Arnold Schwarzenegger
Governor

CUSTOMER STRATEGIES FOR RESPONDING TO DAY-AHEAD MARKET HOURLY ELECTRICITY PRICING

PIER COLLABORATIVE FINAL REPORT

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Please Note Name Change:

On June 16, 1995, the Regents approved the name change from Lawrence Berkeley Laboratory to Ernest Orlando Lawrence Berkeley National Laboratory.

Please note name change:

On March 1, 1997 the Energy & Environment Division was renamed the Environmental Energy Technologies Division.

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Prepared for the
California Energy Commission

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Table of Contents

Acknowledgements ii

Table of Contents iii

List of Figures v

List of Tables vi

Acronyms and Abbreviations vii

Executive Summary ix

1. Introduction 1

2. Background, Approach and Data Sources 5
   - 2.1 Tariff and Market Options 5
     - 2.1.1 Electricity Supply Options 6
     - 2.1.2 Additional Products and Services 7
   - 2.2 SC-3A Price Trends 8
   - 2.3 Weather in Upstate New York 12
   - 2.4 Customer Research 12
     - 2.4.1 Survey Design 13
     - 2.4.2 Survey Administration 14
     - 2.4.3 Survey Response 15
   - 2.5 NMPC Billing Data and Tariff History 16

3. Quantifying and Characterizing Price Response 18
   - 3.1 Measuring Price Response – The Theory of the Firm 18
     - 3.1.1 Interpreting Elasticity of Substitution Results 21
   - 3.2 The Specification of Customer Response to Daily Electricity Price Changes 24
     - 3.2.1 The Indirect Generalized Leontief Input Demand Model 25
     - 3.2.2 Implementation of Demand Models 26
   - 3.3 Response to Market-Based Default Service Electricity Prices 29
     - 3.3.1 Price Responsiveness and the Length of the Peak Period 30
     - 3.3.2 Intensity of Price Response 30
     - 3.3.3 Distribution of Individual Customer Elasticities 32
     - 3.3.5 Impact of Weather on Peak Load and Price Response 34
     - 3.3.6 Some Customers Can be "Priced-Out" of Peak Electricity Usage 35
     - 3.3.7 The Character of Price Response 36
     - 3.3.8 Drivers to Price Response 38
   - 3.4 Aggregate Load Response 40
   - 3.5 Summary 41

4. Customer Adaptation to Default RTP Service 43
   - 4.1 Self-Reported Response Strategies and Use of Enabling Technologies 43
     - 4.1.1 Load Response Strategies 44
     - 4.1.2 Response to What? 45

4.1.3 Enabling Technologies 47
4.2 Linking Customer Characteristics and Circumstances to Estimated Price Response 49
4.3 Barriers to Price Response 54
4.4 Customer Migration and the Search for a Hedge 57
4.4.1 SC-3A Customer Migration Trends 57
4.4.2 Hedging Trends 60
4.4.3 Why Don't Customers Hedge More? 61

5. Discussion: Key Findings and Policy Implications 65
5.1 Deriving and Interpreting the Elasticity of Substitution 66
5.2 Key Findings and Implications 67
5.2.1 The Intensity of Price Response 69
5.2.2 The Character of Price Response 70
5.2.3 Drivers of Price Response 72
5.2.4 Customer Strategies for Responding 74
5.2.5 Barriers to Price Response 76
5.2.6 Customer Acceptance 77

References 81

Appendix A. 2004 SC-3A Customer Survey A-1

Appendix B. The Generalized Leontief Demand Model, Theoretical and Empirical Specifications and Interpretations A-13

Appendix C. Empirical Estimates of NMPC's SC-3A Customers' Response to Day-Ahead Market Electricity Prices A-39

List of Figures

Figure ES-1. Choices Available to SC-3A Customers x
Figure ES-2. Distribution of Customers by their Substitution Elasticity Estimates xii
Figure ES-3. Price Responsiveness by Business Category xiii
Figure ES-4. Self-Reported Load Response Strategies xvii

Figure 2-1. Choices Available to SC-3A Customers 6
Figure 2-2. Major Price Regions in NMPC Service Territory 9
Figure 2-3. Average Peak Prices by Region 9
Figure 2-4. Volatility of Peak Prices by Region 10
Figure 2-5. Trends in Average Summer SC-3A Prices: East Region 10
Figure 2-6. Trends in Summer SC-3A Price Volatility: East Region 11
Figure 2-7. Price Duration Curve: East Region, 2000-2004 Summer Weekdays 11
Figure 3-1. Implementation of Generalized Leontief and Regression Models 27
Figure 3-2. Impact of Peak Period Specification on Average Elasticities of Substitution 30
Figure 3-3. Distribution of Accounts by Elasticity of Substitution 32
Figure 3-4. Distribution of Load by Elasticity of Substitution 33
Figure 3-5. Distribution of Accounts by Elasticity of Substitution and NYISO DR Program Participation 33
Figure 3-6. Reduction in 119 SC-3A Customers' Peak Demand at Various Price Ratios 41
Figure 4-1. Self-Reported Load Response Strategies 44
Figure 4-2. Self-Reported Response Strategies by Business Classification 45
Figure 4-3. Price Responsiveness by Business Category 51
Figure 4-4. Frequency of Monitoring Hourly Prices 55
Figure 4-5. Barriers to Price Response by Business Classification 57

List of Tables

Table ES-1. Elasticity of Substitution Results xi
Table ES-2. Reasons for Responding to NYISO Emergency Events xv
Table ES-3. Barriers to Price Response xix

Table 2-1. Representative Summer Weekday Temperatures in NMPC Service Territory: 2000-2004 12
Table 2-2. Question Topics Included in 2004 SC-3A Customer Survey 14
Table 2-3. 2004 SC-3A Survey Response by Customer Account 15
Table 2-4. Characteristics of SC-3A Customers and 2004 Survey Respondents 16
Table 3-1. Character of Customer Response: Possible Substitution Elasticity Scenarios 22
Table 3-2. Empirical Price Response Models Used in this Study 25
Table 3-3. Phase 1 and Phase 2 Elasticity of Substitution Results 31
Table 3-4. Significance of Weather in Influencing Customers' Load and Price Response 34
Table 3-5. Impact of Weather on Price Response by Business Sector 35
Table 3-6. Characteristics of Customers that can be "Priced Out" of Peak Usage 36
Table 3-7. Character of Price Response: Regression Results 37
Table 3-8. Marginal Changes in Elasticities of Substitution by Business Category 38
Table 3-9. Drivers to Price Response: Regression Results 39
Table 3-10. Price-responsiveness of Customers by Sector 42
Table 4-1. Reasons for Responding to NYISO Emergency Events 47
Table 4-2. How SC-3A Customers Use Enabling Technologies 48
Table 4-3. Characteristics of Price-Responsive and Non-Responsive Customers 49
Table 4-4. Selected Characteristics of Moderately and Highly Responsive Customers 50
Table 4-5. Barriers To Price Response 55
Table 4-6. Reasons for Not Monitoring Hourly Prices Routinely 56
Table 4-7. Trends in SC-3A Customers' Supply Choices 58
Table 4-8. Customers' Reasons for Not Switching 60
Table 4-9. Trends in SC-3A Customers' Hedging Strategies 61
Table 4-10. Reasons for Not Purchasing Financial Hedges 62
Table 4-11. Customers' Reactions to Hypothetical "Real-Time" RTP 63
Table 5-1. Key Findings and Policy Implications 68

Acronyms and Abbreviations

CEC	California Energy Commission
CES	constant elasticity of substitution
CPP	critical peak pricing
DADRP	(NYISO) Day Ahead Demand Response Program
DAM	day-ahead market
DR	demand response
DRRC	Demand Response Research Center
EDRP	(NYISO) Emergency Demand Response Program
ESCO	energy service company
GL	Generalized Leontief
ICAP/SCR	(NYISO) Installed Capacity/ Special Case Resources Program
kW	kilowatt
kWh	kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
MW	Megawatt
MWh	Megawatt-hour
NYISO	New York Independent System Operator
NYPA	New York Power Authority
PIER	Public Interest Energy Research
RTP	real-time pricing
THI	temperature heat index
TOU	time-of-use

Executive Summary

Real-time pricing (RTP) has been advocated as an economically efficient means to send price signals to customers to promote demand response (DR) (Borenstein 2002, Borenstein 2005, Ruff 2002). However, limited information exists that can be used to judge how effectively RTP actually induces DR, particularly in the context of restructured electricity markets.[1]

This report describes the second phase of a study of how large, non-residential customers' adapted to default-service day-ahead hourly pricing. The customers are located in upstate New York and served under Niagara Mohawk Power Corporation (NMPC)'s SC-3A rate class. The SC-3A tariff is a type of RTP that provides firm, day-ahead notice of hourly varying prices indexed to New York Independent System Operator (NYISO) day-ahead market prices. The study was funded by the California Energy Commission (CEC)'s PIER program through the Demand Response Research Center (DRRC).

NMPC's is the first and longest-running default-service RTP tariff implemented in the context of retail competition. The mix of NMPC's large customers exposed to day-ahead hourly prices is roughly 30% industrial, 25% commercial and 45% institutional. They have faced periods of high prices during the study period (2000-2004), thereby providing an opportunity to assess their response to volatile hourly prices. The nature of the SC-3A default service attracted competitive retailers offering a wide array of pricing and hedging options, and customers could also participate in demand response programs implemented by NYISO.

The first phase of this study examined SC-3A customers' satisfaction, hedging choices and price response through in-depth customer market research and a Constant Elasticity of Substitution (CES) demand model (Goldman et al. 2004). This second phase was undertaken to answer questions that remained unresolved and to quantify price response to a higher level of granularity. We accomplished these objectives with a second customer survey and interview effort, which resulted in a higher, 76% response rate, and the adoption of the more flexible Generalized Leontief (GL) demand model, which allows us to analyze customer response under a range of conditions (e.g. at different nominal prices) and to determine the distribution of individual customers' response.

1. Customer Choices

Figure ES-1 provides an overview of the choices available to SC-3A customers since RTP became the default service in late 1998. Customers can purchase their electric commodity from a competitive retailer and they have opportunities to hedge with financial derivatives to offset the risks associated with paying hourly varying energy

[1] Zarnikau (1990), Herriges et al. (1993), Braithwait and O'Sheasy (2001), Schwarz et al. (2002), and Boisvert et al. (2004) examined large customer response to voluntary RTP programs at vertically integrated, regulated utilities and Goldman et al. (2004), the first phase of this study, characterized large customer response to RTP in a competitive retail environment. Charles River Associates (2005) recently examined small customers' response to a critical peak pricing (CPP) pilot.

prices. In addition, since 2001, these customers have had opportunities to earn curtailment incentives by participating in demand response programs offered by the New York Independent System Operator (NYISO). Enabling technology incentives and technical assistance through NYSERDA programs have also been available through most of the study period to assist customers in developing price responsive behaviors.

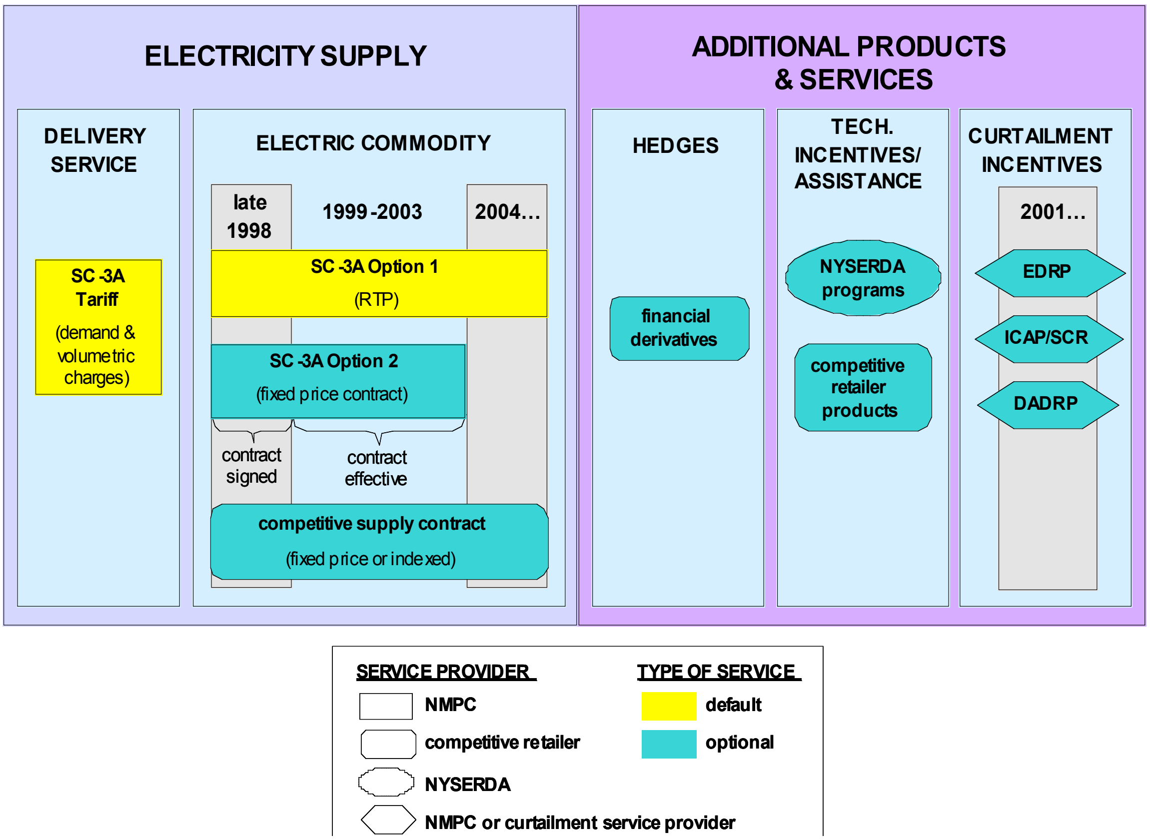


Figure ES-1. Choices Available to SC-3A Customers

2. Deriving and Interpreting the Elasticity of Substitution

Niagara Mohawk's SC-3A customers use electricity as an input to processes that produce intermediate or final consumer goods, or to provide services to consumers or society. Consequently, we hypothesize that these customers make electricity usage decisions in the short run, from day-to-day, based on the value electricity contributes to the customer's overall profit (or, in the case of a government/educational customer, the reduction of overall operating expenses) and information available to them about prevailing hourly electricity prices.

The distribution of NYISO day-ahead electricity prices, which are the basis for SC-3A prices, is such that the majority of days are characterized by a fairly constant pattern of hourly prices (of typically \$50-60/MWh for mid-day hours), with high peak period prices (exceeding \$300/MWh) occurring only on isolated days. Consequently, we portray SC-3A customers' price response as primarily involving the decision to reallocate business activity from an established routine on those days when prices are high. This response involves using less electricity during the high-priced (peak) hours of the day and more during the lower priced (off-peak) hours to meet the day's expected level of business.[2] Accordingly, the appropriate measure of price response is the *elasticity of substitution*, defined as the percentage change in daily peak electricity usage (relative to off-peak usage) in response to a one percent change in relative peak prices.[3]

Substitution elasticities take on values of zero or greater. Non-zero elasticities indicate price response, and the higher the elasticity, the greater the response. We estimated substitution elasticities from customers' hourly load and price data using a Generalized Leontief (GL) model. We also characterized other dimensions of price response, such as the effects of weather, load and nominal prices, and drivers to price response, by regressing elasticity of substitution results against these factors.

3. The Intensity of Price Response

We evaluated the intensity of price response using substitution elasticities derived from the GL model. The following key findings follow from this analysis.

Price response is modest overall – the average elasticity is 0.11

As a group, SC-3A customers' price response is modest – the load-weighted average substitution elasticity of 119 customers included in the model is 0.11 (see **Table ES-1**), which means that their combined ratio of peak to off-peak electricity usage declines by 11% in response to a doubling of peak prices (relative to off-peak prices). This result is consistent with other studies of large customers facing similar pricing circumstances (Herriges et al. 1993, Schwarz et al. 2002, Boisvert et al. 2004).

Table ES-1. Elasticity of Substitution Results

Business Category	**N**	**Average substitution elasticity**
Government/education	34	0.10
Public Works	17	0.02
Commercial/retail	16	0.06
Healthcare	8	0.04
Manufacturing	44	0.16
Total	**119**	**0.11**

At the highest prices observed during the study period, in which the peak price was about five times the off-peak price, we estimate that the 119 customers, as a group, reduced

[2] For customers that respond by curtailing load during peak periods but do not make up usage in the off-peak period, our model underestimates the corresponding peak load reduction (see section 3.1).
[3] This notion of elasticity differs from the more familiar own-price elasticity, but its interpretation is similar, and it is the most appropriate and feasible characterization of price response for large customers, for which electricity is an input. Moreover, estimating own-price elasticities would have required gathering output data from SC-3A customers, which was beyond the scope of this study (see section 3.1).

their peak usage by ~50 MW, about 10% of their combined non-coincident summer peak demand.

Manufacturing customers are most price- responsive, followed by government/education – other sectors have very low elasticities

Manufacturing firms, as a group, are 45% more price responsive than the SC-3A average, with a sector elasticity of 0.16 (Table ES-1). This comports with the conventional wisdom that these customers are good candidates for price response, though there is substantial variation within this group. The government/education sector is also quite price-responsive, with an average elasticity value of 0.10. The commercial/retail, healthcare and public works sectors are relatively unresponsive.

Two-thirds of customers have positive substitution elasticities

Figure ES-2 shows the distribution of SC-3A customers according to their substitution elasticity estimates. Almost two-thirds (65%) exhibit some price response (elasticities > 0.01). The other third appear to use peak and off-peak electricity in fixed proportions, regardless of prices (i.e. zero elasticity). Eighteen percent of customers exhibit relatively high price response (> 0.10), and account for 75-80% of the aggregate demand response.

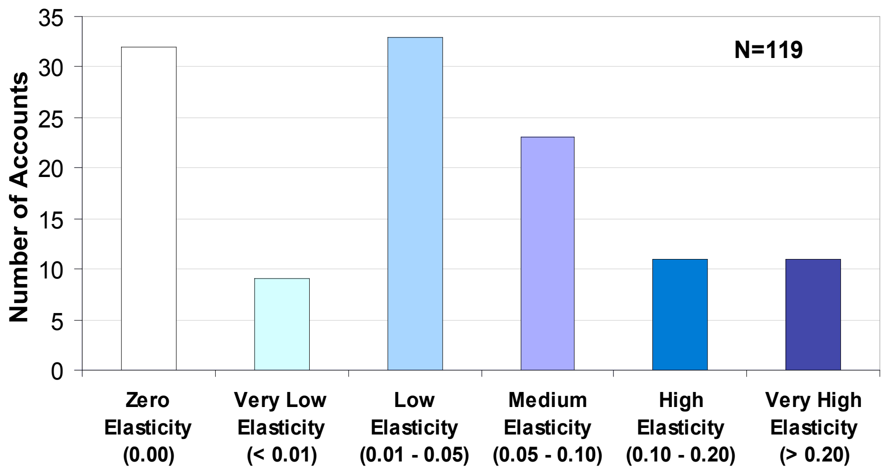


Figure ES-2. Distribution of Customers by their Substitution Elasticity Estimates

Individual customer elasticities vary substantially within sectors – most manufacturing customers are either highly responsive or not at all

An important finding of this study is that elasticity results are not uniform within business sectors (see **Figure ES-3**). This is most pronounced for manufacturing customers. Twenty-seven percent are highly price responsive, with elasticities above 0.10. But 63% are largely non-responsive (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.

The government/education sector, which has a lower overall elasticity, has almost as many highly responsive customers as the manufacturing sector (24%) and proportionally fewer non-responsive customers (42%) (Figure ES-3). The majority of commercial/retail, healthcare and public works customers are non-responsive, although there are exceptions in each of these business sectors.

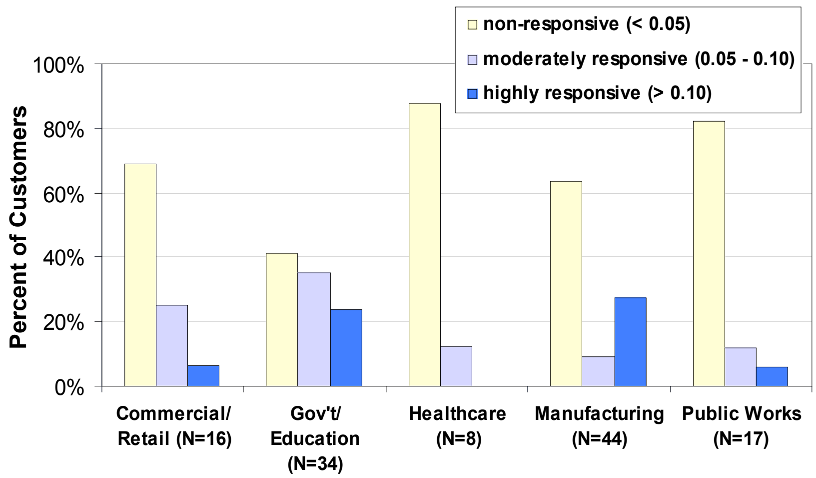


Figure ES-3. Price Responsiveness by Business Category

Policy Implications

The heterogeneity of price response, both among and within business sectors, should be explicitly recognized by policymakers. The common presumption that manufacturing customers are highly price responsive is true for some of these customers, but our results suggest that for many this is not the case at all; this comports with the findings of Taylor et al. (2005) studying similar circumstances. Furthermore, there is significant price response potential from a wide base of government/education customers that should not be ignored. Given that a large proportion of the response (~80%) comes from a small proportion of customers (~20%), policymakers need to expect that a large proportion of customers will not be able to respond at all, at least under the pricing conditions observed in this study and should ensure that hedged alternatives to dynamic pricing are available.

4. The Character of Price Response

We evaluated the character of price response in a regression model that examined the impact of nominal prices and load on price response. Key findings from this research are as follows.

Government/education and commercial/retail customers respond more when nominal prices are higher; manufacturing customers respond more when peak/off-peak price ratios are higher

We find that government/education and commercial/retail customers exhibit higher price response when nominal prices are higher – many of these customers tell us they forego load when prices are high (see section 5, below). Manufacturing firms appear to respond primarily to the peak to off-peak price ratio. Many of these customers report that they shift load rather than forego. The price response of public works and health care customers declines slightly as nominal prices increase.

Government/education customers' response declines slightly as they reach their peak demand

We find that government/education customers' average sector-level elasticity declines slightly (about 3%) when they are operating close to their peak demand. No other sectors exhibited this correlation.

Policy Implication

The finding that certain sectors increase their response when prices are high is encouraging: it implies that RTP can be expected to provide the most response when it is most needed. It is also encouraging that although there is a reduction in government/education customers' response as they reach their maximum demand (which is typically weather-driven), this effect is relatively small. However, we caution that New York's summer climate is moderate relative to other parts of the U.S., and the prices customers faced were seldom high for more than a few hours during the study period. Prolonged hot weather accompanied by high prices could result in response fatigue.

Government/education and commercial/retail customers' response increases on hot days

Government/education customers, on average, increase their price response by about 20% on hot days compared to cooler days and commercial/retail customers' average elasticity doubles. For the other business sectors, there is no or negligible difference in sector-level elasticities between hot and cool days.

Policy Implication

Hot days are correlated with both high SC-3A prices and NYISO DR program events in NMPC service territory. Under the weather and price conditions experienced in upstate New York during our study period, these signals appear to have overridden customers' increased cooling needs on hot days. This suggests that service-oriented customers are willing to put up with a certain amount of discomfort in order to respond to high hourly prices or participate in ISO DR programs. However, we caution that summer weather conditions in upstate New York are less extreme than in other areas, such as inland California.

5. Drivers of Price Response

We investigated drivers to price response – customers' characteristics and circumstances – using a regression model and by examining trends among price responsive and non-responsive customers. Few factors had statistically significant impacts on price response in the regression, partly due to a relatively small sample size.[4] Nonetheless, we highlight

[4] The sample size for this regression was limited to customers that had answered the survey – only 55 customer accounts could be included.

several intuitive relationships that provide insights into the factors associated with price response.

NYISO emergency programs enhance price response, in large part by providing coincident signals to curtail

Participation in NYISO's Emergency Demand Response Program (EDRP) has a statistically significant positive correlation with price response. Because EDRP events were coincident with high day-ahead prices during our study period, it is not possible to extricate customers' response to these two signals. Based on survey and interview results, we know that many customers are aware of this coincidence and may look to NYISO events as a signal that prices are high (see **Table ES-2**). In addition, for many customers, response to emergency programs is motivated by a "good citizen" factor and is viewed more as an obligation to the community than an economic response.

Table ES-2. Reasons for Responding to NYISO Emergency Events

Reason	**Percent of Respondents[a] (N=46)**
To earn EDRP or ICAP/SCR curtailment incentive payments	63%
To avoid paying penalties for not responding to ICAP/SCR events	9%
My organization considers it a civic duty to help keep the electric system secure	59%
NYISO emergencies coincide with high SC-3A prices	30%

[a] Customers were asked to check all reasons that applied, so responses do not add up to 100%.

Contrary to expectations, ICAP/SCR (another NYISO demand response program) participation does not have a discernable impact on price response. We believe that the coincidence of high SC-3A day-ahead prices and NYISO emergency events makes it impossible to identify separate effects for both NYISO programs.

<u>Policy Implication</u>

These results suggest that NYISO EDRP complements response to SC-3A prices. For some customers, notification of events and the opportunity to help out in emergencies are more important than cost savings. Thus RTP alone may not draw out their full price response potential, and policymakers for whom demand response is a primary concern should consider complementing RTP with programs that alert and compensate them for responding to system emergencies.

Load management and information technologies do not influence customer response to hourly prices at the present time

Many SC-3A customers have installed energy management control systems (EMCS), peak load management (PLM) devices and energy information systems (EIS), technologies with the potential to assist price response. However, we found no meaningful statistical relationships between ownership of these technologies and price response. In interviews and surveys, most customers indicated that at present they use these technologies for other purposes than short-term price response, primarily for achieving across-the-board energy savings (permanent load reductions) and/or managing their peak demand.

Policy Implication

Promoting dissemination of enabling technologies is not a sufficient strategy to enhance short-term price response, in part because customers may consider the savings, which are available during only a few hours per year, insufficient to justify the effort or the cost of the equipment. While recent research by Piette et al. (2005) demonstrates the potential for automated DR strategies, customers at present clearly need technical assistance to implement them. There may be a role for energy services companies to provide DR-enabling technologies as part of a larger services and products package, with price response automation included as a value-added feature.

Onsite generation can contribute to significant load response

In the regression, the presence of onsite generation is positively correlated with price response, but this effect is not statistically significant. While over half of SC-3A customers have onsite generation equipment, the majority told us in surveys and interviews that they do not use it for price response. Many of these systems are existing, older backup generators that are wired for reliability purposes only and do not lend themselves to price response. However, among the most price responsive customers, several have onsite generation installed, and a few customers told us in interviews that they have scheduled equipment tests allowed under their operating permits when prices were high.

Policy Implication

Although few SC-3A customers have responded to hourly prices or NYISO events using onsite generation, we observe that for those that have, significant load response resulted. While environmental and health considerations must be taken into account, distributed generation has the potential to create significant new opportunities for price and load response.

"Champions" are probably a significant driver to price response

Based on two years of interviewing customers, we believe the presence of a facility manager willing to take risks to forward price response within his or her organization – an internal "champion" – is a vitally important, though not easily measured, driver to price response.

Policy Implication

While policymakers cannot directly control the presence of champions within customer organizations, programs that offer recognition to such individuals can both reward them for their efforts and promote broader awareness that price response is important.[5]

[5] Similar programs have been instituted for energy-efficiency champions by Energy Star, the Federal Energy Management Program and professional engineering societies (e.g., ASHRAE, Association of Energy Engineers).

6. Customer Strategies for Responding

We explored customers' qualitative load response strategies through survey and interview questions to add context and texture to elasticity results.

