2004a) is the only study to examine large customer response to RTP in the context of retail competition and organized wholesale markets.

² See Goldman et al. (2005) for more information on Phase 2 survey implementation and demand modeling techniques.

3A customers, and their potential impact on customers' incentives to respond to high hourly prices are discussed below.

Figure 1. Options Available to SC-3A Customers



Electricity Supply Options

All SC-3A customers pay common unbundled distribution rates, consisting of volumetric (per kWh) and demand (per kW) charges that collect capacity, delivery and other non-energy costs. For electric commodity service, NMPC customers could choose from several options during the study period.

NMPC option 1—day-ahead market pricing. The default SC-3A commodity service, initially referred to as “Option 1”, applies to all customers that do not select another commodity supply option. It consists of hourly electricity prices derived by adding ancillary services and balancing charges to NYISO’s location-based day-ahead market prices.³ The next day’s prices are posted on the utility’s website by 4 p.m. each day. They are firm and applicable to all metered electricity usage.

In 2000, 60-65% of the 149 SC-3A customers purchased their electricity under the default rate. By the summer of 2004, only 36%, representing 34% of the class load, remained. Though many customers have migrated to competitive suppliers, customer acceptance of the default service tariff design is fairly high.⁴ We believe this is due to increasing numbers of competitive suppliers offering alternatives, relatively low electricity price volatility in recent years, and the tariff’s day-ahead price notification, which provides time for customers to plan and execute their response. Some survey respondents indicated that they would be more likely to leave

³All ancillary services are procured by NYISO, which collects the costs through uplift charges that are assessed to load serving entities based on energy usage.

⁴Survey respondents, on average rated their satisfaction 2.8 out of 5 (5 indicating complete satisfaction).

the utility if the default service were indexed to the real-time market, which affords no advance notice of prices, as has been done in New Jersey and Maryland.

NMPC option 2—hedged forward contract. NMPC offered a hedged alternative, called “Option 2”, on a one-time basis just prior to the implementation of retail competition and default-service RTP in late 1998. Option 2 was a forward contract that offered a pre-determined time-of-use (TOU) rate schedule. Customers electing this option had to specify peak and off-peak electricity quantities to which this pricing schedule would apply for each month of the five years covered by the contract, but they could nominate no usage in certain months or years if they wanted. The terms were somewhat restrictive; customers had to pay for all nominated load whether they used it or not. About 18% of SC-3A customers elected this option. Their average on-peak nomination turned out to cover about 60% of their actual peak-period usage. Option 2 sunset in August 2003.

Competitive retail market alternatives. SC-3A customers have also had the option of purchasing their commodity from competitive retailers since RTP became the default service in 1998. In 2000, only 30% of customers had left NMPC for the competitive market. By 2004, 63% had switched. Much of this increase occurred in 2004 (the last year of the study). This coincides with the expiration of the Option 2 contracts and was also aided by the growth and maturation of the retail market in New York as well as in neighboring states that implemented retail choice and default-service RTP.

Despite these overall trends, there is considerable diversity in SC-3A customers’ migration patterns over the study period. Customers may be categorized into four groups. First, a substantial number of customers never left the utility at all (28%). Of those that did, three-quarters did not return to NMPC once they had left (37% of SC-3A customers). Some (18%) moved back and forth between NMPC and the competitive market. Another group of customers (17%) had already left the utility by the summer of 2000 and never returned.

Customers report that competitive suppliers offered two basic types of commodity pricing during the study period: fixed and indexed. Fixed-rate tariffs reported by customers include TOU and flat-rate pricing, typically applying to all of the customer’s usage. These products reduce or eliminate the customer’s incentive to respond to hourly prices. However, affected customers may still respond to other curtailment signals, such as NYISO emergency program events.

The majority of survey respondents that switched reported taking indexed commodity products. Most were indexed to NMPC’s Option 1 tariff, but some customers reported products indexed directly to the NYISO day-ahead market or to some other reference prices. Reported indexed products typically provided a discount relative to the default SC-3A rate (derived from a shopping credit built into the SC-3A service).

