Chapter VII

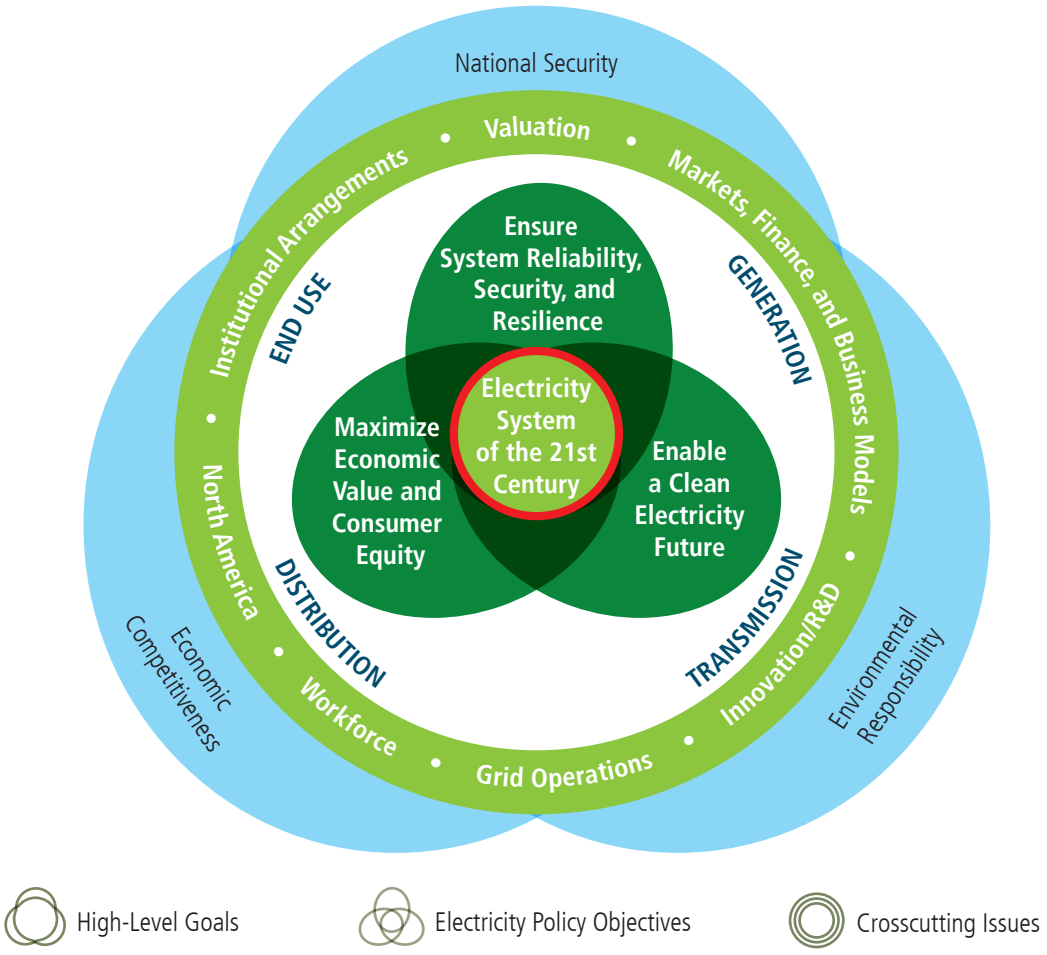
A 21ST-CENTURY ELECTRICITY SYSTEM: CONCLUSIONS AND RECOMMENDATIONS

This chapter highlights many recommendations that will enable the necessary modernization and transformation of the 21st-century electricity system. The 76 recommendations build on the analysis and findings in earlier chapters of this second installment of the Quadrennial Energy Review (QER 1.2). Many of the recommendations will provide the incremental building blocks for longer-term, planned changes and activities, undertaken in conjunction with state and local governments, policymakers, industry, and other stakeholders. The policy, research, and investment choices made today will establish critical pathways for decades.

Key National Security and Reliability Priorities for a 21st-Century Electricity Sector

The electricity sector is a complex system of overlapping interests, investments, and impacts that affect industry, businesses, consumers, and communities served by electricity providers. Accordingly, migration from the present state to a desired outcome for the 21st-century electricity sector (Figure 7-1) requires recognition of critical crosscutting factors that should be addressed as superordinate to the perspectives discussed in preceding chapters. These high-level, crosscutting issues and recommendations address national security, reliability, jurisdictional adjustments, technology investments, streamlined regulatory processes, better gathering and use of data and analysis, and realistic assistance solutions to enable key elements of a 21st-century electricity system.

Figure 7-1. Goals, Objectives, and Organization of QER 1.2



The central finding in the second installment of the Quadrennial Energy Review (QER 1.2) is as follows: "**As a critical and essential national asset, it is a strategic imperative to protect and enhance the value of the electricity system through modernization and transformation.**"

The Electricity System as a National Security Concern

A set of actions and recommendations in QER 1.2 address the fundamental role of the Federal Government: promoting national security and ensuring the national defense. To this end, it is worth restating a key conclusion from Chapter I (*Transforming the Nation's Electricity System: The Second Installment of the Quadrennial Energy Review*) to illustrate the essential and growing role electricity now plays in this fundamental function of the Federal Government. The conclusion of a 2015 report from the Center for Naval Analyses notes,

> "Assuring that we have reliable, accessible, sustainable, and affordable electric power is a national security imperative. Our increased reliance on electric power in every sector of our lives, including communications, commerce, transportation, health and emergency services, in addition to homeland and national defense, means that large-scale disruptions of electrical power will have immediate costs to our economy and can place our security at risk. Whether it is the ability of first responders to answer the call to emergencies here in the United States, or the readiness and capability of our military service members to operate effectively in the U.S. or deployed in theater, these missions are directly linked to assured domestic electric power."[1]

The analysis in QER 1.2 reaches a similar conclusion: the reliability of the electric system underpins virtually every sector of the modern U.S. economy—from food production to banking to health care. Electricity is at the center of key infrastructure systems that support these activities—transportation, oil and gas production, water, finance, and information and communications technology. Electricity-dependent critical infrastructures represent the core underlying lifeline framework that supports the American economy and society.

The range of goods and services that involve grid communications and two-way electricity flows, including the Internet of Things (IoT), represents significant value creation and greatly supports and enhances our economy and global competitiveness. At the same time, these goods and services place new demands on the electric grid for high levels of reliability, smarter components, visibility, analytics, and system-wide planning. These features and services also introduce new vulnerabilities to our electricity system (e.g., accelerated time scales sufficient to require significant automation and cybersecurity) that rise to the level of national security concerns.

These vulnerabilities are underscored by the October 21, 2016, hacking incident of simple home devices. Figure 7-2 shows the location of key data centers that support the Internet (discussed in detail in Chapter I, *Transforming the Nation's Electricity System: The Second Installment of the Quadrennial Energy Review*), as well as the global impacts of this event. In this incident, the "Mirai" botnet used internet-connected devices, including baby monitors, to create the largest denial-of-service attack in history. The impact of this event was amplified by the U.S. Domain Name System company (called Dyn), infecting 100,000 IoT devices deployed throughout the world (Figure 7-3).[2] The IoT devices in foreign countries worked together to attack a U.S. company. This attack underscores the national security and economic vulnerabilities associated with interconnectedness and the growing proliferation of unhardened consumer devices on the distribution network that have the potential to infect bulk power systems.

Figure 7-2. Primary Data Centers for Major Service Providers[3]

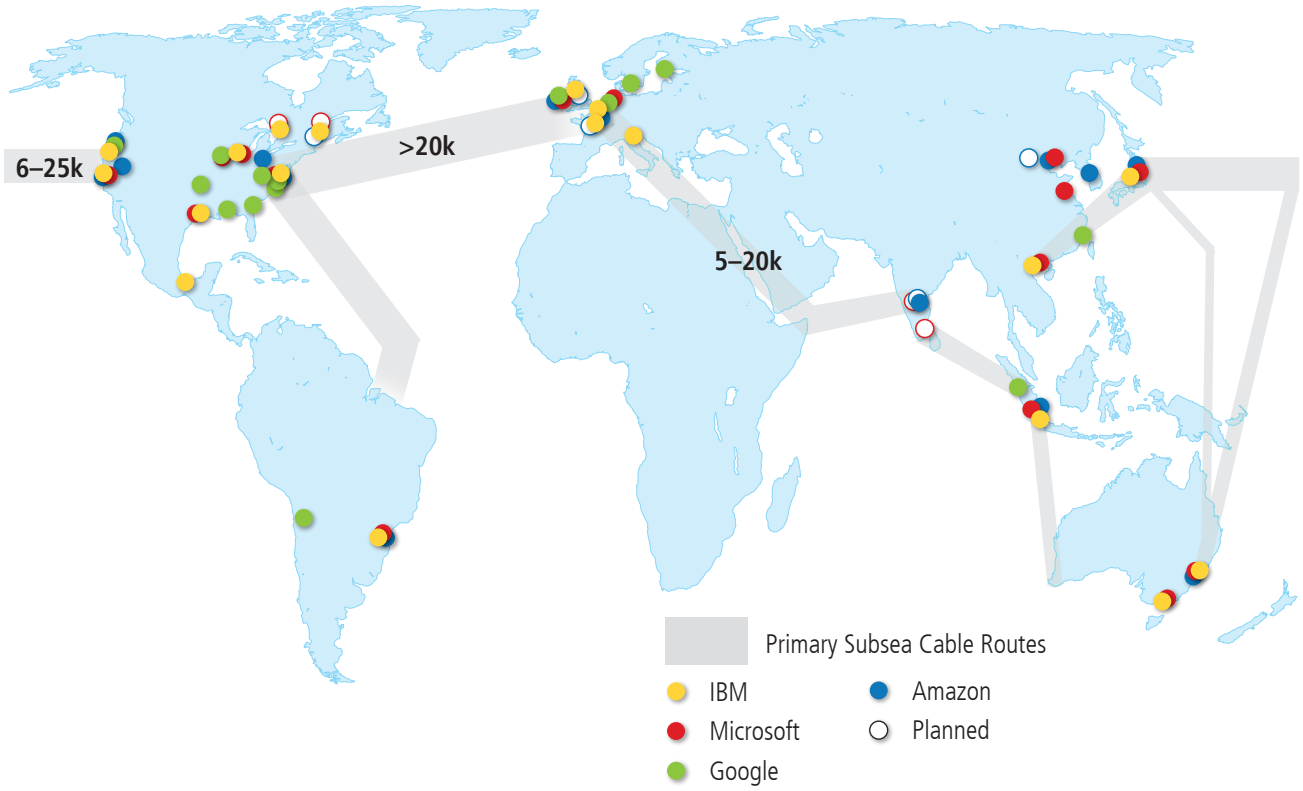
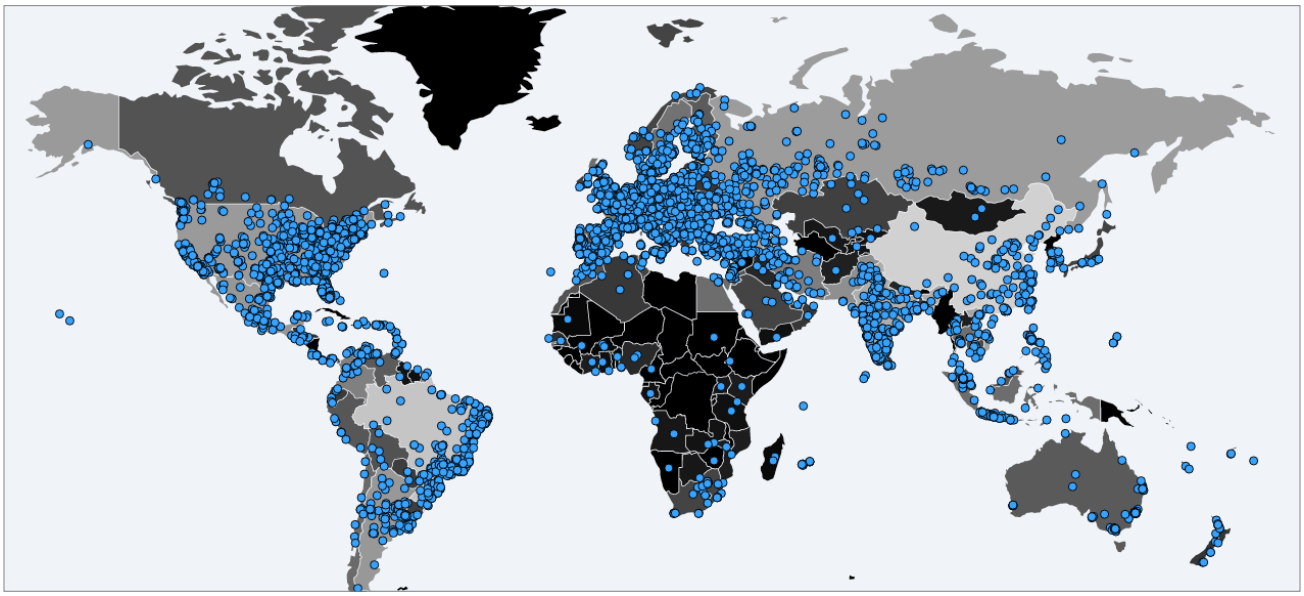


