

DRIVERS OF DEMAND RESPONSE ADOPTION: PAST, PRESENT, AND FUTURE



Issue Brief

Kelly Smith

Global Energy and Sustainability, Building Efficiency
Johnson Controls

Ryan Hledik

Senior Associate
The Brattle Group

The Brattle Group

INTRODUCTION

There is an important new approach to managing today's electricity grid in the United States and beyond. Demand response (DR) – temporary changes to electric loads in reaction to conditions in the grid – is increasingly seen as a central component of the “smart grid” of the future. In the U.S., the aggregate impact of DR is estimated at 58 GW, or 7.6 percent of the peak demand,¹ up 42 percent from two years ago.² The Federal Energy Regulatory Commission (FERC) views the potential for further cost-effective DR to reach as much as 20 percent of the system peak.³ Today, the cost-benefit analysis for DR is underway for electric systems around the world. Proponents point to cost savings, potential environmental benefits, and increased reliability as reasons to invest in a more responsive electric system.⁴

¹ FERC “2010 Assessment of Demand Response and Advanced Metering” (2011)

² FERC “2008 Assessment of Demand Response and Advanced Metering” (2008)

³ The “Full Participation” scenario from FERC “A National Assessment of Demand Response Potential” (2009) <http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf>

⁴ Ahmad Faruqi, Ryan Hledik, Sam Newell, and Hannes Pfeifenberger, “The Power of Five Percent,” *The Electricity Journal*, October 2007.

⁵ See <http://www.conservationsminnesota.org/news/?id=2618>

While DR has gained traction among stakeholders in the U.S. electricity industry (e.g., utilities, regulators, customers and service providers), its adoption has varied significantly across geographies. Some regions have embraced the concept and show remarkable results – one electric cooperative in Minnesota reports that nearly half of its 700,000 residential customers are enrolled in a program that allows utilities to remotely cycle off their air conditioners during peak events.⁵ In contrast, other areas have developed little or no DR.

This paper explores why DR has taken strong hold in some places and not others. By analyzing a set of potential drivers and the levels of DR achieved, we present a first attempt to explore the evolution of DR in recent years and characterize the factors that will influence its role in the future. The analysis uses publicly available data to assess relationships between DR participation and potential drivers.

This is not a rigorous and comprehensive statistical analysis. Rather, the objective is to identify possible drivers qualitatively and test their impact by examining basic patterns in the data. Further, many of the parameters assessed here are related and cannot be interpreted as independent drivers of DR. For example, a state may have low electricity prices because it has a high reserve margin and few reliability concerns, possibly because of a large share of base load generation capacity. Although each of these characteristics is assessed separately in the analysis that follows, it is clear that they are interdependent and must be considered together to present a complete picture of the drivers of DR in that state or region. In addition, factors that do not reveal a correlation in recent data may be emerging as drivers, and a similar analysis performed two or three years from now may give different results.

Table 1 summarizes the potential drivers of DR analyzed for this study and where correlations were identified. The final section presents ideas for developing a framework for future research.

Table 1: Drivers of Demand Response

Drivers	Correlation Identified?
Average retail price of electricity	Yes
Electricity market structure	Yes
Presence of demand-side policy/regulation	Yes
Generation mix	Yes
Reserve margin	Yes
Weather	No
Frequent historical outages	No
Load and population growth	No
DR incentive levels	No
Customer attributes (incidence of central AC, fraction of residential customers)	No

⁶ While we believe the FERC study to be the most complete and accurate depiction of available, enrolled demand response assets in the U.S., it does not present a complete picture because it is only one point in time and depends on how DR was reported by utilities. Our reliance on the FERC assessment also means that we have adopted the definition of DR that was used in that study, which excludes the impacts of permanent load shifting measures (such as time-of-use pricing) and backup generation.

⁷ Data are available in the NADR Model, available for download at <http://www.ferc.gov/industries/electric/indus-act/demand-response/dr-potential/assessment.asp>

⁸ NERC ensures the reliability of the electric grid in North America. Its regions and subregions correspond to the physical infrastructure of the grid, and therefore do not align with state boundaries or other distinctions familiar to many readers. A map of NERC regions is available at <http://www.nerc.com/page.php?cid=1191119>.

EXPLORING THE DRIVERS OF DR

Throughout this report, the primary data source for existing DR penetration is the 2009 FERC study,⁶ “An Assessment of National Demand Response Potential,” which reports the enrolled levels for each state in 2008.⁷ To normalize for the size of the various states, DR enrollment is presented as a percentage of peak demand. In some cases, the dataset was filtered to view a specific customer class or program type. In addition to this study, utility-level DR resources were analyzed for the electric utilities that responded to a 2008 FERC survey. Finally, the North American Electric Reliability Corporation (NERC) provided annual DR and reserve margin data at the level of NERC regions.⁸

The analysis was performed with available data in its original form, with no attempts to map or translate between the utility, state, or regional level. The availability of detailed data on DR is a limitation; future work will benefit from the expanding and improving datasets being created across the U.S. and globally. For the present, we use high-level data on DR enrollment by state or region, although more can certainly be learned by exploring various DR product types (daily, hourly, ancillary services), program structures (event-based, price-based), attributes (inclusion of onsite generators as DR) and administrators (regulated utility, competitive retail supplier, third party service provider).

