Estimating Demand Response Potential for Resource Planning

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ABSTRACT

As electricity demand increases, utility planners are faced with many options for balancing supply and demand, including additional generation capacity, energy efficiency measures, and the increasingly popular demand response (DR) alternative. While numerous studies of energy efficiency potential exist, rigorous studies of the potential for demand response are much less prevalent. This paper summarizes the methodology and results of a DR potential study conducted for the Consolidated Edison Company of New York. The paper illustrates how a combination customer demand data, market segmentation, primary surveys, and secondary research can be used to reasonably estimate the potential for callable load reductions. This paper also details a stochastic modeling approach, whereby Monte Carlo simulation techniques are utilized to better understand the uncertainty inherent in such potential estimates.

Introduction

As electricity demand increases, utility planners are faced with many options for balancing supply and demand, including additional generation capacity, energy efficiency measures, and the increasingly popular demand response (DR) alternative. While numerous studies of energy efficiency potential exist, rigorous studies of the potential for demand response are much less prevalent. This paper summarizes the methodology and results of a DR potential ("callable load") study conducted for the Consolidated Edison Company of New York (Con Edison).

The purpose of the study was to assess "callable load opportunities" in New York City and Westchester County during the next 10 years. For the purposes of this study, callable load opportunities represent short-term reductions in system demand, typically four hours or less in duration, that are provided by individual customers (or aggregated groups of customers) curtailing their electricity consumption or deploying emergency generation on request. Callable load events are initiated by Con Edison, the New York Independent System Operator (NYISO), or the New York Power Authority (NYPA) and can yield measurable load reductions as quickly as 10 minutes from the time that participating customers are notified.

This study achieves <u>two primary objectives</u>:

1. Assess the potential, in megawatts, for peak load reductions that can be called by Con Edison;
2. Present program concepts that provide pathways to cost-effectively achieve this potential.

This paper focuses on the estimation of demand response potential (Objective 1), particularly the results of the analysis and the implications for utility assessment of DR opportunities.

Existing Callable Load Programs

Con Edison currently offers several callable load programs, and many Con Edison customers also participated in demand response programs offered by the New York ISO. In 2007 approximately

783 MW of callable load commitments were enrolled by Con Edison customers in demand response programs. Callable load offerings *currently available* to Con Edison customers include the following four programs:

1. Distribution Load Relief Program (DLRP)
2. Direct Load Control (DLC) Program
3. New York ISO Installed Capacity Program (ICAP)
4. New York ISO Emergency Demand Response Program (EDRP)

Participation in these programs in 2007 was varied, with nearly 500 MW enrolled in the ICAP program, approximately 140 MW each in DLRP and EDRP, and 30 MW in the DLC program.[1] Table 1 presents the breakdown of enrollment by program type, along with the total nominal enrollment value of 783 MW.

Table 1. Enrollment in Con Edison and New York ISO Demand Response Programs, 2007

Program	MW Enrolled
DLRP	138
ICAP	485
EDRP	140
DLC	30
TOTAL	**783**[2]

Curtailment potential from the enrolled customers is somewhat less than 783 MW due to the fact that some DLRP participants are also enrolled in NYISO programs. It is estimated that removing this overlap from the accounting of callable load potential results in approximately 690 MW of unique enrollments. Furthermore, roughly 231 MW of enrollments represent voluntary commitments through either the EDRP or the voluntary component of the DLRP. Historically, participants in the EDRP program have provided load reductions equal to approximately 35% of commitments, and those in the voluntary DLRP have provided reductions of roughly 63% of commitments.[3] Participants in the mandatory programs have achieved, on average, 97% of committed megawatts. The combined effect of the enrollment overlap and the effective curtailment rates is that currently available callable load reductions are currently estimated at approximately 569 MW.[4]

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[1] Enrollment information provided by Con Edison: EDRP and ICAP enrollments based on NYISO data; DLC enrollments from *Con Edison Direct Load Control Program 2006 Annual Report*, Applied Energy Group, Inc.

[2] Enrollment in the four callable load programs through 2007 is estimated at 793 MW. However, updated 2007 values for the DLC program were not incorporated into this report until shortly before publication. As a result, comparisons between current enrollment and future callable load potential are based on the 2006 DLC enrollment of 20 MW, rather than the 30 MW enrolled through 2007. *Estimation of callable load potential is unaffected* by this use of 2006 data.

[3] Event summary data for Zones H, I, and J provided in spreadsheets by Con Edison. 1) "Summary of Con Edison Aggregated Load in EDRP and ICAP Events by Zone from 2001-2007"; 2) "Summary of Con Edison DLRP Events by Zone from 2001-2007."

