Chapter 5 - Implicit Price Elasticities of Demand for Electricity and Performance Results

Overview

A comprehensive evaluation of NYISO's PRL programs would be inadequate without characterizing how well customers performed during PRL events. To accomplish this, we developed and estimated three alternative measures of performance for EDRP.[1] All the measures utilize customer's measured load reduction – the difference between their metered usage and CBL during event hours – as the basis for comparison.[2] The implicit price elasticity measures that load change relative to the prices the customer faces, evoking the usual interpretation of price elasticity. This metric is useful for extrapolating the performance to situations where the inducements to shift are different than what the current programs offer. This year's results are compared to those of last year to provide insight into how performance is changing as the Emergency Demand Response Program (EDRP) grows and matures.

Two additional performance indices, the Subscribed Performance Index (SPI) and the Peak Performance Index (PPI), are developed to provide a metric for comparing customer performance relative to what they said they could do when they subscribed, and relative to their peak usage level, respectively. These metrics allow comparisons of the curtailment yield between customers and among aggregations of customers. Yield is important to system operators that need to estimate the impact of dispatching PRL resources and to program marketers that, facing customer acquisition costs, desire to estimate the profitability of recruiting different customer segments and types.

The Chapter is organized as follows. First, we describe the three measures developed to measure curtailment performance. Then, we discuss the implicit demand elasticities, which are provided on an event, customer, and zonal basis. To help NYSERDA measure its contribution to the PRL program, the elasticities values of customers that received PON funding are compared to

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[1] Due to low bidding activity and the lack of sufficient participant-specific usage data, the measures discusses were not applied to DADRP.

[2] The CBL represents the customer's deemed usage, what it would have consumed during event hours if the event had not been called. The CBL is the average usage during the event hour in the five highest of the previous (to the event day) ten days, excluding any event days.

those of the other EDRP participants. The discussion of performance then turns to the results of the SPI and PPI analyses.

Methods

Implicit Demand Elasticities

The neoclassical theory of the firm is based on the assumption that firms allocate factors of production in such a way as to achieve the profit maximizing output for the firm, given a prevailing set of input and output prices. Implicit in this theory is also the assumption that, for a given set of input prices, factors are allocated by firms in such a way as to produce the appropriate profit maximizing level of output at minimum cost (Ferguson, 1969).

It can be further established that the demand curve for any input or factor of production in the short run is the value of the marginal product (VMP) schedule for that factor. Each value on the VMP schedule represents the marginal product of the input (the additional output that can be produced with an additional unit of an input, all else constant) *multiplied* by the price of the output. This places a dollar value on the additional output produced by the extra unit of input. Thus, the VMP schedule indicates the value to the firm of marginal additions to or subtractions from any given input level.

To summarize, by using an input up to the point that its value in production (e.g., the value of the marginal product) is equal to the price of the input, the firm's profit is maximized. Because of the law of diminishing marginal productivity, if the firm uses fewer than the profit maximizing level of input units, some profit is forgone because the value of the additional output from using the additional unit of input is above the cost of the input. On the other hand, if inputs in excess of the profit-maximizing level are used, the value of the additional output forthcoming from the last unit of the input is below the price of the factor, and profit falls. Profit would be higher by not using this last unit of input. Knowing the demand curve for the firm's inputs provides the means for ascertaining the optimal level of input use. The demand curve also provides the means for ascertaining how input levels would change from any given level as input prices change. These fundamentals provide the basis for measuring how customers respond to changes in electricity prices, and a means for measuring relative price responsiveness.

Simple representations of two separate demand curves (VMP_E) for electricity are shown in Fig. 5-1. Assume that one of these curves characterizes the demand for electricity as viewed by a firm participating in NYISO's DADRP. This curve is labeled $VMP_{E|DADRP}$, and it represents the amounts of electricity that will be demanded at various prices in real time as long as the price the firm is charged (or is paid to curtail load) is known a day in advance. The other demand curve (labeled $VMP_{E|EDRP}$) is assumed to be the demand curve for electricity by the same firm in real time, for prices that are not known until real time. This second demand curve reflects the situation of a firm participating in EDRP. In both cases, as the price of electricity rises, the demand for electricity will fall.[3]

The significant difference in the two curves is that the one corresponding to the demand in real time under EDRP is steeper than the one for the day-ahead market. The reason for the difference is that if a firm is participating in DADRP, it has 24 hours to make necessary adjustments to minimize the effect of a reduction in electricity usage. In the case of EDRP, the customer is informed only two or so hours before it must reduce electricity usage; the firm has less time to make adjustments that can minimize the effect on the firm's production, and generally is less capable of altering its economic activity. Unfortunately, insufficient data are available on DADRP participant usage to estimate the underlying demand curve, so we are not able to compare the performance differences implied in the Figure.

In the customer representation of electricity demand depicted in Fig. 5-1, we assume that the firm plans to consume electricity at the level represented by the CBL and at its current rate of P_B. This rate could be a flat $/kWh charge, it could involve demand and energy charges, or it could be comprised of peak and off-peak TOU-type pricing. But, what level would it operate at if an EDRP event were called and it were offered $500/MWH to reduce load?

Given the profit maximizing argument introduced above, if the firm is going to participate in a PRL program and provide load reduction (represented in Fig. 5-1 as the change in usage from CBL to L_R) the firm would respond along the steeper curve $VMP_{E|EDRP}$. This load reduction would only be forthcoming at a payment level of P_E, which, as illustrated in Fig. 5-1, is substantially higher than P_D. What causes these differences in how customers respond to prices, and how can price responsiveness be measured?

In more precise economic terms, the elasticity of factor demand is defined formally as the percentage change in demand for a factor when the price of the factor is changed by one percent.

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[3] In this analysis, we assume that customers face a predetermined price schedule or rate and that, on occasion, that rate is supplemented with DADRP or EDRP curtailment prices that are several times higher.

In practical terms, the elasticity of demand is calculated as the percentage change in demand for a factor divided by the percentage change in the price of that factor. This elasticity, as with all demand elasticities, is expected to be negative – for as the price of the factor increases, demand for that factor will decrease.

These elasticities of demand can be calculated from program participant data during EDRP program events.[4] Although they are consistent with the performance data, we refer to them as arc or implicit elasticities because they are calculated as the simple algebraic differences in usage that are put in percentage terms by dividing by the beginning CBLs and baseline rates. The estimates are not based on a systematic econometric modeling of repetitive behavior due to price differences for programs in which customers have participated for some extended period of time. Because implicit elasticities are calculated from only a few observations, and because the formulation does not take into account other factors that influence price responsiveness, they are generally regarded as representing only local behavior. In other words, they reflect changes that are associated with price changes very close to those upon which they were calculated. In this case, it means that the elasticities are likely to be accurate for EDRP prices that are close to $500. But, for prices that vary substantially from that level, for example a price of $100/MWh or $1,000/MWh, they may either over- or under-estimate the quantity change. Despite these cautions, the empirical estimates reported below are consistent with more formal analyses conducted elsewhere, and on this basis, the results are very encouraging.[5]

To estimate this elasticity from EDRP performance data, we define the following terms:

CBL = the customer baseline load (the level of load the participant would otherwise consume under its standard tariff rate or its supply contract);

P_B = the participant's standard or contract rate;

P_E = the payment rate received by the participant for load curtailment in EDRP;

P_D = the payment rate received by the participant for a DADRP bid; and

L_R = the load served during the load reduction EDRP event.

CBL - L_R = the load reduction provided in response to EDRP or DADRP payment.

[4] In the discussion that follows, elasticity and factor elasticity are used interchangeably.

The firm's elasticities of demand for electricity under EDRP, corresponding to the factor demand illustrated in Figure 5-1, is now defined as:

(1) $E_{(EDRP)} = \{[(L_R - CBL) / CBL] \div [(P_E - P_B) / P_B]\}$

The data required to estimate this elasticity for each participant are the measured load during the event, the event CBL, and the EDRP curtailment payment level, all of which are available from the NYISO program database. In addition, we need to specify the rate each customer would otherwise have paid for load consumed during the event, which we refer to as the background rate. Because most EDRP participants are served under a default provider (regulated LSE) tariff, we used utility tariff rates to develop an average cost of electricity value for customer types that reflected the size differences characteristic of these rates. Because in many cases the average rate is very sensitive to the underlying load shape, due to demand ratchets and other non-linearities in the rate schedule, the elasticities are likely underestimated.

Performance Metrics: SPI and PPI

An alternative characterization of participants' performance focuses on their actual load reductions delivered during emergency events compared to their subscribed load reduction and non-coincident peak demand, absent any adjustment for relative prices. For this analysis, we define two performance indices, called the Subscribed Performance Index (SPI) and Peak Performance Index (PPI), that can be used to characterize and compare program participants' actual response and technical potential to respond to ISO system emergency events.[6]

The Subscribed Performance Index (SPI) is the ratio of load reduction delivered versus load reduction subscribed. It can be interpreted as a measure that expresses how well a customer or a portfolio of customers performed compared to their pledges, how reliable is their pledge to curtail. This measure is of interest to ISO operators as a way to gauge the reliability of this dispatchable resource based solely its subscription pledge, before actual performance is observed.

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[5] See for example, Herriges, *et al*., 1993; Caves and Christensen, 1980 and Long, *et al*., 2000; Braithwait, 2000; and Patrick, 1990).

[6] Technical potential in this discussion refers to the physical aspect of a participant's ability to curtail load, regardless of the economics of doing so.

We define the Subscribed Performance Index (SPI) in two ways to provide alternative perspectives on the reliability of EDRP resources. One index applies to individual customers, and the other to a portfolio of customers.

<u>The customer-specific subscribed performance index, SPI_c:</u>

(2) $SPI_c = (E_{avg} / E_{sub}) \cdot 100\%$,

where

(3) $E_{avg} = \frac{1}{N}\sum_{t=1}^{N}(CBL_t - E_{actual,t})$

and

N = the number of hours per curtailment event,

$E_{actual,\,t}$ = the facility electric energy in hour t [MWh],

CBL_t = the customer baseline in hour t [MWh], and

E_{sub} = the subscribed load curtailment as provided for each participating customer by NYISO. It is nominated in electric capacity units (MW) delivered for each hour of the curtailment period. Thus, the resulting quantity is an energy measure expressed in MWh.

<u>The subscribed performance index for a portfolio of customers, SPI_p:</u>

(4) $SPI_p = (E_d / E_s) \cdot 100\%$,

where

(5) $E_d = \sum_{i=1}^{M}\left(\sum_{t=1}^{N}(CBL_{i,t} - E_{i,t})\right)$,

(6) $E_s = N \cdot \sum_{i=1}^{M}(E_{sub,i})$,

and

E_d = the total electric energy curtailment <u>delivered</u> by all customers in a program,

E_s = the total electric energy curtailment <u>subscribed</u> by all customers in a program,

CBL_t = the customer baseline of customer i in hour t [MWh],

$E_{i,\,t}$ = the electric energy of customer i in hour t [MWh],

M = the total number of customers in a program,

N = the number of hours per curtailment event, and

$E_{sub,i}$ = the subscribed load curtailment of customer i [MWh].

The SPI is analogous in some sense to the capacity factor assigned to generation, which represents its electric output relative to its design potential. However, unlike generation units that can be expected to perform close to their nameplate rating, customer estimates of their ability to curtail under program circumstances are likely to be somewhat speculative, especially for new participants.

The second performance measure is the Peak Performance Index (PPI), defined as the customer-specific ratio of their average delivered load reduction divided by their non-coincident peak demand. We formally define PPI as:

(7) $PPI = P_{avg} / P_{peak}$,

where

(8) $P_{avg} = \frac{1}{N}\sum_{t=1}^{N}(CBL_t - P_{actual,t})$

and

N = the number of hours per curtailment event,

$P_{actual,\,t}$ = the facility load in hour t [MW],

CBL_t = the customer baseline in hour t [MW], and

P_{peak} = the non-coincident facility peak demand [MW].

The PPI is a useful measure for characterizing the relative technical potential of a customer or a group of customers because its upper value of 1.0 equates to a virtually full shut down. The non-coincident peak represents the customer's highest usage level. Thus, in any event, it can never curtail more than that amount and the PPI is bound from above by a value of 1.0. The SPI is not so constrained. For example, a customer with a PPI of 1.0 indicates that it shed 100% of its facility peak demand during the curtailment period. The PPI can be utilized for identifying barriers and/or additional resource potentials. Market segments with low PPI (e.g., 5%) imply that these customers currently have few load curtailment opportunities and could potentially be targeted for additional technical assistance, education/information, or deployment of more advanced enabling technologies, etc. PPI values, combined with customer size, also provide insights into relative load curtailment potential of acquiring different types of customers.

