CGI

Experience the commitment®

1

The Demand Response Paradox

The World of Demand Response

White Paper Series

About the Author

Mark Knight is Director of Consulting in CGI's utility solutions practice. A graduate of Imperial College, in London, Mark is also a former chairman and a current member of the GridWise Architecture Council (GWAC)—a group formed by the U.S. Department of Energy to promote interoperability in the country's electric power system.

Table of contents

INTRODUCTION

Demand response is not a new concept. The balance of supply and demand is essential for any market and demand response (DR) has provided a method for reducing demand in the electrical grid at points (and times) where supply is limited. It has been a useful tool till now, but our power system is changing.

Historically, we've operated the supply side of the power grid deterministically. By "deterministically" we mean that we estimated the load and then called on the required amount of power to balance that load. This allowed generation to be scheduled a day ahead and the whole system was fine-tuned each day, depending on factors such as unplanned outages and unexpected load variations. In other words, while somewhat predictable, load was treated as a "given" and supply was managed to meet the load.

With over 30% of new generation expected to come from wind energy and other renewables in some regions, the supply/generation side now includes large quantities of renewable resources that are highly distributed and intermittent in nature. They are not completely predictable. As a result, the bottom line is that the supply side is becoming more complex to predict and control[1]. This makes it more difficult to determine the supply available to meet demand, and with renewable micro generation behind the meter, the true nature of demand is obscured. The utility only views net demand, which may appear to be volatile due to the impact of customer generation.

Another factor that influences the changing nature of demand is the increasing power requirements resulting from the adoption of low-carbon technologies, particularly the electrification of heat and transport and the transfer from oil and gas to heat pumps and batteries. The adoption of these technologies can increase the stress on the existing infrastructure, but as with many modern technologies, they are controllable. Control is extremely important when it comes to operating the electric grid and demand that may be monitored or influenced through market signals and coordinated with other resources opens the door for demand response to become part of the solution and create a more intelligent energy future.

By becoming more adaptable, the demand side is changing along with the supply side, and we have a system in a dynamic state of flux. Lowering the costs of measuring and communicating with electrical loads makes them more capable of responding to information and adjusting consumption behavior in useful ways that benefit both the customer and the electrical system. In fact, the demand response method was developed to adjust consumption behavior.

Demand response is one of many resources that have been used historically to satisfy the increasing demand for electricity, but with net energy consumption remaining relatively static in recent years[2], what is the future role, if any, for demand response? Over the last few years, the increases in demand have been offset by improvements in energy efficiency, but over time the increasing use of low-carbon technologies has the potential to increase net energy use again. Demand response has been used for several purposes, and in addition to providing capacity for resource adequacy and planning, the capacity and ancillary services provided by demand response provide operators with additional flexibility in maintaining operating reliability[3]. These uses of demand response will be valuable in the future, just as they are today.

Most customers may not have noticed the transitions that the industry is going through, but we have started along a path that has some fundamental implications for how this sector operates. Perhaps you have a smart meter in your home or business or have seen the occasional wind turbine and a few more solar panels appearing on rooftops or in fields, but the only real change many people have noticed is more outages due to storms and aging infrastructure. Those are not the focus of this paper, but the underlying causes are very relevant to this discussion—aging infrastructure and resource flexibility. We have too much of the former and not enough of the latter.

[1] Mark Knight. "Transactive Energy Builds Resilience." *EnergyBiz*, September/October 2014.

[2] Certainly in North America.

[3] North American Electric Reliability Corporation. *Demand Response Availability Data System (DADS): Phase I & II Final Report*. Report. Princeton, 2011.

ACCELERATING CHANGE

The interesting thing to recognize is that the industry did not simply sit down and decide that there had been no change in the electricity grid for a century and therefore it was time for transformation. Change has been happening gradually for many years now, but its cumulative effect combined with the accelerating opportunities introduced by new technologies and emerging business models are introducing changes that the industry must integrate into the way it functions.

Sometimes we spend too much time looking at the effects of change and not the causes. So while the rate of change may appear to be manageable, an increase in frequency of change will accelerate impact, as new devices will both influence the system directly and interact with each other. To prepare for such a situation, and make measured and effective choices, preparation has to start now. Ad hoc arrangements for whole system change have worked so far. However, as "whole system" effects become significant, a more robust response is clearly required. While these challenges are well managed at present, changes in the industry are already emerging and may be subject to tipping points in the future[4]. In some places, such as Germany, the tipping point may have already arrived.