Figure 7-3. The Global Reach of the October 21, 2016, Hack[4]



The global internet is supported by a worldwide network of subsea cables and large-scale data centers operated by firms such as Amazon, Google, IBM, and Microsoft (Figure 7-2) This global reach and interconnectedness, however, also introduces vulnerabilities for U.S. assets and systems that can be affected by connected devices worldwide, as was seen in the October 21, 2016, "Mirai" botnet attack (Figure 7-3, with blue depicting the global impacts of the attack). The global exposure of the "internet of things" merits deliberate risk-management activities as the electric power sector becomes increasingly interconnected with global communications networks.

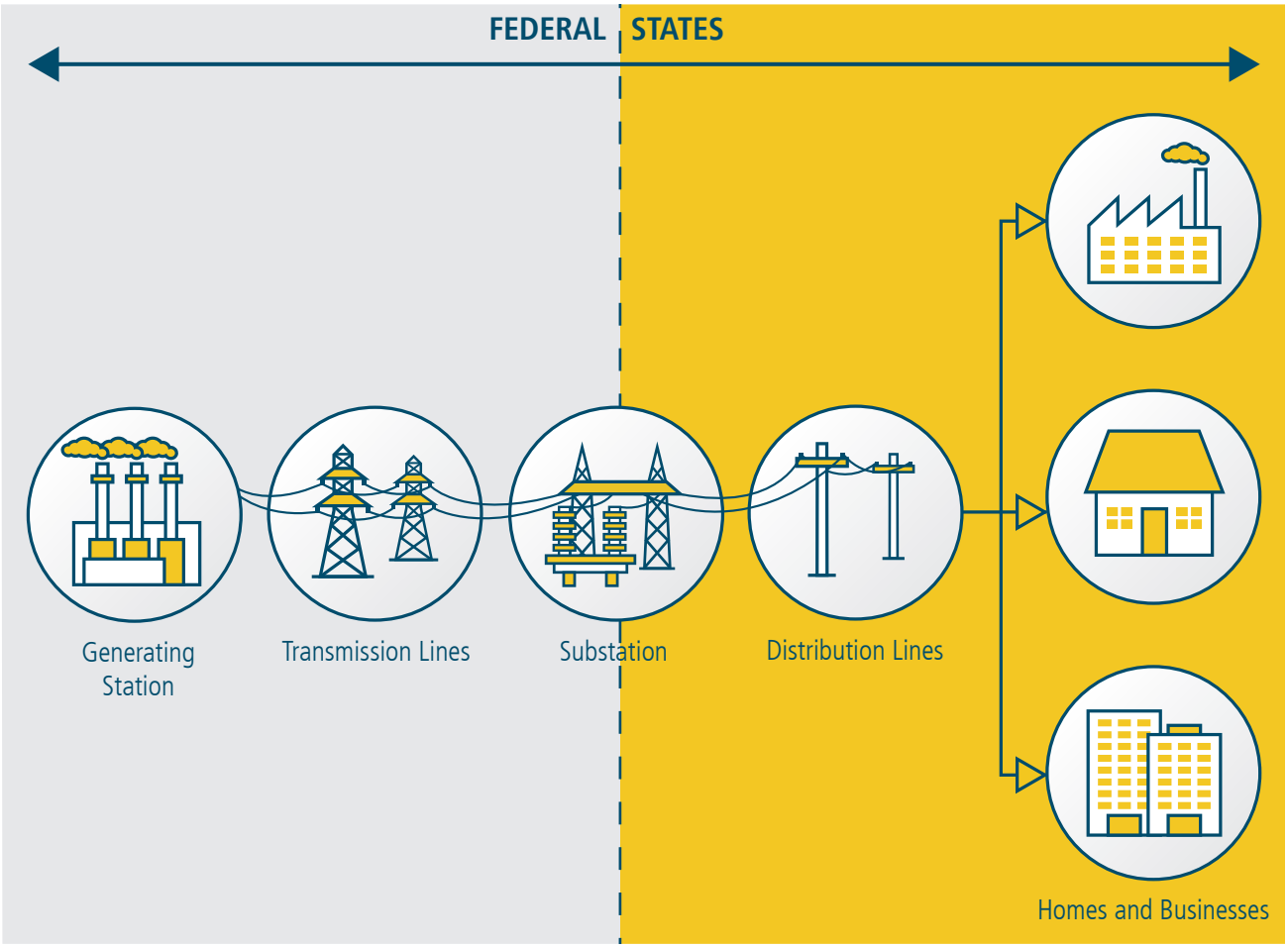
As noted in Chapter I (*Transforming the Nation's Electricity System: The Second Installment of the Quadrennial Energy Review*) and worth repeating here, Congress has recognized the national security implications of the electricity system in the Fixing America's Surface Transportation Act (FAST Act), passed in December 2015. To place the recommendations in QER 1.2 in context, it is important to repeat key language in the Act. The FAST Act gives the Secretary of Energy new emergency authorities for "critical electric infrastructure," where, upon a directive from the President, the Secretary may "with or without notice, hearing or report, issue such orders for emergency measures as are necessary…to protect or restore the reliability of critical electric infrastructure or of defense critical infrastructure during an emergency." These authorities apply to

> "the occurrence or *imminent danger of* [italics added]…electronic communication or an electromagnetic pulse, or a geomagnetic storm event that could disrupt the operation of those electronic devices or communications networks, including hardware, software, and data, that are essential to the reliability of critical electric infrastructure or of defense crucial electric infrastructure…the disruption of the operation of such devices or networks, with significant adverse effects on the reliability of critical electric infrastructure or of defense critical electric infrastructure…a direct physical attack on critical electric infrastructure or on defense critical infrastructure; and significant adverse effects on the reliability of critical electric infrastructure or of defense critical electric infrastructure as a result of such physical attack."[5]

Four essential observations should be made about these provisions. First, there are, in effect, anticipatory authorities in the law, described in the FAST Act as events that present "imminent danger." Second, the provisions of the law are tied to the *reliability* of critical electric infrastructure, directly linking reliability to security. Third, the increasing reliance of the electricity system on natural gas—it is now the number one primary fuel source for power generation for the first time—makes security information about related gas infrastructures a critical component for decision making under the FAST Act. Finally, cyber threats do not respect jurisdictional boundaries.

Figure 7-4 clearly illustrates the interconnectedness of the electricity system; the national security responsibilities included in the FAST Act must be addressed without regard to jurisdictional boundaries.

Figure 7-4. Current Jurisdictional Boundaries and the Security of the Electricity System[6]



The U.S. electricity sector regulatory authorities are generally split between the Federal Government for generation and transmission assets and states for distribution networks. The 2015 FAST Act specifies Federal authorities to address critical electric infrastructure emergencies.

In addition, the interconnectedness of our modern grid was underscored by the Supreme Court's decision on Federal Energy Regulatory Commission (FERC) Order No. 745. While the Court's majority opinion on Order No. 745 acknowledged that FERC, in this order, only addressed wholesale markets, it also noted,

> "It is a fact of economic life that the wholesale and retail markets in electricity, as in every other known product, are not hermetically sealed from each other…To the contrary, transactions that occur on the wholesale market have natural consequences at the retail level. And so too, of necessity, will FERC's regulation of those wholesale matters…When FERC regulates what takes place on the wholesale market, as part of carrying out its charge to improve how that market runs, then no matter the effect on retail rates, [the Federal Power Act] imposes no bar."[7]

Recent FERC actions are designed to address and clarify key security issues, as well as issues raised by two-way flows and a modern electricity system. FERC has issued an order pursuant to the FAST Act to control the availability of sensitive critical energy infrastructure information on "production, generation, transmission and distribution of energy," noting that a single critical energy infrastructure information process is "…the most efficient way to fulfill the statutory mandate of the FAST Act and to avoid any confusion that could result from

different processes for different types of critical infrastructure information."[8] FERC has also taken steps to enable the aggregation of storage, including at customer facilities, examining the need to develop participation models consisting of market rules.[9]

Integrated Planning Needed to Address National Security Imperatives of the Electricity System

National security investments, regardless of scale, are costs that should be born, in part, by the Federal Government acting on behalf of all Americans. Sorting out how costs should be allocated will be a critical success factor in achieving and sustaining a secure grid throughout this century. New authorities must come with appropriate budgets for Federal responsibilities, and costs to be carried by ratepayers must be made explicit as well. Managing investment requirements while keeping affordability in mind must be a key concern of the Federal Government. While most analysts do not think that these costs will cause rate shocks, having mechanisms for clearly articulating the associated Federal and ratepayer costs will be important for security and public acceptance.

QER 1.2 discusses the limits of existing reliability and resilience planning methodologies and processes in Chapter IV (*Ensuring Electricity System Reliability, Security, and Resilience*). There are many planning methods currently used by utilities, ranging from integrated resource planning to more-focused procurement planning. Despite the breadth and depth of current and emerging planning methods, there are gaps in standards, operational definitions, and geographic scope. There are also several levels of planning as well, such as state-level regulatory planning; state energy office planning; independent system operator/regional transmission organization regional planning; North American Electric Reliability Corporation (NERC) regional planning; and FERC planning requirements, which affect all entities regulated by FERC. Still, when aligned with a map of the Nation, there are no adopted common demarcations that enable consistent and seamless planning related to grid security that can serve the need for a national security overlay.

Key Crosscutting Recommendations to Support the Security and Reliability of the Electricity System

Protect the Electricity System as a National Security Asset

The Federal Power Act provides a statutory foundation for an electricity reliability organization to develop reliability standards for the bulk power system. Pursuant to this authority, FERC has certified NERC as the Electric Reliability Organization. Under this arrangement, NERC and FERC have put into place a comprehensive set of binding reliability standards for the bulk power system over the past decade, including standards on cybersecurity and physical security. However, the Federal oversight authority is limited: FERC can approve or reject NERC-proposed reliability standards, but it cannot author or modify reliability standards.

The nature of a national security threat, however, as articulated in the FAST Act, stands in stark contrast to other major reliability events that have caused regional blackouts and reliability failures in the past. In the current environment, the U.S. grid faces imminent danger from cyber attacks, absent a discrete set of actions and clear authorities to inform both responses and threats. Widespread disruption of electric service because of a transmission failure initiated by a cyber attack at various points of entry could undermine U.S. lifeline networks, critical defense infrastructure, and much of the economy; it could also endanger the health and safety of millions of citizens. Also, natural gas plays an increasingly important role as fuel for the Nation's electricity system; a gas pipeline outage or malfunction due to a cyber attack could affect not only pipeline and related infrastructures, but also the reliability of the Nation's electricity system.