Over two-thirds of customers say they can respond

In our 2004 survey, 71% of respondents indicated that they can respond in some way to high prices, NYISO events or public appeals to conserve (see **Figure ES-4**), compared to only 46% in the previous year's survey (Goldman et al. 2004).

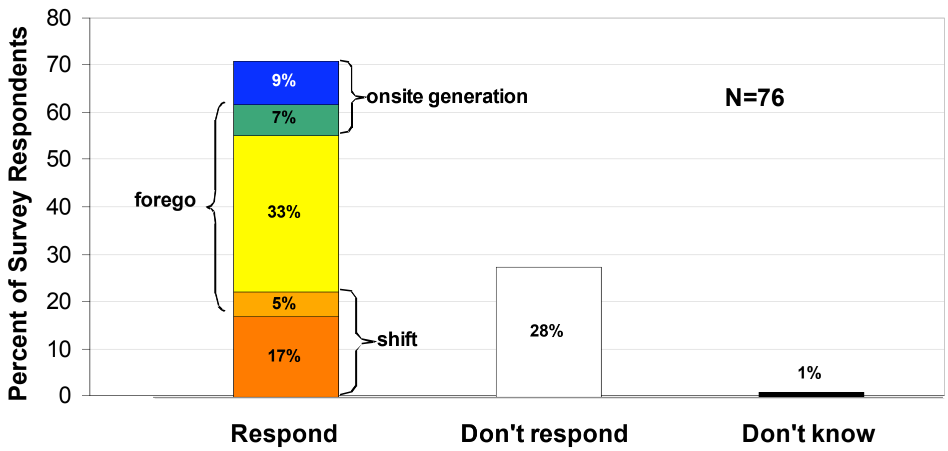


Figure ES-4. Self-Reported Load Response Strategies

Customers employ varied load response strategies – shifting, foregoing, and self-generation

Customers reported deploying three different load response strategies: shifting load from one time period to another (22% of surveyed customers), foregoing discretionary usage and not making it up at another time (45%) and supplying load with onsite generation (16%) (Figure ES-4). Thirteen percent of customers reported more than one load response strategy.

Government/education customers most often forego usage; manufacturing customers are more likely to shift

Most government/education customers (83%) report that they respond by foregoing load and not making it up later. Manufacturing customers display the most variety in the types of load response strategies reported, and report load shifting more frequently than other customer types; 40% of these customers say they can shift.

<u>Policy Implications</u>

There is significant latent response potential but it is diverse in nature. Price response programs and tariff options should be designed to make best use of this diversity. It should also be noted that the load response strategies reported were framed in terms of response to any of the signals SC-3A customers have faced – high SC-3A prices, NYISO events and public appeals to conserve. Thus, while there is considerable latent load response *capability*, it is important to remember that not all customers will necessarily exercise this capability if presented with RTP price signals alone. Other programs to elicit this potential may be necessary for some customers.

What customers say they do and what they seem to do are at odds

We found some contradictions between what some customers say they do and what their actions indicate they actually do. This arose in two critical areas in this study: customers' self-reported load response behavior (e.g., some customers told us they did not respond but had high elasticities) and their participation in NYISO demand response programs (e.g., some customers told us they had responded to events but had never been enrolled in the programs).

We offer four possible explanations for these discrepancies: (1) customers may not recall how they responded to NYISO events and high SC-3A prices, which last occurred two summers prior to the survey, (2) the individuals responding to our survey may not have been directly responsible for making decisions about price response or energy procurement, (3) customers may have answered the survey strategically, telling us what they thought we wanted to hear, or what they wanted us to hear, and (4) our ability to accurately measure customers' behavior is not perfect and may contribute to these discrepancies (e.g., the substitution elasticity may underestimate the response from foregoing load – see section 3.1).

<u>Policy Implications</u>

We urge policymakers to avoid translating the results of surveys or limited pilot analyses into hard and fast rules about customers' inclination and ability to respond to price signals. New programs should be launched with a commitment to study how customers respond over time.

7. Barriers to Price Response

We explored barriers to price response through survey and interview questions. We highlight the following key points from this research.

Most customers report multiple barriers to price response – only ~15% respond without obstacles

Twelve percent of survey respondents reported that they had encountered no barriers in responding to SC-3A prices (see **Table ES-3**). This comports, although not precisely, with our finding that 18% of customers are highly price responsive (elasticities > 0.10). The rest reported up to five barriers each in responding to SC-3A prices.

Table ES-3. 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%

[a] Customers were asked to check all barriers that applied, so responses do not add up to 100%.

Over half of large customers report not having time or resources to monitor prices

The most common barrier to price response – reported by 51% of survey respondents – is a lack of time or resources to monitor day-ahead prices (Table ES-3). Asked specifically how often they monitor prices, ~70% of survey respondents indicated that they rarely or never do so. For some, this all but precludes price response. Others appear to rely on coincident signals – NYISO events or hot weather – to alert them of high prices.

Inadequate incentives keep one-quarter of customers from responding

Almost one-quarter of survey respondents cited inadequate incentives as a barrier to price response (Table ES-3). This suggests that for the other three-quarters of customers, the incentives afforded by SC-3A prices are either sufficient to justify responding, or that other barriers are of greater significance.[6]

Policy Implications

Despite the preponderance of barriers encountered by SC-3A customers, two-thirds have positive estimated elasticity of substitution values. Thus, we believe that some barriers may indeed be overcome with time.[7] However, policymakers should expect that about half of large customers cannot or may have no intention of becoming affirmatively price responsive, regardless of whether alternatives to day-ahead pricing are available to them. Others may be price responsive under regimes of occasional high prices, but may seek to hedge their exposure if prices become too high or volatile. Some smaller fraction, perhaps 20-25%, of highly responsive customers would probably elect to remain on day-ahead pricing and respond to price spikes, even if they occurred with greater frequency

[6] Customers were asked to indicate all barriers that applied to them, but it is possible that they neglected to indicate inadequate incentives if, for example, they never check prices and have never evaluated them, let alone made the determination that they are not high enough to make responding worthwhile.

[7] Indeed, targeted efforts to promote implementation of automated DR technologies and strategies could be effective in eliminating the need for customers to monitor prices actively.

than observed for SC-3A customers. This amount of price responsive load may be enough to abate the worst consequences of wholesale spot market price volatility.

8. Customer Acceptance

Finally, we examined customer acceptance of day-ahead market-based hourly pricing through customer survey and interview questions and by evaluating customers' supplier choice and hedging decisions.

Day-ahead RTP is well accepted by large customers in New York

In two years of administering surveys and interviews, we have heard few complaints about NMPC's default service: customers are relatively satisfied with day-ahead market pricing. Six years after its introduction, 36% of SC-3A customers (representing 34% of SC-3A load) still take their commodity from NMPC on the default rate.[8] Survey respondents indicated that they would be more likely to leave the utility if the default service was indexed to the NYISO real-time market, which affords no advance notice of prices.

Most customers have not hedged: 45-60% were fully exposed to day-ahead prices in 2004

Although the majority of customers interviewed told us they would prefer to hedge against price volatility, as many as 60% of SC-3A customers remain fully exposed to day-ahead market prices, either on the default SC-3A rate or a similarly indexed commodity deal with a competitive retail supplier. We believe that the main explanation for so many customers remaining un-hedged, yet not being very price responsive, is that they are "psychologically hedged": they have evaluated SC-3A prices and the market options available to them and decided that they are comfortable with the risk of remaining on day-ahead pricing and, for some, not responding. This suggests that these customers have adapted reasonably well to competitive market circumstances and are capable of assessing the inherent risks and their aversion to it.

Policy Implications

The acceptance of day-ahead market pricing by SC-3A customers is probably largely a function of the tariff design and price regimes these customers have faced over the past six years. In New Jersey, implementing default-service RTP indexed to the *real-time* market, which affords no advance notice of prices, has resulted in very high switching rates (84% of load) over a shorter time period (two years) (Barbose et al. 2005). This suggests that most large customers require some notice of prices in order to feel comfortable. Customer acceptance of the tariff or program designed to elicit price response is critical, and subjecting them to real-time RTP may result in reduced price

[8] Customers have expressed dissatisfaction with retail market offerings in interviews, in particular an inability to find suppliers interested in serving them or hedges that they felt were reasonably priced. However, we heard fewer complaints in the second year of our study than the first. This, combined with increased customer migration in recent years, suggests that the market is maturing.

response if the vast majority seek out fully hedged supply contracts rather than responding by shifting or curtailing load when peak prices are high.

Market penetration of financial hedges is particularly low

Less than 10% of survey respondents indicated that they had purchased financial derivatives that hedge against electricity price volatility.[9] About half of the rest either could not articulate why they had not or were not sure what a financial hedge is.

<u>*Policy Implication*</u>

Many large customers are apparently unfamiliar with financial hedging products as they relate to energy even after being exposed to day-ahead hourly pricing and competitive retail markets for six years. Policymakers concerned with ensuring adequate hedging options exist initially for customers exposed to default-service RTP should consider efforts to educate customers about financial hedge products and possibly having the default utility offer a hedged alternative during a transition period.

[9] The types of financial hedge products purchased by SC-3A customers are discussed in Goldman et al. (2004).

1. Introduction

This report describes the second phase of a study of large non-residential customer response to default-service day-ahead hourly pricing. The customers, located in upstate New York, are served under Niagara Mohawk Power Corporation (NMPC)'s SC-3A rate class. The SC-3A tariff is a type of "real-time pricing" (RTP) that provides firm, day-ahead notice of hourly varying prices indexed to the New York Independent System Operator (NYISO) Day-Ahead Market. It is the first and longest-running default-service RTP tariff implemented in the context of retail competition. With six years of experience on this tariff, NMPC customers provide a unique opportunity to study relatively long-term response to default-service RTP.

RTP has been advocated as an economically efficient means to send price signals to customers to promote demand response (DR) (Borenstein 2002, Borenstein 2005, Ruff 2002). DR is increasingly recognized as critical to ensuring efficient wholesale electricity market operation, signaling the proper timing and form of investments in new capacity, mitigating price spikes and abating the exercise of market power (Boisvert and Neenan 2003, FERC 2002).[10] The relative paucity of DR in most electricity markets as they are currently designed is attributable to the preponderance of fixed retail electricity rates. In theory, if customers paid prices for electricity that reflected the short-term (typically hourly) variations observed in wholesale market prices, which by design are the marginal supply cost, they would have both the information and incentives required to respond to high prices by reducing their demand. It is this theoretical basis that motivates current interest in RTP and other pricing signals as vehicles for delivery of DR.

While this theory is compelling, very few customers have actually been exposed to RTP and limited information exists that can be used to judge how effectively it actually induces DR. Not only is customers' latent price response potential not well understood, but in restructured retail electricity markets customers face a variety of choices that complicate the incentives they face. For example, in New York, customers may select supply options or financial derivatives that limit or eliminate their exposure to price volatility, thereby limiting their price response potential (either by eliminating their exposure to price signals altogether or by limiting their interest by providing some price protection). On the other hand, SC-3A customers are also allowed to participate in NYISO's statewide DR programs that pay customers to curtail load when prices are high (economic programs) or when system emergencies are declared (emergency programs). These DR programs may enhance customers "price" response if curtailment events are coincident with high prices. Sorting out these often confounding incentives is challenging.

Prior to 2003, few studies of customers' response to dynamic pricing were available in the public domain, in part because very few customers had ever been exposed to dynamic prices. The notable exceptions were Zarnikau (1990), Herriges et al. (1993), Braithwait

[10]Another important benefit of price responsive load is that it obviates a certain amount of generation capacity that would otherwise be needed to meet unresponsive demand, thereby reducing overall resource costs (Braithwait 2005).

and O'Sheasy (2001), Schwarz et al. (2002) and Taylor et al. (2005). All of these studies estimated price response of large commercial and industrial customers that had volunteered for optional RTP programs at regulated, vertically integrated utilities and they all found modest overall load response, the majority of which was typically provided by a minority of customers. Schwarz et al. (2002) and Taylor et al. (2005) found that customers with onsite generation were particularly price-responsive. However, extension of these results to today's restructured markets is problematic because these customers faced RTP in isolation; switching suppliers, purchasing hedges, and participating in DR programs – factors that can confound the incentives created by RTP – were not options for these customers.

Three recent studies published in the public domain address this information gap by analyzing customers' price response. First, as part of a statewide proceeding on demand response, a critical peak pricing (CPP) experiment was designed through a working group process and administered to ~2500 small commercial and residential customers of California's three large investor-owned electric utilities, Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric.[11] The resulting evaluation report estimated elasticities and found measurable reductions in energy usage associated with the observed shifting behavior (Charles River Associates 2005). For residential customers, peak demand reductions were estimated at ~10-15% for critical-peak to off-peak price differentials of up to 10:1. Peak demand reductions for small commercial and industrial customers were smaller (~6-9%). While these results provide insights into small customers' demand for electricity, they do not speak to the behavior of large commercial, industrial and institutional customers, which use electricity as an input to business activity or service provision.

Second, Boisvert et al. (2004) quantified the price response of over 50 large commercial and industrial customers that had volunteered for a two-part RTP tariff at several Central and Southwest Services' utilities in the late 1990s. The class average substitution elasticity was estimated at ~ 0.14, but individual customer elasticties as high as 5 were observed.

Third, in 2003, the California Energy Commission (CEC) Public Interest Energy Research (PIER) program commissioned the first phase of this case study of NMPC customers' response to default-service day-ahead market electricity pricing to address the following policy questions:

- Are customers satisfied with default-service RTP?
- Does RTP deliver demand response?
- What customer characteristics and circumstances drive price response?
- How do RTP and ISO DR programs interact?

[11] Critical peak pricing is another type of dynamic pricing tariff which resembles a time-of-use rate, with previously set prices for electricity, in most hours, but with higher "critical-peak" prices that are communicated to customers when price spikes are experienced in wholesale markets or system emergencies are called (the trigger event is determined by the particular tariff design).

- Do enabling technologies enhance customers' responsiveness?
- To what extent do customers take steps to hedge against price volatility?

This first phase focused on the regulatory context for RTP adoption, customer satisfaction, customers' preferences and choices for hedges and competitive electric commodity supply arrangements, enabling technologies and response strategies and estimates of substitution elasticities based on a Constant Elasticity of Substitution (CES) demand model. The results, published in Goldman et al. (2004), showed modest overall response to prices and found that government/education customers were most responsive, followed by industrial customers. Customer market research indicated that customers were generally satisfied with default-service RTP, but had been somewhat disappointed with retail market offerings. Some factors were found to have a significant impact on elasticity – in particular, participation in the New York Independent System Operator (NYISO) demand response programs greatly enhanced industrial customers' estimated price response, and we found that response from curtailing, rather than shifting, load was significant.

However, several questions remained unanswered in the first phase of this study or had not been clearly elucidated. This second phase, also commissioned by the CEC PIER program, and coordinated by the Demand Response Research Center (DRRC), was designed to:

- further disaggregate price response by business sector,
- identify the characteristics of highly price-responsive customers and attempt to understand differences in price responsiveness within business classifications,
- disentangle customers' response to high hourly prices from response to coincident signals to curtail, such as NYISO DR program events and public appeals to conserve,
- clarify the impact of enabling technologies, particularly onsite generation, on customers' empirical price response estimates and self-reported response strategies,
- characterize the impact of price levels on response in order to look for threshold effects (e.g., customers may increase their response at higher prices or may exhaust their response capability),
- identify important barriers to price response, and
- update customer switching and hedging trends and better understand why customers make the choices they do (e.g., why they stay with default RTP pricing or why they switch).

To accomplish these goals, we developed and administered a second customer survey that targeted these research questions and collected two more years of load and price data from NMPC (2003 and 2004) allowing us to include five summers in our analysis. We also estimated a different demand model in this phase – a Generalized Leontief (GL) model – that is theoretically consistent with electricity usage as an input to firms' or organizations' business activity and is more flexible than the CES model in that it allows for price response to vary as a function of nominal prices.[12]

This report is organized as follows. Chapter 2 provides background on the customers that are the subject of this study, the choices available to them, and the prices they have faced, and describes survey design and administration and other data sources for this study.[13] Chapter 3 focuses on modeling and estimating customer response to hourly prices – it introduces our methodology and treatment of data in the demand model and presents key results, including disaggregated substitution elasticity estimates and factors that influence price response. In Chapter 4, we present customer survey and interview results, including self-reported load response strategies, enabling technology usage, characteristics of price-responsive and unresponsive customers, barriers to price response, and customer migration and hedging choices. In Chapter 5, we synthesize key findings from this study and discuss their implications for policymakers interested in default-service RTP as a strategy for encouraging DR in competitive retail markets. The customer survey, a discussion of the theory of customer electricity demand and the specific equations we estimated, and detailed model results are included as appendices.

[12] A major restriction of the CES model is that customers' price response is assumed to be constant at all prices. This makes the model simpler to estimate and interpret, but does not provide information on threshold responses that many customers report in interviews (Goldman et al. 2004).
[13] Additional background on the context for NMPC's RTP tariff, including the regulatory process and goals, is published in Goldman et al. (2004).

2. Background, Approach and Data Sources

In this chapter, we provide an overview of the Niagara Mohawk customers and the tariff and market options and price regimes they have faced during the study period, which covers the summers of 2000 through 2004. It provides a foundation for understanding the results of models and analyses of customer behavior under default service RTP in Chapters 3 and 4. Furthermore, characterizing these customers and circumstances provides a basis for determining the applicability of these results, especially with regard to price response, to electricity customers in other jurisdictions. Goldman et al. (2004) provides a more extensive discussion of the context and motivations for NMPC's day-ahead market tariff and the process under which it was adopted. We limit the discussion in this chapter to the factual and contextual information necessary to evaluate and extend the results of the analyses presented in this report.

Also in this chapter, we review price and weather trends over the five years of our study period to lay the foundation for quantifying price response, discuss customer survey and interview objectives, administration, response rates and representation by business category and other characteristics, and briefly describe other data sources for this study.

2.1 Tariff and Market Options

NMPC's day-ahead hourly pricing tariff was adopted as the default service for its largest customers – the "SC-3A" class of customers, with peak demand greater than 2 MW – in late 1998. The tariff was part of the utility's rate case filing that inaugurated electric industry restructuring in New York.[14] NMPC's service territory covers the majority of upstate New York and contains many of the state's largest manufacturing and industrial facilities. The competitive choice model adopted included divestiture by NMPC of its generation assets and unbundling of commodity from wires costs to facilitate customer switching and achieve greater pricing efficiency.

The RTP-based default service, employing day-ahead hourly price schedules, was proposed by NMPC and received favorably by large customer representatives and regulators (Goldman et al. 2004). Customers' subsequent acceptance of the tariff is due in large part to its implementation as part of the transition to a competitive market: SC-3A customers have several alternative choices to default-service RTP for their commodity service.[15] **Figure 2-1** provides an overview of the choices available to SC-3A customers since RTP became the default service in late 1998. Customers can purchase their electric commodity from a competitive retailer and they have opportunities to hedge with financial derivatives to offset the risks associated with paying hourly varying energy prices. In addition, since 2001, these customers have had opportunities to earn curtailment incentives by participating in demand response programs offered by the New York Independent System Operator (NYISO). Enabling technology incentives and

[14] New York is somewhat unique in that electricity market restructuring was implemented utility-by-utility by the Public Service Commission, rather than as part of a statewide legislative mandate. NMPC was one of the first utilities to undertake this transition.

[15] Almost a third of these customers had previously participated in voluntary RTP-style programs during the early to mid-1990s and were thus fairly comfortable with the concept of hourly pricing.

technical assistance through NYSERDA programs have also been available through most of the study period to assist customers in developing price responsive behaviors. We discuss these choices in more detail below.

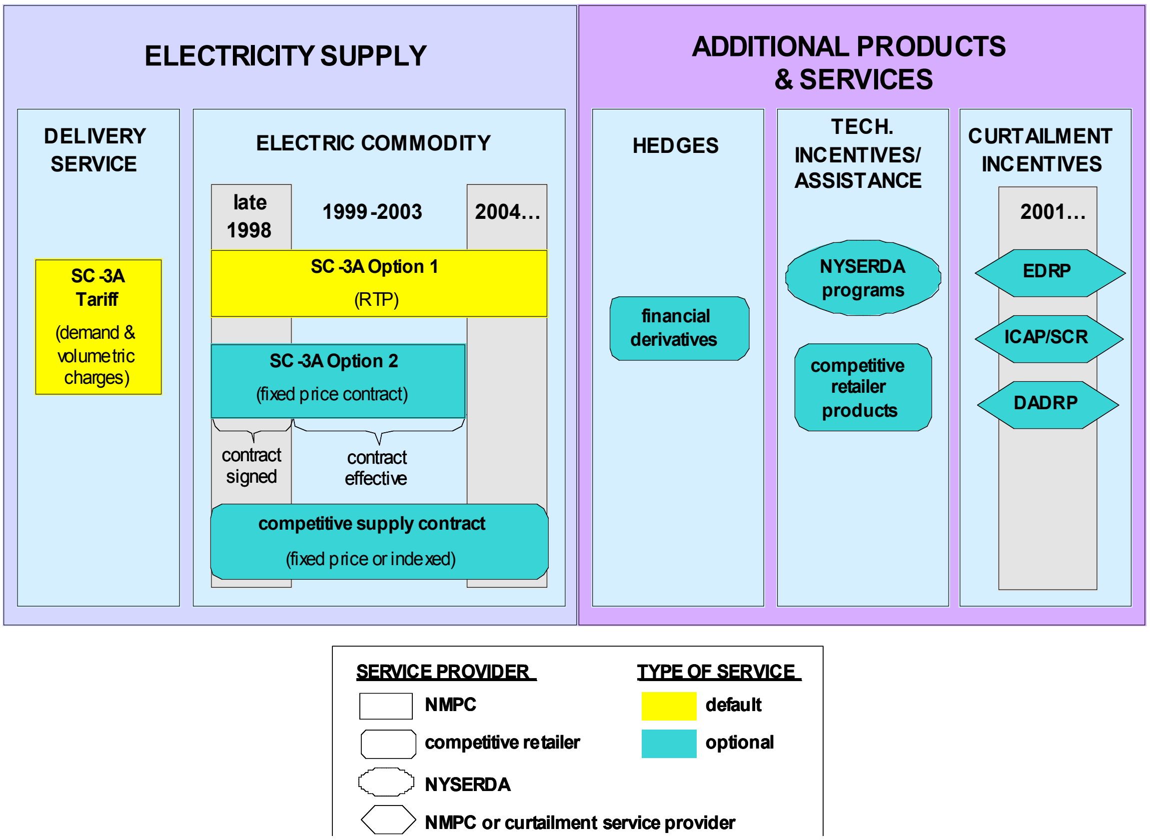


Figure 2-1. Choices Available to SC-3A Customers

2.1.1 Electricity Supply Options

SC-3A customers, regardless of their choice of electric commodity supplier, pay common delivery service rates specified in the SC-3A tariff that consist of demand and volumetric charges (see Figure 2-1). Their choices for electric commodity are as follows.

SC-3A Option 1. The default-service commodity tariff, "Option 1", is indexed to the New York Independent System Operator (NYISO)'s location-based day-ahead market. SC-3A customers that do not select an alternative commodity option are billed for usage in each hour at the prevailing day-ahead price for their voltage level and location, plus an adder that includes NYISO ancillary services charges. The next day's prices are posted by 4pm on NMPC's web site. Because the day-ahead prices are firm, NMPC bears some overnight forecast risk to the extent that real-time and day-ahead prices deviate.

SC-3A Option 2. At the request of large customer representatives, NMPC offered a forward contract as a fixed-rate alternative to RTP, called "Option 2", as part of the transition toward a competitive retail market. Offered only once, just prior to the introduction of retail access in 1998, Option 2 was a time-of-use (TOU) rate that entailed a contractual obligation for up to five years. Customers that selected Option 2 nominated a fixed amount of load for peak and off-peak periods (in MW) in each month of the contract. A pre-determined rate schedule applied to all nominated load. The terms of Option 2 were quite restrictive. It involved a take-or-pay contract, meaning that customers were responsible for paying for all contracted load regardless of whether they used it or not. A one-time, permanent opt-out provision was available for a premium, but customers had had to elect it when the contract was signed.

About 20% of SC-3A customers selected Option 2, and many of them were conservative in the amount of load that they nominated (Goldman et al. 2004). On average, Option 2 customers covered about 60% of their peak demand and a lower proportion of their off-peak usage. The rest of their load was either served on SC-3A Option 1 or from a competitive supply contract. The Option 2 contracts expired in 2003 and were not extended.

Competitive Supply Contracts. SC-3A customers have also had the option of purchasing electric commodity from competitive retailers (referred to as "energy service companies", or ESCOs, in New York) since 1998. Contracts with competitive retailers may be structured as fixed-rate or TOU arrangements, or may entail hourly varying commodity prices indexed to SC-3A Option 1 prices or directly to the NYISO day-ahead market or some other source of prices.

2.1.2 Additional Products and Services

In addition to commodity supply options, SC-3A customers have had access to several other products and services that may impact their price responsiveness (see Figure 2-1).

Financial Hedges. SC-3A customers may purchase financial hedges, which are derivatives separate from the supply of electricity, that hedge against price volatility, usually for a specified volume of electricity. With financial hedges, customers can mitigate some degree of price risk while still facing hourly prices for marginal usage. The specific types of financial hedges taken by SC-3A customers are described in Goldman et al. (2004).

Enabling Technology Incentives and Technical Assistance. During the study period, SC-3A customers have been eligible to participate in public benefits funded programs, offered by the New York State Research and Development Agency (NYSERDA), that provide incentives for installing demand response enabling technologies such as energy management control systems, peak load control devices and energy information systems that provide near real-time access to energy usage data. These programs are designed to encourage participation in NYISO Demand Response (DR) programs. In addition, competitive retailers may offer similar technologies and/or technical assistance as part of a package of load management products and services.

NYISO Demand Response Programs. Since 2001, SC-3A customers have been eligible to participate in NYISO's three demand response programs. The Emergency Demand

Response Program (EDRP) pays a floor price of $500/MWh for load curtailments when NYISO declares emergency events. EDRP curtailment is voluntary; there are no penalties for enrolled customers that fail to curtail when called. Customers that participate in the Installed Capacity/ Special Case Resources (ICAP/SCR) program receive capacity payments for load reduction commitments, and since 2003 energy payments for load curtailed when NYISO declares events. Unlike EDRP, the ICAP/SCR program includes penalties for customers that fail to curtail when program events are called. The Day Ahead Demand Response Program (DADRP), an economic program in which customers bid load curtailments directly into the NYISO day-ahead market, has seen low enrollment by SC-3A customers.

2.2 SC-3A Price Trends

The level and volatility of the prices customers face has a direct impact on how they decide to respond to those prices – by finding a hedge, by managing their electricity usage and responding to price changes, or by taking no action. Here, we describe trends in SC-3A prices on weekdays during the five summers covered by this study: 2000-2005. Where we show average peak and off-peak prices, the peak period is defined as 2-5 p.m. to be consistent with the hours used in our final customer demand model (see section 3.3.1).

Higher, More Volatile Prices in the East. The NMPC service territory covers much of up-state New York and is comprised of two non-contiguous areas (see **Figure 2-2**). The region is characterized by rather mild summer weather with daily summer highs seldom reaching 90 degrees. The service territory, which spans four NYISO load zones, may be divided into three distinct regions – Eastern, Central and Western – that encompass these pricing zones (see Figure 2-2). The Central and Eastern regions are divided by a transmission interface, which periodically becomes congested. At such times the Eastern region, which is closest to downstate New York, experiences relatively high prices and greater volatility than the other NMPC regions (see **Figure 2-3** and **Figure 2-4**). This was a factor particularly in 2000. In later years, peak prices and price volatility have converged in the three regions, though prices remain slightly higher in the East. The Western region, which is physically separated from the rest of NMPC service territory, and where there is an abundance of generation capacity, has experienced similar price patterns to the Central region.