WARNING: Objects on your roadmap may be closer than they appear.

After the Fukushima nuclear accident in Japan 2 ½ years ago, Germany began phasing out nuclear power in favor of wind and solar power. Depending on the weather and the time of day, the country now faces absurd states of energy surplus or deficit[5] and electricity rates have doubled since 2002. The irony is also that in removing nuclear power, the backup power capacity required by wind and solar projects is lacking. This has resulted in a situation where Germany's most heavily polluting coal power stations are now also its most profitable, with many of these plants running at full capacity.

BACK TO THE FUTURE

Over time, greater grid interconnection led to the possibility of more widespread outages, resulting in significant investment in monitoring and control technologies as well as generation scheduling. The advent of microprocessor relays in the 1990s led to the appearance of digital computers in substations. At the same time, several countries opened up competitive access to transmission systems and electricity trading gained a firm foothold. Today we see even more automation and control, with mature electricity markets at the wholesale level, some competitive retail markets, and an increased focus on the environment—with many countries prioritizing clean energy. We also have countries like Germany and areas such as the Pacific Northwest of the U.S. with significant renewable energy sources that have on occasion exceeded the available traditional generation capacity.

So while we change what we do and how we do it (technical innovation, digitization, communication and mobility), at either "end" of the system (generation or consumption) there is one thing that has not and will not change—the basic physics of the system, which will govern any changes that we make.

Yet transition is inevitable and while the laws of physics will not change, the way in which we use the electricity system is undergoing many changes. Look at how quickly Germany changed with the adoption of increased renewable generation. As an industry, we need to be ready for a time when many jurisdictions embrace renewable generation and it transforms the way the system is operated. This does not mean that we have to alter the way that we operate today, but as an industry we need to think about a future when these changes will be required and how the integration of new actors and devices will be made possible. It also involves preparing for an intelligent distribution system, while educating company officers, regulators, legislators and vendors. Above all else, it is necessary to understand this evolving scenario completely, so that we are not caught unaware when the tipping point occurs, but see it coming and plan in advance.

[4] The Institution of Engineering & Technology. *Britain's Power System, The Case for a System Architect*. Report. 2014.

[5] Frank Dohmen, Michael Fröhlingsdorf, Alexander Neubacher, Tobias Schulze, and Gerald Traufetter. "Germany's Energy Poverty: How Electricity Became a Luxury Good." Spiegel Online International. September 04, 2013. http://www.spiegel.de/international/germany/high-costs-and-errors-of-german-transition-to-renewable-energy-a-920288.html.

DR HAS AN IMPORTANT ROLE TO PLAY

So where does demand response fit into this changing world? The electricity grid has been operated deterministically for over a century by matching supply side and demand side resources. It has been done in this manner since the supply side has more controls available and is "dispatchable" to meet the demand for power. However, the laws of physics are immutable and it is not always possible to transport power from traditional centralized generators to locations where it is needed. Power lines and intermediate equipment have limits to the quantity of power that can be transferred, and when additional power has to be moved along those same paths, it becomes a complex job. Just as we add or remove from either sides of an equation when solving linear equations, we can also remove load from one end of a line instead of adding more power at the other end in order to supply the load. This act of removing load is known as demand response. In order to keep the grid balanced and operating within specified limits, centralized systems manage the loads that should be removed and decide how this is done.

"Demand response" refers to the ability of customers to respond to a signal to reduce load. This may be either a reliability trigger or a price trigger from their utility system operator, load-serving entity, regional transmission organization/independent system operator (RTO/ISO), or other demand response provider by lowering their power consumption[6].

Most customers see electricity rates that are based on average costs and bear little relation to the true production costs of electricity as these vary over time. For many customers this is fine, but for those that see their prices as a reflection of wholesale electricity costs, demand response plays a vital role in their ability to manage the price they pay. Generators are dispatched based on a series of complex algorithms, but besides ancillary service requirements and generator ramp rates, etc., dispatching begins with the generators that provide power at the cheapest rates and more expensive generators are added incrementally until the demand side requirements are met. Since most markets compensate all generators based on the price of the highest cost generator, avoiding the incremental next step in price by reducing load can have a significant impact on managing wholesale electricity costs and the prices that are subsequently charged to customers, which typically vary in five-minute increments.

