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M. Kintner-Meyer, Pacific Northwest National Laboratory
C. Goldman, O. Sezgen, Lawrence Berkeley National Laboratory
D. Pratt, Neenan Associates

Energy Analysis Department
Ernest Orlando Lawrence Berkeley National Laboratory
University of California Berkeley
Berkeley, California 94720

Environmental Energy Technologies Division

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Dividends With Demand Response

By Michael Kintner-Meyer, Ph.D., Member ASHRAE, **Charles Goldman, Osman Sezgen,** and **Donna Pratt**

A new wave of demand response (DR) programs offers commercial facilities the opportunity to earn money by managing electrical loads in response to market prices. The DR programs are offered by independent system operators (ISOs), which are entities that operate transmission grids, preserve system reliability, and operate spot market auctions where buyers and sellers can meet to complete their obligations. Programs are designed to integrate load curtailments directly into system operations. ISOs typically pay participants amounts equivalent to what generators are paid for equivalent services.

Some programs resemble legacy utility load management programs, where participants receive an upfront option payment for agreeing to curtail load when asked by the ISO. Others are a variation of the real-time pricing (RTP) programs offered by some utilities. In some cases, ISOs are offering programs that provide unique opportunities to receive market prices for load curtailments. *Table 1* lists various ISO markets and/or services and the typical features of demand response programs in that market. We have categorized DR programs into five basic types with examples of current ISO programs.

Customer's ability and cost to participate in ISO DR programs is influenced by specific program features (e.g., notice, duration and frequency of curtailment, penalties for nonperformance, and payments).† The installed capacity (ICAP),

† Unlike legacy load management programs provided by regulated utilities, ISO program participation is often distinct from the customer's retail service. In some cases, a customer can take commodity service from one entity, get basic network services from the local utility, and participate in the DR program through a third entity.

Feature	Function of DR in ISO Markets				
	Emergency	Day Ahead Electricity	ICAP	Ancillary Services	Balancing
Notice	Two Hours	Prior Afternoon	Two Hours or Less	Five to 30 Minutes	Hours to Minutes
Duration	Four or More Hours	As Bid by Customer and Scheduled by ISO	Two or More Hours	As Bid by Customer and Dispatched by ISO	One to Eight Hours
Frequency	As Dispatched by ISO		Unlimited, Most Likely In Summer Months		Self-Dispatched When Available
Reservation Payment	None	None	Yes (Six Month Market Value)	Yes (Daily Markets)	None
Performance Payment	Yes	Yes	In Some Cases	Yes	Yes
Example Value	$0.50/kWh	$0.05 – $0.99/kWh	$0.05 – $0.50/kWh	$0.01 – $0.99/kWh	$0.01 – $0.50/kWh
Penalty	None	Market Price	Cash and Participant Privilege Penalties	Market Price	None
Reference	NYISO EDRP	NYISO DADRP	NYISO ICAP 2002	CAISO & ISO-NE Class I	ERCOT, Load as a Resource

Table 1: Independent system operators offer programs for unique load management opportunities.

ancillary services, and emergency resources programs treat DR resources as capacity that is *dispatched* by the ISO system operator to meet system needs. ICAP and emergency DR are generally deployed on two-hours notice in emergency situations, when generator capacity to maintain reserves is not available.‡ Ancillary services are scheduled by the ISO a day ahead and called upon as needed on short notice, usually less than 30 minutes. DR resources can also supply the system's energy needs when the price is right for the participant. Customers or load aggregators can bid load curtailments into the day-ahead market and if the price is lower than a competing generation bid, the curtailment is scheduled by the ISO. The customer submits a bid for the next day, which includes a load reduction quantity at a specified price during specific time periods and receives an acceptance or rejection from the ISO by about noon. The balancing market operates in near real-time. Customers can elect to reduce their usage in response to the level and trend of prevailing prices and are paid the final market-clearing price in the real-time energy market.