Because the performance data as provided by the NYISO were expressed in hourly MWh terms, we substituted the power units in the PPI definition above with hourly energy units.

Furthermore, P_{peak} was determined using the maximum hourly CBL load as a proxy for the non-coincident facility peak demand, because customer load profiles were not available.[7]

Implicit Demand Elasticities Results

Using the algebraic form of equation (1), implicit demand elasticities can be calculated for participants using the NYISO EDRP program data that include the CBL, the load reduction, and the price paid for curtailments.[8] We estimated elasticities for those EDRP participants that indicated that they intend to respond to curtailment calls by reducing their usage; we excluded firms whose registration indicated that they intended to use on site generation to achieve a curtailment. With the limited data available, it was not possible to disentangle the separate influences underlying curtailments from those participants offering both to reduce usage and to operate on-site generation. For this reason, our analysis is limited to only a subset (906) of the total 1,711 participants in EDRP (Table 1-18, Chapter 1).

To calculate the implicit elasticities for individual load-curtailing EDRP participants, background electricity rates were derived from published rate schedules.[9] To protect the confidentiality of customers, we do not report elasticities for individual PRL participants. Instead, we provide the range in firm-level elasticities as well as the average elasticities across firms by pricing zone.

Calculated Implicit Demand Elasticities for Electricity

The average estimated implicit factor demand elasticities for 906 EDRP participants that curtailed load, by NYISO pricing zone, are given in Table 5-1, along with the load, CBL and load reduction data that went into their calculations. The curtailment data are for EDRP events called

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[7] Given that system events occurred on two hot summer days (July 30 and August 14), using CBL as a proxy for non-coincident facility peak demand is reasonably accurate for weather-dependent building loads, and somewhat more questionable for businesses whose loads are less weather-dependent (e.g., manufacturing, industrial facilities).

[8] In this analysis, we assumed participants were paid the full amount that the NYISO paid out. In many cases, participants likely received less than this amount as a result of sharing arrangements with their LSE/CSP broker. There was no way to ascertain what these arrangements might have been. But, lowering the price they receive would lower their response, and consequently the elasticity estimates we calculate here would be too high.

[9] Background rates were derived for each LSE and were assigned to all PRL participants located in that LSE's territory. Such rates were derived assuming a 500 kW demand and 60% load factor usage profile for a summer month.

on July 30 and August 14, which included the hours of 1:00 to 6:00 p.m. on both days.[10] The elasticity estimates are based on the minimum price guarantee of $500/MW for the EDRP program for the summer of 2002.[11]

The average zonal elasticities in Table 5-1 and the zonal elasticity ranges and standard deviations in Table 5-2 are based on the percentage reductions in load that are calculated as the difference between the customer's total load over all hours of all event days and its total CBL over all event hours of all event days. This strategy assumes that for event days that are reasonably close together, customers would respond in a similar fashion. This seemed an appropriate assumption after examining the data.

During the EDRP event hours, the EDRP participants included in this analysis consumed a total of 5,941 MWH of electricity, and their corresponding combined CBL was 8,978 MWH (Table 5-1). Thus, the total load relief for these customers was 3,037 MWH over the two event days. This amounts to a 33.8% reduction in the average typical usage, as measured by the difference between the participant's hourly CBL and its actual event usage, in response to the EDRP curtailment call. This is two percentage points higher than the value calculated for participants in the 2001 events (Neenan Associates 2002). By zone, these reductions ranged from a low of about 9.6% in zone G to a high of 58% in zone A.

Relative to the customers' base electricity rates, the *average* calculated price elasticities of demand by customers in the various NYISO pricing zones ranged from a low of - 0.02 in zone G, to a high (in absolute value) of - 0.16 in zone H (Table 5-1).[12] This range begins at a slightly higher level than for the analysis in 2001, and the top end is slightly higher as well. However, the overall average is, -0.03 (Table 5-1), considerably lower than the –0.09 average from 2001 (see Neenan Associates 2002, Table 2-1). One compelling explanation for this result is that the customers finding the most value in EDRP last year probably enrolled in 2002, and perhaps performed slightly higher. Whereas the new participants in 2002 are predominantly customers

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[10] Elasticities were also estimates for two event days in April 2002. Due to low participation in these early-season events, we report the results separately in the Appendix.

[11] Even though customers in some event hours were paid LBMPs above the $500 price guarantee, these prices were not known at the time of curtailment. Therefore, we assumed that the price on which these load reductions were based is the minimum price guarantee.

[12] The elasticity is expected to be negative in sign because load and price should move in opposite directions. ,

with somewhat more limited capacity to respond. This is particularly likely for the several hundred small commercial and residential customers enrolled by LIPA, which comprised a large portion of the overall enrollment increase.

Despite this difference between the two years, these elasticities are still consistent with response elasticities found in more formal price response studies of customers participating in real-time and TOU pricing programs. Moreover, there is substantial variation in these elasticities about the mean (Table 5-2). Some individual participants' implied response elasticities are as large as - 0.47, while several are in the neighborhood of - 0.23. This firm-level variation reflects differences in the ability and willingness of customers to respond on certain days.

For the 23% of customers exhibiting small positive price elasticities (up from the 11% of 2001) on average (Fig. 5-3, first bar), the implication is that usage was on average above the CBL during the events. These customers either found it impossible to curtail load, or in attempting to comply they misjudged their CBL, and usage inadvertently remained above the CBL in the aggregate, even though they may have actually curtailed some electricity usage in response to the call.[13] Again, the large number of smaller, new entrants accounts for the reduction in the overall portfolio performance. This is to be expected as program enrollment reaches out into new customer segments that offer lower curtailment levels, but add valuable diversity.

The estimated implicit elasticities of response varied considerably by the size of a firm's average electricity usage (Fig. 5-4). Because of the large number of LIPA customers this year, the majority of the participants in EDRP had loads below 250kW. Most customers also exhibited low (elasticities greater in algebraic value than - 0.05) to modest (elasticities between – 0.05 and – 0.20) price response.

Although participants with low elasticities dominate all size classes, as electricity consumption levels increase, so did the percentage of participants in that size category with moderate to high elasticities of response (elasticities between – 0.05 and – 0.20 and greater than - 0.20, respectively). This observation is consistent with the belief by some that larger customers have better knowledge of their load shapes, and are thus better able to respond during curtailment

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[13] The CBL is derived from average usage on previous, no EDRP event days. To the extent that the CBL is not representative of what customers would have actual used, because of weather or other effects, then customers may have found that curtailing was not profitable because they would not receive full credit for the actions they undertook. Moreover, there is no penalty for noncompliance, so some customers may have sighed up speculatively, only to find that they could not curtail when an EDRP event were called.

opportunities. The results also show that firms with an average hourly load under one MW generally did not appear to be as responsive as their larger counterparts. These smaller customers may be inherently less capable of curtailing usage under EDRP terms, or they may simply need more education concerning their load shape and assistance on load management strategies to become more effective in reducing load during EDRP events.

Conventional wisdom would also suggest that the performance of EDRP load reduction resources would drop off substantially toward the end of emergency events, especially if the events last for several hours each day and are called over a number of consecutive days as well. Conversely, for those participants with on-site generation, one might also expect that this "fatigue factor" would be minimal, or perhaps non-existent, given these customers' abilities to simply turn on a generator at the event start time and leave it on for the event's entire duration. In contrast to this conventional wisdom, however, it appears that most EDRP participants without on-site generation are more reliable in their load curtailment contribution once they committed to the EDRP event (Fig. 5-5).[14] Although there is some decrease in the overall curtailment level of load reduction resources as each event day progressed, for the most part, load-curtailing participants were able to sustain their load reduction efforts throughout these 5-hour events. Load relief was substantially above the mean in hour 15 on the second day (August 14), which is due to participation of a large resource aggregation for only one-hour. Thus, after taking this into account, load reductions were quite consistent across all hours on the two days, although curtailments on August 14 got off to a slower start than they did on July 31.

Demand Elasticities for NYSERDA vs. Non-NYSERDA Participants

Among summer 2002 EDRP participants, 102 (11%) of the 906 customers for which we estimated elasticities also received funding and completed projects through NYSERDA PONs offered in 2001 and 2002.[15] These NYSERDA programs offered financial assistance to firms for the purchase of load reduction or load shifting technology and/or metering and communications equipment that could have affected customers' decisions to participate in EDRP and increased the amount of load reduction offered during curtailment events.

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[14] This persistence was even more remarkable last year because the events were scheduled on four consecutive days.

[15] NYSERDA provides funding to support customer participation on PRL programs through Program Opportunity Notices (PONs). See Chapter 7 for a description of these programs.

NYSERDA is interested in the performance of this subset of customers relative to the population of participants. To provide this comparison, we have prepared tables that break out elasticity estimates for two subgroups of customers: 2002 EDRP participants in a NYSERDA program (Tables 5-3 and 5-4), and 2002 EDRP participants that did not participate in a NYSERDA program (Tables 5-5 and 5-6).

The average price elasticity of demand for customers in the NYSERDA subgroup is - 0.07 (Table 5-3), over twice as high as the level for other participants, - 0.03 (Table 5-5). The distributions of these implicit elasticities for each subgroup are displayed in Figs. 5-6 and 5-7, respectively. At the zonal level, these average response elasticities ranged from zero in zones K and G to – 0.16 and – 0.17 in zones H and I, respectively, for the NYSERDA participants (Table 5-3). The individual firm elasticities ranged from – 0.47 in zone J to 0.05 (load actually went up during events) in zone A (Table 5-4). For the non-NYSERDA participants, the zonal averages range from a positive 0.13 in zone F to - 0.12 in zone D (Table 5-5). The individual firm elasticities for this sub-group range from – 0.47 in zone J to 2.67 in zone F (Table 5-6). Based on these results, NYSERDA is in fact achieving its goals of improving the performance of the PRL portfolio.

SPI and PPI Results

SPI for NYSERDA vs. Non-NYSERDA Participants

At the time they enrolled in EDRP, customers were asked to provide an indication of the amount of load reduction they anticipated being able to supply during an EDRP event. The program required that they be able to curtail at least 100 kW.[16] In Figs. 5-8 (Daily) and 5-9 (Zonal), we provide comparisons of these initial "subscribed load reduction capacities" to customers' actual average curtailment performance, aggregated over the entire portfolio of customers (SPI_p). The ratio of average actual and subscribed performance (SPI_p) was very consistent, 44.5% on the August 14 and 44.8% on July 30.

As described above, two SPI performance measures were developed. The aggregate index characterizes the EDRP resources as a collective resource, and as such represents an average characterization of performance. The customer SPI index preserves the individuality of

[16] Customers were allowed to aggregate their load(s) with others and subscribe as a single entity to meet this requirement.

performance, and therefore betters characterizes the dispersion of performance among participants.

The aggregate performance of the portfolio of NYSERDA participants, relative to their initial subscription levels, is higher than for the portfolio of other participants. Over the two event days, NYSERDA's participants delivered an average of 53% of their initial indicated subscription amount, and exhibited very low variability, with values ranging from 50.1% to 54.7% of subscription amounts over the two days. This performance was well above the 45% for the non-NYSERDA subgroup. One explanation for this result is that NYSERDA funding provided for greater attention to up-front curtailment capacity auditing, so these customers better understood what they could deliver by way of load curtailments when they registered for EDRP.

In Fig. 5-9, we provide comparisons of these initial "subscribed load reduction capacities" to customers' actual average curtailment performance, aggregated by zones. In some zones participants in NYSERDA programs outperformed the others, while in some zones the reverse was true. Only in zones B, and G did the non-NYSERDA customers significantly "outperform" those who had participated in a NYSERDA 2002 PON.[17] One would clearly have to know more about which NYSERDA programs were implemented in the various zones and the types of customers to explain these zonal differences. Moreover, the character of the participants may also account for the difference, in that the non-NYSERDA customers in those zones may have had more prior experience with load management, or be better endowed naturally to curtail under EDRP provisions.

Fig. 5-10 compares the individual performance of NYSERDA and non-NYSERDA customers by curtailment strategy (i.e., load reduction only vs. on-site generation). On average, NYSERDA participants that relied on load reduction strategies as their curtailment choice significantly outperformed the non-NYSERDA participants, as indicated by the SPI_c of 73% for participants vs. 42% for others. NYSERDA participants who relied on on-site generation to reduce their load did not perform as well as non-NYSERDA participants (SPI_c of 58% vs. 41%). Note that many of the NYSERDA projects were only recently completed, which may have contributed to a lack of readiness to participate during the summer 2002 NYISO system emergency events. However, the specific reasons for the lower SPI_c performance of NYSERDA

[17] There are no NYSERDA participants in zone K.

vs. non-NYSERDA participants using onsite generation are difficult to ascertain and would require individual interviews with the customers.

