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Energizing Policy Evolution for the Grid Revolution

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Abstract
The electricity sector is in the midst of unprecedented change, driven by rapidly evolving technology, changing customer demands, and new business opportunities. These technology and market changes are outpacing the laws, regulations and policies that govern the industry. This paper examines the landscape of new technologies that may disrupt electric sector markets, operations, and planning over the next 20 to 25 years, and highlights the potential laws, rules, and regulations that may need reexamination in light of these changes.

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Disclaimer

Introduction

North America's electricity sector is undergoing rapid and fundamental change. Natural gas and renewable resources—wind and solar—are displacing traditional generation resources like coal and nuclear, with more changes on the horizon. For the first time in history, in April 2015, natural gas-fired generators provided more electricity than those fueled by coal.[1] This trend is expected to continue; in 2016 natural gas generation is expected to surpass coal on an annual basis for the first time ever.[2] These are no longer expected trends but actual indicators of systemic changes occurring in the sector.

The electric power system today is mainly comprised of three main components: generation sources, a long-distance transmission system and a local distribution system, which work in tandem to serve customer load. The transmission system carries bulk power, at high voltages, across long distances from the point of generation. The high-voltage electricity is then "stepped down" to lower voltages required by the distribution system, which transmits power to retail consumers. The technical and operational differences between the transmission and distribution systems create significant demarcations in terms of regulation and oversight. For example, as transmission lines cut across state boundaries and facilitate interstate commerce, they come under federal oversight, while distribution systems, being generally confined within state boundaries, are regulated by state public utilities commissions.

Until recently, electricity was produced exclusively by large-scale generators located far away from customers. The flow of electricity was in one direction, from the generators to the consumers. However, over the past decade a range of new technologies has revolutionized the way the grid is operated. Across the nation, more consumers are becoming active participants in managing the timing and level of their consumption by selling electricity and associated services back to the grid. Technologies like distributed energy resources (DER), which include small generating resources like solar rooftop photovoltaic (PV) systems, smart meters, and smart appliances, are facilitating this increased consumer activity. In 2015, approximately 3,000 MW of distributed solar PV was installed nationwide.[3] Additionally, around 14,800 MW of price-responsive demand, also known as "demand response," was used to balance the grid in the mid-Atlantic region.[4]

These technologies offer insights into end-user consumption patterns, improve the efficiency of transporting electricity along the grid, allow system operators to control the flow of power, and diversify the resource mix to improve the resilience and sustainability of our power grid.

There are several technologies that are expected to have the greatest impact over the next 20 to 25 years based on current market trends.[a] They include:

- Energy Storage
- Electric Vehicles (EVs)
- Distributed Energy Resources (DERs)
- Power Flow Control Technologies
- Information Connectivity and Processing Technologies

As the penetration of these technologies increases, it may require that policymakers reexamine existing policies and conceptualize new ones. Strategically designed policies can ensure that the grid, and society as a whole, captures the maximum benefits that these technologies may offer, such as greater system reliability, affordability, sustainability, resilience,

[a] These technologies were all identified in the 2015 Quadrennial Technology Review (QTR) as technologies that are particularly important in the industry and present opportunities for additional research and development. More in-depth discussions of these technologies can be found in DOE, "Quadrennial Technology Review," Chapter 3, March 2015, accessible via http://www.energy.gov/sites/prod/files/2015/09/f26/Quadrennial-Technology-Review-2015_0.pdf

and flexibility.[b] Widespread use of these technologies and their cumulative effect will highlight deficiencies in the current policy framework. They will also raise numerous important policy discussions, including on:

- Jurisdictional coordination
- Utility business models
- Market designs
- System planning and operations
- Information ownership, data privacy, and cybersecurity

This paper examines the extent to which new technologies can disrupt markets, operations, and planning such that existing laws, rules, and regulations are no longer effective, and it suggests policy considerations that may arise as certain technologies become more common.

Considering these policy implications is particularly timely given the pace at which technology development in the electricity industry is progressing and given the traditional lag time between technology evolution and policy or regulatory responses. Developing policies in parallel with technology evolution, and with an eye toward the future technology landscape, can help capitalize on the opportunities these technologies offer.

It must be emphasized that this paper *does not* address what policies are needed to encourage the adoption of advanced technologies. Rather, it highlights policy questions that may arise if the selected technologies become more widely adopted.

Grid Technologies on the Rise

Energy Storage

A distinguishing characteristic of electricity supply has been that, generally, it must be consumed instantaneously because the capacity to store it has been limited.[c] However, electrochemical batteries and, to a lesser extent, mechanical storage devices such as flywheels, have seen significant growth in recent years.[5] Storage offers the flexibility to warehouse electricity using lower-cost electricity generated during off-peak times and provide it back to the grid as a resource during times of peak demand and higher prices. By decoupling the supply and demand of electricity, storage can help reduce peak loads, increase system efficiency, and provide fast ramping services more cost effectively than traditional resources. Additionally, storage is one of the many options to support increased deployment of renewable resources, like wind and solar, which have variable and unpredictable output. As outlined in the 2015 Quadrennial Technology Review (QTR), storage can also provide both short-term and long-term services to the electric system, and represents an important research and development priority for the industry.[6]

The energy storage market is expected to grow significantly in the next several years; some market observers projecting that by 2021 the market will grow nine-fold relative to its size in 2015 (see Figure 1). This growth is fueled in part by cost declines underpinned by the sharp reduction in storage component costs. From 2015 to 2017 energy storage costs are expected to decline by at least 20 to 25 percent. By 2020, the storage balance of system (BOS) costs—

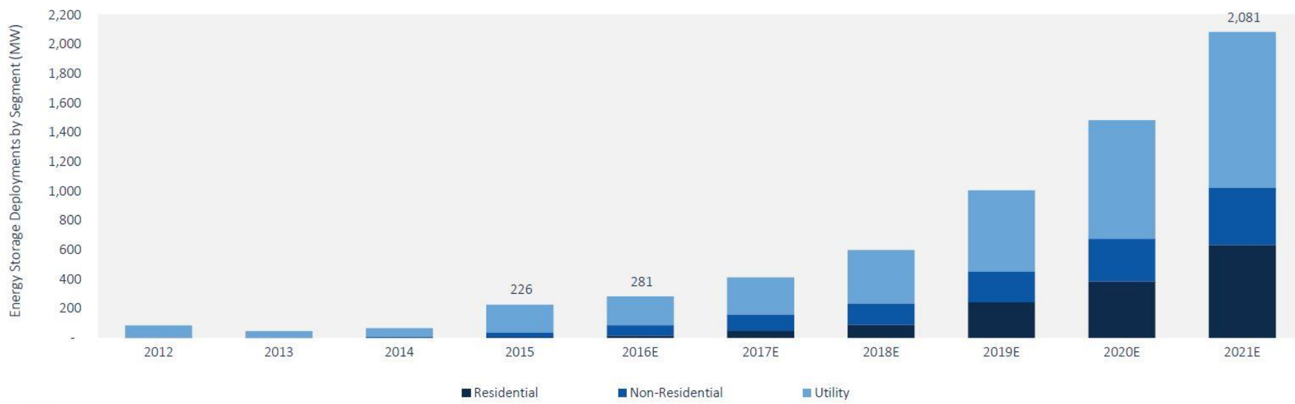
[b] Resilience is the ability of the system to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions like cascading grid failure or natural storms. Flexibility can be considered as the ability of the electric grid to meet variable electric demand at every instant.

