Two kinds of demand-response

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The North American heat wave of 2011 saw temperatures on the eastern seaboard soar past 100°F as grid operators watched peak power consumption break records.[1] This kind of persistent heat has traditionally induced blackouts or brownouts, but not in 2011. The difference? America's PJM and other grid regions had added unprecedented amounts of demand-response capacity onto the grid. For the first time, grid operators can now bend and shape electricity *demand*, almost as they have traditionally dispatched electricity *generation*.

This growing control over electricity demand has far greater potential than most realize, and has terrific implications for making large-scale renewable energy feasible. Shaping demand is a tool for grid operators to avoid blackouts during especially high use, but is also an inexpensive, convenient way to deal with the variability of large-scale renewable energy.

Demand-response programs compensate end-users of electricity for agreeing to reduce their consumption for a specified amount of time. Aggregating many electricity users together can amount to substantial control over demand, giving grid operators important new ways to balance the grid.

Specifically, demand-response can act as:

- *Capacity*, when it moderates peak electricity demand events that happen only a few times per year. This allows grid operators to meet demand without building new power generation capacity.
- *Balancing*, when it balances predictable variation in renewable energy output—this can provide confidence to grid operators as they integrate higher shares of variable renewables.

Somewhat different programs are required for these two forms of demand-response.

Demand-response as capacity

Estimates of the potential for demand-response as capacity depend on a region's mix of power generation resources. Published estimates for many parts of the U.S. range from

[1] PJM. "PJM and members set new record for peak power use." July 22, 2011. http://www.pjm.com/~/media/about-pjm/newsroom/2011-releases/20110722-pjm-and-members-set-new-record-for-peak-power-use.ashx

3 to 9 percent of summer peak demand, [2] while Europe's published potential ranges from 5 to 11 percent.[3] And there is certainly potential in other regions, but they have not yet been studied as thoroughly. Some analysts believe the numbers could be quite a bit higher, but the full potential of demand response has never been tested.

An example can clarify how demand-response as capacity works. EnerNOC is a demand-response aggregator, collecting electricity end-users together to deliver a relatively large chunk of electricity demand for local grid operators to use. Cabot Creamery, a large ice cream producer in Vermont, participates in EnerNOC's demand-response program by choosing to shut down parts of its manufacturing line and some large refrigeration machinery during a few hours each year, reducing its power consumption by up to 1000 kilowatts (one megawatt) during these "demand-response events". These voluntary shutoffs do not affect Cabot's production in any material way, since they can easily vary the time for many of their processes and their cooling systems can "ride through" a few hours of non-operation on thermal momentum. In return for responding to these demand-response events, Cabot Creamery receives about $20,000 each year from EnerNOC.[4]

This kind of demand-response program is much less expensive than building new generation capacity that would only run for a few hours each year. As shown in Figure 1, ten percent of peak demand (measured by maximum power draw) in the U.S. occurs in less than one percent of the hours in the year, making demand-response a cost-effective and reliable way to provide stability during peak demand periods.[6] A 2007 study by the Brattle Group reported that a five percent decrease in U.S. peak demand would yield $3 billion savings in electricity costs each year.[7]

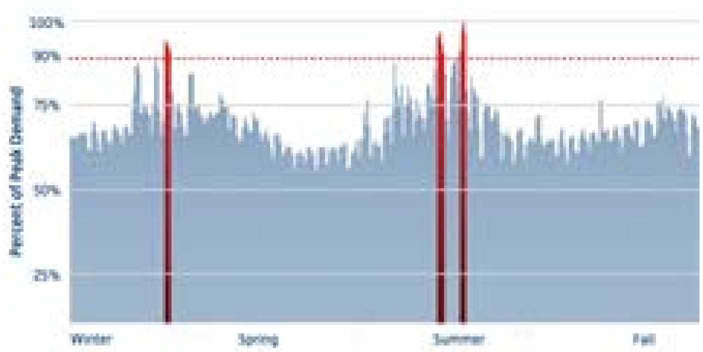

Figure 1. Typical summer-peaking pattern, where demand exceeds 90 percent of the system capacity during only a few periods in the summer months.[5]

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[2] Cappers, Peter, Charles Goldman and David Kathan. (2010). "Demand response in U.S. electricity markets: Empirical evidence." *Energy*. 35(4): pp. 1526-1535.
[3] Tom Whitehouse. "The Demand Response industry in Europe needs policy change to thrive." Oct. 20, 2011. http://www.guardian.co.uk/sustainable-business/demand-response-europe-policy
[4] EnerNOC, Inc. Cabot Creamery makes DemandSMART a Critical Part of Its Environmental Stewardship http://www.enernoc.com/our-resources/case-studies/136-resources/case-studies/281-cabot-creamery-makes-demandsmart-a-critical-part-of-its-environmental-stewardship
[5] EnerNOC. "Demand Response: A Multi-Purpose Resource For Utilities and Grid Operators." 2009. http://drrc.lbl.gov/sites/drrc.lbl.gov/files/LBNL-5555E.pdf
[6] Gottstein, Meg and Lisa Schwartz. (2010). "The Role of Forward Capacity Markets in Increasing Demand-side and other low-carbon resources." The Regulatory Assistance Project.
[7] Faruqui, Ahmed, Ryan Hledik, Sam Newell, and Johannes Pfeifenberger. (2007). "The Power of Five Percent: How Dynamic Pricing Can Save $35 Billion in Electricity Costs." The Brattle Group. <http://www.brattle.com/_documents/UploadLibrary/Upload574.pdf >