Customer Performance by Market Segment

We were also interested in understanding customer performance by market segment and type of business activity. Based on SIC code information, we grouped customers into various business types and, using SPI_c values calculated for individual customers, reported the average SPI_c values, total subscribed load reduction for active participants, and total subscribed load reductions for all participants, segmented by type of businesses and load curtailment strategy (Fig. 5-11). For each group of participants corresponding to a particular load curtailment strategy and business type, we report average SPI_c values only if we had actual performance data for at least five customers in that group. In general, the information in Fig. 5-11 can help NYSERDA program managers target technical assistance, incentives, and/or information to sectors where actual performance lags behind subscribed goals. It also provides insights to NYISO system operators on the likely responses of different types of customers and businesses to system emergencies.

The important specific findings resulting from this analysis are as follows:

- Government and health facilities that utilized on-site generation to curtail loads had average SPI_c values in the 60-80% range. In contrast, the average SPI_c values were more variable among business types that only relied on load reduction strategies. For example, the average SPI_c value was ~65% among manufacturing customers, which comprise the largest single market segment (502 MW of subscribed load reductions among performing customers) of the population of participants. Based on customer survey data, many manufacturing customers shut down entire processes or specific equipment for the duration of an emergency event and resume production at night or the next day. These manufacturing customers tend to be sophisticated energy users with knowledge of their equipment and process loads, which may explain the higher performance values.
- Facilities owned by government agencies and various types of utilities (e.g., telecommunications, water) that actively participated in EDRP events provided a significant contribution of about 90 MW of subscribed load reduction and performed at a relatively high level, with an average SPI_c of 80%. These facilities often have on-site energy managers and well-developed load curtailment plans that explicitly involve

employees, have been involved with demand-side programs for several years, and some have a tradition of participating and providing "voluntary" load reductions during system emergencies.

- Office buildings, recreational facilities and casinos, and educational institutions curtailed load above their subscription targets (i.e., average SPI_c >100%), which suggests that these facilities have greater curtailment capability than they foresee, and in fact represent a value pocket of EDRP resources. However, this result should be interpreted with caution because of small sample size.
- Many educational facilities did not perform at all (e.g. 30 MW total subscribed but only 9 MW subscribed from active customers), although those relatively few facilities that were active in the program performed quite well (SPI_c = 108%).
- Multi-family apartments and health care facilities had average SPI_c values in the 25-40% range and were relatively poor performers. Multi-family apartments generally lack diversity in their load management strategies, with reliance on thermostat reset option or shutting off lights, which are heavily dependent on occupant behavior and difficult to predict. Hospitals and other health care facilities are limited in their load reduction strategies without the support of backup generation. Maintaining clean and comfortable indoor air conditions for health care patients and occupants is of utmost importance and generally cannot be compromised, which may leave relatively few options to curtail loads in order to meet subscription levels. Thus, limited by stringent thermal comfort constraints, health facilities have limited load reduction opportunities aside from on-site generation, which is the dominant curtailment strategy in that sector (8.6 MW of generation vs. 3.1 MW of load reduction).

We also examined average performance of customers of different business types compared to their technical potential (i.e., the Peak Performance Index; see Fig. 5-12). On average, government and unclassified facilities that relied on on-site generation strategies reduced their load by about 50-55%, relative to their CBL. In health care facilities, back-up generation systems were smaller compared to facility load, on average, or were used much more sparingly by these customers, indicated by an average PPI of ~15%. Customers curtailing load in certain types of businesses, such as government/utility facilities, manufacturing, recreational facilities/casinos, and commercial offices, also achieved relatively high PPI values in the 30-40% range. This performance goes against the conventional wisdom that only manufacturing firms are willing to curtail a substantial portion of their electricity usage on short notice. However, for some types of businesses, such as commercial offices and recreational facilities, sample sizes are small; thus results should be interpreted with caution. On average, educational facilities that performed reduced loads by about 20%, while health care facilities reduced usage by less than 10%, compared to their CBL during curtailment events.

Impact of ICAP-SCR Participation on EDRP Performance

Customers in EDRP also have the option of enrolling in the ICAP/SCR program. EDRP/ICAP-SCR participants receive the market value of ICAP but face penalties for non- or under-performance that can exceed the up-front payment. In order to examine the impact of program choice and load reduction strategy on curtailment performance, we grouped customers into EDRP-only participants and EDRP/ICAP-SCR participants and then segmented them by their load reduction strategy (Fig. 5-13). On average, EDRP/ICAP customers had SPI_c values in the ~90-95% range for both load reduction only and on-site generation strategies during the summer 2002 events. These results suggest that EDRP/ICAP customers, irrespective of load reduction strategy, are reliable performers in terms of meeting their subscribed EDRP targets.[18]

On average, EDRP-only customers that utilized load reduction only or onsite generation had SPI_c values of 49% and 41%, respectively, which provides a good overall indicator of actual performance in a voluntary program with no penalties. It is worth noting that even though joint enrollment in EDRP/ICAP is much lower than EDRP only (113 vs. 1105 customers with performance data), the subscribed load reductions among performers are comparable (455 MW vs. 429 MW). On average, joint EDRP/ICAP-SCR customers subscribed individually about 10 times the load curtailment than did customers who subscribed to EDRP only (4 MW vs. 0.4 MW), which suggests that the ICAP program attracts larger customers.

EDRP Resource Performance Curve

Fig. 5-14 provides some insight into the overall distribution of individual customers' SPI_c performance across the resource base comprised of all EDRP participants. In this figure, we include only those customers that reported any load reduction in at least one hour during the July

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[18] Because performance is measured on different metrics, an SPI of less than 100% does not indicate noncompliance with the ICAP/SCR curtailment obligation.

and August events. This adjustment gives a total resource base of 878 MW for active program participants compared to the total subscribed load enrolled in EDRP of 1477 MW.

About 211 MW (24%) of subscribed load performed at or above their subscribed load curtailment pledge (SPI_c >100%). These customers underestimated their curtailment capabilities or were overly cautious in determining their subscribed load reduction target. The remaining 76% of the EDRP resources (667 MW) performed at or below their pledged curtailment levels. By adjusting the subscribed curtailment with the customer's SPI_c performance, we can estimate the full-performance resource equivalents to be about 564 MW. This corresponds to a de-rating factor of 0.64 (564/878 MW=0.64).

EDRP Resource Potential Curve

We also created an EDRP resource potential curve following an approach similar to that used to develop the EDRP resource performance curve (Fig. 5-15). This curve describes the relationship of individual customers' PPI to their subscribed load and characterizes the relative ability of the active EDRP participant pool to curtail load on the electric system (i.e., PPI of 1.0). We aggregated the cumulative load reduction achieved by customers that pursued various load curtailment strategies (load reduction only, onsite generation, or load reduction plus onsite generation), along with the total resource potential curve, for active EDRP participants.

The subscribed load of active EDRP participants was 878 MW. About 42% (365 MW) of that subscribed load reduced their load by 80% or more (PPI > 80%) during the two event days. About 300 MW of the 365 MW load reduction from these customers was achieved by those employing load reduction strategies alone, which we believe was primarily attributable to manufacturing companies shutting down equipment or re-scheduling production processes, based on our customer survey research. The average load reduction among these customers was large: about 8 MW per customer, on average.

At the other end of the PPI spectrum, about 150 MW of subscribed load comes from hundreds of customers that reduced their CBL by less than 20%. This group consists predominantly of small to medium-sized facilities involved in retail and wholesale trade, education, government, health care as well as multi-family buildings. These customers relied primarily on load reductions, except for the health sector, which used small on-site generators combined with load reduction strategies. Typically, these customers either do not have, or chose not to utilize, on-site generation capabilities, and generally do not have remote or centralized control capabilities. This figure shows the diversity of the EDRP resource potential base of active customers.

Summary and Conclusions

The EDRP program was invoked twice during summer 2002, on July 30 and August 14, with a total of ten curtailment hours. The performance data resulting from the two events provides a limited, yet insightful view into the performance characteristics of the participating customers, from which a number of observations and general conclusions can be drawn. We estimated implicit price elasticities of demand and two other performance metrics to analyze the performance of individual customers as well as the portfolio of customer load resources during system emergencies. Highlights of our analysis are summarized below.

Summary of Implicit Price Elasticity Results

- Price elasticities averaged by NYISO pricing zones ranged from a low value of –0.02 in zone G to a high of –0.16 in zone H.
- Across all zones the average price elasticity for the 2002 EDRP program is –0.03, which is considerably lower than the 2001 value of –0.09. The primary reason for this decrease in elasticity is assumed to be the participation of new entrants to the 2002 program that have limited capacity to respond. Participation in EDRP program increased from ~300 customers in 2001 to ~1700 customers in 2002; hundreds of the new participants are small commercial and residential customers.
- Price elasticities vary by customer size, with low elasticities averaged over all zones of less than –0.05 dominating for small and medium sized customers. High elasticity values of above –0.2 were reported for 15% of EDRP's large customers (>4 MW). This result is consistent with the notion that larger customers have better knowledge about their energy utilization pattern and technical capabilities to be able to respond during curtailment events.
- Participants in NYSERDA-funded PONs achieved a price elasticity over twice as high as the level estimated for EDRP participants that did not participate in a NYSERDA-funded PON (-0.07 for NYSERDA participants vs. –0.03 for non-NYSERSA participants).

Summary of Customer Performance Analysis Results

- The average actual load curtailment performance of the 113 EDRP participants that were also enrolled in the ICAP/SCR program was quite reliable (96% of their subscribed load reductions overall and greater than 90% for load reduction only and onsite generation curtailment strategies). It is assumed that the financial consequences of under- or non-performance for ICAP/SCR resources are a key driver underlying this high performance. In aggregate these 113 customers had a subscribed load of 455 MW, and thus accounted for 60-70% of the delivered load curtailment during EDRP events.
- On average, the 1105 EDRP-only customers delivered 42% of their subscribed load reduction commitment when called, which is a useful indicator of actual performance in a voluntary program with no penalties.
- On average, participants in NYSERDA-funded PONs out-performed non-NYSERDA customers relative to their subscribed load reduction commitment (average SPI_c values of 64% vs. 46%). This difference was even more significant for those participants that adopted load curtailment strategies (average SPI_c values of 73% for NYSERDA vs. 42% for non-NYSERDA). However, participants in NYSERDA-funded PONs that used on-site generation strategies did not perform as well as non-NYSERDA participants in EDRP, which may have been caused by a lack of readiness because many participants were new to EDRP in 2002.
- We also analyzed customer performance by business type and load curtailment strategy (e.g. load reduction only, on-site generation, load reduction plus on-site generation). Overall, actual performance compared to subscribed load reduction goals was more variable for those customers that relied on load reduction only vs. on-site generation. The group of manufacturing customers who actively participated in EDRP, comprising the largest single market segment with ~502 MW of subscribed load, performed reasonably well at 65% of subscribed load. Facilities owned by government agencies and various types of utilities performed quite reliably with their load reduction strategies (average SPI_c of ~80%) and represent a significant resource (90 MW of subscribed load from active EDRP participants).
- Several types of businesses or market segments appear to be under-represented in EDRP (e.g. commercial offices), or participants were not very active during summer events

(e.g., education facilities that may have been closed), or were relatively low performers (e.g. multi-family apartments, health care facilities). For these segments, additional technical and financial assistance, information tools, and/or increased utilization of "clean" on-site generation should be considered in order to improve performance and overcome and/or supplement limited load reduction opportunities.

- Government and health facilities that utilized on-site generation to curtail loads had average SPI_c values in the 60-80% range.
- The EDRP resource performance curve provides some insight on the overall distribution of performance across the entire base of active EDRP participants. We found that that 24% of the subscribed load performed at or above the subscribed level (SPI_c>100%). The full performance resource equivalence of the total subscribed load of 878 MW was 564 MW, equivalent to a de-rating factor of 0.64.
- The EDRP resource potential curve characterizes the relative ability of active EDRP participants to curtail load on the electric system through various load reduction strategies. We found that a relatively small number of large customers provided a significant contribution to the overall load curtailment resource with average load reductions of 8 MW. These customers, the majority of whom are manufacturers that shut down equipment or re-scheduled/halted production processes, reduced their usage by 80% or more, relative to their CBL, during EDRP events. Nevertheless, the EDRP resource base is quite diverse, as it also includes hundreds of small to medium-sized facilities spanning many types of businesses (e.g. trade, health care, education, government) and buildings (e.g., multi-family). Approximately 150 MW of subscribed load came from customers such as these, who reduced their usage by less than 20%.

The two analysis approaches highlight key findings. Large customers, many of whom are manufacturing facilities, have the ability to curtail and indicate the willingness to respond to curtailment events at high PPI levels while their performance remains high. A major contributing factor to high performance appears to be joint enrollment in ICAP/SCR program, which provides a steady revenue stream (e.g.. reservation payments) and financial consequences for under- or non-performance. We also identified market segments that are either under-represented (e.g. commercial offices), performed relatively poorly during events (e.g. health care, multi-family), or where a significant fraction of enrolled customers chose not to respond (e.g., educational facilities).

