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Northeast Region Workshop

Pre-read Materials

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WELCOME LETTER

Dear Workshop Participant:

Thank you for participating in the U.S. Department of Energy's (DOE's) Office of Electricity Delivery and Energy Reliability (OE) and GridWise Alliance's (GWA) Northeast Region "The Future of the Grid" Workshop. Your input is critical because this workshop will not only help to develop the Northeast Region's stakeholder-driven vision for our future electrical grid, but it also will serve as the Region's contribution to the broader national vision for the future of the grid.

The electrical grid – as an enabling technology – provides the foundation for America's economic success. Our digital economy, our national security, and our daily lives are highly dependent on reliable, safe, and affordable electricity. The electricity industry is now in the midst of a major transformation that likely will continue for the next two decades. By having thoughtful and provocative conversations now, we can help ensure that electrical grid reliability and security are maintained now and well into the future while encouraging innovation and fostering economic growth during this transition period.

Our goals for the Northeast Region Workshop are broad and ambitious. We will debate and discuss many challenges facing the electricity industry. To help best utilize our time during the workshop, we have compiled this document to describe the scenarios we will be discussing, as well as to provide a summary of regional utility market conditions (e.g., generation mix, use of renewables and new technologies, and any special circumstances) and relevant industry information. So we can have a richer, more informative, and productive workshop, please take a few minute to familiarize yourself with these reading materials.

We look forward to hearing your view on these important issues and anticipate that the Northeast Region Workshop's outcomes will provide significant direction and insights on various stakeholders' visions for the future of the grid.

Sincerely,

Eric Lightner

Director, Smart Grid Task Force

U.S. Department of Energy

Becky Harrison

CEO

The GridWise Alliance

INTRODUCTION

It is an exciting time in the electricity sector as major changes transform the way we generate, deliver and use electricity. These changes are being driven by both new policies and new technologies. Furthermore, the dynamics of the consumer's role in these changes and the need to maintain a secure electrical grid governed by prudent regulations are combining to create a healthy debate that will no doubt take years to play out.

Regardless of our ultimate generation resource mix or production method (i.e., large-scale central plants versus smaller-scale distributed plants), our electrical grid and its operation will always play a critical role in our future electricity infrastructure. In fact, the operation of our grid will become ever complex even as it becomes more critical to the security of our nation's economy in a manner analogous to the ways in which the cellular network has enabled the world of smart phones and mobile applications.

There are a number of issues facing the electricity industry today. We recognize that while these are issues faced by the industry in general, they have regional and local differences that must be understand as we explore how best to modify policies and invest in technology development.

We also recognize that without thoughtful debate and planning, these changes could result in unintended consequences that hinder productivity and innovation. With this in mind, the GridWise Alliance (GWA) and the U.S. Department of Energy Office of Electricity Delivery and Energy Reliability (DOE OE) are partnering to facilitate a series of four regional workshops in late 2013 and 2014 to develop a stakeholder-driven vision of the future grid that includes its capabilities and operational requirements. This series of workshops will culminate with an executive summit in mid-2014 in Washington, D.C. Our goal is to identify and characterize technological capabilities, financial models, and the modifications to policies and regulations that are needed to support safe and reliable electricity delivery.

These regional workshops will bring together thought leaders from all stakeholder groups including utilities, regulators, state government officials, renewable energy providers, suppliers, and industry innovators to develop a shared vision for the grid and grid operators in 2030. Each workshop is targeted to have approximately 60 participants to engage in a series of small, facilitated breakout discussions with their peers. The ideas from each workshop with be summarized in a brief document and provided to the participants.

The result of these efforts will inform national efforts at DOE, help guide an R&D agenda, and serve as a tool to educate all stakeholders including state and Federal policy makers and regulators. These efforts will help us develop a much better understanding of the issues that we must address to achieve the goal of an affordable, reliable, and resilient electrical system that will ensure both a vibrant national economy and protection of our national security.

WORKSHOP DISCUSSION SCENARIOS

WORKSHOP DISCUSSION SCENARIOS

Accurately characterizing what the operation will be of the U.S. electricity delivery system in 2030 is difficult and perhaps even impossible. However, in order to be prepared for the future, it is important to begin thinking and planning for it now. Individuals involved in the current operation of the grid are in the best position to understand the complexity and nuances of grid operations and how changing external factors could impact operations. There are a large number of factors that will determine how the grid must function from policy drivers, to customer expectations, to technological developments.

To narrow and focus our discussion, the Workshop will focus on five main scenarios. The scenarios were selected with the hope of stimulating participants' thinking to drive innovative ideas and possibilities while simultaneously grounding them in reality and what situations are likely today. The four scenarios are not exhaustive of all possible situations but rather have been developed to try to cover a wide range of the grid landscape while also accounting for possible regional uniqueness. During the Workshop participants will be asked to engage in discussions on one of these scenarios.

SCENARIO 1: THE CHALLENGE OF BALANCING SUPPLY AND DEMAND AS GRID COMPLEXITY GROWS

Description

Today, transmission grid operators must ensure there is enough power generation both in terms of wattage and volt-amperes reactive (VARS) to service the load on their systems. To do so, the transmission grid operator must continually adjust the central generation. In some systems, they can also use a limited amount of demand response as another resource to keep the supply and load in balance. Today, for residential demand response, the operator typically sends a signal to switches on customers' air conditioners, water heaters, and/or pool pumps to cut off the load completely or cycle off for a given percentage of time in an hour. This simple but effective mechanism allows the operator to ride through a few critical peaks as an alternative to providing additional generation. In the future, with increasing penetration of distributed energy resources, the distribution grid will have to be able manage two-way power flows and must be able to balance more complex supply and demand options.

The devices on the "customer side" of the meter may include distributed generation; distributed storage; home energy management systems that can control various loads; appliances that can react to pricing signals; and options for charging or discharging electric vehicles.

At the transmission level, utility-scale generation will also be changing to include increasing penetration of non-dispatchable generation such as produced by large-scale wind farms and other renewables as well as utility-scale storage capabilities, all of which will require enhancements to existing balancing capabilities. This increasing dependence on devices at the "edge of the grid" will also require greater interaction between the distribution and transmission grid and grid operators to optimize the balancing of supply and demand functions.

Questions to Ponder

- What do these new balancing requirements mean to the role of the grid, Independent System operator (ISO), and the grid operator?
- What new demands will the increase in distributed energy resources create for the distribution grid and its operators?
- What new demands will increasing distributed and large non-dispatchable resources create for the transmission grid and its operators?
- What is the distribution grid operator's role versus the transmission grid operator's role versus the Independent System operator's role?
- Will ISO transmission operators need more visibility into the distribution grid?
- What new capabilities will be needed to perform this role? Are new tools/models/information needed?
- How will a shifting fuel mix (reduced coal, increased natural gas, increased renewables, etc.) drive or alter grid operational needs?
- How do current policies and regulation have to change to enable these new capabilities and roles?
- What are the financial implications of this transition? How do we ensure grid operators and owners are financially viable?

SCENARIO 2: THE CHALLENGE OF INVOLVING CUSTOMERS AND THEIR ELECTRICAL LOADS IN GRID OPERATIONS AND PLANNING FOR EMPOWERED CUSTOMERS

Description

In the past, for the majority of residential and small commercial electric customers, there has been little or no choice in how they met their electric power needs. The electric utility industry has been a commodity business where – much like the days when Henry Ford made his famous statement: "people can have the Model T in any color – so long as it's black" – electric customers were at the mercy of their power company. Technological innovations, new market structures, and changing customer expectations are shifting this long-held view of end users of electricity. Customers are now becoming empowered. Innovation is occurring across all customer classes with smart devices now commonplace in many residences and businesses around the country.

It's relatively safe to assume that by 2030 every device connected to the grid could be capable of communicating to the grid operator and receiving a control signal. Many of these will be purchased by consumers from various retail suppliers with the expectation that they will "plug and play" with grid operations. In the future, grid owners and operators must change gain a better understanding of customers' needs, desires, and ultimately their choices. They must define and implement an architecture and design that can optimize the management of customer's loads and other distributed energy resources based on how customers have agreed to participate to maximize electric system efficiency and minimize costs.

Currently, customers are beginning to pay more attention to their unique requirements (such as high reliability, clean energy, and/or least cost), and this focus tends to highlight those requirements that are not easily met by the current grid design and operation. For example, Superstorm Sandy and other natural disasters have focused attention on electric power interruptions that occur for many customers, resulting in threats to human health and safety in certain instances. Local generation tends to be the solution customers choose, but typically this is done without consideration for the impact on grid operation when scaled from hundreds to tens of thousands of distributed-scale sources.

Policies are also playing a part in this evolution. Examples of such policies include net metering rules that allow customers to get full retail credit for any power they produce from renewable sources and retail deregulations where new energy service providers can offer innovative rates.

Similarly, the push to reduce power plant emissions has resulted in a significant increase in local clean generation (such as roof-top solar photovoltaic modules), storage systems, and electrified transportation. By 2030, it is likely that local generation and its interaction with major and critical loads will drive operational strategies that are substantially different than current ones. The challenge will be to operate the grid with this diversity at the edge of the grid, incorporating complex economics with complex physical integration. Ancillary services will increasingly be met by controlling devices at the edge of the grid, thus creating challenges of synchronizing the operation of potentially millions of these devices.

Customers will be much more in the driver's seat in this future system with more options for how they react to the price of energy and services. Australia is already experiencing falling overall electricity demand at the same time the country is seeing higher peak demand. As the price of energy increases, customers are likely to make decisions that could drive this imbalance even higher.

Transactive energy is a term coined more than a decade ago to represent this complex interaction between the economics and physics at the edge of the grid. In particular, grid operators in the Pacific Northwest are developing this concept and experimenting with applying it in practice. It represents the type of concept that will be not only important but essential in the electrical grid of 2030.

Questions to Ponder

- How will increasing consumer participation, increasing consumer expectations, and consumer choice impact the operation of the grid? What new capabilities are needed?
- What will end consumers who generate their own electricity (prosumers) expect from the grid and the grid operator?
- How will the consumer role change from what it is today?
- How does this change the role of the distribution grid operator?
- What new role does the distribution grid operator need to play versus the transmission grid operator versus the Independent System Operator?
- Does this increased engagement and empowerment of customers impact the relationship between transmission and distribution?
- How will market structures need to change?
- What impacts and expectations will retail service providers, who own the customers in deregulated retail markets, have on the grid and the grid operator?
- Will customer-owned battery storage be the killer application that directly competes against grid services?
- What new capabilities will grid operators and the grid need in order to meet these new expectations and new role?
- How must current policies and regulation change to enable this new capability and role?
- What are the financial implications for funding grid investments and ongoing operations?
- How will increasing energy prices impact the transition to distributed generation and storage?
- How should utilities plan for those customers who cannot or simply choose not to generate their own electricity to ensure their cost for electricity stays reasonable?
- What are the risks of having the wrong pricing strategy?
- What are the implications for the future workforce both inside the utilities and among third party providers?
- What data sharing challenges can be foreseen?
- What new tools/models/information will grid operators need?

SCENARIO 3: THE CHALLENGE OF HIGHER LOCAL RELIABILITY THROUGH MULTI-CUSTOMER MICROGRIDS

Description

Customers are becoming increasingly aware that the traditional "grid" electricity they have taken for granted is, in many cases, not meeting their needs. Whether customers want cleaner, more reliable, and better quality electricity or just "smarter" options, they are beginning to drive a new market for "non-grid" electricity technologies. These new customer-centric technologies are being developed and deployed at staggering rates and often without sufficient consideration for the impacts they might have on grid operations.

The design and operation of "local grids" – or as they are commonly called *microgrids* – is still evolving with dozens of "beta" versions being built around the country. These new systems can be under the control of a single customer or serve multiple customers, and they will typically utilize the utility grid infrastructure as part of the local microgrid that can be "islanded" as desired. These systems will become more and more sophisticated in the near future resulting in mature markets by 2020 and beyond. Additional information on microgrids is provided later in this report.

David Crane, CEO of NRG Inc., is one of the industry's most vocal advocates for the rapid move to distributed electricity generation resources and the disruptive impact they will have on the traditional grid. NRG is currently testing several Stirling engine-based combined heating and power (CHP) devices for residential application. NRG plans to have units commercially available for sale in late 2014.

Whether it's Stirling engines, rooftop solar photovoltaic modules, fuel cells, batteries, or something else, it is clear that microgrids will evolve to be a dominate force in the operation of the grid by 2030 and beyond. The challenge for grid operators will be to create the appropriate interfaces with these systems to allow optimal operation of the grid, the microgrid(s), and both together.

Questions to Ponder

- What are the implications of this new balancing requirement to the role of the grid and the grid operator?
- What exactly is the distribution operator's role versus the transmission operator's role?
- What new capabilities will be needed to perform these roles?
- What will the "owners" of a microgrid expect?
- What will the customers served by the microgrid expect?
- How will the increase in microgrids impact transmission planning?
- How must current policies and/or regulations change to enable these new capabilities and roles?
- What are the financial implications of this transition?
- What are the implications for the future workforce both inside the utilities and among third party providers?
- How will planning occur for these microgrids? How will it impact the grid operator role?
- How will an increase in microgrids impact infrastructure investments?
- Will new rate structures be needed?

SCENARIO 4: THE CHALLENGE OF TRANSITIONING CENTRAL GENERATION TO CLEAN ENERGY SOURCES—LARGE-SCALE WIND, SOLAR, AND GAS

Description

Across the U.S. and around the globe, we are seeing a transition of central generation from traditional fuel sources to cleaner fuel sources. This transition is being driven by policies, regulations, economics, and public sentiment. Various incentives and increasing market demand have driven down the price for wind and solar, while new policies and regulations are driving up the price of coal, oil, and nuclear. Technological advances have resulted in cheaper natural gas here in the U.S. Together, these conditions are driving a transition in the U.S. large-scale generation mix. This transition is also introducing new challenges and opportunities, bringing new participants into the market, and introducing new operating characteristics for the generation fleet.

This changing large-scale generation mix also brings increasing variability that the grid must accommodate and manage. This variability is resulting in having excess power at times, as well as competing priorities for when the various generators should or must operate. In the Pacific Northwest, the combination of hydroelectric and wind generation has introduced the need to balance these competing priorities. To leverage fully these available resources, the grid operators must consider new ways to manage the load side of the energy value chain equation. At the same time, customers are taking more control of their energy usage. Many are lowering their overall demand for electricity through improved energy efficiency and changing behaviors, or by installing rooftop solar photovoltaic arrays, buying smart appliances, and signing up for other new third-party services that can help them better manage their electricity usage.

These dynamics are changing the role of the grid and the grid operator going forward. They are also challenging traditional planning processes. In an industry where assets traditionally have a 30 year or longer life span, these changes could result in overbuilding some asset capacity and underbuilding others.

Questions to Ponder

- Will these shifts to different generation fuels result in an increased regional approach to siting and leveraging future generation, and if so, what are the implications to the grid?
- What capabilities will be required of the grid to fully leverage non-dispatchable large generation sources such as large-scale wind?
- How does this change the role of the distribution grid and transmission grid operators?
- What role does the distribution grid operator need to play versus the transmission grid operator?
- How must current policies and/or regulations change to enable these new capabilities and roles?
- What are the financial implications of this transition?
- What are the implications for the future workforce both inside the utilities and among third party providers?
- What are the new tools/models/information needed to handle this transition?

NORTHEAST REGION CONDITIONS

NORTHEAST REGION CONDITIONS

This Northeast Region Workshop is focused on the future of the grid in the Northeastern portion of the U.S., specifically in the States of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, and West Virginia, as well as the District of Columbia. These 14 states and the District of Columbia are shaded in green in Figure 1.

Figure 1. States Included in the Northeast Region Workshop

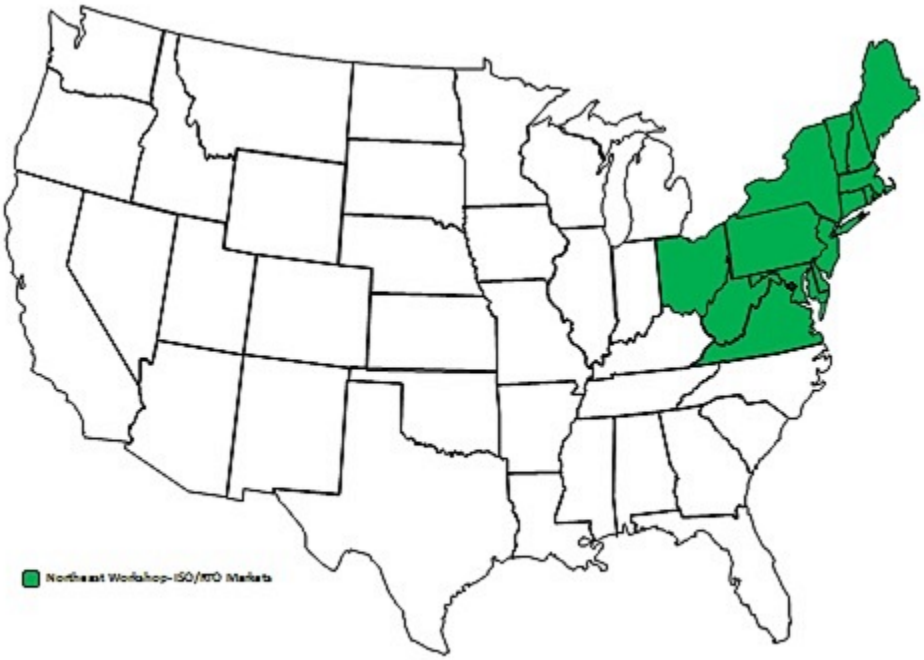
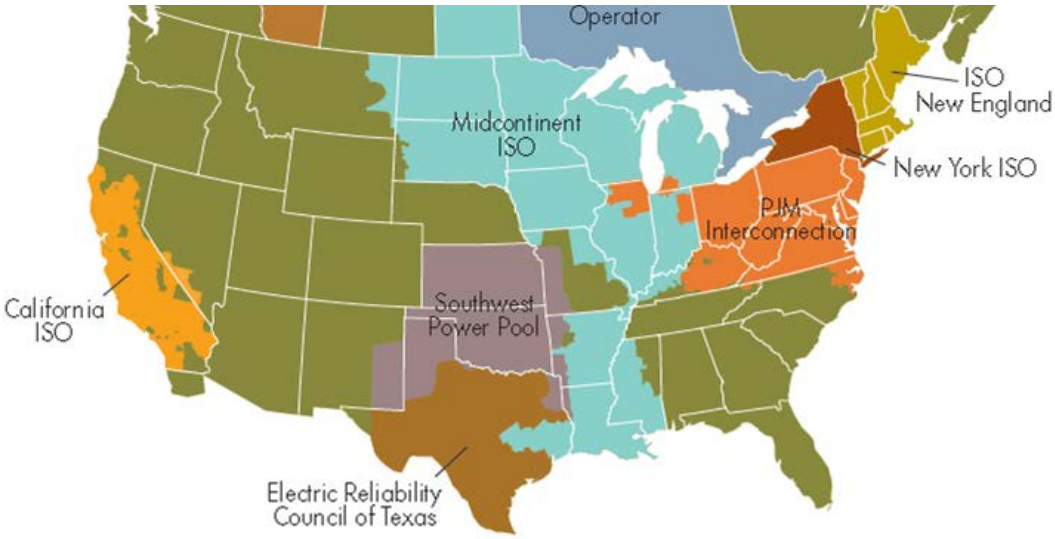


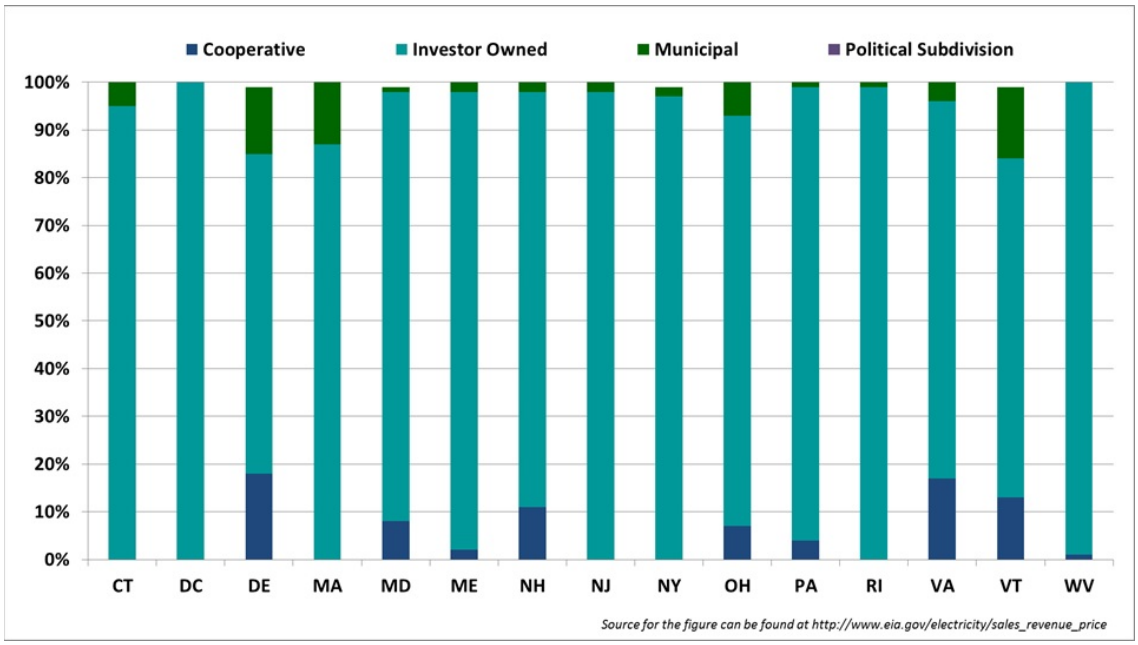
Figure 2 shows a map of the Independent System Operators (ISOs) and Regional Transmission Organizations (RTO) operating areas in the contiguous United States and parts of Canada. Figure 2 shows the RTOs and ISOs operating in the Northeast Region. These include ISO New England (ISO-NE) operating in all six New England states; ISO New York; and PJM Interconnection in the remaining seven states and the District of Columbia [1].

