OPTIMIZING DEMAND RESPONSE

A comprehensive DR business case quantifies a full range of concurrent benefits.

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Electricity load-serving entities (LSEs) face rapid peak demand growth, skyrocketing expansion costs, mounting risks with electricity resource siting, and unprecedented environmental constraints. As a result, the regulatory metric for resource selection has become least-cost, least-risk.

In this context, utilities and regulators increasingly are attracted to the benefits and market potential of new demand-response (DR) capabilities.

DR offers operational flexibility, and emerging third-party DR contracts minimize risks to LSEs and their customers. But after 25 years of using standard practices to evaluate DR's cost-effectiveness, the primary DR benefits remain poorly defined.[1] In most analysis to date, some of DR's most important wholesale and retail benefits have been given short shrift, or ignored completely. For example, the reduction in region-wide prices from the use of DR rarely is quantified or included at all.

It is well accepted that fast, dispatchable DR can avoid the capital and operating costs of peaking-power capacity such as combustion turbines (CT). Increasingly DR also is demonstrating its ability to avoid capital costs and energy losses related to transmission and distribution. DR resources can be offered and traded in capacity markets, and scheduled by an ISO/RTO to avoid operating reserves, short-term energy, and congestion costs.

DR offers a range of business-case benefits. High-value DR can avoid the need for incremental generation, transmission and distribution capacity, while providing environmental mitigation, reducing prices, helping to mitigate market power, and providing additional option value for market participants.

The challenge is to demonstrate how DR can be used to concurrently capture as many high-value benefits as possible. Optimizing DR capabilities to target the highest and best uses will allow utilities and their customers to achieve maximum value and net concurrent benefits.

Demand-Response Continuum

DR reduces electricity use with a spectrum of technologies ranging from simple manual controls to automated digital systems. Dispatchable DR can harness direct load-control (DLC) devices, load-management controls, smart thermostats, advanced metering infrastructure (AMI), and digital energy management systems (EMS). Digital controls can cycle and curtail discretionary loads (lights, motor drives, HVAC systems, *etc.*) and automatically be triggered by price or reliability.

A continuum of DR services illustrates its relative value in comparison to the supply-side capital and operating costs it can avoid. The ability of DR to reduce supply-side costs is largely a function of the following:

- The specific changes in load shape that result from DR;
- The long-term certainty (predictability) of DR over time;
- The short-term reliability of DR over time—*i.e.*, the equivalent of planned and forced outage rates;
- The response rate of DR—*i.e.*, the ramp-rate or load-shift rate; and
- The type of supply-side resources avoided and the subsequent costs reduced.

The ability to avoid supply-side capital cost is directly related to the certainty and predictability of the DR, its availability, and the speed of the DR response. DR that is highly certain and in place for a predictable time has the potential to avoid major supply-side capital costs. In the short-term, neither voluntary price response nor voluntary curtailment can avoid capital-cost additions, because neither are certain enough for planning purposes. The speed of DR in terms of response time must be comparable to the generation that it is credited with avoiding. Generation response is defined by ramp-rate—the ability to change power output in megawatts per minute. DR that responds as fast as a combustion turbine can qualify to avoid a CT. Moreover, DR that responds in an hour is much less valuable than either DR or a CT that responds in 10 minutes or less.

Dispatchable DR can avoid the need for new transmission and at the same time meet reliability requirements.

The short-term certainty of DR—reliability of operation—can be directly compared to the supply-side measure of forced-outage-rate (FOR), which indicates the expected frequency with which it will fail in use. A related measure is the planned-outage-rate (POR), defined as the portion of time the resource is unavailable, for such reasons as planned maintenance. In combination, FOR and POR reflect the amount of time a resource is forecast to be unavailable. DR can be directly compared to supply-side resources in terms of FOR and POR. The track record of some DR shows a low FOR and a POR of almost zero. This demonstrates that some DR resources are more than comparable to a CT, while other DR resources are inferior in terms of reliability.

Often DR is defined as either price response or reliability response. Going beyond this, a DR value continuum is based on two technology categories, dispatchable DR and voluntary DR (*see Table 1*). Higher-value DR can avoid significant long-term capital costs and variable costs. Low-value DR only can reduce short-run variable costs.