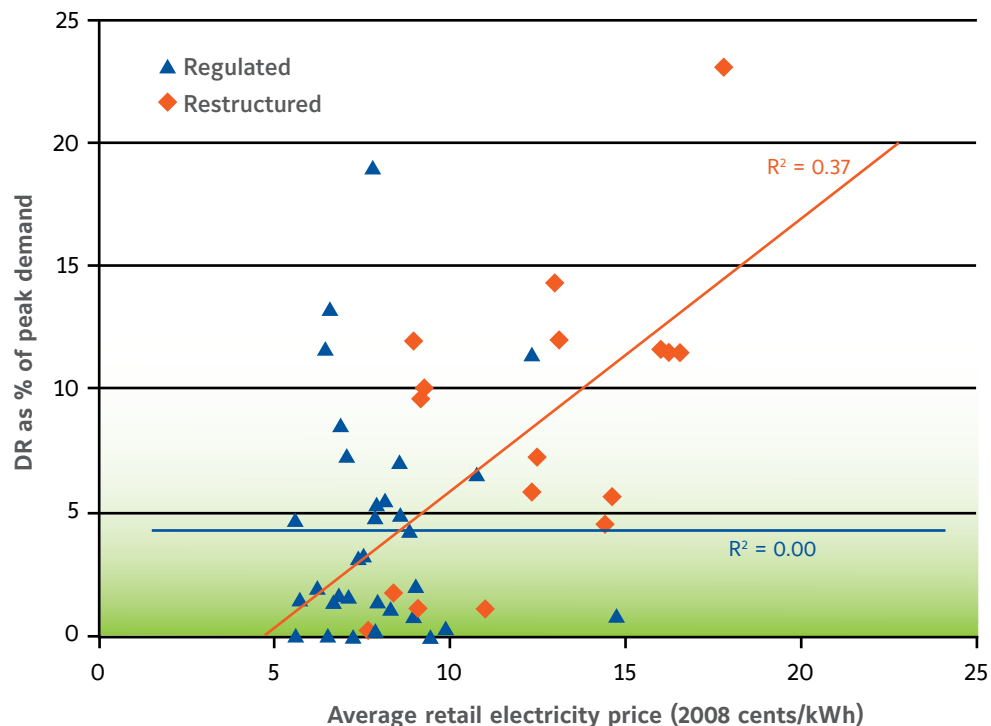
Factors with Correlations Identified

Cost of Electricity

One natural driver for DR is the price of power, especially during peak times. By calling on customers to curtail load, utilities and grid operators can avoid purchasing expensive peak power on the spot markets. In theory, regions with high electricity costs would benefit the most from DR and should therefore pursue more programs and resources. Similarly, customers in high-priced systems should have a stronger incentive to enroll, as they would receive higher rewards through shedding load. A further benefit of DR to customers is the potential for wholesale price mitigation, which is the overall lowering of the marginal electricity price during DR events due to a downward shift in the demand curve. In markets where supply is tight, this impact on market prices can be significant.⁹

A simple proxy for the total (“all-in”) cost of power is the average retail electricity price, available at the state level through the U.S. Energy Information Administration. Average price is different from peak price and is therefore not the ideal variable, but it is analyzed here due to data limitations. The plot of DR enrollment against the retail price of electricity is presented in Figure 1. For the 49 data points in this set (50 states and Washington, D.C., excluding outliers¹⁰) there is a positive correlation between average electricity price and DR enrollment.¹¹

Figure 1: Average retail electricity price versus DR penetration by state



⁹ The Brattle Group, "Quantifying Demand Response Benefits in PJM," prepared for PJM Interconnection, LLC, and the Mid-Atlantic Distributed Resources Initiative (MADRI), January 29, 2007.

¹⁰ In this and other analyses presented in this report, we define outliers as points three or more standard deviations away from the mean.

¹¹ A value of 1.0 would indicate that the electricity price and demand response adoption are perfectly related in a linear fashion. A value of 0 would indicate that there is no linear relationship between the two variables, and a negative value (between 0 and -1.0) indicates an inverse relationship between the two variables.

While there appears to be a positive link between expensive electricity and higher levels of DR, there are important subtleties behind the numbers, suggesting that the retail price of electricity is not the only factor driving DR.

1. Some states, such as Hawaii (excluded as an outlier), have high electricity prices but no significant DR resources. This could be due to customer attributes (e.g., low saturation of central air conditioning) or the evolution of policy supporting demand-side measures in these states.
2. Market structure plays a role. In restructured states where electric generation is separated from retailer providers (red points in Figure 1), the correlation between the average price and the level of DR is strong. However, states with regulated wholesale markets (blue points) show no correlation. (See below for further discussion on market structure.)
3. A wide distribution and relatively low R-squared value suggest that, although average retail price appears to be significant, other factors certainly affect the level of DR enrolled in a particular state.