Thus two important uses of demand response today are to avoid increased electricity prices and overburdening the grid (leading to potential failure). It is one of the options that market operators employ to avoid price spikes and reliability problems, largely due to lack of generation or the existence of transmission constraints, so that most consumers can continue their lives without understanding the vast complexities that go into managing the electricity supply system, described as one of the great engineering achievements of the past 100 years[7].

While demand response has proven to be an effective tool for utilities for many years, switching off heating systems, or adjusting set points for building management systems to shift loads and reduce peak load is yesterday's solution. While it still has a place both today and in the future, addressing new challenges will require fresh mechanisms to ensure interaction between the increasing numbers of parties who participate in the process.

For customers that participate in these programs with their utility today, it is another part of the "invisibility" of the system that these changes are often under the direct control of the utility and many participating customers are not aware that loads are being managed when the programs are active. There are two main reasons for this. Firstly, the operation of the grid is through centralized control systems operated by utilities, and therefore they need the ability to control where and when load is reduced in order to maintain balance. Secondly, in the past, direct control was necessary because customer devices did not have sophisticated built-in intelligence and communication capabilities. This necessitated that utilities install custom communications and control capabilities to operate demand response resources.

[6] Federal Energy Regulatory Commission. *National Action Plan on Demand Response*. Washington, D.C., 2010.

[7] U.S.-Canada Power System Outage Task Force. *Final Report on the August 14, 2003 Blackout in the United States and Canada Causes and Recommendations*. Washington, D.C.: U.S. Dept. of Energy, 2004.

WHAT'S OLD IS NEW AGAIN

Typically, where customers have some control over the process, they may choose to shift their load to a time when power is cheaper, rather than curtailing it completely. For instance, we may see a building being pre-cooled in the summer before a peak load period that has high prices forecasted. But if cooling is turned on to offset surplus generation, how would this get coordinated? And in what way would this be complicated if the generation we were trying to balance was not centrally located, but consisted of thousands of small generators on the distribution system? This is the type of situation that we will increasingly witness as the penetration of distributed energy resources continues and the industry evolves over the next few decades.

The demand response model for the future is not just about reducing demand to avoid expensive generation, but also about increasing demand when intermittent generation is abundant. One way of balancing supply and demand fluctuations is through the use of storage. The traditional electricity system provides numerous theoretical opportunities for the deployment of storage technologies and to serve these diverse prospects, a wide variety of technology choices are being evaluated to store electricity as chemical, thermal and mechanical energy. Building on the growing body of industry research into the application of storage, Southern California Edison (SCE) defined over 20 discrete operational uses of energy storage. These were mapped to a specific location on the electric value chain. SCE also sought to understand each technology[8], its current commercial availability, and how this could be matched with applications and their preferences. The differences in rated power and energy discharge duration for the various technologies are outlined below.