[c] There are a few installations of traditional bulk storage technologies like pumped hydroelectric energy storage and compressed air energy storage; these forms of storage face siting constraints and other challenges that have limited their deployment in recent years.

consisting of inverters, permitting, engineering, procurement, construction, and other costs—are expected to fall by 41 percent.[d] Based on these encouraging trends, the 2015 QTR notes that the global market for utility-scale storage (with economies of scale) is expected to grow from $675 million annually in 2015 to $15.6 billion in 2024.[7]

Policy initiatives at both the federal and the state level are helping to promote greater storage deployment. For example, the Federal Energy Regulatory Commission (FERC) has created guidelines that support market designs which reflect the performance attributes for providing grid services in a way that can allow storage to better reflect the value it provides to the grid.[8] The state of California has set requirements for its electric utilities to procure 1.3 GW of energy storage by 2020.[9] This procurement represents approximately 2.8 percent of the California Independent System Operator's (CAISO) average system peak demand of 45.6 GW.[e]

Figure 1: Energy Storage Deployment by Segment from 2012 – 2021 (Projected)



Source: GTM Research/ESA U.S. Energy Storage Monitor

Electric Vehicles

Electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) run either exclusively (EVs) or partially (PHEVs) on electricity. The projected increase in EV adoption provides both challenges and opportunities for the grid.[10]

For example, EVs provide environmental benefits by reducing tail-pipe emissions. They have the potential to serve as mobile and flexible energy storage units; a vehicle with a 30-kWh battery can store the equivalent of an average U.S. household's daily electricity consumption.[11] Given their ability to both consume and provide power, EVs can also be leveraged for valuable vehicle-to-grid (V2G) services, such as providing energy for local consumption and thereby reducing reliance on expensive generation, or by providing fast-acting responses to absorb the variability of renewable resources. However, their inherently mobile nature can create challenges in terms of effectively integrating them onto the grid.

The market trends for EVs are noteworthy; between 2011 and 2014 EV sales in the United States grew at an annual average rate of 73 percent. As of 2015, the cumulative sales of EVs

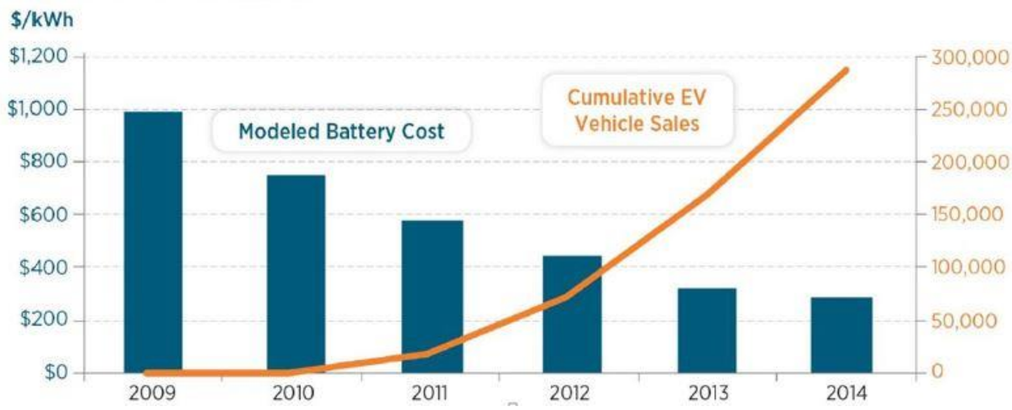
[d] GTM Research, "State of the U.S. Energy Storage Industry: 2015 Year in Review". Balance of system costs include hardware like inverters and containers, soft costs like customer acquisition and interconnection, and engineering, procurement and construction (EPC) expenses.

[e] CAISO manages the flow of electricity for almost 80 percent of California and some parts of Nevada. The peak demand reported is the average for 1998 to 2015. The peak load history is available at: https://www.caiso.com/Documents/CaliforniaISOPeakLoadHistory.pdf

in the U.S. were estimated at approximately 395,000.[12] California and a number of Northeastern states have provided incentives for electric vehicles, including tax credits, purchase rebates, and fuel tax exemptions.[12]

EV battery costs have dropped dramatically; this trend is likely to continue given increased R&D investment from both the public and private sector on EV charging infrastructure (such as charging stations and control algorithms) and battery performance (see Figure 2).[f] President Obama created an initiative to ensure that plug-in EVs are "as affordable and convenient for the American family as gasoline-powered vehicles by 2022." Efforts to reach that goal by the U.S. Department of Energy (DOE) include the investment of more than $225 million.[13] Additionally, on July 21st 2016, the White House unveiled various measures to accelerate the adoption of electric vehicles, which include up to $4.5 billion in loan guarantees and inviting applications to support the commercial-scale deployment of charging infrastructure.[14]

Figure 2: Electric Vehicles Modeled Battery Cost Decline and Cumulative Sales Increase



Source: U.S. Department of Energy

Distributed Energy Resources

Distributed energy resources (DERs) include a broad range of technologies—including solar PV, combined heat and power (CHP), demand response (DR), battery storage, and energy-efficient equipment and appliances—that allow a customer to supply and manage its own electricity during parts or all of the day and use electricity more efficiently.[g]

Distributed energy resources can allow customers to respond to price signals, supplying power (or reducing demand) when the price on the grid is high and consuming power when it is low. These small and modular facilities are cost-effective in many locations, which contributes to their popularity among residential and commercial customers.

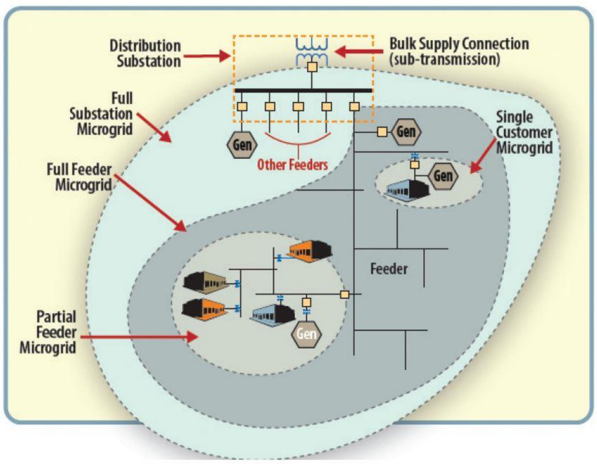
DER technologies, when working in tandem with advanced control technologies, can disconnect from the traditional grid and operate autonomously, thus creating a microgrid. The

[f] Costs are modeled costs for high-volume battery systems, derived from DOE/UIS Advanced Battery Consortium PHEV Battery development projects and are representative of nominal dollars. Sales as reported by market tracker, here "EVs," include all plug-in hybrid and battery plug-in vehicles. See Argonne National Laboratory. 2014 Vehicle Technologies Market Report. March 2015. http://go.usa.gov/3S735 and http://energy.gov/sites/prod/files/2015/11/f27/Revolution-Now-11132015.pdf

[g] Combined Heat and Power (CHP) also known as cogeneration is concurrent production of electricity or mechanical power and useful thermal energy (heating and/or cooling) from a single source of energy. CHPs are generally natural gas-fired.
Demand Response (DR) is a program that compensates end-use (retail) customers for reducing their electricity use (load) when requested by the grid operator during periods of high power prices or when the reliability of the grid is threatened.

2015 QTR notes that research and development into distributed energy resources integration as well as into microgrids is needed to move us from the traditional electric power system to a modern one.[15] Microgrids can exist in multiple different configurations, such as independent, networked, or embedded within another microgrid (see Figure 3).