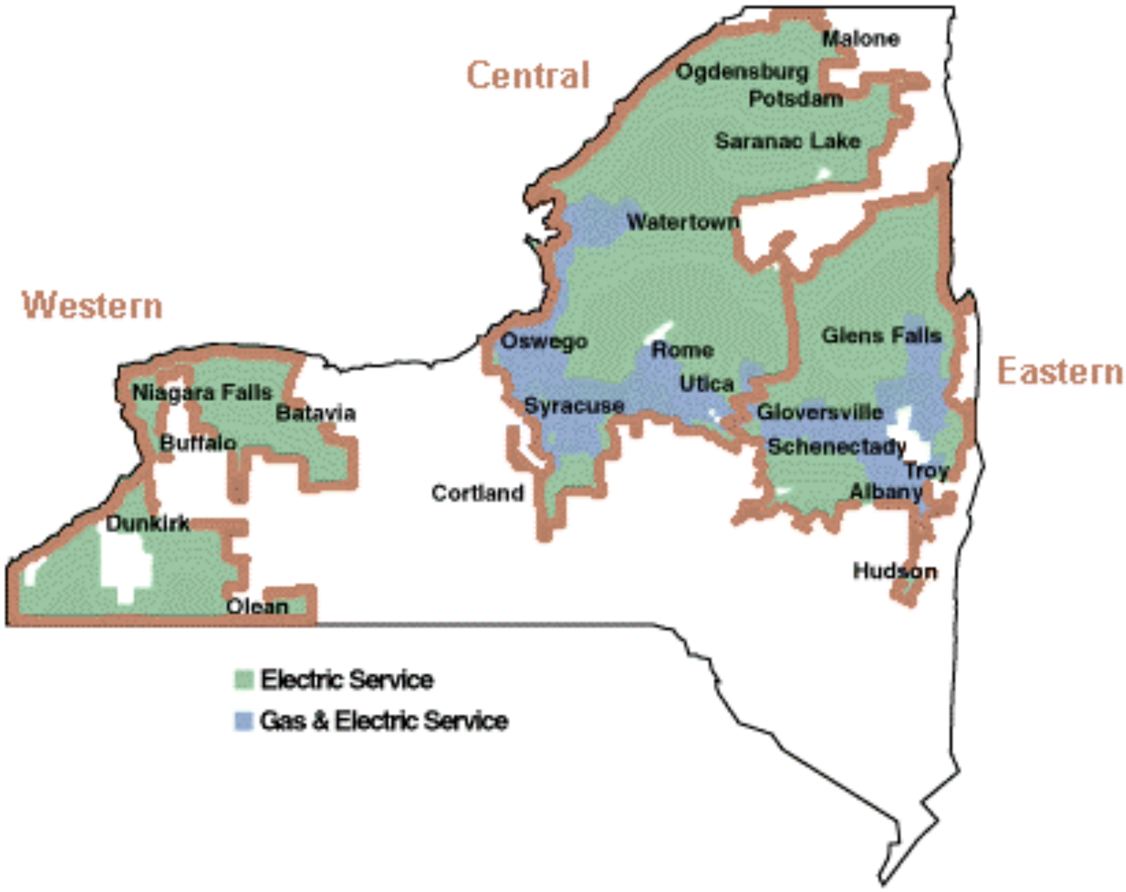
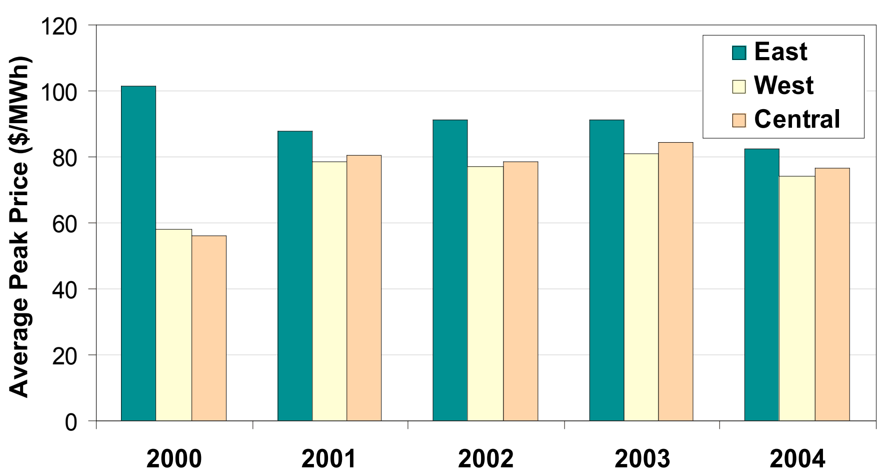
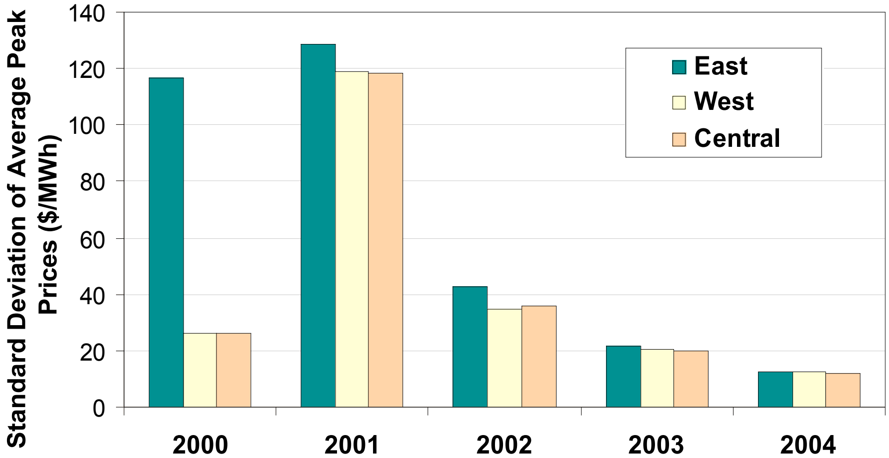


Figure 2-2. Major Price Regions in NMPC Service Territory



Note: Prices are averaged for primary delivery voltage customers and include weekdays during June, July and August only. The on-peak period is defined as 2pm to 5pm.

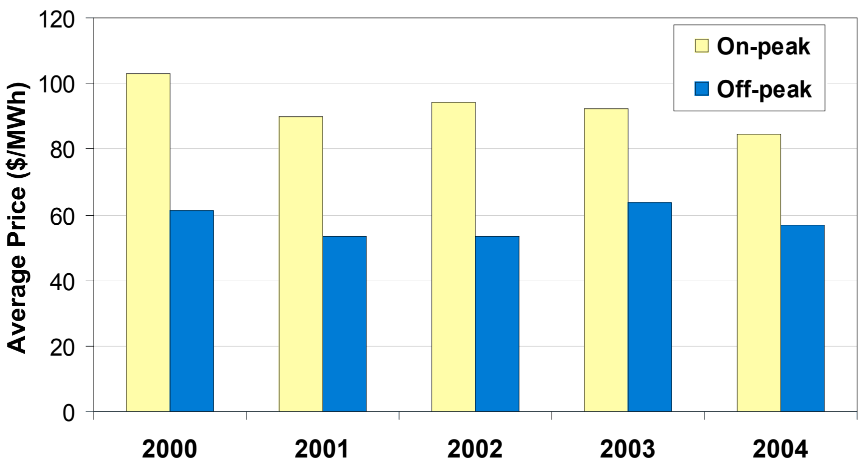
Figure 2-3. Average Peak Prices by Region



Note: Prices are averaged for primary delivery voltage customers and include weekdays during June, July and August only. The on-peak period is defined as 2pm to 5pm.

Figure 2-4. Volatility of Peak Prices by Region

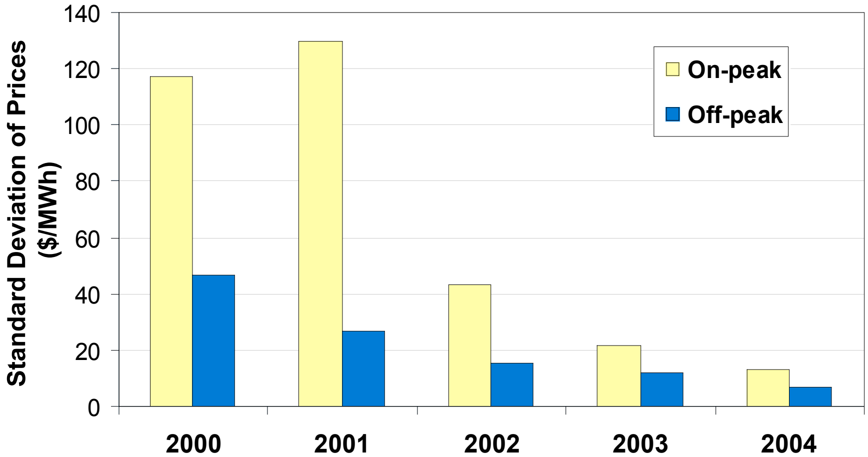
Stability in Average Prices. Average peak and off-peak SC-3A prices over the five summers of our study (2000-2005) have been relatively stable and peak prices have even declined slightly (see **Figure 2-5**). The difference in average summer peak and off-peak prices has diminished over time. The average peak price was 68% higher than the average off-peak price in the summers of 2000 and 2001. By 2004, the average summer peak price was only 48% higher than the average summer off-peak price.



Note: Prices are averaged for primary and secondary delivery voltage customers and include weekdays during June, July and August only. The on-peak period is defined as 2pm to 5pm.

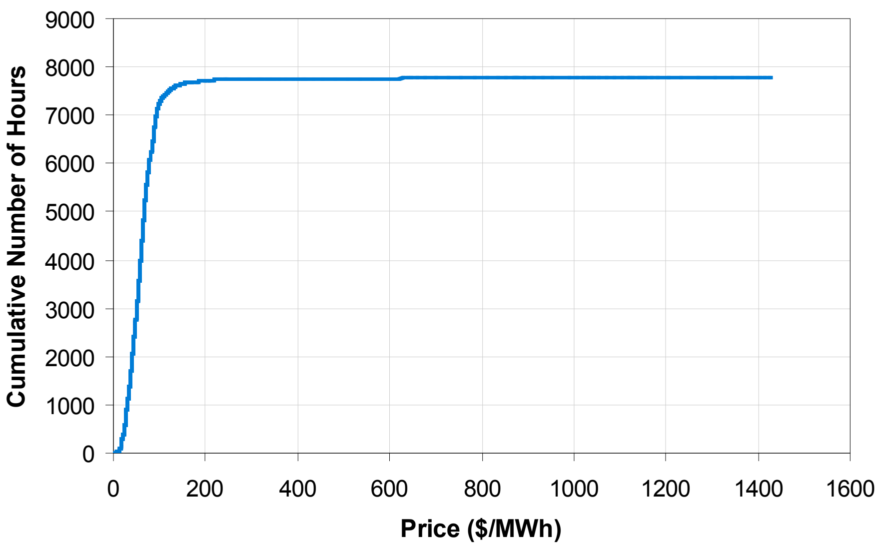
Figure 2-5. Trends in Average Summer SC-3A Prices: East Region

Declining Price Volatility. Price volatility has declined substantially in the last three years of our study (2002-2004) (see **Figure 2-6**). There have consequently been very few price spikes in recent years, limiting our ability to model customers' response to the type of high-price events that motivate many policymakers' interest in RTP.



Note: Prices are averaged for primary and secondary delivery voltage customers and include weekdays during June, July and August only. The on-peak period is defined as 2pm to 5pm.

Figure 2-6. Trends in Summer SC-3A Price Volatility: East Region



Note: Prices are averaged for primary and secondary delivery voltage customers and include weekdays during June, July and August only for the 2000-2004 period.

Figure 2-7. Price Duration Curve: East Region, 2000-2004 Summer Weekdays

Isolated High-Price Events. Over the past five summers, SC-3A customers have been faced with relatively few hours of high prices. In **Figure 2-7**, hourly 2000-2004 summer weekday prices for primary and secondary voltage customers in the Eastern region are averaged and ordered along the y-axis from lowest to highest. In 93% of the hours, prices were below \$100/MWh, and prices were below \$200/MWh for 99% of the hours. Prices were between \$200/MWh and \$500/MWh in only 49 hours over these five summers, and between \$500/MWh and \$1000/MWh during only ten hours. Prices exceeded

$1,000/MWh in eight hours. The highest price observed was approximately $1,400/MWh. All of the prices above $250/MWh occurred in 2000 and 2001. Customers in the Central and Western regions have faced fewer high-priced hours than customers in the Eastern region; prices in these regions did not exceed $1,000/MWh during our study period.

2.3 Weather in Upstate New York

Weather conditions are an important factor to account for in evaluating electricity demand and price response. Hot weather may affect customers' loads, to the extent that they are driven by cooling needs, and may also affect customers' price response, to the extent that cooling loads are discretionary or that customers associate hot weather with high electricity prices. Furthermore, these impacts may vary under different weather conditions. Summer weather in NMPC's service territory is mild relative to other regions of the U.S., and this may influence the transferability of the results of this study.[16]

The Temperature Heat Index (THI), a metric that combines temperature and relative humidity effects, provides context for the weather patterns experienced in upstate New York over the five summers of our study period.[17] **Table 2-1** shows the distribution of average THI values for the hours from 2-5 p.m. at a representative weather station in the Eastern region of NMPC's service territory. On 87% of days, the index was below 90, and it rose above 100 on only four days in five summers. The highest recorded THI was 111.

Table 2-1. Representative Summer Weekday Temperatures in NMPC Service Territory: 2000-2004

THI[a] Value	Number of Days (N = 321)
< 70	34
70-80	121
80-90	125
90-100	37
>100	4

[a] THI = Temperature Heat Index, daily average for the hours from 2-5 p.m.

There is a strong coincidence between hot days, high prices and the NYISO events called during our study period. Eight of the top-ten warmest days were in 2001 and 2002. On four of these days, EDRP events were declared (three in 2001 and one in 2002).

2.4 Customer Research

A major component of the first phase of this study was an in-depth customer survey and follow-up interviews that provided information on customer characteristics and

[16] The empirical aspects of this study concentrates on price response during the summer months as price volatility has been low during the rest of the year (see section 3.2.2).
[17] See section 3.2.2 for a discussion of how this weather metric was used in our analysis of customers' price response.

circumstances. This information was used to develop variables to describe and model price response. Despite the large amount of information collected, several aspects of customer behavior and experience remained unclear. Moreover, due to survey non-response and missing information on key questions, only 32 customers could be included in the final customer demand model in the first phase of this study.

As part of this second phase, we undertook another customer research initiative with two objectives in mind: (1) to improve survey response, both in terms of the overall response rate and in ensuring adequate representation of customer market segments, and (2) to obtain more detail on questions that hadn't been fully answered in the first phase of this project.

2.4.1 Survey Design

In designing the second-phase survey, we addressed our goal of improving customer response by developing a relatively short survey that included only the most essential information. We also offered financial incentives to each customer that answered the survey (see section 2.4.2).

One of the main questions we attempted to clarify in this year's survey is which signals customers respond to (e.g., high SC-3A prices, NYISO emergency events) and why they respond to them. In the 2003 survey, we had asked customers about their response but did not directly ask what they were responding to. Given the various signals that SC-3A customers have faced, we felt that more information was needed to disentangle their response to high SC-3A prices from their response to other, coincident signals. In addition, if customers responded to some signals but not others, we wanted to find out why they did so.

A second key question that we focused on was the impact of enabling technologies on price response. Enabling technologies are equipment and devices, like energy management systems, peak load control devices, and energy information system gateways that help customers devise and execute price response strategies. In the 2003 survey, we had asked customers whether they had installed certain technologies at their facilities that could enable price response, and found no clear correlation between these investments and estimated price response. In this phase of our research, we asked more targeted questions about when the technologies were installed and how they were used.

We also designed the survey to better clarify customers' load response strategies by asking them explicitly about their use of onsite generation as a load response strategy and asking them how they curtail various end uses.

Finally, we asked several questions about barriers to price response, reasons why customers had stayed with NMPC, and their plans for responding to SC-3A prices going forward. The question topics covered by the survey are shown in **Table 2-2**. The complete survey is included in Appendix A.

Table 2-2. Question Topics Included in 2004 SC-3A Customer Survey

Category	Question Topic
Electricity Usage	Timing of usage
	How often customers check prices and, if they don't, why not
	Major changes in electricity usage (e.g., production changes)
Response Strategies	Response to what signals?
	Reasons for response and impact on facility operations
	Response strategies
	Barriers to price response
Enabling Technologies	Which technologies installed
	When the equipment was first used
	Purpose for which equipment is used
Electricity Supply	Electricity intensity
	Rate history
	Reasons for staying with NMPC
Hedging	Details of competitive supply arrangements
	Financial hedges and reasons for not purchasing them
Future Outlook	Plans for future response to SC-3A prices
	Reactions to hypothetical default service tariff indexed to real-time energy markets

2.4.2 Survey Administration

This year's survey was administered in two phases: a set of telephone interviews followed by a self-administered web survey. NMPC supported both phases by providing updated customer contact information and asking its account representatives to personally contact their SC-3A customers to encourage them to participate in the survey.

Telephone Interviews. The in-depth interviews were designed to test the survey instrument prior to implementing the web survey and to obtain additional information on several topics of interest, including specific response strategies, usage of enabling technologies, and specific obstacles to price response. We identified customer attributes that we felt were important to sample representatively and established the population of each among the full survey population of 133 customer accounts. We then identified customers to target for interviews to ensure representation by these groups, outlined as follows:

- customers who hadn't answered the survey in 2003
- customers who we identified as potentially "price responsive" and "not price responsive" as predicted by the demand model estimated in Goldman et al. (2004)
- proportional representation by each of five business categories (described in section 2.4.3)
- customers that had stayed on the NMPC commodity tariff and customers that had switched to competitive retailers

The telephone interviews were conducted between October 19 and November 4, 2004. Prior to scheduling interviews, we emailed the survey to customers along with a cover letter explaining the project and encouraging them to participate. We offered customers a $50 incentive for participating.[18] Altogether, 20 customers were interviewed. Their responses were recorded and included with those of the customers that answered the web survey described below.

Web Survey. This year's web survey was administered initially from December 2 through 20, 2004. We sent letters to each SC-3A customer that had not already been interviewed.[19] Customers were offered a $50 incentive for filling out the survey, and each respondent was entered in a drawing for a $500 prize. The response during this window was less than hoped for. We believe this is due in part to the time of year (just prior to the holiday season) and also to survey "fatigue" as our web survey followed directly after NMPC's annual customer satisfaction survey.

To improve response, we re-opened the survey from January 13 through 28, 2005 and offered each respondent an incentive of $75 as well as a chance to win a second $500 prize.[20] To improve representative coverage and to increase overall response to our goal of 50%, we telephoned selected customers directly and administered the survey orally between February 4 and 16, 2005, offering the same $75 incentive. This last effort was successful: we exceeded our survey response target rate and achieved our targeted market segment representation.

2.4.3 Survey Response

Response to this year's customer survey was extraordinarily high for this type of market research: 57% of our survey population of 133 accounts responded (see **Table 2-3**). Forty of the 76 accounts represented by this year's survey had also answered our previous survey in 2003.

Table 2-3. 2004 SC-3A Survey Response by Customer Account

Business Category	Total SC-3A Customer Accounts	Survey Population*	Survey Responses	Response Rate*	Answered 2003 and 2004 Surveys
Manufacturing	47	40	25	63%	10
Public works	24	22	10	45%	7
Commercial/retail	17	16	8	50%	5
Healthcare	17	15	10	67%	3
Government/education	44	40	23	58%	15
Total	**149**	**133**	**76**	**57%**	**40**

* Several customers indicated in advance that they did not wish to be surveyed. The survey population and response rates correspond to those customers who were approached with the survey.

[18] Customers had the option of taking the incentive themselves or having us donate it to a charity of their choice.
[19] A few customers had indicated to NMPC that they did not wish to be surveyed, and were not approached.
[20] Due to limited response during this phase, we included all customers who had answered the survey or been interviewed up to this point in this second prize drawing.

Based on SIC codes provided by NMPC, we classified customers into five business categories: manufacturing, public works, commercial/retail, healthcare and government/education. We expanded these categories from the three utilized in Goldman et al. (2004) to provide a more detailed characterization of customers by market segment.[21] The response rates for each of these categories range from 45% for public works to 67% for healthcare facilities (Table 2-3).

The full SC-3A population includes 149 customer accounts with a combined non-coincident peak demand of 642 MW. The survey respondents represent this population quite well on the basis of geographic location, supplier choice, customer size, and participation in NYISO DR programs (see **Table 2-4**).

Table 2-4. Characteristics of SC-3A Customers and 2004 Survey Respondents

Customer Characteristic		**Percent of Customer Accounts**	
		All SC-3A Customer Accounts (N=149)	**2004 Survey Respondents (N=76)**
Region	East	33%	37%
	Central	30%	33%
	West	37%	30%
Electric Commodity Supplier (summer 2004)	NMPC	37%	37%
	Competitive Retailer	63%	63%
NYISO DR Program Enrollment (any summers)	EDRP	33%	37%
	ICAP/SCR	24%	18%
	DADRP	3%	3%
Maximum Peak Demand	< 2.5 MW	40%	37%
	2.5 – 5 MW	40%	42%
	> 5 MW	19%	20%

2.5 NMPC Billing Data and Tariff History

For the second phase of this study, we worked with NMPC staff to obtain updated SC-3A customer interval meter and price data and tariff history. The interval meter and price data are hourly and cover the period from January 1, 2000 to September 30, 2004. The tariff history data indicates whether a customer was on Option 1, Option 2, or with a competitive supplier for each month from the spring of 1999 to the fall of 2004. Not only does the data in this phase cover a longer time period than the 2003 study, but the information is more complete, and we undertook a considerable effort to ensure data quality.

We also made use of customer characteristics data that we had received from NMPC in the first phase of this study. This information includes SIC codes, which we used to classify customers into business categories, geographic location, and delivery voltage level.

[21] In Goldman et al. (2004), public works customers were included in the government/education category and healthcare customers were included in the commercial/retail category.

3. Quantifying and Characterizing Price Response

A major goal of this study is to quantify how large commercial, industrial and institutional customers paying day-ahead market-based electricity prices adjust their usage in response to short-term price changes. In particular, we are interested in the intensity, character and major drivers of this response. We accomplish this by estimating substitution elasticities for the SC-3A customers that faced hourly varying prices over five summers (2000-2004), comparing these estimates by customer and business classification, and by developing models that quantify the impact of various factors that we hypothesized could impact customers' response. In particular, we focus on weather effects, peak prices, and a variety of customer characteristics and circumstances, including enabling technology adoption and participation in NYISO DR programs, as drivers for price response.

Quantifying price response assists policymakers and market participants in several important ways. First, substitution elasticity results provide direct empirical evidence of the overall magnitude of price responsive load that can be expected. This provides a basis for developing price-responsive load programs and evaluating what additional DR options may be necessary. Second, understanding the distribution of price response among customers allows public benefits program administrators to identify promising targets for programs that assist with price response. Third, disaggregated elasticity estimates can be the basis for utilities or competitive retailers to anticipate the amount of load response they can expect from their customers at different price levels. This information allows them to bid price-responsive loads into wholesale power markets, thereby allowing DR to compete with supply (Braithwait 2005). Finally, elasticity results can also help policymakers forecast the impact from critical peak pricing (CPP) rate designs.

This chapter begins with a brief discussion of the theoretical basis for the demand model used in this analysis, the interpretation of the substitution elasticity, an overview of the models used in this study, how they were estimated and the data sources included. We then present the results of this research, beginning with the intensity of price response: average substitution elasticity estimates for SC-3A customers overall and for each business category, and the distribution of elasticities within each sector. Next, we describe the character of price response: weather, price and demand impacts on customers' substitution elasticities. Drivers to price response are then presented and discussed. Finally, we estimate the aggregate demand reduction potential of SC-3A customers based on their substitution elasticity estimates.

3.1 Measuring Price Response – The Theory of the Firm

The model for electricity demand used in this study is consistent with the modern economic theory of the firm. According to this theory, firms – or SC-3A customers, in our case study – are assumed to minimize the cost of producing a given level of output by trading off production inputs based on their relative prices. Output, in this case, refers to the customer's business activity – the production of intermediate or final consumer goods or the provision of services to consumers or society – at levels demanded by their customers or clients. Inputs are any goods or services needed to produce this output. Electricity is one such input to SC-3A customers' business activities.

Under hourly electricity pricing, the cost of electricity varies considerably during the day, with the highest prices typically occurring during the afternoon, peak-period hours. We therefore model electricity as two inputs – "peak" and "off-peak" electricity – that can be substitutes or complements, depending on how they are used to support a customer's productive process. In either case, the model assumes that customers decide how much peak and off-peak electricity to use in order to meet their daily output obligations.[22]

During our study period, NYISO day-ahead electricity prices, which are the basis for SC-3A prices, were distributed such that the majority of days are characterized by a fairly constant pattern of hourly prices (of typically $50-60/MWH for mid-day hours), with high peak period prices (exceeding $300/MWh) occurring only on isolated days (see section 2.2). Consequently, we portray SC-3A customers' price response as primarily involving the decision to reallocate business activity on those days when prices are high from an established routine followed on "normal" days.

The established routine of normal business practices require electricity expenditures derived from the operation of machines, lighting, safety, space conditioning and other requirements. According to the economic theory of the firm, these requirements in turn are derived from proscribed or anticipated levels of business activity. Implicitly or explicitly, customers allocate electricity use in each hour of the day according to its value as an input during those hours. This usage pattern might change in response to factors that change the business intensity or schedule, but on a day-to-day basis electricity usage is derived by the expected, and planned for, level of business activity.

The theory of the firm also predicts that the level of peak and off-peak energy used on any day may be adjusted depending on the relative prices for that day. On days with high peak prices, we expect customers to use less electricity during the high-priced hours of the day and more during the lower priced hours to meet the day's expected level of business. In other words, the decision involves substitution of off-peak electricity use for peak usage. It is this relationship – the substitution of off-peak for peak energy – that is explicitly modeled in this study.

To evaluate this response, we estimate *elasticities of substitution* for SC-3A customers exposed to day-ahead hourly prices from their hourly-integrated load and price data. The substitution elasticity is a very specific characterization of electricity demand and price response that is consistent with this portrayal of how customers use and value electricity. Mathematically, it is defined as the percentage change in the ratio of daily peak to off-peak electricity usage in response to a one percent change in the ratio of off-peak to peak electricity prices. It indicates the degree to which a customer minimizes costs by adjusting electricity usage between times of the day, based on relative electricity prices.

[22] This peak vs. off-peak distinction is consistent with how other empirical evaluations of RTP-type tariffs have treated electric commodity (Caves, et al. 1984, King and Shatrawka 1994, Schwarz et al. 2000, Bosivert et al. 2004, Goldman et. al. 2004).

Own-Price vs. Substitution Elasticities

Readers of this report may be more familiar with the *own-price* elasticity of demand than the substitution elasticity measured in this study. Own-price elasticities are somewhat more intuitive – they measure the reduction in a customer's *overall* consumption in response to an increase in the *nominal* price of electricity (rather than changes in the customer's *relative* peak and off-peak electricity consumption due to *relative* price changes) – and provide a direct means to predict load reductions at specific prices.

However, there are two important reasons for estimating substitution rather than own-price elasticities to characterize large commercial and industrial customers' price response: theoretical consistency and data limitations.

Theoretical Consistency

SC-3A customers are large industrial and commercial firms and institutions. All of them use electricity as an input to their business activity in some form. We observe that their daily electricity usage patterns are relatively well defined and comport with prices (high loads during high prices, low loads during low prices); this coincidence between prices and load provides a logical basis for analyzing price response in terms of changes in peak and off-peak usage. Moreover, we observe that customers make short-term decisions about how to adjust their electricity usage. Thus, it makes sense to use the theory of the firm, and the resulting elasticity of substitution, to analyze the relationship between prices and usage during peak and off-peak periods of the day. Although it is possible to derive own-price (Allen partial) elasticities from the GL model, they would restrict "output" to remain constant as electricity consumption patterns change. This makes their interpretation very difficult. The more traditional Marshallian own-price elasticity, which does not hold output constant, cannot be estimated here due to data limitations (see below).

