**Reconsidering the Demand Side**

Morgan Bazilian, Jennifer Layke, William Boyd, Lawrence Jones, Garett Blaney, Brent Barkett, and Cameron Brooks

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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**References**

Abdullah, M. A., et al. (2014). "Assessment of energy supply and continuity of service in distribution network with renewable distributed generation." Applied Energy **113**(0): 1015-1026.

Acevedo, S. S. and M. Molinas (2012). "Identifying Unstable Region of Operation in a Micro-grid System." Energy Procedia **20**(0): 237-246.

Aghamohammadi, M. R. and H. Abdolahinia (2014). "A new approach for optimal sizing of battery energy storage system for primary frequency control of islanded Microgrid." International Journal of Electrical Power & Energy Systems **54**(0): 325-333.

Ai, Q., et al. (2014). "The impact of large-scale distributed generation on power grid and microgrids." Renewable Energy **62**(0): 417-423.

Alagoz, B. B., et al. (2013). "A closed-loop energy price controlling method for real-time energy balancing in a smart grid energy market." Energy **59**(0): 95-104.

Ancillotti, E., et al. (2013). "The role of communication systems in smart grids: Architectures, technical solutions and research challenges." Computer Communications **36**(17–18): 1665-1697.

Arabali, A., et al. (2013). "Cost analysis of a power system using probabilistic optimal power flow with energy storage integration and wind generation." International Journal of Electrical Power & Energy Systems **53**(0): 832-841.

Arteconi, A., et al. (2013). "Domestic demand-side management (DSM): Role of heat pumps and thermal energy storage (TES) systems." Applied Thermal Engineering **51**(1–2): 155-165.

Bagdanavicius, A. and N. Jenkins (2014). "Exergy and exergoeconomic analysis of a Compressed Air Energy Storage combined with a district energy system." Energy Conversion and Management **77**(0): 432-440.

Baziar, A. and A. Kavousi-Fard (2013). "Considering uncertainty in the optimal energy management of renewable micro-grids including storage devices." Renewable Energy **59**(0): 158-166.

Bellekom, S., et al. (2012). "Electric cars and wind energy: Two problems, one solution? A study to combine wind energy and electric cars in 2020 in The Netherlands." Energy **45**(1): 859-866.

Bernardon, D. P., et al. (2014). "Real-time reconfiguration of distribution network with distributed generation." Electric Power Systems Research **107**(0): 59-67.

Bianchi, M., et al. (2013). "Performance analysis of an integrated CHP system with thermal and Electric Energy Storage for residential application." Applied Energy **112**(0): 928-938.

Börjesson, M. and E. O. Ahlgren (2012). 5.07 - Biomass CHP Energy Systems: A Critical Assessment. Comprehensive Renewable Energy. A. Sayigh. Oxford, Elsevier**:** 87-97.

Bortoni, E. C., et al. (2013). "Assessment of the achieved savings from induction motors energy efficiency labeling in Brazil." Energy Conversion and Management **75**(0): 734-740.

Bradbury, K., et al. (2014). "Economic viability of energy storage systems based on price arbitrage potential in real-time U.S. electricity markets." Applied Energy **114**(0): 512-519.

Brennan, T. J. (2010). "Optimal energy efficiency policies and regulatory demand-side management tests: How well do they match?" Energy Policy **38**(8): 3874-3885.

Breukers, S. C., et al. (2011). "Connecting research to practice to improve energy demand-side management (DSM)." Energy **36**(4): 2176-2185.

Broeer, T., et al. (2014). "Modeling framework and validation of a smart grid and demand response system for wind power integration." Applied Energy **113**(0): 199-207.

Brouwer, A. S., et al. (2013). "Fulfilling the electricity demand of electric vehicles in the long term future: An evaluation of centralized and decentralized power supply systems." Applied Energy **107**(0): 33-51.

Budde Christensen, T., et al. (2012). "Can innovative business models overcome resistance to electric vehicles? Better Place and battery electric cars in Denmark." Energy Policy **48**(0): 498-505.

Caliskan, H., et al. (2013). "Thermoeconomic analysis of a building energy system integrated with energy storage options." Energy Conversion and Management **76**(0): 274-281.

Camblong, H., et al. (2009). "Micro-grids project, Part 1: Analysis of rural electrification with high content of renewable energy sources in Senegal." Renewable Energy **34**(10): 2141-2150.

