

**Statement of Dr. Lynn Orr
Under Secretary for Science and Energy
U.S. Department of Energy**

**Before the
Committee on Energy and Natural Resources
United States Senate**

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Introduction

Chairman Murkowski, Ranking Member Cantwell, and Members of the Committee, thank you for the opportunity to testify today on behalf of the Department of Energy regarding energy accountability and reform legislation.

In support of the Administration's all-of-the-above approach to energy and the Climate Action Plan, DOE is leading efforts to move to a low carbon future and doing so by working with some of the Nation's best innovators and businesses to support high-impact applied research, development, and demonstration activities.

With Congress's support, the Department implements a range of strategies aimed at reducing U.S. reliance on oil, saving American families and businesses money, creating jobs, and reducing pollution. We work to ensure that the low carbon technologies of today and tomorrow are invented and manufactured in America.

As Under Secretary for Science and Energy, my job is to coordinate DOE's scientific research efforts and our portfolio of applied energy research and development (R&D) as we transition to a low carbon future. Fundamental science underpins everything we do in the energy sector, and the world of energy applications is rich with opportunity to put the science to work, and also for energy applications to illuminate the opportunities for science that could have game-changing impact. My office is working to enhance the productive links among the science and energy programs as we build and execute the Department's research, development, demonstration and deployment activities.

I have been asked to testify on a package of bills related to energy accountability and reform. The Committee is considering a broad range of 42 bills today, the majority of which have some nexus to the Department of Energy. The Administration continues to review all of these bills and has not formulated a position on them.

I appreciate the ongoing bipartisan efforts to address our Nation's energy challenges, and I look forward to working with the Committee.

Energy Landscape

There has been an energy revolution in the United States over the last decade. We are now the largest combined producer of oil and gas in the world and our oil imports are the lowest they have been in more than 40 years. Natural gas use in power generation has significantly increased and U.S. liquefied natural gas exports are scheduled to start within a year. Wind and solar power generation has grown dramatically, vehicles have reached historic levels of efficiency, and ethanol is now ten percent of U.S. gasoline supply.

The United States is, however, at an energy crossroad. As noted, our energy landscape is dramatically changing with implications for all parts of the energy sector and our economy as a whole. The rapid and dramatic changes in the Nation's energy landscape have created enormous opportunities. At the same time, they pose a set of challenges and opportunities for energy policy makers, investors, non-governmental organizations and industry. These opportunities and challenges come in many forms, and addressing them will require action by many parties, including Congress, the private sector, and public sector.

The Committee's last several hearings have focused on broad topics such as energy infrastructure, energy supply, and today on energy accountability and reform. Over the past year and a half, the DOE has led an Administration wide effort focused on the energy issues facing our Nation, specifically on infrastructure in the first installment of the Quadrennial Energy Review (QER). As you know, this first installment of the QER was released in April and, the Secretary testified in front of this Committee days after its release.

Quadrennial Energy Review (QER)

The first installment of the QER focuses specifically on the critical energy infrastructure that serves as the backbone of our nation's system for energy transmission, storage, and distribution. The development of the QER underscores the strong public interest in advancing key national goals of jobs, competitiveness, energy security and a cleaner energy future. It also provides policy makers with a roadmap for meeting key energy objectives: enhancing energy infrastructure resilience, reliability, safety and security; modernizing the electric grid and our energy security infrastructures; and improving "shared" energy infrastructures—railways, waterways, ports and roads—that move both energy and other commodities. Several crosscutting themes were also considered, including jobs, the environment, infrastructure siting, and integration of North American energy markets.

Some recommendations within the QER will require new authority from Congress, and we look forward to working with you on those issues, which include, but are not limited to:

- Financial assistance to help states make cost-effective improvements in the safety and environmental performance of natural gas distribution systems, focusing on offsetting incremental costs to low-income households and enhanced direct inspection and maintenance programs.
- Updating Strategic Petroleum Reserve release authorities to reflect modern oil markets, and funding for necessary infrastructure life extension and enhanced incremental distribution capacity.
- Analyzing the risks associated with the loss of large power transformers and approaches for mitigating this risk, possibly including the development of one or more transformer reserves, which would require congressional authorization.

To help guide the work of this Committee, a summary version of the QER was developed for policymakers. I ask the Chairman's permission to submit this summary for the record.

Quadrennial Technology Review (QTR)

Later this summer, DOE will complete the second-ever Quadrennial Technology Review (QTR). The QTR will offer a comprehensive analysis of energy technology trends and opportunities, with a focus on identifying the research, development, demonstration, and deployment pathways that will help the Nation achieve greater energy, economic, and environmental security. We look forward to briefing the findings of the QTR for the Committee and your Senate colleagues.