Figure 2. ISO and RTO Operating Regions [2]



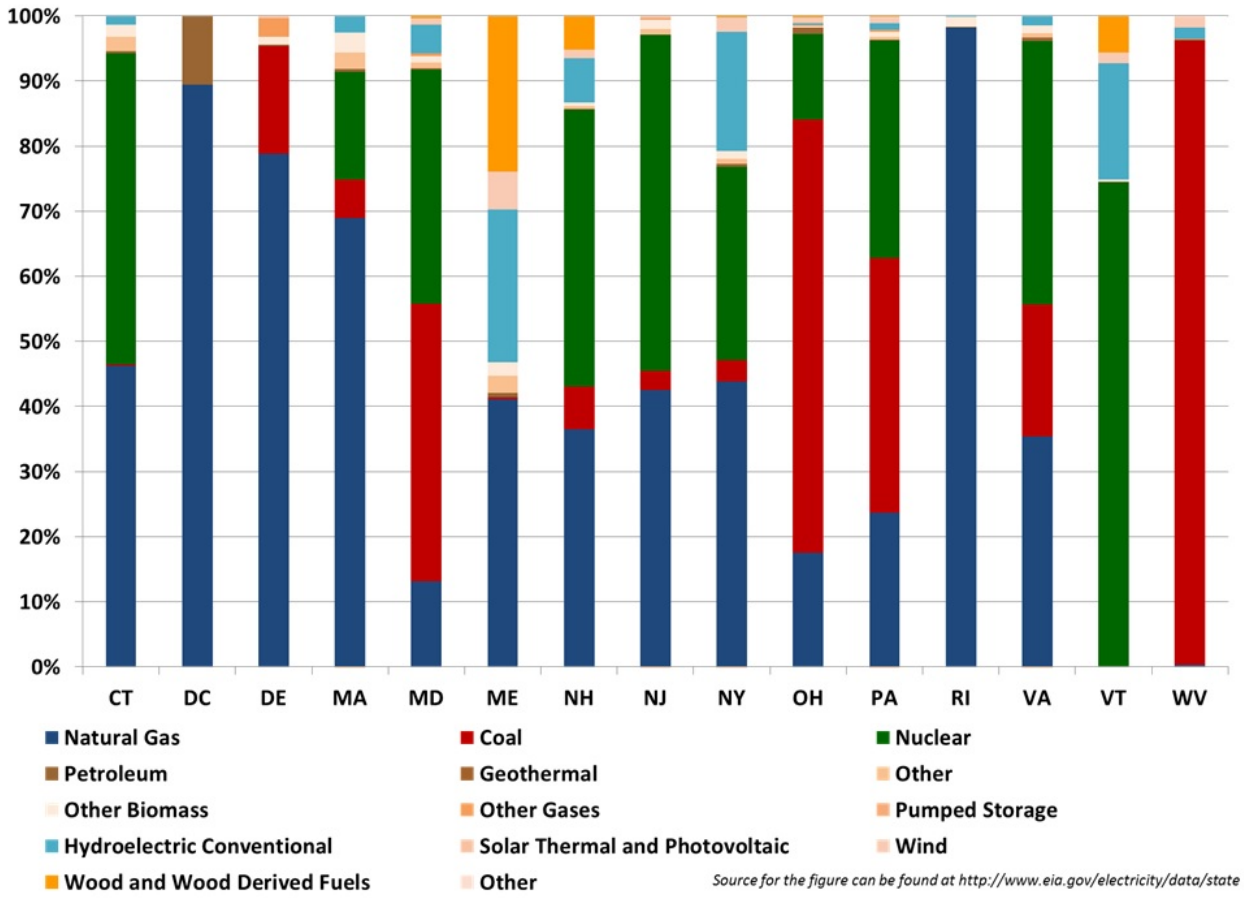
The utility profiles of each state in this Workshop were investigated and the results are shown in Figure 3. Investor-owned utilities (IOUs) are by far the most common in this region with eight states plus the District of Columbia having IOU profile fractions of 90 percent or higher, while only three states have fractions less than 80 percent including one (Delaware) with a fraction less than 70 percent [3]. Municipal and cooperatives comprise the remainder in all 15 state-level or state-equivalent-level jurisdictions in this region.

Figure 3. State Utility Profiles in the Northeast Region



The generation mix of for each state and D.C. in the Northeast Region was investigated and the results are shown in Figure 4. Natural gas (shown in dark blue) is the most common fuel type, supplying over 10 percent of the generation in all but Vermont and West Virginia. In Rhode Island and D.C., natural gas accounts for over 85 percent of generation based on megawatt-hours (MWh). The only state which has a higher reliance on a single fuel is West Virginia which uses coal (shown in red) for 96 percent of its generation. Nuclear power (shown in green) is used in most of the states, including in two states where it accounts for over half of the generation mix, namely, Vermont (74 percent) and New Jersey (52 percent) [3]. Hydroelectric (shown in light blue) is important in Maine (23 percent), New York (18 percent), and Vermont (18 percent) but region-wide accounts on average for only 5.3 percent of generation [3].

Figure 4. State Generation Based on MWh

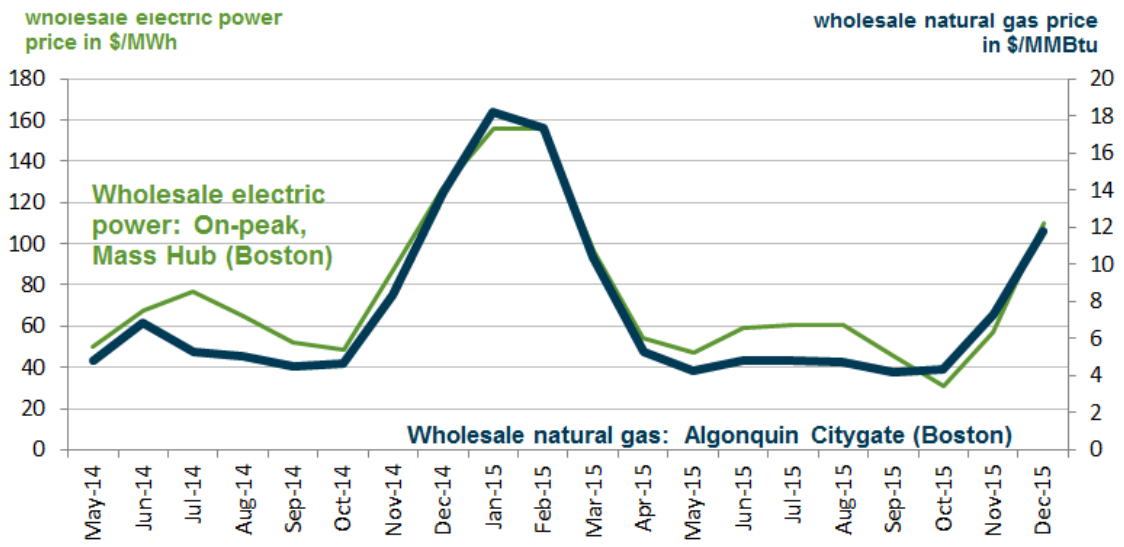


NEW ENGLAND'S DEPENDENCE ON NATURAL GAS

Within in the Northeast Region, the New England states use natural gas (NG) as a primary source for electricity generation with approximately 40 percent of electrical generation capacity coming from natural gas-fired power plants. In addition, New England states use natural gas as a primary source for heating. However, there is no production of natural gas in the region and no underground storage. This

requires NG to be pumped to New England through an extensive network of pipelines from other parts of the U.S. and Canada [4]. As a result, electricity prices are closely linked to natural gas prices with the two moving in tandem as is shown in price projections through the end of 2015 in Figure 5.

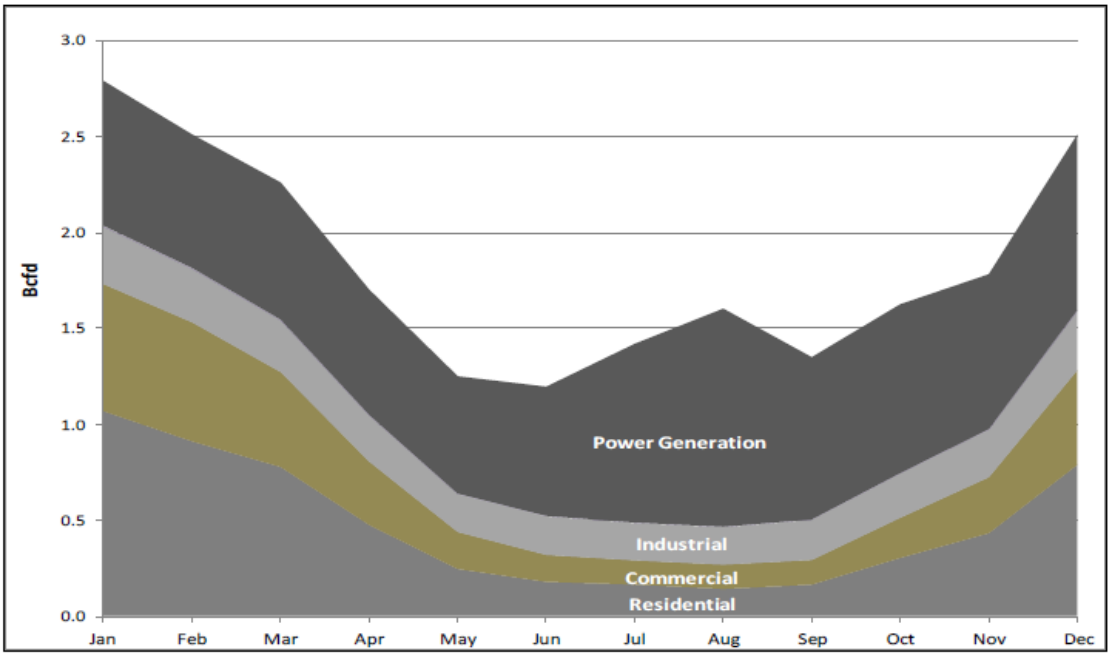
Figure 5. Projected 2014–2015 prices of wholesale electricity and wholesale natural gas in New England [5]



The area's reliance on NG for both power generation and heating can be problematic for ratepayers and utilities in New England's climate. New England has had the highest NG spot prices of any region for the past few winters. From November 1 to December 31, 2012, spot prices at two of the region's three major NG trading locations were $4.25/MMBtu and $6.40/MMBtu, compared to an average of $3.52/MMBtu for the rest of the U.S. [6]. These increased prices continued into the exceptionally harsh winter of 2013-2014 during which New England experienced the highest energy prices ever – twice as high as those of the previous winter [7]. The record number of low-temperature days led to high demand for heating, especially for residential customers. Furthermore, the cold can complicate delivery through the pipelines, requiring distribution companies to cover their costs. In addition to high seasonal demand, high NG prices can be attributed to other factors such as New England's lack of NG production and storage, and its distance from the rest of the North American NG grid.

This situation can result in competing needs between heating and power generation. Gas distribution companies generally base their required capacity on "peak day" demand, meaning that the coldest day in a given period is used to predict the amount of NG the region will require. Thus, an unexpected need for heating, as in the winter of 2013-2014, can threaten electricity generation capability and overall system reliability [8]. Mitigating the risk, though, is the fact that peak demands for heating and generation are generally in opposing seasons. Figure 6 shows the amount of NG used for heating is highest in winter months, and power generation is highest in the summer due to cooling needs. However, generation still makes up a significant portion of NG use, even in the winter.

Figure 6. New England Monthly Gas Consumption by Sector, 2009 [8]



Several entities in the region are working to alleviate the problem. The nonprofit New England States Committee on Electricity (NESCOE) filed a request to ISO-NE in January 2014 urging action on the development of new transmission infrastructure and increased NG supply [9]. NESCOE calls for the ISO's assistance in implementing the states' plans for upwards of 1200 MW of clean energy infrastructure in the region. ISO-NE is expected to assist in planning new transmission capacity and developing new rates and tariffs which further the states' clean energy goals. In terms of the region's demand for NG, NESCOE proposes tariffs on new and existing pipelines in order keep prices stable as future capacity increases.

ISO-NE has already undertaken several measures to ensure more reliable energy delivery, which would help reconcile some of the competition between heating and generation. Several rule changes are upcoming or underway that will enable the ISO to set more accurate prices in the energy market. For example, NG generators are now able to submit offers to ISOs sooner than before through an accelerated schedule for the "Day-Ahead" Energy Market, allowing more time to arrange for fuel deliveries. In the near future, ISO-NE plans to implement other features including the ability to vary supply offers on an hourly basis rather than setting the price once a day [10].

IMPACT OF SUPERSTORM SANDY

Densely populated areas such as the Northeast have been shown to be highly vulnerable to prolonged and disruptive power outages as a result of extreme weather or other high-impact events. This was brought home most forcefully during and in the immediate wake of Hurricane ("Superstorm") Sandy. The consequence of this hybrid powerful hurricane / nor'easter slamming directly into the mid-Atlantic coast with New York City and the Jersey shore in its crosshairs was overwhelming. In its May 2013 post-mortem, the National Weather Service noted the following impacts from Sandy:

- 8.5 million customers without power during and immediately after the storm;
- Record storm surges along parts of the New Jersey, New York, and Connecticut coastline with storm surge flooding exceeding eight feet above ground level in places;
- Power outages from the combined effects of wind and storm surge that in certain places lasted weeks to months [11].

New York's Con Edison utility company estimated its response and restoration costs between $350 million and $450 million [12] while New Jersey Transit estimated its damage total around $400 million [11]. As noted, power outages lasted in some instances for months – stretching well into the winter.

IMPROVEMENTS TO INFRASTRUCTURE RELIABILITY AND RESILIENCY

Superstorm Sandy was the last and most extreme of several extreme weather events in the mid-Atlantic region during a 15-month period that also included Tropical Storm Irene in August 2011; an early season heavy, wet snowfall in New England in October 2011; and the "derecho" severe thunderstorm event of July 2012 in the Metro Washington, D.C. area [13].

As a result of Superstorm Sandy and these other extreme events, a number of Northeast Region states have been exploring in earnest solutions to the problem of disruptive and costly blackouts. In particular, the States of Connecticut, Massachusetts, New Jersey, and New York are attempting to develop microgrids as a way of ensuring resiliency and "hardening" their electrical grid infrastructures. In addition to the microgrid efforts the states of Massachusetts, New York and Pennsylvania have developed Smart Grid plans.

Connecticut

Connecticut is attempting to develop what would be the nation's first statewide microgrid. In June 2012, the state legislature passed and Gov. Dannel Malloy subsequently signed Public Act 12-148 to enhance emergency preparedness and response [14]. Section 7 of the legislation directed the Connecticut Department of Energy and Environmental Protection (DEEP) to establish the Microgrid Grant and Loan Pilot Program to support local distributed energy generation and issue a request for proposals to establish a statewide microgrid network to support critical facilities such hospitals, police and fire stations, water and wastewater treatment plants, public shelters, and other designated buildings. In August 2013, the state approved nine microgrid projects totaling $18 million. In announcing the awards, Gov. Malloy said he would recommend an additional $30 million for the microgrid program [15].

Massachusetts

In late 2013, Massachusetts started requiring utility companies to submit ten-year grid modernization plans. The State's Department of Public Utilities (DPU) has four overarching objectives: reduce outages, optimize demand, integrate distributed resources, and improve workforce and asset management [16]. The plans must aim to implement advanced metering infrastructure (AMI) plus additional features such as outage detection and smart appliance communication and control. Down the line, the State expects utilities to deploy time-of-use rates to its residential customers [17].

National Grid, which serves customers from all over Massachusetts, is implementing in 2014 a smart grid pilot project for 15,000 customers in the City of Worcester. Smart meters have already been installed for all of the participants and new applications and tests are forthcoming [18]. Known as the Smart Energy Solutions program, it is a $172 million dollar investment in electric infrastructure that includes advanced metering and communications systems, as well as plans for smart thermostats, dynamic pricing, and a unique way to display consumption information in-home through digital picture frames [19].

Additionally in January 2014, Gov. Deval Patrick announced a $50 million for a statewide plan to address the present and future impacts of climate change in the state in areas such as public health, transportation, energy, and the built environment [20]. The plan includes a $40 million municipal resilience grant program to help communities harden energy services at critical sites using clean energy technology. The intention is to have the DPU work with utilities in the state to determine ways to accelerate storm hardening and deploy microgrids and resiliency projects for T&D [20].

In February 2014, the Massachusetts Clean Energy Center (MassCEC) published a study to better understand the opportunities to promise and support the development of microgrids [21]. The study considered the Grid Modernization Working Group's proceedings on regulatory frameworks for a smarter grid and grid integration of distributed energy resources. It made a series of recommendations that include deployment of microgrids that also ultimately reduce greenhouse gas emissions. It also recommends the creation of a legal framework for "energy reliability districts" that "promise energy safe havens at the municipal level" [21].