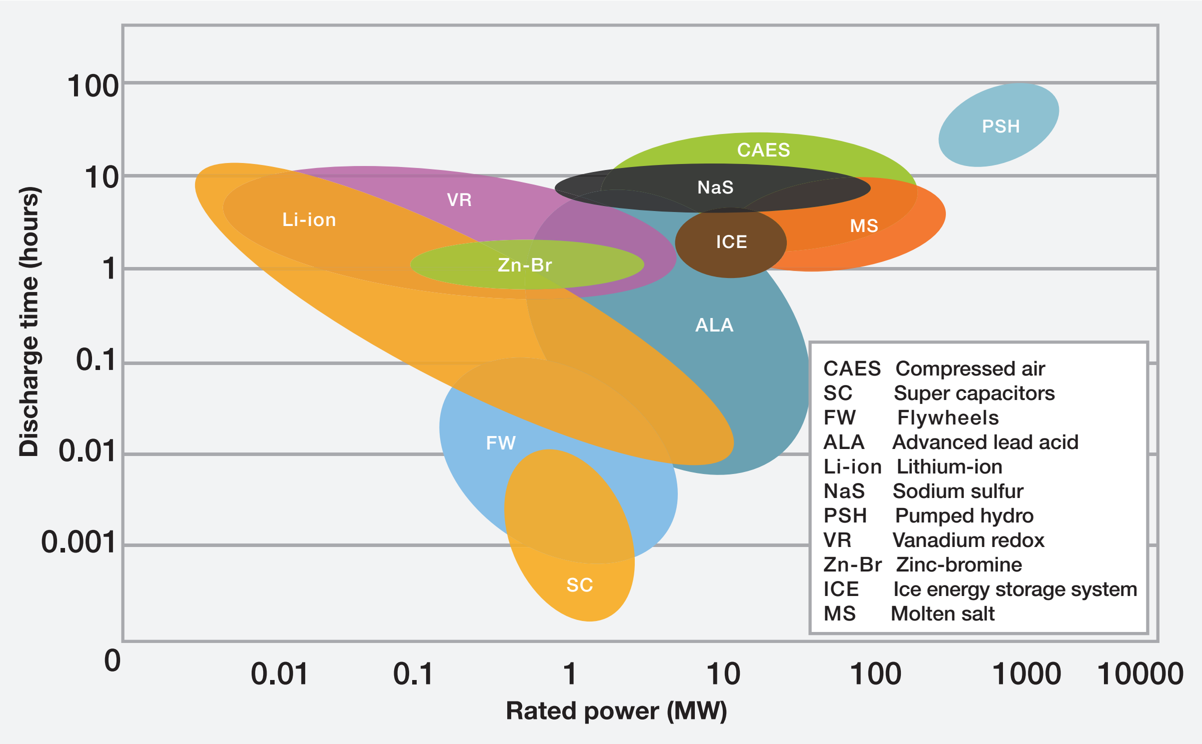

FIGURE 1: POWER AND ENERGY DISCHARGE CHARACTERISTICS FOR STORAGE TECHNOLOGIES

For a more detailed discussion on these technologies, SCE filing provides a good overview and this can be found at: http://www.energy.ca.gov/2011_energypolicy/documents/2011-04-28_workshop/comments/TN_60861_05-20-11_Southern_California_Edison_Company_Comments_Re_Energy_Storage_for_Renewable_Integration.pdf

[8] Johannes Rittershausen, and Mariko McDonagh. *Moving Energy Storage from Concept to Reality*. Report no. Docket 11-IEP-1N. Southern California Edison, 2011.

We are also seeing that the effects of responses to existing policy are creating new problems. The increase of solar and wind generation combined with the retiring of nuclear generation in Germany is one such example. Another example is on the West Coast of the United States, where in California, the independent system operator has been modeling the impact of supply side renewables and it is not a reassuring picture. The result of the study is known as the California Duck Curve, so named because of its resemblance to the profile of a duck (below).

As in Germany, California's renewable resources are increasingly being used to satisfy the state's electricity demand. The figure above shows how changing conditions are expected to impact the state's net load curves in the coming years as forecasted by the California Independent System Operator (CAISO). The net load is calculated by taking the forecasted load and subtracting the forecasted electricity production from variable generation resources—wind and solar power[9]. What is left is the supply profile that has to be supported by conventional generators. Figure 2 shows the impact of policy initiatives on the net demand for electricity.

The two key things to note are that load peaks in the early evening when people return home from work and renewable generation dies out, and this in turn results in a huge generation ramp requirement of approximately 14 GW in three hours that will have to be serviced by traditional generation or out-of-state generation (subject to transmission constraints). It is this need for backup generation to support periods when renewables cannot satisfy the demand for power that has led to the sharp increase in coal generation in Germany.

