Cost Effective Estimation of the Load Impacts from Mass-Market Programs: Obtaining Capacity and Energy Payments in Restructured Markets for Aggregators of Mass-Market Loads

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ABSTRACT

There is a long history of mass-market load management programs and the application of verification protocols to estimate the on-peak load reductions resulting from these programs. The development of demand response programs in response to ISO initiatives in compliance with FERC's May 17, 2000 Order has largely excluded mass-market customers by requiring that each participating customer install revenue quality interval meters. This requirement makes mass-market programs uneconomic. Yet, mass-market programs produce dispatchable load reductions, i.e., load reductions can be obtained within one minute after a curtailment notice is sent out via a page. In addition, customer diversity and the relative constant equipment duty cycles of controlled equipment make these programs some of the most reliable.

One reason for the relative lack of development of mass-market programs compared to large customer programs is the belief that the impacts from demand response can be more accurately estimated for large customers and that verification of mass-market program impacts will pose estimation problems.

This paper has four sections, which include 1) the importance of mass-market demand response programs in mitigating price volatility in increasingly competitive wholesale and retail energy markets, 2) the unique attributes of mass-market load management programs, 3) the factors that affect the ability to accurately estimate curtailed loads in both large-customer and mass-market programs, and 4) approaches to cost effectively obtain estimates of curtailed load in mass-market programs that will justify the payments of capacity and energy credits to mass-market load aggregators.

The Load Management Landscape

The recent supply situation in California and concerns about the adequacy of generation capacity and/or transmission in New England, New York and the Midwest have resulted in an increased focus on customer demand response programs. Developing initiatives that allow customers to be part of the solution is of critical importance for the industry. It can be argued that industry restructuring and the transition to competition have actually reduced retail demand elasticity and demand responsiveness. Reasons for this reduced demand response include the following:

1. The continuation of non-market, flat electricity prices as part of standard offer service available to customers who do not choose an alternative electric provider.
2. A freeze on electricity tariffs, including tariffed load management programs where load management programs are not allowed to enroll new participants.
3. Competitive electricity providers have not stepped in with innovative rate offerings with load management and/or peak period pricing.

Restructuring proceedings in most states have emphasized the recovery of stranded costs and rules designed to prevent incumbent utilities from exploiting market power in wholesale and retail power markets. These issues have dominated rulemaking proceedings, and procedures have been put in place that largely accomplish these initial objectives.

However, retail competition was sold on the premise of customer choice *and* supplier innovation in almost all jurisdictions. Competition in electric markets was supposed to unleash a wave of innovation in offerings, products, and services. However, innovation is critically dependent upon market flexibility and accurate pricing. Today, retail market participants are not allowed to price what is scarce, i.e., peak electric consumption. Before innovation in offerings can be expected, the market must be allowed to function whereby pricing is one of the methods used to allocate scarce commodity supplies.

For mass-market customers, price response options have been further limited due to a bifurcation of incentives for load management between distribution companies and energy suppliers. Distribution companies have the infrastructure to deploy mass-market load management, but it is not clear if they have the incentive required to incur the costs. For example, suppose a distribution company invests in mass-market load management only to have some of the customers on the program switch to an alternate provider at some time in the future. Would the distribution company lose the benefits from having these customers as participants in the program? This can be addressed by having a contract between the distribution company and participating customers that continues to allow the distribution company to implement load management and to obtain credit for the capacity reductions even if another company is providing energy to that customer.[1]

A fundamental question that needs to be addressed is whether the entities that have the infrastructure to provide demand-response programs also have the incentive to provide load management offerings necessary for efficient market operation. Distribution companies are able to aggregate a sufficient number of customers to attain scale in mass-market load management. They have the paging and communications infrastructure needed to implement various control strategies and the back-office systems necessary to develop and maintain a mass-market load management program.

Mass-Market Programs and Demand Response

The problem of inadequate demand response is beginning to receive attention; however, the focus has been on designing offerings for large customers. This focus on large customers has been due to the following:

1. A need in some regions to put demand-response programs in place quickly and a belief that large customer programs can be instituted more quickly.
2. The belief that only large customers with considerable MW curtailment potential can afford to install the metering equipment required to verify load curtailments.
3. A concern that demand-response (e.g., curtailed load) in mass-market programs can not be verified to the same level of accuracy as large customer programs.