Table 1 provides examples of the financial rewards that are attainable under various types of DR programs. The ICAP program provides up-front payments (called reservation or capacity payment), which facilitates financing or funding costs associated with preparing to meet the curtailment obligation. Some ISO ICAP programs also provide for an additional payment for the energy delivered when a curtailment is called. However, noncompliance penalties can consume all of the upfront payment, and result in the habitually noncompliant customer having to pay the ISO money to settle the account at the end of the term.

Conversely, ISO emergency resources programs often do not penalize customers who fail to curtail load in response to ISO requests. However, there is also no guarantee that load curtailments will be called. The ISO programs that require customers to bid into ISO markets (i.e., the day-ahead and ancillary services market) provide customers with greater control. Customers offer their price, quantity, and time to curtail load. Customers avoid unwanted exposure to penalties when they cannot curtail by not submitting a bid. However, the benefits earned depend on prevailing market prices, and the customer's availability to curtail when prices are high.

How to Assess DR Capabilities?

How should customers determine whether or not to participate and select the best program for their facilities, given the multiple programs offered by an ISO? Based on our research into participation in DR programs, we recommend that facility and energy managers first conduct a systematic assessment of their load curtailment capability and develop a supply curve that characterizes the price at which they are willing to curtail at various compensation rates (*Figure 1*). Since DR program events are most likely to occur during summer afternoons, the process should be conducted for that period, at least initially.

Facility managers should compile an inventory of electric usage, equipment and devices. Those that cannot operate independently should be considered as an equipment cluster. Next, the items in the inventory are characterized by whether or not they potentially can be curtailed. Electrical equipment, devices or end use loads that are potentially curtailable are grouped by type of services provided. *Discretionary* services

‡ In the blackout of August 14, 2003 in the Northeast of the U.S., the New York ISO invoked the ICAP and emergency DR programs for the restoration of the New York State power grid. Because of the narrow window of time prior and during the cascading events that led to the blackout, there was insufficient time to invoke the ICAP and emergency DR programs in advance of the system failure.

About the Authors
Michael Kintner-Meyer, Ph.D., is staff scientist at Pacific Northwest National Laboratory, Richland, Wash. **Charles Goldman** is staff scientist and group leader and **Osman Sezgen** is staff research associate in the Electricity Markets and Policy Group at Lawrence Berkeley National Laboratory, Berkeley, Calif. **Donna Pratt** is vice president of Implementation Services at Neenan Associates, Syracuse, N.Y.

are those that the facility could do without for a short period of time. More than 25% of DR program participants report turning off banks of lights or reducing HVAC operation.[1] *Flexible* usage is associated with routine facility operation or services that can be shifted to another time period (e.g., the same day or another day). Examples include recharging batteries, cleaning and maintenance activities, or rescheduling work shifts on event days. Some facilities can use intermediate product or process *storage* to reduce usage during an event without actually reducing the facility's output or services. For example, many paper processing and cement plants report building up electricity intensive feedstock that is drawn down during curtailment events. Wastewater treatment plants store the water to be treated for later processing. Finally, customers with properly configured *on-site generation* can use its output to effect a virtual curtailment.

Next, the curtailable electricity uses are categorized by how much time is required to accomplish their curtailment to align load reduction capability with ISO program notice provisions (Step 3 in *Figure 1*). Those electric uses that require a day's advance planning are separated from those uses/equipment that can be curtailed on the same day with varying amounts of notice (e.g., ranging from 10 minutes to two hours).* For programs that require very short notice (i.e., 10 to 30 minutes), ISOs often require more expensive metering, more frequent communications, and in some cases, cycling requirements for short time periods (e.g., less than an hour). If these additional provisions are difficult for customers, the electric use should be moved to a category with more notice.

The final step involves representing the facility's load curtailment capability in the form of a supply curve (Step 4 in *Figure 1*). This is accomplished by assigning costs for curtailing various types of identified usage elements or equipment clusters in each notice category, and then stacking the elements from lowest to highest curtailment cost. Establishing cost bins will simplify this process. For example, it makes sense to create low, medium and high cost bins (e.g., set at \$0.25/kWh, \$0.50/kWh and \$0.75/kWh, respectively) and sort usage elements and equipment clusters that can be curtailed into these cost curtailment bins.