Customer interviews and surveys conducted in both phases of this study indicate that customers employ a variety of load curtailment strategies. Many say they respond to price increases by reducing discretionary usage during peak periods without making it up later or by serving load with onsite generation, and a few report that they indeed shift usage, but to another day. We acknowledge that input substitution is not the only type of response observed. However, the substitution elasticity is structurally consistent with all these load response strategies because they all result in a reduction in the ratio of peak to off-peak usage in response to higher peak prices (see the inset, *How the Substitution Elasticity Characterizes Foregoing and Other Load Response Strategies*, below). The substitution elasticity cannot separately and consistently account for each of these effects, but neither could the own-price elasticity, which would incorrectly capture the effect of shifting behavior, resulting in precisely the opposite problem. To the extent that SC-3A customers adopt non-shifting response strategies, the substitution elasticity underestimates the associated reduction in peak demand. The implication is that the elasticity estimates in this study are conservative.

Data Limitations

Estimating Marshallian own-price elasticities would require information on either customers' demand in the absence of RTP (e.g., a customer baseline load) or their daily production output (e.g., number of widgets produced each day). The former is not possible (given constraints on the availability of historic hourly interval data), since SC-3A customers have faced RTP for the last six years and no control group is available. The latter, collecting output data, is not practical. Not only would it be beyond the scope of this study, but most customers would not be willing to disclose such sensitive information at any meaningful level of detail. Furthermore, for customers that produce multiple goods or provide services, defining a reliable output metric would be problematic.

The concept of a price elasticity of demand is a useful way to quantify price response. It provides a normalized, relative measure of the change in input intensity in response to prices. Normally, as prices rise, other factors held constant, we expect that electricity usage will decline. The higher the elasticity estimated for a given customer, the greater that customer's response to price changes. The elasticity measure also accommodates comparing the price responsiveness of different business sectors, customers of different sizes, and even drawing comparisons among individual customers.

This measure of price response has been used in a number of previous studies of large customers' response to dynamic electricity prices. Herriges et al. (1993) used substitution elasticities to quantify the price response of participants in Niagara Mohawk's voluntary RTP program, implemented in 1988, which involved some of the same customers in this study. This approach was subsequently used to evaluate other RTP programs that offer similar incentives to adjust loads (hourly prices quoted day-ahead) and involved customers of similar circumstances and character as SC-3A customers (King and Shatrawka 1994, Christensen Associates 1995, Schwarz et al. 2002, Boisvert et al. 2004). The first phase of this study also estimated substitution elasticities from a derived electricity demand model (Goldman et al. 2004).

How the Substitution Elasticity Characterizes Foregoing and Other Load Response Strategies

Customers self-report a variety of strategies for responding to high prices or NYISO emergency events – shifting load within the day, shifting load to other days, foregoing discretionary usage (without making it up later) and serving load with onsite generation (see section 4.1.1). The substitution elasticity assumes that customers respond by shifting load within a single day, and for customers that respond in this way it accurately estimates their response. Other response strategies are also captured by the substitution elasticity because they all result in a reduction in the peak to off-peak load ratio in response to an increase in peak to off-peak prices. However the response by customers that undertake these strategies is *underestimated* – the same level of observed peak load reduction from, for example, foregoing load results in a smaller estimated elasticity than from shifting. The following example illustrates why this is so.

Consider two customers, A and B, that typically (at average prices) use 100 kWh during peak hours and 500 kWh during off-peak hours. Both these customers normally have a usage ratio of 0.2. On a day when prices are high, Customer A shifts 50 kWh from the peak to off-peak hours. His usage ratio falls to 0.09 (50 kWh peak/ 550 kWh off-peak). On the same day, Customer B also foregoes 50 kWh of peak-period usage, but does not change her off-peak usage. Her usage ratio is also reduced, but by a lesser amount than for Customer A, to 0.1. In both cases, peak usage declines by 50 kWh, but from the perspective of the model, the response is lower in the foregoing case. Similar results occur for inter-day shifting and self-generation.

The greater the discretionary effect, the more the substitution elasticity underestimates the actual peak load reduction, perhaps to the extent of 15% or more (an exact determination would require a more complex model specification). Further research should focus on devising ways to classify customers by their response strategies and to correct for this effect.

3.1.1 Interpreting Elasticity of Substitution Results

The elasticity of substitution provides insight into the intensity of a customer's response to high hourly prices as well as a means to compare the response of different groups of customers. The elasticity of substitution takes on values of zero or greater – the higher the elasticity, the greater the customer's intensity of price response. For example, a substitution elasticity of 0.15 means the customer's peak to off-peak usage ratio changes by 15% in response to a 100% change in the off-peak to peak price ratio. A value of one signifies that the shifting of electricity is in exactly in the same proportion as the change in relative prices. Previous studies have found sector-level substitution elasticities ranging from zero to 0.30, although individual customer elasticities in excess of one have been reported (Schwarz et al. 2002).

In this study, we adopt a flexible model for estimating substitution elasticities that allows us to compare individual customers' response on different days (see section 3.2.1). This provides a means to evaluate whether and how their response differs under a range of conditions. Accordingly, several patterns of response that customers might exhibit are identified in **Table 3-1** and described, with examples, below.[23]

Table 3-1. Character of Customer Response: Possible Substitution Elasticity Scenarios

	Scenario		Implication
1.	Substitution elasticity equals zero		Customer is not price responsive under any circumstances
2.	Substitution elasticity depends on the price ratio	a. constant over all price ratios	Customer's price response increases proportionate to increases in the price ratio
		b. varies with the level of the price ratio	Customer's response is disproportionately high at higher price ratios, or
			Customer's response drops off at higher price ratios
		c. peak usage can be "priced out"	Above a threshold price ratio, customer's peak usage is all but eliminated
3.	Substitution elasticity depends on nominal prices		Customer's response increases as nominal prices increase, or
			Customer's response drops off at higher nominal prices

1. **Substitution elasticity equals zero**. Customers with zero substitution elasticities use electricity in fixed proportions. This means that relative electricity prices have no impact on their electricity consumption. This may be due to the nature of their production process (see example) or may simply indicate that they have explicitly or implicitly made a decision not to respond, regardless of electricity prices.

Zero Substitution Elasticity Example

A bakery that bakes cakes in the morning (using electric mixers and ovens) and frosts them in the afternoon (using mixers and refrigeration) is an example of a customer that uses electricity in fixed proportions due to the nature of its production process. Every kWh used in the morning to produce a cake requires an additional and fixed level of electricity in the afternoon to frost and store it. The baker cannot avoid high electricity prices by substituting morning electricity usage to bake more cakes and then save on electricity by not frosting them in the afternoon. For such a customer, there is no possibility for substitution.

2. **Substitution elasticity depends on the price ratio**. This scenario encompasses a variety of situations in which customers' price elasticities are greater than zero and where response is a function of the *ratio* of peak to off-peak prices (not *nominal* prices). For example, a customer's response on a day where the peak price is \$0.10/kWh and the off-peak price is \$0.05/kWh is the same as on a day where peak

[23] Appendix B provides a graphical depiction of these alternative substitution trade-off possibilities.

and off-peak prices are $1.00 and $0.50/kWh respectively. This is because on both days the price ratio is 2:1. There are three sub-cases of this type of response:

a. **Substitution elasticity is constant over all price ratios.** In this case, a customer's response increases in the same proportion with the price ratio over all possible levels of electricity usage. For example, if a customer's response to the price ratio doubling from 2:1 to 4:1 resulted in a 15% increase in the customer's off-peak to peak usage ratio (an elasticity of 0.15), another doubling of the price ratio, from 4:1 to 8:1, would result in another 15% increase in the off-peak to peak usage ratio.[24]

b. **Substitution elasticity varies with the level of the price ratio.** Some customers may exhibit different degrees of response on days with higher or lower price ratios. For some, as peak usage is reduced, further reductions may become increasingly difficult to achieve (see example). For others, the opposite may be true – they may exhibit some threshold price ratio above which response is deemed worthwhile, resulting in higher elasticities on days with higher price ratios.

> **Example of Declining Elasticity with Increasing Price Ratios**
>
> Consider a firm that uses electricity to run conveyor belts, lighting and power to support laborers assembling a product, runs two eight-hour shifts (with a shift change at noon), has some excess capacity and stockpiled parts, and can add labor to increase plant output if needed. If the peak to off-peak electricity price ratio rises, the firm can reassign some labor from the afternoon to the morning shift and still maintain output. To a point, the greater the peak price, the more the firm shifts production. But as the morning production increases, it eventually reduces the overall efficiency of electricity usage, and each increment of shifted production becomes smaller. Nonetheless, marginal substitution of off-peak for peak electricity is always possible.

c. **Peak usage can be "priced out".** Some customers may not be able to substitute peak for off-peak energy over all ranges of production. At some threshold peak usage level, they may encounter a production indivisibility that makes the decision regarding any further peak usage curtailment "all-or-nothing". For example, some customers may simply need to shut down production altogether if peak-period labor drops below some critical level. Others may switch from grid electricity to onsite generation when a critical price ratio is met. The result, in either case, is that peak usage (as seen by the utility) is suspended.

3. **Substitution elasticity depends on nominal prices.** Some customers, particularly those that forego load rather than shift (see section 4.1.1), may respond to *nominal* prices rather than peak to off-peak price ratios. For example, a customer that responds very little on a day where the peak price is $0.10/kWh and the off-peak price is $0.05/kWh might have a very large response on a day with the same 2:1 price ratio but where peak and off-peak prices are $1.00 and $0.50/kWh respectively. For some,

[24] This type of response is assumed for all customers in the CES model employed in Goldman et al. (2004).

this may reflect a nominal price threshold at which response is deemed worthwhile.[25] For others, this behavior may reflect response to NYISO DR programs, which could result in higher elasticities during high-priced hours.[26] Still others may have specific production processes that are amenable to increasing response when nominal prices are high (see example). The opposite may also be the case for some customers: as prices rise, their ability to respond to prices declines. This is plausible for customers whose loads are coincident with high prices (e.g., cooling loads).

Example of Increased Response at Higher Nominal Prices

Consider a customer with a backup production process that affords a greater rate of substitution of off-peak for peak consumption than is possible under the customer's primary production process, but that is employed only when electricity prices are high enough to make it cost-effective to do so. The customer's primary process may also allow for input substitution, but at a lower level, and we may observe a substitution elasticity that holds for the range of prices below which the backup process is deployed. But when nominal peak prices reach a threshold level, the customer's price response, and accordingly its substitution elasticity, increases as it switches to the backup production process.

In summary, a customer's ability to respond to prices can be characterized not only by the level of the substitution elasticity, but also by its dynamic character over a range of price and peak load conditions. This is accomplished by estimating elasticities for all customers and relating differences in them to selected customer characteristics and other circumstances. Our methodology for accomplishing this is described in the next section.

3.2 The Specification of Customer Response to Daily Electricity Price Changes

We adopted three models to study SC-3A customers' price response (see **Table 3-2**). First, substitution elasticities were estimated using an Indirect Generalized Leontief (GL) model. This provides an indicator of the intensity of price response that can be used to explore trends among customers and business sectors. Weather impacts were also an integral part of this model. Substitution elasticity estimates were then used as a dependent variable in two linear regression models designed to answer questions about the character of price response: (1) how price response changes with nominal prices and load and (2) which customer characteristics and circumstances have a statistical correlation with price response.

In the sections that follow, we provide background on the GL model specification, focusing on its strengths and limitations in characterizing price response, and we describe how the three models used in this study were implemented, focusing on the scope of the customers and days included, key data inputs and output indicators. A detailed discussion of the model specifications, including estimated equations, is provided in Appendix B.

[25] Several customers told us in interviews that they would only bother responding if prices reached very high levels.

[26] During our study period, program events have been coincident with high prices, and for EDRP participants we considered the $0.50/kWh floor price paid for curtailments to be the "price" they saw during those hours.

Table 3-2. Empirical Price Response Models Used in this Study

	Model	Goal	Questions asked
1.	Indirect Generalized Leontief	Determine intensity of price response	What is the distribution of price response among customers? What are average elasticities by business sector? What is the overall average elasticity of SC-3A customers? What is the impact of weather on price response? Can some customers be "priced out" of peak usage?
2.	Linear regression	Determine character of price response	Do customers respond more when prices are high? Do customers respond less when they are operating close to their peak demand?
3.	Linear regression	Identify drivers to price response	Which customer characteristics and circumstances are statistical predictors of price response?

3.2.1 The Indirect Generalized Leontief Input Demand Model

The Indirect Generalized Leontief (GL) cost model was chosen to estimate substitution elasticities in this second phase of this study. It provides a highly flexible representation of cost-minimization behavior that places very few restrictions on the nature of the substitution elasticities. However, its mathematical interpretation is complex, as the elasticities must be derived indirectly from the parameter estimates. By contrast, the Constant Elasticity of Substitution (CES) model, which we estimated in the first phase of this study, is appealing because the estimated model parameters *are* the substitution elasticities (Goldman et al. 2004). This facilitates deriving elasticities and testing their significance. However, it embodies the assumption that elasticity is constant over all price ranges (scenario 2.a in Table 3-1). This is highly restrictive and contradicts some customers' reported behavior.[27]

In the first phase of this study, we estimated average elasticities for business sectors, and found substantial differences between sectors (Goldman et al. 2004). But based on customer interviews, we knew that price response varied considerably among customers within each sector. In other words, business activity is not a sufficient predictor of how individual customers respond to daily electricity price changes. The GL model allows us to estimate substitution elasticities for individual customers.[28] This affords greater granularity of results and allows us to look within business sectors at the distribution of non-responsive, moderately responsive and highly responsive customers.

Employing a flexible characterization of input substitution does, however, come at a price. The mathematical complexity of the model makes it difficult to include variables that represent customer characteristics and circumstances on price response directly in the

[27] In both phases of this study we found that SC-3A customers' reaction to peak price increases encompasses a wide variety of behaviors that a CES specification does not capture.

[28] Other efforts to model demand response have also relied on estimated demand models for individual firms, although the functional forms have been different than the one used here (e.g., Schwarz et al. 2002, Taylor et al. 2005, Patrick and Wolak 2001). Certain other studies were based on functional forms that did not allow the substitution elasticities to vary across days for each firm (e.g. Caves et al. 1984, Charles River Associates 2005).

GL demand model.[29] Yet this is one of the major objectives of this study.[30] We were only able to include the effects of price and weather in the GL model. To study the influence of other factors on price response, we took an indirect approach, first estimating the GL model for individual customers on individual days, and then regressing the results against other factors that we hypothesized would impact the character of response or serve as drivers to price response (models 2 and 3 in Table 3-2).[31] The way in which these models were implemented is described below.

3.2.2 Implementation of Demand Models

The GL model was estimated on summer weekdays (not including holidays or the two days of the 2003 northeast blackout) over the five summers, 2000 through 2004, for which we had load and price data.[32] We included customers for all summers in which we knew they had faced hourly varying prices – either NMPC's SC-3A Option 1 tariff or a similarly indexed commodity supply contract with a competitive supplier – for at least some portion of their load.[33] We combined tariff history data with survey responses about commodity supply options to classify customers in each summer of the study – customers that were either fully hedged or had unknown commodity supply arrangements (due to survey non-response) in any period were omitted from the model for those periods. Altogether, 119 customer accounts were included in the GL model for at least one summer each.

The implementation of the three models, including data sources and key outputs, is depicted in **Figure 3-1**. The models were estimated to achieve our analysis goals as follows.

Intensity of Price Response. We began by estimating the GL model iteratively for each of the 119 customers on each of the 321 days included in the study period for which we had determined that they faced hourly prices.[34] This resulted in a separate elasticity of substitution estimate for each customer on each day – over 30,000 estimates altogether (see Figure 3-1). For customers enrolled in the NYISO EDRP program, we replaced the SC-3A price with the $0.50/kWh EDRP floor price during program event hours.

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[29] The algebraic specification of the GL model's arguments is highly non-linear , even after a logarithmic transformation.

[30] In the CES model estimated in Goldman et al. (2004) several such variables were found to be significant drivers of price response.

[31] This estimation strategy is similar to the one used by Schwarz (1990). Schwarz used a GL demand model to estimate household demand response by customer, and used a second regression to relate customer characteristics to the degree of price responsiveness.

[32] The study was restricted to the summer months because that is when NYISO day-ahead prices vary the most and reach their highest levels. Adding additional months of data to the analysis would have worked against the study interests. While prices vary little during these months, loads still vary. Without any additional explanatory variables (such as firm output) to explain these variations, the overall quality of the substitution elasticity estimates would be reduced.

[33] Including customers that were fully hedged and did not see hourly varying prices for marginal usage would have been inconsistent with the GL model specification.

[34] Because some customers took hedged or unspecified contracts for some summers, not all customers were included in the model for the full 321 days.

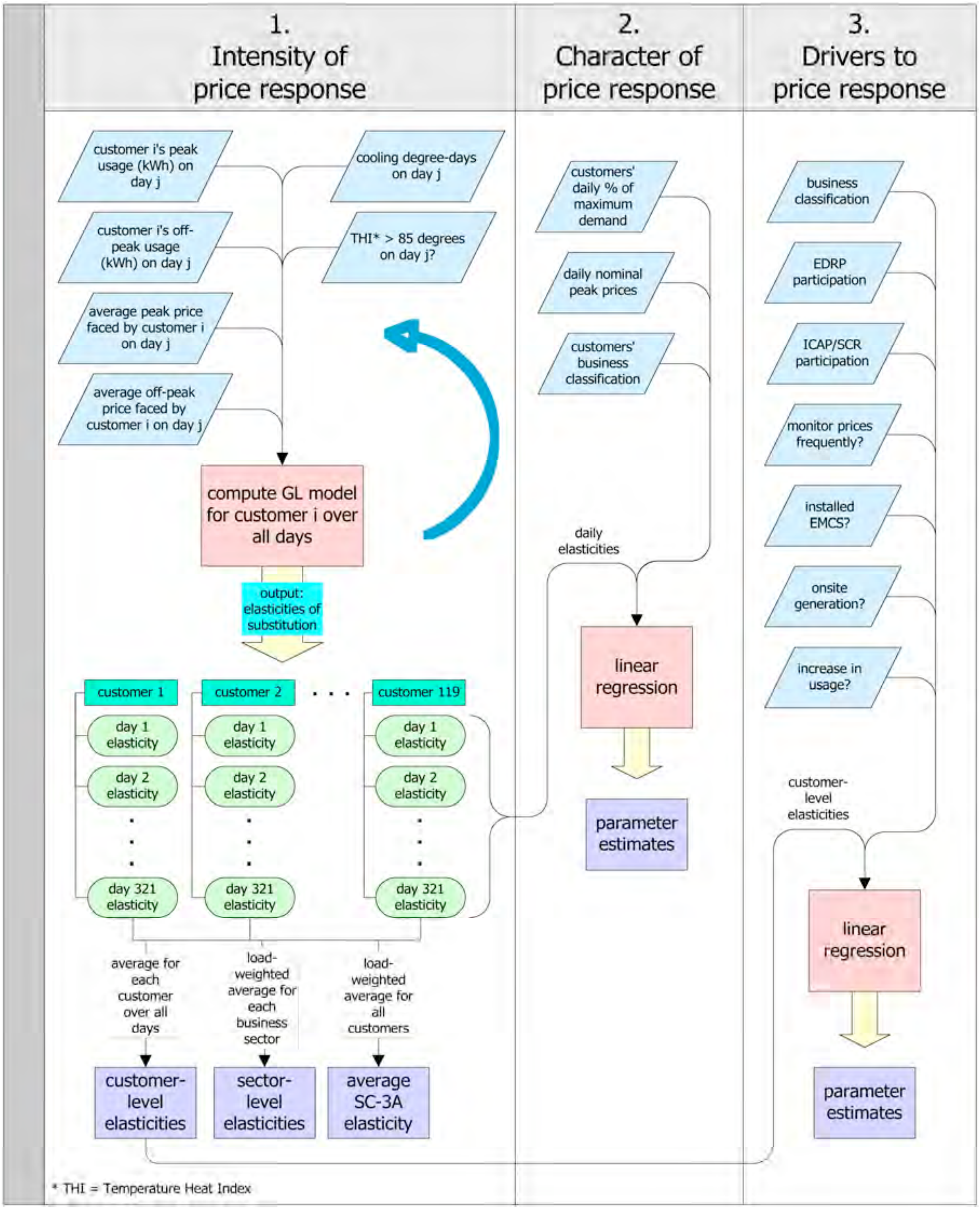

Figure 3-1. Implementation of Generalized Leontief and Regression Models

One problem that we addressed at this stage was determining the length and timing of the peak period. Rather than arbitrarily assign a peak period, we estimated the GL model (as described above) for three possible peak-period definitions – 12-5 p.m., 1-5 p.m. and 2-5 p.m. – to see which provided the most robust elasticity estimates. These results are presented in section 3.3.1. We then selected the best-fit peak period and used it for all subsequent analyses.

To evaluate the intensity of price response, we averaged the daily elasticity estimates in three ways: by customer (average of daily elasticities for each customer), by business sector (load-weighted average of customer elasticities grouped into five business sectors), and for all SC-3A customers (load-weighted average of all customers' elasticities) (see Figure 3-1). These customer-level, sector-level and overall SC-3A results are presented in section 3.3.2.

Two variables were included in the GL model to account for the effect of weather on customers' electricity usage and price response. For some customers, the primary driver of marginal electricity usage is weather – hot summer days cause increased peak loads to serve air conditioning and other cooling needs. Hot days are also coincident with high NYISO day-ahead market prices. To the extent that higher prices are associated with higher loads, the associated upward-sloping demand curve for electricity could confound efforts to identify input substitution in response to relative prices. We corrected for this by including a continuous variable reflecting cooling degree-days as an intercept shifter to control for differences in peak and off-peak electricity usage on summer days that are unusually warm.[35]

Weather can also have the opposite effect on price response. Some customers may be more price-responsive at higher loads if their marginal loads are discretionary. The comfort and convenience they realize from air conditioning, for example, may be foregone if the price is right. To test for this effect, a second, binary weather variable based on the average Temperature Heat Index (THI) was used to distinguish hot from cool days.[36] It was included as a shifter variable on the price ratio and peak usage intensity parameters. The impact of weather on price response, based on these two variables, is discussed in section 3.3.5.

We also used GL parameter estimates to identify customers with the potential to be "priced out" of peak electricity usage (see section 3.1.1). The methodology for doing so is presented in Appendix B, and the results are in section 3.3.6.

Character of Price Response. To evaluate the character of SC-3A customers' price response, we regressed the daily customer elasticities derived from the GL model against the price ratio on each day and the amount of load used by each customer on each day

[35] The study team acknowledges Drs. Borenstein (University of California Energy Institute) and Schuler (Cornell University) for emphasizing the need to employ a specification that lets the data determine the extent of this effect, while exonerating them from responsibility for the method employed. In the first phase of the study, weather was not a significant determinant in the CES specification, although many firms reported having weather-sensitive loads.

[36] The Temperature Heat Index (THI), derived by the National Weather Service during the hours of noon to 5 p.m. is based on daily temperature and dew point values for five weather stations located in the utility's service territory. See Goldman et al. (2004) for details on the construction of the index.

relative to their summer peak demand over the entire study period (see Figure 3-1).[37] We also included customers' business classification in the model to evaluate differences in the character of price response by business sector. The resulting parameter estimates describe how customers' elasticities change on different days in response to these factors. These results are presented in section 3.3.7.

Drivers to Price Response. We also regressed the customer-level elasticities derived from the GL model against a variety of customer characteristics and circumstances that we hypothesized were drivers to price response. The input explanatory variables shown in Figure 3-1 are those that were included in the final model.[38] Survey responses, along with other customer records, provided data on the presence and use of energy management equipment and on-site generation, participation in NYISO demand response programs, overall increases in electricity usage over the study period, and the reported frequency of monitoring SC-3A prices. Because of this, the sample of customers included in this model is limited to those that provided answers to the associated survey questions: we were able to include 55 customers. With the exception of healthcare and public works customers, these 55 customers proportionally represent the other business sectors compared to the 119 customers included in the first two models in terms of both customer numbers and non-coincident peak demand.

The associated parameter estimates describe the impact and significance of these factors in explaining differences in customers' elasticities. These results are presented in section 3.3.8.

3.3 Response to Market-Based Default Service Electricity Prices

In this section, we present and discuss results of this empirical analysis of SC-3A customers' price response. We begin with a discussion of the timing and length of the peak period definition and how this affects elasticity estimates. Then, we present overall and sector-level elasticity of substitution estimates derived from the separate GL demand models estimated for each customer, examine the distribution of customers by their elasticity estimates and discuss the impacts of weather on customers' substitution elasticities. Next, we present results of the two regression models, discussing the impacts of load and price levels on price response and customer characteristics as drivers to price response. Finally, we estimate the aggregate load response of the modeled SC-3A customers at various price levels.

[37] The price ratio and relative peak demand variables are specified in the model as both intercept and slope shifters to account for the possible interaction among these characteristics (e.g., interaction between relative electricity prices and relative peak usage). In addition to an auto-regressive correction that was used in the GL model estimation, the second-stage model is also corrected to account for heteroskedasticity, a condition where the error term depends on the size of the substitution elasticity rather than being identically and independently distributed. The reasons for these two corrections are discussed in Appendix B.

[38] We tested a several other customer characteristics, including customer size, that displayed no discernable relationship with customer elasticities and could not be included in the model.

3.3.1 Price Responsiveness and the Length of the Peak Period

Substitution elasticities were estimated for three alternative peak period definitions – 12-5 p.m., 1-5 p.m. and 2-5 p.m. – to observe how this specification influences price response estimates (see section 3.2.2). The resulting load-weighted average elasticity of substitution over all accounts ranges between 0.05 (12-5 p.m.) and 0.11 (2-5 p.m.).

Figure 3-2 illustrates the load-weighted elasticity estimates for each peak period by business sector. For all sectors but healthcare, the estimates increase as the peak period duration decreases. This difference is most dramatic for the sectors with the highest estimated elasticities – the manufacturing, government/education and commercial/retail sector elasticities for the 2-5 p.m. peak are more than double the estimates for 12-5 p.m. SC-3A prices generally reach their daily high between 2 p.m. and 5 p.m., so it is not surprising that this period reflects customers' highest inducements to respond to prices.

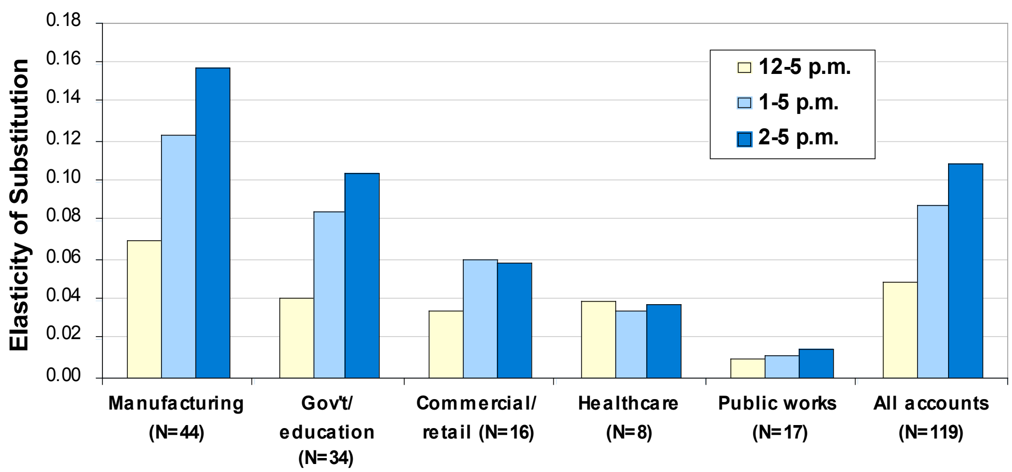

Figure 3-2. Impact of Peak Period Specification on Average Elasticities of Substitution

Based on these results, we designated the hours from 2 p.m. to 5 p.m. as the peak period (and the remaining hours of the day as the off-peak period) for all subsequent results reported in this chapter.