[4] The estimate of 579 MW of achievable callable load reductions from current enrollments assumes that the Average Peak Monthly Demand (APMD) is a reliable method of estimating actual load curtailments. Some other jurisdictions use a customer baseline load (CBL) method based on recent similar-day loads, with a same-day adjustment that can account for changes in baseline loads due to weather.

Defining Potential for Callable Load

"Callable load" opportunities, as discussed above, represent short-term reductions in system demand, typically four hours or less in duration, that are provided by individual customers curtailing their electricity consumption or using emergency generation. Estimating the potential for callable load requires a brief explanation for what is meant by "potential." The literature on estimation of potential savings that has been developed for energy efficiency generally uses the terms "technical" potential, "economic" potential, and "market" (or "achievable) potential.[5] In a general context, these terms have been used as follows:

- *Technical potential* is the MW potential resulting from the most efficient technology or approach being implemented by customers in a sector or segments subject to applicability, feasibility, and technology availability.
- *Economic potential* is based on the options that pass threshold financial criteria subject to applicability, feasibility, and technology availability.
- *Achievable potential* is based on what is likely to be attained in the field and incorporates customer/market factors such as awareness and familiarity with the demand-side management, views towards program offers, marketing, information, and often whether a customer believes that by participating they are contributing to an economic, more reliable electric system for the region.

In terms of technical potential, many customers have the physical capability of shutting off most or all of their facilities; however, for the vast majority of customers, this level of curtailment—while *technically* possible—is not practical. Still, it is common practice to use the observed load sheds at individual facilities (kW shed as a share of peak load) from benchmark DR programs and assume 100% participation of a customer segment to provide a "reasonable technical potential." This is the construct used in this study.

A more practical way to view callable load potential is in terms of the achievable potential—or firm, verifiable reductions that are likely to be achievable given sufficient incentives. This achievable potential may or may not be cost-effective, depending on factors including program administrative costs, incentives required to encourage participation, and the avoided costs attributable to the callable load capability.[6]

A study of *callable load* potential differs from traditional *energy efficiency* potential studies that have been conducted throughout the industry. Reductions in consumption from energy efficiency measures are generally based on technical specifications such as the installation of high-efficiency equipment that has a known increase in efficiency and a known incremental cost compared to standard

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[5] See Optimal Energy, *Guide for Conducting Energy Efficiency Potential Studies,* prepared for the U.S. Environmental Protection Agency, November 2008; Midwest Energy Efficiency Alliance, *Midwest Residential Market Assessment and DSM Potential Study,* March 2006; and TecMarket Works, *The California Evaluation Framework,* June 2004.

[6] There are many factors influencing a customer's decision to participate in a DR program. The level of economic incentive is just one factor, with others including the number and duration of events, the amount of advanced notification provided prior to an event, penalties for under-performance, and even non-program factors such as public relations. For these reasons, and the fact that tariff programs have standard terms for all customers, it is difficult to develop a callable load supply curve that would indicate the number of participants or megawatts that would be provided at varying incentive levels. Developing such a supply curve can be done for the Con Edison market, but would require targeted research methods such as a pilot program testing various incentive levels or a conjoint survey analysis offering customers hypothetical bundles of program elements with several levels of incentives and other program characteristics.

equipment. With some exceptions, the efficient equipment performs as well or better than the standard equipment, and the customer is relatively unaffected.

As discussed above, callable load opportunities are less about using technology which has a measurable change in load, but rather about what actions customers are willing to take and what changes in their business or home environment they are willing to accept. The achievable potential is the load reduction that customers are willing to provide at a given level of incentives and with a given set of available technologies.

Consequently, **this study adopts the approach that achievable potential is the appropriate starting point for estimation,** and that cost-effectiveness is based on the achievable potential passing a screening tool with a benefit-cost ratio of greater than 1.0. Technical potential may be a useful benchmark and is defined as the load reductions that could be expected at 100% participation, with the estimated load curtailment assumptions based on the DR program designs.

Model and Key Inputs

To estimate the potential for callable load reductions, the study team developed the Demand Response Simulator (DRSim™) model in the Analytica® modeling environment (see www.lumina.com). The team selected Analytica® as the modeling environment due to its visual modeling capability, which promotes transparency; integrated Monte Carlo simulation capability; and flexibility in adjusting segmentation and conducting scenario analyses resulting from its Intelligent Array™ algorithm. Key inputs required to estimate the potential for callable load reduction in the DRSim™ model are 1) coincident peak demand, 2) load shed percentages, and 3) participation rates in callable load reduction programs. Each of these inputs is disaggregated, at a minimum, by customer segment and peak demand category. The methods used to estimate or calculate these key inputs are described in this section.