Based on survey responses and tariff history information provided by Niagara Mohawk, we estimate that 7% to 25% of SC-3A customers took an indexed supply product in 2004. Together with customers taking the default service (Option 1), we estimate that 45-60% of SC-3A customers were facing day-ahead, hourly prices in 2004. Clearly, default-service RTP can result in large numbers of customers facing hourly prices, even among those switching to competitive suppliers.

Financial Hedge Products

SC-3A customers could also purchase financial hedges through the retail market. Separate from the supply of electricity, these products provide price risk protection, typically for a pre-specified volume of electricity, with the customer still exposed to hourly prices for marginal usage.⁵ Fewer than 10% of SC-3A customers appear to have purchased these products. In surveys and interviews, most customers were either unclear what a financial hedge is or reported difficulties procuring them, largely due to restrictions or purchasing practices imposed by their organization.⁶

Enabling Technologies

One reason often offered for low price response is that customers lack the information and controls they need to effectively carry out a price response strategy. Many SC-3A customers had available, or installed during the study period, technologies with the potential to enhance their price response capability, in some cases funded by New York State Research and Development Agency (NYSERDA) programs explicitly designed to encourage DR. The impact of these technologies on SC-3A customers' price response is described below.

NYISO Emergency DR programs

Forty-two percent of SC-3A customers enrolled in one or both of NYISO's two emergency DR programs—the Emergency Demand Response Program (EDRP) and the Installed Capacity/ Special Case Resource Program (ICAP/SCR)—for at least one summer between 2001 and 2004.⁷ EDRP is a voluntary program that pays the higher of \$500/MWh or the real-time locational energy market price for measured load reductions when NYISO calls emergency events. ICAP/SCR participants receive capacity payments and, since 2003, energy payments for load curtailed when NYISO declares emergency events. The ICAP/SCR program levies penalties for participants who fail to curtail when called upon. We discuss the contribution of these programs to SC-3A customers' price response below.

How Customers Respond

Customers' survey and interview responses provide important insights into how large customers currently adapt and respond to day-ahead market prices. We highlight the following results.

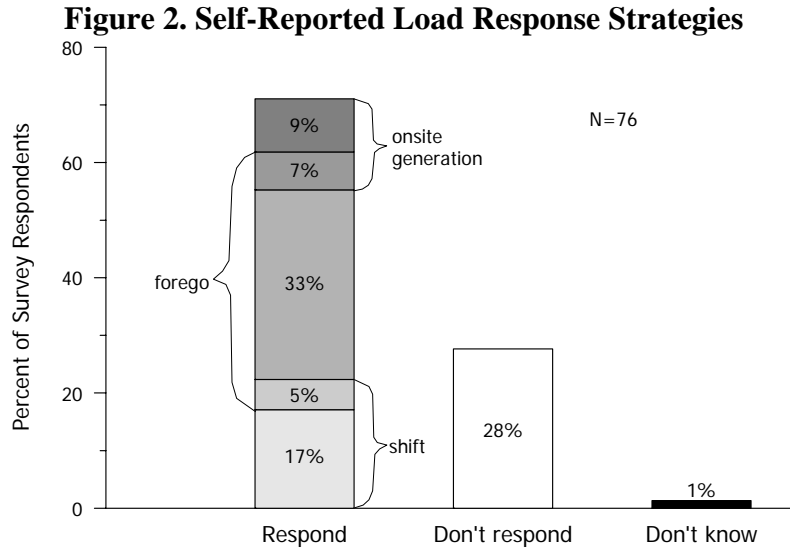
⁵The specific types of financial hedge products purchased by SC-3A customers are described in Goldman et al (2005).

⁶Some reported that different departments are responsible for purchasing energy and financial products, which complicates the decision. Others reported rules prohibiting them from purchasing financial derivatives altogether.