Demand-response as capacity is gaining traction in certain markets. For example, the PJM grid region[8] in the eastern U.S. added more than 8.5 million kilowatts (8.5 gigawatts) of demand-response capacity for the 2012/2013 delivery year.[9] – This single-year addition represents almost 5 percent of PJM's total capacity in 2011,[10] and it was PJM's market structure that enabled this rapid growth. Most electricity markets buy and sell energy (in kilowatt-hours), but PJM also has a market for capacity. Capacity markets are designed to ensure long-term resource adequacy by buying and selling power generation capacity (kilowatts) directly. The sharp increase in demand-response was a major driver in causing the price of capacity in PJM to drop 85 percent in one year. Figure 2 shows the increase in demand response resources, measured in electricity capacity, from the PJM program.

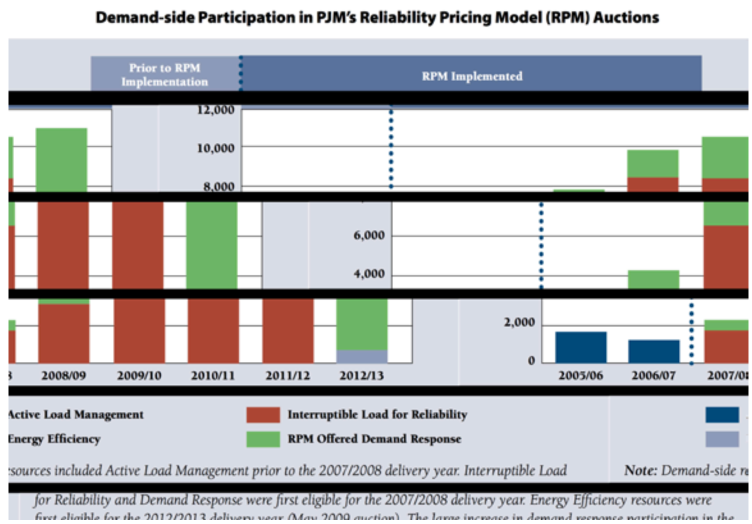

Figure 2. Demand-response growth in PJM.[11]

Demand-response as balancing

Automated demand-response can help balance variable renewables by adjusting demand in real-time to complement available supply. Power from renewable sources can ramp up or down quickly, making markets that plan a day ahead too slow to balance variations. When employing demand-response as balancing, grid operators can directly adjust electricity use whenever weather affects renewable power output.

Using demand-response as balancing can help save money as systems begin to rely on higher shares of renewables. For example, California set a goal to produce 33 percent of its electricity from renewable power by 2020. As grid-scale battery storage remains

[8] PJM is the largest wholesale electricity market in the world. Avoiding just 0.9% of PJM's peak load yields an energy market price reduction of $8-25 per MW-hour, or 5-8% on average, according to Gottstein, Meg and Lisa Schwartz. (2010). "The Role of Forward Capacity Markets in Increasing Demand-side and other low-carbon resources." The Regulatory Assistance Project.

[9] King, Chris. (2012). "How demand response cuts wholesale power costs." Gigaom. http://gigaom.com/cleantech/how-demand-response-cuts-wholesale-power-costs/

[10] PJM. "2011 Annual Report." 2012. http://www.pjm.com/~/media/about-pjm/newsroom/annual-reports/2011-annual-report.ashx

[11] PJM. "2012/2013 RPM Base Residual Auction Results." 2009. http://www.pjm.com/~/media/markets-ops/rpm/rpm-auction-info/2012-13-base-residual-auction-report-document-pdf.ashx

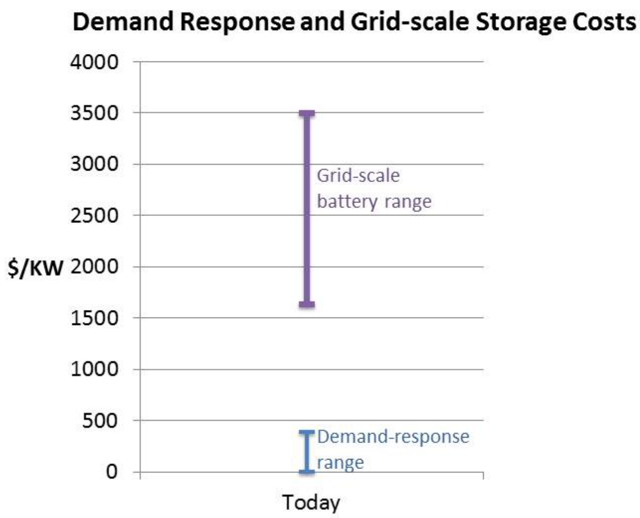

Figure 3. Demand-response is currently cheaper than battery storage[12]

relatively expensive (see Figure 3), automated demand response presents a compelling solution to supply variability.