New Jersey

New Jersey is presently focusing its microgrid efforts on its transit system. This is in response to the massive and costly disruptions from Superstorm Sandy including flooded tunnels and stations. In August 2013, the U.S. Department of Energy (DOE) announced that it was partnering with the State of New Jersey, NJ Transit, and the New Jersey Board of Public Utilities to assess NJ Transit's energy needs and help develop a conceptual design of an advanced microgrid system [22]. The microgrid will have over 50-MW of power from an array of smart grid technologies and distributed energy resources including those from renewable sources [23]. DOE's Sandia National Laboratories will assist NJ Transit in its efforts to enhance the reliability and resiliency of electricity used for its rail and system operations. DOE Secretary Ernest Moniz and New Jersey Gov. Chris Christie signed a memorandum of understanding that established what is known as the NJ TRANSITGRID partnership.

New York

In January 2014, New York Gov. Andrew Cuomo unveiled at a press conference with Vice President Joe Biden a $17 billion strategy known as "Reimagining New York for a New Reality" that seeks to transform the state's infrastructure, transportation networks, energy supply, coastal protection, weather warning system, and emergency management system to protect residents from future extreme weather events. This strategy includes a $40 million competition known as NY Prize to create a series of 10 microgrid systems to help building community-scale power grids for areas with approximately 40,000 residents [24]. The NY Prize competition is in addition to a $20 million competition that Gov. Cuomo announced in October 2013 to create new microgrids in Nassau and Suffolk Counties on Long Island, both of which

were particularly hard hit by Sandy. This money was part of a larger $815 million post-Sandy recovery and rebuilding projects package announced for Long Island [25].

The New York State SmartGrid Consortium (NYSSCG) is a group of public and private leaders in energy including utilities, operators, governments, and academia. They represent these stakeholders in promoting smart grid adoption across the state. NYSSCG has several main priorities including the identification of business and regulatory frameworks that will facilitate grid modernization. They intend to focus on the development of microgrid and distributed energy systems while leveraging private sector investment [26]. Another area of focus involves "showcasing" smart grid and microgrid projects from across the state. A 2010 whitepaper by NYSSCG calls for an investment of $7.2 billion in smart grid technologies by utilities over the next decade that would result in annual savings and avoided costs to ratepayers of $18.9 billion between 2011 and 2025 [27]. NYSSCG issued a press release January 8, 2014 stated that a community-based microgrid approach can be "the means to increase reliability and give local communities more control of their energy systems while also allowing for the adoption of clean and efficiency distributed energy sources such as solar or combined heat and power" [28].

Additionally, the New York Public Service Commission (PSC) has been looking to address some of the states' electricity challenges. In the EEPS Change Order[1] of December 2013, the PSC identified the following key questions with respect to the New York State regulation of distribution utilities:

> "A. What should be the role of the distribution utilities in enabling system wide efficiency and market-based deployment of distributed energy resources and load management?
>
> B. What changes can and should be made in the current regulatory, tariff, and market design and incentive structures in New York to better align utility interests with achieving our energy policy objectives?" [29]

This resulted in PSC staff developing a Report and Proposal addressing these and other related questions. On April 25, 2014, the PSC opened a proceeding in regards to Reforming the Energy Vision (REV) Initiative to examine the regulatory, customer, and market questions addressed in the Report [30]. The focus of the proceeding is to align electric utility practices and the regulatory paradigm with the technological advances in information management and power generation and distribution. These proceedings envision "participation by all stakeholders in collaborative discussions" [30] and comments filed with the commission. It envisions a twin track approach, one of which focuses on matters related to the Distributed System Platform Provider (DSPP) model[2] and how it would impact wholesale markets and customer engagement, and the second focuses on regulatory changes and ratemaking issues [30].

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[1] Case 07-M-0548, Proceeding on Motion of the Commission Regarding an Energy Efficiency Portfolio Standard, Order Approving EEPS Program Changes (issued December 26, 2013) (EEPS Changes Order).

[2] In the report, a new business model for energy service providers is described. In this new model, utilities functions as a Distributed System Platform Provider (DSPP) that actively manages and coordinates distributed resources and provides a market in which customers can optimize their priorities while providing, and being compensated for, system benefits.

Pennsylvania

Pennsylvania's most prominent piece of smart grid legislation is Act 129. Implemented in 2008, it requires electric distribution companies with greater than 100,000 customers to file smart meter technology procurement and installation plans. More specifically, the act requires utilities to install smart meters capable of two-way communication, real-time customer access to consumption data, time-of-use pricing, and automatic control of a customer's power consumption [31].

In compliance with Act 129, FirstEnergy plans to deploy over two million smart meters to its customers in the coming years. Data collected by these meters will be analyzed by the utility in the hopes of increasing reliability and will also be made available to customers. In the future, FirstEnergy may use the installed smart meter capacity in a demand response program [32].

Several other utilities have implemented smart grid methodologies into their distribution infrastructure. Philadelphia's PECO has deployed AMI, including smart meters and in-home devices for usage recording and control, as well as distribution automation on the part of the utility. Similar efforts, with a focus on energy reduction, are being undertaken by the Wellsboro Electric Company (WECo), which serves one of the state's poorest communities. WECo has planned an energy education campaign to help customers use their new technology and reduce their consumption. East Penn Manufacturing intends to construct an advanced energy storage facility at the demonstration scale. The storage system will be able to sell up to 3 MW of frequency regulation to the local load-serving entity [33].

DIVERSIFYING ENERGY RESOURCES

As shown in Figure 4 and described above, the Northeast Region has a high dependency on natural gas resources. As already discussed in the context of the New England states, this is problematic because natural gas is neither produced nor stored in the region and the capacity of existing natural gas pipelines in the region is limited. For those reasons it is worth exploring the potential of alternate fuel sources for electricity generation in the region.

Solar Potential in New Jersey

Although the inherent solar energy potential for the Northeast Region is less than in the Southwest or Southeast U.S., nevertheless, by the end of 2013 three states in this region were in the top 10 for installed solar capacity. These states are New Jersey ranked 3rd at 1,211 MW; Massachusetts ranked 5th at 464 MW; and New York ranked 9th at 247 MW of installed capacity [34]. The key sets of factors affecting solar energy growth in the Northeast Region are:

- Favorable Federal and state financial incentives for installation of solar electric systems;
- Interconnection and net metering policies and related rules that encourage renewable energy usage including solar photovoltaic (PV);
- Improving technologies and steadily dropping prices that are making solar increasingly competitive with fossil fuel sources.

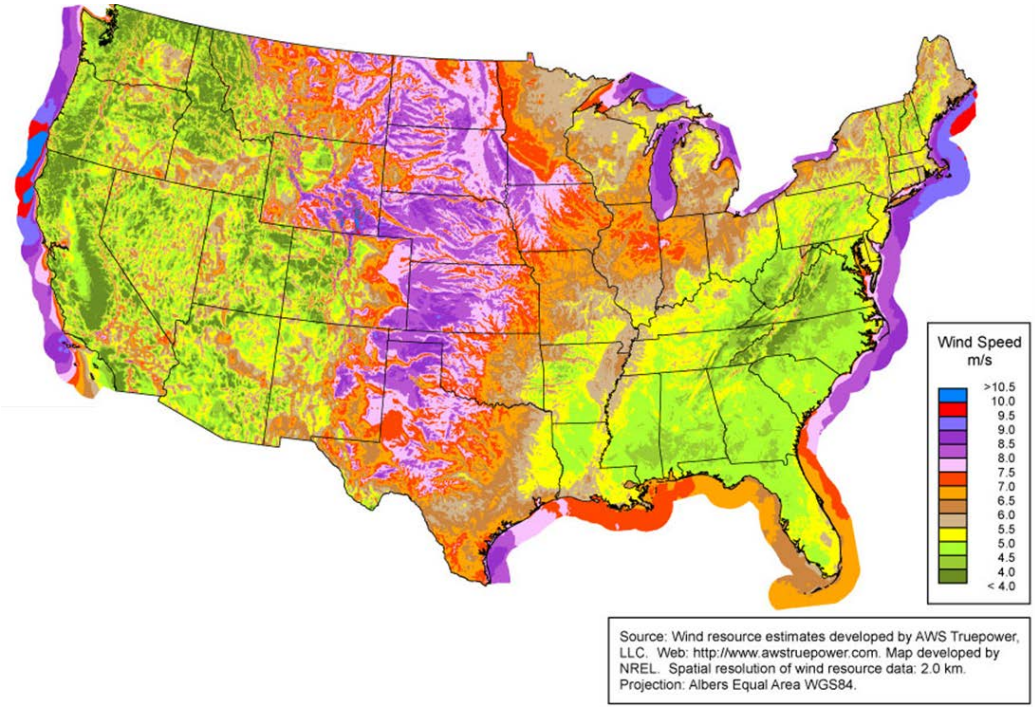
While these factors exist nationwide, there has been a particularly favorable alignment of these factors in Northeast states such as New Jersey. Like all the jurisdictions in the Northeast, New Jersey has

interconnection standards and net metering policies. New Jersey established its Clean Energy Program in 2001 with the Solar Renewable Energy Certificate (SREC) program becoming active in March 2004 [35]. The state's largest utility, PSE&G subsequently established its Solar Loan Program using the state SREC program to provide loans to customers for their solar energy systems that are then repaid using the SRECs generated by these systems. In July 2012, New Jersey enacted legislation to accelerate and increase the RPS solar requirements by four years beginning in 2014 and to increase the carve-outs to 5.5 percent by 2026 [36]. As of March 31, 2014, New Jersey's SREC program reports 27,441 home and business solar PV installations [37].

Offshore Wind Opportunities in Coastal States

Recent analysis by the National Renewable Energy Laboratory shows that the gross wind power resource of the coast of the U.S. more than 4,000 GW, nearly 4 times more than the generating capacity of the current U.S. electric grid [38]. One of the greatest benefits of offshore wind is that the resource, seen in Figure 7, often coincides with the demand centers of major cities and populations located along the nation's coasts. Demonstration projects and interconnection studies are underway primarily along the northeastern seaboard due to the excellent wind resource and demand centers being co-located, as well as the transmission congestion in this region. One such project by the University of Maine developed a 65-foot tall turbine prototype that is 1/8th scale of a full-sized 6 MW turbine and successfully connected it to the grid [39]. This demonstration project was deployed in July 2013 with plans to remain in the water for a year.

Figure 7. Annual Average Wind Speed at 80 m [40]



Hydropower Imports

Hydro-Québec, the large balancing area in the eastern provinces of Canada, has a large hydropower resource of about 35 GW of hydropower capacity compared to 38 GW of peak demand of the area it serves. Hydropower could be used to meet domestic RPS standards and lower the dependency on conventional generation. This imported hydropower currently provides energy and ancillary services to the northeastern United States through five high-voltage interconnection points and replaces predominantly conventional thermal generation in New England and New York [41]. Because hydropower is a dispatchable energy resource, it can provide ancillary services to support the integration of other renewable variable generation sources such as wind and solar power.

Hydro-Québec is currently studying a project for a direct-current interconnection with New Hampshire in collaboration with Northeast Utilities and NSTAR. In May 2009, the Federal Energy Regulatory Commission (FERC) approved the commercial structure of the U.S. portion of the project [41]. Another proposed transmission project is the Champlain Hudson Power Express which would deliver energy from Quebec to the New York City Metropolitan area via High Voltage Direct Current (HVDC) submerged cables [42]. Importing power in the Northeast Region may provide a solution to the area's electricity challenges; however, it is important to note that the U.S. Energy Information Administration predicts total U.S. energy imports to decline over the next 15 years [43].

RENEWABLE ENERGY STANDARDS AND GOALS IN THE NORTHEAST REGION

All 15 jurisdictions in the Northeast Region have either some form of renewable portfolio standard (RPS) including an alternative energy portfolio standard (AEPS) or a renewable portfolio goal. In particular, 11 states (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, and Rhode Island) and the District of Columbia have a legally-binding RPS or AEPS equivalent while the remaining three states (Vermont, Virginia, and West Virginia) have renewable portfolio goals. These standards and goals as of March 2013 are summarized below in Table 1.

Table 1. Northeast Region Renewable Energy Standards & Goals by Jurisdiction [44]

Connecticut: 27.1% RPS by 2020.	**Massachusetts:** 22.1% RPS by 2020.	**Pennsylvania:** ~18% by 2021.
Delaware: 25% RPS by 2026.	**New Hampshire:** 24.8% RPS by 2025.	**Rhode Island:** 16% by 2020.
District of Columbia: 20% RPS by 2020.	**New Jersey:** 20.38% RPS by 2021 plus 4.1% solar by 2028.	**Vermont:** Goal of 20% by 2017.
Maine: 40% RPS by 2017, includes 10% from new sources.	**New York:** 29% RPS by 2015.	**Virginia:** Goal of 15% by 2025.
Maryland: 20% RPS by 2022.	**Ohio:** 12.5% by 2024.	**West Virginia:** Goal of 25% by 2025 for IOUs with 30,000+ customers.

ENERGY EFFICIENCY STANDARDS IN THE NORTHEAST REGION

A number of Northeast Region states also have implemented requirements on their electric utilities to improve energy efficiency through energy savings. Such policies that requires utilities to meet specific energy savings targets according to set schedules is known as an Energy Efficiency Resource Standard (EERS), or alternatively, an Energy Efficiency Portfolio Standard (EEPS) [45]. Eight states in the Northeast

Region have legally-binding EERS including Connecticut, Delaware, Maryland, Massachusetts, New York, Pennsylvania, Ohio, and Rhode Island while another three (Main, Vermont, and Virginia) have energy efficiency resource goals. These standards and goals as of February 2013 are summarized in Table 2.

Table 2. Northeast Region EERS Standards and Goals with Policy Details [46]

Connecticut: 4% of retail load (includes CHP and waste heat recovery).

Delaware: Electricity and peak demand savings equivalent to 15% of 2007 numbers by 2015; natural gas savings equivalent to 10% of 2007 natural gas consumption by 2015.

District of Columbia: No EERS standards or goals.

Maine: 30% reduction of electricity and natural gas sales by 2020.

Ohio: 22.0% reduction of previous 3-year average retail electricity sales by 2025.

Maryland: 15% reduction in per capita energy consumption by 2015 compared to 2007; 15% reduction in per capital peak demand by 2015 compared to 2007.

Massachusetts: Reduce 1,103 GWh electricity in 2012 (statewide); reduce 24.7 million therms by 2012 (statewide).

New Hampshire: No EERS standards or goals.

New Jersey: No EERS standards or goals.

New York: 15% reduction relative to projected electricity use in 2015; gas savings of 112 BCF annually by 2020.

Pennsylvania: 3% of projected June 2009 - May 2010 electricity consumption by May 31, 2013; 4.5% of measured June 2007 - May 2008 peak demand by May 31, 2013.

Rhode Island: Varies by utility.

Vermont: 320,000 MWh electricity savings (3-year goal for 2012, 2013, 2014); summer peak kW savings: 60,800 (3-year goal for 2012, 2013, 2014).

Virginia: 10% electricity savings by 2022 relative to 2006 base sales.

West Virginia: No EERS standards or goals.

For more information on EERE policies, see www.dsireusa.org.

LANDSCAPE OF THE INDUSTRY

LANDSCAPE OF THE INDUSTRY

Almost everything written about the electric power industry these days refers to change: Changing customer demands, changing policies, changing technologies, and even changing business models. Such a dynamic landscape is difficult to characterize and impossible to capture in this document. Nevertheless, this section attempts to provide key highlights that indicate the direction, speed, and magnitude of the changes that will influence the nature of grid operations in 2030 and beyond. The information provided here is not necessarily new and instead is based on the most important and readily-available documents.

In the North American Electric Reliability Corporation (NERC) *2012 Long-Term Reliability Assessment* published in late 2013 [47], it identified broad issues that are impacting the industry and its ability to maintain the reliability of the bulk power system at mandated levels. These findings which are shown in Appendix A represent a comprehensive look at grid reliability and do not necessarily reflect specific regional or local issues. In addition, while they do address a ten year view of the industry, they do not necessarily capture the organic innovation taking place both in the utility industry and among customers.

POLICY TRENDS

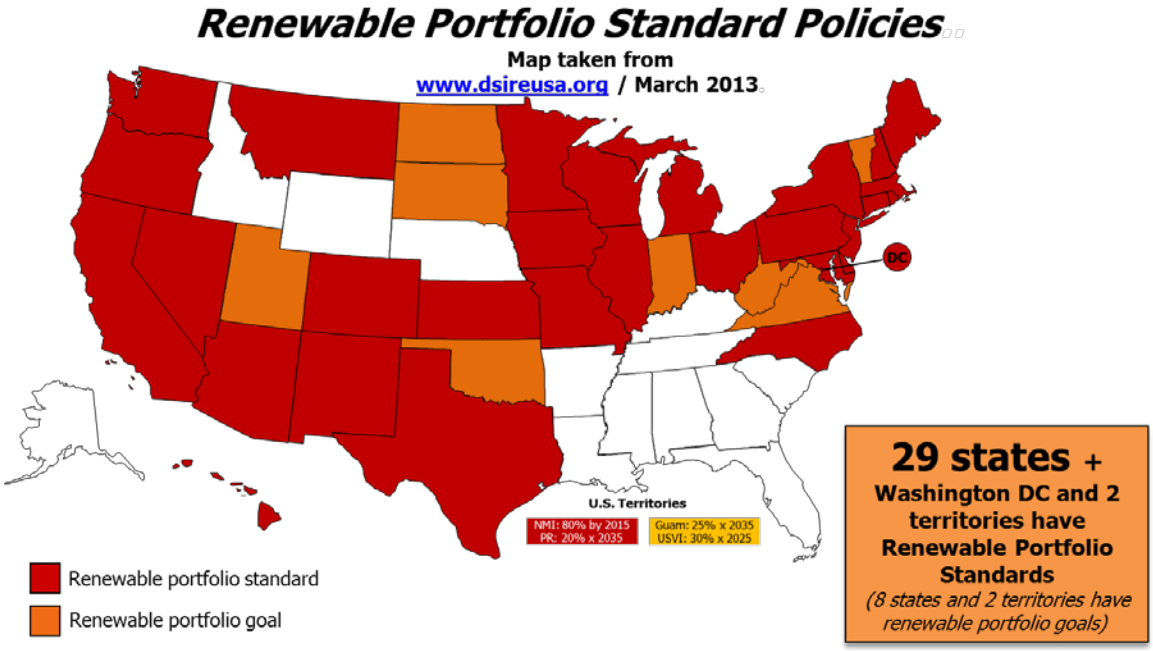
Federal, state, and local policies are all affecting the changes involving the grid and vice versa. This section highlights some of the most important policy developments and trends. While the shifting U.S. political landscape could affect the speed of policy change, it is unlikely to alter significantly the fundamental direction.

Renewable Portfolio Standards

A Renewable Portfolio Standard (RPS) sets a minimum requirement for the share of electricity to be supplied from designated renewable energy resources by a certain date/year. As one would expect, states with RPSs have experienced an increase in the amount of electricity generated from eligible renewable resources. Figure 8 shows the States as of March 2013 that have implemented legally-binding RPSs as well as those that have implemented renewable energy goals. The map is from the Database of State Incentives for Renewables & Efficiency (DSIRE) Data Base that is currently operated by the North Carolina Solar Center with support from the Interstate Renewable Energy Council (IREC) and funded by DOE.