1. **Amend Federal Power Act authorities to reflect the national security importance of the Nation's electric grid.** Grid security is a national security concern—the clear and exclusive purview of the Federal Government. The Federal Power Act, as amended by the FAST Act, should be further amended by Congress to clarify and affirm the Department of Energy's (DOE's) authority to develop preparation and response capabilities. These capabilities will ensure that DOE is able to issue a grid-security emergency order to protect critical electric infrastructure from cyber attacks, physical incidents, electromagnetic pulses (EMPs), or geomagnetic storms. In this regard, Federal authorities should include the ability to address two-way flows that create vulnerabilities across the entire system. DOE should be supported in its development of exercises and its facilitation of the penetration testing necessary to fulfill FAST Act emergency authorities. In the area of cybersecurity, Congress should provide FERC with authority to modify NERC-proposed reliability standards—or to promulgate new standards directly—if it finds that expeditious action is needed to protect national security in the face of fast-developing new threats to the grid. This narrow expansion of FERC's authority would complement DOE's national security authorities related to grid-security emergencies affecting critical electric infrastructure and defense-critical electricity infrastructure. This approach would maintain the productive NERC-FERC structure for developing and enforcing reliability standards, but it would also ensure that the Federal Government could act directly, if necessary, to address national security issues.

2. **Collect information on security events to inform the President about emergency actions, as well as imminent dangers.** DOE should collect targeted data on critical cyber, physical, EMP, and geomagnetic disturbance events and threats to the electric grid to inform decision making in the event of an emergency or to inform the anticipatory authorities in the FAST Act. DOE should concurrently develop appropriate criteria, processes, and definitions for collecting these targeted data using a dedicated information-protection program to safeguard utility data consistent with FERC rules. Reporting will be done on a confidential basis. Updating will be required to address evolving threats. DOE will coordinate the development of analytical data-surveillance and data-protection tools with the National Labs, states, universities, industry, Federal agencies, and other organizations as appropriate.

3. **Adopt integrated electricity security planning and standards.** FERC should, by rule, adopt standards requiring integrated electricity security planning on a regional basis to the extent consistent with its statutory authority. Such requirements would enhance DOE's effectiveness in carrying out its responsibilities and authorities to address national security imperatives and new vulnerabilities created by (1) two-way flows of information and electricity and (2) the transactive role of customers and key suppliers (such as those providing stored fuel for strategic generators). Important national security considerations warrant careful consideration of how generation, transmission, distribution, and end-user assets are protected from cybersecurity risks. Vulnerabilities of distribution and behind-the-meter assets, which may provide an increasing number of potential entry points for access to utility control systems, are threats that can adversely affect the operation of the transmission system; for these vulnerabilities, a careful review of protections is required. To adequately address and support the security requirements of the FAST Act and DOE's implementation of the FAST Act, this review should be performed on an integrated basis, rather than separating the review into the bulk power system and other assets.

   To ensure that there are no unnecessary vulnerabilities associated with state-to-state or utility-to-utility variations in protections, integrated electricity security planning should be undertaken to cover the entire United States, including Alaska, Hawaii, and U.S. territories. FERC should consider having existing regional organizations undertake such planning, as it deems appropriate. FERC should evaluate whether the costs of implementing security measures identified in the integrated electricity security plan are appropriate for regional cost allocation, where such measures are found to enhance the security of the regional transmission electric system.

To the extent necessary, appropriate statutes should be amended to clearly authorize FERC to adopt such integrated electricity security planning requirements. However, FERC should immediately begin to advance this initiative to the maximum extent possible under its current authority by initiating a dialogue, including discussions with DOE and state authorities, and driving consensus on Integrated Electricity Security Plans.

4. **Assess natural gas/electricity system infrastructure interdependencies for cybersecurity protections.** DOE, pursuant to FAST Act authorities and in coordination with FERC, should assess current cybersecurity protections for U.S. natural gas pipelines and associated infrastructure to determine whether additional or mandatory measures are needed to protect the electricity system. If the assessment concludes that additional cybersecurity protections—including mandatory cybersecurity protocols—for natural gas pipelines and associated infrastructure are necessary to protect the electricity system, such measures and protocols should be developed and implemented. This work should build on existing assessments, including those underway at the Transportation Security Administration.

Increase Financing Options for Grid Modernization

Estimates of total investment requirements necessary for grid modernization range from a low of about $350 billion to a high of about $500 billion.[10, 11] Grid modernization is the platform for the 21st-century electricity system, bringing significant value associated with lower electricity bills due to fuel and efficiency savings, more electricity choices, and fewer and shorter outages. The Federal Government currently plays a role in providing tax incentives for the deployment of clean energy technologies (discussed further in Chapter III, *Building a Clean Electricity Future*), as well as Federal credit assistance to facilitate early deployment of innovative technologies.

5. **Expand DOE's loan guarantee program and make it more flexible to assist in the initial deployment of innovative grid technologies and systems.** The design of the current DOE loan guarantee program is focused primarily on financing the deployment of innovative generation technologies. Most DOE loan guarantee recipients, for example, are structured as special project entities that can raise equity outside of regulated business structures and can provide credit security in the form of power purchase agreements. This financing model is not amenable to grid-modernization financing by regulated entities, especially in cases of some technological uncertainty associated with initial commercial deployments. In addition, there will be an ongoing need for innovation in grid technologies beyond the likely availability of current DOE loan guarantee authority. Also, the limitations of the loan program restrict the program to a very small and ever-changing portion of new transmission capacity; more projects and innovation are necessary to transform the grid.

   Modifications to the current DOE Title XVII loan guarantee program are needed to (1) reduce restrictions on numbers/types of projects and time frames (e.g., in order to adequately address innovative transmission capacity needs), and (2) provide clear statutory authority for lending to other public or public/private entities that support transmission and other grid-modernization projects (e.g., state agencies, regional power pools) through on-lending or equity investing. By their nature, transmission projects, especially big projects, involve many entities and jurisdictions. Statutory clarification is needed on indirect lending authorities to such entities for multi-jurisdictional projects.

   Some of the benefits of grid modernization are realized over time, as the electricity system itself is changed by technology and market innovations. Additional funding resources would bridge the gap between investment costs and realization of benefits, and they would enable utilities to invest in grid modernization. A relatively low-cost, permanent Federal financing system could be established by setting up a revolving loan fund with one-time seed capital.

Increase Technology Demonstrations and Utility/Investor Confidence

The future electric grid will require that utilities deploy a wide range of new, capital-intensive technologies. Primary technologies are needed to support increased reliability, security, value creation, consumer preferences, and system optimization and integration at the distribution level. Demonstrating the technical readiness and economic viability of advanced technologies is needed to inspire the confidence of utilities and investors.

6. **Significantly expand existing programs to demonstrate the integration and optimization of distribution system technologies.** The complexity of the issues facing distribution systems—including new technologies, the need for systems approaches, and geographical differences in markets and regulatory structures—points to a significant need for multiple "solution sets" to enable two-way electricity flows on distribution systems; enhance value; maximize clean energy opportunities; optimize grid operations; and provide secure communications. DOE should build upon existing demonstration programs and reflect the Administration's commitment to the doubling of Federal clean energy innovation over 5 years as part of its Mission Innovation initiative. Doing so, DOE should develop a focused, cost-shared program for qualifying utilities to demonstrate advanced distribution-system technologies at the community scale. These technologies include advanced voltage control/optimization systems; dynamic protection schemes to manage reverse power flows, communications, sensors, storage, switching, and smart-inverter networks; and advanced distribution management systems, including automated substations.

   Demonstrations supported by the cost-shared, cooperative agreement program would be specifically designed to inform standards and regulations and increase regulatory and utility confidence in key technologies or technology systems. Under this program, utilities would have to make a positive business case for projects and obtain regulatory approvals for their proposed demonstrations. Preference would be given to multi-utility partnerships with diverse customer profiles and to projects that promote education and training in key academic disciplines that are essential for distribution-system transformation. Cybersecurity plans for all projects would be required and supported by programmatic review of plans and deployments.

   Existing DOE programs, including advanced distribution-management systems, microgrids, communications and sensors, storage, and cybersecurity, should be leveraged to provide technical assistance regarding technological issues, planning and performance evaluation, and institutional needs. A percentage of funding could be dedicated to small, publicly owned utilities. The program should be of sufficient size to have a material impact; it should start in fiscal year (FY) 2018 and be ramped up over the time period identified in the Mission Innovation initiative.

Build Capacity at the Federal, State, and Local Levels

The 21st-century electricity system is becoming increasingly transactive, and properly valuing attributes is key to an efficient system. Application of lessons learned that pair economic and system analysis will lead to a power system that cost-effectively serves customers while providing nationally valued public goods, e.g., reliability, resilience, and acceptable environmental performance.

Advances in electricity technologies (i.e., smart grid processes and solutions) require enhanced capabilities in human resources to ensure the cost-effective selection, deployment, and operations of key technologies.

7. **Provide funding assistance to enhance analytical capabilities in state public utility commissions (PUCs) and improve access to training and expertise for small rural electric cooperative and public power utilities.** Federal support should be provided to states and small utilities to enable them

to better manage the increasing complexities in the electricity system, such as integrating variable energy resources; incorporating energy efficiency, demand response (DR), and storage into planning; developing competencies in various technologies; and making investment and security decisions within uncertain parameters. These issues are highly technical and require a new knowledge base and skillset often within the domain of computer sciences, economics, and cybernetics. At the same time, these entities are dealing with the workforce issues of outside recruitment or retirement across the electricity industry, which QER 1.2 references. DOE should build and cultivate much-needed analytical capacity at the state level over a limited period of time by allocating funding to state PUCs to allow them to hire new or train existing analysts with more sophisticated and advanced skills and build institutional knowledge. Eligibility for state and local funding should be contingent upon demonstration of consideration for Integrated System Planning, which is outlined in this chapter. DOE should support these analysts through an online interactive education and training platform with access to nationally recognized experts. This platform would also be available and tailored to the needs of small utilities. On a national scale, these actions will serve to sustain system reliability and security and bolster resilience.

8. **Create a Center for Advanced Electric Power System Economics.** DOE should provide 2 years of seed funding for the formation of a center designed to provide social science advice and economic analysis on an increasingly transactive and dynamic 21st-century electricity system. The center should be modeled after the National Bureau of Economic Research and be managed by a university consortium. The consortium will establish and maintain a network of experts in economics, the social sciences, and the electricity system; these experts should be from academia, industry, nonprofit institutions, and the National Laboratories. The center will develop new methods where appropriate, serve as advisor and consultant to stakeholders preparing germane analyses, and foster the advancement of students and professionals who are developing expertise in these disciplines. The focus of the center will include power systems evaluation (e.g., valuation, benefit-cost, and competition analysis).