⁷NYISO also offers an economic DR program—the Day-Ahead Demand Response Program (DADRP)—in which only 3% of SC-3A customers enrolled.

Load Response Strategies

We asked customers how they respond to high hourly prices, NYISO emergency events or public appeals to conserve. More than two-thirds reported some sort of response capability (see Figure 2). The most common strategy, reported by 45% of the 76 survey respondents, was foregoing discretionary load without making it up at another time. Twenty-two percent said they could shift load from one time period to another, and 16% reported serving load with onsite generation. Thirteen percent of survey respondents reported more than one load response strategy.



Customers within the same business sectors tended to report similar load response strategies. Government/education customers were most likely to report foregoing load—almost all (83%) reported responding in this way. Survey results suggest that these customers are often willing to respond by curtailing lighting, HVAC or plug loads that often do not require rescheduling. Manufacturing customers reported a wide variety of load response strategies, reflecting the diversity of customers included in this category. About one-third of manufacturing customers reported that they cannot respond at all.

Load shifting was primarily reported by manufacturing customers, although several public works facilities indicated that they can shift load (primarily water or wastewater treatment facilities that reschedule pumping). Onsite generation is reported as a load response strategy by half of healthcare customers; these facilities typically have backup generators installed for power reliability purposes. Commercial/retail customers were the least likely to report undertaking any response behavior.

Impact of Enabling Technologies

Many SC-3A customers have installed technologies and systems that have the potential to enhance price response. Among 76 survey respondents, 49% reported ownership of energy management control systems (EMCS) and/or peak load management (PLM) devices, 41% reported owning energy information systems (EIS) and 55% reported onsite generation. However, the ma-

jority indicated that they do not use these systems to respond to high hourly prices. Instead, EMCS/PLM and EIS devices are typically used for across-the-board energy savings (efficiency-type improvements) or managing peak demand charges. Onsite generation is most often used for emergency backup or reliability reasons. At the same time, many customers reported specific load curtailment actions that are relatively “low-tech”, such as turning off lights, reducing air conditioning and office equipment usage, and asking employees to conserve. Some industrial customers reported shutting down plants or buildings or altering their production processes. We did find a correlation between the presence of onsite generation and highly responsive customers. Overall, though, we were unable to find a meaningful statistical relationship between ownership of these technologies and customers’ price response, although this is probably influenced by a small sample size (we only had sufficient information to perform this analysis on 55 customers). Although pilot studies have demonstrated the potential for semi- or fully automated DR through integrated energy management and information systems (Piette et al. 2005), most large customers currently do not have such practices in place, even though many have the needed equipment. As explanation, some customers told us the potential savings from responding to high hourly prices do not justify investing in strategies to respond. This ties in closely with customers’ reported barriers to price response, which we discuss next.

Barriers to Price Response

Most survey respondents (88%) reported encountering at least one barrier to price response (see Table 1). The most common obstacle, reported by half of respondents, was a lack of time or resources to monitor prices. Fully 70% said they rarely or never review the hourly prices posted by NMPD each day. For some, this precludes price response. Others appear to rely on coincident signals—NYISO emergency events or hot weather—to alert them of high prices. About a third of survey respondents reported encountering institutional barriers to price response.