Of these three reasons, only the first has merit. It may take longer to roll out a mass-market program targeting ten thousand customers than a program focused on the fifty largest customers in a region. However, mass-market programs attaining sizeable reductions (e.g., 15-20 MW) can be rolled out in a matter of months.[2]

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[1] A reviewer of this paper stated that he believed this to be a "strawman" argument and that the limited switching that has occurred in mass markets would make this a non-issue for most distribution companies. However, discussions with several distribution companies have indicated that this is part of their concern. A more general concern is simply the uncertainty with cost recovery and the fact that tariffs were frozen as part of the restructuring settlement. Another factor that has been important for some distribution companies is the contract, which they have negotiated with either their own GENCO or another wholesale supplier to meet their default supply requirements. In this case, the benefits of load management as a peak supply option, which accrue to the wholesale supplier, and agreements for the supplier to pay the DISCO to implement load management have been difficult to negotiate.

[2] The Long Island Power Authority initiated a program in March of this year designed to achieve 20 MW of demand reduction in a period of months (LIPA 2001).

Unique Attributes of Mass-Market Programs

Mass-market programs can provide attributes to the portfolio of demand response initiatives that are not available from large customer programs — namely dispatchability and reliability. These attributes include the following:

- **Dispatchability.** Mass-market programs can provide demand relief within one minute after being called via the use of a paging communications system, which directly contacts the customers' equipment. In fact, the California ISO acknowledged seeing 200 MW of demand drop off the system within one minute of calling on Southern California Edison to implement its mass-market direct load control program.[3] In contrast, larger customer programs typically require a minimum of two hours for customer response, and often the time between notification and required response is four to six hours, or even twenty-four hours for day-ahead programs.
- **Reliability.** It can be argued that mass-market programs are more reliable because of the large number of diverse customers they create and because the load duration curves are more consistent on peak days. If one or two customers in a large-customer program are not online that day, a substantial reduction in demand response may result. This risk is greater for programs dependent upon a few large customers than it is for programs with thousands of customers.

The most common mass-market demand response program is the direct load control of air conditioning, water heaters, and other discretionary uses (e.g., pool pumps in residential applications, irrigation in agricultural applications, and non-critical lighting in commercial applications). The industry has over 20 years of experience with these programs. Table 1 shows the number of customers and controllable load for seven mass-market programs deployed in different regions of the United States. Recent technology developments have provided operational flexibility and experience with different levels of equipment cycling, appropriate control of multiple pieces of equipment at a site, one and two-way communication protocols, and innovative marketing and incentives for customer participation.

Table 1. Existing Mass-Market Load Management Programs
(number of customers and MW under control)

Program	Number of Customers	MW
Southern California Edison	200,000 (residential and agricultural)	280 MW
GPU Energy	80,000	80 MW
PEPCO	150,000	200 MW
Florida Power & Light	600,000	700 MW
Florida Power	470,000	470 MW
ComEd	68,000	80 MW
Northern States Power	250,000	250 MW
Source: Phone conversations with the respective companies.		

In summary, mass-market programs involving the direct load control of equipment at residences, small businesses, and agricultural sites can be economic and provide a truly dispatchable resource, i.e., curtailment within a few minutes after notification. In addition, the diversity of the customer base

[3] Communication with Richard Cromie, Southern California Edison, October 2000.

makes this one of the most reliable capacity curtailment programs available. It is important that this sizeable and economic resource option be allowed to participate in the demand relief programs offered by ISOs and other entities.

The Evaluation Problem for Load Management Programs — Large Customer versus Mass-Market Programs

This section addresses whether verification/evaluation of the demand response is inherently more easily addressed for large customer programs or for mass-market programs. The key issue is whether the ability to place interval meters on all participants in a large customer program necessarily makes that program more reliable and verifiable than a mass-market program.

In response to the May 17, 2000 FERC ruling requiring ISOs to develop demand response programs, the California ISO, the New York ISO, ISO New England and the PJM ISO have proposed demand response programs. At the present time, ISOs and related reliability organizations (i.e., RTOs) have been on the cutting edge of developing demand response initiatives with state regulatory agencies largely content to stay on the sidelines. Each of these ISOs has proposed programs designed for large customer participation and, to their credit, each has developed innovative approaches for the participation of large customers. However, each of the ISOs has also adopted verification rules that effectively eliminate the participation by mass-market customers and programs targeted at mass-market customers.

The California ISO (CAISO 2001) Demand Relief Program calls for revenue quality meters to be installed at each participating site. The compliance calculation takes the metered MW demand during the control period and compares this to a baseline load profile, which is calculated from the "immediately preceding 10 business days." The difference between the control period profile and the baseline load profile for each large customer is the demand response used by the CAISO in settlements. The requirement that each participant in the program have revenue-quality interval meters installed as part of the program makes mass-market programs uneconomic since mass-market programs often have many thousands of participants. Programs at other ISOs have essentially the same requirements.