The Duck Curve (Net load chart)

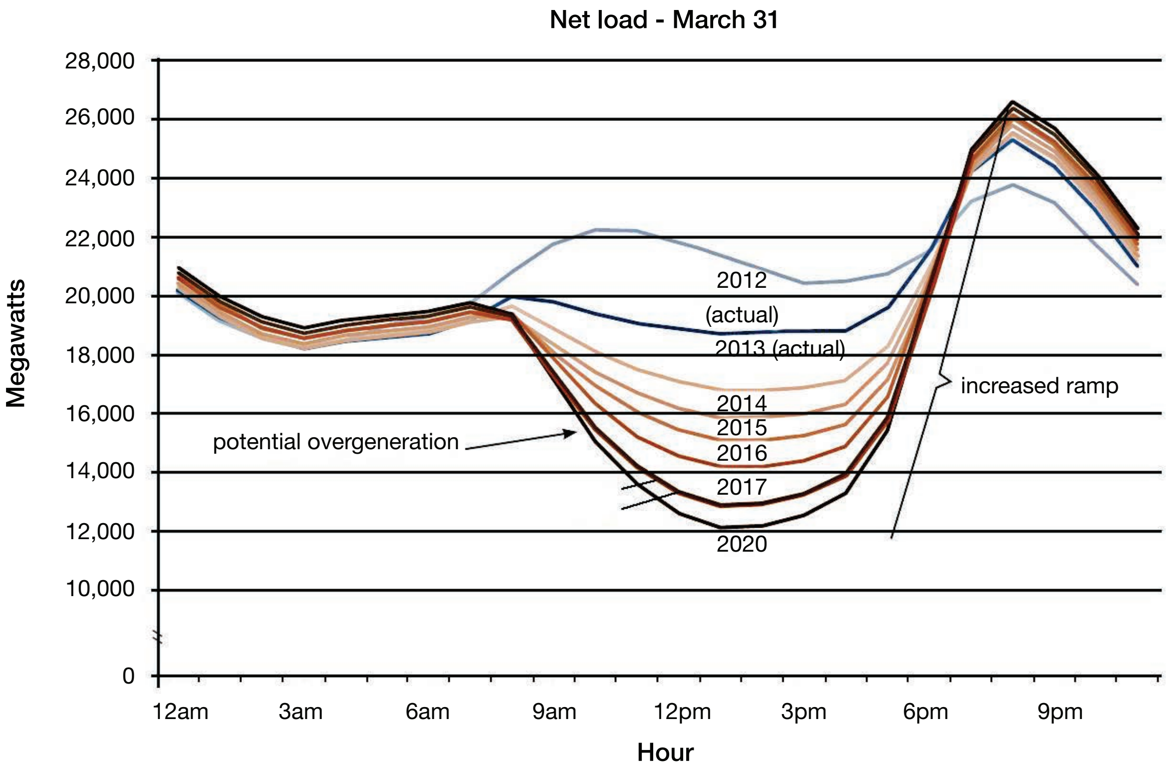

FIGURE 2: THE CALIFORNIA "DUCK" CURVE

[9] California Independent System Operator. *Flexible Resources Help Renewables*. Technical paper. 2013.

Clearly, there will be a strong need for a demand response market in California to help address the early evening generation ramp, but residential customers are also increasingly seizing opportunities to become better environmental stewards by self-generating (small wind turbines in rural areas, rooftop solar generation in urban areas). Real-time interactive monitoring of electricity usage and self-generation provide opportunities for customers to engage in transactions between each other and with traditional utilities—both generating for others and supporting utility energy conservation demands. As technologies such as solar generation get cheaper, lighter and less visually intrusive, more and more people will choose to try these approaches[10].

Today in California, demand response resources are dispatched by utilities on a limited basis and are concentrated in the period between 2:00 p.m. and 6:00 p.m., often the peak ramping hours in the day. The following figure shows that about 50% of demand response was dispatched on a day-ahead basis, while the remaining half was dispatched on a day-of or emergency basis.

As we look at the many changes that are occurring, there are three key hard trends[12] that warrant closer attention:

- The three digital accelerators: the exponential advances in processing power, bandwidth and storage
- The increasing connectivity and communications availability
- The increasing use of renewable generation

Recognizing hard trends give us the ability to plan for disruptions before they happen and gives us the insight we need to create strategies based on a new level of certainty.