3.3.2 Intensity of Price Response

The overall average elasticity of substitution for the 119 customer accounts included in the GL model is 0.11. This means that a doubling of the peak price ratio, other factors held constant, would result in an 11% reduction in the ratio of their peak to off-peak electricity usage. This value is within the range of portfolio substitution elasticity estimates for commercial and industrial customers reported elsewhere (Herriges et al. 1993, Schwarz et al. 2002, Boisvert et al. 2004). However, these other studies focused on customers that were served under a two-part, base-load hedged rate offered by vertically integrated utilities quoting top-of-stack marginal prices. The differences in the design of these services from that of Niagara Mohawks' SC-3A tariff, which prices all metered usage at transparent market prices, led many to speculate that customer price response would be different. Overall, these tariff design differences do not seem to be very influential.

Overall, the model explains 50% of the variation in usage, measured as changes in the ratio of peak to off-peak energy. This is a robust result considering that the only explanatory variables included in the GL model are the price ratio and weather. A test of significance rejects the hypothesis that all estimated parameters are equal to zero. The estimated model parameters and statistical properties are discussed in full in Appendix C.

The sector-level elasticities of substitution derived from the GL model are displayed in **Table 3-3** along with corresponding results from the CES model estimated in the first phase of this study (Goldman et al. 2004). The GL estimates generally comport with the earlier results. The biggest difference is that the manufacturing sector has the highest substitution elasticity value under the GL specification, followed by the government/education sector, the converse of what we found previously. This difference can be explained as follows:

1) a GL model was used, in contrast to the more restrictive CES functional form,
2) the GL model was estimated at the individual customer level, while the CES model was only estimated at the sector level in the first phase,
3) more customers were included in this phase (119 compared to 30 in the final phase 1 model),[39] and
4) a longer time series of data was available (the summers of 2000 through 2004, compared to only 2001 through 2003 in the first phase).

Table 3-3. Phase 1 and Phase 2 Elasticity of Substitution Results

Business Category	Phase 1: CES model[a]		Phase 2: GL model[b]	
	N	Average substitution elasticity	N	Average substitution elasticity
Government/education	11	0.16	34	0.10
Public Works			17	0.02
Commercial/retail	9	0.07	16	0.06
Healthcare			8	0.04
Manufacturing	10	0.12	44	0.16
Total	**30**	**0.14**	**119**	**0.11**

[a] CES = Constant Elasticity of Substitution
[b] GL = Generalized Leontief

We speculate that restricting the substitution elasticity to be constant over all price ranges in the CES analysis obscured underlying price response behavior, which the GL model

[39] Because of the model specification used in Phase 1, only customers with both usage and survey data available could be included in the analysis.

captures more effectively.[40] Moreover, the GL specification provides for a more robust characterization of how customers respond to prices.

3.3.3 Distribution of Individual Customer Elasticities

The distribution of elasticity estimates among the 119 modeled customers is shown in **Figure 3-3**. About 27% of the customers are completely non-responsive – their elasticities are zero. Such customers use peak and off-peak electricity in fixed proportions, regardless of electricity prices (see section 3.1.1). Another 8% have elasticities that are very small (less than 0.01).

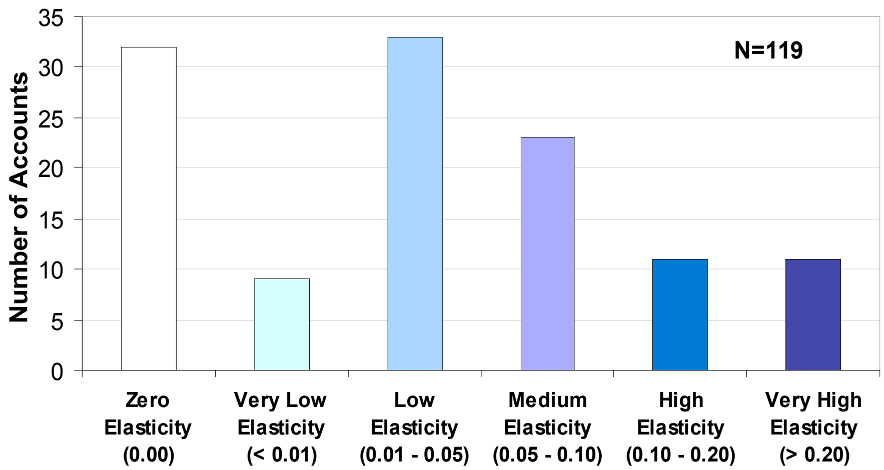

Figure 3-3. Distribution of Accounts by Elasticity of Substitution

Another 28% of customers exhibit very modest response – their elasticities are between 0.01 and 0.05. The remaining 37% have elasticities above 0.05. Nearly half of this group (20 customers, or 18% of the 119 customer population) exhibit average elasticities of substitution above 0.10. This small group of customers provides 75-80% of the overall price response.

SC-3A customers' price-responsiveness is distributed in almost equivalent proportions in terms of load (**Figure 3-4)** as in customer numbers (Figure 3-3). This finding – that there is no discernable correlation between customer size and price responsiveness – refutes the notion that larger customers are more price response than smaller customers within the large commercial/industrial class. Some customers with high peak demand are non-responsive, and some with relatively low peak demand are quite responsive.[41]

[40] A comparison of the GL estimates with those of the CES specification using the same 119 firms reveals that at the mean of the data the differences are minor.
[41] SC-3A customers' summer maximum demands range from about 2 MW to over 20MW. The average maximum demand is ~ 4.3 MW.

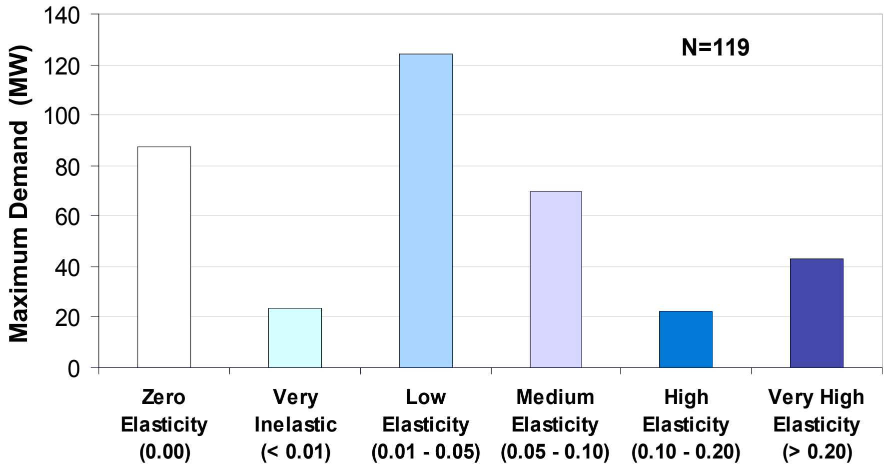

Figure 3-4. Distribution of Load by Elasticity of Substitution

Some SC-3A customers, in addition to facing daily prices, were enrolled in NYISO demand response programs that pay them to reduce load on very short (two-hour) notice. Categorizing customers by NYISO program enrollment and substitution elasticity (**Figure 3-5**) provides insights into whether particularly price-responsive customers are more likely to be attracted to these programs. The results are somewhat surprising. The customers with the highest elasticities of substitution show disproportionately high levels of participation, as we might expect. However, some customers with relatively low elasticities of substitution (under 0.05) enrolled in the NYISO programs, as did a few with no measured price response at all.

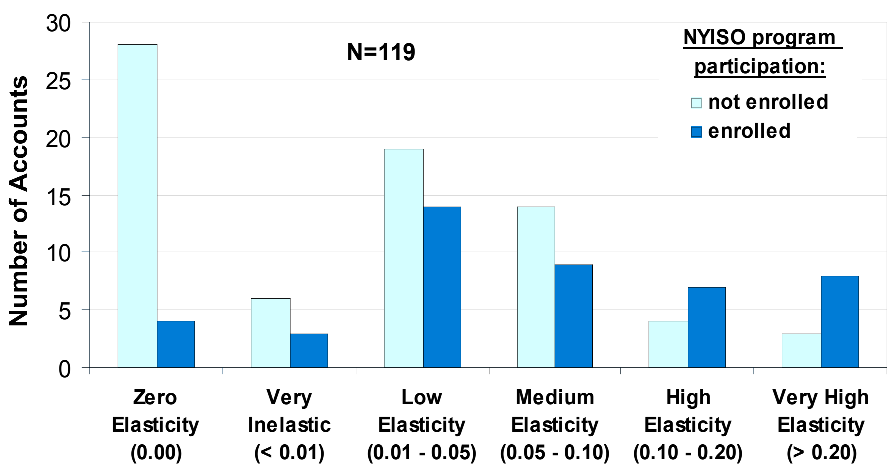

Figure 3-5. Distribution of Accounts by Elasticity of Substitution and NYISO DR Program Participation

These somewhat contradictory results may be explained in several ways. First, if customers respond by foregoing load (rather than shifting), we might observe low elasticities due to the nature of the substitution elasticity, which underestimates response from discretionary load curtailments (see section 3.1). Second, some customers may be enrolled in the NYISO EDRP program but not have curtailed when events were called during the study period, and not have responded to SC-3A prices either. Third, others may have responded to isolated NYISO events but not to SC-3A prices on other days, resulting in small elasticity estimates. Some analysts have advocated against paying for load curtailments through DR programs, arguing that customers on RTP face the same financial incentives to curtail when prices rise high enough. Yet we know from two years of surveys and interviews that some SC-3A customers that respond to NYISO events do not respond to prices. For some, the additional price incentive makes responding worthwhile when the SC-3A price alone does not. But many are willing to respond to NYISO events for other reasons altogether (e.g., to help preserve system reliability) and are less interested in monitoring and responding to SC-3A prices. This is discussed in more detail in Chapter 4. Finally, NYISO events and high SC-3A are highly coincident and may confound results (see section 3.3.8).

3.3.5 Impact of Weather on Peak Load and Price Response

As described in section 3.2.2, we included two weather variables in the GL model. **Table 3-4** indicates the number of customers for which these variables are significant and the sign of the parameter estimates for those that are significant. The results are somewhat mixed. The weather intercept variable, which describes correlations between weather and customers' electricity demand, was statistically significant for about half of the 119 customers, and most of the significant parameters were positive. The slope shifter variable, which measures the effect of weather on the intensity of price response, was significant for ~27% of customers and in most cases was negative.

Table 3-4. Significance of Weather in Influencing Customers' Load and Price Response

Business Category	Impact of Weather on Demand (weather intercept variable)			Impact of Weather on Price Response (weather slope shifter variable)		
	statistically significant[a]		statistically insignificant	statistically significant[a]		statistically insignificant
	positive	negative		positive	negative	
Manufacturing	7	3	34	2	7	35
Government/education	22	1	11	0	8	26
Commercial/retail	12	1	4	3	4	10
Healthcare	6	0	2	1	3	4
Public works	5	1	10	0	4	12
Total	**52**	**6**	**61**	**6**	**26**	**87**

[a] 10% level of statistical significance

The impact of these estimated parameter values on the substitution elasticity is not straightforward. The elasticities are derived from a complex formulation of the GL estimated parameters, and are calculated for each customer and each day; they depend on daily price and customer load quantities, not average values. Consequently, the effect of a positive weather parameter estimate could be positive or negative, depending on the other parameters in the model.[42]

We can, however, illustrate the combined, overall effect of weather on price response. **Table 3-5** shows elasticities for each business sector on normal (cool) days and on hotter than normal days (defined by an average THI value greater than 85 during the 2-5 p.m. peak period). Overall, hot weather is associated with an increase in the average elasticity of 0.109 to 0.113 (about 3.5%). But the sector-level results show that this difference in response is largely due to government/education and commercial/retail customers that typically operate in office buildings or campus settings with substantial cooling loads. For the other business sectors, there is no or negligible difference in sector-level elasticities between hot and cool days.

Table 3-5. Impact of Weather on Price Response by Business Sector

Business Category	**N**	**Average Elasticity of Substitution**	
		cool days[a]	**hot days[b]**
Manufacturing	44	0.16	0.15
Government/education	34	0.10	0.12
Commercial/retail	16	0.05	0.10
Healthcare	8	0.04	0.04
Public works	17	0.02	0.02
Total	**119**	**0.109**	**0.113**

[a] Average Temperature Heat Index (THI) from 2-5 p.m. < 85
[b] Average THI from 2-5 p.m. > 85

Government/education customers, on average, increase their price response by about 20% on hot days compared to cooler days and commercial/retail customers' average elasticity doubles. Thus, while these service-oriented customers may indeed be temperature-sensitive and increase their loads on hot days (to meet greater cooling requirements), their increased price response outweighs this effect substantially. Hot days are correlated with both high SC-3A prices and NYISO DR program events and these signals appear to override these customers' need for increased cooling, at least within the range of temperature and prices observed in upstate New York.

3.3.6 Some Customers Can be "Priced-Out" of Peak Electricity Usage

The flexibility of the GL model enables us to identify customers that reach a relative price threshold at which their usage of peak electricity is effectively eliminated, or "priced out".[43] In other words, at some point, as prices rise, no more substitution is possible, and the price ratio drives peak usage to zero (see section 3.1.1). Five customers

[42] See Appendix B for the specification of the derivation of substitution elasticities from estimated GL model parameters. The complexity of the relationship does not allow us to test for significance using the conventional tests. Moreover, even proxy, bootstrap estimation techniques are computationally burdensome.

[43] See Appendix B for a discussion of how such customers can be identified and their price-out ratios estimated from their GL model parameters.

in our sample exhibit this characteristic – one commercial/retail firm and four government/education customers (**Table 3-6**).

Table 3-6. Characteristics of Customers that can be "Priced Out" of Peak Usage

Customer	Business Category	Elasticity	Onsite Generation?	Peak to off-peak price ratio threshold
1.	Commercial/retail	Very high	Yes	7
2.	Government/education	Very high	Yes	15
3.	Government/education	Very high	Yes	95
4.	Government/education	Very high	Yes	>100
5.	Government/education	Very high	Yes	>100

All five customers exhibit high levels of price response (average elasticities over 0.20). The commercial/retail firm is priced out at a peak to off-peak price ratio of seven. Over the study period, the price ratio never exceeded five, but it is possible for NYSIO prices to reach $1,000/MWh. Under these conditions the price ratio could well reach 10. Based on the character of its estimated average substitution elasticity, this commercial/retail firm would be expected to reduce its peak electricity usage to virtually nothing if this occurred.

The four government/education facilities show a wide range in their "price-out" price ratios, from 15 to well over 100. All of these customers report having on-site generation, but not all indicated that they use it to respond to prices (see section 4.1.3). The very high prices that would be necessary for these four customers to be priced out are unlikely under the current NYISO market structure (e.g., $1,000/MWh cap).

3.3.7 The Character of Price Response

The first of the two regression models we estimated used the price ratio and customers' usage as a percentage of maximum demand as variables to explain differences in customers' estimated elasticities on different days. By including interactive terms made up of the product of business sector dummy variables with these factors, the effects of nominal prices and customers' demand levels on price response were estimated for each business sector (see Appendix B for details).[44]

Data for all 119 customers were used to estimate the parameters of this model. The results are provided in **Table 3-7**. Because the equation in its initial specification exhibited autocorrelation, an AR(1) process was incorporated into the model. The high degree of fit (R^2=0.99) is due in large part to this correction for autocorrelation. The estimated coefficients are all significantly different from zero (t >1).

[44] In each case, only four business-sector parameters are reported – the omitted sector serves as the reference case. We deliberately chose the sector with the lowest parameter estimate as the reference case to facilitate comparison of results (all estimated parameters are positive).

Table 3-7. Character of Price Response: Regression Results

Variable	Parameter estimate	t-Statistic
Peak/off-peak price ratio (PR)	-0.0028	-8.92
Manufacturing * PR	0.0016	2.34
Government/education * PR	0.0241	3.44
Commercial/retail * PR	0.0199	4.22
Public works * PR	0.0010	2.80
Customer's daily % of maximum demand (MD)	-0.0513	-1.99
Manufacturing * MD	0.0487	1.89
Commercial/retail * MD	0.0646	2.43
Healthcare * MD	0.0514	2.00
Public works * MD	0.0509	1.97
AR(1)[a]	0.4657	8.82
N = 119 customer accounts R^2 = 0.99 Durbin Watson statistic = 2.13		

[a] AR(1) is an autocorrelation correction

Using the estimated coefficients from Table 3-7, the effects of changes in the price ratio and in usage relative to maximum demand are summarized in **Table 3-8**. For each business sector, the change in elasticity in response to a unit increase in the price ratio (e.g., from 2:1 to 3:1) and a unit increase in customers' load as a percent of their summer peak demand are shown relative to each sector's un-weighted average elasticity.[45] This provides an indication of the extent to which elasticities are larger for higher nominal peak prices than for lower ones. Positive percentage changes indicate that price response increases as the nominal level of peak prices increases or as customers' approach their peak demand. Negative percentage changes indicate that price responsiveness falls in response to these factors.

The commercial/retail and government/education sectors both exhibit increased price responsiveness at higher price ratios: the former increases by 14.8% and the latter by 13.4% for a 50% increase in the price ratio. Because high price ratios are correlated with high nominal prices in our study period, these customers can be expected to decrease peak usage more at very high market prices than at moderately high prices.[46] Healthcare and public works customers, on the other hand, show the opposite result; their price response drops by 8.1% and 9.5%, respectively, as the price ratio increases by 50%. The manufacturing sector's price response appears to be almost immune to changes in the price ratio.

[45] The un-weighted sector-level elasticities are somewhat different from the load-weighted values reported in section 3.3.2. This reflects differing distributions of customers with respect to elasticity and peak demand within each sector. For the purposes of evaluating load response from various business sectors, the load-weighted values in section 3.3.2 should be used.

[46] We also estimated a similar regression using nominal peak prices rather than the price ratio as a variable, and found similar results, though the model parameters were of less significance. These results are included in Appendix C.

Table 3-8. Marginal Changes in Elasticities of Substitution by Business Category

Business Category	N	Average elasticity	Marginal change in peak to off-peak price ratio[a]		Marginal change in customers' demand relative to their maximum[b]	
			elasticity	% diff. from average	elasticity	% diff. from average
Commercial/retail	17	0.115	0.132	14.8%	0.116	1.2%
Government/education	34	0.159	0.180	13.4%	0.154	-3.2%
Healthcare	8	0.035	0.032	-8.1%	0.035	0.0%
Manufacturing	44	0.087	0.086	-1.4%	0.087	-0.3%
Public works	16	0.018	0.017	-9.5%	0.018	-0.2%

[a] E.g., a change in the price ratio from 2:1 to 3:1
[b] E.g., a change in a customer's demand from 60% to 70% of its maximum demand measured over the study period.

As a result, we infer that on days with very high peak prices, government/education and commercial/retail customers curtail peak usage more than they would on a moderately priced day. From another perspective, if the objective were to induce these customers to curtail (e.g., under a critical peak pricing program), higher price differentials would achieve a greater response. Conversely, higher peak prices seem to reduce the response of the healthcare and public works customers, so using the same prices to induce peak load reductions may work somewhat against this objective for these sectors, which already exhibit relatively low elasticities.

The impact on customers' elasticities of the size of their load relative to their summer peak usage is very small for all sectors. The greatest impact is observed for government/education customers, whose ability to respond is reduced by only 3% for each incremental 10% increase in their demand.[47] This overall result is in contrast to the notion that as customers approach their peak demand they become less price-responsive.

3.3.8 Drivers to Price Response

Our second regression quantifies the impact of several customer characteristics and circumstances on estimated price response (see section 3.2.2). **Table 3-9** presents the estimated parameters for this relationship. The R^2 value indicates that the explanatory variables included in this equation account for about a third of the variation in the average elasticities of substitution for the 55 customers included in the regression.[48]

[47] These incremental changes are additive, so an average government/education customer is 15% less responsive when operating at 50% of peak demand than at 100% of peak demand. Taken in aggregate, these results seem counterintuitive in that government/education customers are more responsive on hot days and as prices rise, but are less responsive as they approach their maximum demand. This can be rationalized by observing the lack of coincidence of high prices, hot days, and high loads for these customers - a finding that runs counter to conventional wisdom for this class of customers.
[48] White's statistic indicates that the error terms do not exhibit heteroskedasticity, so no correction was required.

Table 3-9. Drivers to Price Response: Regression Results

Variable	Parameter estimate	t-Statistic
Intercept	0.1976	0.88
Manufacturing	0.0155	0.17
Government/education	0.1227	1.09
Commercial/retail	0.1640	1.34
Healthcare	0.0590	0.37
EDRP[a] participant	0.1794	2.53
ICAP/SCR[b] participant	-0.0610	-0.63
Monitor prices frequently	0.0579	0.52
Installed EMCS[c]	-0.1489	-2.46
Installed onsite generation	0.0262	0.45
Increase in usage over last 5 years	0.0811	1.34
Average peak to off-peak load ratio	-1.3114	-0.94
White's test statistic	52	0.10
N = 55 customer accounts R^2 = 0.31		

[a] EDRP = Emergency Demand Response Program
[b] ICAP/SCR = Installed Capacity/ Special Case Resource Program
[c] EMCS = energy management control system

In general, the estimated parameter values yield limited insight into the factors that explain differences in customers' ability to reduce peak load in response to price. While many of the coefficients are of the expected sign, only two – EDRP participation and the presence of energy management control systems (EMCS) at customers' facilities – are statistically different from zero (t >2). The lack of significance of other factors could either indicate that they have no effect on customers' elasticities or that the sample size was simply too small to derive a statistically robust model.

The negative coefficient for the EMCS variable is counterintuitive. It suggests that customers with these systems are less able to shift load in response to higher relative peak prices, on average, than customers that do not. This result, however, has been consistent throughout this study (Goldman et al. 2004), and comports with other studies of price response among customers participating in NYISO demand response programs statewide (Neenan et al. 2003). In surveys and interviews, many customers indicated that, for them, the primary purpose for installing an EMCS system is to control maximum demand or achieve energy-efficiency objectives, not short-term price response (see section 4.1.3). While these systems could be adapted, in many cases quite easily, to accommodate responding to SC-3A hourly prices, most customers either do not realize that capability, or have not found exercising it to be worthwhile.

The coefficients on the variables for participation in NYISO's two demand response programs are of different signs. The results for EDRP are intuitive: participation has a positive and significant impact on elasticity, indicating that EDRP participation is correlated with higher than average price responsiveness. However, because of the coincidence of NYISO events with high SC-3A prices during the study period, it is difficult to disentangle how much of the observed response is attributable to EDRP and how much to RTP. But we can infer from the parameter estimate that EDRP, through its financial incentives or the opportunity to help avoid system emergencies (see section 4.1.2), supplements the price response elicited by SC-3A prices.

NYISO calls on EDRP participants with two hours' notice and pays those that curtail the greater of $0.50/kWh or the prevailing market price. Response is voluntary, so no penalty applies for failure to curtail. We expected ICAP/SCR participation to result in at least the same, if not greater, price response than that afforded by EDRP participation because the program not only offers curtailment payments (like EDRP), but levies penalties for customers that do not meet their curtailment obligations. Yet the estimated coefficient on the variable for participation in ICAP/SCR is negative and insignificant. In other words, the specification finds no (or at best a weak) relationship between the imposition of high penalty prices and price response. For ICAP/SCR, the coincidence of the curtailment inducement and the SC-3A prices is even higher than for EDRP. Enrolled customers receive SCR event alerts at about the same time they receive SC-3A prices – mid-afternoon the previous day. We suspect that while in practice the SCR inducement actually increases price response (because it carries a non-compliance penalty), the effects are so intermingled with coincident price signals that separating them is not possible in a statistical sense.

In summary, the coincidence of high day-ahead prices and the declaration of NYISO demand response program events makes it impossible to sort out the relative effects of these signals. Yet we make the following observation: the NYISO programs are operated to preserve system reliability, while SC-3A prices provide economic signals. Concerns about providing double payments to customers that are simultaneously enrolled in NYISO programs and face market prices, under the presumption that they had already planned to curtail, are unwarranted because these programs elicit complementary yet distinct responses that serve equally distinct objectives (avoiding blackouts and reducing wholesale market prices). Moreover, excluding customers from NYISO programs that routinely face and respond to prices may encourage them to hedge against price volatility if the cost of doing so is less than the expected benefits of NYISO program participation. This would only serve to remove the economic benefits of their everyday price response from the system.

3.4 Aggregate Load Response

To portray the overall impact of SC-3A customers' price response, the elasticities of substitution for individual customers were used to simulate their aggregate peak load reductions at various price ratios.[49] The results are illustrated in **Figure 3-6**. At the highest peak to off-peak price ratio observed in the SC-3A price data – 5:1 – the 119 modeled customers are estimated to reduce their peak-period usage by about 50 MW, a 10% reduction from their typical usage. SC-3A customers' aggregate load response is non-linear – it increases as the price ratio increases but at a decreasing rate, especially at ratios above 3:1. This occurs primarily because the relationship between price ratios and the elasticity of substitution is negative for ~57% of the customers (see Table 3-8). As the price ratio increases, the elasticity of substitution decreases modestly among

[49] See Appendix B for a discussion of how load reductions were derived from substitution elasticities.

manufacturing, healthcare, and public works customers. The overall level of load response therefore increases for higher price ratios, but the rate of change for higher and higher price ratios becomes smaller and smaller.

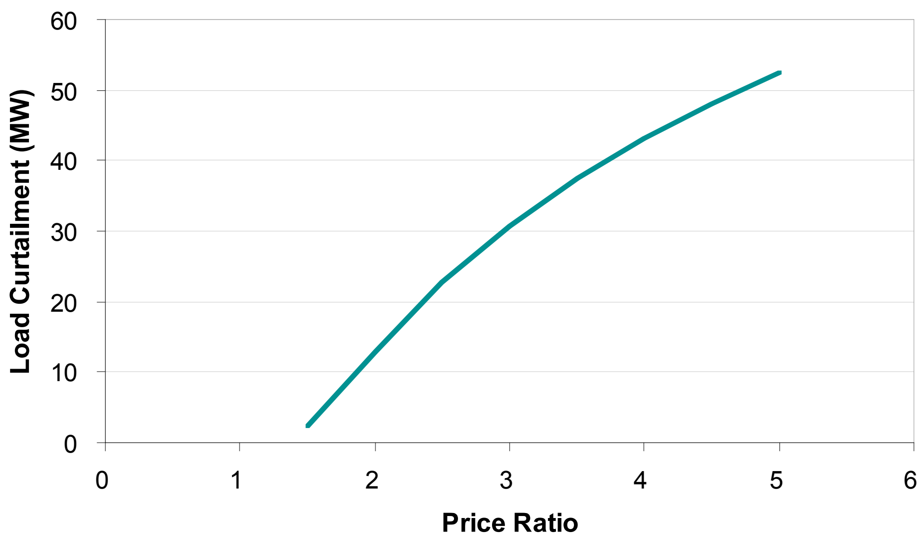

Figure 3-6. Reduction in 119 SC-3A Customers' Peak Demand at Various Price Ratios

What would the response be if prices were much higher (i.e., if the NYISO price cap of $1,000/MWh were raised or eliminated, resulting in price ratios of 10 or more)? The shape of the aggregate response curve suggests that price response would increase with higher price ratios. However, as the price climbs higher, certain customers' elasticities would be further reduced resulting in fewer and fewer additional megawatts of load reduction. At some price level, these customers would approach the point where they would simply exhaust their potential and thereafter be unable to provide additional load reductions. In addition, if price volatility increased, it is conceivable that more customers might decide to fully hedge themselves, reducing or eliminating their incentives to respond to high prices and offsetting some or all of the increases in aggregate demand response at higher price levels.

