**Reconsidering the Demand Side**

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1. **Introduction**

For decades, and despite heroic efforts (Lovins, 1977), the demand side aspect of the energy equation has suffered a lack of “sex appeal”. This is changing, however, through a suite of new technologies, policy and regulatory frameworks, business models, consumer engagement, and cross-sectoral fertilization. Those changes are also bringing new definitions of what we can consider as the “demand-side” - the traditional classification of supply, demand, and infrastructure in the energy sector is thus no longer wholly appropriate. It is evident that these solutions are not solely technical, rather they have often emerged from business or financial model innovations (e.g., third party solar leases, aggregation of demand response) and/or new regulations and policies (e.g., net metering, retail market design, treatment of demand response in wholesale power markets). Additionally, one could argue that in many instances favorable policies (e.g., RPS, EERS) are providing the market certainty/stability needed to spur these technological innovations. This short essay considers how a conceptual framework that views them together as an ecosystem of innovations with exciting and non-linear impacts and benefits might be formulated. We provide numerous references to the literature in order to both acknowledge the large body of work, and to provide a foundation for more integrated work.

Power systems can be considered as large machines. They are generally comprised of long-lived, relation-specific generation assets combined with an infrastructure for transmission and distribution that delivers electricity to end users. The “machine” is operated within a very small frequency range, and thus intimately connected from top to bottom. Given the physical nature of electricity and the lack of widely available storage, it generally has to be balanced in real time across multiple temporal and spatial scales. We can now conceive of this machine in a different way than in the past (Outhred, 2003). The changing landscape of energy sector motivations, including, *inter alia,* climate change mitigation, increased awareness of air pollution issues, energy access for the poor, and the need to consider the increasing penetration of variable renewable energy, are together facilitating a significant transition in the power sector. It is perhaps a happy coincidence that solutions to many of these challenges are now emerging at the “downstream” end of the power sector. Viewed as a whole, the system is moving from a static, analogue model built around the scale economies available from central power stations to a dynamic and digital one that places a premium on a more active and participatory demand side. The growing agreement on this is evidenced in Figure 1 (PWC, 2013) – three of the four technology clusters cited as having the “most impact” fall within the demand side domain.

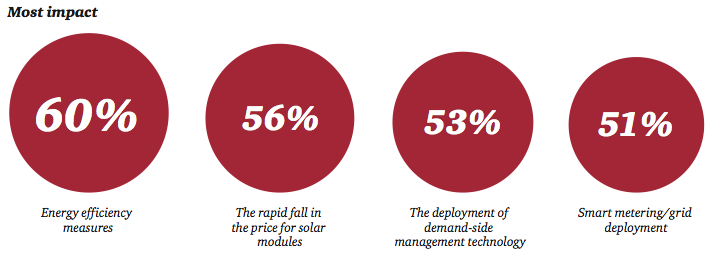


Figure 1: Percentage of respondents saying these technology developments will have a high or very high impact on their market (PWC, 2013).

Hence, the time is ripe to re-consider the vocabulary of the demand side to better capture these new realities. Together, these technical and business advances can have enormous impacts, while building on prior successes.[[1]](#footnote-1) As noted in “Reinventing Fire” (2011), historical experience demonstrates that the U.S. can deliver lower energy consumption while maintaining significant economic growth. Amory Lovins wrote, “To shrink U.S. energy use while GDP grows 158% is not a fantasy; in nine of the 36 years through 2009, the U.S. economy actually did raise energy productivity faster than GDP grew. [This can be done] with major competitive, security, health, and environmental advantages, simply by using energy in a way that saves money, modulating demand unobtrusively over time to match energy’s real-time value, and optimizing supply from the cheapest, least risky sources”. This growing focus on the demand-side is mirrored in the IEA’s WEO 2013 – where energy efficiency is considered the largest “resource to move to a climate friendly pathway” (Figure 2).

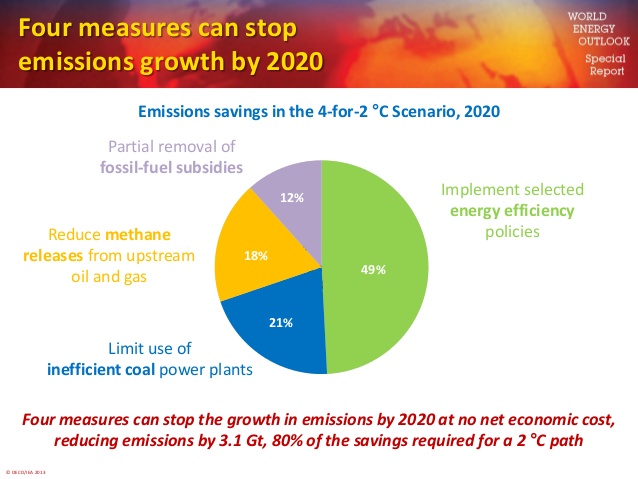


Figure 2: Emission savings in IEA (4-for-2C, 2020) climate scenarios (IEA, 2013)

1. **Individual innovations**

We briefly highlight several key demand-side innovations that are altering the *status quo* of the power sector, and changing the way we think about the demand side. Numerous graphics are available that try to capture the complex set of new relationships and interactions; Figure 3 is useful in this regard.