Figure 3: Microgrid Configurations



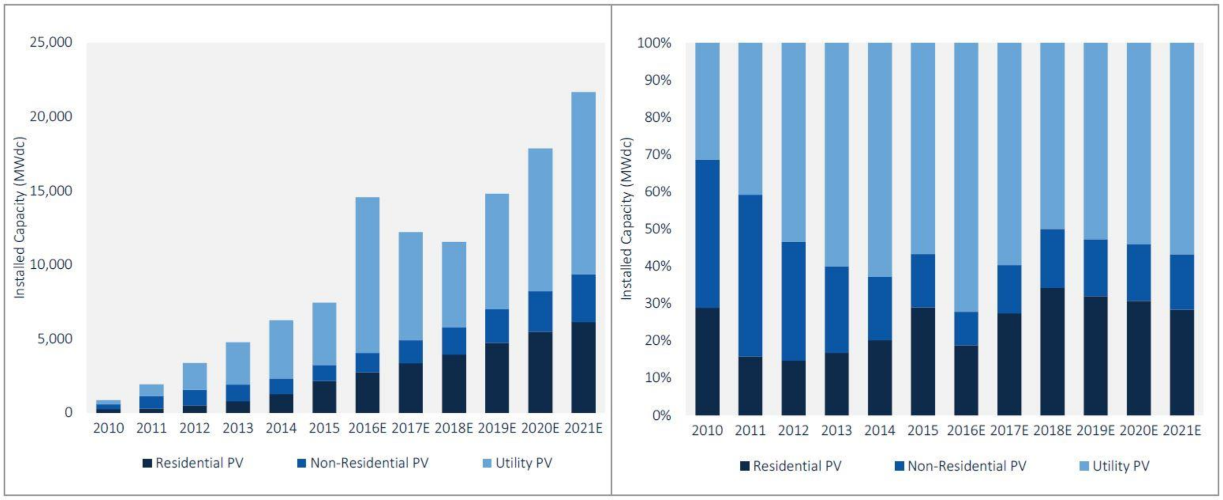
Source: Quadrennial Technology Review/Sandia National Labs

Such a system can be used to provide power to remote locations, such as a military base, or to improve the resiliency of the electric grid by effectively managing the cascade of a grid fault resulting from a natural disaster, or to respond to intentional cyber and/or physical attacks. For example, CHP installations and campus microgrids at hospitals and universities in New York and New Jersey were continuing to generate electricity and provide some service relief in the aftermath of Hurricane Sandy in 2012.[16]

Many states are proactively responding to the increasing levels of DERs and greater possibility of microgrid integration by working to ensure that the regulatory and market environments recognize these new types of resources. New York's "Reforming the Energy Vision" (REV) strategy has a goal of incorporating DERs and microgrids into the planning, management, and operation of the electric system. California, Hawaii, and Minnesota have similar initiatives in process.[17] These initiatives are contributing to the development of a next-generation framework that will facilitate DER integration to improve grid reliability, resiliency and efficiency.

The costs of DERs, especially solar PV, have declined, and are expected to fall even further. DOE's SunShot Initiative projects that residential system costs will reach $1.5/W to $3/W in 2020, a decline of 16 to 33 percent from the 2014 levels. Similarly, commercial system costs are expected to reach $1/W to $1.75/W by 2020, which is 26 to 33 percent lower than 2014 levels.[18] Overall installations of residential solar PV are expected to increase as well (see Figure 4). These cost reductions, coupled with those of other allied technologies like energy storage and communication technologies will enable microgrids to be more economically viable as well.

Figure 4: U.S. PV Installation Forecast by Segment 2010-2021 (Projected)



Source: GTM Research/SEIA U.S. Solar Market Insight 2016

Bulk Grid Power Flow Control Technologies

Advanced grid power electronics systems offer the ability to dynamically control the flow of electrons on the grid, in effect making the electric grid behave like a pipeline, with pressure valves to manage flow from the source to the sink.

The Flexible AC Transmission System (FACTS) is one such technology that enables precise control of the flow of electricity and aids in improving the utilization of the existing bulk grid infrastructure. High-voltage direct current (HVDC) is being recognized as an efficient means of transmitting power over long distances from generating resources that are remote from load centers.[h] Emerging power flow control techniques like Transmission Topology Control Algorithms (TCA) have shown that power flow on transmission lines can now be controlled more efficiently and dynamically. TCA can be equated to an advanced traffic-management system for the grid, managing electron flow instead of traffic flow.[19]

DOE has extensively supported research in next-generation grid power electronic materials (like advanced semiconductors) and systems (like FACTS). In 2014 President Obama announced several initiatives to foster industry-academic partnerships on semiconductor research and manufacturing.[i]

Private investment in HVDC transmission expansion is on the rise. DOE has recently approved the development of a 705-mile HVDC transmission line.[j] Several other projects like the New England Clean Power Link and Champlain-Hudson Power Express are proposed and would bring clean power from Hydro-Quebec in Canada to customers in Massachusetts and New York. A recent National Oceanic and Atmospheric Administration (NOAA) study showed that an extensive HVDC overlay can help in greater integration of renewables, cutting power sector

[h] HVDC uses direct current to transmit power. Direct current (DC) is the unidirectional flow of power. Batteries, solar PV, and other technologies produce direct current only. This differs from more commonly used alternating current (AC), in which the electric charge reverses direction periodically.

[i] In January 2014 President Obama announced the selection of a North Carolina-headquartered consortium of businesses and universities, led by North Carolina State University, to lead a manufacturing innovation institute for next-generation power electronics.

[j] In March 2016 DOE decided to participate in the development of the Plains and Eastern Clean Line project, which is a 705-mile long HVDC transmission line slated to bring in 4,000 MW of power from the Oklahoma and the Texas Panhandle region to South and Southeastern U.S.

carbon emissions by 80 percent from 1990 levels.[20]

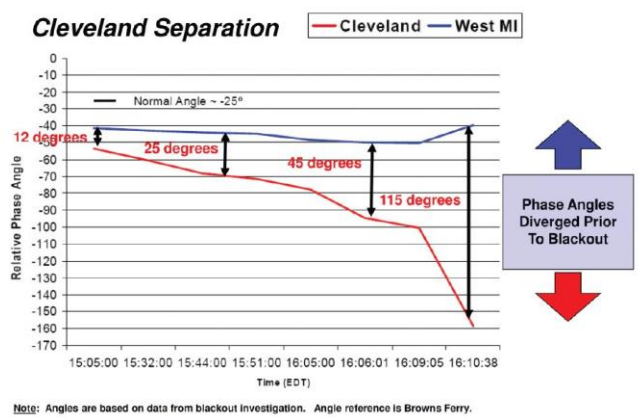
New materials like silicon carbide (SiC) and gallium nitride (GaN) have the potential to displace existing silicon-based power electronics hardware with equipment having higher efficiencies and greater capabilities. By 2015 the cost of standard SiC wafers was roughly 10 percent of the costs in 2002 when the technology was introduced, a decline of 90 percent in just over a decade.[21] Venture capital support is being provided for some emerging start-ups in the grid power electronics field, where new technologies for power flow control are being explored. The boundaries of advanced power electronics systems are being pushed further by these startups and other efforts.[k]

Information Connectivity and Processing Technologies

The electric grid is not isolated from the "Big Data" trends that have occurred in other industries. In the electric industry, sensing and communication technologies installed at various points along the grid have made new data collection possible. The information they gather provides insight into the operation of key equipment and a better understanding of how customers use electricity. These information technologies are essentially the eyes and ears of the power grid. They provide enhanced visibility and sophisticated monitoring capabilities to the grid operator. They also provide consumers with information about their personal electricity consumption and can help customers make more informed consumption pattern decisions.