Inform Electricity System Governance in a Rapidly Changing Environment

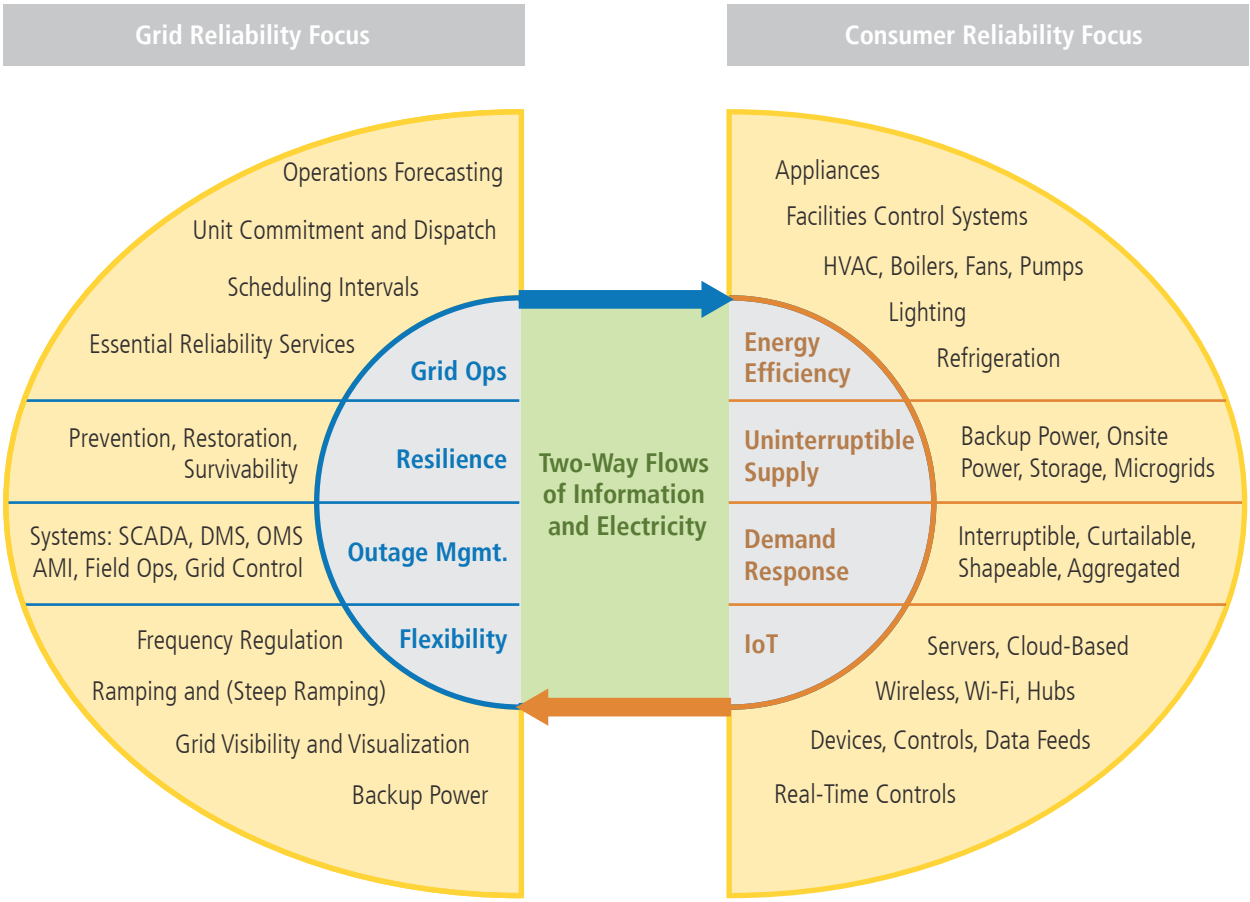
The rapid rate of change in the electricity sector today often exceeds the ability of institutions and governance structures to respond in a manner sufficient to meet critical national goals and objectives. This is particularly true in the resolution of jurisdictional disputes over responsible price formation and valuation. Clarification and harmonization of roles and responsibilities for developing pricing can reduce market uncertainty, facilitate the achievement of policy goals, and reduce costs to ratepayers.

9. **Establish a Federal advisory committee on alignment of responsibilities for rates and resource adequacy.** DOE, in collaboration with the National Association of Regulatory Utility Commissioners, should convene a Federal advisory committee that reports to the Secretary or the Secretary's designee to examine potential jurisdictional concerns and issues associated with harmonizing wholesale and retail rates and tariffs. This advisory committee will evaluate and make recommendations (where appropriate) on the way in which the organized markets reflect state policy; pricing mechanisms for maintaining resource adequacy; state and Federal roles in pricing and operation of distributed energy resources (DER), storage, and microgrids; the role of aggregators; and mechanisms for implementing consumer protection across the various markets and jurisdictions. The advisory committee will represent a broad cross-section of industry and stakeholders. An annual report will be prepared by this advisory committee for the Secretary that identifies the impact of governance issues and recommends solutions.

Maximize Economic Value and Consumer Equity

Consumer options for electricity services have grown dramatically, enabled in part by the smart grid and the IoT, and supported by significant consumer demand. New consumer options range from building efficiency technologies that reduce consumer costs for high-quality electricity services, to distributed generation (DG) technologies, to technologies for dynamic energy management. In addition to technology options, different utility business models also have a significant impact on consumer value and compensation. Utilities still provide a majority (84 percent) of the electricity supplied nationwide;[12] however, in the 16 states and the District of Columbia where retail competition is allowed, 58 percent of industrial load, 44 percent of commercial load, and 7 percent of residential load have switched to competitive energy suppliers.[13] These technologies can create value for both grid operators and consumers; adequate and accurate valuation of these new services is essential for maximizing their value. As noted in Chapter IV (*Ensuring Electricity System Reliability, Security, and Resilience*), these two-way flows are affecting both consumer demands for reliability, as well as reliability requirements for grid operations. The key components of both consumer and grid reliability are highlighted in Figure 7-5.

Figure 7-5. Electric Service Reliability Increasingly Interactive between Grid and Consumer



The development and adoption of new consumer technologies and services has dramatically outpaced those of the grid. The electricity sector is adapting to the demands placed on the grid by the two-way flows with new market structures, technological solutions, interconnection and reliability standards, and complex grid controls enabled by widespread operational data. The evolution of technologies and services on both sides of the grid will likely continue at the same or an accelerated pace. Maintaining—or increasing—grid reliability in the midst of these changes will require new approaches in both the public and private sectors.

Acronyms: supervisory control and data acquisition (SCADA), distribution management system (DMS), outage management system (OMS), advanced metering infrastructure (AMI), heating, ventilation, and air conditioning (HVAC).

The two-way flows and different expectations about reliability between consumers and grid operators can benefit both grid operators and consumers if flows are transactional and collaborative. In the alternative, two-way flows can significantly complicate grid operations. Grid operators must adapt to increased consumer options that can both positively and negatively affect grid reliability by changing their systems, processes, and technologies. Only when each group equally understands the depth of grid and consumer interdependencies can the 21st-century electricity sector be fully realized.

Tailor and Increase Tools and Resources for States and Utilities to Effectively Address Transitions Underway in the Electricity System

States and electric utilities are responsible for making critical decisions regarding how to improve the reliability, affordability, and sustainability of the electric grid; officials from state agencies and utilities provided comments as part of the QER stakeholder process on the Federal role in informing these decisions. Technical assistance, improved regional consideration in program offerings, and new analysis for decision making will allow the Federal Government to respond to the needs of states and utilities in ensuring consumer value and equity in the electricity system of the 21st century.

10. **Improve energy management and DR in buildings and industry.** Communication-capable and programmable energy-management systems that monitor and control energy-using appliances and equipment have demonstrated substantial potential to reduce both volumetric (kilowatt-hours) and peak (kilowatt) electricity demand, delivering significant economic value and service benefits to both consumers and utilities. This joint DOE-Environmental Protection Agency (EPA) initiative could further accelerate the deployment of communications-capable control systems that can deliver improved energy management and DR for residential buildings, small-to-medium commercial buildings, and comparable industrial facilities.

11. **Create a multi-sector initiative to improve efficiency of miscellaneous electric loads (MELs) through research and development (R&D), testing, labeling, targeted incentives, and minimum standards.** MELs are a broad, rapidly growing, and poorly understood group of end users, which can be addressed by building upon existing DOE and EPA efforts. Working with utilities, states, manufacturers, and other key stakeholders, this DOE, Energy Information Administration (EIA), and EPA initiative could gather data, set priorities, and take action to increase R&D, improve testing and labeling, and implement targeted incentives and minimum standards. Together these actions could improve the efficiency and management of MELs in the residential, commercial, and industrial sectors.

12. **Increase Federal support for state efforts to quantitatively value and incorporate energy efficiency, DR, distributed storage, and DG into resource planning.** DOE and EPA should leverage existing programs to provide targeted capacity building and related analytical support to states on the merits of incorporating the value of energy efficiency, DR, distributed storage, and DG in resource planning; meeting environmental goals; and extracting additional value from advanced metering infrastructure networks and resulting data and digital services.

13. **Conduct an analysis of the potential for deployment of demand side (energy efficiency, DR, DG, storage) technologies.** While numerous studies have indicated significant cost-effective potential from energy efficiency investments, there is an incomplete patchwork of different energy efficiency potential studies and other distributed resources at the utility or state level that use a variety of methodologies. These studies, which typically consider only energy efficiency, do not take into account the potential to integrate energy efficiency investments with other consumer options, such as DR, DG, and onsite storage—technologies to which consumers have growing access. DOE, with input from EPA, should conduct a study of the national potential for demand-side resources with sufficient geographic resolution to more effectively value and integrate DER into state and national electricity policy, while meeting environmental goals.

14. **Increase state-level clean energy financing.** DOE and the Department of the Treasury, in coordination with other Federal agencies, will identify promising practices in the types of state-level policies, mechanisms, and incentives that support system evolution to a cleaner grid, e.g., property-assessed clean energy (PACE) financing. These efforts will provide states with the tools and potential solutions to better leverage state resources and deploy clean energy. As part of sharing promising practices, DOE and the Department of the Treasury would help standardize contracts/financing structures for nontraditional project structures.

15. **Evaluate the potential to further increase energy savings and reduce costs to consumers and manufacturers through appliance efficiency standards.** DOE's minimum appliance efficiency standards have resulted in significant energy savings for consumers and businesses across a wide range of products. DOE, working with the Department of the Treasury and EPA, will evaluate approaches for further increasing or optimizing energy savings to consumers, while reducing costs for manufacturers and consumers.

Expand Federal and State Financial Assistance to Ensure Electricity Access for Low-Income and Under-Served Americans

Analysis indicates that electricity costs represent a disproportionate share of total income for low-income Americans. Increased funding for proven, state-administered programs and enhanced data and tools for targeting assistance can reduce this "electricity burden." Ensuring that the costs of the rapid transition of the electricity system are not disproportionately borne by low-income Americans is a top priority; low-income Americans should also be able to share in the benefits from an electricity system transition.

16. **Increase Low Income Home Energy Assistance Program (LIHEAP) and Weatherization Assistance Program (WAP) funding.** Low-income Americans in areas across the country face disproportionate burdens from electricity costs. Congress should increase Federal support for low-income home weatherization, through DOE's WAP, over the next 5 years to weatherize 100,000 homes per year, including support for training and improving auditing tools. Congress should also create a mandatory contingency funding mechanism for LIHEAP, as described in the President's FY 2017 budget.

17. **Evaluate incentives to cut electricity bills for low- and moderate-income households.** The Federal Government should improve the coordination between WAP and LIHEAP to ensure optimal use of resources and increased benefits to households served. The Federal Government should encourage state and local governments to (1) take full advantage of the use of LIHEAP funds for weatherization, (2) use the National Renewable Energy Laboratory's solar savings-to-investment ratio calculator to identify cost-effective areas for solar projects, and (3) find other ways to make it easier for low-income households to access the long-term savings possible from energy efficiency and renewable energy. In particular, DOE should evaluate the impacts of utilizing WAP and LIHEAP to decrease energy bills (i.e., from energy efficiency retrofits and installing renewable energy projects). In addition, state and local governments should ensure human services providers educate low-income clients receiving bill assistance about opportunities to save on their electricity bills through energy efficiency and renewable energy programs, and they should actively encourage participation in those programs.

18. **Strengthen incentives for public housing authorities to invest in renewable energy and energy efficiency.** Small- and medium-sized housing authorities are often unable to participate in existing energy performance contracting (EPC) options because of a lack of capital or interest from energy services companies. This project would incentivize such public housing authorities to use existing resources to make energy upgrades by allowing them to retain energy cost savings outside of an EPC contract. Congress should authorize a pilot program to allow public housing authorities to retain a greater portion of the savings realized from investments in energy efficiency and renewable energy. The

Office of Public and Indian Housing at the Department of Housing and Urban Development (HUD) would focus the pilot on strengthening incentives for housing authorities, especially smaller and medium-sized housing authorities, to invest their Capital Fund dollars in energy efficiency or renewable energy. The pilot would provide an alternative to the long-standing EPC program, which has primarily served larger housing authorities.