RPSs vary widely in terms of program structure, enforcement mechanisms, size, and application, but they all have some common features. Another feature several states use to meet these requirements is a Renewable Electricity Credit (REC) trading system structured to minimize the costs of compliance [48].

Figure 8. States with Renewable Portfolio Standards [48]



DSIRE has summary maps similar to the one shown in Figure 8 for various financial incentives and other policies that promote renewable energy in the U.S. The data from some of those DSIRE maps are summarized in Table 3. The right column lists the financial incentive or policy. In the next three columns their adoption levels across the U.S. are summarized [48].

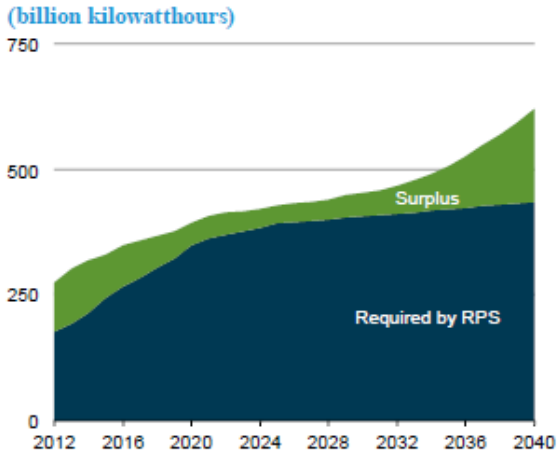
Table 3. U.S. Adoption of Incentives and Other Policies That Promote Renewable Energy [48]

Financial Incentive or Regulatory Policy	# of States	D.C.	# of Territories
3rd Party Solar Purchase Power Agreement (PPA) Policies	At least 22	Yes	1
Grant Programs for Renewables	22	No	2
Interconnection Policies	43	Yes	1
Loan Program for Renewables	41	No	0
Net Metering Policies	43	Yes	4
Property Assessed Clean Energy (PACE) Financing Policies	29	Yes	0
Property Tax Incentives for Renewables	38	Yes	1
Public Benefits Funds for Renewables	15	Yes	1
Rebate Programs for Renewables	16	Yes	2
Sales Tax Incentives for Renewables	28	No	1
Tax Credits for Renewables	24	No	0

EIA's *Annual Energy Outlook 2013* (AEO2013) released in April 2013 models the aggregate RPS requirement for the various state programs in what is called the Reference Case. The Reference Case model takes into account the impacts of state laws requiring the addition of renewable energy generation or capacity by utilities doing business in the states. The results are shown in Figure 9. It shows that states in general are projected to meet their ultimate RPS targets. As stated in AEO2013: "most states are meeting or exceeding their required levels of renewable generation based on qualified generation" [49]. This is partially due to the industry having a strong impetus to act prior to repeated temporary expirations and eventual predicted sunsets of Federal renewable energy incentives.

Most RPS targets are tied to retail electricity sales. With relatively slow growth in electricity sales throughout most of the country, the renewable generation entering service recently has gone farther toward meeting proportionally lower targets for absolute amounts of energy (that is, for kWh of energy, as opposed to energy as a percentage of sales) [49].

Figure 9. Total Renewable Generation Required for Combined State Renewable Portfolio Standards and Projected Total Achieved, 2012-2040 [49]

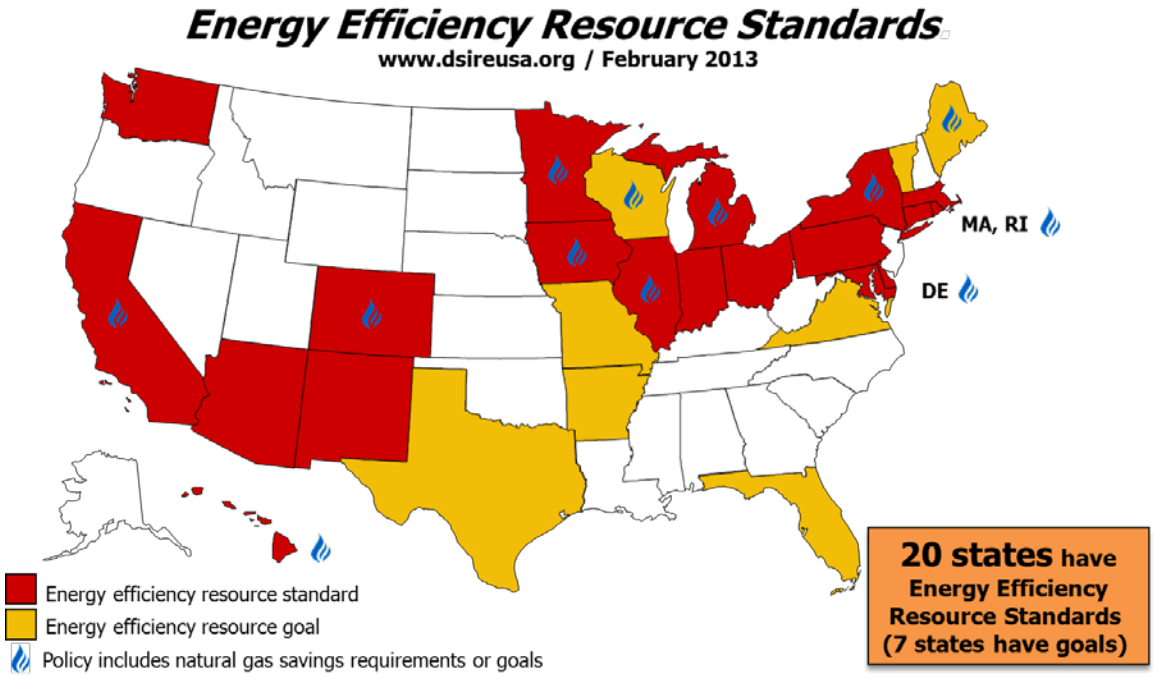


Based on the adoption rate of RPSs, the majority of the country is driving toward a minimum share of electricity to be supplied from renewable energy even without a national-level RPS program. The projection in Figure 9 shows that the amount of renewable generation being produced is greater than the amounts required by most or all states' RPSs, as indicated in the green area in the chart above. The grid will need to accommodate this additional renewable energy; therefore, it will be necessary to forecast the generation from these resources and communicate with them along the different points of the grid.

Energy Efficiency Resource Standards

An energy efficiency resource standard (EERS) requires utilities to meet specific targets for energy savings from energy efficiency measures. An EERS is sometimes coupled with a state's RPS policy and is included as a "lower-tier" resource [50]. Figure 10 shows the States as of February 2013 that have implemented EERSs.

Figure 10. States with Energy Efficiency Resource Standards [48]

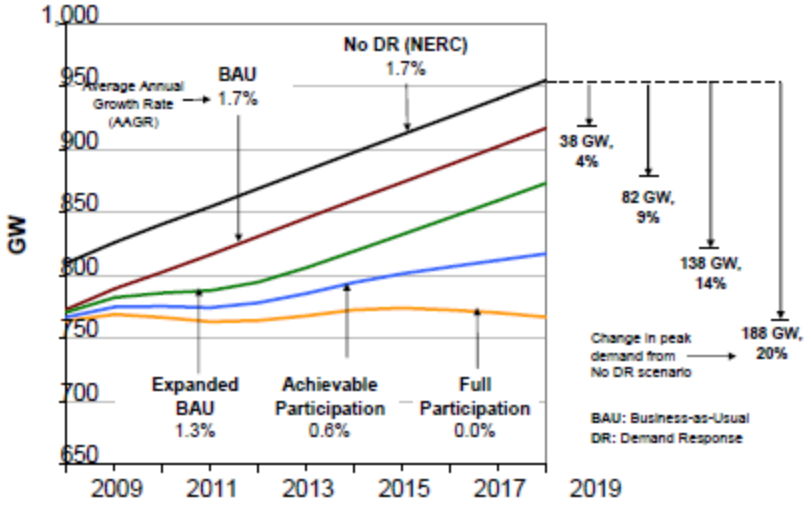


Demand Response Policies

Demand response (sometimes abbreviated "DR") encompasses a range of incentive mechanisms aimed at reducing customers' demand for electricity. These mechanisms typically consist of incentive payments, dynamic pricing plans, and other strategies used to change the consumption patterns of end-users. Although generally aimed at reducing loads at times of peak demand, demand response can also include actions that change any part of a utility's load profile.

A 2009 Federal Energy Regulatory Commission (FERC) study of demand response potential predicted varying levels of reduction in peak demand based on a number of different scenarios [51]. Figure 11 shows different peak demand forecasts under the various scenarios presented in the FERC study projected running through 2018.

Figure 11. U.S. Peak Demand Forecast by Scenario [51]



If existing demand response policies were to continue, shown on the graph in Figure 11 as the "Business-as-Usual (BAU)" scenario, the U.S. could expect to see a reduction of 38 GW, or 4 percent in peak demand from the base case by 2019. By contrast, assuming a nationwide adoption of demand response programs where dynamic pricing is the norm, this model indicates a 188 GW drop, corresponding to a 20 percent reduction in peak demand by 2019. This would not only keep pace with the annual growth rate, but it would also reduce the peak load from its starting point in 2009. This shows that effective demand response policies can have significant impacts on the nation's energy consumption and prices. They can also save utilities and customers substantial amounts of money.

Demand response is being encouraged by FERC through its National Action Plan on Demand Response [52], by Pacific Gas & Electric's InterAct tool, and by a host of other national, state, and local actions. Legislative plans have been set in motion in several states that put forth goals for reduction of peak demand. For example, the Michigan Public Service Commission's *Michigan's 21st Century Energy Plan* released in 2007 and the State of New Jersey's Board of Public Utilities' *2011 Energy Master Plan* both call on utilities to employ demand response practices [53] [54]. In 2009, legislation was passed in both Maryland and Colorado that set goals for energy consumption and peak demand reduction with the latter allowing cooperatively-owned utilities to set inclining block rates for residential customers [52]. This means that the more energy a household uses, the higher is the per kilowatt hour cost it faces, thus incentivizing households to reduce their consumption. These actions help lower the overall demand for electricity, which in turn might help counter the need for upgrades to transmission and distribution infrastructure due to additional loads entering into the grid.

Oftentimes states' demand response actions are implemented through retail programs, some of which may not require new enabling technologies such as smart meters. This was the case in Arizona, where its two major utilities offered time-of-use (TOU) pricing that attracted 30 to 40 percent of the residential market without requiring in most cases new equipment to be installed.

California has had demand response regulations in place for a number of years including TOU pricing since 1978. These policies have contributed to the fact that the state's energy usage has remained constant for 30 years despite the overall increase for the U.S. as a whole [52]. In addition, California's Energy Action Plan has gained recognition for deploying advanced metering initiatives and dynamic pricing. In what was the country's first dynamic pricing pilot, California adjusted rates for 2,500 customers to reflect the changing demand and account for peak loads. The program was considered a success, as it provided valuable data about customers' willingness to participate in a demand response program, and many customers elected to keep the experimental pricing scheme.

Environmental Requirements

Anticipated environmental regulations are an important topic within the industry today. Current uncertainty and future regulations could have a significant impact on the future generation mix.

The U.S. Environmental Protection Agency (EPA) is authorized under Section 111 of the Clean Air Act to "develop regulations for categories of sources which cause or significantly contribute to air pollution which may endanger public health or welfare" [55]. As part of the Climate Action Plan, a Presidential Memorandum in June 2013 directed the EPA to issue proposed standards, regulations, or guidelines to address carbon pollution from modified, reconstructed, and existing power plants by June 2014 and to provide a revised proposal for carbon pollution standards for future power plants by September 2013 [56]. The timeline for these and other actions set by the President is shown in Table 4.

Table 4. Timeline for Carbon Pollution Standards [56]

Activity	Deadline
Issue a new proposal for carbon pollution standards for future power plants	September 20, 2013
Issue proposed carbon pollution standards, regulations, or guidelines, as appropriate, for modified, reconstructed, and existing power plants	June 1, 2014
Issue final standards, regulations, or guidelines, as appropriate, for modified, reconstructed, and existing power plants	June 1, 2015
States submission of implementation plans to EPA	June 1, 2016

In September 2013, EPA began proposing standards for reductions in carbon emissions from new plants. The proposal has since been revised and is in the public comment stage with written comments being accepted through May 9, 2014. The current action proposes an emission limit of 1,100 pounds carbon dioxide (CO_2) per MWh for coal-fired power plants using integrated gasification combined cycle (IGCC) technology [57]. For efficient natural gas combined-cycle (NGCC) plants, proposed emission limits are 1,000 lbs. CO_2/MWh for larger units and 1,100 lbs. CO_2/MWh for smaller units [57].

Currently, there are no proposed EPA emissions standards for CO_2 in existing power plants. There are Federal guidelines developed by EPA which are used by individual states to facilitate in the formation of

their own emissions reduction plans. States have a significant amount of flexibility and autonomy when setting their standards, although these plans are subject to review by EPA [58].

In addition to carbon pollution standards, there are Mercury and Air Toxics Standards (MATS), enacted in 2011, that require power plants to limit their emissions of toxic air pollutants such as mercury and arsenic. These standards apply to all hazardous air pollutants (HAPs) emitted by coal-fired and oil-fired electrical generating units (EGUs) with a capacity of 25 MW or greater [59]. Existing sources of air pollution have four years (since the final rule was published in 2012) to comply with MATS, and EPA estimates that this should be sufficient time for most, if not all, sources to come into compliance [59].

On March 28, 2013, EPA finalized updates to emission standards for new power plants as shown in Table 5. Included in these standards are limits for particulate matter, mercury, sulfur dioxide (SO_2), and other pollutants, such as heavy metals and acidic gases [60]. According to EPA, there are approximately 1,100 existing coal-fired units and 300 oil-fired units affected by the MATS [61].

Table 5. Emissions Standards for New EGUs [62]

TABLE 1—REVISED EMISSION LIMITATIONS FOR NEW EGUS

Subcategory	Filterable particulate matter, lb/MWh	Hydrogen chloride, lb/MWh	Mercury, lb/GWh
New—Unit not designed for low rank virgin coal	9.0E–2	1.0E–2[a]	3.0E–3.
New—Unit designed for low rank virgin coal	9.0E–2	1.0E–2[a]	NR.
New—IGCC	7.0E–2[b] 9.0E–2[c]	2.0E–3	3.0E–3.
New—Solid oil-derived	3.0E–2	NR	NR.
New—Liquid oil—continental	3.0E–1	NR	NR.

Note: lb/MWh = pounds pollutant per megawatt-hour electric output (gross).
lb/GWh = pounds pollutant per gigawatt-hour electric output (gross).
NR = limit not opened for reconsideration (77 FR 9304; February 16, 2012).
[a] Beyond-the-floor value.
[b] Duct burners on syngas; based on permit levels in comments received.
[c] Duct burners on natural gas; based on permit levels in comments received.

TABLE 2—REVISED ALTERNATE EMISSION LIMITATIONS FOR NEW EGUS

Subcategory/pollutant	Coal-fired EGUs	IGCC[a]	Solid oil-derived
SO_2	1.0 lb/MWh	4.0E–1 lb/MWh[b]	1.0 lb/MWh
Total non-mercury metals	NR	4.0E–1 lb/GWh	NR
Antimony, Sb	NR	2.0E–2 lb/GWh	NR
Arsenic, As	NR	2.0E–2 lb/GWh	NR
Beryllium, Be	NR	1.0E–3 lb/GWh	NR
Cadmium, Cd	NR	2.0E–3 lb/GWh	NR
Chromium, Cr	NR	4.0E–2 lb/GWh	NR
Cobalt, Co	NR	4.0E–3 lb/GWh	NR
Lead, Pb	2.0E–2 lb/GWh	9.0E–3 lb/GWh	NR
Mercury, Hg	NA	NA	NR
Manganese, Mn	NR	2.0E–2 lb/GWh	NR
Nickel, Ni	NR	7.0E–2 lb/GWh	NR
Selenium, Se	5.0E–2 lb/GWh	3.0E–1 lb/GWh	NR

NA = not applicable.
NR = limit not opened for reconsideration (77 FR 9304; February 16, 2012).
[a] Based on best-performing similar source.
[b] Based on DOE information.

Federal Smart Grid Legislation

Over the past decade, Congress has demonstrated its interest in electric grid issues in various ways including through legislation. The Energy Independence and Security Act (EISA) of 2007 included Title XIII that is specific to the development of a smart grid. Often overlooked in Title XIII is an opening paragraph stating that "it is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system…." Title XIII then defines 10 key features of a modern electrical grid system including dynamic optimization of grid operations, integration of distributed resources, and integration of smart consumer devices, among others. Title XIII also provides for demonstration projects, interoperability, the Smart Grid Task Force, and Federal matching funds for

smart grid investments by utilities. These provisions serve as the basis for substantial funds that were authorized under the 2009 American Recovery and Reinvestment Act. Congress continues to consider new legislation to address cyber-security concerns, privacy and data access for consumers, and other policies related to grid modernization.

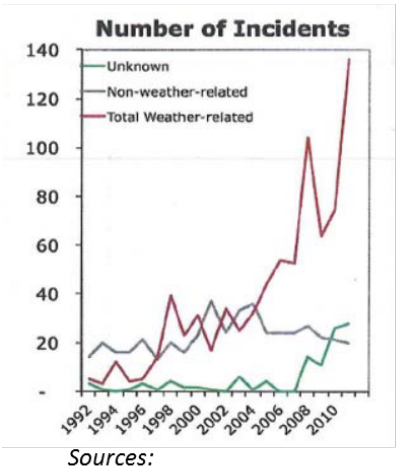
VERY LARGE SCALE WEATHER EVENTS

On October 29, 2012, Hurricane ("Superstorm") Sandy made landfall in southern New Jersey. Damage from Sandy has been estimated at $50 billion. The storm also left as many as 8.5 million customers without power for periods ranging from days to weeks to even months [11]. Recovery in the affected areas even now is not entirely complete.

In the last two years there have been at least six very large-scale events (VLSEs) in the U.S. including floods, windstorms, snowstorms, hurricanes, and prolonged droughts that have triggered wildfires. These six VLSEs are listed in Figure 12 in the top right table. Power delivery systems are vulnerable to these events and data on the left side of Figure 12 suggests that outages from weather-related events are on the rise.

These outages have real cost implications to utilities and consumers. Various studies have concluded that storm-related power outages cost the U.S. economy between $20 billion and $55 billion in a typical year. Depending on the outage duration the interruption could cost an industrial consumer over $4,000 [63]. The true impact on customers is difficult to measure and includes not only inconvenience but often threats to safety and health.

Figure 12. Weather-Related Power Outages



2011-2012 Extreme Events and Reported Customers Affected by Power Outages

Event	Date	Region	Customers Affected*
Superstorm Sandy	October 2012	Northeast	8.1M
"Derecho"	July 2012	Mid Atlantic	4.2M
Early Season Snow	October 2011	New England	3.0M
Hurricane Irene	August 2011	Mid Atlantic	3.2M
Western Wildfires	July 2012	California, Colorado	2.0M
Windstorm	November 2011	Southern California	0.4M

* Adopted from the Energy Information Administration.

Average Cost of a Power Interruption in the U.S.

Duration of Interruption	Residential	Commercial	Industrial
Momentary	$2.64	$733	$2,294
1 Hour	$3.27	$1,074	$3,943
Sustained Interruption*	$3.62	$1,293	$5,124

*The mean duration of a sustained interruption is 106 minutes.