Phasor measurement units (PMUs) are one example of sensing technology. These devices collect data on the status of the power grid at finer time scales. This information helps to detect possible points of failure on the network, directing responses and capturing data for post-event analysis. If operators had had PMU technology they might have been able to detect the onset of the 2003 blackout in the Northeast, which was preceded by what is called a "phase-angle separation" (see Figure 5).[l]

Figure 5: Example of Synchrophasor Data Analysis: August 14, 2003 Blackout



Source: QTR/North American Electric Reliability Corporation

PMUs are becoming more common; utilities deployed nearly 1,700 PMUs by 2014 across the U.S. and Canada, funded largely by the 2009 American Recovery and Reinvestment Act.[m]

Technology such as advanced metering infrastructure (AMI) — which is an integrated system of devices that provides two-way communication between customers' meters and the utility company—are also increasing information connectivity. AMI installations have grown substantially in recent years; by 2014, nearly 59 million AMI meters were installed across the country, reaching approximately 37 percent of

[k] ARPA-E's Green Electricity Network Integration (GENI) program is supporting development of small, mass-production-capable Distributed FACTS technology. Superconducting materials with almost zero losses have been successfully deployed in some pilot projects. Costs and performance in real-world application are being studied to gain greater understanding of this technology.

[l] U.S. Department of Energy, QTR, Chapter 3, p.61 September 2015.

[m] NASPI (2014). Synchrophasor Technology Fact Sheet. North American Synchrophasor Initiative (NASPI).

U.S. customers.[n] The deployment of AMIs offers greater visibility into activities at the distribution and customer level.

AMI is one of the many technologies helping to advance the "Internet of Things" (IoT) concept for the electric grid. IoT is a technology and network structure consisting of sensors, software, and other devices that enable predictive responses through coordinated data collection, data processing, and cognitive learning. Each component in the IoT framework is unique, with its own computing system and capabilities, but is able to interoperate within the existing internet infrastructure. For example, a "smart" thermostat today, enabled with internet communication, is able to receive weather data and react to daily temperature fluctuations while continuing to learn about its occupant's schedule and comfort level.

Information connectivity and visualization (via internet or communication interfaces) is also allowing end-use consumers to be more thoughtful in their energy consumption and interact with the grid more effectively through lifestyle choices like smart thermostats, smart water heaters, and lighting controls. The data provided by these devices can be used to create personalized/customized incentives for consumers to decrease their load during peak time. Some utilities across the country are actively exploring pilot programs to learn and take advantage of these new technologies and the IoT framework to further integrate energy efficiency and price-responsive demand programs.

Information is often most useful when it can be translated into action. IoT and data processing technologies are helping translate information into action faster than ever before.

Policies to Keep Pace with Technology Evolution

Increased adoption of these advanced electric technologies has the potential to fundamentally change the electric power industry and its operation. In turn, these technologies bring into question some of the underlying principles for regulation, oversight, and policymaking that have guided the development of the industry for decades. The changes occurring in the power sector would not be the first time that rapid technology evolution has outpaced the laws, regulations, and rules that govern an industry.

For example, in the telecommunications industry, technology advancements have transformed, and in some cases merged, the traditionally separate roles of services providers, such as local telephone companies, long-distance companies, satellite transmitters, radio broadcasters, cable television companies, cellular carriers, fiber-optics access providers, wireless cable operators, and more. Suppliers and products continue to be governed by policies based upon the old technological regime. Additionally, innovations have spurred the development of a wide range of products and services, many that didn't exist when policies and regulations were developed. Regulations have not kept pace with the technological development.[22]

Even in the United States, technology in some sectors continues to evolve more rapidly than associated policies. Policies defining acceptable use of drones have been slow to take shape even though drones are becoming quite common. Policies related to self-driving cars are far off, though they are a hot topic in the technology community. Policy action on cybersecurity has evolved far more slowly than the ability of attackers to hack into consumer information, such as credit card data.

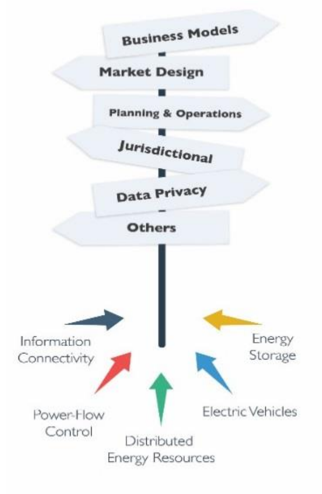
Similarly, advances in electrical technologies are beginning to spur debate on changes in laws and policies needed to govern the orderly evolution of the industry, and more issues may emerge. Modifying the laws, rules, and public policies

[n] Compiled by ICF based on EIA-861 data.

impacting an industry undergoing rapid changes due to technology evolution can either facilitate or hinder the ability of markets to capitalize on the benefits that technology development can provide.

Today we are at a crossroads where appropriate policy discussions and changes in the near and medium term can help capitalize on the benefits that advanced technologies offer, such as improving the reliability, efficiency, sustainability, resilience, flexibility, and affordability of the electric power grid. This paper identifies five key focus areas where changes to laws and policies are likely to be needed:

- **Reforming Business Models in the Energy Sector –** how prices are set, how companies earn money, and how operational efficiency can be achieved.
- **Redesigning Electricity Markets –** how the energy markets are structured and designed.
- **Revamping System Planning and Operations** – how long-term forecasting, resource planning, and day-to-day activities are conducted.
- **Renegotiating Jurisdictional Boundaries –** how jurisdictional boundaries are determined and how coordination between authorities is undertaken.
- **Ensuring Information Privacy and Determining Data Ownership –** how customer data is owned and protected and how information can be used.



Discourse on these topics would be most effective if conducted in parallel with technology evolution. It is important for a wide spectrum of policymakers to participate in these conversations, since the influx of emerging technologies has a ripple effect across systems, markets, and jurisdictions.

Similarly, it is important for policymakers to understand the breadth of technologies that will alter the status quo of the electricity industry. Consequently, this wide range of technologies will highlight gaps in and challenges for the existing policy framework. Often it will be the amalgamation of these technologies that will have the greatest policy implications. Table 1 summarizes the key disruptive technologies and the policy areas they are expected to impact.

Table 1: Disruptive Technologies Will Create Challenges for Current Policy Frameworks

Policy Categories → Technologies ↓	Business Models	Market Design	Planning & Operations	Jurisdictional Boundaries	Information Privacy & Data Ownership
Distributed Energy Resources (DER)	✓	✓	✓	✓	✓
Electric Vehicles (EVs)	✓		✓	✓	✓
Energy Storage	✓	✓	✓		
Power Flow Control		✓	✓	✓	
Information Connectivity	✓		✓		✓

Incentives for Reforming Utility Business Models Are Inadequate

The traditional utility business model is centered around utilities earning a specified rate of return[o] on the volumetric sale of electricity served by capital-intensive fixed assets. The "regulatory compact" commits utilities to serve demand within their franchised service territory in return for a guarantee that electricity prices will be sufficient to recover costs and provide a reasonable rate of return on their capital investments.[23] This arrangement—referred to as cost-of-service regulation—worked when load was steadily increasing.