19. **Improve HUD data and utility benchmarking.** In order to reduce taxpayer costs on tenant utility bill allowances, Congress should enact legislation allowing HUD and property owners to access whole-building, aggregated energy consumption and expenditure data for HUD-assisted properties (i.e., whole-building utility data) and appropriate funding for HUD to implement its utility benchmarking strategy, including building out the information technology (IT) systems needed to link current systems with benchmarking software.

20. **Encourage public-private partnerships to underwrite and support clean energy access for low- and moderate-income households.** The Federal Government should align public funding programs and encourage private-sector investment to help make energy efficiency and renewable energy accessible to households that do not qualify or are unlikely to be served by WAP. The bank regulatory agencies are encouraged to publicize recently issued Community Reinvestment Act guidance concerning loans financing renewable energy or energy efficiency improvements, which help reduce operational costs and maintain the affordability of single-family or multifamily housing.

21. **Provide assistance to address rural, islanded, and tribal community electricity needs.** The Tribal Indian Energy Loan Guarantee Program provides loan guarantees for renewable energy on Indian land and is authorized under the Energy Policy Act of 2005. Indian lands have over 9 million megawatts (MW) of renewable energy potential. Because of the lack of capital, only 125–130 MW have been built. Most tribes do not meet eligibility requirements for existing loan guarantee programs. Existing rural and islanded electricity systems generally rely on imported (nonlocal) diesel fuel oil and, consequently, are high in cost and produce significant emissions. Renewable electricity generation and other electricity technologies have the potential to lower cost and reduce emissions on such systems, yet they may require new technology capabilities or significant technical expertise to successfully integrate into such systems. The Federal Government should increase support for grants and technical assistance to allow isolated communities that rely on expensive diesel-generated electricity to install more renewable energy, such as wind, small-scale hydro, or solar energy.

Increase Electricity Access and Improve Electricity-Related Economic Development for Tribal Lands

The interdependencies of electricity access, health, economic wellbeing, and quality of life underscore the importance of universal access to electricity. While recent data on electricity access on tribal lands are limited, there are still areas that lack adequate access to electricity despite the Nation's commitment to full electrification, which dates back to the Rural Electrification Act of 1936. More recent anecdotal evidence suggests that the problem broadly persists. It is a moral imperative that the Federal Government support tribal leadership and utility authorities to provide basic electricity service for the tens of thousands of Native Americans who currently lack access to electricity and to foster the associated economic development on tribal lands. Federal agencies should also support renewable energy acceleration and economic development opportunities through renewable energy incentives, workforce development, financing program improvements, and improved consultation with tribes.

22. **Support the achievement of full tribal land electrification.** Over 10 years and building upon existing programs, DOE, the Department of the Interior (DOI), and the Department of Agriculture (USDA) will provide technical assistance for distribution infrastructure with the goal of supporting tribal communities' efforts to achieve complete electrification (Indian tribes, including Alaskan Natives, on

Indian lands), while respecting the sovereignty and culture of tribal and Alaska Native communities. DOE, DOI, and USDA should support development of distribution infrastructure to provide access to household electricity and electricity distribution that enable productive economic activity and public services.

23. Support advanced technology acceleration and economic development opportunities for tribal lands. While wind energy and solar energy have grown exponentially in recent years, tribes have not been able to fully take advantage of their wind or solar resources. DOE and DOI could accelerate renewable energy development on tribal lands and economic development in tribal communities through new incentives and financing support, workforce-development resources, and enhanced consultation with tribes.

Strengthen Rural Electricity and Broadband Infrastructure

The Federal Government has historically supported the expansion of access to affordable electricity and communications service in rural America, with major initiatives continuing today mainly through USDA. The lack of access to broadband in rural areas means that these consumers lack access to DR technologies, such as smart meters, smart thermostats, and other technologies, which can reduce pollution, help consumers save electricity, improve overall grid resilience and reliability, and enhance economic development. Broadband expansion into these regions would significantly advance grid modernization goals, while providing significant communications, connectivity, and educational benefits to numerous regions of the country. Supporting broadband access in sparsely populated rural areas, many of which are low-income areas, is not, however, profitable for the private sector. Federal support would help enhance security, environmental, and economic development goals.

24. **Leverage utility broadband build-out to expand public broadband access in rural areas.** Many rural areas presently lack access to public broadband service, which is required to take advantage of these consumer smart grid technologies. The Federal Government should continue to modernize Federal programs to expand support for rural broadband, smart grid, and smart home technologies. USDA should update guidance for the Rural Development Community Facility Program to make broadband projects eligible, revise regulations to expand eligibility for the Rural Utilities Service (RUS) Telecommunications Program, and expand financing for smart grid and communications improvements for energy management in the RUS Electric Program.

25. **Increase opportunities for small and rural utilities to utilize USDA's electricity financing programs.** USDA should develop and implement a strategy to remove barriers to participation in its RUS financing program for energy efficiency and renewable energy investments, which would support Congress' intent to provide Federal financial support for ratepayers served by small and rural utilities. DOE and USDA should strengthen collaboration on strategic priorities, including developing a strategy to increase the use of USDA's financing programs by borrowers and supporting the technical needs of small and rural utilities, in part through their industry stakeholders.

26. **Improve the competitiveness of USDA's financing for small and rural utilities.** Congress should give USDA's RUS the authority to refinance its loans to small and rural utilities to stay competitive and reflect economic changes in the broader economy. Congress should undertake legislative action to unlock USDA's renewable energy financing under Section 317(c) of the Rural Electrification Act.

Enable a Clean Electricity Future

Achieving a clean, affordable, and reliable electricity sector for the 21st century is a key national objective. The transition for accomplishing this objective is complicated and will require major changes in the generation resource mix; in the valuation of key services; and in the way the grid is operated. Managing this complex set of changes while ensuring affordability, reliability, and security for electricity consumers, will require focused investments, incentives, and policies in key areas, including the following: optimizing the management of many different types of generation; enhancing the visibility, integration, and valuation of load-shaping and consumer technologies; enabling the development and diffusion of distributed and utility-scale storage technologies; managing the large-scale integration of variable energy resources and DER into grid operations; and supporting the ongoing need for dispatchable baseload generation. This transition will also require a core investment in operational and predictive analytics, including control algorithms and granular grid-visualization tools. Clean electricity options from generation to end use need to be advanced through a combination of additional research, development, and demonstration (RD&D) across the portfolio of solutions and additional policy that encourages the most cost-effective options.

Transform the Electricity System through Leadership in National Clean Electricity Technology Innovation

Private-sector investment in clean energy technology faces many barriers; for example, prices do not reflect the costs and benefits of clean energy, investments are made in a highly regulated environment, and there are high capital costs and lengthy time horizons for R&D and capital stock turnover in comparison to many other sectors (e.g., IT). Increased investments in electricity technology innovation are essential for the transformation of the electricity system. Federal investments have a history of success and have been leveraged by the private sector to create significant economic value. Case studies on nuclear energy, shale gas, and solar photovoltaic power, among many other electricity-related technologies, demonstrate the instrumental role of Federal investment in early-stage R&D.

27. **Significantly increase Federal investment in clean electricity RD&D.** The current scale and speed of clean electricity innovation is short of what is needed for meeting the Nation's clean energy and climate goals; yet, there is a series of barriers to the private sector investing adequate amounts on its own. The American Energy Innovation Council in 2010 identified specific needs for government involvement in accelerating energy innovation, and it recommended that Federal clean energy funding be more than tripled as the minimum level required to maintain America's competitive edge. Pursuant to the Mission Innovation initiative, the Federal Government should double clean energy R&D funding across all relevant Federal agencies from $6.4 billion to $12.8 billion between FY 16 and FY 21.

28. **Implement regional clean energy innovation partnerships.** Create cost-shared, technology-neutral innovation partnerships based in multi-state regions. These partnerships intend to accelerate clean energy R&D, including electricity, by tailoring project portfolios to the needs, opportunities, innovative capabilities, and intellectual and economic infrastructure of those regions. The FY 17 DOE Mission Innovation request includes initial funding of $110 million for regional partnerships.

29. **Expand clean electricity innovation analysis and tools.** Improve the data, metrics, analysis, and tools used to plan DOE's investments in clean energy innovation. Although there is substantial research on the value and impact of innovation for individual technologies, there are few robust measures and quantitative assessments of energy innovation. Enhanced energy-innovation frameworks and models that include policy interactions are needed to characterize the relationship between inputs and outputs of energy innovation, help inform investment, and deploy scarce innovation dollars.

30. **Continue reducing barriers to deploy clean energy technologies.** Since 2008, the cost of solar, wind, storage, and electric vehicle (EV) technologies has decreased by more than 50 percent. DOE should continue working to cut the costs of solar, wind, storage, and EV technologies through its world-class programs. DOE should continue work to reduce the cost of solar more than 50 percent by 2030; make EVs cost-competitive with gasoline-powered cars by 2022; decrease the price of energy storage; and develop the next-generation wind technologies, including offshore technologies and tall turbines, to expand the geographic reach of cost-competitive wind.

31. **By 2030, reduce the electricity intensity of newly constructed residential and commercial buildings by at least 50 percent relative to typical new building construction today.** Buildings, which last for decades, account for significant portions of electricity demand and greenhouse gas emissions in the United States. Ensuring highly efficient new construction will capture decades of energy savings for American families and businesses. DOE, in consultation with EPA, should set a goal, establish baselines, and scale up activities to deploy energy-efficient technologies and DER in newly constructed residential and commercial buildings.

Address Challenges to Large-Scale, Centralized Clean Generation

Regardless of the energy source, there are a number of challenges to deploying large, centralized power-generation facilities. Lower electricity prices, largely related to low-cost natural gas, are reducing the economic viability of other clean generation resources, especially nuclear energy. Nuclear power currently provides 60 percent of zero-carbon generation in the United States. Hydropower is one of the oldest and most established forms of electricity generation, contributing 6 percent of the electricity generated in the United States in 2015 and 19 percent of zero-carbon generation. Non-hydropower renewables—including wind, solar, geothermal, and biomass—accounted for about 7 percent of electricity generated in the United States in 2015. Each of these technologies faces a range of siting constraints, licensing and permitting processes, or environmental concerns, which can be broad and extensive; this can make new large-scale deployments difficult. In some cases, these deployments can take a decade or more to build. A combination of Federal coordination, licensing support, analysis of financing opportunities, and RD&D can help address these barriers.

32. **Analyze financing for advanced large-scale generation.** Alternative financing and organizational structures should be explored for advanced large-scale generation, including small modular reactors, advanced reactors, enhanced geothermal, concentrated solar power, offshore wind, and advanced carbon capture and storage projects. Many of these new, larger systems require sponsors to make significant upfront capital investments, and several also contain technology risk, which creates barriers for lenders and regulators. For example, it is currently challenging for state PUCs to allow a regulated utility to begin construction on an advanced new nuclear or carbon capture and storage plant with guaranteed rate base recovery. DOE should analyze potential opportunities to support the financing options for advanced, large-scale generation by utilities and others, building upon existing programs where applicable.

33. **Increase funding for the life-extension R&D program to ensure maximum benefits from existing nuclear generation.** The existing DOE research program to resolve technical issues with regard to subsequent license renewals for existing nuclear plants should be significantly expanded to accommodate the expected increase in renewal applications. Expansion would also enable the continued operation of existing plants through technology development, as well as improve performance and reduce costs and the use of high-performance computing to simulate reactor processes.

34. **Increase support for advanced nuclear technology licensing at the Nuclear Regulatory Commission.** Congress should provide funding to the Nuclear Regulatory Commission for the certification and licensing of advanced reactors, including the development of advanced reactor certification and licensing criteria, and processes for general public outreach, as reflected in the President's FY 17 budget proposal. In addition, Congress should authorize and fund a program at DOE to support advanced reactor license applicants, especially in the development and submission of pre-applications.