Sources:
Weather-Related Power Outages and Electric System Resiliency.
The Gridwise Alliance. Lessons Learned from Superstorm Sandy and Other Extreme Events. June 2013.

Table 6 shows the variety of causes for outages including weather-related and other causes and the estimated total impact for each cause.

Table 6. Source and Size of Power Outages

		% of events	Mean size in MW	Mean size in customers
Weather Related Outages	Earthquake	0.8	1,408	375,900
	Tornado	2.8	367	115,439
	Hurricane/tropical storm	4.2	1,309	782,695
	Ice storm	5.0	1,152	343,448
	Lightning	11.3	270	70,944
	Wind/rain	14.8	793	185,199
	Other cold weather	5.5	542	150,255
	Fire	5.2	431	111,244
Other causes of outages	Intentional attack	1.6	340	24,572
	Supply shortage	5.3	341	138,957
	Other external cause	4.8	710	246,071
	Equipment failure	29.7	379	57,140
	Operator error	10.1	489	105,322
	Voltage reduction	7.7	153	212,900
	Volunteer reduction	5.9	190	134,543

Since Superstorm Sandy, much more attention is being given to reliability by local leaders who are considering a variety of options for local generation to address the most critical loads. In these cases cost becomes less important, and investments are being made in distributed power systems where standard economic arguments breakdown.

CUSTOMER LOAD AND DEMAND PROJECTIONS

Projections for future electricity needs are being estimated by several organizations. Table 7 shows projections for 2035 electricity sales ranging from 4,421 billion kWh to 5,316 billion kWh with residential sales increasing between 16 and 48 percent as compared to the 2011 baseline. Residential sales are the largest component of electricity sales in all but the Energy Ventures Analysis (EVA) projection [64]. Despite this increase, and as is discussed below, average electricity demand per household is actually expected to drop.

Not shown in this table is the transportation sector. Because of improvements in fuel economy standards, transportation sector energy use is expected to stay constant through 2040. However, electricity sold to the transportation sector is expected to triple to 19 billion kWh in 2040 with increasing sales of electric plug-in LDVs [64] [65]. While small compared to these other areas, electric vehicles might be important at the local distribution level and are discussed further in the Forthcoming Technologies section.

Table 7. Comparison of 2035 Electricity Projections [64]

	2035 Projections in billion kilowatt-hours (kWh)[3]					
	2011 (baseline)	EIA (AEO2013)	IHGSI	INFORUM	NREL	EVA
Electricity Sales	3,725	4,421	5,316	4,406	4,824	4,923
Residential	1,424	1,661	2,001	1,718	*Not reported*	2,116
Commercial/ Other Use	1,326	1,618	1,983	1,710	*Not reported*	2,292
Industrial	976	1,142	1,332	978	*Not reported*	515

Table 8 shows projections for 2035 electricity prices ranging from 10.1 to 11.9 cents per kWh with the highest prices occurring in the residential sector.

Table 8. Comparison of 2035 Electricity End-Use Prices [64]

	2035 Electricity Prices in 2011 cents per kWh3				
	2011 (baseline)	EIA (AEO 2013)	IHGSI	INFORUM	NREL
Average price	9.9	10.1	11.9	10.5	11.7
Residential	11.7	12.1	14.1	12.2	*Not reported*
Commercial	10.2	10.1	12.3	10.6	*Not reported*
Industrial	6.8	7.1	8.1	7.1	*Not reported*

EIA projects average electricity demand per household to decline by 6 percent by 2040 based on less consumption from lighting, PCs, laundry, and refrigeration and increased consumption from HVACs, TVs and other devices [64] [65]. For comparison, an American Council for an Energy-Efficient Economy (ACEEE) study on the long-term energy efficiency potential projects a 2 percent decrease in residential energy use by 2050 with savings coming from heating and lighting [66].

[3] Projections were made by the Energy Information Administration (EIA), IHS Global Insight, Inc. (IHGSI), Interindustry Forecasting Project at the University of Maryland (INFORUM), National Renewable Energy Laboratory (NREL), and Energy Ventures Analysis (EVA).

CENTRAL AND DISTRIBUTED POWER GENERATION

Technological advancements and policies are moving the U.S. generation mix away from coal and towards cleaner technologies such as natural gas, wind, and solar. One Presidential action directs the Department of the Interior to permit 10 Gigawatts (GW) renewables projects (such as wind and solar) on public lands by 2020 [67]. This will impact where and how power is generated on the electrical grid. The variability of wind and solar generation presents more complex control and economic scenarios for grid operators. Energy storage systems are being added to reduce the impact of supply variability and peak demand on transmission and distribution. While providing value, they are also another component in the system that needs to be monitored, controlled, and optimized. Smaller-scale distributed power generation is becoming more economical and widespread, especially when it provides additional features such as high reliability.

Nuclear

The level of nuclear capacity in the U.S. has remained relatively constant for many years, accounting for an approximate 20 percent share of national power generation since the last new reactor came online in Tennessee in 1996. Although five reactors went offline between 1997 and 1998, modifications to existing reactors have compensated for the loss in capacity. Nuclear plants are able to produce energy at rates much closer to their designed capacity than other forms of energy. This allows a relatively small number of plants (104 reactors located in 65 plants as of 2012) to make up a significant share of the U.S.'s actual power generation – generating the most after coal and natural gas in 2011 [68].

Looking ahead, as more reactors are taken offline than are replaced even while electricity demand increases, nuclear energy's share of generation capacity will inevitably decrease. The U.S. EIA's reference case in the *2014 Annual Energy Outlook (Early Release)* predicts a decrease in nuclear capacity from 102 GW in 2012 to 98 GW in 2020, despite 6.2 GW of new and uprated capacity coming online during this period. Challenging economic conditions which are increasing the operations and maintenance costs of nuclear plants are cited as the reason for many predicted closures. However, EIA also predicts that after 2025, as additional reactors are built, nuclear capacity will return to its original overall capacity [69].

Due to the unique approval process for nuclear power plants, it can be a decade or more between conception and full online status for a reactor. The extensive application, licensing, and regulatory processes and complex construction surrounding nuclear power plants make it difficult to pinpoint individual completion dates.

The Nuclear Regulatory Commission (NRC) had active applications for 28 new reactors as of 2012, and four new reactors now under construction (Vogtle Units 3 and 4 and Summer Units 2 and 3) are expected to come online between 2017 and 2019 [70]. The new Vogtle reactors, the first to receive construction approval in 30 years, are expected to have a combined capacity of 2.2 GW [71]. The V.C. Summer units are also designed with a 2.2 GW capacity [72]. These are large-capacity plants that well serve base loads but have less flexibility for variable demand.

Worldwide support for nuclear energy understandably dipped after the 2011 Fukushima nuclear disaster. The American Enterprise Institute conducted a public opinion study and while 57 percent of Americans surveyed favored using nuclear energy, 62 percent would disapprove a nuclear power plant in their community [73]. However, according to a March 2013 Gallup survey, 37 percent of respondents they would like more emphasis on nuclear power while 32 percent said they would like less emphasis and 28 percent said they would like the same emphasis [73]. Clearly Americans are divided over nuclear power.

Coal

According to EIA, in 2012, coal was used for about 37 percent of the 4 trillion kWh of electricity generated in the U.S. that year [74]. The National Energy Technology Laboratory (NETL) tracks the development of new coal plants and has found that actual capacity of completed plants has been significantly less than proposed capacity. NETL's 2002 report listed 11,455 MW of proposed capacity for the year 2005 but only 329 MW were actually constructed. In 2011, 1,599 MW of new capacity was announced and 2,890 MW were canceled. Combined capacity of plants scheduled for retirement by 2020 is 24.7 GW or 7 percent of the total U.S. coal generation capacity [75].

There are several projections on coal's viability as a generation source over the intermediate and long-term, and they make differing predictions. NERC showed coal's contribution to be approximately 30 percent in 2012 and projects its share of the market will drop to less than 27 percent by 2022 based on 16 GW of capacity retirement [47]. EIA's reference case shows coal-fired plants as the largest source of electricity generation in 2011 at 42 percent with its market share declining to 35 percent in 2040. Other EIA scenarios show coal-fired generation could be between 28 percent and 40 percent by 2040 [49]. EIA also projects that by 2040, 15 percent of the coal plants active in 2011 will be retired while only 3 percent of new generation capacity added will be from coal. This is due to Federal and state environmental regulations and uncertainty about future limits on greenhouse gas emissions such as CO_2 [64] [65].

One example of where regulations are affecting coal generation is at the Tennessee Valley Authority (TVA). In 2010 the TVA entered into consent agreements with EPA, four states, and several environmental groups over the pollution from 11 coal-fired power plants. TVA is in the process of retiring 30 percent of its coal fleet and evaluating the compliance cost for much of the rest [76]. Economic decisions based on environmental regulations, life of the plants, and presently inexpensive natural gas are contributing to the shifting capacity mix.

Large power plants have high capital costs that are recuperated over the life of the plant, typically 20 or more years. Once coal-fired generation is replaced, it is unlikely that utilities will switch back. While newer generation technologies are cleaner, their capital and operational costs will be different, and utilities will need to address these issues in their business models.

Natural Gas

There has been a surge in production of natural gas in the U.S. due to the shale revolution increasing recoverable supplies and bringing down prices for this fuel. Low natural gas prices have created more demand for natural gas from the power sector [77].

According to EIA, in 2012, natural gas was used for about 30 percent of the U.S. electricity generated [74]. There are several projections on natural gas as an electricity generation source. The Joint Institute for Strategic Energy Analysis (JISEA) studied natural gas in the energy sector, and in its "Baseline – Mid-EUR" case, it projected natural gas combined-cycle and natural gas combustion-turbine capacities nearly doubling from 2010 to 2050 [78]. NERC showed natural gas generation to be 38.5 percent in 2012 and projects the natural gas share of the market will increase to 39.7 percent by 2022 based on 32 GW of capacity additions, although conceptual projections show an additional 68 GW [47]. EIA shows natural gas generation increasing its market share from 24 percent in 2011 to 30 percent in 2040 with natural gas-fired plants accounting for 63 percent of capacity additions during that period. Inexpensive natural gas makes existing natural gas plants more competitive with coal and lower capital costs makes natural gas-fired plants a viable choice for new generation capacity [49].

Forecasts of the future price of natural gas vary significantly. To hedge against increasing natural gas prices many utilities lock in fuel prices from suppliers. Should natural gas prices increase in the future, the utilities will (as they typically do) pass those costs along to consumers with a potentially major impact on the cost of their electricity.

Wind

In the last five years, there has been a surge in wind power deployments across consumer, industrial, and commercial sectors in the U.S. In 2012, cumulative land-based wind deployment was 60 GW as compared to 12 GW five years earlier. In 2012, wind deployment accounted for 43 percent of new electrical generation capacity in the U.S., the most of any generation technology. Additionally, the combined potential of land-based and off-shore wind is about 140 quads (quadrillion BTUs), which is 10 times U.S. electricity consumption today [79].

The success of wind deployments can be attributed to a variety of factors. These include the increase in turbine size which lowers the cost; the larger production volumes that also help lower costs; production tax credits; and the improved capacity factor of plants from sophisticated operators which increase the time plants are operational and thus producing revenues [79].

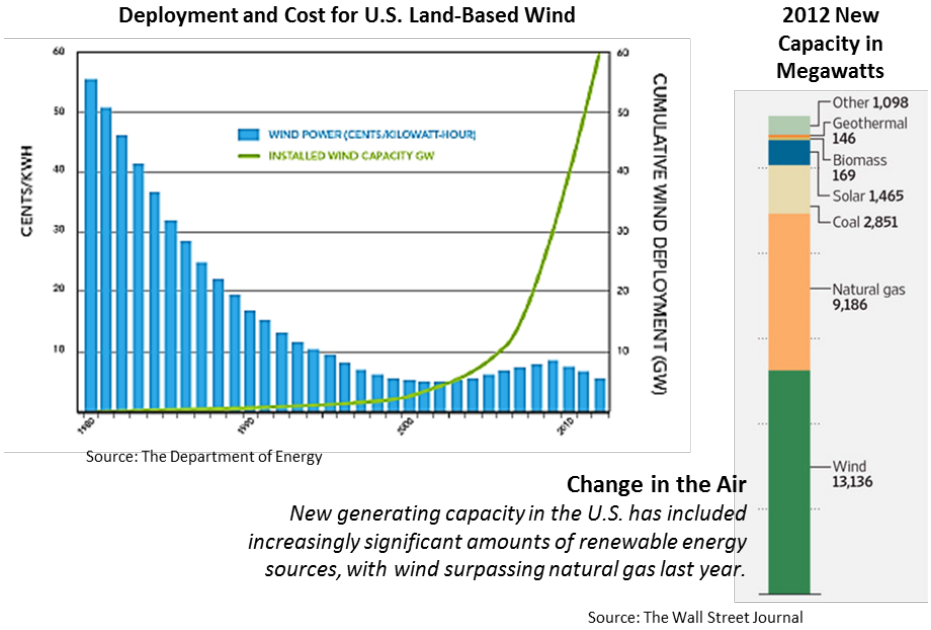
Looking ahead, DOE estimates that as much as 20 percent of projected U.S. electricity demand by 2030 could be met by wind power given policy support and continued technological improvements [80]. Although wind represents at present only 3.5 percent of the total electricity market, it is growing rapidly and regionally where the resource is abundant. For this reason, wind power is poised to be disruptive to other power generation technologies. Integration studies such as *Western Wind and Solar Integration Study* and the *Eastern Renewable Generation Integration Study* are being completed to examine the

impact large penetrations of variable generation sources will have on the electrical grid, and on the development of planning and operations tools for flexibility and stability of the electrical grid [81] [82].

Figure 13 provides an overview of land-based wind energy assets in the United States including a time-series chart of the deployment (installed capacity in GW) and cost (in cents/kWh) and a bar chart of new capacity additions in 2012.

There has also been tremendous growth in wind energy outside the United States, especially in Europe. By the end of 2012, Europe had 110 GW of wind capacity on the grid [83]. Germany is home to over 21,500 wind turbines, a fact that has posed some interesting challenges for the country. When generation exceeds demand and energy storage is not feasible, generation must be shed. However, German energy laws stipulate that non-green power generation must be shed first, lowering the capacity factor and revenues for those plants. Another challenge has been the variable nature and high concentration of wind on the electrical grid. This has resulted in large changes in capacity requiring new tools and methods for system operations to improve flexibility and maintain network stability [84].

Figure 13. Wind Power Deployment

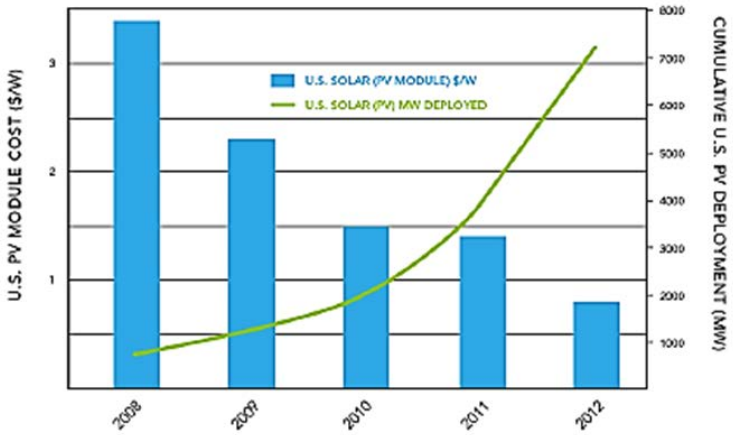


Solar

Solar is another renewable power generation technology that has made tremendous strides in recent years. As shown in Figure 14, cumulative solar photovoltaic (PV) deployment in 2012 was 7.3 GW, 10 times the deployment capacity of 2008. The EIA's AEO2013 projects commercial PV capacity increasing between 6.5 and 7.4 percent annually through 2040, depending on various policy scenarios [49]. As with wind, solar represents a small portion of total electricity market, but it is growing rapidly and

regionally where the resource is abundant. For this reason, it too can be both disruptive to other power generation technologies and pose challenges to the electrical grid.

Figure 14. U.S. Deployment and Cost for Solar PV Modules [79]



Solar deployment costs consist of the PV module and any inverters or batteries (i.e., equipment costs) and the so-called "soft costs" for permitting and installation. The drop in cost for a PV module is partly responsible for the dramatic increase in deployment. As the blue bars in Figure 14 show, PV module costs since 2008 have dropped by a factor of four to a 2012 price of about $0.80/watt. Soft costs in the U.S. are still high, averaging about $3.34/watt or approximately five times those of Germany. However, utility incentives, new financing options, and the current 30 percent Federal investment tax credit (scheduled to revert to 10 percent in 2017) have helped this technology achieve cost parity with electrical generation from natural gas, coal, and oil in many parts of the U.S. and put this technology within reach for the average homeowner or business [49] [79].

By 2030, local solar projects likely will be of sufficient scale to impact the operations of many local utilities. There are several large examples of distributed solar generation coming on-line in the U.S. The retail giant Walmart has installed solar PV modules on about 200 of its ~100,000 square foot stores delivering over 71 million kWh of energy annually. With about 4,500 stores in the U.S., and a goal of being served by 100 percent renewable energy, this could be a significant impact on the electrical grid [85] [86]. Figure 15 shows one such Walmart store with a large rooftop array of solar PV modules.

Figure 15. Distributed Solar on Walmart Store [86]

In Arizona roughly 500 new rooftop solar installations are completed each month. The state's largest utility, Arizona Public Service (APS), has 20,000 homes in its territory with solar PV modules. Residential systems are generally on the order of 7 kW, resulting in a reduction of about two-thirds in the electrical utility bills for these houses. However, Arizona utilities argued that with the net metering practice, these homeowners were unfairly benefiting from the electrical grid's 24/7 power supply without paying for the maintenance costs for power plants and transmission lines. In November 2013, the Arizona Corporation Commission voted to add a monthly fee of $0.70/kW to the bills of all customers that install new solar systems. In other states, utilities have the same argument so this Arizona vote may create momentum to levy a similar fee in other states [87].

Europe's experience with integrating solar energy could benefit the U.S. By the end of 2012, Europe had 70 GW of solar capacity on the grid with 22.3 GW in Germany [83]. As with other renewable resources, solar generation is variable, and this can produce load balance issues for the grid. A case in point occurred in Germany one day in February 2013, when its national electric grid experienced a large positive system imbalance due to this variability. On this day there was quite a bit of snow on the PV modules that did not melt as estimated, which resulted in less power from the PV and a system imbalance that required an activation of reserves [83]. Forecasting accuracy of solar generation will be increasingly important as more PV systems are installed.

Other Renewables

While wind and solar energy will tend to dominate in the next decade and beyond, other renewable resources such as geothermal, hydroelectric, and biopower will also have an impact. The EIA's AEO2013 shows that the renewable generating capacity of the combination of all renewable energy technologies will account for nearly one-fifth of total generating capacity in 2040 [49]. The National Renewable Energy Laboratory (NREL) concluded in its *Renewable Electricity Futures Study* that a combination of a flexible electric system with today's commercially-available renewable electricity generation technologies can supply 80 percent of total U.S. electricity generation by 2050 [88].