Table 1. Barriers to Price Response

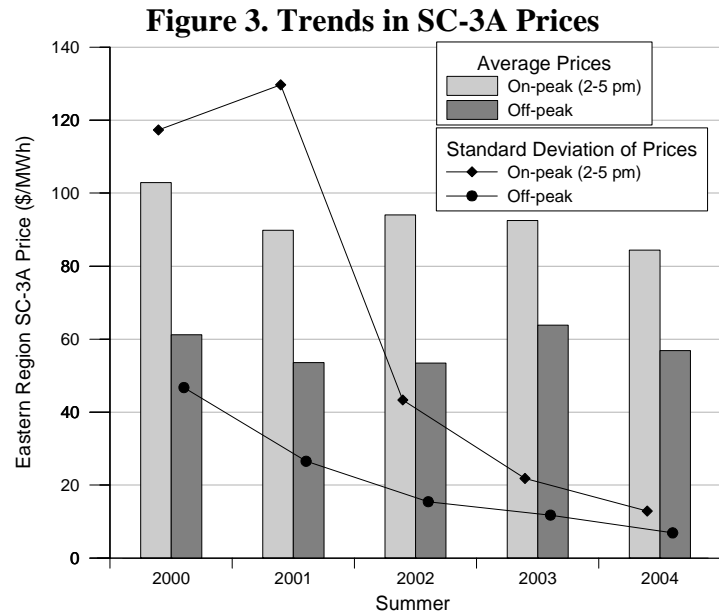
Barrier	Percent of Respondents^a (N=76)
ORGANIZATION/ BUSINESS PRACTICES	
Insufficient time or resources to pay attention to hourly prices	51%
Institutional barriers in my organization make responding difficult	30%
Inflexible labor schedule	21%
INADEQUATE INCENTIVES	
Managing electricity use is not a priority	22%
The cost/inconvenience of responding outweighs the savings	22%
RISK AVERSION/HEDGING	
My organization’s management views these efforts as too risky	13%
Flat-rate or time-of-use contract makes responding unimportant	12%
OTHER BARRIERS	3%
NO BARRIERS ENCOUNTERED	12%
DO NOT KNOW	3%

^aCustomers were asked to indicate all barriers that applied, so the responses do not add up to 100%.

SC-3A price volatility was modest during the study period, particularly in the most recent years (see Figure 3). While there were instances of very high prices (in excess of \$500/MWh),

they were isolated to a few summer days and declined in frequency and severity in the later years of the study. Accordingly, about 22% of survey respondents cited inadequate incentives as an obstacle to price response. This may suggest latent capability that might be expressed under conditions of greater price volatility, or that could be brought out with appropriate training and technology.

Despite these reported obstacles, analysis of SC-3A customers' billing records suggest that a sizeable number of them adjusted their usage when prices were high. We describe this response next.



Note: Prices are shown for the Eastern region of NMPC service territory. Prices and price volatility in other NMPC regions were somewhat lower.

Price Response Estimates

We estimated price elasticities from customers' metered electricity usage and the prices they faced during the five summers of the study (2000-2004). Customers were included in the analysis for all summers in which they paid SC-3A prices, or an indexed equivalent, for some or all of their usage. 119 of the 149 SC-3A customers met this criterion for at least one summer.

Interpreting the Elasticity of Substitution

The elasticity of substitution is used in this study to describe the price response of SC-3A customers, which are large industrial, commercial and institutional customers that use electricity as an input to producing intermediate or final goods or providing services to consumers or society.⁸ This metric describes the extent to which a customer shifts usage that would normally occur

⁸Like virtually all studies of large customer response to RTP, we estimated the substitution elasticity, rather than the *own-price* elasticity more often used for smaller customers, for two reasons. First, because large customers are businesses (not consumers), it is theoretically consistent to portray their energy usage as a tradeoff in substitutable com-

during the peak hours of the day to off-peak hours in response to a change in the ratio of peak and off-peak prices.⁹

Mathematically, the elasticity of substitution is defined as the proportional change in peak to off-peak usage in response to a one-percent change in peak to off-peak prices. For example, a customer with an elasticity of 0.15 should reduce peak-period electricity usage by 15% (relative to off-peak electricity) in response to a doubling of the price ratio (e.g., an increase in peak prices from 5 to 10¢/kWh, with off-peak prices held constant).¹⁰ The substitution elasticity is always positive. The higher the elasticity, the greater the observed load response.

Aggregate Price Response

The overall level of price response from SC-3A customers is modest, but encouraging: the load-weighted average elasticity of substitution is 0.11. This result is consistent with other studies of large customer price response (Boisvert et al 2004, Herriges et al 1993, Schwarz et al 2002).