3.5 Summary

The results of this empirical research indicate that the traditional classification of customer price response according to business sector can be misleading. While manufacturing customers have the largest sector-level elasticity, and 24% have elasticity values above 0.10 (see **Table 3-10**), individual manufacturing customers' elasticities are distributed over all response intensity categories, including 27% that are not able to respond at all.

Table 3-10. Price-responsiveness of Customers by Sector

Business Category	N	Price Response (elasticity):					
		none (0.00)	very low (0.00-0.01)	low (0.01-0.05)	moderate (0.05-0.10)	high (0.10-0.20)	very high (> 0.20)
Manufacturing	44	27%	11%	25%	9%	16%	11%
Government/education	34	18%	3%	21%	35%	9%	15%
Commercial/retail	16	31%	13%	25%	25%	6%	0%
Healthcare	8	13%	13%	63%	13%	0%	0%
Public works	17	35%	12%	35%	12%	0%	6%

Government/education customers show a wide range in price responsiveness. Eighteen percent of individual customers have elasticities of zero, yet one-quarter exhibit elasticities above 0.10, almost as many as in the manufacturing sector. The healthcare and public works sectors have the lowest sector-level substitution elasticities, and there are no customers in these sectors with elasticities over 0.10. Clearly, estimating the price response potential of large customers by business activity alone misrepresents the inherent price response potential for many individual customers.

Statistical model results indicate that customers in the government/education and commercial/retail sectors are more responsive as peak prices increase relative to off-peak prices. In the other sectors, the reverse is true, although the size of the effect is not as large. There is also limited evidence that the ability to respond to price is abated as customers approach their maximum demand.

Our efforts to distinguish customer characteristics that are drivers to price response was less productive, in part due to the relatively small sample of customers that could be modeled. However, the data collected from surveys administered to these customers provide another, qualitative, means to characterize who responds to prices, and why. That inquiry is taken up further in Chapter 4.

4. Customer Adaptation to Default RTP Service

In Chapter 3, we quantified customer's price responsiveness using a customer demand model specification and characterized some of the factors that influence their elasticities of substitution of off-peak for peak electricity. However, the empirical model cannot fully characterize the complexity of customer behavior, as it does not account for some important aspects of price response. Some factors that are basically qualitative in nature (such as barriers to price response) are not easily quantified. Moreover, the practical limitations on gathering information on customer characteristics, operating practices and firm output, along with survey non-response, constrains the empirical specification of the customer demand model.

In this chapter, we supplement model results with information that addresses these issues and provides context for empirical results. This is accomplished using data on customer adaptation to RTP synthesized from two years of customer surveys and interviews. We begin with customers' self-reported load response strategies, the signals they respond to and the deployment and use of enabling technologies. Next, we link individual customers' estimated substitution elasticities to their specific circumstances, focusing on the attributes and strategies of customers that are particularly price-responsive compared to those that are not price-responsive. Then, we discuss barriers to price response reported by customers. Finally, we discuss trends in SC-3A customer's commodity supply choices and hedging options over time as they relate to customer's actions undertaken to reduce or eliminate exposure to hourly prices.

4.1 Self-Reported Response Strategies and Use of Enabling Technologies

In Chapter 3, we estimated price response quantitatively using a GL model and linked elasticity estimates to various customer characteristics and circumstances. However, the GL model does not describe price response qualitatively – it does not describe *how* customers respond. Rather, it assumes that customers respond in one specific way – by shifting load that would otherwise have been scheduled during peak hours to the off-peak hours of the same day. As a result, price response from other possible load response strategies, shifting load to subsequent days, foregoing consumption altogether (without making it up later), or transferring load from the grid to onsite generation, may be underestimated by the GL model (see section 3.1). In addition, the model assumes that all response is to *prices*, yet SC-3A customers have seen other signals to curtail, including declared NYISO emergencies and, on one occasion during our study period, a call from the state Governor's office to curtail.

We explored these qualitative aspects of load response through the analysis of survey questions and customer interviews. Together, these results provide context for empirical load response results, and also provide a means to compare how well the model's predictions about individual customers' price response match customers' self-reported behavior (see section 4.2).

4.1.1 Load Response Strategies

In our customer survey, customers self-reported three types of load response strategies: shifting load from one time period to another (22% of surveyed customers), foregoing electricity use completely and not making it up at another time (45%) and supplying load with onsite generation (16%) (see **Figure 4-1**).[50] Some customers report more than one response strategy – 6% have both shifted and foregone load and 7% have both foregone load and used onsite generation. Almost 30% of the 76 customers surveyed indicate that they are unable to respond at all. This is substantially lower than the 54% of survey respondents that indicated they could not curtail in our previous survey (Goldman et al. 2004).

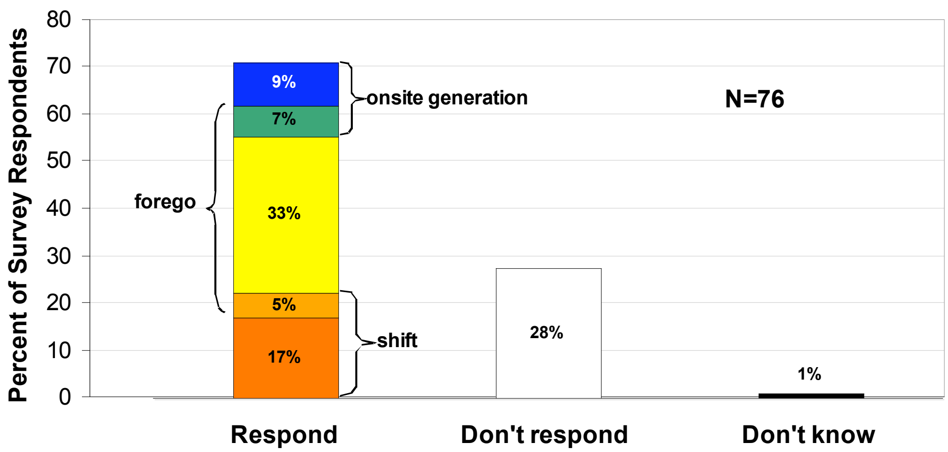

Figure 4-1. Self-Reported Load Response Strategies

Of the 17 customers that reported responding to prices by shifting load, 65% told us that they typically reschedule that load to the next day (47%) or a subsequent day (18%). Only six customers (35%) said they typically shift to another time the same day. Therefore, among our sample of 76 survey respondents, only 8% indicated that they respond in the way implicitly assumed by the GL model – by shifting load within the same 24-hour period. This suggests that the GL model results in Chapter 3 may underestimate the actual reduction in peak usage from SC-3A customers' load response on high-priced days.

Among the 34 customers that reported foregoing load, 65% told us that foregoing discretionary usage has minimal or no impact on their facility's operations.[51] Twenty percent reported significant inconvenience or employee discomfort and 9% indicated that they have to adjust their business operations to accommodate this load response.[52]

[50] The question asked about customers' response to any of hourly SC-3A prices, NYISO Emergencies or public appeals to reduce electricity consumption.
[51] Twenty-one customers reported slight inconvenience or employee discomfort and one indicated no impact at all.
[52] The remaining 6% answered "don't know" to this question.

Different types of customers appear to have adopted different response strategies (see **Figure 4-2**). Government/education customers are most likely to respond by foregoing load and not making it up later – almost all (83%) report that they respond in this way. This, along with earlier survey results reported in Goldman et al. (2004) suggest that these customers are typically willing to respond by curtailing lighting, HVAC or plug loads that often do not require rescheduling. Manufacturing customers display the most variety in the types of load response strategies reported, reflecting the diversity of customers included in this category. About one-third of manufacturing customers report that they cannot respond at all.

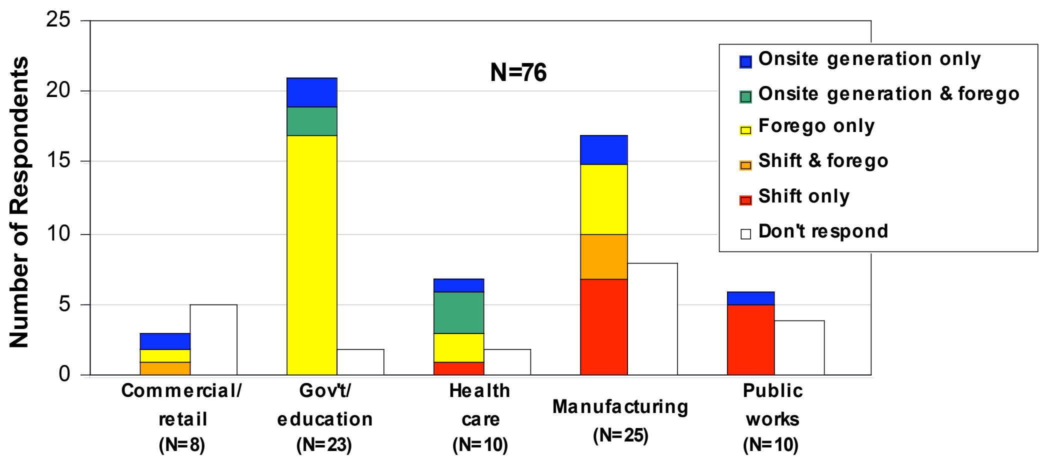

Figure 4-2. Self-Reported Response Strategies by Business Classification

Load shifting is primarily reported by manufacturing customers, but several public works facilities indicated that they can shift load. Based on customer interviews, it appears that most of this response is by water or wastewater treatment facilities that can reschedule pumping operations when prices are high or NYISO calls for emergency curtailments. 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. While some may make use of them when prices are high or NYISO emergencies are called, the elasticities computed for these customers are low (see section 3.3.2). Consistent with their low elasticities, commercial/retail customers are the least likely to report undertaking any response behavior.

4.1.2 Response to What?

Day-ahead hourly prices are not the only signals that SC-3A customers were exposed to during the study period. Since 2001, 42% of SC-3A customers have enrolled in EDRP or ICAP/SCR, NYISO's DR programs that offer customers payments for reducing load when called, for at least one summer (see section 2.1.2). Even customers that are not enrolled in the NYISO programs may be aware of NYISO emergency events, by monitoring the NYISO website or through news broadcasts or public appeals to conserve, and may contribute additional load curtailments.

We asked customers to tell us which conditions – high hourly prices, NYISO emergency events, public appeals to conserve, or major changes in their facility operations – had caused them to change their electricity use from normal levels or serve load with onsite generation. Of the 76 survey respondents, only 5% claimed to have responded to high hourly prices; 80% said they had not and 15% did not know. Self-reported response to NYISO emergency events was much higher: 60% claimed to have responded to NYISO events, 37% said they had not, and 3% didn't know.[53] These findings support the significance of EDRP enrollment in explaining price response, but also reveal inconsistencies between self-reported data and other information available to us. For example, only 35% of surveyed customers have enrolled in NYISO programs, yet 60% say they respond to calls for curtailments specific to these programs. It is also interesting that while only 5% of survey respondents say they respond to high prices, we find statistically that almost 50% have altered load patterns when prices are high. These disparities may indicate that the individuals participating in our survey do not know or do not remember important aspects of their response or are answering the survey strategically. The interplay of coincident signals – high prices, NYISO events and hot weather – probably confuse the matter.

We asked the 46 customers that attested to responding to NYISO emergencies to tell us why they had done so. The most commonly cited reason, not surprisingly, is to earn incentive payments; 29 customers (63%) gave this reason (see **Table 4-1**). Here too, their responses contradict what we know about their experience with these programs. Only about half (14) of these customers were enrolled in NYISO programs in 2001, 2002 or 2003, the years when NYISO events were called. Twelve customers that cited this reason were not enrolled in the program during these years. Another three were enrolled but did not receive curtailment payments.[54] Helping to keep the electric system secure appears to be almost as important to customers as receiving payments; 44% of enrolled respondents indicated that their organization considers it their civic duty to do so. It is also notable that 44% of customers responding to NYISO emergencies said they do so at least in part because they coincide with high SC-3A prices. This suggests that some customers may look for external signals that prices are high, rather than specifically monitoring and responding to high SC-3A prices.[55] Thus, some response appears to be attributable to customers simply being made aware that prices are high through other, coincident events.[56]

[53] Fifty-three percent of respondents said they had responded to public appeals. However, since there was only one such event during our study period, and we believe the question may have elicited strategic responses, we are cautious in interpreting this result.
[54] Nonetheless, these customers may have tried to reduce load but not been successful at earning payments.
[55] The results in section 4.3, which deal with how customers monitor prices, support this finding.
[56] In other words, the NYISO programs serve to alert customers that prices are high and thereby trigger reductions. This raises the prospect that price response might be increased by simply providing customers with a way to chose a trigger price, one at which they intend to respond, and sending notice on days when the next day's prices exceed that threshold.

Table 4-1. Reasons for Responding to NYISO Emergency Events

Reason	Percent of Respondents[a] (N=46)
To earn EDRP or ICAP/SCR curtailment incentive payments	63%
To avoid paying penalties for not responding to ICAP/SCR events	9%
My organization considers it a civic duty to help keep the electric system secure	59%
NYISO emergencies coincide with high SC-3A prices	30%

[a] Customers were asked to check all reasons that applied, so responses do not add up to 100%.

4.1.3 Enabling Technologies

In the survey, we asked customers about three types of technologies that have been supported by NYSERDA's peak-load reduction programs and that have the potential to assist customers with load response: (1) energy management control systems (EMCS) and/or peak load management (PLM) devices, (2) energy information systems (EIS) that provide near real-time access to facility electricity usage data and (3) onsite generation. Forty-nine percent of customers reported having installed EMCS/PLM devices. Most (59%) of these systems were installed in 2000 or earlier. EMCS/PLM devices are most commonly installed by government/education facilities. EIS systems were installed by 41% of survey respondents. Adoption of this technology has been quite recent; 75% of EIS systems were installed in 2002-2004. Fifty-five percent of customers told us they have onsite generation capacity installed. This technology is most common among healthcare customers, where it is in many cases required by statute or practical considerations.

Despite the potential for these technologies to facilitate price response, their impact on estimated price response is not clearly discernable (see section 3.3.8). While the presence of onsite generation does contribute to higher elasticities, customers that had installed EMCS and/or PLM devices actually had lower substitution elasticities than those that didn't and EIS installation did not appear to contribute one way or another to price response.[57] These apparently contradictory results are explained by customers' survey responses regarding how they actually use these technologies (see **Table 4-2**). Only a small number of respondents (7% to 23% of customers installing each of the three enabling technology categories) reported using these technologies to respond to high hourly prices.

For example, only 16% of respondents with EMCS or PLM devices indicated that they use them for short-term price response. The most common uses for these technologies are facility/process automation and reducing overall electricity bills (76% and 65% respectively). Many customers also use these systems specifically to reduce peak demand charges. EIS systems are also commonly used for these purposes, as well as for monitoring and analysis of process energy usage to identify potential savings. Only 23% of customers with these systems use them to respond to high hourly prices.

[57] The result pertaining to onsite generation is not statistically significant.

Table 4-2. How SC-3A Customers Use Enabling Technologies

Purpose	Percent of Respondents Using Technology for Specific Purpose[a]		
	EMCS or PLM Devices[b] (N=37)	Energy Information Systems (EIS) (N=31)	Onsite Generation (N=42)
To respond to high hourly prices	16%	23%	7%
To reduce overall electricity bills	65%	37%	5%
To reduce peak demand charges	41%	39%	2%
Facility/process control automation	76%	35%	—
Monitoring and analysis	—	29%	—
Emergency backup/reliability	—	—	95%
Cogeneration	—	—	5%

[a] Customers were asked to check all purposes that applied to each technology, so responses do not add up to 100%.
[b] EMCS = Energy management control systems; PLM = Peak load management

Although onsite generation could be a significant factor influencing elasticities of substitution, customers indicated that they primarily use this technology for other purposes than short-term price response. The majority of customers owning self-supply equipment (95%) cited emergency backup or reliability as its purpose, with only 7% reporting that they use their generators to respond to high electricity prices.[58] Evidence from customer interviews suggests that, for some, this strategy involves running permitted tests on their emergency generators during high-price events.[59]

We believe that the majority of the onsite generation equipment currently in place at SC-3A customers' facilities was installed prior to default-service hourly pricing being introduced. A current NYSERDA program designed to encourage "clean generation", particularly combined heat and power applications (cogeneration), is accelerating deployment of a new wave of onsite generation technology that is more amenable to short-term price response than legacy systems that are often wired for emergency backup purposes.[60] Several of the most price responsive SC-3A customers have onsite generation installed (see section 4.2) – further dissemination of newer, more flexible technologies may improve opportunities for price response.

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[58] This result appears to contradict the 16% of customers reporting load response strategies involving onsite generation (Figure 4-1). However, the load response question was framed more broadly, asking about strategies for responding to any of high hourly prices, NYISO emergencies or public appeals to conserve.
[59] Environmental permits for emergency generators in New York allow them to be run a specified number of hours per year for testing purposes.
[60] However, standby charges for onsite generation will limit the amount of new generation installed, even with support from NYSERDA. In interviews, several customers noted that they are interested in self-generation but feel that standby charges make it uneconomical. A report commissioned by NYSERDA also noted standby charges as the greatest barrier to distributed generation in New York state in general (Hedman et al. 2002).

4.2 Linking Customer Characteristics and Circumstances to Estimated Price Response

In Chapter 3 we explored the link between customers' substitution elasticities and their characteristics and circumstances with the help of a heuristic regression model. This specification was less fruitful than we had hoped, in part due to too few observations, and in part due to the inherent co-linearity of many factors. Furthermore, the regression analysis focuses on the quantitative influence customer characteristics exert on the substitution elasticity estimate. Our extended study of these customers has revealed that a wide range of factors influence price response, many of which are not amenable to quantification.

In this section, we supplement that analysis by categorizing the customers into different groups based on their GL elasticity estimates and looking for trends that further explain which customer characteristics are associated with price responsiveness. While not all of these associations meet the statistical test of significance, they do provide insights to policymakers about which customers are most likely to respond to hourly prices.

Table 4-3. Characteristics of Price-Responsive and Non-Responsive Customers

Characteristic/Circumstance		**Percent of customers that are…**	
		Price Responsive (> 0.05)	**Non-Responsive** (< 0.05)
Information available for all 119 customers in GL model		***N=45***	***N=74***
Business Category	Manufacturing	36%	38%
	Government/education	44%	19%
	Commercial/Healthcare/Public Works	20%	43%
Geographic Location	East	31%	42%
	Central	29%	31%
	West	40%	27%
Delivery Voltage	Transmission or sub-transmission	60%	46%
	Primary or secondary	40%	54%
NYISO EDRP	Enrolled	47%	23%
	Received incentive payments	27%	19%
Information based on survey responses		***N=25***	***N=36***
Load Response Strategy	Shift load	24%	25%
	Operate DG	20%	11%
	Forego load	52%	33%
	None	16%	42%
Enabling Technology	EMCS or PLM devices available	56%	36%
	EIS available	40%	33%
	Onsite generation available	60%	56%

We classified the 119 customers included in the GL model into two categories: "price-responsive" customers, with estimated substitution elasticities greater than or equal to 0.05, and "non-responsive" customers, with elasticities less than 0.05 (see **Table 4-3**). We also identified customer characteristics and circumstances that we hypothesized could distinguish these two groups of customers. Forty-five of the 119 customers fall into the price-responsive category. The remaining 74 customers have either zero or very low elasticities. To gain further insights into the more explanatory factors we also segregate the price-responsive customers into “highly responsive” (> 0.10) and “moderately responsive” (0.05 to 0.10) customers (**Table 4-4)**. The factors summarized in the two tables are discussed in terms of their influence on price-responsiveness below.

Table 4-4. Selected Characteristics of Moderately and Highly Responsive Customers

Characteristic/Circumstance		**Percent of customers that are…**	
		Highly Responsive (>0.10)	**Moderately Responsive** (0.05-0.10)
Information available for all 119 customers in GL model		***N=22***	***N=23***
Business Category	Manufacturing	55%	17%
	Government/education	36%	52%
	Commercial/Healthcare/Public Works	9%	30%
Delivery Voltage	Transmission or sub-transmission	77%	43%
	Primary or secondary	23%	57%
NYISO EDRP	Enrolled	59%	35%
	Received incentive payments	36%	17%
Information based on survey responses		***N=9***	***N=16***
Load Response Strategy	Shift load	33%	19%
	Operate DG	22%	19%
	Forego load	22%	69%
	None	22%	13%

Business Category. Price-responsive customers (those with elasticities greater than 0.05) are more likely to be government/education facilities than any other business category (see Table 4-3). On the surface, this appears to contradict the finding in Chapter 3 that manufacturing customers, not government/education ones, provide the most price response. However, although there are more price-responsive government/education customers overall, they are more likely to be moderately than highly responsive, constituting 52% and 36% of these groups respectively (see Table 4-4). Manufacturing customers represent roughly the same share of both price-responsive and non-responsive customers (36% and 38%, respectively), but those that are price-responsive tend to be very price responsive and account for over half (55%) of this group of customers.

Figure 4-3 shows the proportional breakdown of customers by these same responsiveness categories in each business category. The government/education sector has the most price-responsive customers (59%), with a large proportion of moderately responsive customers (35%), and a significant proportion of highly responsive customers as well (24%). Manufacturing customers exhibit a “bipolar” distribution: 64% are non-responsive, 27% are highly responsive, and only 9% are moderately responsive. These findings coupled with the larger number of manufacturing customers explain the overall higher elasticities for this business category (0.16) than for government/education (0.11).

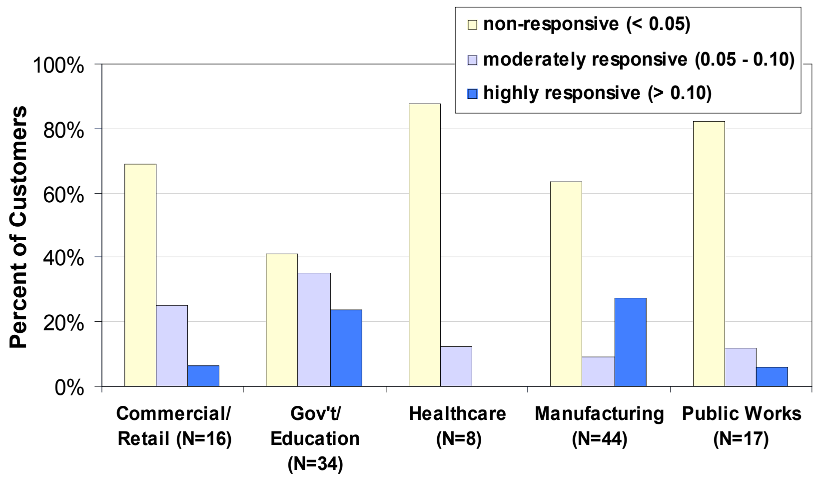


Figure 4-3. Price Responsiveness by Business Category

Non-responsive customers are most highly represented by commercial, healthcare, and public works facilities (43%) (Table 4-3). The results in Figure 4-3 support this – most of the customers in these groups are non-responsive, although there are some exceptions. The low sector-level elasticity results in Chapter 3 for these business categories are thus not surprising.

Geographic Location. We expected to see more price-responsive customers in the eastern region of NMPC's service territory because prices were higher and more volatile in this region, particularly in 2000, 2001 and 2002. Instead, we find that price-responsive customers are slightly more likely to be located in the western region (40% versus ~30% of customers in each of the other regions) (see Table 4-3). Conversely, non-

A Closer Look at Manufacturing Customers

To explain why some manufacturing customers have very high elasticities while others show very little response, we examined customer characteristics within this group.

While enabling technologies do not correlate with price responsiveness among SC-3A customers overall (see sections 3.3.8 and 4.1.3), fifty percent of highly responsive manufacturing customers told us they have EMCS/PLM devices installed compared to only 25% of non-responsive manufacturing customers. Similarly, EIS owners comprise 75% of the highly responsive manufacturing customers but only 47% of non-responsive ones. We find no such correlation with onsite generation.

Self-reported load response strategies are also well correlated with responsiveness among manufacturing customers. Three quarters of highly responsive manufacturing customers indicated shifting as their only response strategy. Only 29% of non-responsive manufacturing customers indicated that they shift load. These results comport in part with the conventional wisdom that industrial customers may be able to shift production processes in response to high prices, but demonstrates that this is true for only a subset of these customers.

Highly responsive manufacturing customers also tend to be large: 75% had peak demand greater than 2.5 MW. All of them are served at the transmission or sub-transmission voltage level, compared to 68% of non-responsive manufacturing customers. They are also more likely to have been enrolled in EDRP and to have responded to EDRP events in 2001 and 2002.

In summary, large manufacturing customers that own EMCS/PLM devices and/or EIS, are served at transmission or sub-transmission levels and enroll/participate in EDRP are more likely to be highly responsive than those who do not have these characteristics.

responsive customers are somewhat more likely to be located in the eastern region than the other two regions.

This result does not seem to be explained by more customers hedging in the eastern region than other regions. More than 80% of eastern region customers were exposed to SC-3A prices during all three years of high prices (2000-2002). The lack of correlation between higher prices and responsiveness either indicates that the difference in prices between these regions was insufficient to provide significantly different price incentives, or it may indicate other differences between customers located in the different parts of upstate New York, with more responsive ones located in the western region.

Voltage Level. Delivery voltage level is highly correlated with customers' price responsiveness. Customers that receive electricity at transmission or sub-transmission voltages are more likely to be price-responsive than not (see Table 4-3), and this is particularly so for highly responsive customers (Table 4-4). Delivery voltage can be viewed as a proxy for customer size – customers with higher peak demand are significantly more likely to take transmission or sub-transmission level delivery (p-value < 0.01) – but customers must be located near high voltage transmission lines to take advantage of this service, which provides a substantial discount over primary and secondary voltage service.

Participation in EDRP. Because the NYISO EDRP program provides additional financial incentives to participants to reduce usage during NYISO-called emergency events and promotes awareness of coincident high prices, we expect to see a correlation between EDRP participation and price responsiveness. Not surprisingly, price-responsive customers are more likely to have been enrolled in EDRP (47%) than non-responsive customers (27%) (see Table 4-3). Highly responsive customers are also much more likely to have been enrolled (59%) than moderately responsive customers (36%) (see Table 4-4).

Curtailing during events and receiving payments for EDRP curtailments is less correlated with responsiveness: 27% of price-responsive customers received payments compared to 19% of non-responsive customers, and 36% of highly responsive customers received payments compared to 17% of moderately responsive customers.[61] If we look at only EDRP-enrolled customers, the results are non-intuitive: 57% of EDRP-enrolled price-responsive customers received payments from NYISO compared to more than three quarters (76%) of EDRP-enrolled non-responsive customers.

These results indicate that EDRP enrollment is an important factor in customers' responsiveness, but actual incentive payments are less well correlated. This suggests that ISO DR programs may enhance price response in other ways than just paying for

[61] The somewhat counter-intuitive result that customers who responded to EDRP events are not responsive may be explained, at least in part, by our imputing of the $500/MWh EDRP floor price during events for these customers – this reduces the elasticity estimate for these customers relative to others that paid a lower SC-3A price and had the same load response.

curtailments. Simply by making customers more aware of electricity costs, markets and reliability issues, DR programs may make customers more price-responsive in general.

An additional consideration is the "good citizen" factor. In surveys of NYISO demand response program participants, many indicate that responding to calls for curtailment by the ISO is viewed as a corporate obligation that is not seen as price response but an obligation to the community (Neenan et al. 2003). Such customers may rationalize curtailing in response to an incentive when system reliability is apparently at stake, but do not do so for essentially the same remuneration in the form of avoided high SC-3A prices.