Greater value can be captured by DR resources that tap concurrent DR services. The highest value DR concurrently can provide major benefits from all seven benefit categories, includ-

TABLE 1 **DEMAND RESPONSE VALUE CONTINUUM**

Higher value demand-response (DR) capabilities can avoid significant long-term capital costs and variable costs, while low value DR can only reduce short-run variable costs. The left-hand column presents a continuum of DR technologies from highest value (Dispatchable) to lowest value (Voluntary Response). The seven remaining columns present specific DR value streams or benefit categories.

DR Technology Capacity/ Energy	Generation Capacity/ Losses	Transmission Capacity/ Losses	Distribution Benefit	Environmental Market Prices	Lower Power Mitigation	Market Value	Option
Dispatchable DR							
EMS/Auto-DR for fast ramping	High	High	High	Medium	High	High	High
DLC/EMS for Ramping	High	High	Medium	Medium	High	High	High
Auto-DR, price response certainty	High	High	Medium	Medium	High	High	High
Schedule trigger for price or congestion	High	High	High	Low	Medium	High	Low
DLC for 30 minute response	Medium	Medium	Medium	Low	Medium	Medium	NA
Voluntary DR							
Voluntary RTP/TOU	Medium	Low	Low	Medium	Medium	High	NA
Interruptible	Low	Low	Low	Medium	Low	Medium	NA

ing: 1) generation capacity and energy/congestion; 2) transmission capacity and losses; 3) distribution capacity and losses; 4) environmental benefits; 5) lower market prices for capacity and energy;[2] 6) market mitigation (price volatility and market power); and 7) option value to hedge risks and provide insurance.

Communications and controls are essential to leverage high-value DR technology. New AMI can leverage DR technology to provide greater certainty of DR control and to communicate results, which then allows the utility to harness concurrent benefits. Additionally, other direct consumer benefits allow utilities and regulators to address a range of customer concerns, including the ability to better control their utility bills, energy consumption and carbon footprint.

A critical question to answer is which specific services can a DR resource concurrently provide, to avoid the need for specific supply-side resources? DR resources that provide a larger portfolio of services obviously provide greater value.

Avoided Generation

DR's primary benefits arise from its ability to reduce or avoid generation resources, both in terms of fixed capital costs and variable energy costs.

Avoided variable costs include fuel, line and transformer losses, and variable O&M—the energy components of electricity costs. Both firm and non-firm DR resources properly can be credited with reducing specific variable costs.

In order for DR to be credited with avoiding supply-side capital cost it must avoid load equally or better than a comparable supply-side resource (proxy) would serve load if the DR weren't available. It must respond operationally as quickly as, or quicker than, the supply-side proxy. It also must be equivalent or better in terms of certainty and predictability, and must exhibit a ramp-rate that is equal or better than the supply-side resource. Finally, it must have comparable or higher short-term reliability (in terms of FOR and POR) than the supply-side resource.

DR's value for avoiding supply-side capital costs depends on the resource it's displacing. A critical distinction in power markets is the difference between firm power and non-firm power. Firm power is backed up by operating reserves (spinning reserves and non-spinning reserves), while non-firm power is not.

Avoided firm resources should account for, and sum up, all related capital costs and variable costs. Non-firm DR such as voluntary DR or voluntary price response is less certain, as it lacks the obligation to perform when a contingency occurs, such as a forced outage in generation or transmission. During repeated days of a heat-storm, voluntary price response becomes less reliable, because customer response to price declines as summer heat increases. DLC, on the other hand, performs as a firm resource with certainty and predictability, and thus can avoid the construction of dedicated supply-side resources.

Assessing Reliability

For DR to avoid a supply-side resource it must be needed for system reliability, or it must be more cost-effective than the replacement resource. In either case, the reliability of the DR resource must equal or exceed that of the supply resource it's displacing.

The need for long-run capacity may be based on LSE requirements to satisfy planning-reserve criteria, which usually are set by states. An alternative to planning-reserve criteria is regional or local resource adequacy (RA). RA better defines specific reliability requirements, including ramp rate and availability during specific hours and in specific locations.

Separately, operating-reserve (OR) requirements are defined in each region to ensure short-run reliability. OR includes at least non-spinning reserves (or cold reserves) and spinning reserves (hot reserves). Non-spinning and spinning reserves must be available on a timely basis under specific notice provisions and at pre-specified capacity levels. Thus, the ability of DR to qualify as OR capacity depends on its responsiveness and speed as well as its communications system.