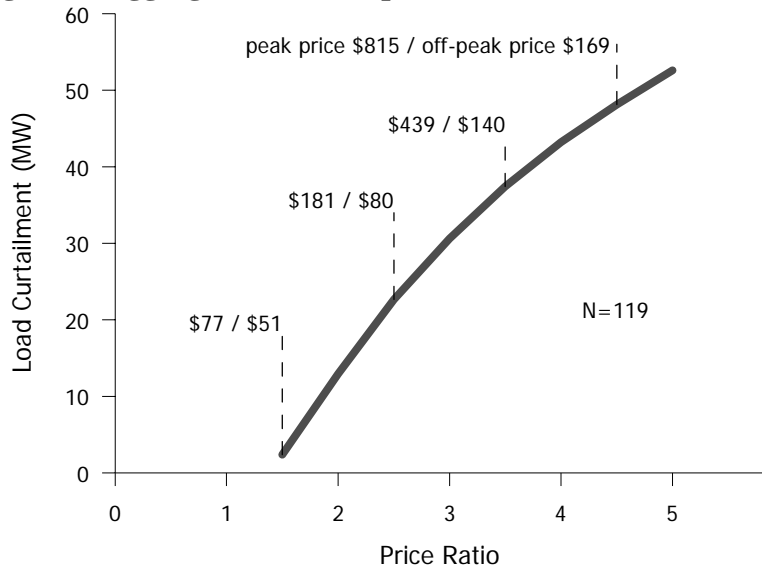
Policymakers are particularly interested in the peak load reductions from RTP—the amount of DR they can expect at high prices. Estimated aggregate load response for the 119 customers is shown in Figure 4. At peak prices five times higher than off-peak prices (the highest price ratio observed during the study period) this group of customers would be expected to curtail their electricity usage by about 50 MW. This is about 10% of their combined summer peak demand.

modities (peak and off-peak electricity) that must be purchased in order to fulfill their business activities. Second, although the own-price elasticity has the advantage of providing a more direct measure of load reductions (in kW) than the substitution elasticity (which is a relative measure), calculating meaningful own-price estimates requires accounting for changes in business activity that might alter electricity usage independently of prices. For industrial customers, this might be approximated by production data (e.g., number of widgets produced). For service-oriented customers—the majority of our study population—defining a metric for business activity is more challenging. In either case, collecting this type of information from customers is infeasible, because it is both sensitive and onerous to collect.

⁹We defined the peak period empirically. Based on a preliminary analysis of customers' usage data, the period from 2pm to 5pm afforded the most distinct patterns in customer usage in response to prices.

¹⁰The substitution elasticity assumes that reductions in peak usage are made up kWh for kWh in off-peak periods (e.g., load shifting), yet many SC-3A customers told us they curtail load or switch to onsite generation. The substitution elasticity underestimates such customers' peak period load response by ~5-10%. We have not attempted to correct for this.