Geothermal resources are found primarily in the American West and Southwest. The technology is still emerging, but the potential for this resource is about 500 GW according to NREL. Hydroelectric energy ("hydropower") is already a primary source of energy in the Pacific Northwest. NREL estimates the U.S. hydropower potential is 152 to 228 GW [88]. Biopower is available in many regions and with an increase

in energy crops and harvesting technologies in the future, NREL estimates a corresponding 100 GW of dedicated biopower capacity [88]. By contrast AEO2013 projects much smaller amounts of geothermal (5 GW) and biopower (7 GW) plants entering operation. While these numbers are much less than wind and solar, they nevertheless represent a doubling in biopower capacity and a tripling in geothermal capacity from 2010 to 2040 [49].

FORTHCOMING TECHNOLOGIES

New companies are emerging that are focused on providing new energy products to consumers. Established companies such as Home Depot, Lowe's, and Best Buy are focused on relatively inexpensive products that integrate energy management devices with other home automation products. Other companies are focused on commercial-scale energy storage, fuel cells, etc., with an emphasis on convenience and security. While only some of these products will ultimately be commercially successful in these emerging markets, it is clear that innovation is just beginning.

High Voltage Direct Current (HVDC) Transmission

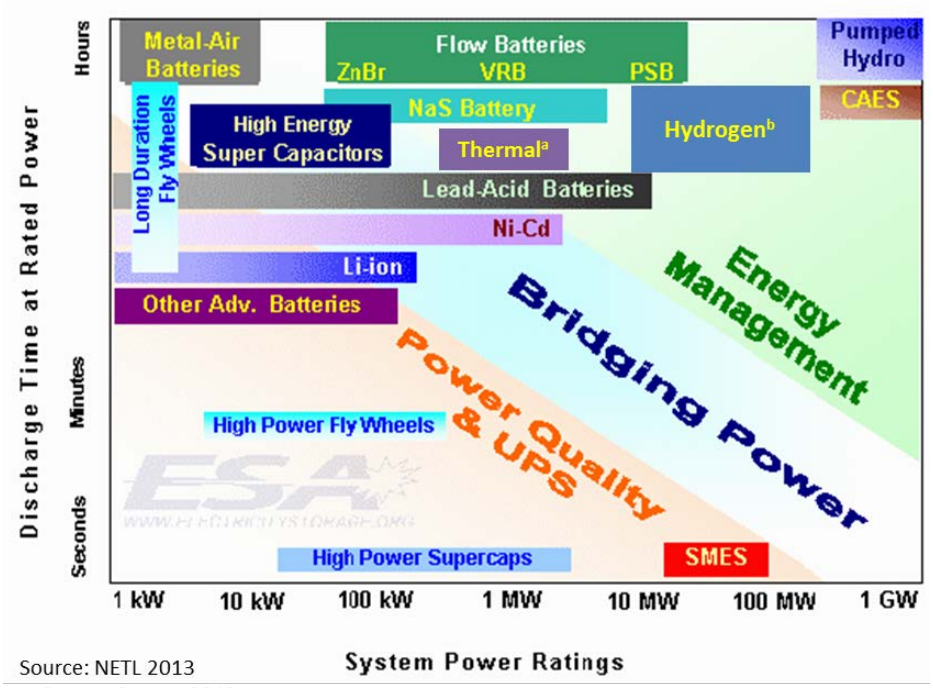
High-voltage direct current (HVDC) was the first means of transmitting electric power over a distance. Today this technology is re-emerging as a possible replacement for alternating current (AC) high voltage lines. DC lines result in overall higher efficiency and reliability than an equivalently-sized AC system [89]. There are approximately 4,000 circuit miles of HVDC lines in the U.S. whereas there are over 180,000 circuit miles of AC lines [90]. Countries such as Sweden, Germany, China, and Brazil also have HVDC transmission lines. Clean Line Energy is developing a series of DC transmission lines to deliver thousands of megawatts of renewable power from the windiest areas of the U.S. to cities with a strong demand for clean, reliable energy. The company is proposing to develop four HVDC transmission lines, each capable of transporting up to 3,500 MW of renewable energy from renewable-rich regions in the Midwest to load centers in the Eastern and Western U.S. [91].

Energy Storage

Today's grid operator manages most fluctuations on the electrical grid by adjusting generation to maintain reliability and to adhere to strict conventions on voltage and frequency. In the future, clean energy variable generation such as wind and solar will have significantly increased, and policies are already in place or underway in most states to give them preference in meeting demand needs. Given the increased variability, energy storage technologies might provide flexible solutions throughout the electricity value chain.

Energy storage systems are designed with different energy densities, response times, time of operation, and power levels depending on the target application. The primary issues energy storage systems address are energy management, bridging power, and power quality. There are several technologies available that perform these energy storage functions from pumped hydro, which is a fairly mature technology, to capacitors and flywheels, which today are only feasible in niche markets. Figure 16 shows the discharge time for different types of energy storage systems (i.e., different system power ratings) and the primary issues that each type addresses.

Figure 16. Power Ratings and Discharge Times for Energy Storage Technologies



Source: NETL 2013

a. Source: Sopogy 2013.

b. Source: NREL 2010.

CAES = compressed air energy storage; Li-ion = lithium-ion; Ni-Cd = nickel cadmium; NaS = sodium sulfur; PSB = polysulfide bromide; SMES = superconducting magnetic energy storage; VRB = vanadium redox battery; ZnBr = zinc bromide

There are several examples of these technologies already deployed within the grid. Sodium sulfur (NaS) batteries have been in commercial use for over 10 years at the megawatt scale with over 300 MW installed globally. On the consumer side thermal energy storage systems are being used for bridging power applications and to help shave peak demand. Thermal storage uses off-peak electricity to store cooling or heating energy and then during peak demand uses that energy to meet power needs. The fashion retail store Nordstrom at the Ala Moana Center in Honolulu uses this technology to produce 43 tons of ice every night which helps cool the 210,000 square foot store during the day. Figure 17 shows the rooftop thermal energy storage system at the Ala Moana Center. As a result, the three-story store uses about half the electricity of a similarly sized retailer during daytime hours [92].

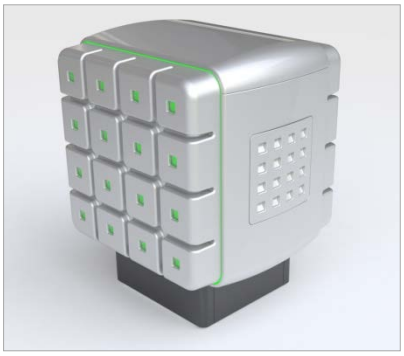
Figure 17. Rooftop Thermal Energy Storage [92]

Energy storage is gaining state support. California now has a mandate for increasing energy storage that requires that the state's investor-owned utilities must begin buying a combined 200 MW of energy storage technology by 2014 and reaching 1,325 MW by the end of 2020. This recent decision was made in accordance with state law AB 2514 which was passed in 2010. This law calls for the integration of renewable energy and the reduction of greenhouse gas emissions of 80 percent below 1990 levels by 2050 [93].

Fuel Cells

Appliance-size fuel cells that provide both heat and power are just emerging today, but they may very well be common place in 2030 and beyond. These systems will decrease vulnerability associated with electrical grid outages by generating their own electricity for users with a system nearly impervious to hurricanes, thunderstorms, and similar dangers, while simultaneously helping the environment.

Figure 18. Redox Power Systems Residential Fuel Cell Design [94]



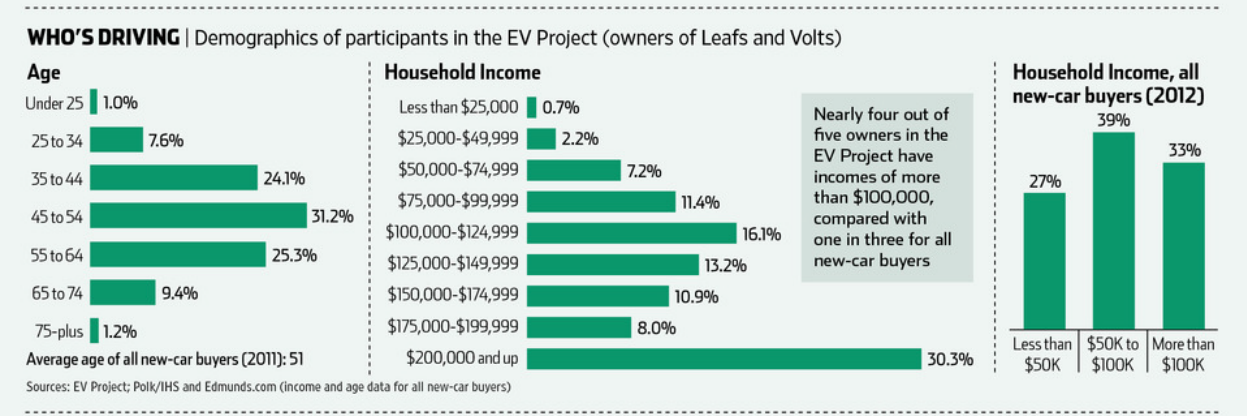
Redox Power Systems is working on a solid oxide fuel cell for residential applications that is 1/10th the size and cost of commercial units today with a nameplate capacity of 25 kW. Figure 18 shows a picture of such a residential fuel cell design. The system uses natural gas fuel to electrochemically convert methane to electricity. The goal is to generate onsite power and, optionally, to have an off-the-grid capability at a price competitive with current energy sources [94].

Electric Vehicles

Electric vehicle (EV) sales account for less than 1 percent of total new light duty vehicle (LDV) sales but several incentives are aimed at boosting their adoption [95]. Today's EV purchasers are primarily city dwellers in places such as Los Angeles, San Francisco, Seattle, New York, and Atlanta. Figure 19 provides a demographic snapshot of who drives EVs and includes information on age and household income. The largest group of purchasers tends to be between the ages of 45 and 54 with household incomes greater than $100,000. EV drivers typically drive 9,000 miles per year as compared to 13,500 miles per year for all cars in the United States [96]. Figure 19 also compares this income information to the 2012 household income of all new-car buyers.

> "In March 2012, President Obama announced the *EV Everywhere Grand Challenge*—to produce plug-in electric vehicles (PEVs) as affordable and convenient for the American family as gasoline-powered vehicles by 2022." [120]

Figure 19. Demographics of PEV drivers [96]



Despite the limited demographic purchasing EVs, there are several factors at play helping to increase the general market penetration. These include the following:

- President Obama's launch of the EV Everywhere Grand Challenge to make the cost of plug-in EVs on part with gasoline-powered vehicles by 2022.
- The nearly 50 percent drop in the cost of EV batteries that has occurred in the past four years through high volume production [97].
- DOE's efforts with industry and academia to double the battery pack energy density [97].
- State support, in particular, eight states (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, and Vermont) that have pledged to adopt measures to make it easier to own an EV. Collectively, these states represent nearly one-quarter of America's auto market. Their shared goal is to achieve sales of at least 3.3 million zero-emissions vehicles by 2025. This would represent 25 percent of the LDV annual sales [98].

Other factors positively influencing EV market share are purchasing incentives such as the Federal government tax credit of up to $7,500 and state government incentives including tax credits and rebates [99]. Lastly, there is the large difference in fueling costs between EVs and conventional gasoline-powered vehicles. Nationally, EV fueling costs are about one-third those for vehicles running on gasoline.

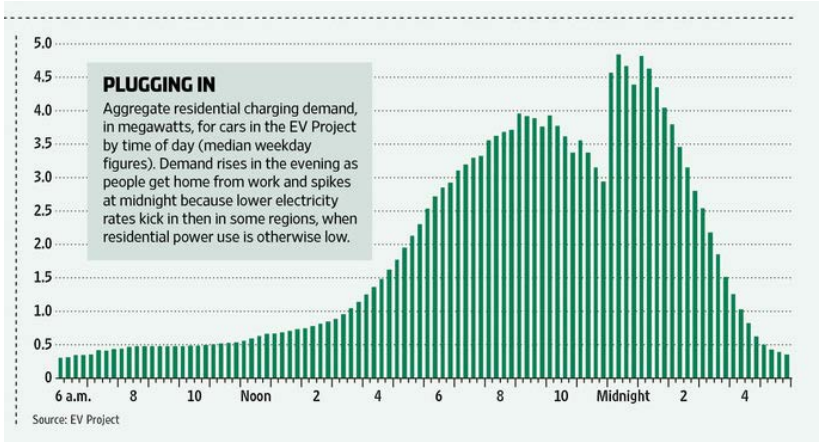
Together, all of these factors are favorably aligned with promoting and expanding EV market share. With this increased market penetration, though, will come significantly increased transportation sector demands for electricity.

The vehicle industry has been working tirelessly to install charging stations nationwide. As of June 2013, there were over 18,000 public and private charging stations across the U.S. with a dozen states (including Arizona, California, Florida, Illinois, Massachusetts, Michigan, New York, North Carolina, Oregon, Tennessee, Texas, and Washington) representing the majority of all installations [100]. In support of the President's EV Everywhere Challenge, DOE has launched the Workplace Charging Challenge aimed at increasing by tenfold over the next five years the number of U.S. employers offering EV charging installations [101].

Already there are several neighborhoods with high EV concentration. Pecan Street Research (PSR) Analytics analyzed over 2,500 vehicle charge events between June 1, 2013 and August 31, 2013 in a randomly selected subset of 30 homes in Austin, Texas. It found that charging behavior is more diverse than predicted and thus represents a much more manageable energy load than anticipated [102]. However, how charging will impact the electrical grid still remains to be seen.

Figure 20 shows aggregate residential charging demand (in MW) over a typical day. Today, a majority of residential charging is done with Level 1 and Level 2 chargers. In the State of Washington, some of the 14 DC quick chargers on the West Coast Green Highway were used 10 times more often than others [103]. In 20 years, technological advancements could make common in the home these quick chargers, wireless charging, or some other charging method. With states supporting a larger number of EVs in the market place, utilities will need to evaluate their distribution systems against these possible demand scenarios.

Figure 20. Residential Demand in a High PEV Penetration Neighborhood [96]



Demand Side Components

Data from the *Buildings Energy Data Book* of March 2012 shows residential and commercial buildings consume 74 percent of U.S. electricity, and this figure is forecasted to grow a few percentage points by 2030 [104]. Some of the end-use consumption is from lighting, PCs, water heating, refrigeration, cooking, and HVACs. Lighting, in particular, has undergone a dramatic change in recent years as described in the section directly below. In addition, low-cost, high-power computing has created opportunities for network-connected smart appliances with alert and remote control features for residential use. Commercial and industrial organizations are often looking to reduce bottom line operational costs through operational efficiency improvements. As a result, improvements in the end-use components have the potential to significantly affect how electricity is consumed.

Light Emitting Diode (LED) Lighting

Both residential and commercial consumers are making the switch to light emitting diode (LED) lighting technology (also called solid state lighting technology). In 2009, fewer than 400,000 LED lights were deployed across the U.S., but by 2013, deployment had grown to nearly 20 million LED lights, an increase of 50 times. Although LEDs cost more up front, they also last as much as 25 times longer than the traditional incandescent light bulb. In 2012 some LED lighting products cost $50 each, but just one year later many LEDs cost less than $15 [79].

Additionally, the consumer gains quite a bit from a LED lighting product's efficiency. Consider that a standard 60-watt incandescent light bulb can be replaced by a ~9-watt LED light that is 84 percent more efficient and with much less wasted heat. With the LED lasting over two decades, consumers could save over $140 for every incandescent bulb swapped for an LED replacement. DOE's Office of Energy Efficiency and Renewable Energy (EERE) projects that by 2030 LED solid-state lighting will save over $30 billion a year in electricity costs and cut America's energy consumption for lighting in half [79].

This transition in lighting impacts not only utilities' revenues but also their operating costs. Incandescent bulbs have a power factor (PF) of about 1, which means the actual power consumed (in

watts) and the apparent power (in volt-amperes) are equal. However, Energy Star has a minimum PF of 0.70 for LED lights greater than 5-watts and no minimum PF for LED lights less than 5-watts [105]. This means a 10-watt LED with a PF of 0.7 pays for 10 watts, but the utility would have to generate 1.4 times that power in volt-amps to run that light and pay for the additional generation. At the individual bulb level this is not significant but as LED lighting products gain more market share, the aggregate additional power needs will become an important consideration for utilities [106].

Residential

New refrigerators, dishwashers, washers, dryers, thermostats, carbon monoxide detectors, and smoke detectors are being sold with embedded computers capable of providing consumers monitoring, user habit learning, customizability, remote notification, and 24/7 remote control. Appliances such as washing machines and dishwashers can be programmed to operate during times convenient for the consumer or during the evening to minimize the noise disturbance from the operation. In the future, these appliances could be configured to respond to demand response signals or time differentiated rates to maximize savings for the customer, to modify peak demand, and in general to help improve grid operations. These appliances represent only a tiny fraction of the market today, but they are expected to become increasingly mainstream in market penetration through the 2010s and could reach up to $35 billion in sales by 2020 [107].

Commercial and Industrial

Building energy demand, a major cost component of any business operation, can be broadly divided into lighting, general heating and cooling, and plug load. By implementing smart efficiency measures, such as those listed in Table 9, it is estimated that by 2035 the annual savings for the commercial sector from these technologies could reach $30 billion to $60 billion [108]. Similarly, for the industrial sector, annual savings by 2035 could range from $8 billion to $25 billion [108]. This expected improved building efficiency could help reduce electricity demand growth as the technologies become more widely deployed and even newer technologies are developed. These technologies will increasingly allow buildings to respond in near real-time to grid conditions such as voltage and frequency levels.

Table 9. Smart Energy Measures for Commercial Sector [108]

Measure	Savings Range	Estimated Applicability
Smart Building Components	5% - 20%	10%
Smart Lighting	0% - 75 %	35%
Smart HVAC Components	15%	10% - 15%
Advanced Building Mgmt. Systems (BMS)	10% - 30%	10% - 20%
Smart Grid	10%	10%
User Interfaces	10% - 20%	10%
Office Equipment and Cloud Computing	2% - 50%	50%
Refrigeration Energy Management	30%	30%
Smart Fume Hoods	10% - 30%	15%
Miscellaneous	20% - 50%	2%

CONDITION AND REACH OF EXISTING INFRASTRUCTURE

The electrical grid connects approximately 144 million end-use customers with about 5,800 major power plants and includes over 450,000 miles of high voltage transmission lines [109]. In recent decades, the majority of transmission investment has been directed toward constructing new facilities to meet customer load demands. Meanwhile, relatively little has been invested in refurbishing existing facilities. This has resulted in much of the current power system infrastructure, whether generation, transmission, or distribution equipment, becoming outdated and in need of refurbishment, replacement, or upgrades in order to comply with new standards and meet demand [47].

Nearly 70 percent of the grid's transmission lines and power transformers are now over 25 years old and the average age of U.S. power plants is over 30 years [109]. Some transmission and distribution components are over 80 years old. In the latter half of the upcoming 10-year period, a number of nuclear units are expected to undergo refurbishment or retirement. A number of coal units will cease burning coal by 2014, with conversion to other fuels being considered as just one of several options [47].

Updating the existing infrastructure will present many challenges such as the availability of spare parts, the obsolescence of older equipment, the ability to maintain equipment due to outage scheduling restrictions, and the aging of the work force and resulting lost knowledge due to personnel retirements. Although many companies have sustainment programs in place for asset renewal, NERC asserts that it is the overall scope of the problem that presents the greatest challenge [47].