35. **Develop environmental mitigation technologies for hydropower.** Increase funding for RD&D to better understand and mitigate the environmental impacts of new and existing hydropower projects. Continued operation of some existing facilities and deployment of new facilities depend upon demonstration and acceptance of environmental mitigation technologies and strategies for facilities of all sizes.

36. **Promote responsible operation, optimization, and development of non-Federal hydropower.** Organize a national dialogue to address potential licensing and re-licensing processes that would encourage the responsible operation, optimization, and development of non-Federal hydropower in a manner that maximizes opportunities for low-cost, low-carbon renewable energy production, economic stimulation, and environmental stewardship to provide long-term benefits for the Nation.

Address Significant Energy-Water Nexus Issues Affecting—and Affected by—the Electricity System

Electricity systems and water systems are, in many cases, interconnected. Water is a critical requirement for many electricity generation technologies. Two-thirds of total U.S. electricity generation—including many coal, natural gas, nuclear, concentrated solar power, and geothermal plants—requires water for cooling. In addition, carbon capture, utilization, and storage (CCUS) technologies have significant water demands. Electricity is also required for water and wastewater conveyance, treatment, and distribution. From a full-system perspective, the joint reliance of electricity and water systems can create vulnerabilities (e.g., drought impacts on thermoelectric generation and hydropower), but it can also create opportunities for each system to benefit from well-designed integration. Such challenges and opportunities can be addressed through improved policy integration; data collection; modeling; analysis; research, development, demonstration, and deployment (RDD&D); and engagement with stakeholders.

37. **Launch an electricity-related energy-water nexus policy partnership with Federal, state, and local partners.** DOE should create an electricity-related energy-water nexus policy partnership with states, related organizations, local governments, and other Federal agencies, where appropriate; this policy partnership would discuss ways to improve and better integrate existing energy and water policies with respect to goals, data, metrics, and compliance dates. Many energy and water policies are designed to address only energy or water, but not both, potentially leading to conflicting incentives and unintended consequences that could be avoided through more integrated policy design. In support of the partnership, DOE should develop an Integration Analysis Framework to map out broad, system-wide benefits and potential vulnerabilities of energy-water systems integration (at multiple temporal and spatial scales) to inform relevant decision makers. This analysis framework would serve to enable valuation of costs and benefits associated with energy-water systems.

38. **Support additional RDD&D to reduce water requirements for carbon capture technologies.** Provide additional funding to complement existing efforts in technology RDD&D to reduce water requirements of carbon capture systems, including capture systems themselves (solvents, membranes, materials), as well as integration of the capture system with the generation plant or industrial facility. Reduced water use at power plants and other industrial facilities outfitted with CCUS would lower water withdrawal and consumption out of natural water bodies and could make CCUS technology more attractive in water-scarce areas.

Provide Federal Incentives for a Range of Electricity-Related Technologies and Systems

A package of tax incentives targeted at specific market segments can support an all-of-the-above energy strategy by helping to reduce the costs of deploying and using innovative, commercially available energy technologies. The economies of scale and "learning by doing" promoted by such deployments support continued technology cost reductions and greater market competition.

39. **Expand tax incentives for renewable electricity, EVs, and energy efficiency.** Consistent with the current Administration's Green Book proposal, expand the list of technologies eligible for Federal tax incentives to include other sources of low-carbon generation beyond wind and solar, and extend the time frame for the Production Tax Credit (PTC) and Investment Tax Credit (ITC). The PTC should also be made refundable, available to otherwise eligible renewable electricity consumed directly by the producer, and also available to individuals who install solar electric or solar water-heating property on a dwelling. In addition, implement the proposed reform to the EV tax credits and extension of commercial building energy efficiency tax credits included in the President's FY 17 budget.

40. **Extend the time frame and the total capacity allowed under the PTC for nuclear generation.** Current law provides a $0.018/kilowatt-hour PTC for new nuclear plants placed in service by 2020 and places a capacity cap of 6,000 MW. Extend the eligibility date so that reactors placed in service after 2020 could qualify and increase the capacity cap.

41. **Provide tax credits for CCUS.** Provide a tax credit, such as the proposal to create $2 billion in refundable ITCs for 30 percent of eligible CCUS equipment and infrastructure in the President's FY 17 budget; create a refundable sequestration tax credit ($10 per metric ton for carbon dioxide that is stored and reused, and $50 per metric ton for carbon dioxide that is stored and not reused); index to inflation; or implement reforms to the existing 45Q tax credit that would achieve similar goals. Expand eligibility to include industrial-sector applications of CCUS.

42. **Assess business model inequities associated with Federal electricity financial incentives and public-private partnerships.** DOE should assess the current utilization of energy tax credits by ownership type, including the impact of proposed changes to the tax code on the ability of entities to utilize incentives. DOE should also identify options to increase the impact of tax credits on the deployment of clean energy assets. Relevant topics could include the usage of tax credits by tax-exempt entities, the exclusion of ITCs from normalization, Federal financing for public power and rural electric cooperative utilities, and the possibility for expanded use of public-private partnerships.

43. **Increase power purchasing authorities for the Federal Government from 10 to 20 years.** The Federal Government is currently subject to goals and mandates for the purchase of clean energy which, if achieved, can help to catalyze action in the private, state, and local sectors. However, widespread Federal Government clean energy purchases are constrained by generally applicable procurement rules that prohibit entering long-term contracts. Congress should authorize all Federal agencies to negotiate 20-year power purchasing authorities for clean energy.

Address a Range of Power Plant Siting Issues

The land-use requirements for different types of power generation reflect significant differences between the various types of infrastructure and their operational requirements.

44. **Evaluate and develop generation-siting best practices.** DOE and DOI should initiate a 2-year series of technical workshops to evaluate generation-siting best practices, environmental impacts, mitigation options, and risk to inform decision making by developers and regulators. The workshops will draw upon state and local permitting expertise and experience. They will issue reports to provide developers and regulators tools and best practices for streamlining and potentially standardizing underlying requirements for environmental impact studies and siting analysis. Permitting of projects should continue expeditiously during this process.

45. **Support improved regional and interregional transmission planning processes.** DOE should fund the development of a systematic monitoring program to enable valuation of new transmission facilities, measure the outcomes of FERC Order Nos. 890 and 1000, and develop methodologies to improve their effectiveness. The objective of FERC Order No. 1000 is to identify methods and approaches that enable the selection of the "best" set of transmission facilities (i.e., the more efficient or cost-effective transmission facilities selected in a regional transmission plan for purposes of cost allocation). It aims to accomplish this by (1) establishing requirements for regional transmission planning and interregional transmission coordination processes, and (2) opening transmission investment to non-incumbent owners. However, because implementation of FERC Order No. 1000 is in the early stages and no systematic monitoring system is in place, it is not possible to assess whether its requirements are having their intended effects. Success would mean that transmission planning and cost allocation would be effectively supporting transmission, while also reducing costs, sustaining or improving reliability, reducing congestion, and/or meeting transmission needs driven by public policy requirements.

46. **Modernize electricity transmission permitting procedures.** DOE should expand the domestic coverage of its Regulatory and Permitting Information Desktop (RAPID) Toolkit, which contains information related to critical state requirements. The Toolkit should be updated to include the 36 states that currently have no transmission-related information in the Toolkit. This would provide support for the Federal Permitting Improvement Steering Council, which was tasked with modernizing Federal infrastructure permitting to create efficient project delivery and improve outcomes. One step in reducing complexity is providing developers, government agencies, tribes, and other affected entities access to information relating to Federal and state policies and requirements that would expedite their involvement.

Ensure Electricity System Reliability, Security, and Resilience

System reliability has been an essential expectation of electricity consumers since the development of the modern electricity system. Reliability is formally defined through metrics describing power availability or outage duration, frequency, and extent of the outage. The utility industry is primarily responsible for ensuring system reliability through risk-management strategies to prevent disruptions from reasonably expected hazards. Risk-management practices need to keep pace with the emerging threat environment, particularly cybersecurity and severe weather associated with climate change. The grid's growing interconnectedness and incorporation of new energy resources also create new risks and vulnerabilities, even as they create significant new value to all users of the electricity system.

For these reasons, the traditional definitions of reliability alone may be insufficient to ensure future system integrity and available electricity services. U.S. policies, markets, and institutional arrangements must evolve to reflect this new reality. Actions and approaches are needed to integrate resilience concerns into system planning and reliability standards, prioritize investments in reliability and resilience, quantify the benefits of investments that address emerging or low-probability hazards, broaden the range of risk-reduction options, improve flexibility through activities both pre- and post-disruption, and ultimately, focus on maintaining and improving energy delivery outcomes for the customer under all conditions.

A focus on evolving hazards, new metrics, better analysis, finer data granularity, and strong interdependencies between grid operators and consumers frames the scale and scope of necessary sector transformation. These challenges could be mitigated through a combination of standards, risk-management methods and processes, and collaboration across industry, state, local, and Federal stakeholders.

Support Industry, State, Local, and Federal Efforts to Enhance Grid Security and Resilience

Some types of extreme weather events are projected to increase in frequency and intensity. Cyber threats to the electricity system are increasing in sophistication, magnitude, and frequency. Physical threats remain a concern. These challenges could be addressed through a combination of cost-benefit analyses, standards, and collaboration across industry, state, local, and Federal stakeholders. The following recommendations build upon and extend current initiatives, such as DOE's Grid Modernization Initiative and Partnership for Energy Sector Climate Resilience.

47. **Develop uniform methods for cost-benefit analysis of security and resilience investments for the electricity system.** DOE should develop methods for calculating the costs and benefits of investments in resilience solutions, as well as methods for managing the risks associated with many types of high-impact, low-frequency events or emerging and rapidly evolving threats related to climate change, cyber or physical attacks, or combined threats. This could be implemented in part through the establishment of a "community of practice" for valuation of electricity sector reliability and resilience, providing a stakeholder forum for sharing current practices and developing uniform valuation methods.

48. **Provide incentives for energy storage.** Provide a financial incentive to reduce the cost and support deployment of non-emitting energy storage. Qualified storage includes equipment that receives, stores, and delivers energy using batteries, compressed air, hydrogen storage (including hydrolysis), thermal energy storage, regenerative fuel cells, flywheels, capacitors, superconducting magnets, technologies, and systems that provide the verified services and benefits or technologies.

49. **Improve and upgrade existing Federal hydropower operations.** Fifty percent of U.S. hydropower is Federally owned. DOE, the Army Corps of Engineers, and the Bureau of Reclamation should convene relevant stakeholders to identify and discuss opportunities to improve existing Federal hydropower. Relevant topics to address include technology upgrades; increases in generation, capacity, and essential reliability service capabilities; operations and maintenance efficiency; acquisition improvements; funding flexibility; and mitigating impacts from hydropower.

50. **Account for emerging threats in reliability planning.** Reliability standards and planning requirements should be updated to increase electricity sector resilience to emerging and rapidly evolving hazards, like climate change and cyber and physical threats. The Federal Government should take formal steps to update reliability planning standards for the bulk power system. States, cooperatives, and public power should update or establish new requirements for resource planning and other planning processes for distribution systems. States should also update design standards for critical infrastructure and annually update Energy Assurance Plans accordingly. Similarly, standard-making organizations (e.g., the American National Standards Institute and the Institute of Electrical and Electronics Engineers [IEEE]) should take steps to evaluate whether new performance standards and testing procedures are needed to ensure that electrical equipment is resilient to rapidly evolving hazards.

51. **Support grants for small utilities facing cyber, physical, and climate threats.** Small utilities cover over 75 percent of the Nation's landmass, including sensitive and military installations.[a] The combination of large service territories, minimal staffing, limited budgets, lack of access to tax incentives, and low

[a] Although such facilities frequently have backup power capabilities, the durability of such backups is typically limited to fuel supplies on hand.

customer density presents challenges to small utilities addressing such new and evolving threats. DOE and USDA's RUS should work together to develop risk-management tools, provide grants for shared staff to implement solutions (such as through joint action and/or generation and transmission programs), and host workshops to facilitate knowledge transfer to support small utilities as they address these challenges.