Electricity Market Structure

The economics and the logistics of DR vary significantly across the U.S. and in other developed countries. While the basic concept is consistent everywhere, there are numerous variations in the details – communication formats between grid operators and customers, notification times, event-triggered incentives or time-dependent prices, and measurement and verification requirements. Market structure is important to DR; in many cases an organized wholesale power market facilitates DR,, and the rules and conditions of the particular market define the opportunity for customers, enhancing or hindering participation. The power market can be categorized in three primary ways, which are not mutually exclusive. Each is correlated with DR penetration.

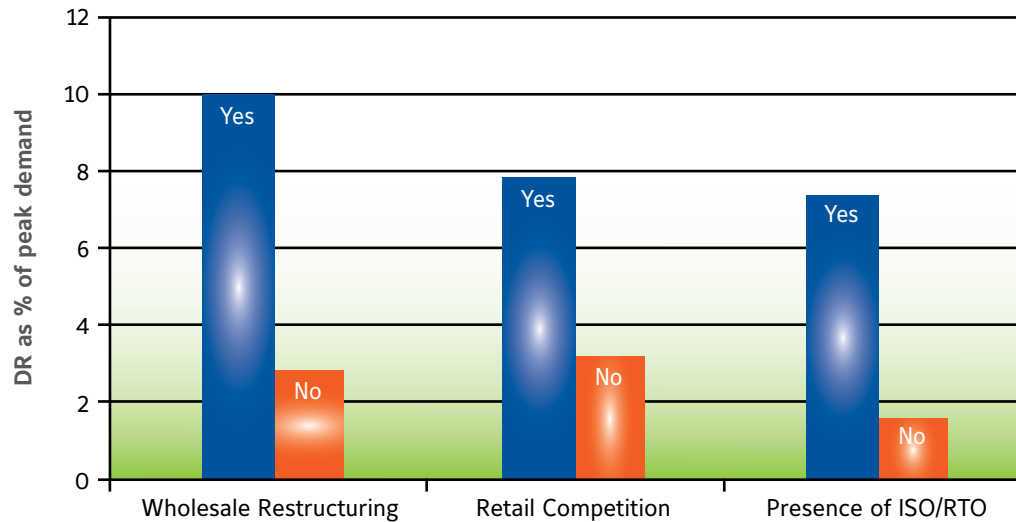
1. Wholesale market restructuring – With 18 states at some stage of restructuring (generation assets owned by companies other than utilities), there is an opportunity for demand reductions to participate in the supply side of the market. This factor has become more important through the efforts of the FERC, which has sought equality between supply- and demand-side resources in the interstate power markets it regulates.¹²
2. Retail competition – Breaking from the traditional vertically integrated utility model, 19 states have created competitive retail markets for electricity in which each customer can choose from multiple suppliers. Through competition, retailers can create innovative tariffs and rate structures, suggesting the possibility for attractive benefits for customers able to shed load.
3. Presence of ISO/RTO – Approximately two-thirds of the electricity customers in the U.S. are located within Independent System Operator (ISO) or Regional Transmission Operator (RTO) regions – organizations responsible for ensuring that the lights stay on.¹³ Several of these entities (PJM, ISO-NE, NYISO, ERCOT) have emerged as important players in DR by facilitating the market transactions that allow DR resources to benefit from their participation. The ability for DR to participate in the capacity market is particularly important, as avoided capacity cost is typically the primary financial benefit DR programs provide.

¹² Federal Energy Regulatory Commission Order 719, "Wholesale Competition in Regions with Organized Electricity Markets" 18 CFR Part 35, October 2008.

¹³ See www.isorto.org

For each of these factors, market structure is correlated with higher levels of DR. As shown in Figure 2, the DR resources enrolled in a state are highest when restructuring, retail competition, an ISO or RTO, or a combination of these exists.

Figure 2: Electricity market structure and DR penetration



As expected, there is significant overlap between the states making up these groups. These correlations are not mutually independent, but they can be viewed as a general trend toward an open, competitive and structured electric power market. The relative success of DR in regions with these characteristics suggests that similar markets could be good candidates for DR.¹⁴

However, the relative immaturity of demand-side resources' participation in wholesale electricity markets leaves questions. For example, how much of the DR resources reported by the market players are truly unique, as opposed to double-counting potential load reductions that are enrolled in other programs? Also, some market rules allow distributed generation (e.g., diesel-fired backup generators) to enroll as DR, while others do not. Both of these factors suggest that the levels of DR reported here may overstate the actual load reduction available to the grid. In addition, the market mechanisms that determine the conditions for DR participation are in flux; how will the rapid growth of DR in wholesale markets affect the broader picture (e.g., prices and auction results)?