Figure 4. Aggregate Load Response of 119 SC-3A Customers



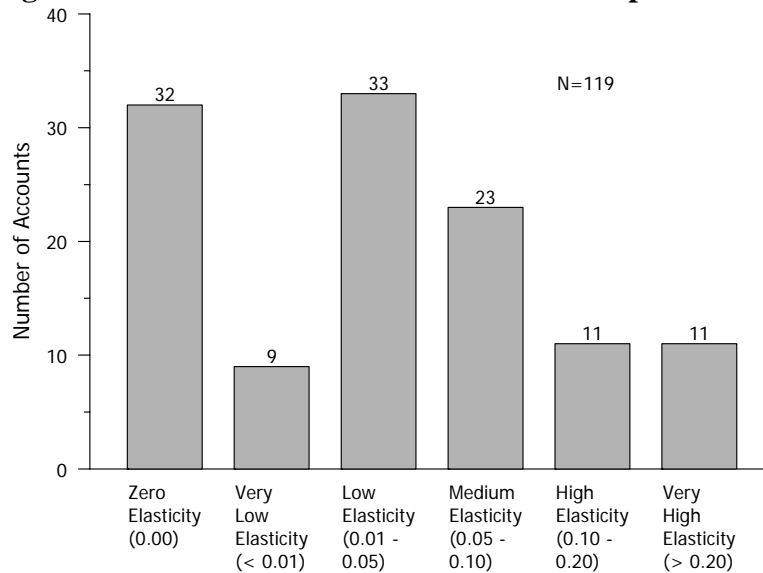
Response Varies by Business Sector

We estimated load-weighted sector-average elasticities for each business sector. The manufacturing sector exhibited the highest elasticity, of 0.16. Government/education customers are also quite price-responsive (0.10)—an important finding given the common assumption that industrial customers are the best candidates for price response. The other sectors—commercial/retail, health care and public works—are considerably less responsive, with average elasticities of 0.06, 0.04 and 0.02, respectively.

Individual Customer Response

While the sector-level results above show clear distinctions between different customer groups, they mask considerable variation in price responsiveness among customers within each group. About one-third of customers had zero elasticity estimates. This means that they used peak and off-peak electricity in fixed proportions, regardless of prices. For the other two-thirds of customers, with positive substitution elasticities, we observe some degree of price response; although there is wide variance in this capability (see Figure 5). Eighteen percent of the customers provide 75-80% of the aggregate demand response.

Figure 5. Distribution of Customers' Price Responsiveness

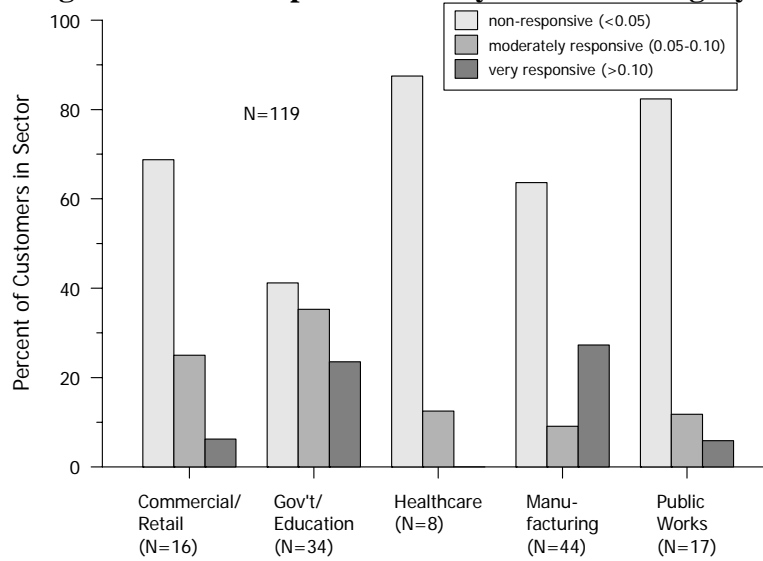


Within business sectors, there is wide variation in price response (see Figure 6). This is most pronounced for manufacturing customers. Twenty-seven percent are highly price responsive, with elasticities above 0.10. But 63% are essentially unresponsive (elasticities < 0.05), including 27% with zero elasticities. The high average level of price response for this sector is provided by a few, very responsive customers. Within the government/education sector, price responsiveness is somewhat more evenly distributed.

Influence of NYISO Emergency Programs

While the need for improved DR is widely acknowledged, the relative roles and merits of pricing and incentive-based mechanisms for achieving it are the subject of considerable debate (Boisvert and Neenan 2003; Borenstein 2002; Ruff 2002). As already noted, 42% of NMPC's SC-3A customers enrolled in NYISO's emergency DR programs, which offer incentives to curtail load when emergency events are declared. The experience of these customers, exposed to both RTP and DR programs, provides some insights into this issue.