However, more efficient technologies and devices, as well as the growth in distributed generation (such as solar PV), have led to a drop in sales and a corresponding drop in the generation required from utility-owned, centralized generating units. This has decreased utilities' ability to recover fixed costs of operations without raising electricity prices. Consequently, the growth of distributed generation is perceived by many utilities as a risk—it not only reduces electricity sales but also imposes significant integration costs as greater levels of monitoring and control are needed to maintain reliability. This requires utilities to invest in technologies like sensors and data processing platforms to better monitor and manage the system. These additional "soft" costs may further stress the utility business model, as it can be difficult for the utilities to recover their costs for these technologies during regulatory rate case proceedings.

Policymakers and stakeholders can work to establish performance-based incentive structures for both consumers and utilities so that the friction emerging from technology adoption can be minimized or mitigated. Such performance-based measures will (1) incentivize utilities to encourage the deployment of efficient technologies even if they result in a drop in volumetric sales, and (2) compensate the end-users of such technologies based on appropriate rate designs that capture the

[o] Regulated rates of return typically apply only to Investor-Owned Utilities (IOUs) that are regulated by a state public utility commission. Generally speaking, public power entities and cooperatives are often exempt from state rate regulation.

"fair economic value" that the technologies bring to the grid.

Pay-for-performance metrics that incentivize utilities to improve the utilization of existing assets (lines, transformers, generators) can be very effective in deferring infrastructure investments (the costs of which are passed on to the consumers) while allowing the utilities to remain profitable. Similarly, progressive utilities should be incentivized appropriately to deploy advanced technologies, such as DER systems, power flow control systems, and other controls and information systems that bring efficiency, reliability, or other benefits to the end-users. The rewards should be commensurate with the risks that the utilities undertake for these technologies, given that some of the technologies may still be emerging. Regulators in some states, like New York, have begun deliberating on the issue of ratemaking reforms to reward the utility for improving system efficiencies and allow consumers to be more responsive to price signals.[p]

Similarly, consumer incentives for resource adoption like DR, CHP, and solar PV could be tied to the economic value that these resources provide to the power grid. Recent rate structure initiatives, like "Value of Solar" efforts, provide fair compensation to the end-users based on avoided variable and fixed costs of grid operations, as well as infrastructure deferrals.[q] Mechanisms such as time-of-use (TOU) pricing may need to be more widely introduced to better capitalize on the opportunities provided by distributed technologies, helping both customers and utilities achieve desired economic rewards.

Business models should support the policy goals of improving affordability, sustainability, flexibility, reliability, resiliency, and efficiency. For example, emerging business models in the area of shared renewables, like "Community Solar" programs, can allow consumers with limited financial or solar resources to buy or lease a portion of a shared solar system. This allows the utilities to increase the amount of renewable energy in the generation portfolio (thereby achieving sustainability goals) while being able to more effectively control the intermittent resource (thereby improving flexibility). Incentives and rates should be allocated to the consumers in a just and fair manner, recognizing the costs and benefits of such programs. Additionally, utilities can act as aggregators by compiling consumer-sited resources to tackle specific locational issues on the distribution grid. Aggregation implies that a wide range of distributed resources can work in a synchronous manner to act as one combined resource. Currently, third-parties are aggregating DERs, energy storage and flexible loads to provide service in the wholesale markets and service transmission system needs. Utilities, with their detailed understanding of the distribution system, may undertake similar activities at the distribution level to enhance service quality and improve customer engagement.

As emerging technologies become ubiquitous, the traditional regulatory approach and the framework of applying those principles may need revising to ensure maximum net social benefit. Additionally, the environmental, sustainability, and resilience benefits of these emerging technologies may need to be given equal consideration in regulatory and ratemaking discussions.

[p] New York State Public Service Commission (NYPSC), "Case 14-M-0101: Order adopting a ratemaking and utility revenue model policy framework."

[q] In March 2014, the Minnesota Public Utilities Commission (MPUC) approved the methodology for calculating the value of a solar (VOS) tariff as devised by the Minnesota Department of Commerce. Available here: http://mn.gov/commerce-stat/pdfs/vos-methodology.pdf

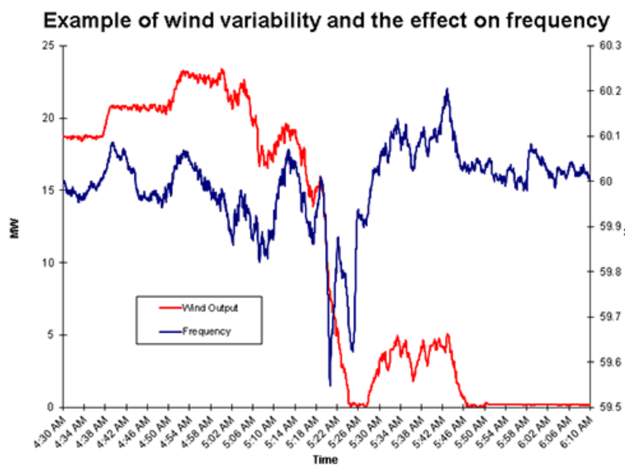
Current Market Design May Limit the Benefits of Emerging Technologies

Technology evolution has the potential to disrupt wholesale electricity markets. One of the guiding principles of the present wholesale market design is to send adequate and timely economic signals to attract new generation and transmission resources that can reliably keep pace with the demand for electricity. These new entrants earn revenue by providing energy and reliability services.

However, under a scenario with high penetration of DERs and renewable energy, the opportunity to earn revenue from selling energy may decrease[r], and therefore may be insufficient to attract new entrants. Other technologies may have a similar effect on the market. For example, power flow controllers can help reduce electricity price spikes by relieving transmission congestion, thus improving the efficiency of the market and lowering energy prices. Decreased energy prices may result in markets not being able to provide adequate financial incentives for new resources to enter the market. This can threaten the reliability of system operations, since having adequate resources available is key to grid reliability. Thus, developing new or reforming existing resource requirement mechanisms may be needed going forward.[s] This is especially important given that new resource entry has an inherent lag while resource exit can be almost instantaneous.

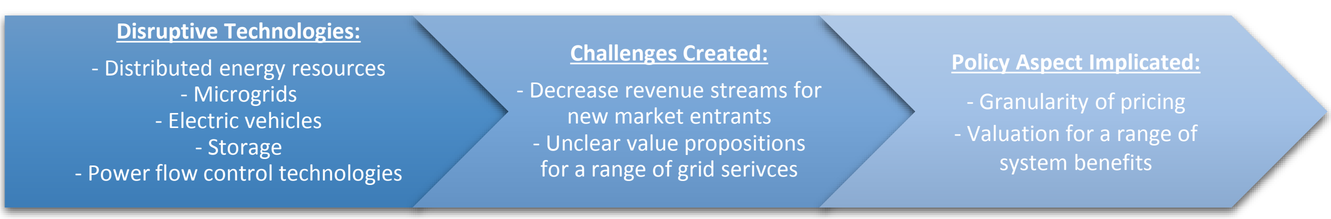
The power output from non-hydro renewable generators is unpredictable and variable. Solar PV and wind output for the next day depend on whether it will be a sunny or a cloudy day; the steadiness (or variability) of the output is therefore governed by the cloud movement. This can lead to drastic peaks and valleys in the daily load curve, manifesting as frequency fluctuations on the grid (shown in Figure 6).