These updates will become more and more necessary as the age of infrastructure begins to show. The grid resiliency report entitled *Economic Benefits of Increasing Electric Grid Resilience to Weather Outages* issued by the Executive Office of the President in August 2013 states the following:

"The age of the grid's components has contributed to an increased incidence of weather-related power outages. For example, the response time of grid operators to mechanical failures is constrained by a lack of automated sensors. Older transmission lines dissipate more energy than new ones, constraining supply during periods of high energy demand. And, grid deterioration increases the system's vulnerability to severe weather given that the majority of the grid exists above ground." [109]

However, the carrying capacity of existing lines is expensive and time consuming to upgrade. DOE-funded analysis currently underway at the Idaho National Laboratory aims to increase transmission capacity during windy conditions through concurrent cooling of the transmission line and through monitoring and controls of a Dynamic Line Rating Tool. An increase in wind speed of 5 mph blowing at a right angle to a high-voltage line can cool the line enough to increase its carrying capacity 30 to 50 percent. By applying this knowledge to the Dynamic Line Rating Tool, the existing infrastructure can allow for increased levels of generation with minimal grid upgrades [110].

In addition to analysis, the Federal government has allocated billions of dollars to replace, expand, and refine grid infrastructure. The American Recovery and Reinvestment Act of 2009 allocated $4.5 billion for investments in technologies to modernize grid. These smart grid technologies utilize remote control and automation to better monitor and operate the grid. Between June 2011 and February 2013, Recovery Act funds have been used to deploy 343 advanced grid sensors, upgrade 3,000 distribution

circuits with digital technology, install 6.2 million smart meters, and invest in 16 energy storage projects. These investments have contributed to significant increases in grid resilience, efficiency, and reliability [109].

Smart Grid Projects/Technologies

The American Recovery and Reinvestment Act of 2009 tasked DOE with distributing $4.5 billion in funding to smart grid projects across the country. Collectively, these projects have the potential to drastically change the power grid landscape of the United States. The two largest initiatives are the Smart Grid Investment Grant (SGIG) program and the Smart Grid Demonstration Program (SGDP). DOE's Office of Electricity Delivery and Energy Reliability (OE) is responsible for managing these five-year programs [111].

The first of these large initiatives, SGIG, focuses on deploying existing smart grid technologies, tools, and techniques to improve grid performance. Meanwhile, the other large initiative, SGDP, explores advanced smart grid and energy storage systems and evaluates performance for future applications. These projects are focused on regional demonstration projects and energy storage projects. For information about individual smart grid projects under the American Recovery and Reinvestment Act of 2009, visit http://www.smartgrid.gov/recovery_act/project_information.

While the impact of these investments is still being analyzed in most cases, the benefits are clear. Based on the results of these projects, the industry will develop new and better solutions and fine tune the design and implementation for future projects to maximize the benefits.

Microgrids

A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that collectively acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode [112].

North America is the leading market for microgrids, featuring 63 percent (992 MW) of the total worldwide installed microgrid capacity of 1,581 MW [113]. This worldwide capacity is expected to increase to over 9,100 MW by 2020 with North America's share of this capacity expected to grow to almost 6,000 MW. Worldwide annual revenue from microgrids is expected to reach between $30 million and $60 million by 2020 [113].

The U.S. Department of Defense (DoD), as the single largest energy consumer in the world, is a crucial driver of microgrid development owing to its extreme sensitivity to T&D disruptions at its various bases around the world. Roughly two dozen facilities across all branches of the military are engaged in some form of microgrid implementation, often including the integration of renewable energy generation such as wind and/or solar [114].

Beyond DoD, public investment has come from various Federal and state agencies including DOE, the Federal Emergency Management Agency, and the California Energy Commission. Some of the larger projects are occurring at the University of California, San Diego; in Salem, Oregon; and in Bridgeport,

Connecticut. These projects focus on topics such as islanding, EV integration, environmental disaster response, and distributed renewable energy generation management.

Managing microgrid integration is an important aspect of grid evolution, both because this integration requires careful planning, and because this is a crucial element in solving current grid issues such as distributed renewable energy generation and increasing grid resiliency during natural disasters.

"Smart Cities"

The term "Smart City" currently has a number of different connotations depending on where and how the term is specified. For some cities, this is as simple as "smart" street lighting; for others, it refers to a highly-integrated sensor network that provides real-time information regarding city service usage such as beaches, libraries, and parking. European cities such as Málaga [115] and Eindhoven [116] fall into the former category, while cities such as Santander [117] exemplify the latter concept.

In general, though, the term refers to the real-time creation and consumption of data streams in order to provide an adaptive or informed response to a citizen need or demand. Planning organizations are just starting to design smart cities, making it a clear priority looking forward. It is already impacting energy consumption data availability in many cities.

The amount of data being created and collected by municipalities and utilities is growing rapidly and by some estimates, it is expected to double every two years until 2020 [118]. The data will largely be generated by vast automated sensor networks. This "Internet of Things" is expected to generate an estimated 40 trillion gigabytes of data [118]. Leveraging the data will be fundamental for municipalities to understand, because it is one of the basic components of the value architecture of future smart cities. Without understanding what is being measured and what that measurement says, municipalities and utility operators run the risk of being drowned by a metaphorical tsunami of unintelligible data points and statistics, or, worse yet, drawing the wrong conclusions by using answers to questions they did not want to ask [119]. Figure 21 provides a schematic representation of this smart city value architecture. It shows high-level characteristics as well as more specific features, components, and desired outcomes.

Moving forward, electrical grid stakeholders need to be both intelligent providers and consumers of smart city data and services. This means planning grid development in conjunction with local and regional planning authorities in order to maximize participation in smart cities.

Figure 21. Smart City of the Future Value Architecture [118]

While still in their infancy, these kinds of plans represent the next evolution of large scale city planning and have many details to work out (e.g., privacy concerns, etc.).

WORKS CITED

[1] FERC, "Regional Transmission Organizations (RTO)/Independent System Operators (ISO)," 2 April 2014. [Online]. Available: http://www.ferc.gov/industries/electric/indus-act/rto.asp. [Accessed 21 April 2014].

[2] ISO/RTO Council, "ISO/RTO Council Map," 2011. [Online]. Available: http://www.isorto.org/site/c.jhKQIZPBImE/b.2604471/k.B14E/Map.htm. [Accessed 16 January 2014].

[3] Gridwise Alliance, *Visioning State Data 10_07_13,* Washington DC: Gridwise Alliance, 2013.

[4] U.S. Department of Energy, "Quadrennial Energy Review on Infrastructure Constraints in New England," 2014.

[5] C. Peterson, "Projected 2014–2015 prices of wholesale electricity and wholesale natural gas in New England," Energy Information Administration.

[6] Energy Information Administration, "Short-Term Energy Outlook Supplement: Constraints in New England likely to affect regional energy prices this winter," 8 January 2013. [Online]. Available: http://www.eia.gov/forecasts/steo/special/pdf/2013_sp_01.pdf. [Accessed 22 April 2014].

[7] D. Carkhuff, "Report: New England needs to add 2 billion cubic feet of natural gas pipeline," 11 February 2014. [Online]. Available: http://portlanddailysun.me/index.php/newsx/local-news/11369-report-new-england-needs-to-add-2-billion-cubic-feet-of-natural-gas-pipeline. [Accessed 22 April 2014].

[8] ICF International, "Assessment of New England's Natural Gas Pipeline Capacity to Satisfy Short and Near-Term Electric Generation Needs," 15 June 2012. [Online]. Available: http://psb.vermont.gov/sites/psb/files/docket/7862relicense4/Exhibit%20EN-JT-15.pdf. [Accessed 22 April 2014].

[9] New England States Committee on Electricity, "Request for ISO-NE technical support and assistance with tariff filings related to electric and natural gas infrastructure in New England," 2014.

[10] ISO New England, "2014 Regional Energy Outlook," 2014.

[11] NWS-NOAA, "Service Assessment: Hurricane / Post-Tropical Cyclone Sandy, October 22 - 29, 2012," Silver Spring, MD, May 2013.

[12] Con Edison Media Relations, "Con Edison's Restorations on Track for Storm Customers," 11 November 2012. [Online]. Available: http://www.coned.com/newsroom/news/pr20121111_2.asp. [Accessed 25 April 2014].

[13] The GridWise Alliance, "Improving Electric Grid Reliability and Resilience: Lessons Learned from Superstorm Sandy and Other Extreme Events," The GridWise Alliance, Washington DC, 2013.

[14] State of Connecticut Office of the Governor, "Microgrid Grant and Loan Pilot Program," August 2012. [Online]. Available: http://www.cga.ct.gov/2012/ACT/Pa/pdf/2012PA-00148-R00SB-00023-PA.pdf. [Accessed 28 April 2014].

[15] GreenBiz.com, "Connecticut plans nation's first statewide microgrid," 9 August 2013. [Online]. Available: http://www.greenbiz.com/news/2013/08/09/connecticut-plans-nations-first-statewide-microgrid. [Accessed 28 April 2014].

[16] Massachusetts Department of Public Utilities, "Investigation by the Department of Public Utilities on its own Motion into Modernization of the Eletric Grid," 23 December 2013. [Online]. Available: http://www.mass.gov/eea/docs/dpu/electric/12-76-a-order.pdf. [Accessed 24 April 2014].

[17] J. S. John, "Massachusetts Makes Smart Grid Mandatory," GreenTech Media, 31 December 2013. [Online]. Available: http://www.greentechmedia.com/articles/read/massachusetts-makes-smart-grid-mandatory. [Accessed 24 April 2014].

[18] National Grid, "Smart Energy Solution," 2014. [Online]. Available: https://www1.nationalgridus.com/SmartEnergy-MA-RES. [Accessed 25 April 2014].

[19] J. Berst, "National Grid enters next phase of important smart grid pilot," SmartGridNews.com, 19 February 2014. [Online]. Available: http://www.smartgridnews.com/artman/publish/Projects_Demo_Pilots/National-Grid-enters-next-phase-of-important-smart-grid-pilot-6362.html#.U14oj_ldUYE. [Accessed 25 April 2014].

[20] State of Massachusetts Office of the Governor, "Governor Patrick Announces $50M For Comprehensive Climate Change Preparedness Initiatives," Press Release, 14 January 2014. [Online]. Available: http://www.mass.gov/governor/pressoffice/pressreleases/2014/0114-climate-change-preparedness-investment.html. [Accessed 28 April 2014].

[21] DNV KEMA Energy & Sustainability and Peregrine Energy Group, "Microgrids: Benefits, Models, Barriers and Suggested Policy Initiatives for the Commonwealth of Massachusetts," 3 February 2014. [Online]. Available: http://images.masscec.com/uploads/attachments/2014/03/Microgrids%20-%20Benefits,%20Models,%20Barriers%20and%20Suggested%20Policy%20Initiatives%20for%20

the%20Commonwealth%20of%20Massachusetts.pdf. [Accessed 28 April 2014].

[22] Energy.Gov, "Energy Department Partners with State of New Jersey to Study Ways to Improve the Reliability of New Jersey's Transit System in Aftermath of Superstorm Sandy," 26 August 2013. [Online]. Available: http://energy.gov/articles/energy-department-partners-state-new-jersey-study-ways-improve-reliability-new-jersey-s. [Accessed 28 April 2014].

[23] NJ Transit, "Making NJ TRANSIT Stronger and More Resilient," 26 August 2013. [Online]. Available: https://www.njtransit.com/tm/tm_servlet.srv?hdnPageAction=PressReleaseTo&PRESS_RELEASE_ID=2884. [Accessed 28 April 2014].

[24] State of New York Office of the Governor, "Governor Cuomo Announces Broad Series of Innovative Protections; Vice President Biden Credits Governor Cuomo's Storm Plan as A Model for Future Recovery Efforts," Press Release, 7 January 2014. [Online]. Available: http://www.governor.ny.gov/press/01072013-cuomo-biden-future-recovery-efforts. [Accessed 28 April 2014].

[25] State of New York Office of the Governor, "Governor Cuomo Announces $815 Million for Next Phase of Long Island Recovery From Superstorm Sandy," Press Release, 24 October 2013. [Online]. Available: http://www.governor.ny.gov/press/10242013-long-island-recovery. [Accessed 28 April 2014].

[26] New York State SmartGrid Consortium, "Priority Initiatives," 2013. [Online]. Available: http://nyssmartgrid.com/about-us/priority-initiatives/. [Accessed 24 April 2014].

[27] New York State Smart Grid Consortium, "Smart Grid Roadmap for the State of New York," 15 September 2010. [Online]. Available: https://www.smartgrid.gov/sites/default/files/doc/files/NYS_SmartGrid_Consortium_Smart_Grid_Roadmap_for_State_New_Yo_201012.pdf. [Accessed 24 April 2014].

[28] New York State Smart Grid Consortium, "New York State Smart Grid Consortium Applauds Gov. Cuomo's Vision for Community-Based Energy Solutions," 8 January 2014. [Online]. Available: http://nyssmartgrid.com/wp-content/uploads/NYS-Smart-Grid_State-of-the-State-Response_FINAL_010814.pdf. [Accessed 28 April 2014].

[29] State of New York Public Service Commission, "CASE 07-M-0548 – Proceeding on Motion of the Commission Regarding and Energy Efficiency Portfolio Standard," 26 December 2013. [Online]. Available: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={7705D91D-ACB8-4560-9984-D1545DDD2D0E}. [Accessed 5 May 2014].

[30] State of New York Public Service Commission, "CASE 14-M-0101 - Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision," 24 April 2014. [Online]. Available:

http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B9CF883CB-E8F1-4887-B218-99DC329DB311%7D. [Accessed 2 May 2014].

[31] L. Schwartz, "State Policies on Smart Grid," 13 May 2009. [Online]. Available: https://www.smartgrid.gov/sites/default/files/doc/files/State_Policies_on_Smart_Grid_200910.pdf. [Accessed 24 April 2014].

[32] Smartmeters.com, "FirstEnergy Adopts Itron's Smart Grid Solution in Pennsylvania," 9 March 2014. [Online]. Available: http://www.smartmeters.com/the-news/smart-grid-news/4424-firstenergy-adopts-itrons-smart-grid-solution-in-pennsylvania.html. [Accessed 24 April 2014].

[33] SmartGridNews.com, "Pennsylvania Smart Toolkit," 10 November 2011. [Online]. Available: http://www.smartgridnews.com/artman/publish/Projects_Toolkits/Pennsylvania_Stimulus_Toolkit-754.html#.U12JEvldUYF. [Accessed 24 April 2014].

[34] Solar Energy Industries Association, "State Solar Policy (Click on State)," SEA, 2014. [Online]. Available: http://www.seia.org/policy/state-solar-policy. [Accessed 23 April 2014].

[35] SEIA, "What's a solar renewable energy credit (SREC)?," SEIA, [Online]. Available: http://www.seia.org/about/solar-energy/solar-faq/what%E2%80%99s-solar-renewable-energy-credit-srec. [Accessed 25 April 2014].

[36] SEIA, "New Jersey Passes Legislation to Stabilize Its Solar Market," SEIA, 23 July 2012. [Online]. Available: http://www.seia.org/news/new-jersey-passes-legislation-stabilize-its-solar-market. [Accessed 25 April 2014].

[37] New Jersey Clean Energy Program, "SREC Registration Program," April 2014. [Online]. Available: http://www.njcleanenergy.com/renewable-energy/programs/solar-renewable-energy-certificates-srec/new-jersey-solar-renewable-energy. [Accessed 25 April 2014].

[38] Department of Energy, "Offshore Wind Projects: 2006 - 2012 (DOE/EE-0792)," December 2012. [Online]. Available: http://www1.eere.energy.gov/wind/pdfs/offshore_energy_projects.pdf. [Accessed 25 April 2014].

[39] The University of Maine, "DeepCWind Consortium," DeepCWind Consortium, [Online]. Available: http://www.deepcwind.org/. [Accessed 25 April 2014].

[40] AWS Truepower, LLC and NREL, "United States - Land-Based adn Offshore Annual Average Wind Speed at 80 m," January 2012. [Online]. Available: http://www.boem.gov/uploadedImages/BOEM/Renewable_Energy_Program/Renewable_Energy_Guide/Wind%20Speed%20Map.jpg. [Accessed 29 April 2014].

[41] Hydro-Québec, "Developing Outside Markets," 2011. [Online]. Available: http://hydroforthefuture.com/projets/34/developing-outside-markets. [Accessed 25 April 2014].

[42] Transmission Developers Inc., "Champlain Hudson Power Express: Project Development Portal," 2014. [Online]. Available: http://www.chpexpress.com/project-details.php. [Accessed 28 April 2014].

[43] U.S. Energy Information Administration (EIA), "AEO2014 Early Release Overview," 16 December 2013. [Online]. Available: http://www.eia.gov/forecasts/aeo/er/early_production.cfm. [Accessed 29 April 2014].

[44] DSIRE, "DSIRE - Rules, Regulations & Policies for Renewable Energy," US DOE/EERE, IREC, and North Carolina Solar Center, March 2013. [Online]. Available: http://www.dsireusa.org/summarytables/rrpre.cfm. [Accessed 22 April 2014].

[45] DSIRE, "Glossary / Energy Efficiency Resource Standards (EERS)," US DOE/EERE, IREC, and North Carolina Solar Center, 2013. [Online]. Available: http://www.dsireusa.org/glossary/. [Accessed 23 April 2014].

[46] DSIRE, "DSIRE Solar - Rules, Regulations & Policies," February 2013. [Online]. Available: http://www.dsireusa.org/incentives/index.cfm?EE=1&RE=1&SPV=0&ST=0&searchtype=EERS&sh=1. [Accessed 22 April 2014].

[47] North American Electric Reliability Corporation, "NERC 2012 Long-Term Reliability Assessment," November 2012. [Online]. Available: http://www.nerc.com/files/2012_ltra_final.pdf. [Accessed 18 November 2013].

[48] North Carolina State University, "Summary Maps. Database of State Incentivies for Renewables & Efficiency (DSIRE)," March 2013. [Online]. Available: http://www.dsireusa.org/summarymaps/index.cfm?ee=0&RE=0. [Accessed 17 January 2014].

[49] U.S. Energy Information Administration, "Annual Energy Outlook 2013," April 2013. [Online]. Available: http://www.eia.gov/forecasts/aeo/pdf/0383(2013).pdf. [Accessed 14 November 2013].

[50] North Carolina State University, "Glossary. Database of State Incentives for Renewables & Efficiency (DSIRE)," 2013. [Online]. Available: http://www.dsireusa.org/glossary/. [Accessed 16 January 2014].

[51] Brattle Group, "A National Assessment of Demand Response Potential," Federal Energy Regulatory Commission, 2009.

[52] Federal Energy Regulatory Commission (FERC), "National Action Plan on Demand Response," 17 June 2010. [Online]. Available: https://www.ferc.gov/legal/staff-reports/06-17-10-demand-response.pdf. [Accessed November 2013].

[53] Michigan Public Service Commission, "Michigan's 21st Century Electric Plan," January 2007. [Online]. Available: https://www.michigan.gov/documents/mpsc/21stcenturyenergyplan_185274_7.pdf. [Accessed 13 March 2014].

[54] N.J. Board of Public Utilities, "2011 New Jersey Energy Master Plan," 6 December 2011. [Online]. Available: https://nj.gov/emp/docs/pdf/2011_Final_Energy_Master_Plan.pdf. [Accessed 13 March 2014].

[55] U.S. Environmental Protection Agency (EPA), "Section 111(d) Plans," 14 March 2013. [Online]. Available: http://www.epa.gov/region07/air/rules/111d.htm. [Accessed 16 January 2014].