52. **Support mutual assistance for recovering from disruptions caused by cyber threats.** Utilities have a long history of providing mutual assistance in the event of traditional disruptions, but as the grid becomes more reliant on digital technology, cyber and cyber-physical threats present new and distinct challenges to system restoration. DOE, in coordination with interagency partners and industry, should increase support for private-sector efforts to respond to significant cyber incidents on the electric system.

53. **Support the timely development of standards for grid-connected devices.** Common interoperability standards are critical to enabling the distribution system to accommodate the growth of grid-connected technologies at large scale and to potentially improve grid cybersecurity. DOE should work with the National Institute of Standards and Technology to increase the pace of standards development so that it aligns with the rapid development and deployment of grid-connected devices.

54. **Support development of an enhanced reliability service class for commercial customers.** When there is a power failure, a new and growing class of commercial customers lose significant economic value immediately. The electricity demand of individual commercial customers is of insufficient scale, however, to support options similar to those of large industrial customers, who can pay their utilities to install additional feeders to enhance service reliability. This lack of scale and rate options has led some commercial customers to pursue third-party options (e.g., storage, backup generators, onsite generation) to improve their electricity reliability. Associated grid defections could affect the overall customer and rate base. Analysis is needed to inform new rates for this class of customers. DOE should encourage states to consider having utilities offer enhanced reliability through commercial service packages that provide reduced outages, higher reliability, and quicker recovery for interested customers.

55. **Improve system reliability through analysis of backup-generation best practices.** Many industrial, commercial, and residential customers utilize onsite backup power generation during electricity disruptions. There have, however, been several high-profile failures of backup generation that have had significant impacts on consumers and businesses. Also, as load management grows in importance, so does the visibility of the level and reliability of backup generation, as well. Finally, key lifeline infrastructures and defense facilities depend on backup generation. DOE should conduct a nationwide study of backup generation; it should specifically identify related gaps and critical needs for consumers, critical infrastructure, and sensitive facilities. This analysis should further consider interconnection approaches for backup generation to improve overall system resilience and reliability through the update and adoption of IEEE 1547 interconnection standards. This analysis should also take into account cost-effectiveness and environmental performance. DOE should consider the outcomes of this analysis and provide recommendations on best practices for backup generation and on how to maximize its value for grid operations, lifeline networks, and consumers.

56. **Develop guidance, best practices, and protocols for select categories of distribution equipment and consumer grid-interactive devices.** Distribution system-wide outages could be induced by disrupting interconnected DER and their associated data feeds to the distribution grid, especially during critical peak demand or by causing lasting damage to a distribution transformer. DOE will do this in coordination with the National Institute of Standards and Technology and industry.

57. **Require states to consider the value of DER, funding for public purpose programs, energy and efficiency resource standards, and emerging risks in integrated resource or reliability planning under the Public Utility Regulatory Policies Act (PURPA).** PURPA section 111(d) establishes Federal standards for regulated electric utilities that State public PUCs "must consider." Because rates of distribution utilities are not directly regulated by the Federal Government, PURPA amendments serve to preserve the legal authority of the states to amend or establish new standards. Without statutorily dictating any final state decisions, Congress should amend PURPA to require state PUCs and nonregulated utilities to consider the following: (1) the costs and benefits of DER and alternatives in rate design and integrated resource planning, (2) stable funding for public purpose programs, (3) energy efficiency resource standards, and (4) emerging risks in integrated resource or reliability planning.

Improve Data for Grid Security and Resilience

As the Nation increasingly relies on electricity to power the economy and support consumer options and choices, the consequences of electricity outages are rising. The United States currently lacks sufficient data on all-hazard events and losses. Such data would help utility regulators, planners, and communities analyze and prioritize security and resilience investments.

58. **Establish Federal standards for maintaining and sharing common data on Presidentially declared natural disasters and physical attacks affecting the electricity system.** DOE and the Department of Homeland Security should improve the collection, curation, and accessibility of data related to the impacts of disasters along with detailed characterizations of the nature and cause of each disaster. By improving the availability and quality of historical disaster impact data, the government and its partners can develop improved risk models, as well as gain the ability to more effectively locate and more clearly understand points of vulnerability within existing systems. Defining data standards would increase the ability of Federal agencies to manage and share disaster impact data by making it possible to merge and query disparate data sets by common feature, such as Presidential disaster declaration number. Types of data that would be more readily available as a result of this effort include detailed characterization of the nature and cause of each disaster, as well as the extent and degree of associated impacts (such as power outages, fatalities, injuries, property losses), and other data to inform decision making that will help communities better prepare for and respond to future disasters.

59. **Enhance coordination between energy-sector information sharing and analysis centers and the intelligence communities to synthesize threat analysis and disseminate it to industry in a timely and useful manner**. The nature of cyberspace and its associated threats requires individuals, organizations, and the government to actively participate in incident response activities. Increased coordination would provide deeper analysis of threats based on both classified and unclassified data available from the operational and enterprise environments.

Encourage Cost-Effective Use of Advanced Technologies that Improve Transmission Operations

Permitting and planning are necessary but complex processes that can slow transmission development and increase costs. Other barriers restrain the use of new technologies that can increase transmission system-capacity utilization and improve reliability and security, as well as other planning priorities.

60. **Promote deployment of advanced technologies for new and existing transmission.** DOE should work with stakeholders to identify, analyze, and develop recommendations for removing barriers to the valuation and deployment of advanced technologies for new and existing transmission, such as those that enhance reliability, security, and affordability through visibility and control. DOE should explore a range of legislative and regulatory options and analytically test their potential effectiveness on both a stand-alone basis and a collective basis to enable deployment of technologies that cost-effectively

increase existing transmission-capacity utilization (i.e., remove barriers to technology solutions that enable greater transmission utilization of existing transmission capacity). In addition, DOE should identify and mitigate barriers to technologies that can increase transmission-capacity utilization and create a framework for future work based on the experiences of work in capacity utilization, synchrophasors, and storage.

Improve EIA's Electricity Data, Modeling, and Analysis Capabilities

EIA provides all levels of stakeholders—government, companies, and customers—with data to inform the evaluation and development of policies that affect the electricity grid. More timely and publicly accessible data on how system operations are changing and on how efficiency and renewable energy are specifically affecting them would facilitate the development of Federal and state policies and investments needed to ensure the reliability, resilience, and security of the grid. Substantially improved electricity transmission data and related analyses by EIA would support significant improvements in the effectiveness of a broad range of government policies and programs, including market design and transmission planning.

61. **Expand economic modeling capability for electricity.** EIA should be able to more accurately reflect the role of energy efficiency, DR, electricity storage, and a variety of DG technologies in current and future energy consumption to better inform investments and modeled policy scenarios.

62. **Expand EIA data collection on energy end uses.** EIA should expand the scope and frequency of its data collection on energy end uses and services in the residential, commercial, and industrial sectors, including the use of new data-collection methods and tools, in order to enable a more detailed representation by region, income, and other characteristics.

63. **Expand EIA hourly data collection on power system operations.** EIA should expand the scope of the current grid operations data collection to require (1) net generation by energy source (e.g., coal, solar, wind, natural gas, nuclear) and (2) subregional detail for large balancing authorities in order to inform investment decisions and provide higher-resolution and more quickly delivered data on how system operations are changing. EIA should continue to evaluate new definitions for National Energy Modeling Systems Electricity Market Module.

64. **Expand EIA data collection on electricity transmission.** EIA should improve the scope, frequency, and resolution of transmission data collection by (1) developing a regional transmission organization/independent system operator dashboard on the operation of centrally organized, wholesale power markets; (2) collecting and maintaining information on the utilization of the bulk transmission system that complements current data collection; and (3) improving reporting on transmission investment and on the functioning and outcomes of transmission planning activities, to enable analysis on whether transmission policies and regulations are achieving their intended effects. All proposed activities should be undertaken through processes that comply with existing data-collection protections.

65. **Support EIA's collection of additional data on electricity and water flow for water and wastewater utilities.** Electricity usage in delivering water services represents a significant portion of U.S. electricity consumption (estimated at 3 to 4 percent of total electricity consumption) and may present major opportunities for both efficiency and renewable generation; however, EIA does not currently collect this data in its surveys. EIA should expand its data collection to include annual electricity and annual water flow (millions of gallons) by water and wastewater utilities, in order to enable identification of new opportunities for electricity use and savings.

Electricity Workforce of the 21st Century: Changing Needs and New Opportunities

Support the Electricity Sector Workforce

The electricity sector is undergoing a number of significant shifts in structure, energy sources, and applications as the industry modernizes and evolves. The full potential of these shifts will, however, only be realized if the electricity sector workforce appropriately adapts and grows to meet the needs of the 21st-century electricity system. The Federal Government has an interest in the development of this workforce.

66. **Support cyber-physical systems (CPS) curriculum, training, and education for grid modernization and cybersecurity.** The December 2010 report of the President's Council of Advisors on Science and Technology, titled "Designing a Digital Future," highlighted the unique importance and challenges of CPS, such as the power grid. One of the challenges with such systems is the lack of a dedicated and trained, cross-disciplinary workforce skilled at comprehending, designing, and managing CPS. This presents an acute challenge in the realm of power-sector cybersecurity, where cyber and cyber-physical threats are presenting new and distinct challenges. Prevention, mitigation, and response and recovery efforts require a workforce that understands the unique electric sector IT and operational technology systems and challenges; however, the industry currently faces a shortage of such workers. The Federal Government—through the Department of Education, DOE, National Science Foundation, and others—should sponsor development and deployment of CPS and cybersecurity educational curricula with community colleges, universities, and institutions of higher education to meet the grid-modernization needs of the 21st-century electricity system; they can do this by offering grants and supporting programs for educational institutions to develop and deploy CPS and power-sector cybersecurity educational curricula.

67. **Enhance and align skills-based training and electricity sector workforce development.** The Federal Government has multiple resources that help address the difficulty employers are experiencing in hiring skilled workers in the electricity sector. To facilitate access to these Federal programs, the following steps should be taken:

    - DOE should, with other Federal agencies (e.g., the Department of Labor [DOL], National Science Foundation, Department of Commerce, Department of Education, and Department of Defense), coordinate Federal initiatives on electricity sector education and training, including programs to facilitate national training credentials in new electricity technologies.
    - DOL should expand its pre-apprenticeship programs.
    - DOE should expand its existing programs to increase the number of internships, fellowships, traineeships, and apprenticeships.
    - DOE, DOL, and the Department of Defense should work together to create workforce opportunities for veterans, to build a more inclusive workforce, and to bring clean energy job training to low- and moderate-income communities.
    - DOL and DOE should develop a single resource web portal to inform industry and potential employees about the multiple Federal agency workforce development initiatives and resources.

68. **Support Federal and regional approaches to electricity workforce development and transition assistance.** Changes in the electricity sector are increasing the need for a diverse and specialized workforce. To ensure electricity sector workers maintain the capabilities required to provide for reliable and affordable electricity in a rapidly changing environment, DOE (in partnership with other agencies) should facilitate programs and regional approaches for workforce development. Federal funding and technical support should enhance existing programs on workforce diversity; apprenticeship and apprenticeship-readiness programs; skills-based training and education; transition assistance; and curriculum development. Workforce assessment tools should be developed to complement training programs. Federal agencies should coordinate their efforts through the interagency Energy and Advanced Manufacturing Workforce Initiative, staffed by DOE. Unemployed workers nearing but not yet eligible for retirement may have difficulty retraining after careers built on specialized skills that are no longer in demand in the modern electricity industry. Retirement-transition assistance should be provided to these workers. Where possible, Federal agencies should leverage existing government, nongovernment, labor, and industry workforce consortia.