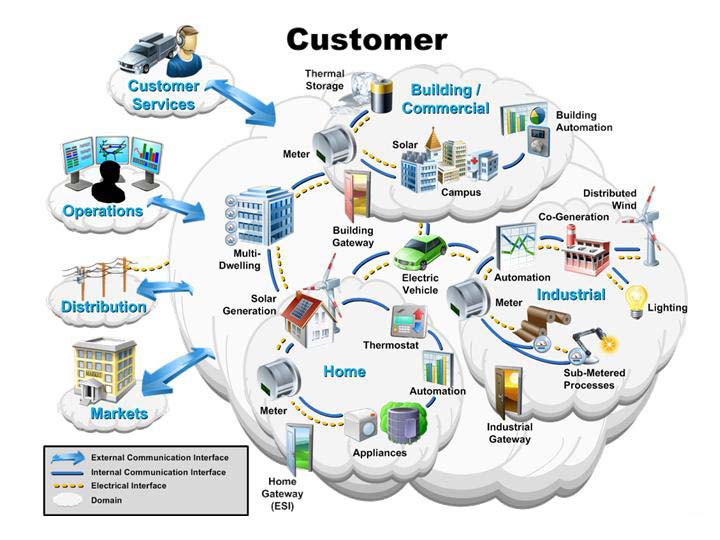


Figure 3: Schematic of a new type of power system configuration (Pediain.com, accessed 2014).

While there are overlapping aspects with the categorization we use below, it is simply intended to make explicit the wide array of developments that are emerging simultaneously in this dynamic space.