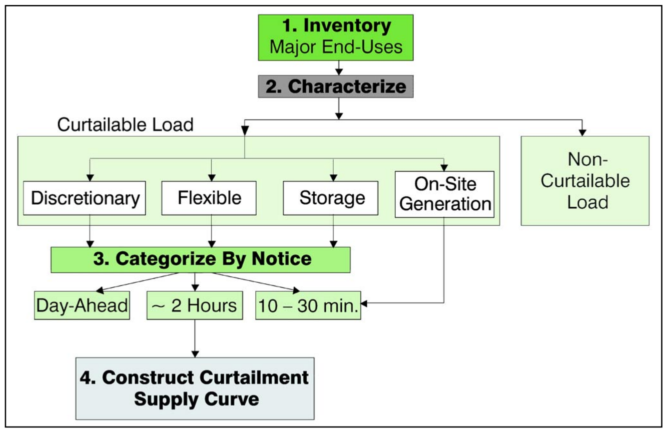

Figure 1: Process to develop supply curve of curtailment capability.

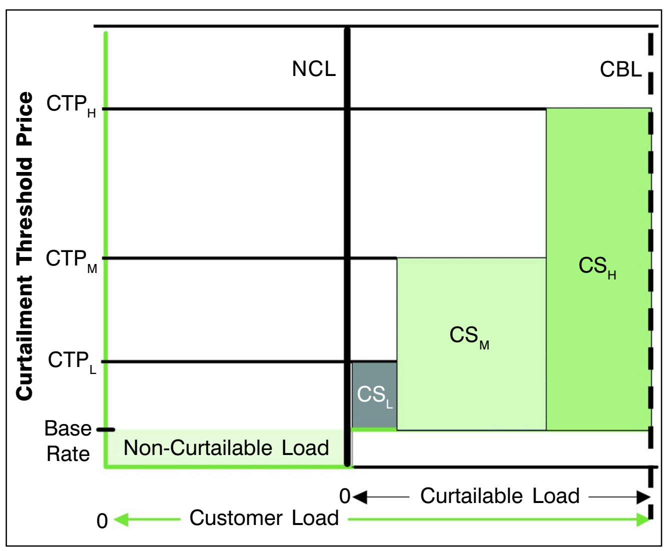

Figure 2: Generic facility curtailment supply curve.

How do you estimate costs of curtailing various types of usage elements or equipment clusters and other impacts on the facility? Curtailing discretionary usage involves direct costs such as labor or other costs associated with shutting equipment down. Facility managers must also value any potential inconvenience to building occupants from reduced services or amenities, which is harder to quantify. Customers that can curtail flexible usage must recover the costs associated with that shift (e.g., additional labor costs, paying overtime, or added materials and process costs). Storage is possible only by making investments in holding facilities for process feedstock, the amortized cost of which must be recovered, at least in part, from curtailment payments. Operating on-site generation incurs fuel and operation and maintenance costs.

Figure 2 provides a stylized example of the results of this load curtailment assessment process. The curtailment supply curve is interpreted as follows. On the horizontal axis, the first block of load is considered firm and non-curtailable. The remaining load represents the supply of curtailable load that is available at different curtailment prices, up to the maximum usage, represented by the customer baseline (CBL). The points on the vertical axis represent curtailment threshold prices (CTP). The facility would require a low curtailment price (CTP_L) to curtail the amount represented by the first load curtailment supply block (CS_L). Subsequent blocks (CS_M and CS_H) are available, but at higher payment levels (CTP_M and CTP_H). The curtailment supply curve of *Figure 2* furnishes the basis for the development of a bidding strategy by the customer. The curtailment supply curve represents the customer's cost of curtailment. The bid curve is fundamen-

*In assessing time required for electric uses/equipment to curtail, customers should create categories that are consistent with their ISO's specific notice requirements.