Figure 6: Wind Variability on Maui Electric Grid



Source credit: Maui Electric

Mitigating the impacts of variability on the grid requires having other resources available to provide flexibility to quickly step in and help meet the demand spikes. Markets have typically compensated these flexibility resources by valuing both energy (i.e., the amount of electricity provided, kWh) and capacity (i.e., the capability to provide electricity, kW). However, in the future—if technologies like storage are heavily relied upon



[r] This is due to the fact that these resources require no fuel and therefore can provide energy at low or zero cost. This reduces the potential revenue streams for new entrants.

[s] Resource requirement signaling is undertaken through either capacity markets or scarcity adders. In capacity markets resources get paid for availability, i.e., the generation resource should be available when the system is approaching peak conditions or is facing an emergency. Essentially the resources sell reliability. Similarly, scarcity adders are additional compensation provided to resources performing during system emergencies or peak load conditions. "Scarcity" here implies that all available generation up to service load is being used and the system may be utilizing reserve or stand-by generation as well to meet peak demand.

to provide flexibility to the grid—markets may need to value how *quickly* a resource can be up and running to provide flexibility. Or market mechanisms may be needed for valuing how *frequently* a resource can be cycled on or off the system to provide support.

Similarly, other technologies can provide a range of benefits to the grid and to society, but the market does not currently assign a value to those services. For example, distributed energy resources, particularly when organized into microgrids, not only contribute to system reliability but also enhance system resilience.[t] Market mechanisms to value resilience or "self-healing" capability after an emergency have not been developed and may need greater deliberation moving forward. Additionally, DERs can help solve local power quality issues by providing voltage support (which helps ensure reliability), but market mechanisms are needed to value these types of ancillary services.

DERs, microgrids, and EVs can all provide considerable system benefits based on their location on the grid and when they contribute services. However, market mechanisms are needed to improve system operators' visibility of these resources and to encourage their participation in market operations. One approach to encouraging their participation is to develop pricing that recognizes their locational value.

Mechanisms that value the resources based on their contribution to the transmission and distribution system as an *integrated* system are also needed. For example, many regional electricity markets currently provide granular locational prices down to individual nodes or substations on the transmission system, which allows market participants to make informed decisions about when to operate. As technology improves, markets may need to develop mechanisms to extend locational pricing information down to the distribution system to allow customers to receive and even respond to pricing signals. More granular pricing would also allow system operators to have greater visibility of these resources on the system and to use them more efficiently.

Ultimately, future markets may need to compensate for a broader range of benefits than simply reliability—such as flexibility, fast-ramping capabilities, and resiliency. As emerging technologies alter the electricity market, the need for developing new products that align with the emerging paradigm will need guidance from policymakers.

Routine Operating and Planning Practices May Need Revision to Address Benefits and Constraints of Emerging Technologies

Advanced power flow control technologies, advanced sensors, and increased information connectivity will give system operators more control of the power grid and greater ability to operate the grid more efficiently. If system operators have better insight into and control of activities at various points along the grid they can better optimize grid performance and reduce their reserve margins (i.e., back-up services) that add cost to the operation of the grid. Thus, the introduction of such technologies may create a need to review the standards, guidelines, and practices in place today for planning and operating the system.[u]

Traditionally, planning for the grid focused on maintaining reliability through redundancy, i.e., requiring more generation available than the

[t] On February 12, 2013 a Presidential Policy Directive (PPD) on Critical Infrastructure Security and Resilience was issued. This directive calls for proactive and coordinated efforts among various federal agencies to maintain, secure, and develop resilient critical infrastructure.

[u] Reviews of planning standards are not new occurrences for the electric grid. Some notable events in the recent past which have had far-reaching impacts on grid planning and reliability and monitoring standards include the formation of power pools (ISOs and RTOs) and the Northeast blackout of 2003.

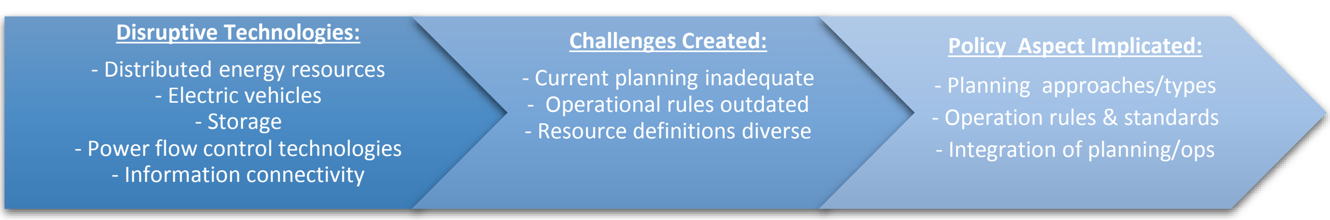
anticipated peak demand. This concept is called reserve margin, i.e., having generation on reserve for meeting peak demand. The current planning protocols are based on typical reserve margins of 10 to 15 percent.[24] Having generation on reserve imposes system costs as these assets must be compensated to be on stand-by mode. Advanced technologies, such as power flow controllers and synchro-phasors, can improve the situational awareness and controllability of the power grid and ultimately the utilization of the infrastructure. This could lead to a revision of planning standards, potentially relaxing present reserve margin requirements. Lower reserve margins could reduce costs, but would likely require significant policy and regulatory assistance in making the changes and in evaluating reliability concerns that such a scenario may create.

Uniform standards, market rules, and practices are typically lacking for emerging technologies such as energy storage and DERs. This can discourage new resources from entering the energy market.[v] For example, under the California Independent System Operator (CAISO) rules, an energy producer's battery storage is counted for resource adequacy purposes if it can supply electricity for four hours. In other markets, rules governing the contribution of storage facilities might be unclear or nonexistent. This is mainly due to the multiplicity of functions that a storage resource can serve; i.e., it can produce power (like generators) and consume power (like load). Thus, this has created ambiguity in its treatment either as a load, generator or both. Such inconsistencies in resource definition may lead to inefficient allocation of capital and potentially discourage needed investments. Clear standards and market rules would address this concern. Similarly, standards governing the capacity contribution from DERs and the rules for their participation in wholesale markets must evolve.

Additionally, increased DER penetration may drive the need for the creation of a centralized Distribution System Operator (DSO) at the distribution level, an analog to the role served by an Independent System Operator (ISO) at the transmission level. A DSO could coordinate DER dispatch for efficient system operation. The framework and function of the DSO will require deliberation from policymakers on a wide range of jurisdictional and regulatory topics, such as creation of communication standards with DERs and the provision of deterring rules for sharing system data with customers and DER providers. In addition to the DSO framework, guidelines on the interaction and coordination between the ISO and DSO on issues of data interoperability and information sharing will also be needed. For example, for transmission planning, the ISO may look to the DSO for information on the location and availability of resources (hourly, seasonally, or annually).

Other technologies, such as EVs, which are inherently mobile, will also complicate the planning process for utilities and the ISOs. EVs are not confined to a specific utility's territory. Thus, as EVs become more ubiquitous, the utilities must not only accurately forecast the EV demand (load) within their service territory but they must also predict when portions of that load are likely to leave their territory and/or when additional load may enter it.

The traditional planning and operation process assumes that resources are stationary, including customer-sited resources such as EVs. The



[v] Resource Adequacy is a broad term indicating that the system has sufficient resource capacity to meet peak demand and an administratively determined buffer requirement also known as reserve margin.

inherent nature of EVs complicates this process. For example, a utility/EDC may expect an EV to be available for grid support services because it is owned by a customer within its service territory (see below in Figure 7, EDC #1 Territory). However, when the utility calls upon that EV resource, it may no longer be available because it has moved (see Figure 7, In Transit). It may be available at an alternate location (e.g., an office building) in another utility/EDC's service territory where it was *not* accounted for during that utility's planning and operations process (see Figure 7, EDC #2 Territory). This may require probabilistic planning in the future.