* As part of the growth of RE, **distributed generation** assets such as residential solar energy are growing rapidly due to system cost declines, new business models (such as leasing) (see e.g., Holtmeyer, Wang et al. 2013, Ipinnimo, Chowdhury et al. 2013, Khamis, Shareef et al. 2013, Prenc, Škrlec et al. 2013, Vahl, Rüther et al. 2013, Abdullah, Agalgaonkar et al. 2014, Ai, Wang et al. 2014, Bernardon, Mello et al. 2014, Esmaili, Firozjaee et al. 2014, Kechroud, Ribeiro et al. 2014) and policy incentives (net metering). Combining distributed sources of electricity with non-traditional “sources” such as storage and onboard power management can reduce the risks related to electric supply reliability and quality (Lovins, 2011). Challenges include: tariff designs and net metering policies, cross-subsidies, availability of storage, impacts of bi-directional power flows in distribution systems, and utility business models.
* **Demand management and response** from aggregating small-scale flexible demand, or from larger systems, is occurring in periods down to very “fast” response (a matter of seconds or less). This area relates to both the management of demand and how it interacts with the power system and markets. Dynamic and digital aspects of demand management are an important aspect, and include aspects of dynamic pricing, and “economic” (as opposed to traditional capacity) demand management. Likewise, large utility demand response programs are becoming more innovative. Emerging digital technologies are also playing a large role, such as digital two-way thermostats, smart thermostats, automation (building automation, auto demand response, etc.), and fault detection and diagnostics. Related, changing tariff structure and market bidding rules are emerging (see e.g., Gelazanskas and Gamage 2014, Brennan 2010, Breukers, Heiskanen et al. 2011, Qureshi, Nair et al. 2011, Choi, Lee et al. 2012, Zehir and Bagriyanik 2012, Arteconi, Hewitt et al. 2013, Kyriakarakos, Piromalis et al. 2013, Marzband, Sumper et al. 2013, Meidani and Ghanem 2013, Silvente, Aguirre et al. 2013, Finn and Fitzpatrick 2014, Warren 2014). Challenges include: financial incentives, behavioral understanding, market rules, measurement and verification of associated impacts, rate design, business models, and technology adoption.
* **Smarter grids** are being built all over the world. Despite definitional issues under this large heading, the deployment of smart meters, distribution system and control technologies, and automation of transmission and distribution system infrastructure are increasing. Much of the literature alluded to in other sub-sections also relates to Smart Grids. In addition, research platforms, such as the European Platform for Smart Grids, have emerged – as well as business alliances (e.g., GridWise Alliance, The Smart Grid Alliance). Challenges include: standards for interoperability, cybersecurity, consumer participation, utility business models, asset utilization and opitimization, data and information overload, rate design.
* **Intelligent devices and smart buildings** (transactive energy) as well as lighting, better data gathering systems (e.g., PMUs), IT interfaces, energy management systems, building data analytics to optimize energy use, continuous commissioning, auto DR, and control systems are helping change how the power system works and is operated (see e.g., Cardenas, Gemoets et al. 2012, Pagani and Aiello 2014, Alagoz, Kaygusuz et al. 2013, Ancillotti, Bruno et al. 2013, De Ridder, D’Hulst et al. 2013, Knapp and Samani 2013, Mah, Wu et al. 2013, Markovic, Zivkovic et al. 2013, Phuangpornpitak and Tia 2013, Pogaru, Miller et al. 2013, Broeer, Fuller et al. 2014, del Real, Arce et al. 2014, Fadaeenejad, Saberian et al. 2014, Giannantoni 2014, Siano 2014). Challenges include: communication standards and interfaces, power system engineering, human capacity development.
* **“Deep” energy efficiency** in “smart” buildings, appliances, and management systems are together changing how we can conserve energy in the residential and commercial sectors. In addition, industrial processes are being optimized through these methodologies and technologies (see e.g., Bortoni, Nogueira et al. 2013, Hackl and Harvey 2013, Praznik, Butala et al. 2013, Rosenow, Platt et al. 2013, Schueftan and González 2013, Singh, Mahapatra et al. 2013, Thiede, Posselt et al. 2013, Yoo, Jeong et al. 2013, Lo 2014, Peruzzi, Salata et al. 2014). In developing economies, these tools are being used in coordination with expansion planning. Challenges include: principal-agent issues, financing models, and information provision.
* **Combined heat and power (CHP) and district heating and cooling (DHC) systems** have been evolving for decades. Today there are case studies that show not only the thermodynamic and efficiency benefits of CHP and DHC, but also how they can serve as elements of thermal storage to improve load curves in the power system (see e.g., Gandiglio, Lanzini et al. 2014, Börjesson and Ahlgren 2012, Chen, Wang et al. 2012, Zuwała 2012, Bianchi, De Pascale et al. 2013, de Santoli 2013, Lo Basso et al. 2013, Fubara, Cecelja et al. 2013, Meybodi and Behnia 2013, Motevasel, Seifi et al. 2013, Nuytten, Moreno et al. 2013, Pantaleo, Candelise et al. 2014, Pohl and Diarra 2014). Challenges include: interaction with markets, financial signals, and planning.
* **Microgrids** are witnessing a renaissance of sorts in both developed and developing economies. In developed countries, microgrids are being installed as a means to enhance the resilience and stability of the power system. In developing countries, microgrids that are “backward compatible” are being deployed to meet energy access goals (see e.g., Camblong, Sarr et al. 2009, Xiao-xiao, Ming-chao et al. 2011, Acevedo and Molinas 2012, Eghtedarpour and Farjah 2012, Niknam, Azizipanah-Abarghooee et al. 2012, Raman, Murali et al. 2012, Baziar and Kavousi-Fard 2013, Kamel 2013, Petreuş, Daraban et al. 2013, Malakar, Goswami et al. 2014, Sanchez, Molinas et al. 2014, Zeng, Zhao et al. 2014). Challenges include: standards, grid interaction, and financing.
* The rise of **electric vehicles** may soon have a material impact on the operation and finances of the power system depending on the scale of deployment. So far, while this is limited to a small number of countries, it may turn out to be a significant driver of change on the distribution edge of the system (see e.g., Dias, Haddad et al. 2014, Loisel, Pasaoglu et al. 2014 , Bellekom, Benders et al. 2012, Budde Christensen, Wells et al. 2012, Finn, Fitzpatrick et al. 2012, Grenier and Page 2012, Hedegaard, Ravn et al. 2012, Brouwer, Kuramochi et al. 2013, Hennings, Mischinger et al. 2013, Saisirirat, Chollacoop et al. 2013). Challenges include grid-to-vehicle and vehicle-to-grid concepts, control issues, infrastructure ownership, and standards.
* **Storage systems** are maturing**.** These technologies will likely be core parts of the power system with the rise of variable generation. Advances in battery and other storage systems are happening worldwide – including new regulatory initiatives such as California’s storage mandate[[2]](#footnote-2) (also see e.g., Arabali, Ghofrani et al. 2013, Caliskan, Dincer et al. 2013, Koh, Yong et al. 2013, Sigrist, Lobato et al. 2013, Taraft, Rekioua et al. 2013, Aghamohammadi and Abdolahinia 2014, Bagdanavicius and Jenkins 2014, Bradbury, Pratson et al. 2014, Campbell and Bradley 2014, Fallahi, Nick et al. 2014, Karellas and Tzouganatos 2014, Serban and Marinescu 2014). Challenges include: market interaction, cost, regulatory treatment, and technology pathways.