DR can provide dispatchable ramping capacity that displaces older, less efficient, more polluting resources, and enables integration of renewable resources (*e.g.*, solar and wind resources).[3] The use of long-term dispatchable DR contracts to provide non-spinning reserve is accepted by the Western Electric Coordinating Council (WECC). Other DR features, such as verifiability, may needed to meet OR requirements.[4] PacifiCorp uses 90 MWs of residential and commercial DR on the Wasatch Front transmission constraint (the Cool Keeper resource) to satisfy WECC requirements for Non-Spinning Reserve.[5] Adding value, RA and OR criteria can be simultaneously satisfied by dispatchable DR that provides ramping capacity with certainty to meet system or local peak needs. Generally, this requires a loss-of-load-probability or loss-of-load-expectation analysis.

Dispatchable DR can operate during transmission or distribution contingencies to reduce peak loads on equipment and increase reliability. In these settings, DR preserves reliability and lowers equipment replacement and maintenance costs. At specific grid locations, DR can reduce the need for reactive power and reliability-must-run plants, both related to shortages in T&D or local generation capacity. Accordingly, long-term dispatchable DR can avoid the need for new transmission and at the same time meet RA and OR requirements.

In a recent California settlement on cost-effectiveness, major benefits are attributed to DR that avoids the cost of transmission and distribution.[6] DR benefits are particularly notable

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when they reduce T&D capacity requirements in load-growth areas. Avoided T&D benefits are attributable to DR resources that meet "right place" and "right certainty" criteria. These criteria are used to ensure DR is targeted to avoid specific T&D costs, namely: **1**) in load growth areas where construction of new electricity infrastructure is required but for DR; **2**) where specific DR resource increase power-delivery capacity; **3**) where DR can provide certainty of long-term load reduction and little risk of after-the-fact retrofit/replacement; and **4**) where DR is relied on to reduce local T&D equipment loads.

The track record for dispatchable DR shows that it produces a significant energy-efficiency effect.[7] DR applied to residential air-conditioning might cause building temperatures to increase slightly, but the reduced on-peak energy use usually is greater than the increased shoulder-peak energy use (during the snap-back period). This energy efficiency effect generally results in less NOx, SOx, and greenhouse gases (GHG).

Market Benefits

DR dispatched to meet reliability needs results in reduced capacity and energy costs and might yield congestion benefits. Areas with high local electricity costs can benefit substantially from DR, particularly if wholesale price caps are relaxed and prices reflect load-pocket and regional constraints without significant averaging. Hence, DR can be an excellent hedge against high local capacity, energy, and congestion costs.

LSEs in most ISOs/RTOs rely on out-of-market (OOM) power–that is, power imported from outside the market—during emergencies. As markets increasingly apply scarcity pricing to reflect super-peak market energy needs (*e.g.*, in ERCOT and CAISO), dispatchable DR can be delivered in OOM and scarcity pricing markets to provide additional benefits.

ISOs and RTOs have aimed to dispatch all DR before requests for OOM or scarcity pricing occur. But this stops DR from participating in these markets on comparable terms with generators. This suggests that revising ISO/RTO policies would enable DR providers to participate directly in OOM and scarcity-pricing transactions.

DR's use is limited in most jurisdictions to an option contract to provide electrical capacity under emergency conditions. The full option value of DR, however, does not reflect its value as

TABLE 2 — DEMAND RESPONSE BENEFITS

Demand response capabilities provide benefits in terms of both capacity and energy benefits, in both retail and wholesale markets. A comprehensive DR business case quantifies these benefits.

DR Contract Benefit Stream, Firm Resource	Capacity Benefits	Energy Benefits
Planning Reserve Margin or Resource Adequacy	LSE-Retail/ Wholesale Market	
Energy & Congestion Benefits		Wholesale Market
Grid Losses		Wholesale Market
Operating Reserves • Non-Spinning Reserves • Spinning Reserves • Frequency Regulation	Wholesale Market	
T&D Capital Cost Avoided	Wholesale/LSE-Retail	
Market Price Reductions	Wholesale Market	Wholesale Markets
Retail Losses		LSE-Retail
Environmental and GHG Benefits		LSE-Retail
Market Power Mitigation		Wholesale Market
Scarcity-Pricing		Wholesale Market
Out-Of-Market (bilateral)		Wholesale Market
Option Value	Wholesale Market	

Building a DR Business Case

A comprehensive business case for demand-response (DR) capabilities depends on a systematic process to quantify its costs, benefits and potential across a range of applications. Such a process includes the following steps:

- Define customer specific load-shapes based on particular DR technologies;
- Consistent with NERC, ISO/RTO, and LSE criteria, define each DR service in terms operations, certainty, response rate, and reliability;
- Specify the availability of the DR by customer group and location;
- Quantify and sum the major DR benefit streams and all related costs;
- Perform cost-effectiveness analysis in net-present-value terms; and
- Define scenarios that optimize DR resource mix and maximum value.