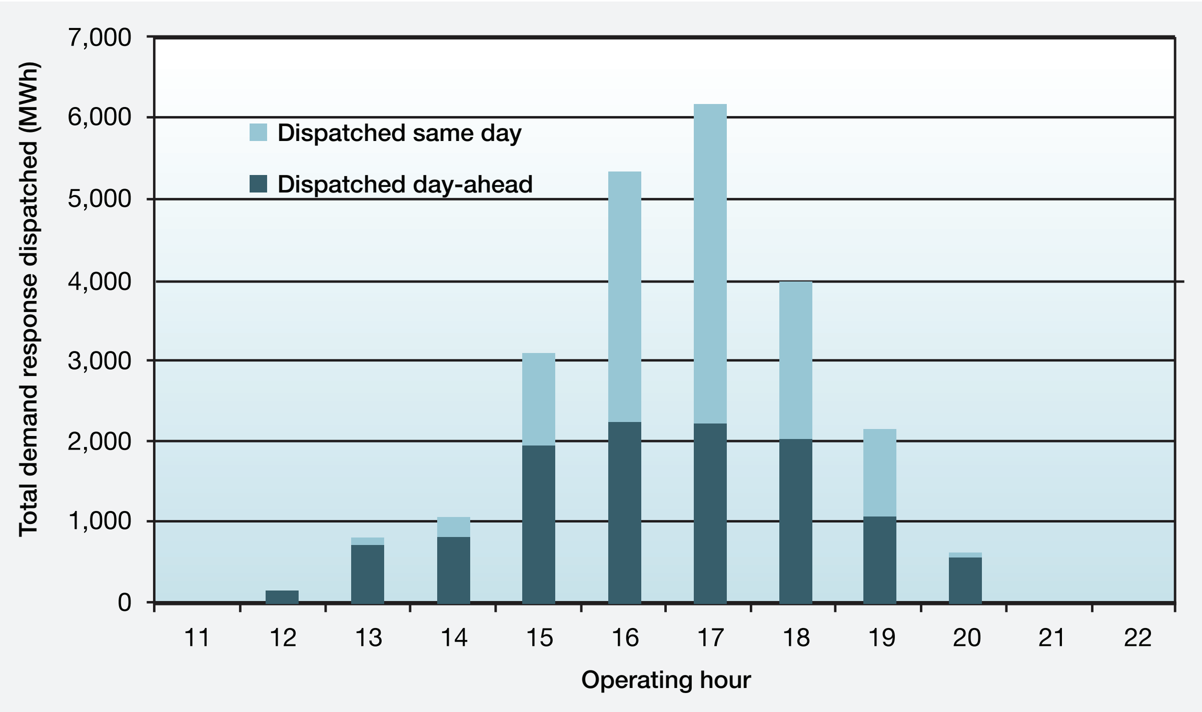

FIGURE 3: DEMAND RESPONSE PROGRAMS DISPATCHED IN 2013[11]

[10] Tom Sloan. "Why Care About Transactive Energy?" Public Utilities Fortnightly. November 2014. http://www.fortnightly.com/fortnightly/2014/11/why-care-about-transactive-energy.

[11] California Independent System Operator. 2013 *Annual Report on Market Issues and Performance*. Report. 2013.

[12] Daniel Burrus. "Improve Planning By Separating Hard Trends From Soft Trends." Burrus Research. February 12, 2014. http://www.burrus.com/2014/02/improve-planning-by-separating-hard-trends-from-soft-trends/.

THE BENEFITS OF DEMAND RESPONSE

It has been said[13] that if Thomas Edison could see the industry today, he would recognize it as being much the same as it was 100 years ago, but that may not be the case for much longer. The changes already described are having a great impact on the distribution system, where the biggest transformation is occurring. So while demand response may not be a new tool, it still has an important role to play, and it can be argued that its value will increase as changes continue.

The reason that it still has an important role to play is because the most important benefit of demand response is improved resource efficiency in electricity production due to closer alignment between prices and the value that customers place on electricity. This increased efficiency creates a variety of benefits that fall into four groups[14]:

- **Participant financial benefits** are the bill savings and incentive payments earned by customers that adjust their electricity demand in response to time-varying rates or incentive-based programs.
- **Market-wide financial benefits** are the lower wholesale market prices that result because demand response averts the need to use the most costly-to-run power plants during periods of high demand, driving production costs and prices down for all wholesale purchasers. In the long term, sustained demand response lowers aggregate system capacity requirements, allowing load-serving entities (utilities and other retail suppliers) to purchase or build less new capacity. Eventually these savings may be passed on to most retail customers as bill savings.
- **Reliability benefits** are the operational security and adequacy savings that result because demand response lowers the likelihood and consequences of forced outages that impose financial costs and inconvenience on customers.
- **Market performance benefits** refer to demand response's value in mitigating suppliers' ability to exercise market power by raising power prices significantly above production costs.