Load Response Strategies. Matching up customers' self-reported load response strategies to their estimated elasticities produces some interesting results. First, we find that 58% of "non-responsive" customers indicated some type of load curtailment strategy. Conversely 17% of "price-responsive" customers self-reported that they do not respond at all (see Table 4-3). Among price-responsive customers, the most common strategy is foregoing electricity usage; this was indicated by more than half of these customers. Looking within the price-responsive customers, it appears that moderately responsive customers are most likely to forego load (Table 4-4). Highly responsive customers are slightly more likely to shift load than use other load response strategies. A

Portrait of the "Top Ten" Price Responders

Eleven of the 119 customers included in the GL model have average elasticity estimates that are very high (greater than 0.20). We examined the characteristics of these "top ten" customers to see if we could determine what drives their extremely price-responsive behavior.

All except one of these facilities have been exposed to hourly-varying prices for at least four of the past five years. None of them elected the hedged alternative tariff offered by NMPC at the inception of customer choice in 1998. Most of these customers (64%) have also never bought their electricity from a competitive supplier. Very high elasticities coupled with being on the default hourly-varying tariff when other options such as flat rates are available suggests that these customers have chosen to be exposed to hourly varying prices. Furthermore, they have demonstrated their ability to respond to high, volatile prices through substantial changes in their intra-day usage patterns.

Four of the eleven customers are public order and safety facilities, one is a college, one is a recreational facility, and the remaining five customers are manufacturing facilities in the paper, cement and milling industries. One feature common to these eleven customers is that nine of them are served at the sub-transmission or transmission voltage level. Eight have been enrolled in EDRP for at least two of the four years that the program has been administered. Those that were enrolled in EDRP during 2001 and 2002, when events were called, responded to those events. Two have enrolled in ICAP/SCR.

Only four of these eleven customers responded to our 2004 survey, limiting what we can infer about their self-reported response strategies. Of these four, two indicated that they have onsite generation capability, one has an EIS system and the other has both EMCS/PLM devices and EIS. However, none of these customers indicated that they used these technologies for responding to high prices. One of them claimed to have no load response strategy at all, yet appears to be responding affirmatively to prices or other curtailment inducements.

To summarize, the most highly responsive SC-3A customers are typically (but not exclusively) manufacturing and government facilities that take their power at the transmission level, and that have enrolled in EDRP. This lends at least some credence to the proposition that NYISO programs supplement price response from default service RTP pricing.

surprising number of "highly responsive" customers indicated in their survey responses that they do not respond. This discrepancy between what some customers tell us and what we measure from their load and price data may either indicate that their electricity demand varies due to some factor correlated with prices that we are unable to account for, or that these customers understated their response capabilities. This could be because the individuals answering the survey were not aware of their facilities' actual response strategies – when we conducted the survey in late 2004, it had been over two years since they had seen significant price spikes. Finally, this anomaly may be the result of strategic survey response – customers may have told us what they wanted us to hear, or what they thought we needed to hear.

Enabling Technologies. In Chapter 3, we noted based on regression results that enabling technologies did not enhance SC-3A customers' price responsiveness, and discussed potential explanations in section 4.1.3. Nonetheless, we do see a slight positive correlation between price-responsiveness and enabling technologies in Table 4-3. Price-responsive customers are somewhat more likely to own all three types of enabling technologies than non-responsive customers, though these results are not statistically significant. We conclude that for the most part, many customers with the technical capability to manage loads against hourly prices do not (or do not know how to) utilize that capability.

4.3 Barriers to Price Response

A number of barriers to price response were expressed by SC-3A customers in interviews and surveys. In the survey, we specifically asked customers to indicate barriers they had encountered in responding to high hourly prices. Only 12% of respondents indicated that they had not encountered any barriers at all (see **Table 4-5**). The remaining 88% reported anywhere from one to five barriers to price response. The pervasiveness of barriers cited by customers is consistent with individual customer-level demand model results, which indicate that a significant number of customers (27%) are not price responsive at all (zero elasticities), and another 36% have low elasticities of substitution (<0.05).

We categorized the barriers reported by customers into three broad areas: organization/business practices, inadequate incentives and customers being risk averse and/or having hedged (Table 4-5). Each of these is discussed below.

Organization/Business Practices. Over two-thirds of surveyed customers indicated that they have encountered at least one barrier related to their organization's or business' practices or structure (Table 4-5). Twenty-one percent indicated inflexible labor schedules as a barrier to price response, and 30% cited institutional barriers. In interviews, several customers mentioned complaints from building occupants as a major barrier. This was particularly prevalent for customers with landlord-tenant relationships. As one put it, "re-setting the thermostats too frequently would drive tenants nuts."

Table 4-5. 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%

[a] Customers were asked to check all barriers that applied, so responses do not add up to 100%.

Over half of survey respondents cited insufficient time to monitor hourly prices as a barrier to price response (Table 4-5). When asked specifically how often they monitor day-ahead hourly prices, ~70% indicated that they rarely or never monitor day-ahead SC-3A prices (see **Figure 4-4**). Only 14% told us that they monitor day-ahead hourly prices routinely. Thirteen percent indicated they check day-ahead prices only when other factors suggest that they may be high (e.g., when the weather is hot or NYISO emergency events are called), and 3% said they check prices on a weekly basis.

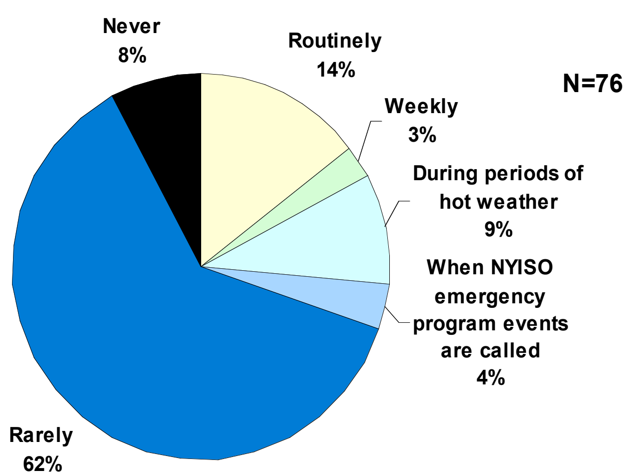


Figure 4-4. Frequency of Monitoring Hourly Prices

The 86% of customers that indicated that they do not monitor prices routinely were asked for their primary reason for not doing so. Over one-third cited resource or technology limitations (**Table 4-6**). For 28%, having procured a hedged commodity contract made this exercise irrelevant. Almost 20% said that another party is responsible for monitoring prices on their behalf.

Table 4-6. Reasons for Not Monitoring Hourly Prices Routinely

Reason	Percent of Respondents (N=65)
Limited resources to do so	34%
Limited technology to do so	3%
Hedged commodity contract makes monitoring prices irrelevant	28%
Another party is responsible for monitoring prices	18%
Electricity prices are not a high priority	3%
Unable to respond, so don't check prices	3%
Unaware that prices change hourly	2%
Other	3%
Do not know	6%

In interviews, we asked customers if they would monitor prices more frequently if they were higher or more volatile. Six out of 20 interviewees said they would consider doing so, and one said he definitely would. Another customer said it would depend on how high prices were, and how often, noting that a single-day, short duration price spike would not change his behavior. Four customers told us they do worry about high prices even though they do not monitor them routinely – their strategy is to try to check prices during severe weather or NYISO emergency events.

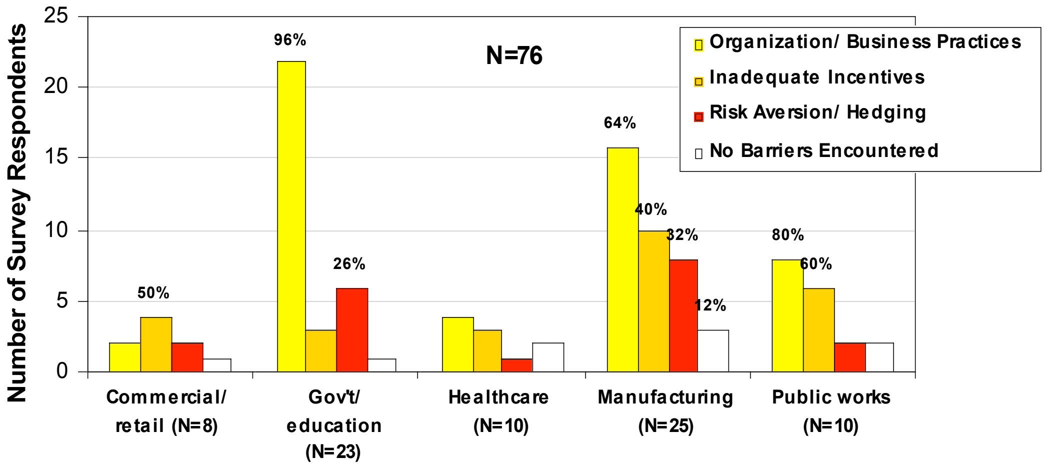
Inadequate Incentives. One third of customers cited barriers related to inadequate price incentives to respond (Table 4-5). Twenty-two percent indicated that managing electricity use is not a priority – for these customers, electricity costs may not be a large enough portion of their bottom line to invest the time necessary to manage them. An equal number of customers felt that the cost or inconvenience of responding was greater than the potential savings. In interviews, some customers told us they would only respond if prices stayed high for several hours. As one put it, "a single hour does not ruin it for us. The financial impact is much greater if high prices continue for several hours." Another told us, "it's not worth the effort for just one hour".

Both of these barriers are related to the fact that electricity price volatility in NMPC's service territory has historically been relatively low and that price volatility has been declining for the last three years (see section 2.2). Even in the Eastern region, with the highest prices during our study period, prices were above $500/MWh in only 18 hours. Under this price regime, it appears that some customers do not see sufficient opportunity for savings from curtailing load relative to the costs of responding.

Risk Aversion/Hedging. Seventeen percent of customers cited risk aversion or having taken a hedge as a barrier to price response (Table 4-5). Thirteen percent of survey respondents indicated that their organization's management views price response as too risky. Twelve percent said they had hedged their electricity costs either physically or financially, and did not see price response as necessary.[62]

[62] Three of the seven customers who responded that "flat rate or TOU contracts makes responding unimportant" were partially or fully hedged according to their survey responses.

The types of barriers to price response reported differ substantially among business classifications (see **Figure 4-5**). For government/education customers, the most common barriers are related to organization/business practices; 96% of these customers reported at least one such barrier. Though also common among manufacturing and public works customers, other barriers are also important. For these and commercial customers inadequate incentives were cited by 40-60% of customers. This result suggests that the organization's bottom line factors into the decision to respond to prices more for these customers than for government/education customers. Barriers related to risk aversion and/or hedging are most common among manufacturing customers.



Note: Customers were asked to check all barriers that applied, so responses do not add up to 100%.

Figure 4-5. Barriers to Price Response by Business Classification

4.4 Customer Migration and the Search for a Hedge

NMPC's day-ahead market commodity tariff was implemented in a complex environment. In interpreting customers' response to RTP, it is important to consider the interacting incentives afforded by their retail market choices. SC-3A customers have been free to leave NMPC at any time since RTP was implemented as the default service tariff, and have also had the option of purchasing financial hedges to reduce their exposure to price risk from SC-3A or similarly indexed commodity prices. In this section, we examine trends in SC-3A customers' migration patterns between the regulated utility and competitive retail suppliers over the last five years. We also describe customers' hedging choices over the same time period, drawing on tariff history data complemented by survey and interview results.

4.4.1 SC-3A Customer Migration Trends

The combinations of electric commodity supply choices available to SC-3A customers and the number choosing them over time are shown in **Table 4-7** (the data are for summers only). In addition to day-ahead hourly pricing ("Option 1"), NMPC offered a fixed rate supply contract ("Option 2") that expired in 2003. Customers selecting Option

2 could nominate some or all of their load on this rate – any residual power requirements could be met with a competitive supply contract or under SC-3A Option 1.

Table 4-7. Trends in SC-3A Customers' Supply Choices

Supply Option			**Number of Customer Accounts in Summer of…**				
			2000	**2001**	**2002**	**2003**	**2004**
Only SC-3A Option 1			90	99	87	66	54
SC-3A Option 2	Full load		2	1	1	1	N/A
	Partial load with:	SC-3A Option 1	11	7	5	4	
		competitive supply – fixed rate	5	4	5	3	
		competitive supply – indexed rate	0	0	0	2	
		competitive supply – unknown rate	3	5	6	6	
All NMPC			**111**	**116**	**104**	**82**	**54**
Competitive supply	Fixed-rate contract		8	6	11	11	16
	Indexed contract		1	1	3	10	10
	Unknown contract type		28	25	30	45	68
All Competitive Supply			**37**	**32**	**44**	**66**	**94**
Information not available			1	1	1	1	1
Total			**149**	**149**	**149**	**149**	**149**

Customer migration rates were quite modest until 2002, ranging from 21% to 30%.[63] In the last two years, however, there has been a marked increase in the number of customers leaving the utility; as of the summer of 2004, 63% had left.[64] The sunset of Option 2 probably explains this increase to a large extent, as customers that had made nominations began to search for other options. Though there appears to have been an increase in the number of hedged competitive supply contracts over time, the share of hedged contracts among known agreements has declined (see Table 4-7). The majority of new competitive supply contracts are indexed, not hedged. Based on these results and customer interviews, we believe that switching is probably driven by the desire to hedge for the most risk-averse customers. Others are taking advantage of the shopping credit defined in NMPC's restructuring agreement and, possibly, more attractive indexing arrangements.[65]

The observed increase in customers leaving NMPC Option 1 default service for the competitive market in 2003 and 2004 probably reflects a combination of two additional factors: (1) customers may have watched the market play out for a few years before deciding to switch, or (2) the number of suppliers and the variety of contract options appears to have taken off in recent years, primarily due to a maturing retail market as several adjacent states have also adopted RTP-type default service (Barbose et al., 2005).

[63] These percentages count customers with Option 2 nominations in combination with a competitive supply contract as still being served by the regulated utility.

[64] An equivalent proportion of SC-3A customers' load had switched as of 2004 – 66% – indicating that switching rates are unrelated to customer size.

[65] NMPC adds NYISO ancillary services charges it incurs for serving SC-3A customers to NYISO day-ahead hourly prices. Some competitive retail suppliers may be able to offer a lower price if their exposure to NYISO uplift costs is less than NMPC's.

We asked customers who had remained with the utility for any period during the last five years why they had not switched. The most commonly reported reasons were institutional barriers within their organizations and the inability to find a competitive supply contract that was preferable to the default service; almost a third of customers provided each of these reasons for not switching (**Table 4-8**). Among the latter group, some reported difficulty finding a competitive supplier to serve them, some did not find the type of contract they were looking for (long term or hedged contracts), and a significant number of customers appear to have evaluated offers and decided that they were too expensive or did not provide enough savings to justify the switch. The observed increase in customer migration is likely attributable to customers becoming more comfortable evaluating retail market offers and overcoming internal procurement barriers over time, as well as retailers providing more and possibly better-priced options to customers as the market has matured. An example of a customer that took steps to overcome institutional barriers is described in the adjacent inset (*Overcoming Institutional Barriers to Switching*).

Overcoming Institutional Barriers to Switching

A large number of government/education and public works customers cited institutional barriers, usually procurement rules that allocate decision-making authority to an overseeing agency or that require lengthy requests for proposals (RFP) and bid evaluation processes that make it difficult or impossible to switch to a competitive supplier, even when doing so would save the institution money.

One such customer, frustrated by rules that were ill-suited to procuring electricity, took the initiative to have them changed. He approached his facility's governing agency with a proposal to revise procurement rules for energy, arguing that the RFP process in place took too long to lock in electricity prices offered by competitive suppliers. His proposal included establishing an energy advisory group with representatives from both the overseeing agency and his facility that has the authority to lock in energy prices. The change required the governing legislative body to pass a resolution, but, as this interviewee put it, "I just had to demonstrate that we would save $80,000 per year and they listened".

This customer's story demonstrates that it is possible to overcome seemingly intractable barriers, in this case to switching, but it may also be possible to address barriers to price response in this way. More importantly, it underscores the importance of having a "champion" within an agency, someone who is willing to take the initiative to overcome obstacles.

Even though switching is on the increase, 37% of SC-3A customers still remain on default-service hourly pricing, six years after its introduction (see Table 4-7). Another large group of customers has switched to competitive suppliers and signed contracts that are indexed to the SC-3A rate. This group could represent 7% to 25% of the NMPC SC-3A accounts (depending on assumptions regarding customers with unknown supply contract types)[66]. Relative to other jurisdictions that have implemented default-service RTP and experienced very high switching rates, the number of SC-3A customers willing

[66] Ten of 26 survey respondents (7% of the total 149 SC-3A accounts) indicated that they had an indexed contract with a competitive retail supplier in 2004. If we assume that the 68 customers known to buy commodity from a competitive supplier (but for whom we don't know the type of contractual arrangement) have similar contractual arrangements as survey respondents (i.e., 38% have contracts indexed to day-ahead hourly prices), then 36 customers (or 24% of SC-3A accounts) may be exposed to day-ahead hourly prices.

to remain on SC-3A hourly pricing is extraordinarily high (Barbose et al. 2005). We believe that the major reason for this difference is that NMPC's tariff involves day-ahead prices, while other states that have implemented default-service RTP have indexed these tariffs to real-time markets. In the following sections, we will discuss hedging by SC-3A customers and will argue that the combination of day-ahead firm price notice and low volatility relative to real-time markets represents a "hedge" in the SC-3A default service rate compared to "real-time" RTP.

Table 4-8. Customers' Reasons for Not Switching

Reason for staying with NMPC	**Percent of Respondents[a] (N=54)**
Institutional barriers in my organization make switching difficult	31%
Could not find a preferred alternative	31%
Could not find an ESCO[b] willing to serve my organization	*4%*
Could not find a hedged (flat-rate) contract	*2%*
Unavailability of long-term contracts	*11%*
ESCO offers have been too expensive	*15%*
The savings offered by ESCOs have not been enough to justify the switch	*26%*
My organization has signed a long-term contract with NMPC	4%
Prefer NMPC's prices, reputation or service	6%
My organization has a NYPA[c] allocation	4%
My organization made Option 2 nominations	7%
My organization buys power directly from NYISO	13%
Other	4%
Do not know	26%

[a] Customers were asked to check all reasons that applied, so responses do not add up to 100%.
[b] Competitive retail electricity suppliers are termed "ESCOs" in New York.
[c] The New York Power Authority (NYPA) provides low-cost power allocations under economic development rationale.

4.4.2 Hedging Trends

SC-3A customers have had three alternatives for hedging against electricity price volatility. First, in 1998, customers had the one-time choice of nominating some or all of their projected load on NMPC's fixed rate forward contract, Option 2, for up to 5 years (these contracts expired in August 2003). Second, at any time during the study period, customers could switch to a competitive supplier that offered a fixed-price commodity contract (e.g., a flat rate or time-of-use rate contract). Third, customers could purchase financial hedge products, separate from the delivery of electricity, that functionally hedge against some degree of price volatility.

We classified customers by combining rate history information with survey responses on the types of commodity contracts and financial hedges entered into by customers in each of the last five summers (**Table 4-9**). We considered customers to be "fully hedged" if they had either taken their full load on Option 2 or signed a hedged commodity contract. We considered them to be "partially hedged" if they had taken Option 2 for only part of their load (with either Option 1 or an indexed contract for residual power) or if they had purchased a financial hedge in conjunction with Option 1 or an indexed commodity contract. Customers on Option 1 or indexed commodity contracts that saw hourly varying prices for their entire load were classified as "not hedged". For many customers, survey non-response or incomplete survey information prevented us from making a definitive classification of their hedging behavior ("unknowns" in Table 4-9).[67]

Table 4-9. Trends in SC-3A Customers' Hedging Strategies

Hedging Strategy	**Number of Customer Accounts in Summer of…**				
	2000	**2001**	**2002**	**2003**	**2004**
Hedged	29	27	31	29	19
Fully	*15*	*11*	*17*	*15*	*16*
Partially	*11*	*11*	*8*	*8*	*3*
Unknown degree	*3*	*5*	*6*	*6*	*0*
Not Hedged	53	56	50	46	35
Unknown	67	66	68	74	95
Total	**149**	**149**	**149**	**149**	**149**

Overall, the percentage of customers that are fully or partially hedged has remained fairly constant over the last five years at 33-39% of accounts with enough information to make this determination (Table 4-9). The number of customers known to be fully hedged has also remained fairly constant over time. It appears that fewer customers were partially hedged in the most recent years – this may be related to the sunset of Option 2. The majority of customers that are hedged do so with electricity supply arrangements (Option 2 or fixed-rate competitive supply contracts). The number of customers taking financial hedges, separate from the supply of electricity, has increased over the last five years; nonetheless, it appears that this strategy is still adopted by less than 10% of customers that provided information about these products.[68] Finally, it should be noted that the number of customers with missing information has increased over time ("unknowns" in Table 4-9).

4.4.3 Why Don't Customers Hedge More?

In interviews with SC-3A customers it was clear that many customers would prefer to hedge than be exposed to price volatility. Other research also suggests that large electricity customers want to hedge. For example, in market research performed by Tractebel Energy Services (2004, 2005) among commercial and industrial customers in the Northeast and Texas, 80-85% indicated that they would prefer hedged to indexed electricity pricing. Why, then, have so few SC-3A customers actually done so? We propose two reasons for the observed difference between what customers say they want

[67] Customers were included in the GL model if they were either not hedged or partially hedged (see section 3.2.2). Altogether, 119 customer accounts met these criteria in at least one summer of our study. These customers are classified as "partially hedged", "not hedged" or "unknown" in Table 4-9; some of the "unknowns" could be identified as either not hedged or partially hedged, so we were able to include them in the model, but could not distinguish them in the table.

[68] We believe that some customers misinterpreted our survey questions about financial hedges, in part because most customers that said they had financial hedges also indicated they had fully hedged supply contracts (and having both would be redundant), and also because some customers that were interviewed were not familiar with the concept of a financial hedge. Thus, these results should be interpreted with caution.

and what they actually do: (1) some customers have been unable to find suitable hedges, and (2) given the market circumstances that SC-3A customers have faced, they are what we call "psychologically" hedged.

Difficulty Finding Hedges. In both years of this study, a number of customers indicated in interviews that they had experienced difficulties finding hedged supply contracts. Some told us they couldn't find them at all, and others that the offers they received were too high priced for them to consider. These complaints were noted somewhat less frequently in the second year of our survey, suggesting either that there are more or better priced offers on the table in recent years, or that customers have re-evaluated their desire to hedge given their market experience.

SC-3A customers have also had the option to purchase financial hedges, but relatively few customers have done so. In a survey question, we asked customers why they had not. A few customers (7%) indicated they had searched for a financial hedge but found the risk premium too expensive (**Table 4-10**). Twenty-two percent cited institutional barriers, and about one-third of customers had already hedged with a supply contract. Over 50% of the customers that had not entered into a financial hedge either did not know why they hadn't purchased one or were not sure what a financial hedge is. This may reflect a culture within firms and institutions that sees financial products as distinct from energy supply contracts or under which the two products may be procured by different departments and people.[69]

Table 4-10. Reasons for Not Purchasing Financial Hedges

Reason for not purchasing financial hedge	Percent of Respondents[a] (N=60)
Offered hedges were too expensive	7%
Institutional barriers in my organization make procuring financial hedges difficult	22%
My facility already has a hedged supply contract[b]	27%
My organization is comfortable managing risk without a financial hedge	7%
Not sure what a financial hedge is or why I would need one	23%
Other	3%
Do not know	27%

[a] Customers were asked to check all reasons that applied, so responses do not add up to 100%.
[b] Includes fixed-rate competitive supply contracts, Option 2, and NYPA allocations.

"Psychological" Hedging. Based on our market research with SC-3A customers, we propose that some customers that have not taken steps to hedge against electricity price volatility are in fact "psychologically" hedged. What we mean by this is that customers have observed SC-3A prices over the last six years, along with the hedging options available to them, and are apparently comfortable managing day-ahead market price risk without a hedge. In part, this can be explained by the price regimes they have faced. Relatively few price spikes and declining volatility in summer peak prices have probably led customers to conclude that the risk of remaining on the SC-3A rate or an indexed

[69] The majority of the people that answered our surveys were energy or facility managers or people responsible for procuring energy.

supply contract is small. In interviews, some customers have told us that "there aren't enough high prices to worry about". So, when high prices are encountered, they do not set off any alarm because such occurrences were anticipated and factored into their decision to not hedge or make plans to respond.

This level of comfort may also reflect the fact that SC-3A prices are indexed to the day-ahead market. By contrast, in New Jersey, implementing default-service RTP indexed to the PJM real-time market in which prices are revealed after the fact resulted in high customer migration rates in a very short time frame (Barbose et al. 2005). Because real-time market prices tend to be more volatile than day-ahead prices, and because they afford no advance notice of prices, day-ahead hourly prices may be seen by customers as less risky.[70]

We specifically asked SC-3A customers what they would do if the default SC-3A rate were indexed to the real-time market, with no advance price notice. Only 5% said they would remain on the SC-3A rate for commodity service (see **Table 4-11**). Twenty-eight percent said they would switch or consider offers from competitive retail suppliers for commodity service. Almost half of customers said they did not know what they would do.

Table 4-11. Customers' Reactions to Hypothetical "Real-Time" RTP

Action Customer Would Take if SC-3A Default Service Was Based on NYISO Real-Time Market	**Percent of Respondents (N=76)**
Continue buying commodity service from NMPC	5%
Continue buying commodity service from an ESCO	18%
Switch to an ESCO for commodity service	13%
Consider offers from an ESCO for commodity service	15%
Do not know	49%

[70] Moreover, Taylor and Schwarz (2000) quantified the welfare benefits from providing advance notice of prices and found that the benefits of providing customers with time to react to price changes outweighed the cost to the utility of bearing forecast risk.

5. Discussion: Key Findings and Policy Implications

This study was initiated almost three years ago to provide insight into how customers adapt to market-based default service electricity pricing. In 1998, Niagara Mohawk Power Corporation (NMPC) became the first utility in the U.S. to incorporate day-ahead, hourly ISO market based prices into an unbundled default service tariff. Our study group consists of many of NMPC's largest customers: the SC-3A service classification of ~150 commercial, industrial and institutional customers with peak demands in excess of 2 MW. However, from the onset, competitive retailers have provided alternatives.

This study was funded by the California Energy Commission (CEC)'s PIER program through the Demand Response Research Center (DRRC). Since the 2000-2001 electricity crises, policymakers in California have been considering means of increasing price response by retail customers to mitigate extreme prices. Day-ahead hourly pricing, often referred to generically as real-time pricing (RTP), is one of the tariff structures under consideration. Another is critical-peak pricing (CPP), which differs from RTP in that dynamic price changes are invoked only under specified circumstances (not in every hour as is the case for RTP), and are usually triggered by system conditions (e.g., forecasted or actual shortfalls in operating reserves) or very high prices to elicit response when it is most needed.

SC-3A customers have faced short periods of high prices on several occasions over the study period (2000-2004), thereby providing an opportunity to assess customers' abilities to respond to volatile hourly prices. The mix of NMPC's large customers exposed to day-ahead hourly prices – roughly 30% industrial, 25% commercial and 45% institutional – is also comparable to that of California, although the types of industrial facilities are not identical. The nature of the SC-3A default service attracted competitive retailers offering a wide array of pricing options, from fully hedged flat rates, to financial hedges, to prices indexed to the NYISO day-ahead prices. These customers also had opportunities to receive payments for curtailments under demand response programs implemented by NYISO.

These attributes of SC-3A customers – the wide range of customer circumstances, load sizes and profiles, business activity, experience with dynamic pricing, availability of enabling technologies, retail market choices and NYISO DR program opportunities – are conducive to quantifying the intensity of price response (the price elasticity) and characterizing the factors that drive it. They also provide an opportunity to study how customers decide when and how to hedge against price volatility, and to determine if default RTP and ISO demand response initiatives are complementary forces, or redundant incentives to reduce load.

We begin this chapter with a brief discussion of the model used to estimate price response and how to interpret elasticity of substitution results. The next section identifies and describes key findings, organized around several themes, and discusses their implications for policymakers interested in price response from RTP in the context of retail competition, or who are considering dynamic pricing as default service for other reasons.