We have seen some erosion in the overall price elasticities between 2001 and 2002, which is assumed to be caused by a multitude of small new program entrants in 2002. This suggests that further downward pressure on performance can be expected if additional, smaller customers enter the program and shift the overall make-up for the resource pool toward smaller customers. However, comparisons of NYSERDA versus non-NYSERDA participants suggest that technical and financial assistance and deployment of enabling technologies, combined with targeted marketing, education, and information, can improve performance and increase participation among smaller customers.

Table 5-1. Average Zonal EDRP Event Performance by EDRP Customers in the Summer, 2002, All Event Hours

	Participants*		Load (MWH)		CBL (MWH)		At $500/MW Load Reduction (MWH)		Implicit Price Elasticity**	
Zone	Number	%	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
A	51	6%	27.6	50	65.8	114	38.18	90	-0.07	0.08
B	19	2%	10.1	24	15.2	34	5.08	11	-0.07	0.06
C	46	5%	10.4	21	14.4	29	4.04	19	-0.04	0.06
D	6	1%	1.8	2	2.5	2	0.72	1	-0.06	0.06
E	28	3%	7.2	8	8.8	10	1.59	4	-0.05	0.12
F	26	3%	16.5	32	29.0	48	12.52	30	0.04	0.54
G	6	1%	109.7	199	121.4	222	11.67	24	-0.02	0.02
H	4	0%	2.2	2	4.9	3	2.64	2	-0.16	0.05
I	13	1%	10.0	10	12.5	11	2.45	3	-0.10	0.12
J	40	4%	16.8	41	20.1	42	3.26	8	-0.08	0.11
K	667	74%	2.6	7	2.9	8	0.29	1	-0.03	0.05
Avg.##			**6.3**		**9.6**		**3.30**		**-0.03**	
Totals	**906**		**5,941**		**8,978**		**3,037**			

*These EDRP participants offered only load reduction. Those that supplied on-site generation, or both generation and load reduction are not included.

**These implicit price elasticities are calculated according to equation (3) above. See the text for more details of the calculations.

##These are weighted averages, weighted by the proportion of firms in each zone.

These load reductions are calculated by substituting the estimated price elasticities into equation (3) and solving for the reduction in load when P_E is set either at $250 or $750/MW.

Table 5-2. Implicit Price Elasticities by EDRP Customers, Summer, 2002

Zone	Participants	Implicit Price Elasticity of Demand			
		Minimum	Maximum	Average	Standard Deviation
A	51	-0.23	0.05	-0.07	0.08
B	19	-0.22	0.02	-0.07	0.06
C	46	-0.23	0.17	-0.04	0.06
D	6	-0.13	0.01	-0.06	0.06
E	28	-0.23	0.45	-0.05	0.12
F	26	-0.23	2.67	0.04	0.54
G	6	-0.04	0.00	-0.02	0.02
H	4	-0.23	-0.13	-0.16	0.05
I	13	-0.47	-0.01	-0.10	0.12
J	40	-0.47	0.02	-0.08	0.11
K	667	-0.21	0.13	-0.03	0.05

*These EDRP participants offered only load reduction. Those supplying on-site generation, or generation and load reduction are not included.

Note: See the footnotes to Table 5-1 for more details about the calculations.

Table 5-3. Average Zonal Performance by NYSERDA's EDRP Customers in the Summer, 2002, All Event Hours

	Participants*		Load (MWH)		CBL (MWH)		At $500/MW Load Reduction (MWH)		Implicit Price Elasticity**	
Zone	Number	%	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
A	24	24%	11.4	26	32.3	66	20.83	47	-0.07	0.09
B	7	7%	10.5	13	16.2	24	5.78	11	-0.05	0.05
C	32	31%	7.2	9	12.5	26	5.22	22	-0.04	0.04
D	4	4%	1.9	2	2.1	2	0.22	0	-0.03	0.04
E	4	4%	6.7	5	9.4	8	2.78	3	-0.09	0.07
F	10	10%	21.7	36	40.3	55	18.62	24	-0.10	0.08
G	0	0%	0.0	0	0.0	0	0.00	0	0.00	0.00
H	4	4%	2.2	2	4.9	3	2.64	2	-0.16	0.05
I	5	5%	6.8	7	10.7	8	3.83	4	-0.17	0.17
J	12	12%	28.4	73	32.9	75	4.51	9	-0.11	0.12
K	0	0%	0.0	0	0.0	0	0.00	0	0.00	0.00
Avg.##			**11.6**		**21.2**		**9.58**		**-0.07**	
Totals	**102**		**1,214**		**2,203**		**989**			

*These EDRP participants offered only load reduction. Those that supplied on-site generation, or both generation and load reduction are not included.

**These implicit price elasticities are calculated according to equation (3) above. See the text for more details of the calculations.

##These are weighted averages, weighted by the proportion of firms in each zone.

These load reductions are calculated by substituting the estimated price elasticities into equation (3) and solving for the reduction in load when P_E is set either at $250 or $750/MW.

Table 5-4. Zonal Implicit Price Elasticities for NYSERDA's EDRP Customers, Summer 2002

		Implicit Price Elasticity of Demand			
Zone	Participants	Minimum	Maximum	Average	Standard Deviation
A	24	-0.23	0.05	-0.07	0.09
B	7	-0.11	0.02	-0.05	0.05
C	32	-0.21	0.01	-0.04	0.04
D	4	-0.07	0.01	-0.03	0.04
E	4	-0.19	-0.04	-0.09	0.07
F	10	-0.21	0.01	-0.10	0.08
G	0	0.00	0.00	0.00	0.00
H	4	-0.23	-0.13	-0.16	0.05
I	5	-0.47	-0.08	-0.17	0.17
J	12	-0.47	-0.01	-0.11	0.12
K	0	0.00	0.00	0.00	0.00

*These EDRP participants offered only load reduction. Those supplying on-site generation, or generation and load reduction are not included.

Note: See the footnotes to Table 5-3 for more details about the calculations.

Table 5-5. Average Zonal EDRP Event Performance by Non-NYSERDA EDRP Customers, Summer, 2002

	Participants*		Load (MWH)		CBL (MWH)		At $500/MW Load Reduction (MWH)		Implicit Price Elasticity**	
Zone	Number	%	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
A	27	3%	42.0	61	95.6	138	53.60	115	-0.08	0.08
B	12	1%	9.9	29	14.6	40	4.68	12	-0.08	0.07
C	14	2%	17.5	35	18.8	36	1.35	3	-0.04	0.09
D	2	0%	1.7	0	3.4	1	1.73	0	-0.12	0.01
E	24	3%	7.3	8	8.6	11	1.39	4	-0.04	0.13
F	16	2%	13.2	30	21.9	43	8.70	33	0.13	0.68
G	6	1%	109.7	199	121.4	222	11.67	24	-0.02	0.02
H	0	0%	0.0	0	0.0	0	0.00	0	0.00	0.00
I	8	1%	12.0	11	13.6	13	1.58	2	-0.06	0.04
J	28	3%	11.9	12	14.6	14	2.72	7	-0.07	0.10
K	667	83%	2.6	7	2.9	8	0.29	1	-0.03	0.05
Avg.##			**5.7**		**8.2**		**2.50**		**-0.03**	
Totals	**804**		**4,728**		**6,775**		**2,047**			

*These EDRP participants offered only load reduction. Those that supplied on-site generation, or both generation and load reduction are not included.

**These implicit price elasticities are calculated according to equation (3) above. See the text for more details of the calculations.

##These are weighted averages, weighted by the proportion of firms in each zone.

These load reductions are calculated by substituting the estimated price elasticities into equation (3) and solving for the reduction in load when P_E is set either at $250 or $750/MW.

Table 5-6. Zonal Implicit Price Elasticities by Non-NYSERDA EDRP Customers, Summer 2002

Zone	Participants	Implicit Price Elasticity of Demand			
		Minimum	Maximum	Average	Standard Deviation
A	27	-0.23	0.01	-0.08	0.08
B	12	-0.22	0.00	-0.08	0.07
C	14	-0.23	0.17	-0.04	0.09
D	2	-0.13	-0.11	-0.12	0.01
E	24	-0.23	0.45	-0.04	0.13
F	16	-0.23	2.67	0.13	0.68
G	6	-0.04	0.00	-0.02	0.02
H	0	0.00	0.00	0.00	0.00
I	8	-0.13	-0.01	-0.06	0.04
J	28	-0.47	0.02	-0.07	0.10
K	667	-0.21	0.13	-0.03	0.05

*These EDRP participants offered only load reduction. Those supplying on-site generation, or generation and load reduction are not included.

Note: See the footnotes to Table 5-5 for more details about the calculations.