Coincident Peak Demand

The study team first estimated non-coincident peak demand for each customer segment by analyzing hundreds of thousands of customer records provided by Con Edison. Analysis of NAICS code classification and demand billing data permitted disaggregation by customer segment and peak demand category (e.g., >300 kW or <300 kW). The product of non-coincident peak demand and the coincidence factor (also calculated by the study team) for each segment results in the estimated coincident peak demand by customer segment and peak demand category. The sum of peak demand across all customer segments yields the total system peak demand of 12,807 MW for 2007.

Load Shed Percentages

To estimate the ability of each customer segment to shed load during a demand response event, two complementary approaches were used. The first approach entailed conducting a literature search to identify existing estimates of the fraction of load that has been shed by participants in various demand response programs in different customer segments. The second approach involved calculating the fraction of peak demand committed by customers currently enrolled in demand response programs in the Con Edison service territory. The final values used in the DRSim™ model for load shed fraction equally weighted the results from the two different approaches. Typically load shed value were in the range of 15% to 20% of peak load, depending on the customer segment, with industrial, government offices, and educational facilities exceeding 30%. Further, standard errors on the estimates were calculated to provide a measure of the uncertainty in each input parameter. Where insufficient data were available to calculate a standard error, a value of 50% of the estimate was used.

Participation Rates

Another key parameter in the DRSim™ model is the percentage of customers who are assumed to be willing to participate in demand response programs. This value is especially difficult to estimate and is arguably the largest contributor to uncertainty in the final estimate of load shed reduction potential. Estimates of participation rates in other demand response studies are typically "broad-brush" and depend largely on the judgment of the estimator (EPRI 2008).[7] While judgment is also used in estimating participation rates in this study, a somewhat more rigorous approach is used in this analysis to account for observed differences in participation rates among customers of different sizes.

In the DRSim™ model, the baseline participation rate for residential customers was assumed to be 20% of customers with central air conditioning. For non-residential customers, participation rates were assumed to be a function of peak demand category, with 10% of demand participating in the "under 20 kW" customer group and as much as 50% of demand participating in the "over 1000 kW" customer group. Note that these participation rates are based on the share of demand in each group, not the share of customers. This means that participation by just a few larger customers can create a relatively high participation rate. For example, Con Edison has one participating customer with multiple sites that contributes roughly 50 MW of load curtailment, which offset low participation rates from smaller customers within that size category.

Achievable Potential

Achievable potential for callable load reduction is that which could reasonably be achieved using a diverse portfolio of demand response programs that address multiple market segments and curtailment methods. Achievable potential is by definition lower than technical potential (which assumes 100% participation) in that it considers the likelihood that customers will actually participate in a demand response program. *Achievable potential represents the estimated firm load curtailments that can be provided by Con Edison customers concurrent with the system peak in 2017.*

Two different scenarios were defined for the estimates of achievable potential, a *Shed Scenario* and a *Generation Scenario*. For brevity, only the *Shed Scenarios* are discussed in this paper.[8] The following discussion of the load shed scenario presents estimates for total achievable curtailment potential. These "total achievable" estimates include curtailments from both load shedding *and* use of emergency generation. In the load shed scenarios, the emergency generation assumptions are held constant at the base case (medium scenario) level.

In the *Shed Scenario,* the only variable changing in the DRSim™ model relative to the baseline values is the assumed participation rate (as a percentage of non-coincident peak demand for each customer segment) of customer accounts engaging in *load shed activities*. All assumptions regarding the utilization of emergency generation for demand response are held constant at baseline levels. The baseline participation rates described earlier (which are taken as the *medium* level in the scenario) are varied by customer segment to generate *low, medium, and high* scenarios for participation. For residential customers, the assumed participation rates are 10% for the low scenario, 20% for the medium