5.1 Deriving and Interpreting the Elasticity of Substitution

Niagara Mohawk's SC-3A customers use electricity as an input to processes that produce intermediate or final consumer goods, or to provide services to consumers or society. Consequently, we hypothesize that these customers make electricity usage decisions in the short run, from day-to-day, based on the value electricity contributes to the customer's overall profit (or, in the case of a government/educational customer, the reduction of overall operating expenses) and information available to them about prevailing hourly electricity prices.

The distribution of NYISO day-ahead electricity prices, which are the basis for SC-3A prices, is such that the majority of days are characterized by a fairly constant pattern of hourly prices (of typically $50-60/MWh for mid-day hours), with high peak period prices (exceeding $300/MWh) occurring only on isolated days. Consequently, we portray SC-3A customers' price response as primarily involving the decision to reallocate business activity from an established routine on those days when prices are high. This response involves using less electricity during the high-priced, peak hours of the day and more during the lower priced, off-peak hours to meet the day's expected level of business. In other words, the decision involves substitution of off-peak electricity use for peak usage. Accordingly, the appropriate measure of price response is the *elasticity of substitution*, defined as the percentage change in daily peak electricity usage (relative to off-peak usage) in response to a one percent change in relative peak prices.

This notion of elasticity differs from the more familiar own-price elasticity, but its interpretation is similar, and it is an appropriate and feasible characterization of price response for large customers. (Moreover, estimating own-price elasticities would have required gathering output data from customers, which was beyond the scope of this study.[71]) The model we employ is conducive to estimating own-price response as well as substitution elasticities, though it is conservative.[72]

Substitution elasticities take on values of zero or greater. A value of zero has a special interpretation. It indicates that relative electricity prices have no impact on electricity consumption due to the nature of how electricity is used by the customer during the day. Positive elasticities indicate price response, and the higher the elasticity, the greater the response. We expect individual customers to exhibit a variety of price response intensities, even within the same general line of business, due to subtle but important differences in how electricity contributes to business activity.

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[71] To calculate an own-price elasticity, which measures the reduction in demand in response to a price increase in absolute terms, information on either customers' demand in the absence of RTP (e.g., a customer baseline load) or their total production output (e.g., number of widgets produced each day) would have been necessary. The former is simply not possible, since SC-3A customers have faced RTP for the last six years and no control group is available. The latter is not practical, as collecting firm output data would require resources beyond the scale of this project and would be unacceptable to customers.

[72] The substitution elasticity underestimates the response from customers that forego electricity usage without making it up later or respond with onsite generation (see section 3.1).

The substitution elasticity provides a means to compare the intensity of price response among different customers and customer groups. We employ a Generalized Leontief (GL) model of firm behavior that estimates substitution elasticities from customers' load and price data over the study period. We also characterized other dimensions of price response, such as the effects of weather, load and nominal prices and drivers to price response by regressing elasticity of substitution results against various factors. We hypothesize that a customer's ability and inclination to respond cannot be predicted by its business activity or size alone.

Customer interviews and surveys conducted in both phases of this study indicate that customers employ a variety of load curtailment strategies and behaviors. Many customers say they respond to price increases by reducing discretionary usage during peak periods without making it up later, and a few report that they indeed shift usage, but to another day. We acknowledge that input substitution is not the only type of response observed. However, the substitution elasticity is structurally consistent with all these load response strategies – foregoing load, using onsite generation, and shifting usage to other days – because they all result in a reduction in the ratio of peak to off-peak usage in response to higher peak prices. Our model specification cannot separately and consistently account for each of these effects, but no model can. To the extent that these behaviors are present, our model underestimates the reduction in peak demand from these other response strategies.[73] The implication is that our elasticity estimates are conservative.

5.2 Key Findings and Implications

We highlight several key findings and policy implications from this second-phase case study of SC-3A customers' response to default-service, day-ahead market RTP. **Table 5-1** summarizes these findings and the related policy implications. Each of these findings and implications are discussed in detail in the following sections.

[73] To illustrate, for a customer that foregoes load and does not make it up later, we observe a reduction in peak usage and no corresponding change in off-peak usage. This results in a reduction in the peak to off-peak usage ratio, but one of lesser magnitude than for a customer that reduced the same amount of load and made it up in the off-peak period. Thus, the model captures but *underestimates* the response from foregoing usage. Similar results occur for inter-day shifting and self-generation.

Table 5-1. Key Findings and Policy Implications

Key Findings		Policy Implications
Intensity of Price Response	Price response is modest overall – the average elasticity is 0.11	Business activity alone is not an accurate predictor of price response. Policymakers should recognize the heterogeneity of response and ensure that hedging opportunities exist for customers that cannot respond. Public benefits technical assistance programs should be targeted to those that need it most
	Two-thirds of customers have positive substitution elasticities	
	Manufacturing customers are most price- responsive (0.16), followed by government/education (0.10) – other sectors have very low elasticities	
	Individual customer elasticities vary substantially within sectors – most manufacturing customers are either highly responsive or not at all	
Character of Price Response	Government/education and commercial/retail customers respond more when nominal prices are higher	RTP can be expected to provide the most response when it is most needed.
	Government/education customers' response declines slightly as they reach their peak demand	
	Government/education and commercial/retail customers' response increases on hot days	Weather effects may be even more important in areas such as inland California
Drivers of Price Response	NYISO emergency programs enhance price response, in part by providing coincident signals to curtail	For some customers, notification of events and fulfilling a perceived community obligation to curtail are more important than cost savings – RTP should be complemented with DR programs that alert and compensate customers for responding to system emergencies
	Load management and information technologies do not influence customer response to hourly prices at the present time	Disseminating information gateway technologies is not enough – large customers need assistance to develop load response strategies
	Onsite generation can contribute to significant load response	Distributed generation can create opportunities for price and load response
	"Champions" are probably a significant driver to price response	Programs to recognize the efforts of champions can promote price response
Customer Strategies for Responding	Over two-thirds of customers say they can respond	There is significant latent response potential but it is diverse in nature – programs and/or tariff options should be designed to make best use of this diversity
	Customers employ varied load response strategies – shifting, foregoing, and self-generation	
	Government/education customers most often forego usage; manufacturing customers are more likely to shift	
	What customers say they do and what they seem to do are at odds	Policymakers should avoid making hard and fast rules based on surveys or pilots
Barriers to Price Response	Most customers report multiple barriers to price response – only ~15% respond without obstacles	Some barriers may be overcome with time with customer education and technical assistance, but policymakers should expect that about half of large customers cannot or have no intention of responding to prices, at least under current pricing conditions
	Over half of large customers report not having time or resources to monitor prices	
	Inadequate incentives keep one quarter of NMPC customers from responding	
Customer Acceptance	Day-ahead RTP is well accepted by large customers in New York	Default service based on day-ahead prices is an acceptable compromise for most large customers; it affords greater notice of prices, and may result in higher demand response than real-time RTP
	Most customers have not hedged: 45-60% were fully exposed to day-ahead prices in 2004	
	Market penetration of financial hedges is particularly low	Many customers are unfamiliar with financial products as they relate to energy and may require education if this market is to develop

5.2.1 The Intensity of Price Response

We evaluated the intensity of price response using substitution elasticities derived from a GL model (see sections 3.2 and 5.1). We draw the following key findings from these results.

Price response is modest overall – the average elasticity is 0.11

As a group, SC-3A customers' price response is modest – the load-weighted average substitution elasticity is 0.11, which means that their combined ratio of peak to off-peak electricity usage declines by 11% in response to a doubling of peak prices (relative to off-peak prices). This level of price response is consistent with other studies that have evaluated of the behavior of large customers facing similar pricing circumstances (Herriges et al. 1993, Schwarz et al. 2002, Boisvert et al. 2004).

At the highest prices observed during the study period, in which the peak price was five times the off-peak price, we estimate that these customers, as a group, reduced their peak usage by ~50 MW, about 10% of their combined summer peak demand of about 500 MW.

Two-thirds of customers have positive substitution elasticities

Almost two-thirds of SC-3A customers (65%) exhibit some price response (elasticities > 0.01), but for many of them the response is small. The other third, with zero elasticities, appear to use peak and off-peak electricity in fixed proportions, regardless of prices. Eighteen percent of customers exhibit relatively high price response (> 0.10), accounting for ~75-80% of the aggregate demand response.

Manufacturing customers are most price- responsive (0.16), followed by government/education (0.10) – other sectors have very low elasticities

Not all sectors exhibit the same intensity of price response. Manufacturing firms, as a group, are 45% more price responsive than the average, with a sector elasticity of 0.16. This comports with the conventional wisdom that these customers are good candidates for price response, though there is substantial variation within this group. The government/education sector was also found to be quite price-responsive, with an average elasticity value of 0.10. The commercial/retail, healthcare and public works sectors are relatively unresponsive, with respective elasticities of 0.06, 0.04, and 0.02.

Individual customer elasticities vary substantially within sectors – most manufacturing customers are either highly responsive or not at all

An important finding of this study is that elasticity results are not uniform within business sectors. This is most pronounced for manufacturing customers. Twenty-seven percent of manufacturing firms are highly price responsive, with elasticities above 0.10. But 63% are largely non-responsive (elasticities < 0.05), including 27% with zero elasticities.

Thus, the high average elasticity for this sector is provided by a few, very responsive, customers.

The government/education sector, which has a lower overall elasticity, has almost as many highly elastic customers as the manufacturing sector (24%) and proportionally fewer non-responsive customers (42%). The majority of commercial/retail, healthcare and public works customers are non-responsive, although there are some price-responsive customers in each group.

Policy Implications

The heterogeneity of price response, both among and within business sectors, should be explicitly recognized by policymakers. The common presumption that manufacturing customers are highly price responsive is true for some of these customers, but our results suggest that for many this is not the case at all. Furthermore, there is significant price response potential from a wide base of government/education customers that should not be ignored. Given that a large proportion of the response (~80%) comes from a small proportion of customers (~20%), policymakers need to expect that a large proportion of customers will not be able to respond at all, at least under the pricing conditions observed in this study and should ensure that hedged alternatives to dynamic pricing are available. Disaggregated customer characteristics and elasticity information can be used to target public benefits programs toward those customers with the greatest need for price-response assistance. Competitive retailers may also use this information to identify and target price-responsive customers.

5.2.2 The Character of Price Response

We evaluated the character of price response in a regression model that examined the impact of nominal prices and load on price response (see section 3.3.7). Key findings from this research are as follows.

Government/education and commercial/retail customers respond more when nominal prices are higher; manufacturing customers respond more when peak/off-peak price ratios are higher

We find that government/education and commercial/retail customers exhibit higher price response when nominal prices are higher. For government/educational customers, who tend to respond by foregoing load (and not making it up in the off-peak period), this makes intuitive sense. Manufacturing firms appear to respond primarily to the peak to off-peak price ratio. These customers tend to respond by shifting load rather than curtailing, so it makes sense that their response is motivated by the daily price ratio. The price response of public works and healthcare customers declines slightly as nominal prices increase.

Government/education customers' response declines slightly as they reach their peak demand

We find that government/education customers' average sector-level elasticity declines slightly (about 3%) when they are operating close to their peak demand. No other sectors exhibited this correlation.

<u>*Policy Implication*</u>

The finding that certain sectors increase their response when prices are high is encouraging: it implies that RTP can be expected to provide the most response when it is most needed. It is also encouraging that although there is a reduction in government/education customers' response as they reach their maximum demand (coincident with high prices due to their temperature sensitivity) this effect is relatively small. However, we caution that New York's summer climate is moderate relative to other parts of the U.S., and the prices study customers faced were seldom high for more than a few hours during the study period. Prolonged hot weather accompanied by high prices could result in response fatigue.

These results also have implications for the design of CPP tariffs for large commercial and industrial customers, in which an arbitrary high price is used to elicit price response when it is needed. The conventional thinking is that a very high price is needed, but our results suggest that this is true for only some customers, while excessively high prices may be punitive for others. If feasible, the most efficient design would discriminate among sectors to achieve predictable load reduction results.

Government/education and commercial/retail customers' response increases on hot days

Government/education customers, on average, increase their price response by about 20% on hot days compared to cooler days and commercial/retail customers' average elasticity doubles. For the other business sectors, there is no or negligible difference in sector-level elasticities between hot and cool days.

<u>*Policy Implication*</u>

Hot days are correlated with both high SC-3A prices and NYISO DR program events in NMPC service territory. Under the weather and price conditions experienced in upstate New York during our study period, these signals appear to have overridden government/education and commercial/retail customers' need for increased cooling on hot days. This suggests that some service-oriented customers are willing to put up with a certain amount of discomfort in order to respond to high hourly prices or participate in ISO emergency DR programs. However, we caution that summer weather conditions in upstate New York are less extreme than in other areas, such as inland California. Whether the promise of greater price response as temperatures rise suggested by our results would hold up under more extreme conditions is unclear. The importance of accounting for weather effects in modeling price response should not be understated.

5.2.3 Drivers of Price Response

We investigated drivers to price response – customers' characteristics and circumstances – using a heuristic regression model (section 3.3.8) and by examining trends qualitatively among price responsive and non-responsive customers (section 4.2). The model results were somewhat disappointing – few factors had statistically significant impacts on price response – partly because the sample size was limited to customers that had answered the survey. Nonetheless, we highlight several intuitive relationships that provide insights into the factors that cause customers to be price responsive or not.

NYISO emergency programs enhance price response, in large part by providing coincident signals to curtail

In the regression model, participation in NYISO's Emergency Demand Response Program (EDRP) has a significant positive correlation with price response. This statistical finding is supported by survey responses that indicate that customers are more accustomed to respond to NYISO emergency events than SC-3A prices directly. Because EDRP events have been coincident with high day-ahead prices during our study period, it is not possible to extricate customers' response to these two signals. Based on survey and interview results, we know that many customers are aware of this coincidence and may look to NYISO events as a signal that prices are high. In addition, for many customers, response to emergency programs is motivated by a "good citizen" factor and therefore is viewed more as an obligation to the community than an economic response.

Not surprisingly then, there is a strong correspondence between customers' price responsiveness and EDRP participation. Almost 60% of highly responsive customers (with elasticities >0.10) were enrolled in EDRP. By contrast, only 36% of moderately responsive customers (0.05 – 0.10) and 27% of non- or somewhat responsive customers (< 0.05) were enrolled.

Contrary to expectations, ICAP/SCR (another NYISO demand response program) participation does not appear to have a discernable impact on price response, statistical or otherwise. One would think that the threat of penalty for not curtailing that goes with ICAP/SCR would result in measurable price response from this program. We believe that the coincidence of high SC-3A day-ahead prices and the incidence of NYISO demand response program curtailment events makes it impossible to identify separate effects for both NYISO programs.

<u>Policy Implication</u>

These results suggest that NYISO EDRP complements SC-3A prices in eliciting price response in important ways. For some customers, notification of events and the opportunity to help out in emergencies are more important than cost savings. Thus RTP alone may not draw out their full price response potential, and policymakers for whom demand response is a primary concern should consider complementing RTP with DR programs that alert and compensate them for responding to system emergencies.

Load management and information technologies do not influence customer response to hourly prices at the present time

Many SC-3A customers have installed energy management control systems (EMCS), peak load management (PLM) devices and energy information systems (EIS), technologies that have the potential to assist with price response. However, we found no meaningful statistical relationships between use of these technologies and price response. In interviews and surveys, most customers indicated that, at present, they use these technologies for other purposes than short-term price response, primarily for achieving across-the-board energy savings (permanent load reductions) and/or managing their peak demand.

Policy Implication

Promoting dissemination of enabling technologies is not a sufficient strategy to enhance short-term price response, in part because customers may consider the savings, which are available during only a few hours per year, as insufficient to justify the effort or the cost of the equipment. While recent research by Piette et al. (2005) demonstrates the potential for automated DR strategies, customers at present clearly need technical assistance to implement them. There may be a role for energy services companies to provide DR-enabling technologies to customers as part of a larger package of products and services, with price response automation included as a value-added feature.

Onsite generation can contribute to significant load response

In the demand model, the presence of onsite generation is positively correlated with price response, but this effect is not statistically significant. While over half of SC-3A customers have onsite generation equipment, the majority told us in surveys and interviews that they do not use it for price response. Many of these systems are existing, older backup generators that are wired for reliability purposes only and do not lend themselves to price response. However, among the most price responsive customers, several have onsite generation installed, and a few customers told us in interviews that they have scheduled equipment tests allowed under their operating permits when prices were high.

Policy Implication

Although few SC-3A customers have responded to hourly prices or NYISO events using onsite generation, we observe that for those that have, significant load response resulted. While environmental and health considerations must be taken into account, distributed generation has the potential to create significant new opportunities for price and load response.[74]

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[74] Some distributed generation technologies may increase overall pollutant emission levels if they emit more than the marginal generation units they replace. In addition, even if overall emissions from onsite generation are lower than for the marginal units, the relative proximity of onsite generation units to residences and workplaces may result in higher rates of human pollutant exposure.

"Champions" are probably a significant driver to price response

Because we found few characteristics of statistical significance in describing price response, we know there must be other, more subtle, factors that explain why customers that are otherwise "identical" – in size, business practice and other easily observed factors – exhibit substantially different degrees of price responsiveness. Based on two years of interviewing customers, we believe the presence of a facility manager willing to take risks to forward price response within his or her organization – an internal "champion" – is vitally important, though not easily measured. While the savings from price response might be a small fraction of total electricity costs, and an even smaller portion of an organization's total operating costs, committed energy managers often direct their efforts toward areas they can influence and, for many, price response is such an opportunity.

Policy Implication

While policymakers cannot directly control the presence of champions within customer organizations, programs that offer recognition to such individuals can both reward them for their efforts and promote broader awareness that price response is important. Similar programs have been instituted for energy-efficiency champions by Energy Star, the Federal Energy Management Program and professional engineering societies (e.g., ASHRAE, Association of Energy Engineers).

5.2.4 Customer Strategies for Responding

We explored customers' qualitative load response strategies through survey and interview questions to add context and texture to elasticity results (see section 4.1.1). The following findings demonstrate the diversity of responses, as well as the mismatch between some customers' self-reported behavior and the price response we observe.

Over two-thirds of customers say they can respond

In our 2004 survey, 71% of respondents indicated that they can respond in some way to high prices, NYISO events or public appeals to conserve. This is substantially higher than the 46% that said they could respond in the previous year's survey (Goldman et al. 2004). This comports with the empirical finding that about two-thirds of customers exhibit positive elasticity of substitution values.

Customers employ varied load response strategies – shifting, foregoing, and self-generation

Customers reported deploying three different load response strategies: shifting load from one time period to another (22% of surveyed customers), foregoing discretionary usage and not making it up at another time (45%) and supplying load with onsite generation (16%). Thirteen percent of customers reported more than one load response strategy.

Government/education customers most often forego usage; manufacturing customers are more likely to shift

Most government/education customers (83%) report that they respond by foregoing load and not making it up later. Manufacturing customers display the most variety in the types of load response strategies reported, and report load shifting more frequently than other customer types; 40% of these customers say they can shift.

<u>Policy Implications</u>

There is significant latent response potential but it is diverse in nature. Price response programs and tariff options should be designed to make best use of this diversity. It should also be noted that the load response strategies reported were framed in terms of response to any of the signals SC-3A customers have faced – high SC-3A prices, NYISO events and public appeals to conserve. Thus, while there is considerable latent load response *capability*, it is important to remember that not all customers will necessarily exercise this capability if presented with RTP price signals alone. Other programs to elicit this potential may be necessary for some customers.

What customers say they do and what they seem to do are at odds

In this and similar studies of price response that we have conducted, we have been confronted with a discrepancy between what some customers say they do and what their actions indicate they actually do. This arose in two critical areas in this study: customers' self-reported load response behavior and their participation in NYISO demand response programs.[75] We found that six out of nine survey respondents who were very price responsive (elasticity > 0.10) said they could not respond, while one customer that claimed to respond had a low substitution elasticity (<0.05). Nine of the twenty-nine customers that attested to having curtailed load to earn NYISO DR program incentive payments had never been enrolled in the programs. Twenty-four of the forty-three customers that we verified had received payments for program curtailments claimed that they had not responded to any signals at all (prices, NYISO emergencies or public appeals to conserve).[76]

There are a number of possible explanations for these discrepancies. When we conducted the survey, it had been two summers since NYISO events and high SC-3A prices had occurred. Our questions were framed over the entire study period (five years previous), and it is likely that some customers did not accurately remember if or how they had responded. In some cases, we believe that the individuals responding to our survey were not directly responsible for making decisions about adjusting usage in response to prices or about energy procurement and consequently may not have been able to accurately

[75] We also encountered inconsistencies regarding customers' supplier histories. Some customers told us that they'd been with a competitive supplier for periods when their billing information indicated they'd been with NMPC. The converse was also true in some cases.
[76] We observed the same phenomenon in evaluating the performance of ISO-based demand response programs, where customers that were paid for curtailing during events reported that they had not responded to any requests to curtail (Neenan et al. 2003).

describe their organization's experience. Strategic survey response is another possibility – some customers may have provided answers that reflected what they thought we wanted to hear, or what they wanted us to hear.

Finally, we acknowledge that our ability to accurately measure customers' behavior is not perfect and may contribute to these discrepancies. For example, the elasticity of substitution underestimates the load response from customers that forego discretionary usage (see section 5.1). In some cases, particularly where the foregoing response is small, this may lead us to conclude that a customer that actually does provide some load response is not responsive at all.

Policy Implications

In light of these issues, we urge policymakers to be creative and not translate the results of surveys or limited pilot analyses into hard and fast rules about customers' inclination and ability to respond to price signals. New initiatives should be launched with a commitment to study how customers react to opportunities to participate. This should include efforts to quantify, to a high degree of resolution, how customers that face hourly prices actually respond, as well as to collect qualitative information from customers to provide interpretive context for empirical results.

5.2.5 Barriers to Price Response

We explored barriers to price response through survey and interview questions. We highlight the following key points from this research.

Most customers report multiple barriers to price response – only ~15% respond without obstacles

Twelve percent of survey respondents reported that they had encountered no barriers in responding to SC-3A prices. This comports, although not precisely, with our finding that 18% of customers are highly price responsive (elasticities > 0.10). The rest of the respondents each reported one to five barriers to responding to SC-3A prices.

Over half of large customers report not having time or resources to monitor prices

The most common barrier to price response – reported by 51% of survey respondents – is a lack of time or resources to monitor day-ahead prices. Asked specifically how often they monitor prices, ~70% of survey respondents indicated that they rarely or never do so.[77] For some, this all but precludes price response. Others appear to rely on coincident signals – NYISO events or hot weather – to alert them of high prices.

[77] Another implication of this finding is that customers may not pay attention to off-peak prices and consequently do not take advantage of load-building opportunities when prices are low. This is in contrast to how many predecessor voluntary RTP programs have been promoted to customers: as a tradeoff between paying occasional high prices in return for load-building during low-priced hours.

Inadequate incentives keep one-quarter of customers from responding

Another barrier of concern to policymakers designing dynamic pricing tariffs is the size of the incentives created by high hourly prices. Almost one-quarter of survey respondents cited inadequate incentives as a barrier to price response. This suggests that for the other three-quarters of customers, the incentives afforded by SC-3A prices are either sufficient to justify responding, or it may be that other barriers are of greater significance.[78] If the incentives were much higher, it is not clear if price response would be more widespread, or if rigidities in customers' electricity usage are so entrenched in business practices that price response would not be practical, regardless of how high prices became.

Policy Implications

Despite the preponderance of barriers encountered by SC-3A customers, two-thirds of them have positive estimated elasticity of substitution values. It appears that some customers have been able to overcome many of these barriers, at least during the isolated occurrences of high prices and NYISO events of the last few years. Thus, we believe that some barriers may indeed be overcome with time. Indeed, targeted efforts to promote implementation of automated DR technologies and strategies could be effective in eliminating the need for customers to monitor prices actively.

However, policymakers should expect that about half of large customers cannot or may have no intention of becoming affirmatively price responsive, regardless of whether alternatives to day-ahead pricing are available to them. Others may be price responsive under regimes of occasional high prices, but may seek to hedge their exposure if prices become too high or too volatile. Some smaller fraction, perhaps 20-25%, of highly responsive customers would probably elect to remain on day-ahead pricing and respond to price spikes, even if they occurred with greater frequency than observed for SC-3A customers. This amount of price responsive load may be enough to abate the worst consequences of wholesale spot market price volatility.

5.2.6 Customer Acceptance

Finally, we examined customer acceptance of day-ahead market-based hourly pricing through customer survey and interview questions and by evaluating customers' supplier choice and hedging decisions.

Day-ahead RTP is well accepted by large customers in New York

In two years of administering surveys and interviews, we have heard few complaints about NMPC's default service: customers are relatively satisfied with day-ahead market pricing. Six years after day-ahead market pricing was introduced, 36% of SC-3A customers (representing 34% of SC-3A load) still take their commodity from NMPC on

[78] Customers were asked to indicate all barriers that applied to them, but it is possible that they neglected to indicate inadequate incentives if, for example, they never check prices and have never evaluated them, let alone made a determination about the incentives they afford.

the default rate.[79] Survey respondents indicated that they would be more likely to leave the utility if the default service was indexed to the NYISO real-time market, which affords no advance notice of prices.

Most customers have not hedged: 45-60% were fully exposed to day-ahead prices in 2004

Although the majority of customers interviewed told us they would prefer to hedge against price volatility, as many as 60% of SC-3A customers remain fully exposed to day-ahead market prices, either on the default SC-3A rate or a similarly indexed commodity deal with a competitive retail supplier. We believe that the main explanation for so many customers remaining un-hedged, yet not being very price responsive, is that they are "psychologically hedged": they have evaluated SC-3A prices and the market options available to them and decided that they are comfortable with the risks associated with day-ahead market pricing. Many of these customers may not be price responsive, having already rationalized and accepted a certain degree of price risk as part of their decision not to hedge.

Policy Implications

The acceptance of day-ahead market pricing by SC-3A customers is probably largely a function of the tariff design and price regimes these customers have faced over the past six years. In New Jersey, implementing default-service RTP indexed to the *real-time* market, which affords no advance notice of prices, has resulted in very high switching rates (84% of load) over a shorter time period (two years) (Barbose et al. 2005). This suggests that most large customers require some notice of prices in order to feel comfortable. Day-ahead RTP is seen as less risky by customers than real-time RTP and is therefore much more likely to be accepted by them. Ultimately, policymakers must rely on customers to provide price response. It follows that their acceptance of the tariff or program designed to elicit this response is critical, and subjecting them to real-time RTP may result in reduced price response if the vast majority seek out fully hedged supply contracts rather than responding by shifting or curtailing load when peak prices are high.

Market penetration of financial hedges is particularly low

We asked customers to indicate whether they had purchased financial derivatives that hedge against electricity price volatility and found that less than 10% of survey respondents had done so. About half of the rest either could not articulate why they had not or were not sure what a financial hedge is. This may reflect a culture within firms and institutions that sees financial products as distinct from energy supply contracts or under which the two products may be procured by different departments and people.[80]

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[79] Customers have expressed dissatisfaction with retail market offerings in interviews, in particular an inability to find suppliers interested in serving them or hedges that they felt were reasonably priced. However, we heard fewer complaints in the second year of our study than the first. This, combined with increased customer migration in recent years, suggests that the market is maturing.

[80] In addition, some customers may have institutional rules preventing them from purchasing derivatives – this too can be a barrier to financial hedging.

Policy Implication

Many large customers are apparently unfamiliar with financial hedging products as they relate to energy. This lack of awareness, observed among large customers exposed to day-ahead pricing and competitive retail markets for six years, strongly suggests that customers require education if a robust market for these products is to develop. Policymakers that are concerned about ensuring adequate hedging options exist initially for customers exposed to default-service RTP should consider efforts to educate customers about financial hedge products and possibly having the default utility offer a hedged alternative (such as NMPC's Option 2) during the transition period.

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