Although the grid today meets load expectations through synchronized operation of generation, transmission and distribution systems, the planning processes to meet load growth can be disjointed. Integrated planning has the potential to enhance system efficiency by determining the optimal combination of new investments and existing grid components. Technology advancements will further warrant this planning. For example, power flow control technologies can improve the utilization of grid infrastructure and how power flows, thus deferring the need to build new transmission lines or other assets if effectively incorporated into planning.

The growth in DERs and EVs is also expected to increase the importance of integrated transmission and distribution planning, as these technologies exert wide-ranging system impacts based on how and when they change the patterns and levels of load on the grid. Taking an integrated approach to forecasting and planning investments for the grid will require the formulation of new frameworks and standards for such plans.

The growth of DERs will require regulators to review and reinforce some existing guidelines. For example, under FERC Order 1000, non-transmission alternatives like DERs need to be evaluated against conventional technologies on a level basis when considering transmission expansion projects.[w] However, rigorous analysis of non-transmission alternatives is not typically undertaken. As DER costs decline and they are increasingly viewed as effective means of transmission deferral, guidelines on considering non-transmission alternatives during the transmission planning process will be needed or existing guidelines will need to be better enforced.

Additionally, technologies such as PMUs allow for increased visibility into grid operations and performance. This provides system operators with better awareness of the likelihood of an immediate or near-term fault and enables them to take corrective measures more quickly. This is especially true when combined with information processing algorithms that produce predictive analytics. System operators across multiple regions or systems could share this information to make more immediate decisions about essential market operations such as dispatching generation and making financial settlements. More generally, advanced sensing technologies will facilitate proactive operation of the grid. Achieving these technological benefits, however, will require that policymakers consider what interoperability and communication standards may be needed to permit and help streamline the sharing of data traffic between different technology platforms and among various operators.

Energy industry planning is necessarily based on and confined to existing technology, but the developers of emerging technologies can assist in developing scenario-based, anticipatory planning that addresses uncertainties faced by the industry. Enhanced information handling and processing will provide capabilities to move beyond the current five- to ten-year planning horizon, which has been guided by the critical, but limiting, focus of preserving reliability. Going forward, planning will need to integrate additional parameters like resiliency and resource flexibility in addition to reliability and economic affordability. Policymakers may want to consider the

[w] FERC Order No. 1000 reforms the Commission's electric transmission planning and cost allocation requirements for public utility transmission providers.

formulation of guidance or standards that permit the capture of such enhanced planning scenarios.

Figure 7: Mobile Resource Integration Challenge

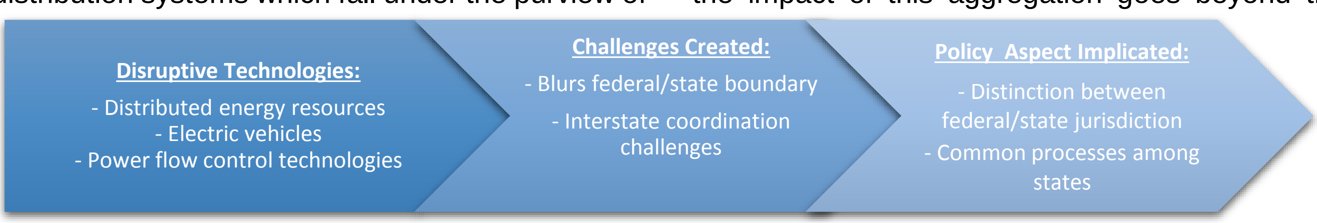
Source: ICF International

Emerging Technologies Will Challenge Current Jurisdictional Boundaries

The emergence and proliferation of advanced technologies may raise jurisdictional questions of who has oversight over these technologies, how they are classified, when and where they are used, and who benefits from the potential new value streams or other opportunities they provide. For example, electric vehicles in aggregate can provide valuable services to the grid. They can serve as energy storage or provide onsite ancillary services to help grid operators respond more quickly to disruptions in the system.

However, the mobility of EVs raises a number of interesting jurisdictional questions. For example, an EV may charge in one state while it discharges, for grid support purposes, in a different state. If the EV receives compensation for grid support services in the second state, it could be viewed as a form of interstate commerce, thus making the transaction susceptible to federal jurisdictional oversight, even though the EVs are connecting to distribution systems which fall under the purview of state regulators. Furthermore, the distribution infrastructure enabling this interstate commerce may also be subject to federal jurisdiction. This issue could become prominent in multi-state metropolitan areas where large percentages of the population live in one state yet work in another. This is true for the Washington metropolitan area, including the District of Columbia and parts of Maryland, Virginia, and West Virginia, or the New York metropolitan area including parts of New York, New Jersey, and Connecticut.

Similarly, customer-sited DERs like rooftop PV or distributed storage that can provide infrastructure deferral and bulk grid support services also pose jurisdictional oversight questions. These resources are currently outside the purview of FERC or NERC jurisdiction because they are located on the distribution system, under state jurisdiction.[x] If utilities or DSOs begin to aggregate DERs in order to provide their services into the wholesale market, the impact of this aggregation goes beyond the



[x] North American Electric Reliability Council (NERC) is a not-for-profit international regulatory authority whose mission is to assure the reliability of the bulk power system in North America. NERC develops and enforces reliability standards; annually assesses seasonal and long-term reliability; monitors the bulk power system through system awareness; and educates, trains, and certifies industry personnel. NERC's area of responsibility spans the continental United States, Canada, and the northern portion of Baja California, Mexico.

state boundary in which the DERs reside. This aggregation could subject the utility or DSO to federal oversight in addition to the current state oversight.

Additionally, some current standards define a planning and operational boundary between transmission assets (under federal jurisdiction) and distribution assets (under state jurisdiction). For example, FERCs "Seven Factor" and "Mansfield" tests provide guidelines to distinguish local distribution facilities from transmission facilities.[y] Some of the assessment criteria include the traditional assumption that the distribution facilities' power flow is unidirectional and does not affect the reliability of the transmission system. However, the entry of DERs challenges this notion by enabling bidirectional power flow on the distribution system that *can* impact the reliability of the transmission system. Additionally, with more interconnected transmission and distribution infrastructure as well as integrated planning, the line between transmission and distribution (and the corresponding boundary between federal and state jurisdiction) may become blurred.

Another area where federal-state jurisdictional coordination challenges may arise will be in the effective integration of long-haul HVDC transmission lines. These lines are generally longer than current AC transmission lines and will cut across multiple state boundaries. Streamlining transmission siting and approval procedures will become critical for timely completion of such projects. The need to develop a standardized process for approving transmission siting that could be used across many state regulatory authorities will warrant greater attention. Additionally, a lack of clarity in the implementation of FERC Order 1000 cost allocation principles can create uncertainties in project costs for some market participants. The challenges may be due to the approaches used to determine beneficiaries of projects included in the regional plans for cost allocation. FERC Order 1000 requires that costs be allocated commensurate with expected benefits from the projects.

Regulators can request a broad review of cost allocation approaches in light of approaches that have resulted from contested cases. Market participants can identify factors that could result in challenges to their process and proactively develop solutions. Market participants could also derive best practices and applicable lessons from cases that have worked effectively.