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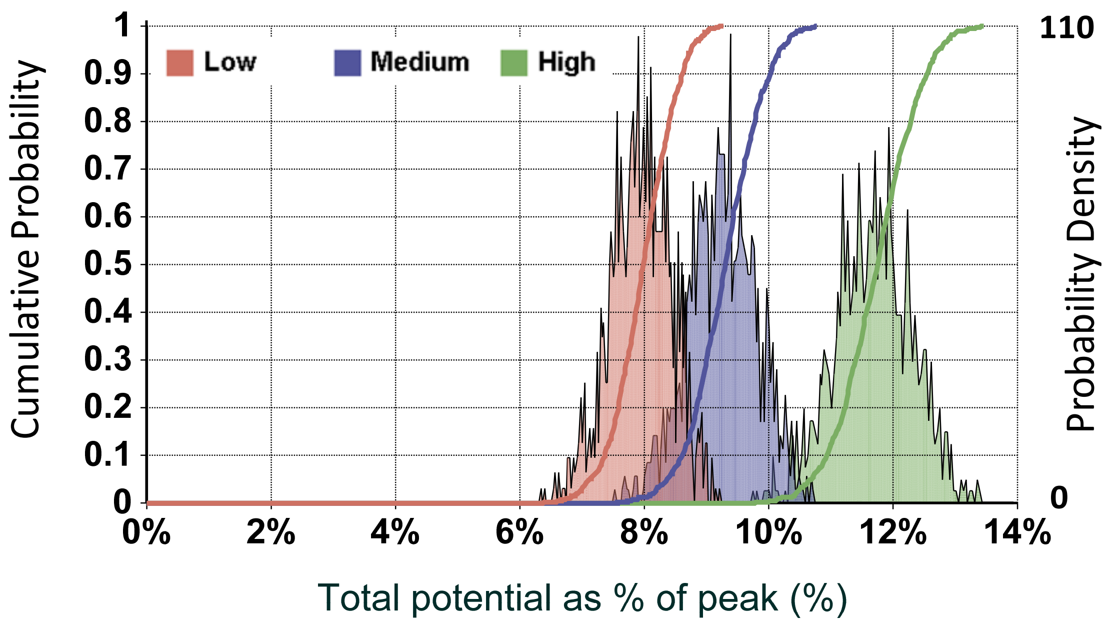
[7] For example, round number, judgment-based estimates for participation ranging from 5% to 50% depending on the application are seen in a recent DR potential study conducted by the Electric Power Research Institute (EPRI) See EPRI and Edison Electric Institute, *Potential for Energy Efficiency and Demand Response in the U.S., 2008 to 2030*, 2008.

[8] For the full report, see http://www.summitblue.com/dyn_downloads/1224695582.pdf.

case, and 30% for the high case for customers with central air conditioning. The high scenario also allows for 10% participation by residential customers without central air conditioning, which represents a situation where advances in communications technology and cooperation with manufacturers could allow for direct load control programs to be applied to room air conditioning as well. For non-residential customers, participation rates for the high and low scenarios were assumed to be a factor of 0.8 (low) and 1.2 (high) times the baseline participation rate (which is assumed for the medium scenario).

Figure 1 portrays the *cumulative distribution functions* and the *probability density functions* for total achievable potential (including both load shed and generation) as a percentage of peak demand for callable load reduction for the high, medium, and low *load shed participation scenarios*. As this is the first introduction of a cumulative distribution function and a probability density function in this report, a short explanation of Figure 3 is warranted. Each line represents the probability (read from the leftmost vertical axis) that the achievable potential for callable load reduction will be lower than the value on the horizontal axis. For instance, there is a 90% chance the achievable potential as a percentage of peak demand would be lower than 8.6% (1,284 MW), 10% (1,493 MW), and 12.5% (1,874 MW) for the low, medium, and high scenarios, respectively. Likewise, there is a 10% chance the achievable potential as a percentage of peak demand would be less than 7.4% (1,089 MW), 8.6% (1,273 MW), and 10.9% (1,612 MW) for the low, medium, and high scenarios. The mean values for achievable potential are 8% (1,188 MW), 9.3% (1,384 MW), and 11.7% (1,746 MW) for the three scenarios, respectively.