Figure 6. Price Responsiveness by Business Category



Empirical evidence shows that NYISO emergency programs enhance price response. EDRP participants had higher elasticities than non-participants, even though we explicitly accounted for the incentive payment price in the demand model.¹¹ This suggests that customers do not respond to EDRP events in the same way as to hourly prices, even when the financial incentives are equivalent.

In surveys and interviews, more customers told us they respond to NYISO program events (60%) than high hourly prices (5%). They cited multiple reasons for responding to NYISO programs. While 63% reported responding to earn curtailment incentives, 59% told us they respond as part of a perceived civic duty to help keep the electric system secure. In such cases, responding is seen more as obligation to the community than an economic decision. In addition, 30% noted the coincidence of NYISO emergency events and high hourly prices as a reason for responding to NYISO program events. As discussed above, most customers say they do not actively monitor SC-3A prices. For some, NYISO emergency events, which coincide with high prices, serve to alert them that electricity prices are high.

Drawing from these results, we make the following observations. First, day-ahead RTP and emergency DR programs fulfill separate needs through distinct designs and attributes. Day-ahead RTP involves routinely sending price signals to customers on a day-ahead basis (12-24 hour timeframe). It promotes *economic* price response, in which customers are motivated by savings from curtailing usage when prices are high. This response provides system-wide benefits in the form of lower wholesale market clearing prices. In contrast, NYISO emergency programs send signals on a contingency basis (two-hour timeframe) to promote *emergency* response, thereby providing system reliability benefits.

There are also considerable synergies in implementing day-ahead RTP in conjunction with emergency programs. In interviews, we encountered customers who had developed response strategies specifically to respond to NYISO programs which they subsequently adapted to

¹¹See Goldman et al (2005) for a discussion of the treatment of NYISO program incentives in the demand model.

respond to high SC-3A prices. The converse was also true for other customers. Thus, RTP can provide a training ground for customers to respond in emergency DR programs, and vice versa.

We conclude that day-ahead RTP and emergency DR programs complement each other and should not be viewed as an “either-or” proposition.

Price Response “Champions”

While business type and NYISO emergency program participation are well correlated with price response, there is still substantial unexplained variation in individual SC-3A customers’ elasticities among these groups. We examined several other factors that could potentially drive price response, and found some correlations (e.g., onsite generation appears to be a driver for the most highly responsive customers) but none that were statistically significant. However, based on two years of interviewing and surveying SC-3A customers, we are convinced that an important, though difficult to measure, driver is the presence of a price-response “champion” within customer organizations. Champions are individuals willing to take the initiative to advance price response as a priority within their organization, often identifying creative ways to overcome obstacles to price or emergency program response that may transform company policy beyond their tenure. For example, we encountered individuals at public institutions who had taken initiatives to their governing agencies to permanently alter procurement rules, giving them more flexibility in managing energy costs. Others had simply taken the time to learn about their options in a changing environment and taken full advantage of available opportunities to control their energy costs.

Conclusions

The experience of NMPC’s SC-3A customers provides a unique source of information on how large customers adapt to default-service day-ahead market pricing in the context of retail competition over several years. The results provide evidence that default-service day-ahead RTP does promote everyday economic price response among large customers, even among many who have switched suppliers but still elect to face day-ahead market prices. However, while two-thirds of customers exhibit some price response, about 20% account for 75-80% of the observed demand reductions. Differences in price response among customers are driven not only by business sector, but are strongly influenced by participation in NYISO emergency DR programs, as well as other, less tangible factors such as the presence of price response “champions”. Policy-makers need to recognize that not all large customers are alike, and most are currently not very price responsive. This is in part because they do not adopt fully automated DR strategies, even though many have installed the technologies necessary to do so. This suggests that there is a role for targeted technical assistance programs to help customers develop and implement more sophisticated price response strategies with the goal of improving overall DR potential.

Acknowledgements

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