Market structure appears to be important for cultivating DR, but it is not the only factor. In fact, DR has been shown to thrive in regions that have not been fully restructured. In California, for example, regulatory initiatives and the efforts of utilities and their contractors have led to significant impacts (approximately 5 percent of peak demand), despite the absence of a centralized capacity market.¹⁵

Strength of Demand-Side Policies and Regulation

While the structure of the electricity market and its operating conditions provide a foundation for DR, there are also policies that affect the uptake of DR in a particular state. In the U.S., it is common for electric distribution utilities to be regulated by a commission of elected or appointed officials.¹⁶ In addition, many state legislatures have mandated improvements in energy efficiency and other demand-side initiatives, and this trend has increased in recent years. Even in so-called "deregulated" jurisdictions, the FERC is active in defining the rules by which the markets are run. Policy is therefore a crucial component of the DR landscape in any area.

¹⁴ This will, however, still depend on the specific system conditions in the region – if a region with a restructured power market has, for example, very high reserve margins and/or low capacity market prices, DR may have lower market penetration.

¹⁵ In California, bilateral contracts for capacity are established in order to meet a state-mandated resource adequacy requirement.

¹⁶ Virtually all investor-owned utilities are regulated, as well as some electric cooperatives and municipal utilities.

Two data sources were employed to examine the impact of policy on the penetration of DR.

1. The presence of legislative or regulatory actions that directly support DR. The source for this data is a legislative primer document produced by the Demand Response Coordinating Council, including state-by-state assessments of DR policy in the U.S.¹⁷
2. The general legislative climate supporting energy efficiency in the state. To characterize the policy support for efficiency, the state scorecard analysis by ACEEE was applied.¹⁸

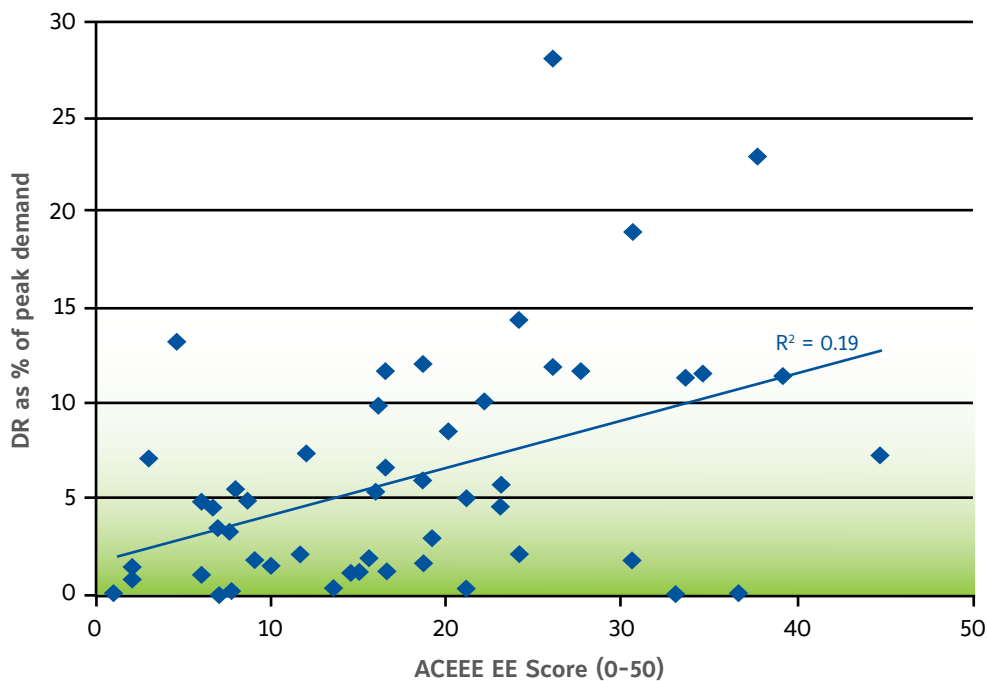
Both strong DR policy and a high energy efficiency score correlate with higher levels of DR. Table 2 shows the average DR levels for states with and without devoted DR policy, indicating that states with supportive demand-side policy have more than double the penetration of DR than those without, with a statistical confidence of 95 percent.¹⁹

Table 2: DR-enabling policy and level of DR enrollment

	Median DR Level (% of peak demand)
No DR Policy	2.9
DR Policy	10.0

A similar effect is evident when comparing the energy efficiency scorecard ratings of states (a general indication of a state that takes a proactive approach to demand-side initiatives). As displayed in Figure 3, states with a higher score for energy efficiency appear to show somewhat higher levels of DR, even though the ACEEE rating does not explicitly account for DR.