Figure 1. Total Achievable Potential as a Percentage of Peak Demand

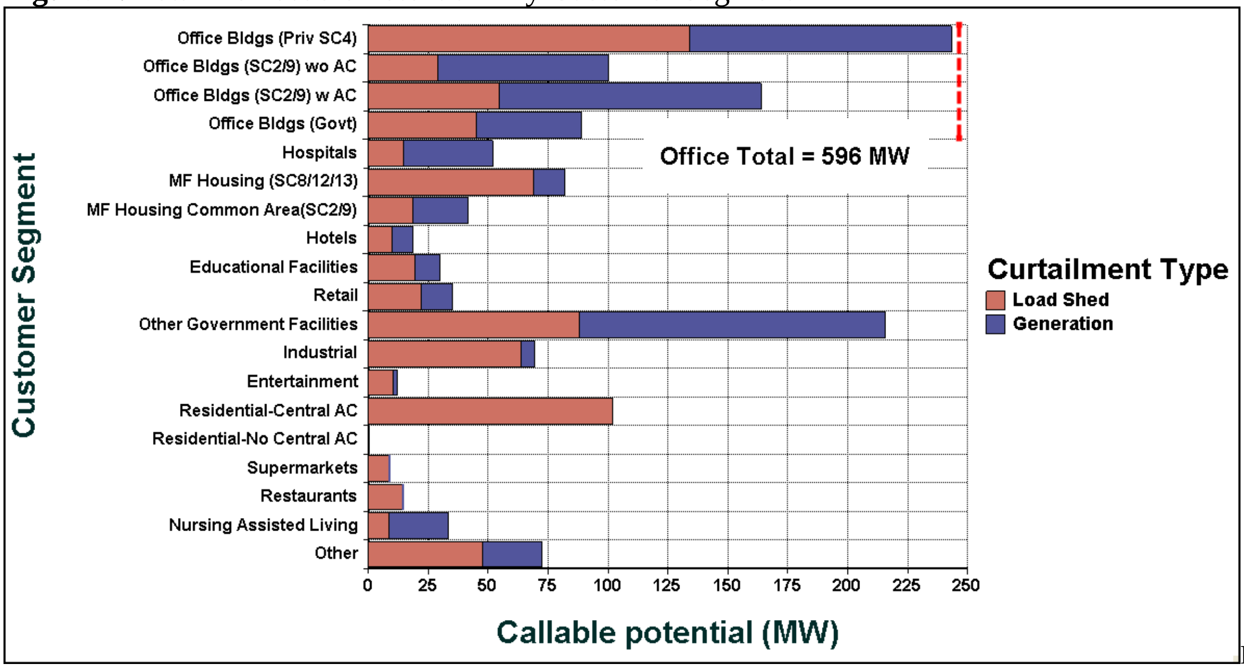


The remainder of this section breaks down the achievable potential for callable load reduction by customer segment and curtailment type (*i.e.*, by load shed[9] and emergency generation). For results presented in the section, all model values are held constant at the baseline (medium) values for clarity Additionally, although a probability distribution exists for each model output, only the mean values of the output of interest are reported in this section.

[9] Load shed refers explicitly to activities where electricity demand is reduced (via foregone electricity consumption), as opposed to reduction of electricity generation required at the utility due to use of distributed generation at the customer site.

The total achievable potential is again 1,384 MW for the baseline values of model input parameters.[10] As can be seen in Figure 2, office buildings provide the greatest opportunity for callable load reduction due to a large peak demand (resulting in a high load shed potential) combined with abundant emergency generation. A total of 596 MW of achievable potential, or 43% of the total achievable potential, is estimated for office buildings when the four office sub-segments are combined.

Figure 2. Total Achievable Potential - By Customer Segment



Note: *Customer segmentation by account.*

Other government facilities (*e.g.*, transit systems, public schools, wastewater treatment, correctional facilities) also provide abundant load reduction potential at an estimated 216 MW, again due largely due the high peak demand of this customer segment combined with substantial installed emergency generation resources. The residential sector (with central AC) provides the third largest potential with an estimated 102 MW of reduction through direct load control of central air conditioning. Office buildings, government facilities, and residential customers together comprise a total achievable potential of 914 MW, or 66% of the total achievable potential of 1,384 MW.