1. **Towards a new definition**

Issues of market design, regulatory reform, policy incentives, and business and financing models cut across all of these areas. The challenge of coordination and system operation accompanying these innovations are also considerable, adding to the complexity of the power system and requiring a combination of flexibility, forecasting, planning, and control that can enable these demand-side activities while maintaining grid stability. Given the plurality of current regulatory and policy frameworks (both in the U.S. and abroad), this will obviously play out differently in different contexts. But whatever the policy/regulatory context, each of these cross cutting issues will need to be approached in a manner that leverages the innovations at the technical level.

Thus, dynamic pricing and improved retail electricity markets could provide important means for realizing the benefits of these innovations in restructured markets. Likewise, rules that allow for the aggregation and bidding of demand response into wholesale power markets (FERC Order 745), or demand reductions associated with EE installations – see PJM’s rules for treatment of demand response in forward capacity markets – provide alternative ways to incentivize demand response in the absence of dynamic retail pricing. A review of regulatory proceedings in the United States reveals that several states are examining structural market changes that may increase markets for demand response and distributed generation. In September 2013, for example, the California Public Utility Commission initiated a rulemaking that proposed a market design under which utilities would procure demand response from a competitive market managed by the California Independent System Operator, rather than the current utility-managed demand response “programs” (R.13-09-011). Similarly, in December 2013 the New York Public Service Commission declared that they and “other policy makers can no longer afford to think of energy efficiency and distributed clean energy resources as peripheral elements of the electric system that require continuous government support. Rather, the time has come to manage the capabilities of these customer-based technologies as a core source of value to electric customers (Case 07-M-0548)”. It is clear that regulators are examining market designs that will advance the adoption of the technologies and new business models.

In all these areas, the use ofinformation and communications technology **(**ICT) systemsis increasing rapidly, enhancing the level of information exchange between customers and utilities (Lovins, 2011)**.** As an example the increased data coming from Smart Grid systems and monitoring technologies such as Phasor Measurement Units (PMUs) are changing historical consideration of data management. Big data issues in general are now a core part of the power sector, along with associated privacy and cyber security concerns (Jones, 2013). As a result of the many interacting issues, analytics and planning must also evolve to appropriately reflect this dynamism of demand. This has implications for regulatory frameworks governing resource planning to shorter term modeling for the sub-hourly and sub-second timeframes.

As a result of the innovations described, we must now alter our consideration of what were traditionally considered to be “downstream” demand issues in power systems. Any new definition must account for a much more dynamic set of issues that spans well beyond the boundaries of the energy sector. As individual consumers, households, and businesses begin to participate actively in the power system in ways never contemplated by the traditional system, it is time to replace older ways of thinking about the grid with a new set of concepts and definitions. Rather than viewing all of these “demand-side” innovations individually or as part of a portfolio of discrete distributed energy resources, which has obvious echoes of an older, more passive concept of the demand-side, we propose to view them as part of a larger, dynamic cluster of activitiesthat is turning the power system upside down and enabling more “horizontal” interactions than the vertical architecture of the traditional system allowed. We also view this as an open-ended process that is plural, experimental, and recursive - a realization in many ways of the “soft energy paths” that Lovins (1977) articulated more than thirty-five years ago.

What is perhaps most distinctive today is the highly interrelated nature of these developments and their growing intelligence. As the power sector becomes embedded within the emerging “internet of things” the demand side looks less like a collection of individual activities and behaviors and more like a complex, distributed system of intelligent devices that is combining behaviors and technologies in new ways. Traditional categories of generation and load (supply and demand) no longer make sense in the face of this dramatic revolution from below.

But, of course, bottom up processes still need coordination, guidance, and enabling frameworks from above. They need, in other words, smarter top-down policies and programs that align business models and regulatory frameworks at multiple levels and across multiple sectors, that empower consumers to become active participants in the grid, and that are durable enough to provide the necessary signals for investments but also flexible enough to accommodate an increasingly dynamic set of activities.

The demand side is no longer simply an object of regulation and incentives programs. It is in the process of becoming the most active part or the power sector with its own generative, emergent properties. As the various innovations discussed in this paper are combined in new and unpredictable ways, what was previously viewed as the static, end-use part of the sector needs to be reconsidered for what it is becoming—the most dynamic, empowered, and intelligent part of the sector.

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1. See e.g., <http://www.raponline.org/featured-work/energy-efficiency-resources>; <http://www-05.ibm.com/de/energy/pdf/plugging-in-the-consumer.pdf>; <http://www.eei.org/ourissues/finance/Documents/disruptivechallenges.pdf>; <http://www.americanprogress.org/wp-content/uploads/2012/08/0709_CleanEnergyWeb1.pdf> [↑](#footnote-ref-1)
2. http://spectrum.ieee.org/energywise/energy/renewables/californias-firstinnation-energy-storage-mandate [↑](#footnote-ref-2)