Fig. 5-1. Price Elasticities of Demand for Electricity: Equal Load Reduction

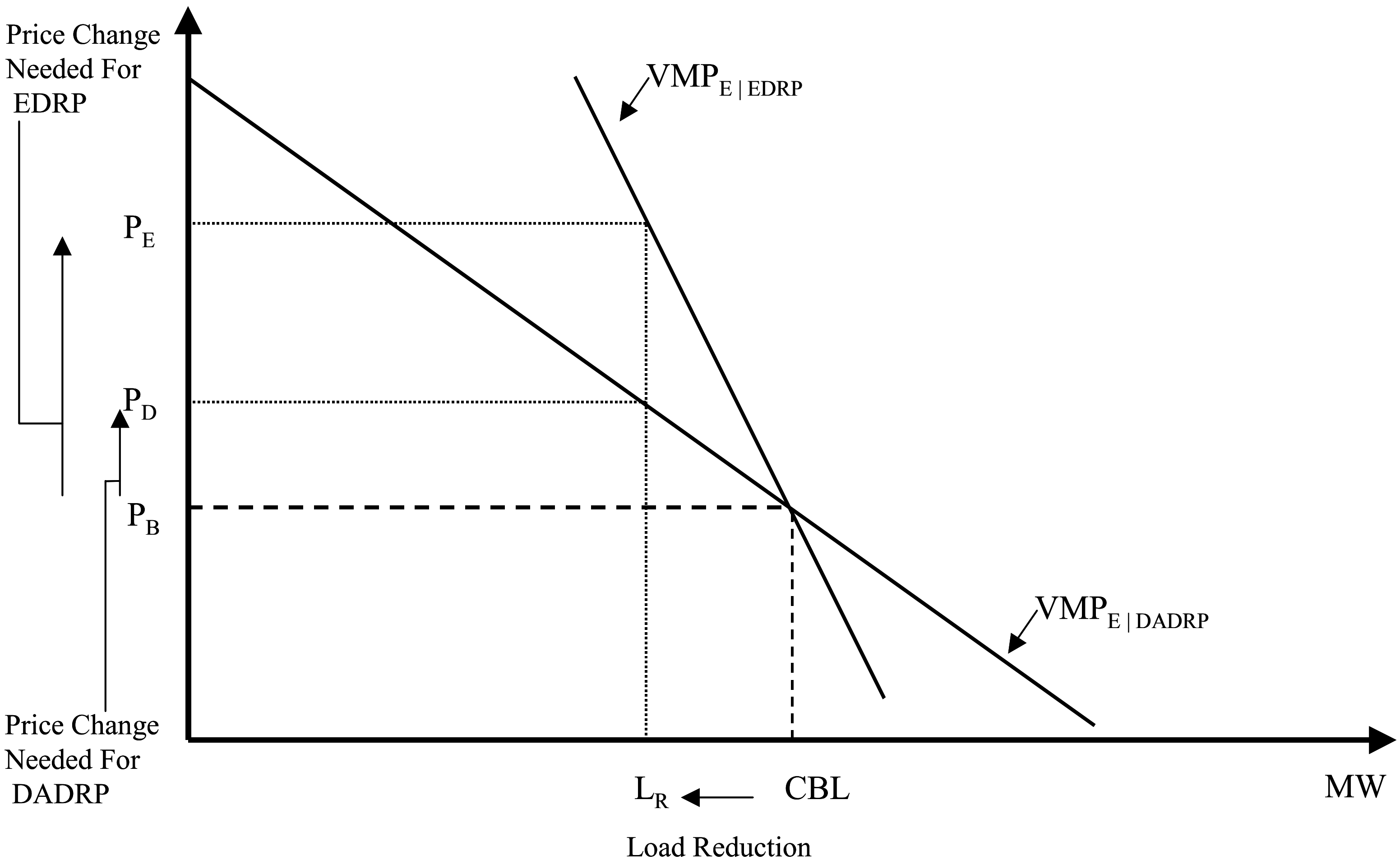


Fig. 5-2. Price Elasticities of Demand for Electricity: Equal Price Change

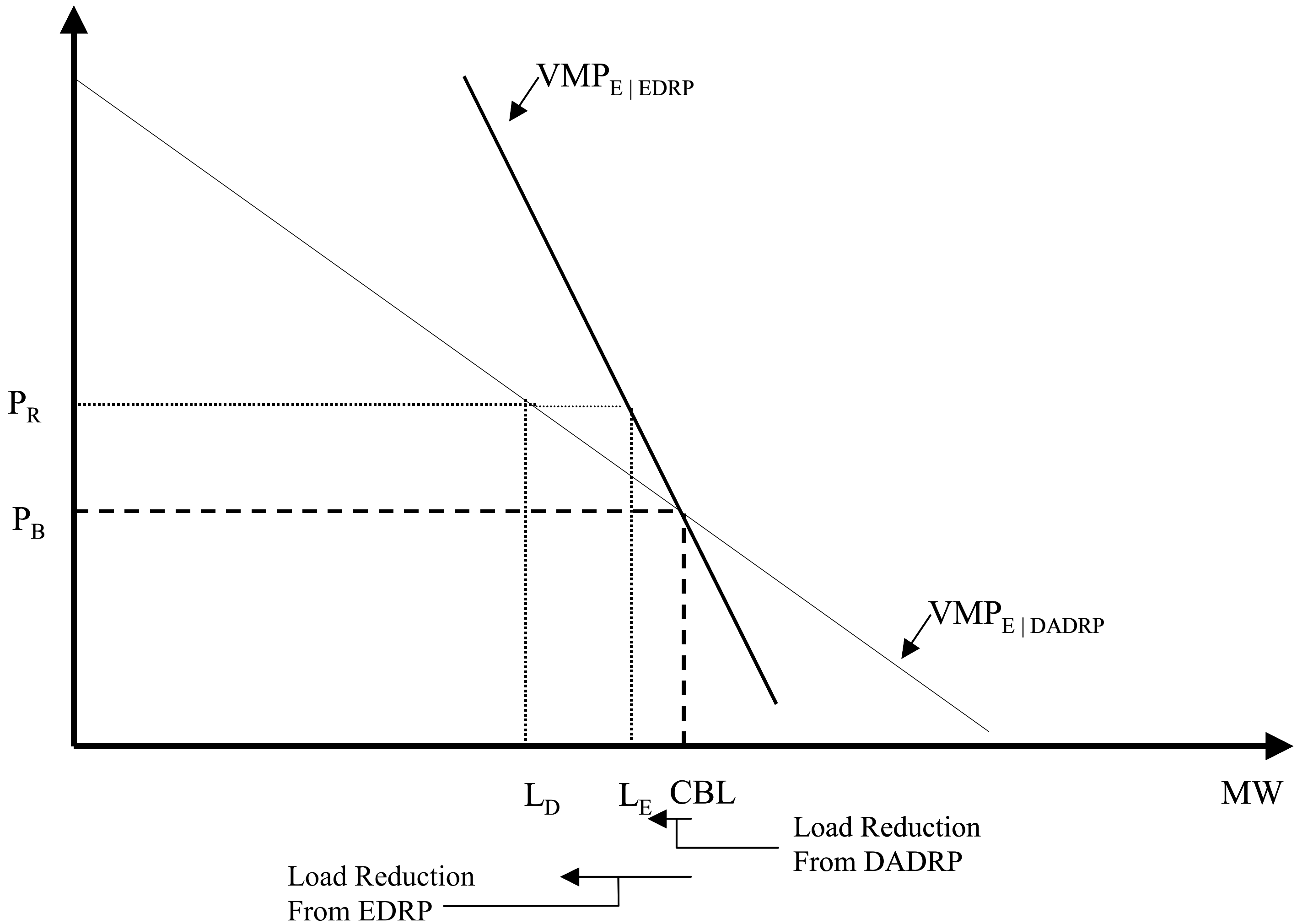


Fig. 5-3. Distribution of EDRP Customers by Elasticity of Demand for Electricity During Summer 2002 EDRP Events

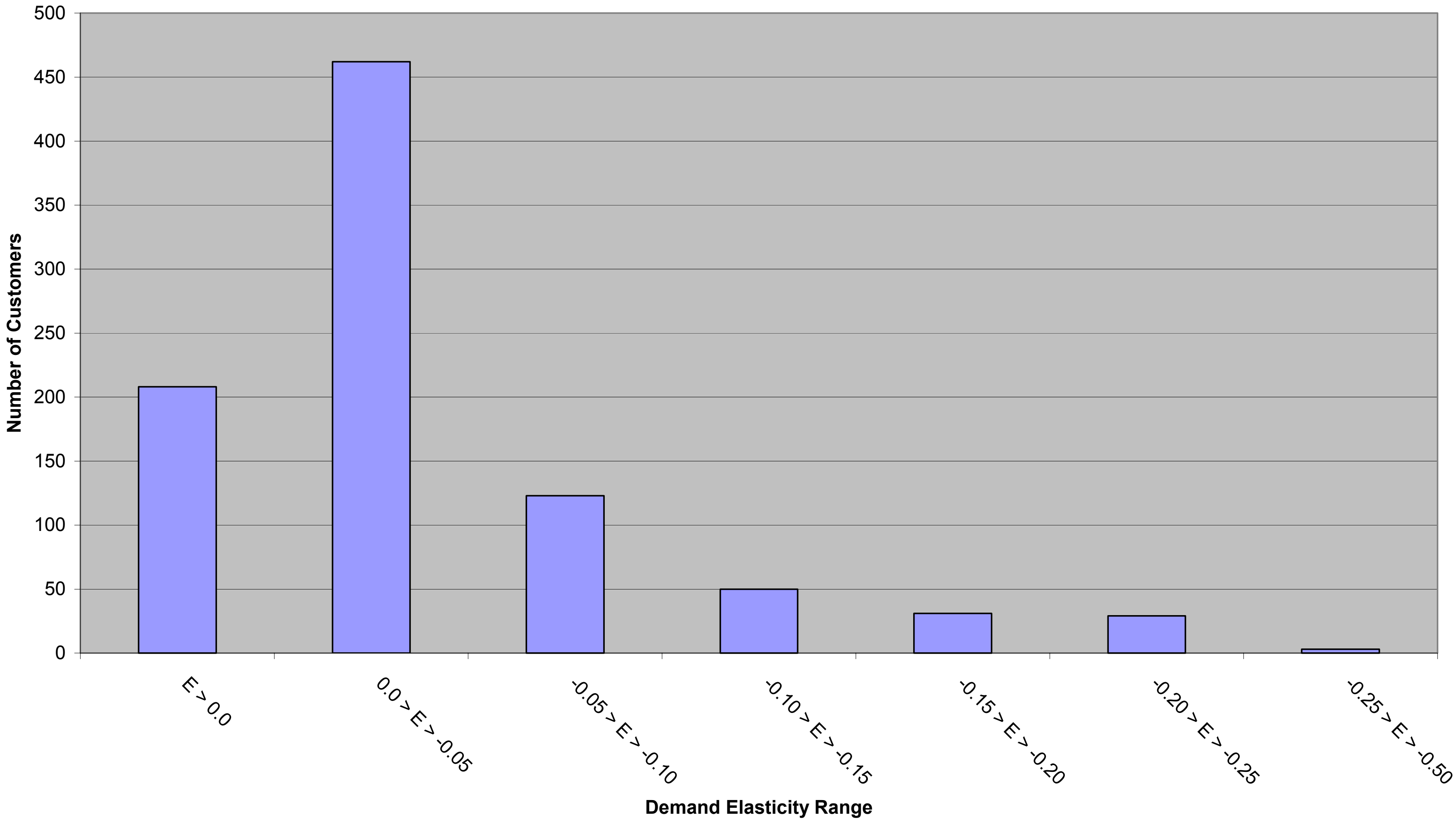


Fig. 5-4. Distribution of Elasticities by EDRP Participant's Electricity Consumption Level