Figure 3: State energy efficiency score versus DR penetration



¹⁷ U.S. Demand Response Coordinating Council, "Demand Response and Smart Metering Policy Actions since the Energy Policy Act of 2005," prepared for the National Council on Electricity Policy, Fall 2008. http://www.demandresponsecommittee.org/Final_NCEP_Report_on_DR_and_SM_Policy_Action_08.12.pdf

¹⁸ Maggie Eldridge, Max Neubauer, Dan York, Shruti Vaidyanathan, Anna Chittum, and Steve Nadel, ACEEE, "The 2008 State Energy Efficiency Scorecard" (2008). <http://www.aceee.org/research-report/e086>

¹⁹ To test the statistical confidence of this effect, we utilized hypothesis testing based on t-score statistics, a method suited to small sample sizes. This method assumes a normal distribution for the two sets of data (with and without DR policy).

Interestingly, the impacts of DR policy and energy efficiency policy are similar when it comes to driving DR participation. This can be partially explained by the cognitive link between these two from both the utility and policy perspectives. In many organizational structures, both DR and energy efficiency are included as demand-side management, and indeed there is significant overlap between the states with DR policy and those scoring high on the energy efficiency rating.

Again, neither of these correlations is strong enough for policy to be considered the only factor shaping the penetration of DR. But directionally, it is clear that policy plays a role.

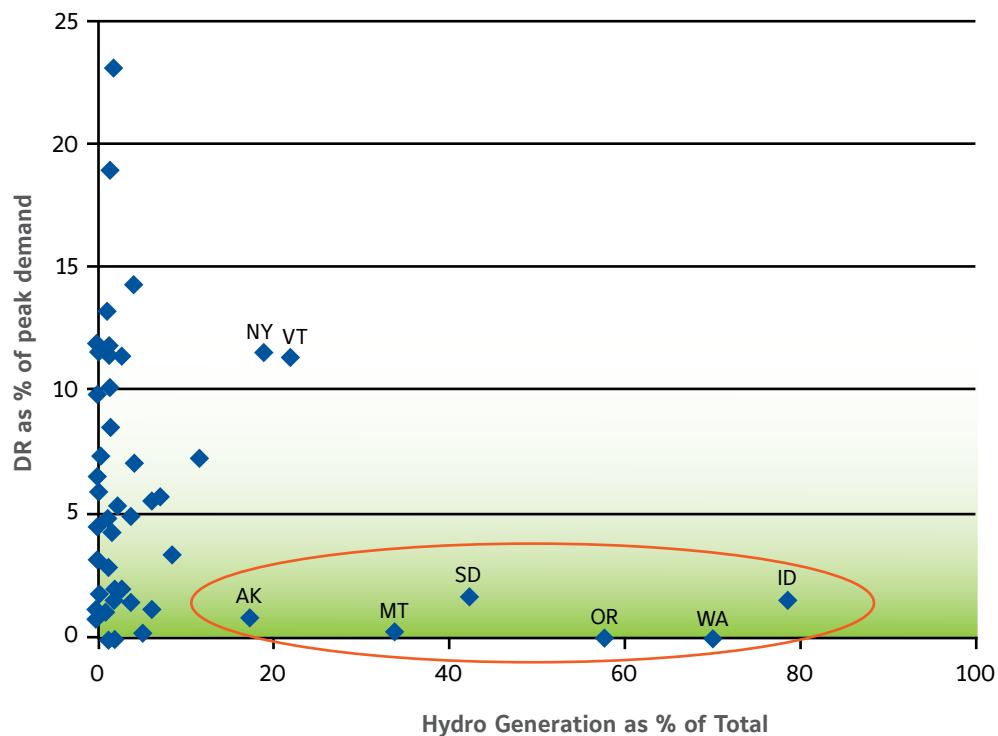
Generation Mix

An interesting exception to the link between progressive policy and DR is the Pacific Northwest, where regulators, utilities, and other stakeholders have been pursuing efficiency for decades and yet have little DR participation today.^{20,21} One explanation for this discrepancy is the high quantity of hydroelectric generation in the region, which provides significant peaking capacity but is energy constrained. In addition to the renewable nature of the resource, hydro power has built-in energy storage capacity, as operators can adjust the flow of water to the turbines to accommodate changing demand. By relying on this inherent storage capability, hydroelectric operators can alleviate peak demand issues and thereby reduce the need for DR. This seems to be a factor in the evolution of DR in the Northwest, evidenced by the tail of high-hydro, low-DR points in Figure 4. An important note here is the “tipping point” at which hydroelectric resources can no longer provide adequate flexibility for the system. Operators in hydro-heavy regions are seeing these events with increasing frequency in the face of growing load, annual fluctuations in the water level, and increasing policy constraints on hydro plant operations. As a result, decision-makers in these regions are turning to DR to mitigate risk and improve system economics.

²⁰ DR has fluctuated over the years in the region served by the Bonneville Power Administration. In Oregon, for example, there are 5 MW of non-generation demand response resources today. However, during the Western Electricity Crisis of 2000-1, estimated DR reached as high as 335 MW. (See Schwartz, 2003)

²¹ Lisa Schwartz, Oregon Public Utilities Commission, “Demand Response Programs for Oregon Utilities” (2003).