End-Use Inventory		Load Reduction Capabilities				Cost	
		Discretionary		Self-Supply	Labor Hours	Labor for Load Reduction/Fuel Cost	Cost ($/kWh)
HVAC	1,000 kW	Reset Thermostat	60 kW		2	$120	0.40
Lighting	900 kW	Dim Lighting at Perimeter	90 kW		2	$120	0.27
Escalators, Elevators	270 kW	Shut Off Escalators	100 kW		1	$60	0.11
Office Equipment/Other	850 kW						
Emergency Generator	450 kW			450 kW	1	$60 plus $0.12/kWh For Fuel	0.15
Total (Load)	**3,000 kW**		**250 kW**				
Total (Gen.)				**450 kW**			
Total (Load+Gen.)			**700 kW**				

Table 2: Inventory and characteristics of demand responsiveness for hypothetical building.

tally composed of the curtailment supply curve plus a profit or other bidding constraints that the ISO may impose. For instance, a bid curve with a 10% profit margin would elevate the price thresholds by 10% for the same load reduction amount.

We recommend that customers test their load curtailment strategy before committing to a DR program that has penalty clauses for non- or partial performance. Some ISO programs require customers to demonstrate that their subscribed or claimed load curtailments can be achieved.

Potential Benefits from DR Programs

To illustrate this load curtailment assessment process and the potential benefits of customers participating in ISO DR programs, we consider a hypothetical commercial building in New York City with a summer daytime peak demand of 3 MW and is considering enrolling in the New York Independent System Operator (NYISO) DR programs. In this example, we consider only usage in the discretionary and on-site generation categories. The facility manager estimates that he has 700 kW of load curtailment capability, about 23% of summer peak demand, comprised of 250 kW of discretionary load and 450 kW of self supply (*Table 2*). The costs for executing individual curtailment strategies include labor estimates to manually turn off equipment, monitor load curtailment performance and restore the load after the event. We estimated a labor rate of $60/hour. To evaluate the benefits of curtailing, we assumed a five-hour curtailment period (from noon to 5 p.m.) that is coincident with highest electric demand period for the building. *Table 2* shows total cost of each measure as well as the cost per energy unit curtailed over the five-hour event. Costs for individual load reduction strategies range between $0.11 and $0.40 per kWh. Other impacts on the facility such as valuing any reduction in service or amenity levels, which are more difficult to quantify, are not included.

Figure 3 illustrates the supply curve of selected load reduction measures inventoried in *Table 2*.

Given the results of the load reduction assessment, it appears to be cost effective for the hypothetical facility to participate in three DR programs: ICAP, day-ahead market and emergency resources.[§]

To estimate the potential benefits, we examine two scenarios: (1) manually executing and monitoring the measures and restoring the load after the event, and (2) a scenario in which the customer invests and upgrades the facility's energy management and control system (EMCS). The EMCS upgrade reduces the cost of dispatching load reductions by enabling the facility operator to remotely trigger and monitor the load reduction, and to restore the load after the event. To improve the flexibility and cost effectiveness of the automated load reduction dispatch, we estimated that it would cost about $32,000 for automation that included the installed cost for lighting and HVAC controls, and remote controls for the escalators. Additional controls for the emergency generator would cost $68,000. We assume that the customer has an interval meter that is sufficient for settlement and billing with the ISO. The future revenue estimates are based on price data from NYISO markets for the summer of 2001.[†]

The day-ahead market program requires customers (or load aggregators) to develop a bidding strategy based on curtailment availability, costs, and the likelihood of being scheduled given their forecast of day-ahead electricity market prices. For our example, the facility decides to bid curtailments at its curtailment cost for a five-hour time block (noon to 5 p.m.). Customers can bundle measures together and bid shorter time blocks (e.g., two hours), particularly if the inconvenience to the occupants is a significant concern, but that influences the revenue potential. In our example, at a bid price at $0.05/kWh

§ The emergency program benefits are not estimated in the following example because they are influenced by factors other than price. Because of the expensive telemetry requirements and the very short notification for the ancillary services and balancing, these two programs also are not considered in our example.

†NYISO price data for 2001 are available at: www.nyiso.com/markets/index.html.