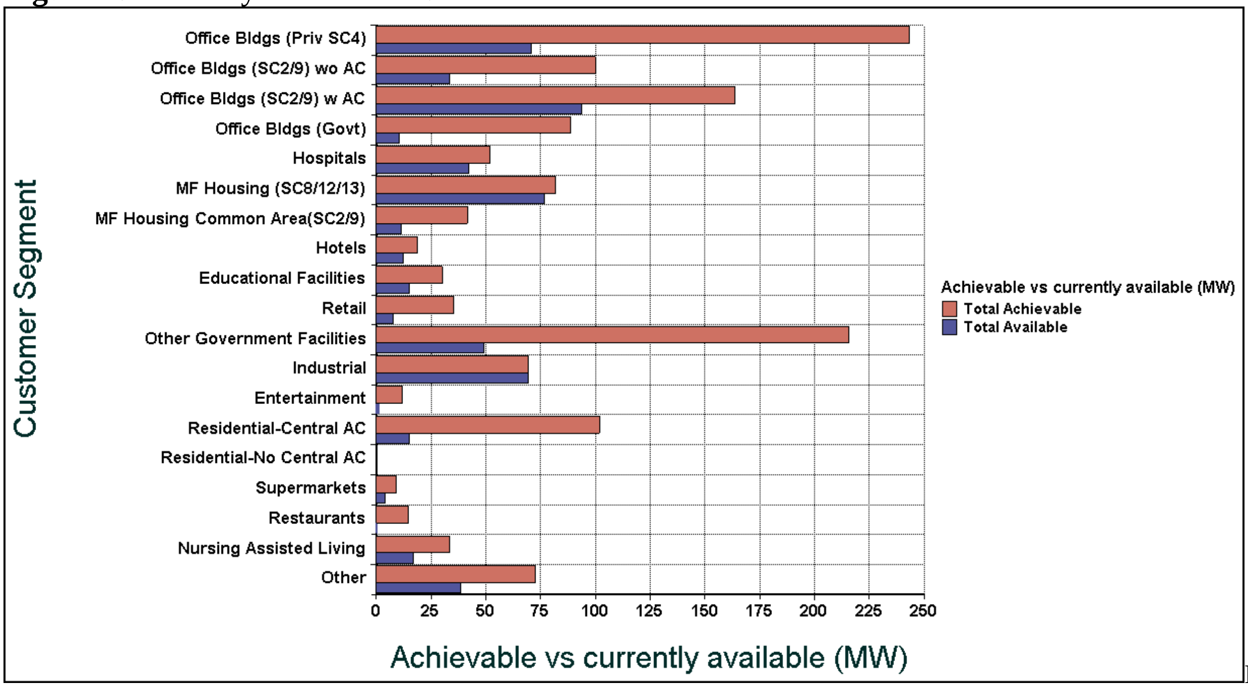
Gap Analysis

The gap analysis compares previously described estimates of *currently available* demand with *achievable potential* to better understand the gap between available demand response resources and the achievable potential estimated for 2017. It was noted above that *currently available* callable load reduction has been adjusted for both overlap in program enrollment and historical rates of curtailment during called events. Furthermore, unlike the potential curtailments estimated here, *the currently available reductions are not necessarily available at the time of system peak demand and therefore may over-estimate reductions that can be provided when needed most.* All estimates are mean values using baseline (medium scenario) model parameter assumptions.

[10] Load reduction values assume a forecast 2017 peak demand of 14,900 MW, which is net of savings from energy efficiency measures.

Figure 3 compares the currently available load reduction with achievable potential load reduction for each customer segment. Few customer segments appear to be near saturation, and most have significant unrealized potential for additional callable load capability. In particular, government facilities and residential (with central AC) customers are under-represented considering their large values for estimated achievable potential relative to current participation levels; and the office sector holds the greatest potential in terms of the megawatts of unrealized load curtailment potential. As discussed in above, available demand response resources are estimated to be 569 MW, whereas the achievable potential is estimated to be 1,384 MW, a difference of 815 MW.

Figure 3. Currently Available vs. Achievable Potential



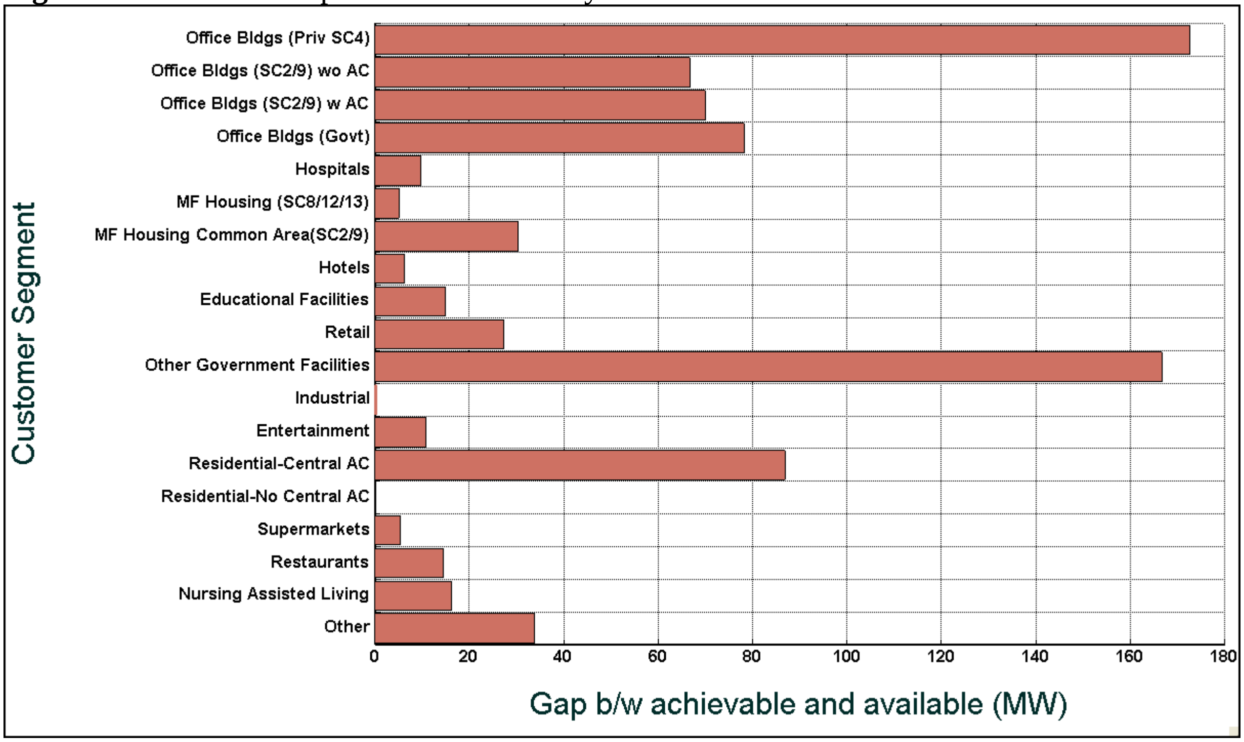
Note: *Customer segmentation by account; these potential estimates include curtailments from both load shed activities and use of emergency generation.*