Campbell, T. and T. H. Bradley (2014). "A model of the effects of automatic generation control signal characteristics on energy storage system reliability." Journal of Power Sources **247**(0): 594-604.

Cardenas, J. A., et al. (2012). "A literature survey on Smart Grid distribution: an analytical approach." Journal of Cleaner Production(0).

Chen, X. P., et al. (2012). "A domestic CHP system with hybrid electrical energy storage." Energy and Buildings **55**(0): 361-368.

Choi, G. B., et al. (2012). Optimal planning of energy management system under demand uncertainty. Computer Aided Chemical Engineering. B. Ian David Lockhart and F. Michael, Elsevier. **Volume 30:** 347-351.

De Ridder, F., et al. (2013). "Applying an Activity based Model to Explore the Potential of Electrical Vehicles in the Smart Grid." Procedia Computer Science **19**(0): 847-853.

de Santoli, L., et al. (2013). "Energy characterization of CHP (combined heat and power) fuelled with hydrogen enriched natural gas blends." Energy **60**(0): 13-22.

del Real, A. J., et al. (2014). "Combined environmental and economic dispatch of smart grids using distributed model predictive control." International Journal of Electrical Power & Energy Systems **54**(0): 65-76.

Dias, M. V. X., et al. (2014). "The impact on electricity demand and emissions due to the introduction of electric cars in the São Paulo Power System." Energy Policy(0).

Eghtedarpour, N. and E. Farjah (2012). "Control strategy for distributed integration of photovoltaic and energy storage systems in DC micro-grids." Renewable Energy **45**(0): 96-110.

Esmaili, M., et al. (2014). "Optimal placement of distributed generations considering voltage stability and power losses with observing voltage-related constraints." Applied Energy **113**(0): 1252-1260.

Fadaeenejad, M., et al. (2014). "The present and future of smart power grid in developing countries." Renewable and Sustainable Energy Reviews **29**(0): 828-834.

Fallahi, F., et al. (2014). "The value of energy storage in optimal non-firm wind capacity connection to power systems." Renewable Energy **64**(0): 34-42.

Finn, P. and C. Fitzpatrick (2014). "Demand side management of industrial electricity consumption: Promoting the use of renewable energy through real-time pricing." Applied Energy **113**(0): 11-21.

Finn, P., et al. (2012). "Demand side management of electric car charging: Benefits for consumer and grid." Energy **42**(1): 358-363.

Fubara, T., et al. (2013). Model-based Assessment of the Role of Natural Gas-based Micro-CHP in Residential Energy Supply Systems. Computer Aided Chemical Engineering. K. Andrzej and T. Ilkka, Elsevier. **Volume 32:** 343-348.

Gandiglio, M., et al. (2014). "Design and optimization of a proton exchange membrane fuel cell CHP system for residential use." Energy and Buildings(0).

Gelazanskas, L. and K. A. A. Gamage (2014). "Demand side management in smart grid: A review and proposals for future direction." Sustainable Cities and Society(0).

Giannantoni, C. (2014). "The Relevance of Emerging Solutions for Thinking, Decision Making and Acting. The case of Smart Grids." Ecological Modelling **271**(0): 62-71.

Grenier, A. and S. Page (2012). "The impact of electrified transport on local grid infrastructure: A comparison between electric cars and light rail." Energy Policy **49**(0): 355-364.

Hackl, R. and S. Harvey (2013). "Framework methodology for increased energy efficiency and renewable feedstock integration in industrial clusters." Applied Energy **112**(0): 1500-1509.

Hedegaard, K., et al. (2012). "Effects of electric vehicles on power systems in Northern Europe." Energy **48**(1): 356-368.

Hennings, W., et al. (2013). "Utilization of excess wind power in electric vehicles." Energy Policy **62**(0): 139-144.

Holtmeyer, M. L., et al. (2013). "Considerations for decision-making on distributed power generation in rural areas." Energy Policy **63**(0): 708-715.

Ipinnimo, O., et al. (2013). "A review of voltage dip mitigation techniques with distributed generation in electricity networks." Electric Power Systems Research **103**(0): 28-36.

Kamel, R. M. (2013). "Maintaining stability of standalone Micro-Grid by employing electrical and mechanical fault ride through techniques upon fixed speed wind generation systems." Energy Conversion and Management **74**(0): 149-161.