(as used in the DR investment scenario), we estimate that the facility's bid would be accepted for 98 days based on 2001 NYISO prices in New York City. For a higher bid price, the chance lessens that the wholesale prices will exceed the bid price. As the facility's bid price is reduced, additional curtailments are scheduled, which increases their payments from the ISO (i.e., revenues to the customer).

The revenue for the five-hour curtailment of more than 98 selected days is calculated by multiplying the curtailment amount (kWh) by the hourly clearing price of electric energy ($/kWh) for the 98 curtailment periods. During these periods, the hourly clearing price of electric energy is equal to or greater than the bid price and changes every hour. The revenue estimates were determined based on NYISO market clearing price data of the day-ahead market for a six-month summer period in 2001.

The ICAP program requires 24/7 availability of the load curtailment resource for a minimum contract period of one month with two hours or less of response time. In our example, the emergency generator is the only resource that can meet the availability requirement since we assume that the facility cannot meet the load curtailment obligation by reducing loads if an event occurs outside of normal operating hours.

Table 3 summarizes estimated revenues and profits by the curtailment strategy for the two DR programs (day-ahead market program and ICAP). Results are provided for investment and no investment scenarios during a six-month summer period in 2001. The results indicate that the DR investment significantly lowers the curtailment cost, which permits the customer to lower the bid price to $0.05/kWh.‡ Thus, the revenues and the profits for the curtailment strategies are higher than those for manual load curtailment scenario. The investment in the EMCS system upgrade would increase annual profits by about $5,600. This represents a five- to six-year payback on the investment of $32,000. This payback time is at the lower end of the range and generally acceptable to these kinds of customers. But the enhanced automation capability from the upgraded EMCS system decreases the response time for these strategies. The customer can now seriously consider participating in the ICAP program and committing the 250 kW of load reduction measures, which would generate additional revenue of about $13,000 ($52.5/kW × 250 kW). Given the improved economics, the facility may be more willing to accept the relatively low risk that the ISO may call an ICAP event outside of the normal operating hours of the facility (e.g., nighttime).

We conducted a sensitivity analysis and applied an additional inconvenience cost of $2/kW to the cost of the lighting and thermostat reset measures. This inconvenience cost is based on an outage cost estimate and represents 50% of what is generally accepted to reflect the cost to customers of a curtailment on very short notice.[2] An inconvenience cost of $2/kW for the thermostat reset measure, on top of the operating cost for executing the measure, significantly raises the customer's curtailment costs

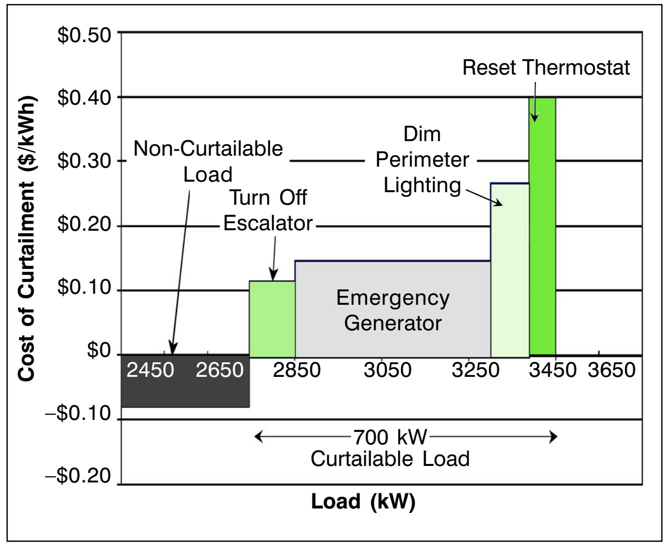

Figure 3: Curtailment supply curve for hypothetical building.

and bid price (from $0.05/kWh to $0.45/kWh), resulting in a decrease of annual revenue and profits. Using the example of *Table 3* for the DR investment scenario, the profits for the lighting and thermostat reset measure would be reduced from $3,600 to $300.

This example shows that many co mmercial customers may require either an up-front or ongoing payment to seriously consider investing in enhanced automation to participate in DR programs. Participating in ICAP-type markets provides the up-front reservation payments, which are particularly attractive if load aggregators or other third parties offer insurance products to cover losses incurred when ICAP calls do not coincide with the resource availability in the commercial buildings sector. In such a market environment where risk can be managed, DR activity and investment in DR automation will be more attractive to facility managers.