Figure 4: Fraction of hydroelectric generation versus DR penetration (2008)

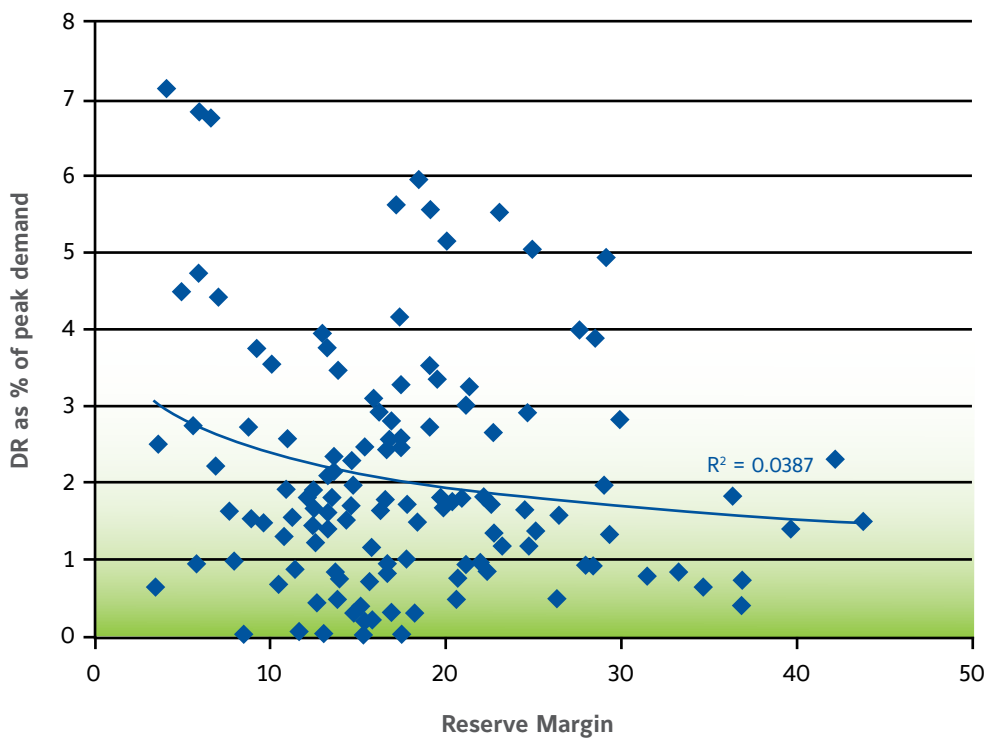


Reserve Margin and Reliability

One of the most frequently mentioned benefits of DR is its ability to alleviate short-term reliability concerns on the electric grid. With aging infrastructure and rapidly increasing demand for power in many parts of the U.S., balancing supply and demand has presented a challenge.

Because of its ability to be quickly deployed without major infrastructure investments, DR has been proposed as one solution to maintain sufficient reserve margins.²² To test the adoption of this theory in practice, annual reported reserve margins from 22 unique NERC regions and subregions were compared to NERC data on DR for the same regions, between 2003 and 2010. The results of this comparison are displayed in Figure 5.

Figure 5: Reserve margin versus DR penetration, by year and NERC region



²² Reserve margin is a measure of electric system health, representing the degree to which the capacity of the system exceeds the expected peak demand. For this report, a simple reserve margin was calculated using data from NERC; for each region, reserve margin is the total capacity divided by the internal demand, minus one.

As expected, regions with higher reserve margins have lower levels of DR. The correlation (logarithmic for best fit) is much weaker than those presented above; there are many instances of low DR coupled with slim reserve margins and high DR levels with healthy reserve margins. However, the directional relationship in these results suggests that, at least to a small degree, the designers and operators of power markets are viewing DR as a viable option for managing the grid. This uptake is remarkable considering the strong emphasis on reducing risk in the power industry; DR has very limited performance data when compared to conventional generation assets, and those concerned with grid reliability raise questions about the duration of DR resources beyond the short (1-3 year) contracts typical among today's participants.

As noted above, U.S. DR in the last decade has been characterized primarily by its use as a capacity resource, with curtailments of several consecutive hours (e.g., hot summer afternoons). While DR appears

to have been used as a solution for conventional peak demand issues, the rise of Renewable Portfolio Standards and other policies is quickly changing market dynamics and system needs. With high fractions of electricity provided by variable energy resources such as wind and solar, it could be necessary to compensate for unexpected variations of up to 20 or 30 percent of the total system load on a short timescale (clouds covering solar panels or sudden drops in wind²³). In the future, the reliability value of DR has potential alleviate these problems, any day, anytime.²⁴

Factors Without Correlations Identified

While the factors explored above appear to have had an impact on the evolution of DR adoption, several other potential drivers did not reveal a correlation with the level of DR. This does not necessarily rule them out as possible explanatory variables for DR adoption rates. Rather, additional analysis is needed to better understand their relationship to DR market penetration in the past, and could reveal correlations in the future. In some cases, these drivers may represent untapped opportunities for DR.