Karellas, S. and N. Tzouganatos (2014). "Comparison of the performance of compressed-air and hydrogen energy storage systems: Karpathos island case study." Renewable and Sustainable Energy Reviews **29**(0): 865-882.

Kechroud, A., et al. (2014). "Distributed generation support for voltage regulation: An adaptive approach." Electric Power Systems Research **107**(0): 213-220.

Khamis, A., et al. (2013). "A review of islanding detection techniques for renewable distributed generation systems." Renewable and Sustainable Energy Reviews **28**(0): 483-493.

Knapp, E. D. and R. Samani (2013). Chapter 1 - What is the Smart Grid? Applied Cyber Security and the Smart Grid. E. D. Knapp and R. Samani. Boston, Syngress**:** 1-15.

Koh, L. H., et al. (2013). "Impact of Energy Storage and Variability of PV on Power System Reliability." Energy Procedia **33**(0): 302-310.

Kyriakarakos, G., et al. (2013). "Intelligent demand side energy management system for autonomous polygeneration microgrids." Applied Energy **103**(0): 39-51.

Lo, K. (2014). "A critical review of China's rapidly developing renewable energy and energy efficiency policies." Renewable and Sustainable Energy Reviews **29**(0): 508-516.

Lovins, A. (1977).  Soft Energy Paths: Towards a Durable Peace. Harper.

Lovins, A. (2011). Reinventing Fire. Chelsea green Publishing.

Loisel, R., et al. (2014). "Large-scale deployment of electric vehicles in Germany by 2030: An analysis of grid-to-vehicle and vehicle-to-grid concepts." Energy Policy(0).

Mah, D. N.-y., et al. (2013). "The role of the state in sustainable energy transitions: A case study of large smart grid demonstration projects in Japan." Energy Policy **63**(0): 726-737.

Malakar, T., et al. (2014). "Optimum scheduling of micro grid connected wind-pumped storage hydro plant in a frequency based pricing environment." International Journal of Electrical Power & Energy Systems **54**(0): 341-351.

Markovic, D. S., et al. (2013). "Smart power grid and cloud computing." Renewable and Sustainable Energy Reviews **24**(0): 566-577.

Marzband, M., et al. (2013). "Experimental validation of a real time energy management system for microgrids in islanded mode using a local day-ahead electricity market and MINLP." Energy Conversion and Management **76**(0): 314-322.

Meidani, H. and R. Ghanem (2013). "Multiscale Markov models with random transitions for energy demand management." Energy and Buildings **61**(0): 267-274.

Meybodi, M. A. and M. Behnia (2013). "Australian coal mine methane emissions mitigation potential using a Stirling engine-based CHP system." Energy Policy **62**(0): 10-18.

Motevasel, M., et al. (2013). "Multi-objective energy management of CHP (combined heat and power)-based micro-grid." Energy **51**(0): 123-136.

Niknam, T., et al. (2012). "An efficient scenario-based stochastic programming framework for multi-objective optimal micro-grid operation." Applied Energy **99**(0): 455-470.

Nuytten, T., et al. (2013). "Comparative analysis of latent thermal energy storage tanks for micro-CHP systems." Applied Thermal Engineering **59**(1–2): 542-549.

Pagani, G. A. and M. Aiello (2014). "Power grid complex network evolutions for the smart grid." Physica A: Statistical Mechanics and its Applications(0).

Pantaleo, A., et al. (2014). "ESCO business models for biomass heating and CHP: Profitability of ESCO operations in Italy and key factors assessment." Renewable and Sustainable Energy Reviews **30**(0): 237-253.

Peruzzi, L., et al. (2014). "The reliability of technological systems with high energy efficiency in residential buildings." Energy and Buildings **68, Part A**(0): 19-24.

Petreuş, D., et al. (2013). "Low cost single stage micro-inverter with MPPT for grid connected applications." Solar Energy **92**(0): 241-255.

Phuangpornpitak, N. and S. Tia (2013). "Opportunities and Challenges of Integrating Renewable Energy in Smart Grid System." Energy Procedia **34**(0): 282-290.

Pogaru, S. S., et al. (2013). "Investigating the Impacts of Modeling Variables- A Case Study with Smart Grid Demand Response." Procedia Computer Science **16**(0): 440-448.