The requirement that each participating customer install a revenue quality interval meter is simply unnecessary. This requirement has little to do with the accuracy and integrity with which demand response can be verified. In fact, an argument can be made that mass-market load response programs can cost-effectively produce more accurate estimates of demand response than can be obtained for large customer programs where interval meters are installed for each participant.

The design of these verification protocols overlooks the fact that accurate values of demand response are less dependent upon the accuracy with which control period loads are measured via interval meters and more dependent upon the accuracy with which the baseline load profile is estimated. The accuracy and integrity of verification is principally dependent upon the assumed baseline load profile. For the CAISO Demand Relief Program, the baseline load profile represents what each participating customer would have used if he had not controlled demand as part of the demand relief program. The difference between the estimated load profile for each customer and what that customer actually would have used on that day largely determines the accuracy of the estimated demand response for each large customer.

The variability in day-to-day and hour-to-hour load profiles will be the factor that most significantly influences the accuracy of the estimated demand response. In general, many large customers have discrete production processes that determine their daily and hourly load profiles. If a given process is not scheduled for a "control day" or for those hours subject to control, then the baseline load profile will not be an accurate indicator of what that large customer would have used, had a control day not been called.

Conversations with ISO personnel and others on demand response committees have indicated that there are concerns that mass-market load control programs might be subject to "gaming" by customers. However, gaming would appear to be a concern for large customer programs as well. To illustrate, participating customers know that their baseline load profile is the average of the preceding 10 days' load profiles. If the control days call for load to be reduced from the 1 p.m. to 9 p.m., then customers will have an incentive to run production processes during non-control days that increases the baseline profile. Even if there are no designed plans to impact the baseline load profile, the customer's demand response may be overestimated if a production process was not scheduled for the day on which ISO called for demand relief. In any event, concerns about gaming should apply to large customer programs as well as mass-market programs.

The ability to accurately verify curtailed load will depend upon the ability of the assumed baseline to accurately predict what the load would have been during a curtailment period. In contrast to large customers, the duty cycles of air conditioning and other equipment under control can be expected to exhibit less day-to-day and hour-to-hour variability on peak days. This is particularly true for small commercial customers that increasingly are becoming the focus of mass-market demand response programs since their businesses are generally open every day and maintain regular schedules.[4] As a result, the baseline load profile for mass-market programs is likely to be estimated more accurately and the overall demand response estimated using this baseline is likely to be more accurate. This is likely to be true even if the mass-market program uses a sample of participants with interval meters to estimate current consumption as opposed to large customer programs where every participant has an interval meter installed.

The assumption that accurate estimates of demand response from a group of customers is dependent upon extremely detailed metering of control period consumption with the greatest possible accuracy for each customer is simply erroneous. You can meter everything there is to meter with whatever frequency and periodicity that is technically achievable and not substantively improve upon the estimates of demand response. The reason is that the accuracy of the demand response impact estimate for a group of customers is more dependent upon the accuracy with which the baseline load profile is developed than the exact precision that is achieved for the control period consumption. Any demand response estimate is the difference between a baseline profile and the lowered demand. Metering one of these points extremely precisely does not necessarily increase the accuracy of the attained demand response. Therefore, the impact estimation problem is largely dimensioned by how accurately the baseline load profile can be determined. This changes the focus of the verification protocols to load participants with regular daily and hourly load profiles as being the best candidates for participation in demand response programs, if the goal is to accurately verify demand response impacts.

Verification Protocol for Mass-Market Demand Response Programs

An acknowledgment that demand response for both large customer programs and mass-market programs is in fact an estimate whose accuracy is largely determined by the calculated baseline load profile (which by necessity is based on assumptions and can never be known with certainty) allows for a more rational discussion of the relative merits of alternative approaches for verification of mass-market

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[4] Examinations of the economics of direct load control (DLC) programs targeted at the small business segment show these programs to be quite cost effective. The operation of DLC programs can reduce the concerns or severe discomfort that discouraged some businesses from participating in earlier programs. In addition, most residential programs produce, on average, 1 kW for each participating customer on a fully diversified load basis. Small business customers contribute, on average, 20 kW because, in part, their load is less diversified. This provides a 20X gain in benefits, with only about a 4X increase in program costs. As a result, the small business sector is becoming a focal point of the next generation of mass-market load management programs. For more information see Violette 2001.

program impacts. Within this framework, the aggregate baseline load profiles for mass-market load control participants are what the load shape for participating customers would have been on control days, if a control day had not been called.