Moreover, researchers at the Lawrence Berkeley National Lab note that the infrastructure for automated demand response already exists. Automated demand-response could already provide between 180 and 900 thousand kilowatts of load control in California, and with modest system upgrades it could provide as much as 1.8 million kilowatts[13] (which would be equivalent to more than 30 percent of California's installed wind and solar capacity today[14]). This automated demand response works by connecting with a building's heating, ventilation, air conditioning, and lighting systems to adjust them in real-time as grid conditions change.

Automated demand response can work in several different ways. To date, the most common form of automated demand-response responds to electricity prices, but the same technology could be expanded to help grid operators adjust demand in real-time to optimize for maximum renewables (see Figure 4). For example, weather stations can keep track of changing conditions, shifting the heating and cooling cycles in commercial and residential buildings

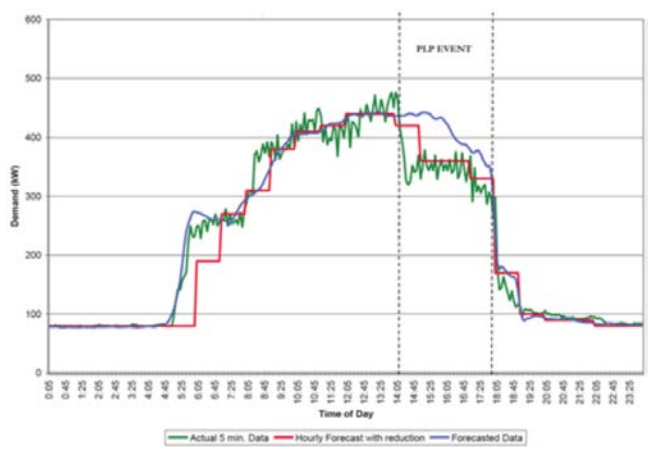

Figure 4. Automated demand-response can respond to drops in supply.[15]

[12] Grid-scale battery cost range data for 2012 from: Watson, D.S., N. Matson, J. Page, S. Kiliccote, and M.A. Piette (Lawrence Berkeley National Laboratory); K. Corfee, B. Seto, R. Masiello, J. Masiello, L. Molander, S. Golding, K. Sullivan, W. Johnson, and D. Hawkins (KEMA). *Fast Automated Demand Response to Enable the Integration of Renewable Resources.* California Energy Commission. http://drrc.lbl.gov/sites/drrc.lbl.gov/files/LBNL-5555E.pdf Demand-response cost range data for 2012 from: Pacific Gas & Electric, Southern California Edison, and PJM.

[13] Chan, Allan. "The Building as an Energy Storage Device: Fast Demand Response as a Solution to Intermittent Renewables." 2012. http://eetd.lbl.gov/newsletter/nl40/eetd-nl40-1-fastdr.html

[14] From the American Council on Renewable Energy (2011): 3927 MW wind + 1564 solar PV + 393 MW concentrated solar thermal.

[15] Kiliccote, S., M.A. Piette, G. Ghatikar, E. Koch, D. Hennage J. Hernandez, A. Chiu, O. Sezgen, and J. Goodin. *Open Automated Demand Response Communications in Demand Response for Wholesale Ancillary Services.* November 2009. Presented at the *Grid-Interop Forum 2009*, Denver, CO, November 17-19, 2009. http://drrc.lbl.gov/system/files/lbnl-2945e.pdf

to times during the day where renewable electricity is abundant, saving consumers money and minimizing strain on the grid.[16] Smart appliances are another example; appliances like dishwashers or washing machines can receive data from grid operators about when to turn on or off, based on the value of load adjustments to balance supply.[17] As technology for electric vehicles continues to improve, they can be aggregated together to provide real-time frequency regulation services for the grid when they are plugged in – providing a valuable service for grid operators and creating a new revenue stream for consumers.[18]

Demand-response is poised for growth as the electricity system transforms

The age of renewable energy is here. The price of solar power is less than half of what it was two years ago, and installed capacity in the US has more than tripled in that time.[19] A quarter of Germany's annual electricity demand is already being met by wind and solar, and last year China generated more electricity from renewables than all the electricity consumed in Australia and Canada combined.[20]

Demand-response is a very important tool for keeping electricity system costs low while enabling higher shares of renewable electricity on the grid. By avoiding the need for new "peaker" capacity and offering grid operators an easily-dispatchable resource to balance renewables, demand-response is ushering in a flexible new clean electricity system.

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[16] Earth Networks."e5 Demand Response." 2012. http://earthnetworks.com/Products/e5DemandResponse.aspx
[17] GE. "Manage your home with an entire suite of GE Profile appliances enabled with Brillon technology." 2012. http://www.geappliances.com/home-energy-manager/appliance-energy-consumption.htm
[18] The Federal Energy Regulatory Commission's recent Order 755 says that regulation services should be paid according to the value they deliver to the grid; in effect, this helps vehicle-to-grid technology that can respond more quickly than traditional combustion turbines.
[19] GTM Research, 2012.
[20] Data from U.S. Energy Information Administration, 2012.