All-of-the-above Approach

An essential focus of the Department of Energy is helping our nation lead the transition to a clean, low carbon energy economy in order to enhance our energy security and mitigate the impacts of climate change. The Department serves this goal principally through supporting advancements in science and technology across the energy spectrum.

In the last year, we have seen important accomplishments across the Department's technology portfolio that highlight this all-of-the-above approach. We have geologically sequestered 10 million metric tons of CO₂ through DOE-supported projects. Two commercial-scale cellulosic ethanol facilities supported by DOE grant or loan guarantees have commenced operations. We have commissioned one of the world's largest battery storage systems at the Tehachapi Wind Energy Storage Project. ARPA-E's grant program has attracted more than \$850 million in private follow-on funding to 34 projects, with 30 ARPA-E teams forming new companies.

The Office of Energy Efficiency and Renewable Energy (EERE) has launched the Frontier Observatory for Research in Geothermal Energy (FORGE), a first-of-a-kind field laboratory to deploy enhanced geothermal energy systems, and the first round of awardees was announced last month. The Office of Nuclear Energy has successfully completed the first five-year program at the Consortium for Advanced Simulation of Light Water Reactors (CASL) nuclear modeling

Hub at the Oak Ridge National Laboratory, and continues its work toward design and licensing support of a small modular nuclear reactor with advanced safety features.

I would like to take this opportunity to talk about a few existing programs that focus on the work represented by legislation being considered today.

Office of Energy Efficiency and Renewable Energy

EERE's energy efficiency portfolio seeks to improve the energy efficiency of the Nation's homes, buildings, and industries. The Building Technologies, Advanced Manufacturing, Weatherization and Intergovernmental Programs, and Federal Energy Management Program Offices develop and help provide businesses, consumers, and government agencies with innovative, cost-effective energy-saving solutions to improve their energy efficiency. This includes the development of higher-efficiency products, new ways of designing homes and buildings, and new ways of improving the energy intensity and competitiveness of American manufacturers. EERE's energy efficiency portfolio also supports better integrating the built environment with our energy system to combat costly peaks in energy demand and to increase the capabilities and value of buildings and facilities.

EERE's renewable power portfolio supports developing solutions to significantly increase the amount of cost-competitive electric power that is generated from renewable resources across the Nation. The Solar, Geothermal, and Wind and Water Power Technologies Offices within EERE help advance technology RD&D to cost-effectively harness the United States' abundant and diverse supply of renewable resources. While each renewable power technology has unique tradeoffs, EERE seeks to ensure the development of multiple renewable power technology options for every region of the country, enabling the U.S. to diversify its energy portfolio and better protect our environment and respond to the threat of climate change.

EERE's sustainable transportation portfolio supports research, development, and demonstration work and efforts to break down market barriers for a variety of domestic and cost-effective sustainable transportation technologies. Broadly, the Vehicle, Bioenergy, and Hydrogen and Fuel Cell Technologies Offices support two key parallel solution pathways: (1) using less energy to move people and freight and (2) replacing conventional fuels with cost-competitive, domestically produced, sustainable alternative fuels with lower greenhouse gas emissions. Because most petroleum use in the transportation sector occurs in personal vehicles and heavy trucks, EERE's portfolio emphasizes transportation technologies in these areas.

Office of Electricity Delivery and Energy Reliability

The Office of Electricity Deliverability and Energy Reliability's (OE) mission is to lead national efforts to modernize the electricity delivery system, enhance the security and reliability of America's energy infrastructure, and facilitate recovery from disruptions to the energy supply. OE leads the Department's efforts to strengthen, transform, and improve our energy infrastructure so that consumers have access to reliable, secure, and clean sources of energy. The

goal for the future grid is to provide a platform that delivers reliable, affordable, and clean electricity to consumers where they want it, when they want it, and how they want it.

To accomplish this vital mission, OE works closely with private industry and Federal, state, local, and tribal governments on a variety of initiatives to modernize the electric grid and enhance key characteristics of the U.S. electric transmission and distribution systems, which include:

- Reliability – consistent and dependable delivery of high quality power;
- Flexibility – the ability to accommodate changing supply and demand patterns and new technologies;
- Efficiency – low losses in electricity delivery and more optimal use of system assets;
- Resiliency – the ability to withstand and quickly recover from disruptions and maintain critical function;
- Affordability – more optimal deployment of assets to meet system needs and minimize costs;
- Security – the ability to protect system assets and critical functions from all hazards; and
- Minimal environmental footprint – grid system designs that reduce total environmental impact of grid components and connected systems.

Improvements to all of these operational capabilities, together with end-to-end protection from manmade and natural threats, are necessary for a modern and reliable grid.

Office of Fossil Energy

The Office of Fossil Energy (FE) advances technologies related to the reliable, efficient, affordable, and environmentally sound use of fossil fuels which are essential to our Nation's security and economic prosperity. FE leads Federal research, development, and demonstration efforts on advanced carbon capture, and storage (CCS) technologies to facilitate achievement of the President's climate goals. FE also develops technological solutions for the prudent and sustainable development of our unconventional domestic resources.