From a policymaker's perspective, the adoption of a range of advanced technologies creates opportunities for ironing out the jurisdictional limitations which may potentially inhibit the benefits of these resources. Collaboration between system operators, jurisdictional authorities, and policymakers could be mutually beneficial for the development of policies to capitalize on the system-wide advantages that emerging technologies can provide. There is a need for open communication among these parties to foster collaboration on best practices and develop common understanding about shared jurisdiction.

[y] The Seven Factor Test was set forth in FERC Order 888. It includes seven factors for determining whether facilities are used in local distribution or transmission and the corresponding jurisdiction. For additional information see 153 FERC ¶ 61,384 "Order on Local Distribution Determination," issued December 31, 2015. The Mansfield Test provides five factors. It was first outlined in Mansfield Municipal Electric Department v. New England Power Co., 94 FERC ¶ 63,023 at 65,170, aff'd, Opinion No. 454, 97 FERC ¶ 61,134 (2001), reh'g denied, Opinion No. 454-A, 98 FERC ¶ 61,115 (2002) (*Mansfield*).

Current Privacy and Data Protection Laws and Standards May Be Outpaced by Emerging Technologies

Greater adoption of advanced technologies will produce valuable information on both consumer behavior and the way operations are conducted on the grid. This raises important questions for policymakers regarding information ownership, data privacy and cybersecurity. For example, as penetration of customer-sited technologies become more universal—such as EVs and DERs, in conjunction with AMI and devices like smart thermostats, home automation systems, and other monitoring and control systems—the volume of customer information available increases. Further, as DERs begin to provide an increasing number of grid services, system operators will need to monitor the performance of these resources in real time.[25] While this monitoring can help improve grid reliability, it also raises questions regarding how much insight it gives the system operator into customer behavior and if at some point that knowledge jeopardizes customer information privacy.

Table 2: Estimated Number of Nodes/Control Points per Entity Type

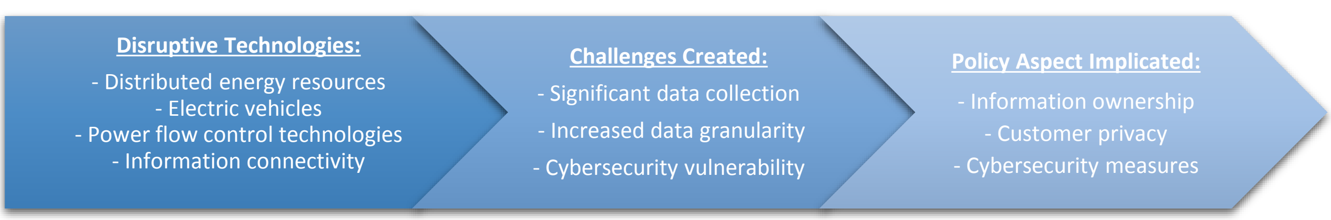
Entity type	Number of nodes
Regional	<20
Control area	~200
Distribution	~1,500
Market participant	~500
Supply	~10,000
Building	~150,000,000

Source: QTR/GridWise Architecture Council

Table 2 shows the number of potential control points (or nodes) per entity type, with buildings having the highest number by a large margin.

Determining who has ownership of this information (e.g., the utility, the building owner/customer, or the smart device provider), who should have access to this information, and what information can be used for improving system planning or operations may be of interest to policymakers and regulators. This may be especially true when the data involves content that could allow outside entities to draw conclusions regarding patterns of home occupancy and customer routines. Similarly, tracking EV usage patterns is critical for providing visibility into end-use consumption to improve system planning, but it can also capture sensitive information on customer habits, which need protection.

As DERs, energy storage, and EVs become increasingly integrated with the grid, a failure of these devices can challenge the reliability and stability of the bulk grid. Such a situation can arise when the communication link between the DSO and the DER devices breaks, and the DERs may not be able to perform as per the directives from the DSO. DERs in this sense can be seen as "critical" grid infrastructure, which may require developing standards to advance the cyber and physical security of DERs and the enabling technologies that are similar to the NERC Critical Infrastructure Protection (CIP) standards that exist for the bulk system.[z] It is expected that as the interconnection and interaction of emerging technologies with the grid increases, there will be



[z] The NERC CIP (North American Electric Reliability Corporation critical infrastructure protection) plan is a set of requirements designed to secure the assets required for operating North America's bulk electric system.

an increase in the access points from which to initiate a cyber attack on the grid. This is especially true as these technologies generally use internet-based protocols to communicate with each other, the device owner and/or the aggregator in some cases. It may be necessary to enhance the current risk assessment frameworks related to cybersecurity.

Sensors (such as PMUs) provide granular insight on the current state of the system that enables quicker, more informed decision making to ensure grid reliability. However, protecting the specifics and accuracy of grid information from cyber attacks is critical. If appropriate security measures are not in place, the data can be accessed by cyber or physical attackers to map information on critical assets or tamper with the system and disrupt service. The recent coordinated physical attack on a substation in California and the cyber attack on the Ukrainian distribution grid are reminders of the criticality of information and data protection needs. Additionally, as information and data are shared across multiple systems, ensuring that data integrity is maintained will require revisions to current information technology, enhanced data sharing, and communication protocols.

It is also possible that ubiquitous use of these sensor technologies could lead to opportunities for more automated decision making, which in case of a cyber attack can lead to cascading effects, potentially impacting safety and reliability of the grid. However, it is expected that sensors installed on the utility system will comply with established security standards and practices. However, there may be a concern that integrated devices like aggregated DERs which interact with utility systems may not be under the purview of utility security practices and standards, potentially creating additional entry points for cyber attacks. It also raises questions for system operators and policymakers regarding the degree of manual intervention and decision making that may be desired or needed.

Ultimately, the barrage of data from new and emerging sensor technologies and customer-sited devices needs sophisticated encryption. As the penetration of these technologies increases, a thorough revision of cybersecurity protocols and practices may need to be undertaken to address these challenges.

Conclusion

The electricity industry is undergoing a period of profound transformation driven by technology advancements. By 2040, the industry could look significantly different than it does today in terms of the penetration of key technologies and our reliance on them. The future industry could include widespread adoption of utility-scale storage devices and electric vehicles, heavy reliance on distributed generation technologies such as solar PV, common use of microgrids, abundant use of power flow control technologies, and significant information connectivity.

Greater penetration of these technologies—both individually and cumulatively—will have far-reaching policy implications and raise key questions regarding system operations and planning, utility business models, market structures, information ownership/privacy and cybersecurity, and jurisdictional coordination.

For policymakers involved in making decisions that impact the electricity industry, either directly or indirectly, it is of critical importance to understand the directions in which technologies in this industry are evolving, especially when the rate of technology development progresses more rapidly than the associated policy initiatives. Technologies will play a key role in influencing the grid of the future. An understanding of their disruptive impacts on planning, rate design, system architecture, and regulatory models will be needed by policymakers going forward. It is also necessary for policymakers to recognize the interdependencies between emerging technologies and the cumulative impact that a range of advanced technologies will have on policy frameworks. Awareness of the implications of these technologies can help inform policy choices, now and in the future, to ensure that policy initiatives do not inadvertently hinder the opportunities provided by advanced technologies but instead help capitalize on the potential benefits they can offer.

Policymakers should not be deterred by the policy questions being raised—there will always be challenges *and* opportunities in the path of technology evolution and integration. These will require informed and conscientious policymaking that effectively addresses the widespread deployment and integration of a host of promising technologies.

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