The most straightforward approach for validating demand response for a mass-market demand response program would involve installing interval meters on a suitable sample of participants. In general, a 10 percent sample is viewed as adequate. This would produce a sample of 1,000 participants out of a population of 10,000 program participants.

However, this straightforward sampling approach using a sample of interval meters is *unlikely* to produce levels of accuracy that will allow the ISO or a similar settlements entity to provide capacity and energy payments to a mass-market program aggregator. Instead, a slightly more sophisticated approach is needed to produce levels of precision on which capacity and energy payments can be justified and to address perceived risks in mass-market demand response programs.

As an illustration, a recent evaluation of a direct load control program for air conditioners in the Western United States produced a mean impact estimate of .71kW per participant.[5] There were a total of 600 participants in the program and metered data were obtained on a sample of 50 participating customers. The standard deviation for this sample was 1.01 kW.

The reason the standard deviation is so large is that approximately 35 percent of the participants had zero or minimal impacts from the program on control days, i.e., their AC unit was shut off on that day, either because they were on vacation or because they were "free-riders" and typically turned off their AC units during the day. The number of participants with near zero impacts results in a bimodal distribution with a large variance and standard deviation for the sample.[6]

A 90 percent confidence interval with a standard deviation of 1.01 yields a confidence interval of +/- .24 kW or +/- 34 percent. This level of precision may not be accurate enough for a settlement agent to grant capacity and energy payments to mass-market programs.

One way to improve the precision of the estimate is to move beyond a simple sampling approach and take advantage of the fact that some information will be available on the population of participants. This allows ratio estimates to be developed that will have nearly an order of magnitude (or more) increase in precision.[7] The population information could be as simple as the AC unit nameplate rating; however, a better approach would utilize duty cycle information on each participating customer along with an equipment nameplate rating to produce an initial estimate of impacts for each customer. New load control technology uses powerline carrier technology or radio frequency (RF) technology to communicate between a household gateway (sometimes this is a communicating thermostat) and the controlled appliances.[8]

These gateways can record duty cycle information for each appliance for any baseline load profile period (e.g., the hours immediately before a control period or loads similar temperature days).

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[5] This pilot study only examined air conditioning loads which accounts for the impacts being smaller than those observed in programs that include additional loads such as electric water heaters and pool pumps.

[6] Recall that the variance is the sum of the squared differences between each observation and the mean of the sample. With many observations occurring on the lower boundary (i.e., taking on a zero or even a slight negative value), the variance is necessarily greater than would be the case for a distribution that had a more central tendency. It is important to note that the non-normality of the sample distribution does not bias the statistical tests since the sampling distribution will still have a normal distribution, albeit with a larger variance.

[7] Discussions of ratio estimates can be found in most textbooks on statistics. Ratio estimation in the context of load management program impact estimation can be found in EPRI 1991; ORNL 1991; and Violette 1993.

[8] This gateway technology is being installed by the Long Island Power Authority (see LIPA 2001). Also, Honeywell Inc. is developing an RF based direct load control module with an internet gateway that will allow for run-time data to be collected for each appliance under control (Communication from Ann Slavec, 2001a of Honeywell on the specifications for two-way communicating load management equipment). Other companies also are developing similar technology for use in load management programs.

The data recorded in these gateways are the number of minutes a piece of equipment is on or off during each hour. The data collected on runtime by the communicating thermostat (or other gateway) on runtime are combined with compressor nameplate data to provide an estimate of kW impacts.[9]

The ratio estimation approach is constructed by drawing a sample of participants and installing interval meters on this sample. In the context of this ration estimation, a sample size of 100 participants (regardless of the number of participants in the program) should be adequate. The use of the run-time data combined with estimates of kW draw should provide accurate initial estimates of demand response impacts. The use of interval data on a sample of 100 of these participants as validation should produce a ratio estimate of between .95 and 1.05, with a standard deviation of approximately .10. The precision around an impact estimate using this approach will be +/- 2 percent for a 90 percent confidence interval.[10] This level of accuracy should be as high or higher than what is obtained for large customer programs and will provide the basis for awarding capacity and energy payments.

Another performance risk that has been expressed as a concern by ISO personnel is a failure in the paging communications system. On occasion, weather or other sources of interference might prevent an area from receiving the load control signal. The gateways being developed in the new load control modules have the capability of providing an acknowledgement signal, i.e., a reply that indicates that the signal was received. This is not needed for every participant, but could be performed on a geographic sample of participants.[11]

The verification protocols proposed for mass-market programs would involve three steps:

- **Step 1.** Use run-time data available from all on-site equipment for all participants. These data can be paged into a central server using the two-way radio communications or they can be called in daily or weekly using phone lines.
- **Step 2.** Use a sample of interval kW meters to confirm impacts and develop a ratio estimate of the metered load impacts to calculated impacts based on run-time data.
- **Step 3.** Use gateways being developed in the new load control modules to provide an acknowledgement signal for a geographic sample of participants.