[56] Office of the Press Secretary, "Presidential Memorandum -- Power Sector Carbon Pollution Standards," The White House, 25 June 2013. [Online]. Available: http://www.whitehouse.gov/the-press-office/2013/06/25/presidential-memorandum-power-sector-carbon-pollution-standards. [Accessed 27 January 2014].

[57] U.S. Environmental Protection Agency (EPA), "Standards of Performance for Greenhouse Gas Emissions from New Stationary Sources: Electric Utility Generating Units," 8 January 2014. [Online]. Available: http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2013-0495-0001. [Accessed 16 January 2014].

[58] U.S. Environmental Protection Agency (EPA), "What is EPA Doing | Carbon Pollution Standards," 23 September 2013. [Online]. Available: http://www2.epa.gov/carbon-pollution-standards/what-epa-doing. [Accessed 16 January 2014].

[59] U.S. Environmental Protection Agency (EPA), "Basic Information | Mercury and Air Toxics Standards," 10 April 2012. [Online]. Available: http://www.epa.gov/mats/basic.html. [Accessed 12 December 2013].

[60] U.S. Environmental Protection Agency (EPA), "Fact Sheet: Updates on the Limits for New Power Plants Under the Mercury and Air Toxics Standards (MATS)," 28 March 2013. [Online]. Available: http://www.epa.gov/mats/pdfs/20130328fs.pdf. [Accessed 30 December 2013].

[61] U.S. Environmental Protection Agency (EPA), "Fact Sheet: Mercury and Air Toxics Standards for Power Plants," 21 December 2011. [Online]. Available: http://www.epa.gov/mats/pdfs/20111221MATSsummaryfs.pdf. [Accessed 30 December 2013].

[62] U.S. Environmental Protection Agency (EPA), "40 CFR Parts 60 and 63: National Emission Standards for Hazardous Air Pollutants From Coal-and Oil-Fired Electric Utility Steam Generating Units, Federal Register Volume 78, Number 79," 24 April 2013. [Online]. Available: http://www.gpo.gov/fdsys/pkg/FR-2013-04-24/pdf/2013-07859.pdf. [Accessed 30 December 2013].

[63] K. H. LaCommare and J. H. Eto, "Understanding the Cost of Power Interruptions to U.S.," Ernesto Orlando Lawrence Berkeley National Laboratory (LBNL), September 2004. [Online]. Available: http://certs.lbl.gov/pdf/55718.pdf. [Accessed 30 November 2013].

[64] U.S. Energy Information Administration, "Market Trends — Electricity," May 2013. [Online]. Available: http://www.eia.gov/forecasts/aeo/MT_electric.cfm. [Accessed 5 November 2013].

[65] U.S. Energy Information Administration, "Today in Energy: State Fact Sheets on Residential Energy Consumption," 19 August 2013. [Online]. Available: http://www.eia.gov/todayinenergy/detail.cfm?id=12591. [Accessed 5 November 2013].

[66] J. A. Laitner, "The Long-Term Energy Efficiency Potential: What the Evidence Suggests," American Council for an Energy-Efficient Economy (ACEEE), 2012.

[67] Executive Office of the President, "The President's Climate Action Plan," The White House, June 2013. [Online]. Available: http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf. [Accessed 23 November 2013].

[68] U.S. Energy Information Administration, "Energy in Brief," 14 December 2012. [Online]. Available: http://www.eia.gov/energy_in_brief/article/nuclear_industry.cfm. [Accessed 27 December 2013].

[69] U.S. Energy Information Administration, "Annual Energy Outlook 2014 Early Release," 2013. [Online]. Available: http://www.eia.gov/forecasts/aeo/er/pdf/0383er(2014).pdf. [Accessed 27 December 2013].

[70] US Department of Energy, "Quarterly Nuclear Deployment Scorecard - October 2013," Office of Nuclear Energy, October 2013. [Online]. Available: http://energy.gov/ne/downloads/quarterly-nuclear-deployment-scorecard-october-2013. [Accessed 27 12 2013].

[71] Georgia Power, "Plant Vogtle Units 3 and 4," [Online]. Available: http://www.southerncompany.com/what-doing/energy-innovation/nuclear-energy/pdfs/vogtle-nuclear-brochure.pdf. [Accessed 27 December 2013].

[72] International Atomic Energy Association, "PRIS - Country Details: United States," IAEA Power Reactor Information System, 26 December 2013. [Online]. Available:

http://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=US. [Accessed 26 December 2013].

[73] American Enterprise Institute, "Polls on the environment, energy, global warming, and nuclear power," 17 April 2013. [Online]. Available: http://www.aei.org/article/politics-and-public-opinion/polls/polls-on-the-environment-energy-global-warming-and-nuclear-power-april-2013/. [Accessed 16 January 2014].

[74] U.S. Energy Information Administration, "Energy Explained. Electricity in the U.S.," 5 November 2013. [Online]. Available: http://www.eia.gov/energyexplained/index.cfm?page=electricity_in_the_united_states. [Accessed 26 January 2014].

[75] National Energy Technology Laboratory, "Tracking New Coal-Fired Power Plants," 12 January 2012. [Online]. Available: http://www.netl.doe.gov/coal/refshelf/ncp.pdf. [Accessed 15 November 2013].

[76] K. Otterbourg, "UNCLE SAM'S RIVER," 28 October 2013. [Online]. Available: http://www.kenotterbourg.com/TVA.pdf. [Accessed 9 November 2013].

[77] Moody's Investor Services, "Moody's: Growth prospects for Canada's largest pipelines diverge," 7 November 2013. [Online]. Available: https://www.moodys.com/research/Moodys-Growth-prospects-for-Canadas-largest-pipelines-diverge--PR_286209. [Accessed 17 November 2013].

[78] J. Logan, "Natural Gas and the Transformation of the U.S. Energy Sector: Electricity," NREL/TP-6A50-55538 The Joint Institute for Strategic Energy Analysis, 2012.

[79] L. Tillemann, "Revolution Now. The Future Arrives for Four Clean Energy Technologies," 17 September 2013. [Online]. Available: http://energy.gov/sites/prod/files/2013/09/f2/Revolution%20Now%20--%20The%20Future%20Arrives%20for%20Four%20Clean%20Energy%20Technologies.pdf. [Accessed 18 November 2013].

[80] "2012 Wind Technologies Report; 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply," U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2012, 2008.

[81] National Renewable Energy Laboratory (NREL), "Western Wind and Solar Integration Study," September 2013. [Online]. Available: http://www.nrel.gov/electricity/transmission/western_wind.html. [Accessed November 2013].

[82] National Renewable Energy Laboratory (NREL), "Eastern Renewable Generation Integration Study," 2010. [Online]. Available:

http://www.nrel.gov/electricity/transmission/eastern_renewable.html. [Accessed November 2013].

[83] K. De Vos, "Wind and PV integration: European Experiences".

[84] R. Fuchs, "Wind energy surplus threatens eastern German power grid," European Dialogue, January 2011. [Online]. Available: http://www.eurodialogue.org/Wind-energy-surplus-threatens-eastern-German-power-grid. [Accessed November 2013].

[85] Walmart, "Renewable Energy," 2013. [Online]. Available: http://corporate.walmart.com/global-responsibility/environment-sustainability/renewable-energy. [Accessed November 2013].

[86] D. Hull, "Walmart's Solar Strategy," Silicon Beat, 11 March 2013. [Online]. Available: http://www.siliconbeat.com/2013/03/11/walmarts-solar-strategy/. [Accessed 16 November 2013].

[87] "Arizona Regulators Raise Solar Rates," [Online]. Available: http://abcnews.go.com/US/wireStory/arizona-regulators-raise-solar-rates-month-20895284. [Accessed 16 November 2013].

[88] T. Mai, D. Sandor, R. Wiser and T. Schneider, "Renewable Electricity Futures Study: Executive Summary. NREL/TP-6A20-52409-ES," National Renewable Energy Laboratory, Golden, CO, 2012.

[89] Clean Line Energy Partners, "Projects," [Online]. Available: http://www.cleanlineenergy.com/projects. [Accessed 26 January 2104].

[90] U.S. Energy Information Administration, "Table 8.10.A Existing Transmission Capacity by High Voltage Size, 2012," 12 December 2013. [Online]. Available: http://www.eia.gov/electricity/annual/. [Accessed 27 January 2014].

[91] CleanLine Energy Partners, "Transmission Projects Overview," January 2014. [Online]. Available: http://www.cleanlineenergy.com/projects. [Accessed 16 January 2014].

[92] J. Song, " Nordstrom keeping customers cool with ice.," Honolulu Advertiser, 18 March 2008. [Online]. Available: http://the.honoluluadvertiser.com/article/2008/Mar/18/bz/hawaii803180341.html . [Accessed 10 May 2013].

[93] R. L. Hales, "California's New Energy Storage Initiative," San Diego Loves Green, 19 October 2013. [Online]. Available: http://www.sandiegolovesgreen.com/cpuc-decides-that-utilities-must-start-buying-energy-storage-technology/. [Accessed 23 November 2013].

[94] W. Pentland, "Redox Power Plans To Roll Out Dishwasher-Sized Fuel Cells That Cost 90% Less Than Currently Available Fuel Cells," 14 August 2013. [Online]. Available: http://www.forbes.com/sites/williampentland/2013/08/14/redox-power-plans-to-roll-out-dishwasher-sized-fuel-cells-that-cost-90-less-than-currently-available-fuel-cells/. [Accessed 17 November 2013].

[95] Inside EVs, "Monthly Plug-In Sales Scorecard," Inside EVs, November 2013. [Online]. Available: http://insideevs.com/monthly-plug-in-sales-scorecard/. [Accessed 13 November 2013].

[96] Y. Chernova, "Who Drives Electric Cars? A close-up look at a small but fast-growing group of Americans," Wall Street Journal, 23 September 2013. [Online]. Available: http://online.wsj.com/news/articles/SB10001424127887324123004579055112450200336. [Accessed 23 November 2013].

[97] U.S. Department of Energy, "EV Everywhere Grand Challenge Blueprint," 31 January 2013. [Online]. Available: http://www1.eere.energy.gov/vehiclesandfuels/electric_vehicles/pdfs/eveverywhere_blueprint.pdf. [Accessed November 2013].

[98] M. L. Wald, "8 States Teaming Up to Support Electric Cars," NY Times, 24 October 2013. [Online]. Available: http://www.nytimes.com/2013/10/25/business/energy-environment/coalition-of-states-seeks-to-spur-use-of-electric-cars.html?ref=earth&_r=2&. [Accessed 23 November 2013].

[99] U.S. Department of Energy, "Fact #789: Comparison of State Incentives for Plug-In Electric Vehicle Purchases," 22 July 2013. [Online]. Available: http://www1.eere.energy.gov/vehiclesandfuels/facts/2013_fotw789.html. [Accessed 5 November 2013].

[100] U.S. Department of Energy, "Fact #795: Electric Vehicle Charging Stations by State," 2 September 2013. [Online]. Available: http://www1.eere.energy.gov/vehiclesandfuels/facts/2013_fotw795.html. [Accessed November 2013].

[101] U.S. Department of Energy, "EV Everywhere Charges Up the Workplace," 31 January 2013. [Online]. Available: http://energy.gov/articles/ev-everywhere-charges-workplace. [Accessed November 2013].

[102] Pecan Street Research Institute, "Report: Impact of Electric Vehicle Charging on Electric Grid Operations Could Be More Benign than Feared," 24 October 2013. [Online]. Available: http://www.pecanstreet.org/2013/10/report-impact-of-electric-vehicle-charging-on-electric-grid-operations-could-be-more-benign-than-feared/. [Accessed November 2013].

[103] E. Loveday, "Washington State: 14 Quick-Charge Stations Record Over 10,000 Charging Sessions Since May 2012," Inside EVs, November 2013. [Online]. Available: http://insideevs.com/washington-state-14-quick-charge-stations-record-over-10000-charging-sessions-since-may-2012/. [Accessed November 2013].

[104] U. S. Department of Energy, "Buildings Energy Data Book, 1.1: Buildings Sector Energy Consumption," March 2012. [Online]. Available: http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=1.1.9. [Accessed 30 November 2013].

[105] U.S. Environmental Protection Agency (EPA), "ENERGY STAR® Program Requirements for Integral LED Lamps," 13 May 2011. [Online]. Available: http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf. [Accessed 29 November 2013].

[106] B. Ehrlich, "LED and Power: Quality Matters," GreenSpec, 18 October 2012. [Online]. Available: http://greenspec.buildinggreen.com/blogs/led-and-power-quality-matters. [Accessed 29 November 2013].

[107] Navigant Research, "Smart Appliance Market to Reach Nearly $35 Billion Annually by 2020," Navigant Research, 6 February 2013. [Online]. Available: http://www.navigantresearch.com/newsroom/smart-appliance-market-to-reach-nearly-35-billion-annually-by-2020. [Accessed October 2013].

[108] E. A. Rogers, R. N. Elliott, S. Kwatra, D. Trombley and V. Nadadur, "Intelligent Efficiency: Opportunities, Barriers, and Solutions," 24 October 2013. [Online]. Available: http://www.aceee.org/research-report/e13j. [Accessed 23 November 2013].

[109] President's Council of Economic Advisers, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," August 2013. [Online]. Available: http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf. [Accessed 13 November 2013].

[110] Idaho National Laboratory (INL), "Concurrent Cooling and Dynamic Line Rating Tool," 2013. [Online]. Available: http://www1.eere.energy.gov/wind/pdfs/inl_powerline_cooling_factsheet.pdf. [Accessed 16 January 2014].

[111] U.S. Department of Energy, "Smartgrid.gov: Recovery Act Smart Grid Programs," [Online]. Available: http://www.smartgrid.gov/recovery_act/overview. [Accessed 1 December 2013].

[112] D. T. a. M. Smith, *Microgrid Exchange Group,* Washington DC: DOE.

[113] Navigant Research, "Market Data: Microgrids - Forecasts for Commercial/Industrial, Community/Utility, Campus/Institutional, Military, and Remote Microgrids: 2013-2020," Q1 2013.

[114] Pike Research, "Military Microgrids - Stationary Base, Forward Operating Base, and Mobile Smart Grid Networks for Renewables Integration, Demand Response, and Mission-Critical Security," 4Q 2012.

[115] Endesa Red S.A., "Smart Grids," Endesa Red S.A., 2012. [Online]. Available: http://www.smartcitymalaga.es/. [Accessed October 2013].

[116] Eindhoven, "Eindhoven to launch prototype trials for intelligent lighting applications," 2013. [Online]. Available: http://www.eindhoven.nl/inwonersplein/leefomgeving/slim-licht.htm. [Accessed October 2013].

[117] Santander, "Smart Santander," [Online]. Available: http://www.smartsantander.eu/. [Accessed October 2013].

[118] IDC Government Insights, "Smart Cities and the Internet of Everything: The Foundation for Delivering Next-Generation Citizen Services," IDC Government Insights, October 2013.

[119] N. Silver, The Signal and the Noise: Why Most Predictions Fail - but Some Don't, Penguin Group, April 2013.

[120] U.S. Department of Energy, "EV Everywhere Grand Challenge Blueprint," 31 January 2013. [Online]. Available: http:/www1.eere.energy.gov/vehiclesandfuels/electric_vehicles/pdfs/eveverywhere_blueprint.pdf. [Accessed 13 November 2013].

APPENDIX A - KEY FINDINGS FROM NERC 2012 LONG-TERM RELIABILITY ASSESSMENT

Significant Fossil-Fired Generator Retirements Over Next Five Years

Due largely to the unique confluence of final and potential environmental regulations, low natural gas prices, and other economic factors, about 71 GW of fossil-fired generation is projected to retire by 2022, with over 90 percent retiring by 2017. With the exception of the Electric Reliability Council of Texas (ERCOT), the retirement of this capacity does not pose significant resource adequacy concerns. Reserve Margins are likely to be reduced, but to levels that are still above targets. However, retirements over the next three to four years may raise issues related to system stability and the need for transmission enhancements, which if not addressed could cause reliability concerns in some areas.

Increased Risk of Capacity Deficiencies in ERCOT as Planning Reserve Margins Projected to Fall Below Targets

Starting as early as next year, the ERCOT Planning Reserve Margin is anticipated to be 13.4 percent, which is below the NERC Reference Margin Level and ERCOT planning target of 13.75 percent. At these levels, the risk of insufficient generation resources to meet peak demand increases beyond reliability targets.

Resources Sufficient to Meet Reliability Targets in Most Areas

For the majority of the bulk power system, Planning Reserve Margins appear sufficient to maintain reliability through the long-term horizon. However, there are significant challenges facing the electric industry that may shift industry projections, adding considerable uncertainty to the long term assessment. Future uncertainties include electricity market changes, fuel-prices (natural gas, in particular), potential environmental regulations, and renewable portfolio standards.

Increased Dependence on Natural Gas for Electricity Generation

Increased dependence on natural gas for electricity in some areas has increased the need for all gas users, electric system planners and operators, and policy makers to focus more sharply on the interaction between the electric and gas industries. The adoption of highly efficient combined-cycle technology by the electric power industry and the emergence of shale gas have altered the relative economics of gas-fired generation. As a result, the dependence on natural gas by the electric power sector has increased significantly. Trends in fuel-mix changes highlighted in this assessment identify gas-fired generation as the primary choice for new capacity with almost 100 GW of Planned and Conceptual capacity expected over the next 10 years, which represents almost half of all new generation capacity.

Long-Term Generator Maintenance Outages for Environmental Retrofits

A significant generation retrofit effort is expected over the next 10 years in order to comply with Federal and state- level environmental regulations. A majority of environmental controls are expected to be put in place to meet air regulations by April 2016. In total, 339 unit-level retrofits on fossil-fired generation will be needed, totaling about 160 GW. However, there is still significant uncertainty in the forecasted values as maintenance schedules have not yet been fully evaluated by all areas.

Renewable Resource Additions Introduce New Planning and Operational Challenges

Renewable resources are growing in importance in many areas of North America as the number of new facilities continues to increase. The share of capacity from renewable resources will continue to grow, especially as significant additions are projected for both wind and solar throughout North America. In 2012, renewable generation, including hydro, made up 15.6 percent of all on-peak capacity resources and is expected to reach almost 17 percent in 2022. Contributing to this growth is approximately 20 GW of on-peak Future-Planned capacity and an additional 21.5 GW of on-peak Conceptual capacity. It is vital that these variable resources are integrated reliably and in a way that supports the continued performance of the BPS and addresses both planning and operational challenges.

Transmission Growth to Accommodate New and Distant Resources

As recent as five years ago, transmission was being constructed at a rate of about 1,000 circuit miles per year. In the last five years, over 2,300 circuit miles were constructed per year, more than doubling actual builds in the previous five years. With the current plans in place, that rate is expected to increase to 3,600 miles per year over the next five years. NERC-wide, almost a quarter of new transmission is specifically linked to the integration of renewable generation.

Increases in Demand-Side Management Help Offset Future Resource Needs

All areas are projecting at least some increased availability of Demand-Side Management (DSM) over the next 10 years to reduce peak demands, contributing either to the deferral of new generating capacity or improving operator flexibility in day-ahead or real-time time operations. NERC-wide, DSM is projected to total roughly 80,000 MW by 2022 (or about 7 percent of the on-peak resource portfolio), offsetting approximately six years of peak demand growth. However, unlike traditional generating resources with many decades of historic data for analysis, the long-term projections of DSM involve greater forecasting uncertainty—particularly with Demand Response resources.