- **Weather** – DR is often suggested as a mitigating solution for peak electrical demand caused by large cooling loads on hot days. However, we could find no correlation between average summer temperature extremes and levels of DR participation. One explanation for this is a discrepancy in the data. DR participation is expressed in terms of enrollment, which would depend on system planning that typically assumes average weather conditions. It is likely that DR events are called more often during times of extreme temperatures, and therefore we might expect to see a correlation if performance data (rather than enrollment) were available.
- **Frequent outages** – To test the possibility that DR has been implemented to mitigate blackouts and brownouts, we compared DR levels with the frequency and impact of reliability events. The data source for reliability is a paper from Lawrence Berkeley National Laboratory tracking the reliability of the U.S. electric power system.²⁵ We found no correlation. However, the fact that calls to DR resources are included in the emergency protocols for many electric systems proves that DR is used as a reliability “backstop.”²⁶
- **Load and population growth** – In places where growth is significant, DR has been recommended as an alternative to building new capacity. However, we found no evidence that areas with stronger growth (both electric load and population) have achieved higher levels of DR. The state-level forecasts in the National DR Potential Study provided the data source.²⁷
- **DR incentive levels** – Perhaps surprisingly, the level of utility incentives provided for DR does not appear to be a factor in driving participation. To test incentive level, we compared the average incentive for peak reductions (\$/MW) reported in the Energy Information Administration’s Form 861.²⁸
- **Customer attributes** – DR has been particularly successful among certain sectors and customers with particular attributes. For example, large industrial customers provide bulk reductions under interruptible tariffs, and residential air conditioners are important for direct load-control programs. However, the data analyzed for this report do not reveal a significant role for customer attributes in driving overall DR levels. Using data from the FERC potential assessment, we examined sectoral mix (residential, commercial, industrial) and saturation of residential central air conditioners. Neither revealed a correlation with DR participation.

²³ In 2008, a drop in wind power combined with other factors to create a reliability condition in Texas. Within ten minutes of the shortfall, over 1,100 MW of demand response resources were activated, alleviating a potential blackout and allowing the system to recover. See <http://www.reuters.com/article/2008/02/28/us-utilities-ercot-wind-idUSN2749522920080228>

²⁴ The phrase “any day, any time” originates from the Demand Response Research Center at Lawrence Berkeley National Laboratory, where researchers are increasingly interested in “Fast DR” as an ancillary service.

²⁵ Joseph Eto and Kristina Hamachi LaCommare, Lawrence Berkeley National Laboratory, Tracking the Reliability of the U.S. Electric Power System,” October 2008. <http://eetd.lbl.gov/EA/EMP/reports/lbnl1092e-puc-reliability-data.pdf>

²⁶ Personal correspondence with John Moura at the North American Electric Reliability Council, January 2011.

²⁷ FERC “A National Assessment of Demand Response Potential” (2009) <http://www.ferc.gov/legal/staff-reports/06-09-demand-response.pdf>

²⁸ U.S. Dept of Energy, Energy Information Agency Form 861, File 3 (2008): <http://www.eia.doe.gov/cneaf/electricity/page/eia861.html>

POTENTIAL FUTURE DRIVERS OF DR ADOPTION

There are several potential future uses of DR that could act as drivers of program adoption in the longer term. Expanding markets, increased adoption of technology, energy and climate policy, and even economic recovery could affect DR in the coming decade. Here are a few potential drivers.

- **Market expansion** – While DR has evolved from interruptible power arrangements between utilities and large industrial customers and direct load control programs that cycle off residential air conditioning, it has been slow to penetrate the bulk of the commercial sector, where customers insist on maintaining control over their operations and require attractive terms to participate. As the marketplace evolves through innovative business models and enabling technology, more customers will be interested in an expanding array of DR opportunities, expanding the resource around the world.²⁹
- **Climate policy** – As economies around the world evolve toward reduced greenhouse gas emissions and low-carbon growth, there is a need for technology and market solutions that enable this change. DR is part of a more flexible electricity system, allowing both supply and demand to interact frequently and at scale. In a carbon-constrained world, this flexibility can shift generation away from greenhouse-gas-emitting sources and therefore reduce carbon emissions in a meaningful way.³⁰
- **Renewable energy policies** such as Renewable Portfolio Standards and Feed-in Tariffs – In many U.S. states and European nations, significant amounts of renewable, variable energy resources are expected to come online in the next five to 10 years. Grid operators are tasked with identifying cost-effective ways to integrate these variable resources into the market without sacrificing system reliability. DR is being considered as one potential solution. In particular, automated (technology-based) DR, such as direct load control, has the potential to provide fast response that could potentially participate in ancillary services markets, such as spin or even regulation.³¹
- **Wholesale energy markets** – In addition to the capacity markets that have been central to the development of DR in parts of the United States, wholesale market operators administer energy markets in which participants (traditionally power generators or day-traders) buy and sell power on an hourly or more frequent basis. Some of these markets have opened up for DR resources to participate, and policy has been proposed that would encourage the inclusion of DR in energy markets across the country.³²
- **Smart metering** – As advanced metering infrastructure continues to be deployed to customers across the U.S. and internationally, many retailers will be taking full advantage of the new capability that this infrastructure offers by providing customers with innovative rate designs and technologies that are designed to produce more responsive demand.
- **Electric vehicles** – Another potentially valuable future use of DR is to encourage efficient charging patterns in regions with high levels of plug-in electric vehicle (PEV) adoption. Left uncontrolled, PEV charging could lead to significant increases in the system peak, as owners return from work in the early evening and plug in their vehicles. A well-designed time-of-use rate could encourage charging during lower-priced off-peak hours. Additionally, direct control of the charging devices could be used to address location-specific reliability issues caused by unexpected levels of PEV charging.