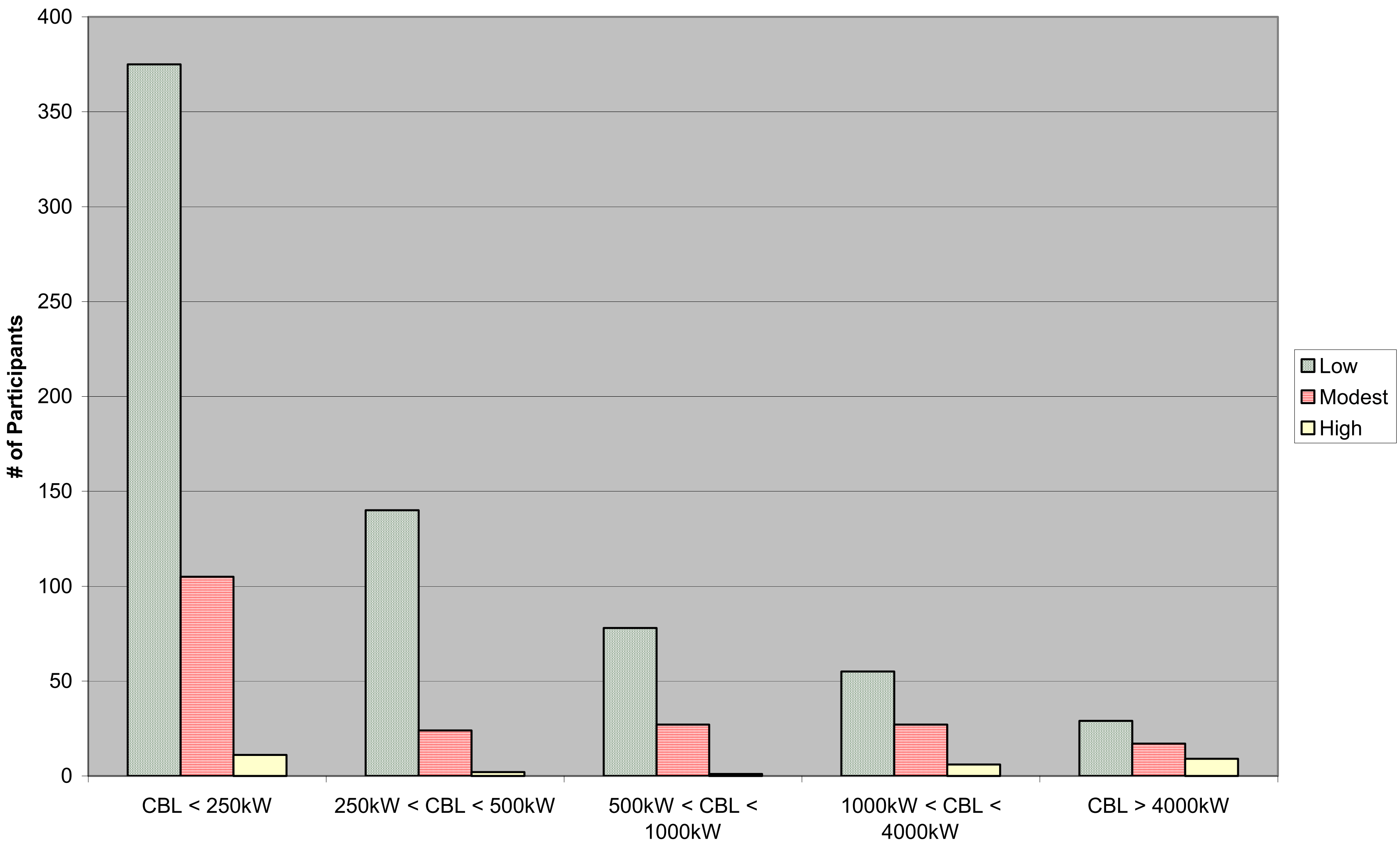


Fig. 5-5. NYISO-Wide 2002 EDRP Event Performance

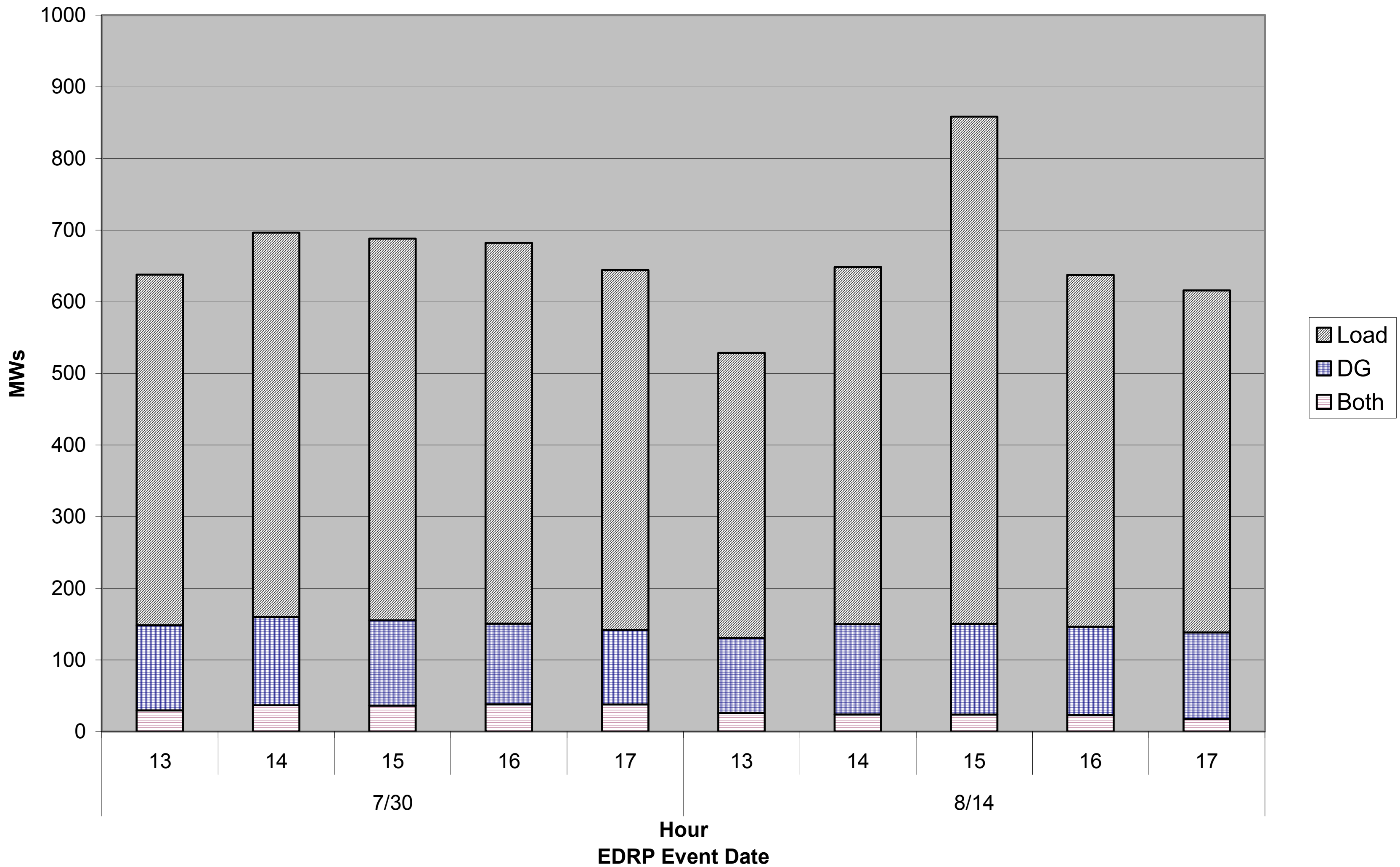


Fig. 5-6. Distribution of NYSERDA'S EDRP Customers by Elasticity of Demand for Electricity During Summer 2002 EDRP Events

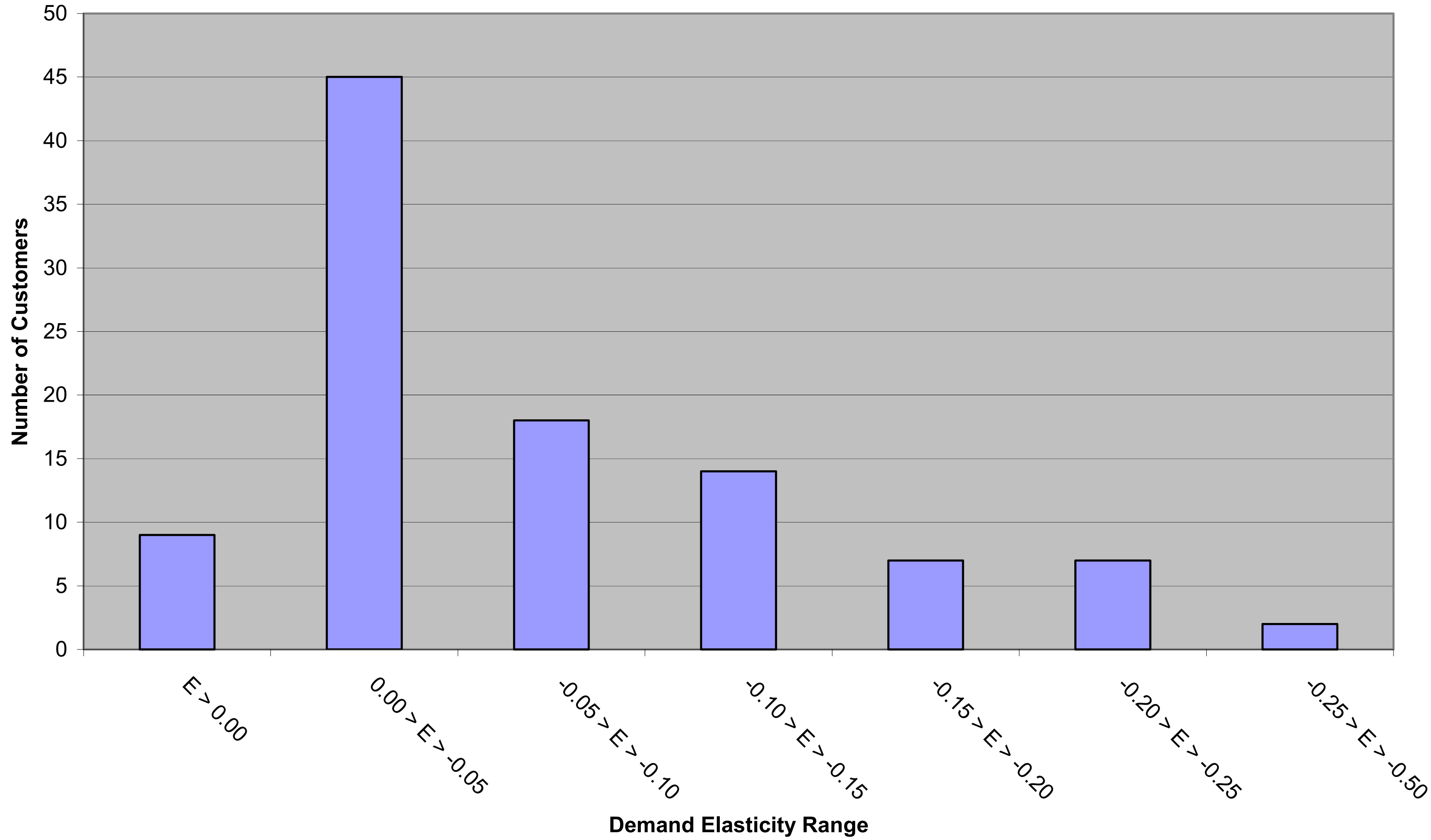


Fig. 5-7. Distribution of Non-NYSERDA EDRP Customers by Elasticity of Demand for Electricity During Summer 2002 EDRP Events

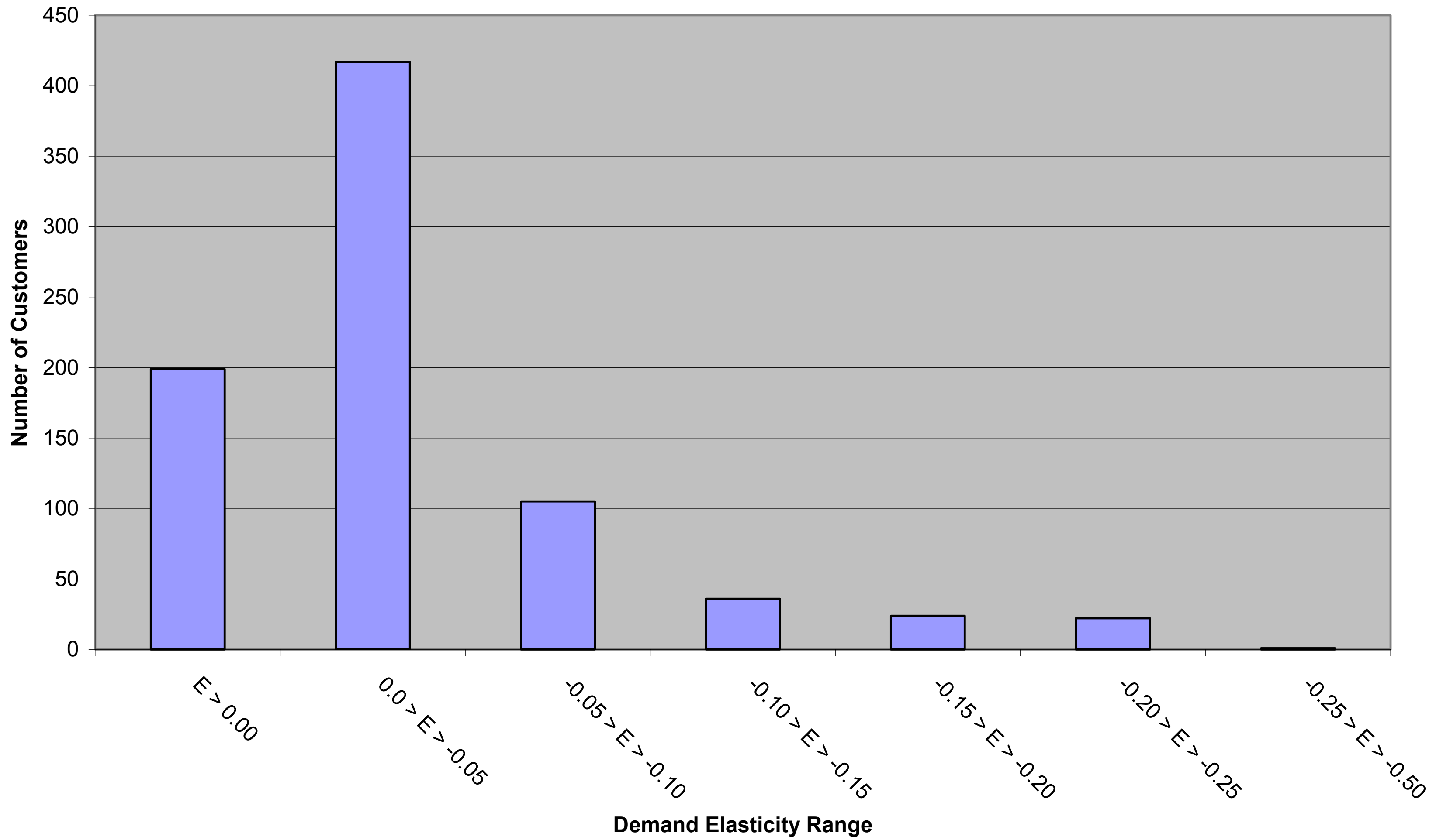


Fig. 5-8. Ratio of Average Hourly EDRP Performance to Initial Subscribed Load Reduction Capability by EDRP Event Day