The verification protocols contained in the three steps outlined above should provide the necessary confidence and precision to allow ISOs or other settlement agents to provide aggregators of mass-market loads both verified capacity and energy payments on the same basis as these payments are made to large customers.

Conclusion

Direct load control of equipment at residences, small businesses, and agricultural sites can be economic and provide a truly dispatchable resource, i.e., curtailment within a few minutes after

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[9] A more detailed specification for generating these initial estimates would include a combination of spot-watt metering for individual air conditioning compressor units, collecting run time data using runtime loggers in the gateways, recording compressor nameplate data, and recording humidity and temperature data throughout the control period. Temperature and humidity data can be collected at several sites distributed throughout the control area. This approach is presented in "LGE Energy's DLC Evaluation Plan" filed before the Kentucky PUC, October 2000 available from the authors or Mr. Scott Cooke at LG&E.

[10] This gain in precision has not been proven in the field, but is based on other research using ratio estimates and the assumption that there will be a close correlation between the initial kW estimates using the duty cycle data and the estimates for the sample of 200 using the interval meters. Assuming that the runtime data collected by the gateway would allow for the identification of those sites where impacts were essentially zero, the variance decreased from 1.01 to .5. This combined with a larger estimate of impacts for those sites where impacts occurred and resulted in a +/-10 percent precision at a 90 percent level of confidence.

[11] See "LIPA Air Conditioning Direct Load Control" (2001) for an example of this signal verification protocol.

notification. In addition, the diversity of the customer base makes this one of the most reliable capacity curtailment programs available.

A requirement that detailed interval metering be conducted at every participating site makes mass-market programs uneconomic. The assumption that accurate estimates of demand response from a group of customers is dependent upon extremely detailed metering of control period consumption for each customer is simply erroneous. The reason is that the accuracy of the demand response estimate for a group of customers is more dependent upon the accuracy with which the baseline load profile is developed than the exact precision that is achieved for the control period consumption. Any demand response estimate is the difference between a baseline profile and the lowered demand. Metering one of these points extremely precisely does not necessarily increase the accuracy of the attained demand response.

It is important that all sizeable and economic resource options be allowed to participate in the ISO demand response and demand relief programs. Mass-market load management provides a verifiable capacity option for the ISO and the monthly capacity reservation payments provide an important incentive to energy service providers to expand this resource. The three-step approach outlined in this paper should provide the basis for verified capacity and energy payments to aggregators of mass-market load management.

Finally, the demand response programs under development by ISOs should provide all customers with options for participation and the ability to manage their on-peak energy use. At present, ISO programs are limited to large customers because of the design of the program. High on-peak prices impact all customer segments and programs should be developed to allow all customer groups to participate in these programs and better manage their energy use. As a result, demand response programs should be open to all customers (including smaller customers) that demonstrate that they can curtail load on demand. This would also allow ISOs to take full advantage of rapidly developing technology, which makes mass-market load control an economic and reliable capacity resource.

References

CAISO. 2001. *California Independent System Operator Corporation Second Request for Bids to Provide Demand Relief (Load) for Summer 2001.* March.

EPRI. 1991. *Impact Evaluation of Demand-Side Management Programs — Volume 1: A Guide to Current Practice.* #EPRI CU-7179. Palo Alto, CA: Electric Power Research Institute Pubs. Vol. 1. February.

LIPA. 2001. "LIPA Air Conditioning Direct Load Control." Michael Marks. Applied Energy Group, Inc. Presented at the Price-Responsive Load Management Conference: A New Opportunity in New York State Electricity Markets. March 22-23.

ORNL. 1991. "Chapter 5: Data Analysis for DSM Program Evaluation." In the *Handbook to DSM Program Evaluation.* Edited by Eric Hirst and John Reed. #ORNL/CON –336. December. Washington, DC: NTIS Pubs.

Violette, Daniel. 1993. "Statistically Adjusted Engineering (SAE) Estimates — What Can the Evaluation Analyst Do about the Engineering Side of the Analysis?" *In Proceedings of the International Energy Program Evaluation Conference.* #CONF-930842. August: 656. Chicago, IL: NTIS pubs.

Violette, Daniel. 2001. "Opportunities for Load Management in Mass Markets." *In Proceedings of the EEI Retail Energy Services Conference.* Chicago, IL. March.