²⁹ Kelly Smith and Michelle Quibell, "Technology in Commercial Buildings: a Key to Scaling up Demand Response", Institute for Building Efficiency, July 2010. http://www.institutebe.com/InstituteBE/media/Library/Resources/Smart%20Grid_Smart%20Building/Issue-Brief--Scaling-Up-Demand-Response.pdf

³⁰ Meg Gottstein and Lisa Schwartz, "The Role of Forward Capacity Markets in Increasing Demand-Side and Other Low-Carbon Resources," Regulatory Assistance Project, May 2010. http://raponline.org/docs/RAP_Gottstein_Schwartz_RoleofFCM_ExperienceandProspects2_2010_05_04.pdf

³¹ Theodore Gates Hesser, "The Future of Demand Response," prepared for the Natural Resources Defense Council, September 2010.

³² FERC Notice of Proposed Rulemaking, 18 CFR Part 35, August 2010. <http://www.ferc.gov/EventCalendar/Files/20100802113647-RM10-17-000.pdf>

CONCLUSION AND NEXT STEPS

In this paper, we have identified some of the key drivers of DR adoption based on an analysis of available historical data. Energy price levels, market structure, demand-side policy, generation mix, and reserve margin all appear to have an impact on the market penetration of DR programs. However, none of these relationships represent a strong correlation, suggesting that the reality of DR evolution relies on a combination of these and other drivers. Other factors, such as demand growth rate and outage frequency, could also play a role but did not reveal correlations in the data examined here; they require further exploration. Additionally, future drivers like renewables integration and PEV charging do not appear in the historical data but could influence the path DR takes in the longer term.

We have also identified important next steps for research in this area. Specifically, the quantitative approach for determining the extent to which each of these drivers influences adoption could be improved through a more rigorous econometric analysis. This approach would involve developing a single regression model, with the various drivers of DR as explanatory variables of DR market penetration. Such an approach would allow us to account for interactions between the explanatory variables and develop an estimate of the relative predictive power of each variable. One challenge in this approach is the availability and resolution of the necessary data. While data on some of the DR drivers described above is available at the state level, other data is only available at the regional, ISO, or utility level. Mapping the data to a consistent level of geographic granularity – and filling in the data gaps – is feasible and is likely to produce new insights and findings, but that would require further research and analysis.³³ Introducing further granularity in the analysis could also lead to new insights – for example, distinguishing between price-triggered DR and reliability-triggered DR and separately quantifying the impact of the drivers of each.

³³ This approach would, of course, require a sophisticated analytical framework to account for the relative importance of variables that are not independent (e.g., policy impacts market structure, reliability impacts price).

Ultimately, this analysis is a starting point. An understanding of the historical adoption of DR will help identify settings where advancing DR will be valuable. A key pivot in the DR landscape identified in this research is the role of policy. In restructured, competitive markets, the rulemaking process of regulatory entities can facilitate DR by allowing it to participate alongside electric supply. In vertically integrated regions, regulatory actions can align incentives for utilities and legislation can drive DR programs. With an important stake in the development of DR in the future, policy-makers at both the state/territory and national level can benefit by analyzing the experience of the past. In addition, this analysis can support utility planners, service providers and other stakeholders seeking to expand the influence of this resource as we move toward the smart grid of the future.

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ABOUT THE AUTHORS

Ryan Hledik is a senior associate based in the San Francisco office of The Brattle Group, an economic consulting firm. His expertise is in assessing the impacts, costs, and benefits of smart grid programs and strategies. Mr. Hledik received his M.S. in Management Science and Engineering from Stanford University. The views expressed here are solely those of the author and are not necessarily shared by The Brattle Group or its clients.

Kelly Smith is a program manager at the Johnson Controls Institute for Building Efficiency, where he drives research and analysis on demand response, smart grid and energy efficiency. His interests include the market, policy and technology issues behind efficient, high-performing and sustainable buildings. Mr. Smith earned his M.S. in plasma physics at the Massachusetts Institute of Technology.

If you are interested in contacting the author(s), or engaging with the Institute for Building Efficiency, please email us at: instituteforBE@jci.com.

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