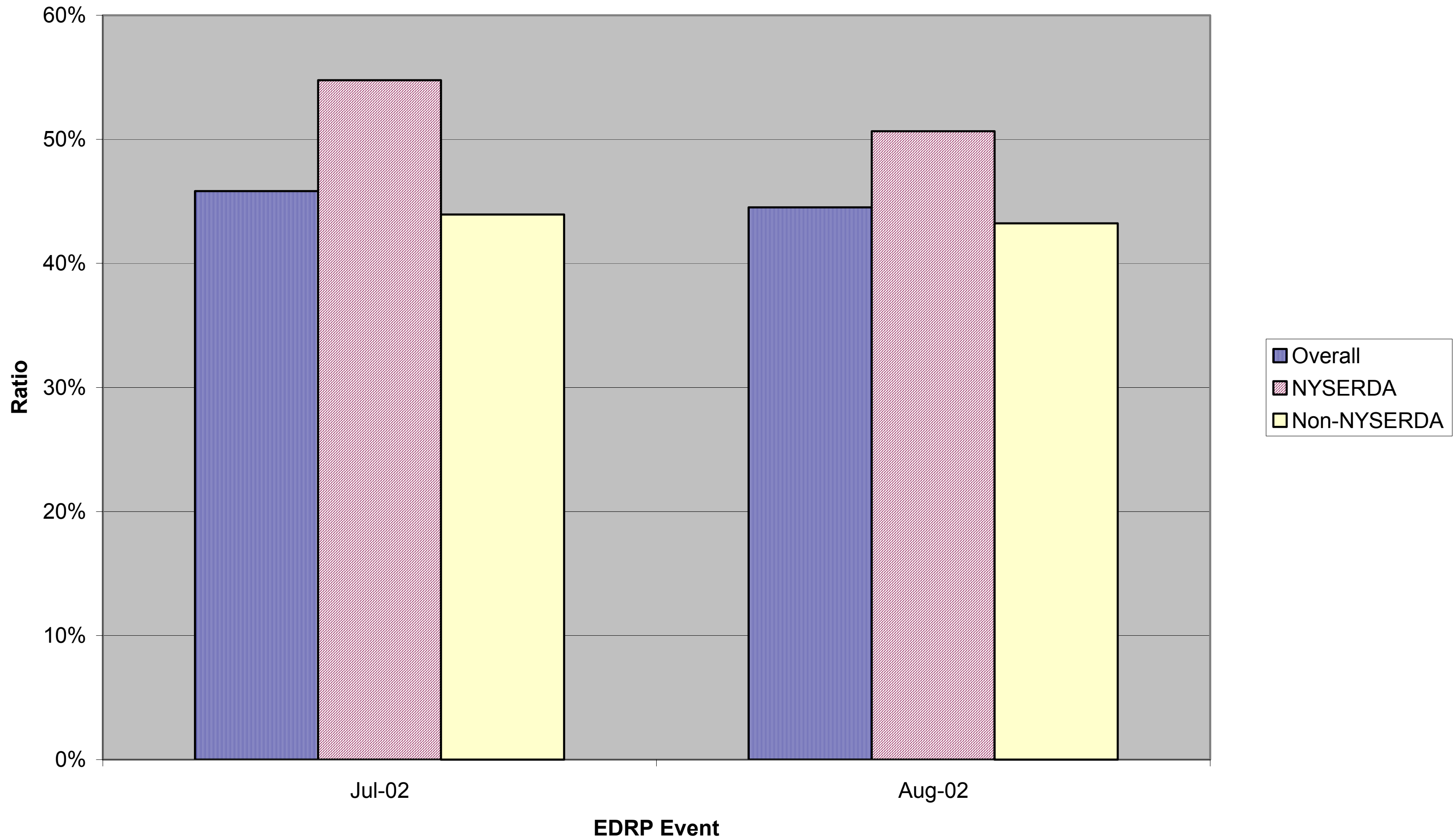


Fig. 5-9. Ratio of Average Hourly EDRP Load Curtailment Performance to Initial Subscribed Load Reduction Capability by Zone

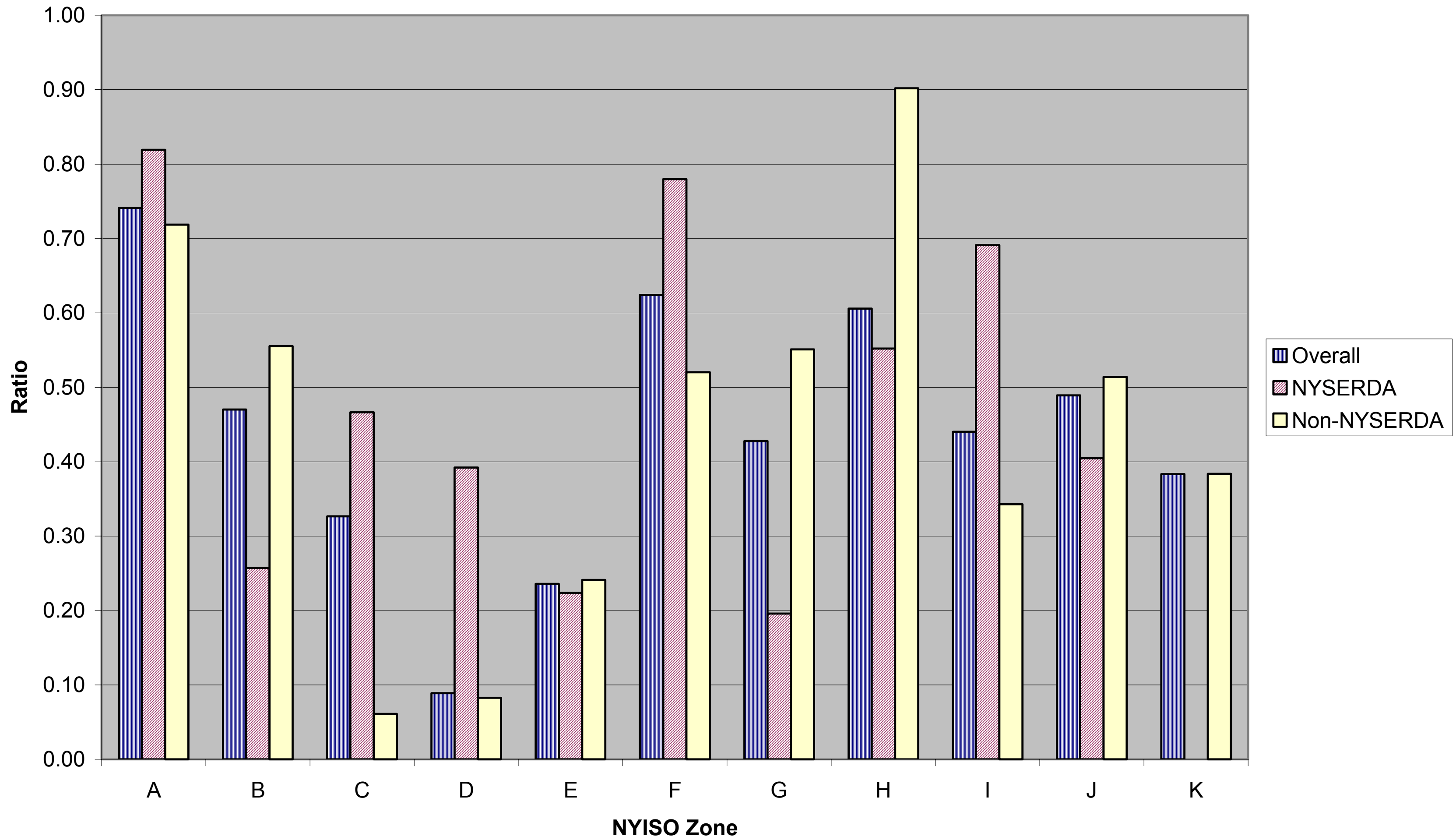


Fig. 5-10. SPI_c for NYSERDA and non-NYSERDA participants for EDRP Summer 2002 events

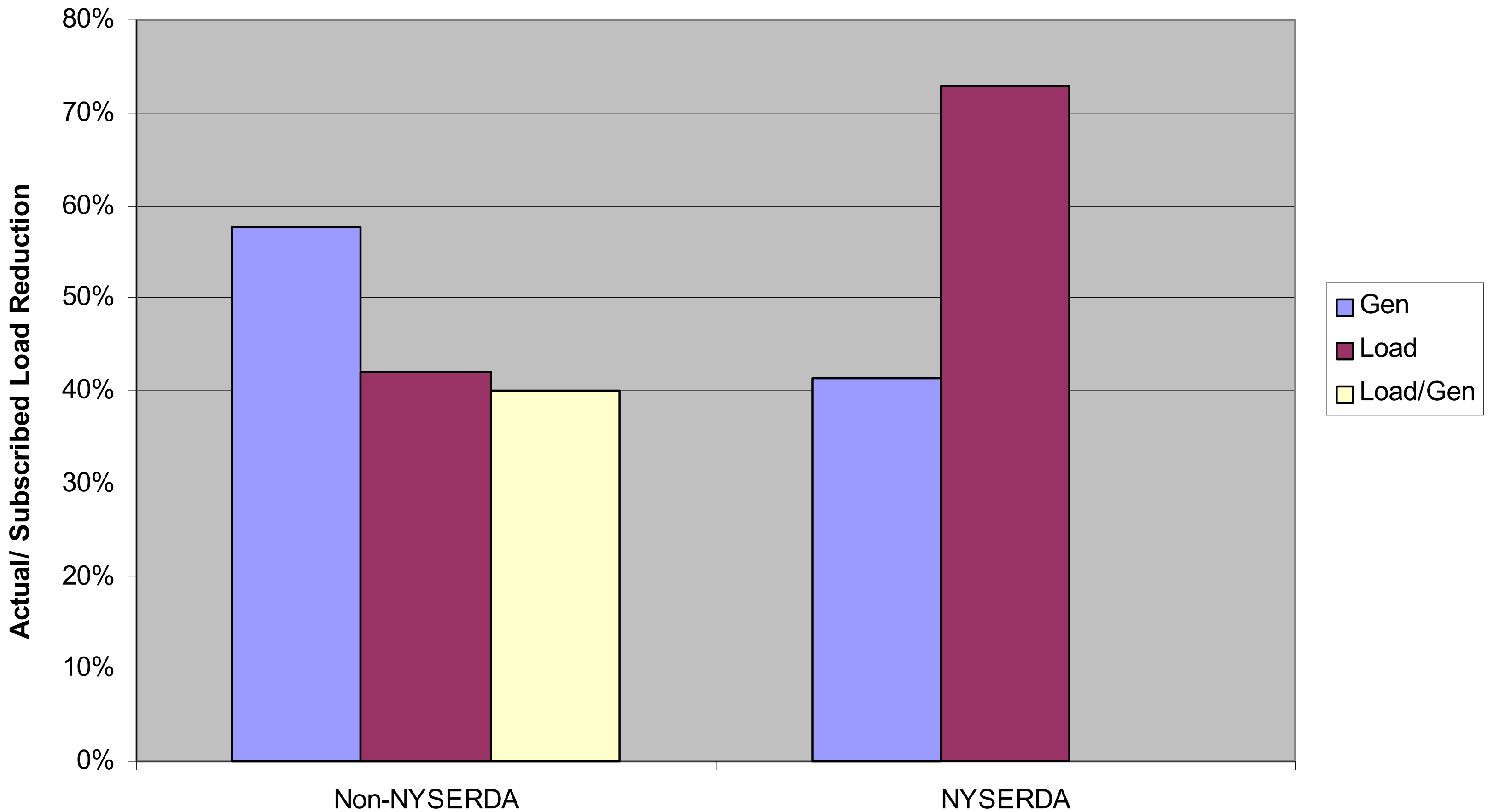
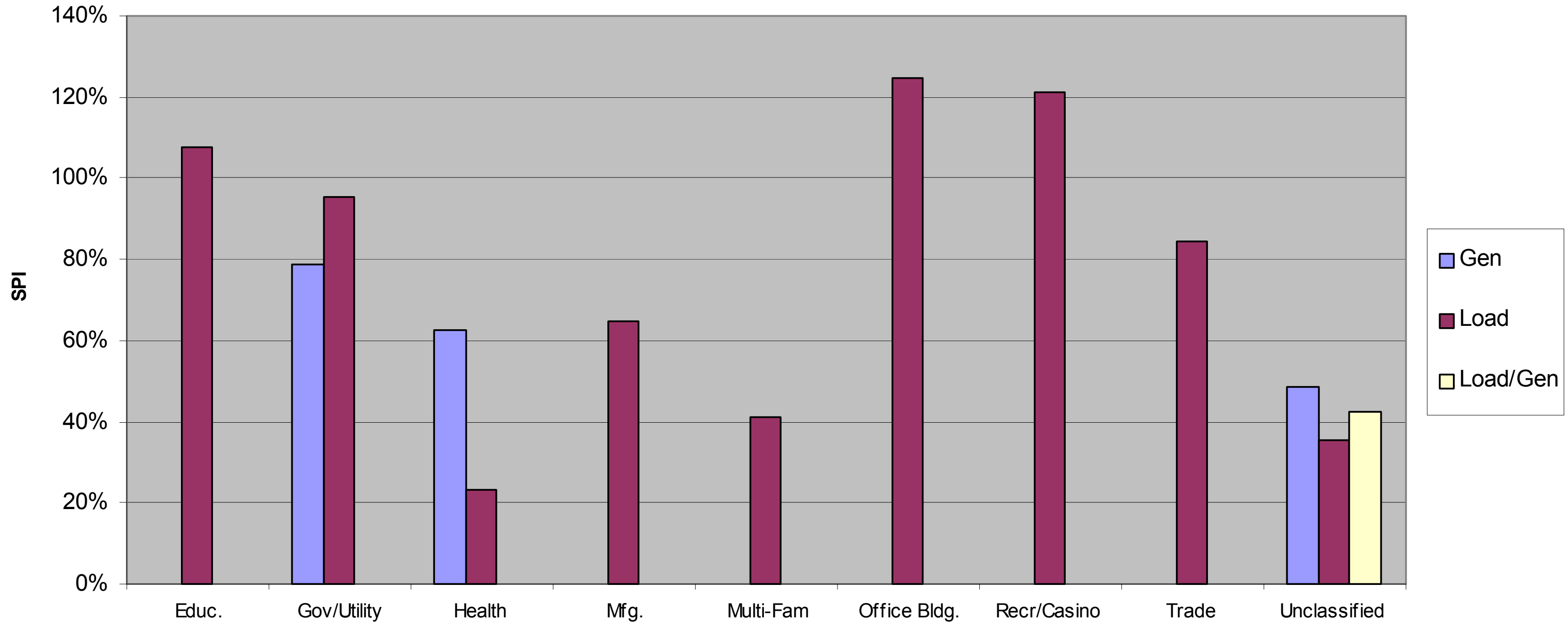