Major challenges include the difficulty of determining avoided capacity costs and relevant market prices for the period of the analysis. For example, T&D capital cost avoided must be defined for specific locations, and congestion benefits must reflect DR location and availability. Further, optimization to determine the highest-value uses of DR requires sophisticated management and analysis. From this analysis and further experience, refinements can be made to maximize concurrent DR benefits. –***ECW***

a hedge, particularly to reduce capital costs, fuel risk, price risk, counter-party risk, and to ensure sufficient fast ramping capacity given the increasing use of renewable resources.

DR has additional benefits because it is rolled out incrementally and can be used flexibly on a locational basis. Ideally, dispatchable DR would be traded as a standard financial product. To capture option value, a DR trader must be capable of maximizing its value, which requires sophisticated management.

Most DR resources have characteristics similar to a limited hydropower resource, which uses a finite quantity of water each season and thus might best serve peak capacity needs. Optimizing its use is a challenge. Likewise, most DR is constrained by the number of hours and the specific times when it is available. This suggests DR's value depends on optimizing its use for several key purposes:

- Meeting planning reserve margin (15 to 17 percent) or resource adequacy needs;
- Reducing super-peak prices and obtaining congestion benefits, directly or through congestion revenue rights (CRR) contracts;
- Displacing non-spinning or spinning reserves;
- Avoiding T&D capital and operating costs on specific circuits;
- Reducing emissions of NOx, SOx and GHG;
- Serving scarcity pricing or market-purchases at super-peak periods; and
- Exploiting the option value of load reduction.

Many of these value streams can be captured during normal DR operations with proper triggers and without double-dipping. A dispatchable DR resource concurrently can provide local resource adequacy, non-spinning reserves, and T&D avoidance, and then be dispatched to provide energy and congestion benefits, reduce grid losses, and lower NOx, SOx and GHG emissions. Of course, ISO/RTO rules must be observed to preclude false trading and to ensure committed resources remain available when called.

Concurrent Benefits

Today, DR is used largely as an emergency interruptible resource of value only after dispatch of all supply-side resources. This practice has constrained the role DR can play. Before DR can achieve its full potential as a cost-effective resource, a number of other impediments must be overcome, in both wholesale and retail markets. Most notably, supply-side and DR resources need to be valued on an equivalent basis. For example, in most wholesale markets, DR is credited with resource adequacy, but not with operating reserve benefits. A comparable CT, however, is credited with both.

To make a fair business case for DR, it should be compared directly with generation, transmission, and distribution resources. High-value DR captures a set of concurrent benefits, particularly when its use is optimized. Beyond this, DR coupled with AMI uses digital control and communications to produce higher-value services. Thus, next steps are to define the combined business case for DR plus AMI and energy efficiency resources. These combined resources will capture even greater concurrent benefits, allowing utilities to make the most rational and economical use of America's energy resources.

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ENDNOTES

1. See for example, C. Danforth and E. Woychik, *Standard Practice for Cost-Benefit Analysis of Conservation and Load Management Programs*, Joint Report of the California Public Utilities Commission and the California Energy Commission, February 1983.
2. See, Brattle Group, *Quantifying Demand Response Benefits in PJM*, PJM Interconnection and MADRI, Jan. 29, 2007; and Faruqui A., "Breaking Out of the Bubble: Using Demand Response to Mitigate Rate Shocks," *Public Utilities Fortnightly*, March 2007.
3. See, *e.g.*, California Public Utilities Commission Decision 07-12-052 (20 December 2007) on *Long-Term Power Procurement*.
4. See, CAISO *Demand Response Resource Users Guide: Version 3.0*. This explains how DR can qualify as Participating Load to directly provide Operating Reserve including Non-Spinning Reserve.
5. J. Bumgarner, *Smart Energy Today: The Right Tools for the Job*, PacifiCorp Energy, 2007.
6. Comments of Large Energy Consumers Association, Comverge, Inc., Division of Ratepayer Advocates, et al., in CPUC R. 07-01-041 (19 November 2007), Appendix A.
7. Nemtzow D., D. Delury, and C. King 2007. The Green Effect, *Public Utilities Fortnightly*, March.