Pohl, E. and D. Diarra (2014). "A method to determine primary energy savings of CHP plants considering plant-side and demand-side characteristics." Applied Energy **113**(0): 287-293.

Praznik, M., et al. (2013). "Simplified evaluation method for energy efficiency in single-family houses using key quality parameters." Energy and Buildings **67**(0): 489-499.

Prenc, R., et al. (2013). "Distributed generation allocation based on average daily load and power production curves." International Journal of Electrical Power & Energy Systems **53**(0): 612-622.

PwC. (2013). “Energy transformation: The impact on the power sector business model..” <http://www.pwc.com/gx/en/utilities/global-power-and-utilities-survey/assets/pwc-global-survey-new.pdf>.

Qureshi, W. A., et al. (2011). "Impact of energy storage in buildings on electricity demand side management." Energy Conversion and Management **52**(5): 2110-2120.

Raman, P., et al. (2012). "Opportunities and challenges in setting up solar photo voltaic based micro grids for electrification in rural areas of India." Renewable and Sustainable Energy Reviews **16**(5): 3320-3325.

Rosenow, J., et al. (2013). "Fuel poverty and energy efficiency obligations – A critical assessment of the supplier obligation in the UK." Energy Policy **62**(0): 1194-1203.

Saisirirat, P., et al. (2013). "Scenario Analysis of Electric Vehicle Technology Penetration in Thailand: Comparisons of Required Electricity with Power Development Plan and Projections of Fossil Fuel and Greenhouse Gas Reduction." Energy Procedia **34**(0): 459-470.

Sanchez, S., et al. (2014). "Stability evaluation of a DC micro-grid and future interconnection to an AC system." Renewable Energy **62**(0): 649-656.

Schueftan, A. and A. D. González (2013). "Reduction of firewood consumption by households in south-central Chile associated with energy efficiency programs." Energy Policy **63**(0): 823-832.

Serban, I. and C. Marinescu (2014). "Battery energy storage system for frequency support in microgrids and with enhanced control features for uninterruptible supply of local loads." International Journal of Electrical Power & Energy Systems **54**(0): 432-441.

Siano, P. (2014). "Demand response and smart grids—A survey." Renewable and Sustainable Energy Reviews **30**(0): 461-478.

Sigrist, L., et al. (2013). "Energy storage systems providing primary reserve and peak shaving in small isolated power systems: An economic assessment." International Journal of Electrical Power & Energy Systems **53**(0): 675-683.

Silvente, J., et al. (2013). Hybrid time representation for the scheduling of energy supply and demand in smart grids. Computer Aided Chemical Engineering. K. Andrzej and T. Ilkka, Elsevier. **Volume 32:** 553-558.

Singh, M. K., et al. (2013). "An analysis on energy efficiency initiatives in the building stock of Liege, Belgium." Energy Policy **62**(0): 729-741.

Taraft, S., et al. (2013). "Wind Power Control System Associated to the Flywheel Energy Storage System Connected to the Grid." Energy Procedia **36**(0): 1147-1157.

Thiede, S., et al. (2013). "SME appropriate concept for continuously improving the energy and resource efficiency in manufacturing companies." CIRP Journal of Manufacturing Science and Technology **6**(3): 204-211.

Vahl, F. P., et al. (2013). "The influence of distributed generation penetration levels on energy markets." Energy Policy **62**(0): 226-235.

Warren, P. (2014). "A review of demand-side management policy in the UK." Renewable and Sustainable Energy Reviews **29**(0): 941-951.

Xiao-xiao, Z., et al. (2011). "Study on protection Scheme for Micro-grid with Mobile Energy Storage Units." Procedia Engineering **16**(0): 192-197.

Yoo, S., et al. (2013). "Thermal transmittance of window systems and effects on building heating energy use and energy efficiency ratings in South Korea." Energy and Buildings **67**(0): 236-244.

Zehir, M. A. and M. Bagriyanik (2012). "Demand Side Management by controlling refrigerators and its effects on consumers." Energy Conversion and Management **64**(0): 238-244.

Zeng, Z., et al. (2014). "Policies and demonstrations of micro-grids in China: A review." Renewable and Sustainable Energy Reviews **29**(0): 701-718.

Zuwała, J. (2012). "Life cycle approach for energy and environmental analysis of biomass and coal co-firing in CHP plant with backpressure turbine." Journal of Cleaner Production **35**(0): 164-175.

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)