Meet Federal Commitments to Communities Affected by the Transformation of the Electricity Sector

To achieve the transition to the electricity sector of the 21st century smoothly, quickly, and fairly, the Federal Government should offer a synthesized package of incentives that address the needs of the most important stakeholders both within and outside the electricity sector. Many of these needs are addressed through other recommendations on this list, including incentives to reduce the cost of flexible and clean assets, encourage the deployment of new and improved technologies throughout the electricity supply chain, and train workers for 21st-century electricity jobs. Recognizing that the shift to the 21st-century electricity system can impact communities that depend on 20th-century resources, the following recommendations provide transition assistance for communities affected by the multi-decadal decline in coal production.

69. **Fulfill Federal commitment to fund coal miner retiree benefits.** Over the last 50 years, coal miners have repeatedly foregone increases in wages in exchange for pension and healthcare benefits. These benefits are now imperiled by (1) the recent bankruptcy of three of the largest public coal companies in America—allowing those companies to avoid fully funding their employees' benefit funds—and (2) the declining ratio of active contributing workers relative to beneficiaries in the health and pension funds. Recognizing the commitments to support coal miner retirement benefits made by the Federal Government in the 1946 Krug-Lewis Agreement, the 1992 Coal Industry Retiree Health Benefit Act, and the 2006 amendments to that act, and also recognizing the contribution that coal miners have made to the U.S. economy, the Administration strongly supports legislation that would transfer funds to the largest multi-employer health and pension fund serving retired coal miners and their families, thereby ensuring that it can continue paying benefits.

70. **Meet the Federal commitment to appropriate sufficient funding to accomplish the mission of the Abandoned Mine Lands (AML) Fund.** DOI's Office of Surface Mining Reclamation and Enforcement estimates that there are more than $4 billion worth of high-priority, health- and safety-related, abandoned coal mine lands in the United States. At the same time, the AML Fund has an unspent balance of $2.5 billion dedicated to reclaiming these sites. The AML fees should be returned to their original 1977 levels to raise additional reclamation funds, and disbursements from the AML Fund should be accelerated over the next 5 years, enhancing economic development in distressed coal communities through reclamation employment.

Enhancing Electricity Integration in North America

Increase North American Cooperation on Electric Grid and Clean Energy Issues

Cooperation on electricity is needed to strengthen the security and resilience of an integrated, cross-border electricity grid, as well as to provide increasing amounts of clean energy and improve economic competitiveness across North America. A clear understanding of the regulatory requirements at the Federal and state levels for the permitting of cross-border transmission facilities, a sharing of best practices, and an exploration of potential future cooperation on grid-management issues will limit uncertainties and improve policy coordination at the multilateral and international levels. This includes implementing the target established in the 2016 North American Leaders Summit to increase clean power to 50 percent of the electricity generated in North America by 2025.

71. **Increase U.S. and Mexican cooperation on reliability.** In 2005, the United States and Canada codified an international reliability framework based on an electricity reliability organization. As Mexico moves ahead with electricity reform and looks to expand their electricity system (including planning for international transmission), an international commitment to reliability would signal good progress toward improved electricity system management across North America. A commitment to working jointly on reliability was also included in the statement from the North American Leaders Summit in June 2016, where these leaders "committed to deepened electric reliability cooperation to strengthen the security and resilience of an increasingly integrated North American electricity grid."[14] The U.S. Government should increase cooperation on reliability between the United States and Mexico by establishing bilateral reliability principles between the United States and Mexico.

72. **Advance North American grid security.** In December 2016, the United States and Canada released a Joint United States–Canada Grid Security Strategy framing how these two countries plan to work together to strengthen the security and resilience of the electric grid. This plan included strategy against the growing threat from cyber attacks and climate change impacts. This recommendation aims to complete that objective through the sharing of best practices and exploration of potential future cooperation on grid security issues with Mexico, in parallel with implementation of the Joint United States–Canada Grid Security Strategy and domestic Action Plans.

73. **Promote North America clean energy infrastructure development by sharing best practices for community engagement.** Lessons learned from sharing across regional entities can be a challenge, but the Federal Government can provide a forum for that engagement. This recommendation proposes that the U.S. Government initiate a series of high-level meetings with Canada and Mexico to share best practices relating to community engagement for clean energy infrastructure development throughout North America.

74. **Promote permitting of cross-border transmission facilities.** The "Regulatory Side-by-Side Governing Permitting of Cross-Border Electricity Transmission Facilities between the United States and Canada" summarizes existing regulations as of the time of publication. The document has proved incredibly useful as a resource for other analytical efforts and in informing discussion about simplifying or harmonizing regulations. Expanding this work to Mexico as the energy reforms move ahead would be very helpful to developers and governments. In addition, high-level meetings to improve community engagement for infrastructure can be supported by an effort at DOE with partners in Canada and Mexico to complete and update the Regulatory Side-by-Side and expand the RAPID Toolkit to the North America cross-border context. Consistent with the "North American Climate, Clean Energy, and Environment Partnership Action Plan," DOE should promote permitting of cross-border transmission facilities by expanding the

RAPID Toolkit. Expansion of this toolkit will enable a clear understanding of the regulatory requirements at the Federal and state levels for the permitting of cross-border transmission facilities, in addition to those for bulk transmission.

75. **Modernize international cross-border transmission permitting processes.** Building upon Executive Order 13604, "Improving Performance of Federal Permitting and Review of Infrastructure Projects," a 2013 Presidential Memorandum titled "Transforming our Nation's Electric Grid through Improved Siting, Permitting, and Review" aims to modernize transmission permitting processes. The Presidential Memorandum directed Federal agencies to create the integrated interagency pre-application process (IIP) across the Federal Government (1) to help identify and address issues before the formal permitting process begins and (2) to improve coordination of permitting across Federal, state, and tribal governments. On September 21, 2016, DOE's Office of Electricity Delivery and Energy Reliability announced a final rule for the IIP. The IIP process encourages robust early coordination prior to the submission of a formal transmission permit application. That includes increased engagement with DOE as a coordinating agency, as well as relevant state, local, and tribal stakeholders. The principles of the IIP have already been successfully applied to two existing and recent Presidential permit applications for clean energy transmission. Building on these activities, DOE should modernize international cross-border transmission permitting processes by implementing a pre-application process and update the Presidential Permitting rules.

76. **Increase North American clean energy and technical coordination.** Technical discussions have the potential to support better coordination on clean energy and climate goals, primarily through the creation of more robust North American modeling capabilities and wider accounting of clean energy and carbon emissions associated with cross-border trade. Technical discussions can also continue and enhance cooperation on energy information exchange across North America. In addition, technical discussions should focus on increasing North America wholesale electricity markets' cooperation by sharing best practices for market development. As North America moves toward greater integration, there should be continued engagement on the cross-border impacts of climate and clean energy policies in order to limit uncertainties and improve policy coordination at the multilateral and international levels. There is a need for analytical tools and models that can estimate the value of technology deployment and summarize the impacts of policies in the clean energy and climate policy space. Specifically, models and studies are needed to examine (1) policy levers and incentives for clean energy and technologies to achieve climate goals; (2) the emissions impacts of jointly planning climate action and policies for climate and clean energy; (3) the impacts of cross-border trading on clean energy development, emissions, and the electricity system; and (4) the impacts of market policies, including cross-border trading schemes for carbon and emissions. With new modeling capabilities and through technical discussions, DOE should explore the impact of enhanced cross-border trade on greenhouse gas emissions, economic development (in all countries, and collectively), as well as system reliability. Specific analysis could model market structures and examine the interplay between short-term operational flexibility and long-term financial certainty; examine the impact of enhanced U.S. imports of Canadian hydropower on carbon emissions and U.S. renewable energy development; examine best practices for the development of wholesale electricity markets; study Mexico's integration into the Western Climate Initiative; and explore impacts on the U.S. renewable energy industry, end-use costs for consumers, and the impacts of adjustments in subnational policies on clean energy consumption across the continent.

Conclusion

The electricity sector has been, and will continue to be, an indispensable tool to enable the United States to meet its linked national goals. Thanks to technology innovation and more than a century of development, the electricity system is already an extraordinary national asset. It has supported significant progress toward economic prosperity, equity, environmental responsibility, and security and resilience. The QER 1.2 identifies many approaches that can build on this success to advance—and accelerate—the electricity system's role in meeting these goals.

Endnotes

1. Center for Naval Analyses (CNA) Military Advisory Board, *National Security and Assured U.S. Electrical Power* (CNA Military Advisory Board, November 2015), 1, https://www.cna.org/CNA_files/PDF/National-Security-Assured-Electrical-Power.pdf.

2. Scott Hilton, "Dyn Analysis Summary of Friday October 21 Attack," *Dyn*, October 26, 2016, http://dyn.com/blog/dyn-analysis-summary-of-friday-october-21-attack/.

3. Cisco, *Cisco Global Cloud Index: Forecast and Methodology, 2015–2020* (Cisco, 2016), White Paper, http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.pdf.

4. Botnet Tracker, "Mirai," Malware Tech Website, accessed October 21, 2016, https://intel.malwaretech.com/botnet/mirai/?h=24.

5. Fixing America's Surface Transportation Act, Pub. L. No. 114-94 (2015), https://www.congress.gov/114/bills/hr22/BILLS-114hr22enr.pdf.

6. Peter Behr and Blake Sobczak, "Grid Hack Exposes Troubling Security Gaps for Local Utilities," E&E News, July 20, 2016, http://www.eenews.net/stories/1060040519.

7. Federal Energy Regulatory Commission (FERC) v. Electric Power Supply Association (EPSA) et al., October Term 2015, No. 14-840, https://www.supremecourt.gov/opinions/15pdf/14-840_k537.pdf .

8. Regulations Implementing FAST Act Section 61003 – Critical Electric Infrastructure Security and Amending Critical Energy Infrastructure Information; Availability of Certain North American Electric Reliability Corporation Databases to the Commission, 81 Fed. Reg. 93732 (December 21, 2016), https://www.federalregister.gov/documents/2016/12/21/2016-28322/regulations-implementing-fast-act-section-61003-critical-electric-infrastructure-security-and.

9. Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators, 81 Fed. Reg. 86522 (November 17, 2016), https://www.federalregister.gov/documents/2016/11/30/2016-28194/electric-storage-participation-in-markets-operated-by-regional-transmission-organizations-and.

10. C. Gellings, Gale Horst, Mark McGranaghan, Paul Myrda, Brian Seal, and Omar Siddiqui, *Estimating the Costs and Benefits of the Smart Grid: A Preliminary Estimate of the Investment Requirements and the Resultant Benefits of a Fully Functioning Smart Grid* (Palo Alto, CA: Electric Power Research Institute, March 2011), https://www.smartgrid.gov/files/Estimating_Costs_Benefits_Smart_Grid_Preliminary_Estimate_In_201103.pdf.

11. John McCue, Andrew Slaughter, Suzanna Sanborn, Kartikay Sharma, Deepak Vasantl Shah, Negina Rood, Rob Young, and James Loo, *From Growth to Modernization: The Changing Capital Focus of the US Utility Sector* (Deloitte, 2016), https://www2.deloitte.com/content/dam/Deloitte/us/Documents/energy-resources/us-er-from-growth-to-modernization.pdf.

12. Mathew J. Morey and Laurence D. Kirsch, *Retail Choice in Electricity: What Have We Learned in 20 Years?* (Madison, WI: Christensen Associates Energy Consulting and Electric Markets Research Foundation, February 2016), https://www.hks.harvard.edu/hepg/Papers/2016/Retail%20Choice%20in%20Electricity%20for%20EMRF%20Final.pdf.

13. Mathew J. Morey and Laurence D. Kirsch, *Retail Choice in Electricity: What Have We Learned in 20 Years?* (Madison, WI: Christensen Associates Energy Consulting and Electric Markets Research Foundation, February 2016), https://www.hks.harvard.edu/hepg/Papers/2016/Retail%20Choice%20in%20Electricity%20for%20EMRF%20Final.pdf.

14. White House, Office of the Press Secretary, "North American Climate, Clean Energy, and Environment Partnership Action Plan," White House, June 29, 2016, https://www.whitehouse.gov/the-press-office/2016/06/29/north-american-climate-clean-energy-and-environment-partnership-action.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