Multi-family housing (SC8/12/13) appears to be near saturation, with currently available curtailments from multi-family accounts nearly as high as the estimated potential. The industrial sector also appears near saturation. The reasons for this may be the prevalence of smaller accounts and the fact that the coincidence factor for industrial facilities is among the lowest of all non-residential customer segments. Additionally, it should be considered that demand response programs have been offered in New York for nearly a decade and have been heavily marketed by aggregators whose core business is enrolling customers in DR programs. As of 2007, two-thirds of the 1,338 MW of ICAP enrollments were signed up through aggregators.[11]

The difference between the currently available load reduction and achievable potential is portrayed for each customer segment in Figure 4. As described above office buildings, government facilities, and residential customers together represent an *achievable* potential of 914 MW, or 66% of the total achievable potential of 1,384 MW. Similarly, these three segments represent the largest *gap* between currently available and achievable potential for callable load reduction, collectively accounting for 641 MW of the total gap of 815 MW (69% of the total gap).

[11] New York ISO. FERC Compliance Filing, Docket Nos. ER01-3001 and ER03-647, January 15, 2008.

Figure 4. Estimated "Gap" Between Currently Available Curtailments and Achievable Potential



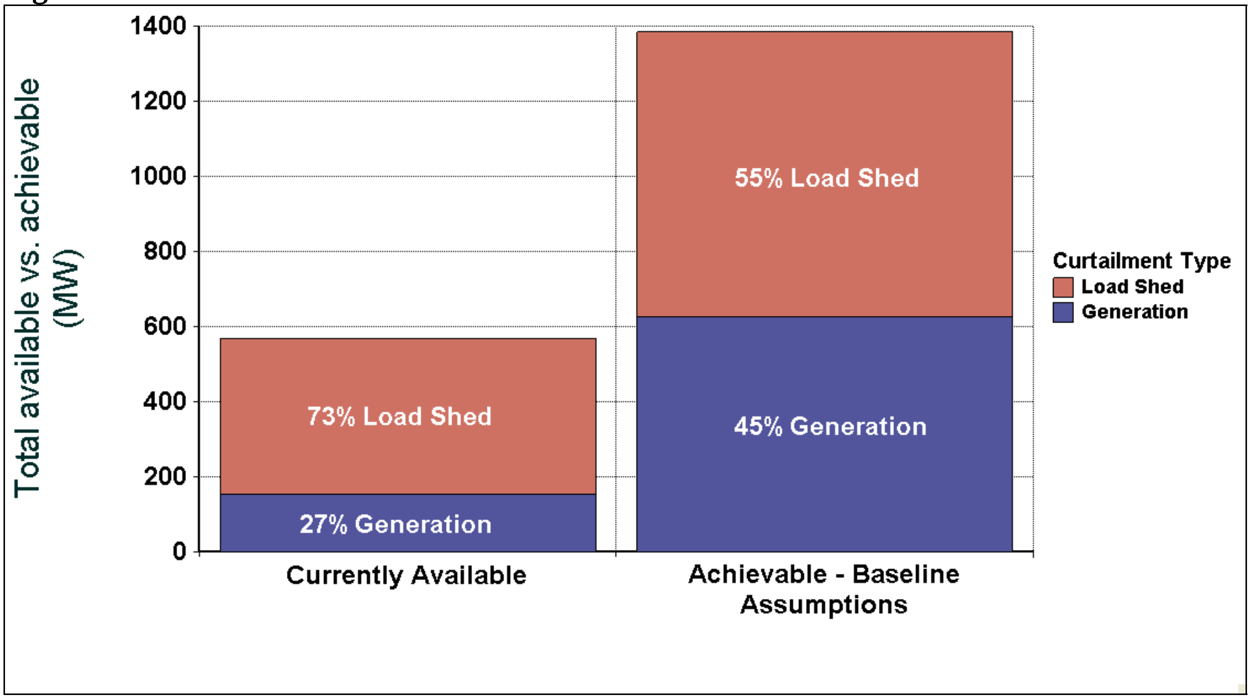
Contribution of Load Shed vs. Emergency Generation