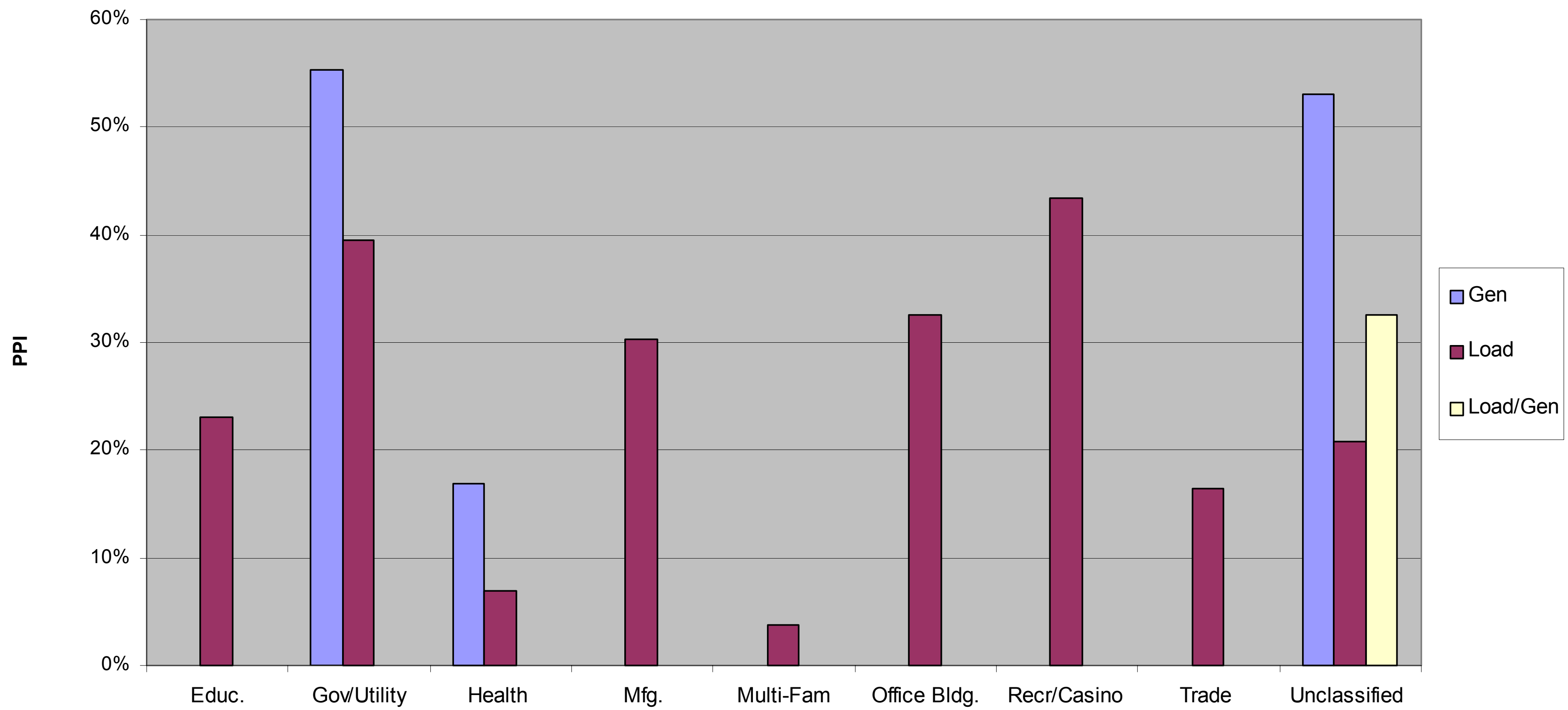
Fig. 5-11. SPI_c by Business Type and Load curtailment strategy for Summer 2002 EDRP events



	Educ.	Gov/Utility	Health	Mfg.	Multi-Fam	Office Bldg.	Recr/Casino	Trade	Unclassified
Subscribed MW of Active Participants	9	90	13	502	3	5	2	13	246
Subscribed MW of All Participants	30	123	28	558	9	8	5	26	551

The category "Unclassified" corresponds to SIC code 9900 and other non-classified aggregated load

Fig. 5-12. Peak Performance Index (PPI) by Business Type and Load Curtailment Strategy



Subscribed MW of Active Participants	9	90	13	502	3	5	2	13	246

The category "Unclassified" corresponds to SIC code 9900 and other non-classified aggregated load

Fig. 5-13. Ratio of Actual Load Reduction to Subscribed Load Reduction by Program Participation

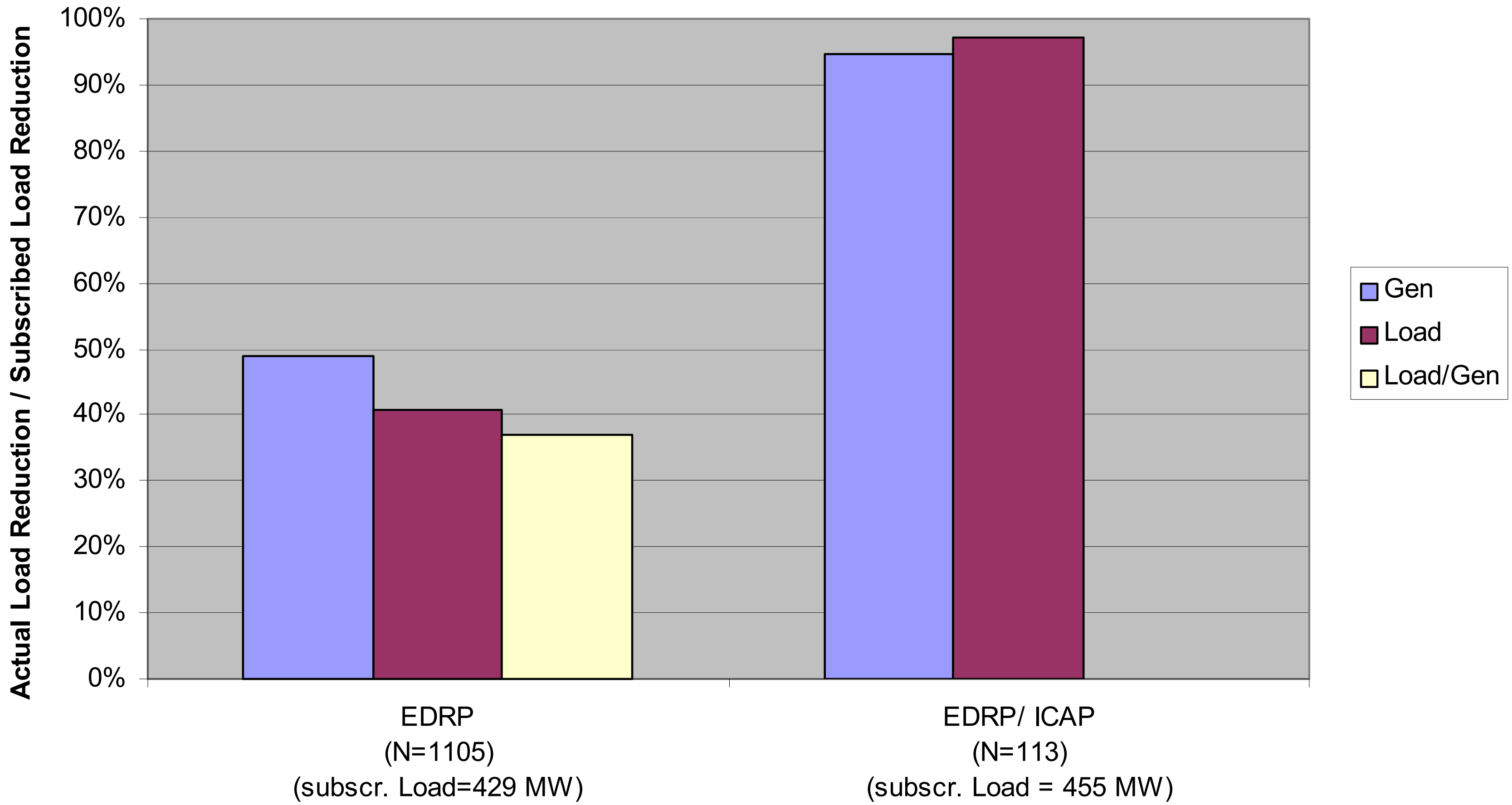


Fig. 5-14. EDRP Resources in Descending Order of Individual Subscribed Performance Index (SPI_c)

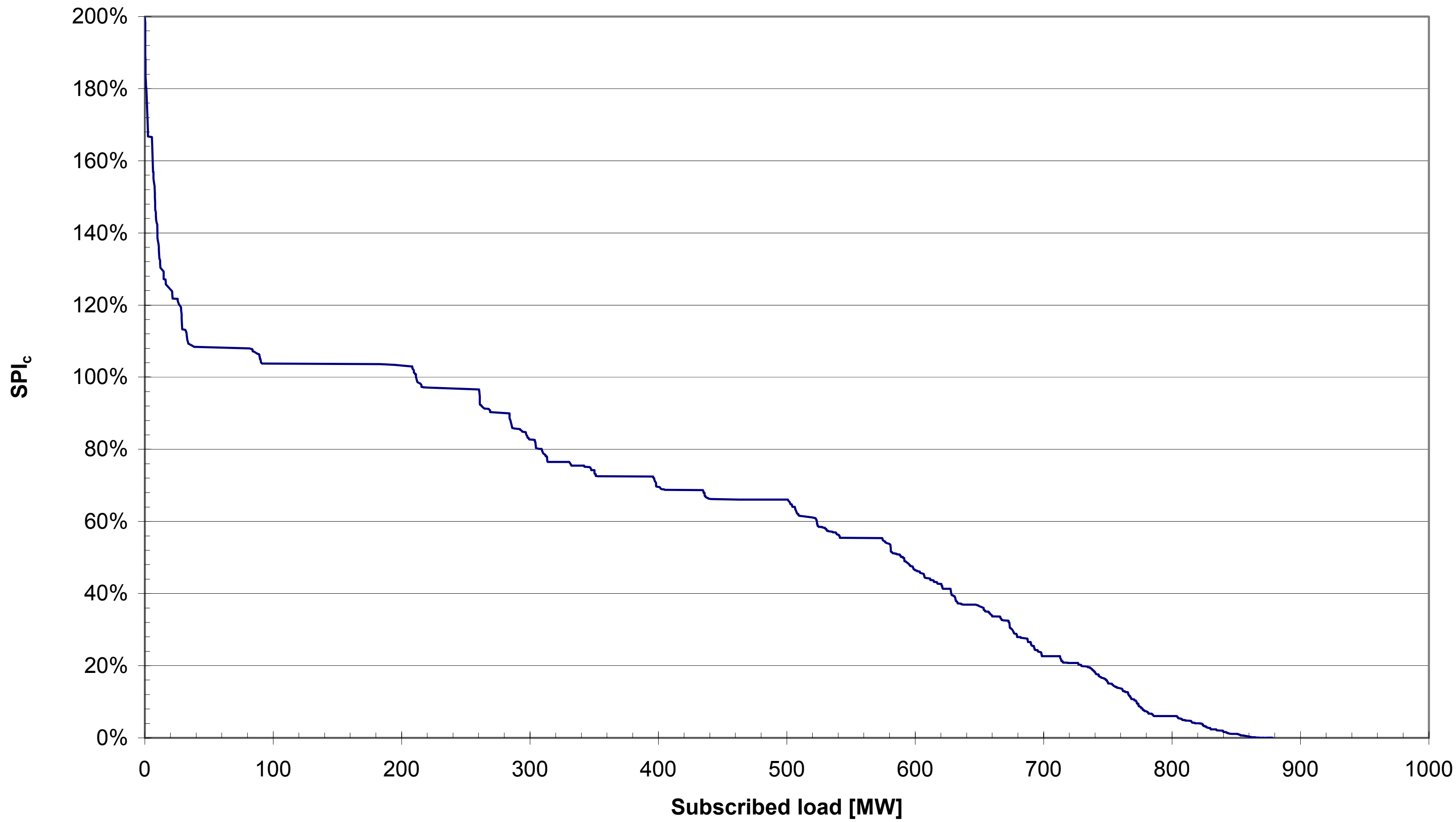


Fig. 5-15. EDRP Resources in Descending Order of Individual Peak Performance Index PPI