[13] Robert Catell, chairman of the New York State Smart Grid Consortium, at a smart grid event in New York City at New York University (NYU) in February 2010.

[14] U.S. Department of Energy. *Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them*. Report. 2006.

SO WHERE IS THE PARADOX?

As new business models and opportunities emerge as a result of the changes in the industry, there will be increasing opportunities for interaction, and presumably more services offered for customers to engage with each other through the grid. Currently, the biggest roadblock to demand response is the lack of consumer motivation. There is also the question of just how much demand response is required to manage today's grid or whether there are other ways to achieve the same results. But when demand response includes supply following opportunities, how will that change things?

Finding a way to create a consumer benefit is essential to the success of demand response, especially as the need for a more responsive grid develops at the edges, in response to changing technologies and behaviors. Indeed, the recent New York Reforming the Energy Vision (NYREV)[15] Order anticipates that technology innovators and third-party aggregators (energy service companies, retail suppliers and demand-management companies) will develop products and services that enable full customer engagement. The utilities acting in concert will constitute a statewide platform that will provide uniform market access to customers and Distributed Energy Resources (DER) providers.

If consumers have no way of benefiting from utilizing additional benefits offered by a smart appliance or from adopting a new service, they will have no interest in buying one, or at least not for those purposes. Therefore, without a demand from customers, there is no business incentive for potential smart appliance manufacturers to invest in product design in the first place, as there is no market to sell them[16].

Anticipating that demand would appear, an international standard for energy management[17] was published in 2012 featuring an Energy Management Agent (EMA) that manages energy consumption and generation for household appliances. These will need communication interfaces and control programs that enable interaction with the EMA. The customer will enter parameters into the EMA, including a monthly budget for electricity and preferences for appliance usage. The introduction of the EMA may offer new business opportunities for adding energy management features to appliances that can differentiate these products in the marketplace. Such appliances might be valued by consumers, who would pay a premium or might receive subsidies from utilities and government conservation programs[18].

In the end, there are several paradoxes that we have to consider, **which are elaborated further in our future whitepaper editions**:

- Without smart appliances, consumers will not be able to set and forget.
- Without active demand for smart appliances, their adoption will be slow.
- The cost of a large appliance means it will not get replaced until obsolete, whether or not the replacement is smart.
- In the time it will take for mass consumer participation, some grid scale benefits will shrink due to increases in efficiency.
- The technology to build new services is available today, but market demand is not.
- Demand response was designed for a centrally controlled load following paradigm, but the future will be a supply following decentralized control paradigm.
- Initial demand response programs were based on direct control without any intelligence, but future demand response programs will use distributed intelligence with devices responding to signals based on consumer values.

[15] New York State Reforming the Energy Vision.

[16] Mark England. "The Demand Response "Catch-22" (and How to Fix It)." SmartGridNews. March 6, 2013. http://www.smartgridnews.com/story/demand-response-catch-22-and-how-fix-it/2013-03-06.

[17] ISO/IEC 15067-3:2012, Home Electronic System (HES) application model - Part 3: Model of a demand-response energy management system for HES.

[18] Kenneth Wacks. "The Impact of Transactive Energy on Appliances." Appliance Design. April 3, 2014. http://www.appliancedesign.com/articles/93975-the-impact-of-transactive-energy-on-appliances.

Founded in 1976, CGI is one of the largest IT and business process services providers in the world. We combine innovative services and solutions with a disciplined delivery approach that has resulted in an industry-leading track record of delivering 95% of projects on time and within budget. Our global reach, combined with our proximity model of serving clients from 400 locations worldwide, provides the scale and immediacy required to rapidly respond to client needs. Our business consulting, systems integration and managed services help clients leverage current investments while adopting technology and business strategies that achieve top and bottom line results. As a demonstration of our commitment, our client satisfaction score consistently measures 9 out of 10.

Visit cgi.com for more information.