The previous section compared the currently available and achievable potential load reduction by customer segment. This section focuses on the relative contributions of load shed and emergency generation to both currently available load reduction and achievable potential for load reduction. A significant shift in the relative contributions of these two different curtailment methods would be required if the achievable potential is to be realized.

As described above, an estimated 569 MW of callable load reduction is currently available for demand response. Of this 569 MW, an estimated 358 MW, or 73% of the total, is estimated to come from load shed activities, with the remaining amount coming from emergency generation.[12] As can be seen in Figure 5, the current 73% contribution from load shed drops to only 55% for future achievable potential, indicating increasing reliance on use of emergency generation as demand response resources are expanded (45% of total curtailment, up from 27% currently).

[12] The estimate of currently available callable load resources is derived from the breakdown of existing resources into DLRP, ICAP, EDRP, and DLC programs combined with the following estimates of the percentage of resources coming from emergency generation by program: EDRP - 32%, ICAP - 15 %, DLRP – 68%. EDRP and ICAP estimates of percentage generation are derived from NYISO data. The DLRP value of 68% from generation was derived by Nexant in its evaluation of Con Edison's DLRP program (see *DLRP Program Evaluation Final Report*, Nexant, Inc., February 26, 2008.).

Figure 5. Current vs. Achievable Breakdown - Load Shed and Generation



More specifically, load reduction through use of emergency generation would have to increase from the currently estimated 154 MW to 626 MW, an addition of roughly 472 MW (or 306%). In contrast, load reduction from load shed activities would increase from a currently estimated 415 MW to an estimated achievable potential of 758 MW, an 83% increase over the currently available load reduction through load shedding.

Conclusions

The DR potential analysis described above employed customized modeling techniques developed specifically for analyzing demand response programs. By contrast, "DSM potential" models, which address the potential for non-dispatchable energy efficiency, may not be well-suited for demand response. The modeling framework employed was based on Analytica® software that allows for the detailed calculations of complex spreadsheets while maintaining a high degree of transparency in inputs and calculations. Key inputs to the model include coincident peak loads, participation rates, curtailment rates, and ownership of onsite generation—each disaggregated by market segment and size.

Participation was estimated in discrete scenarios, based on rates that have been observed in New York and other markets. Curtailment rates were measured as a percentage of peak demand and were estimated stochastically based on the distribution of load curtailment estimates from published sources and other secondary research. This approach allowed for estimation of base case, low, and high scenarios of DR potential, each of which can be presented as a probabilistic distribution.

Results of the base case DR potential modeling suggest that callable load programs could provide nearly 1,400 MW of load curtailments by 2017 or more than 9% of the forecast peak demand. The 90% probability band covers a range between approximately 1,250 MW and 1,500 MW. More than 90% of the base case curtailments are expected to be provided by non-residential customers, owing to the prevalence of residential high-rise apartment buildings with window/wall air conditioning units that are not easily controlled through cycling. Due to the density of commercial buildings equipped with energy management systems, office buildings alone account for 43% of the potential, much of it capable of short-notice response that could provide added value and perhaps even ancillary services.

Total DR resources available in 2017 are estimated to be more than double the amount of load curtailment achievable in 2007, after accounting for the fact that much of the currently enrolled capacity is represented by “voluntary” commitments that often prove not to be available, as opposed to firm obligations. The increase in DR capability is expected to be provided in nearly equal amounts by load shedding and use of onsite generation.

The study resulting from this work was submitted to the New York Public Service Commission and represents a significant advance in estimation of the potential for callable load reductions to meet utilities’ long-term resource needs. Through processes such as the one described above, utilities can better understand the magnitude of load reductions that DR programs are capable of providing in their service territories, and they can more accurately assess requirements for new generation and other supply alternatives. Moreover, utilities and their load curtailment providers can use this type of analysis to better target marketing efforts, thereby increasing their return on investment in demand response activities.