The economics of the EMCS-upgrade investment further improve when the entire value chain of the enhanced controls and monitoring capabilities is considered. This includes improved HVAC troubleshooting capabilities, energy efficiency monitoring, improved operation and maintenance opportunities as well as managing overall peak demand.

Conclusions

To assist facility managers in assessing whether and to what extent they should participate in DR programs offered by ISOs, we introduced a systematic process by which a curtailment supply curve can be developed that integrates costs and other program provisions and features. This curtailment supply curve functions as a bid curve, which allows the facility manager to incrementally offer load to the market with terms and conditions acceptable to the customer. We applied this load curtailment assessment process to a stylized example of an office

‡ For 2002, NYISO established a floor price for demand bidders in the day-ahead market of $0.05/kWh ($50/MWh).

				Day Ahead			ICAP		
	Measures	**Programs**	**Operating Cost ($/kWh)**	**Day Ahead Bid ($/kWh)**	**Revenues ($/kW)**	**Events**	**Commitment (kW)**	**Revenues ($/kW)**	**2001 Summer Profit**
Manual Load Curtailment, No DR Investment	Turn Off Escalators	Day Ahead	0.11	0.114	13.4	14			$500
	Turn Emergency Gen-set On	ICAP	0.15				450	52.5	$23,600
	Dim Lights in Perimeter Zones	Day Ahead	0.27	0.4	4.1	1			$200
	Reset Thermostats	Day Ahead	0.40	0.4	4.1	1			$100
								Total (Day Ahead)	**$800**
								Total	**$24,400**
Manual Load Curtailment With DR Investment	Turn Off Escalators	Day Ahead	0.02	0.05	39.9	98			$2,800
	Turn Emergency Gen-set On	ICAP	0.13				450	52.5	$23,600
	Dim Lights in Perimeter Zones	Day Ahead	0.03	0.05	39.9	98			$2,400
	Reset Thermostats	Day Ahead	0.04	0.05	39.9	98			$1,200
								Total (Day Ahead)	**$6,400**
								Total	**$30,000**

Table 3: Revenue and profit estimates for selected curtailment measures based on Summer 2001 NYSIO market data.

building, using programs offered by NYISO to provide detail and realism.[1,3]

Based on our stylized representation of customer circumstances imposed upon an actual DR program, we offer the following conclusions:

• ISO DR programs offer facilities new and potentially attractive opportunities to be compensated for load curtailments at market price.

• Discretionary loads that typically represent between 5% and 20% of summer peak demand using manual approaches, offer limited benefits.

• But, by offering even modest curtailments in low-risk programs, customers gain experience that can lead to expanded participation in programs with more attractive benefits, even though they are accompanied by greater risks.

• Investments made to automate these curtailment actions can enhance customer DR capability, but may have relatively long payback times (five years or greater).

• Participation in ICAP-type programs that offer up-front, reservation payments provides opportunities for a more certain stream of benefits that can help justify and support investments in upgraded EMCS systems. These enhanced automation capabilities also may enable facility managers to realize other benefits, such as the ability to manage and control peak demand, receive near-real-time feedback on hourly energy usage, and obtain improved energy information and general improved O&M capabilities. However, ICAP-type programs impose performance risks during off-hours when DR resources are not available.

• A facility that has a reliable on-site generator may recover any required investments in controls or reduced emissions relatively quickly in ISO-based capacity markets that offer up-front reservation payments. But, participation may be restricted by environmental regulations.

• Our research indicates that many facility managers are participating in emergency DR programs and earning cash benefits initially by using existing control systems, and time-honored and low cost actions such as manually switching off lighting and other discretionary equipment. Over time, we anticipate that this experience will provide them with the wherewithal to incrementally expand their curtailment capability so they can participate in other ISO DR programs with higher rewards.

In summary, facility managers should reevaluate the opportunities to turn their load management capabilities into cash.

Acknowledgments

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