FE also manages the Nation's Strategic Petroleum Reserve (SPR). The SPR, with a capacity of 727 million barrels, serves as the largest stockpile of government-owned emergency crude oil in the world. The SPR helps ensure U.S. energy security by providing protection against disruptions in U.S. oil supplies. It also allows the United States to meet, in combination with commercial stocks, its International Energy Agency (IEA) obligation to maintain strategic oil stocks equal to ninety days of net oil imports.

In addition to the SPR, FE oversees the Northeast Home Heating Oil Reserve, which provides a short-term supplement to commercial home heating oil supplies in the Northeast in the event of a supply interruption.

Office of Science

The Office of Science (SC) continues its distinguished history of making important investments in basic research, scientific user facilities, and facility construction across our six program areas:

- Advanced Scientific Computing Research (ASCR) supports research to discover, develop, and deploy computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to DOE.
- Basic Energy Sciences (BES) supports research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies.
- Biological and Environmental Research (BER) supports fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future.
- Fusion Energy Sciences (FES) supports research to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation of fusion energy.
- High Energy Physics (HEP) supports research to understand how the universe works at its most fundamental level by discovering the most elementary constituents of matter and energy, probing the interactions among them, and exploring the basic nature of space and time itself.
- Nuclear Physics (NP) supports research to discover, explore, and understand all forms of nuclear matter, including experimental and theoretical research to create, detect, and describe the varied forms of nuclear matter that can exist, including those that are no longer found naturally.

Other Topics of Legislation

This hearing also includes bills that, while not under my direct purview, are related to DOE. There are several bills relating to the Loan Program Office, which issues loans and loan guarantees to accelerate the commercial deployment of clean energy projects and advanced vehicle manufacturing in the U.S. The program works with the private sector to fill a critical role in the marketplace because commercial banks and bondholders are often unwilling to finance the first few commercial-scale projects that use a new technology since there is not yet a history of credit performance or operation.

The LPO currently manages a more than \$30 billion portfolio of projects, including the first new nuclear power plant to be licensed and constructed in the United States in more than thirty years,

some of the largest utility-scale solar facilities in the world, dozens of retooled auto manufacturing plants producing some of America's best-selling vehicles, the world's largest solar thermal energy storage system, and many other ground-breaking projects. Overall, these loans and loan guarantees have resulted in more than \$50 billion in total project investment. As of March 2015, \$22.3 billion has been disbursed and \$5.4 billion of principal and interest has been repaid to the U.S. Treasury; actual and estimated losses to date represent approximately 2% of the more than \$30 billion of closed and committed loans and loan guarantees which compares favorably to the private sector.

Further, there are several bills regarding the national laboratories, of which 13 come within the purview of my office. In fact, I have been fortunate enough to visit all of DOE's national laboratories. The Energy Secretary has made it a cornerstone of his tenure to strengthen and enhance the relations between the Department and the national laboratories. To this end, we have established a regular strategic dialogue with the labs through leadership councils involving lab directors, Chief Operating Officers, and other key managers. Those coordinated efforts include standing up the National Laboratory Policy Council, which consists of the National Lab Directors Council leadership and senior Departmental leadership, and the National Laboratory Operations Board, led by the Office of the Under Secretary for Performance and Management which includes representatives from the labs' Chief Operating Officers and Chief Research Officers, as well as programs within the Department that steward labs.

There are also a number of ongoing efforts to review lab issues, including the congressionally directed Commission to Review the Effectiveness of the National Energy Laboratories and the Secretary of Energy Advisory Board, which is looking at important issues to keep DOE's national laboratories on the cutting edge of scientific development.

We are making good progress in these efforts, and are continuing to strengthen and enhance our national laboratory system, a priority that the Secretary and I share with you. While it is important to look at streamlining and improving the operations of our national labs, I am concerned that some of the proposed provisions in introduced legislation would weaken DOE oversight of the laboratories.

Conclusion

Through research and development, deployment, and collaborations at all levels of government and the private sector, the Department of Energy aims to support an efficient transition during our Nation's energy revolution. While significant progress has been made, continued investments are necessary to capture the full set of opportunities.

The Administration looks forward to continuing to work with the Congress on bipartisan energy legislation to boost U.S. competitiveness and job creation.

Thank you again for the opportunity to be here today, and I would be happy to answer your questions.

Summary

TRANSFORMING U.S. ENERGY INFRASTRUCTURES IN A TIME OF RAPID CHANGE: THE FIRST INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW

SUMMARY FOR POLICYMAKERS

The U.S. energy landscape is changing. The United States has become the world's leading producer of oil and natural gas combined. The country is less dependent on foreign oil, as a percentage of national oil consumption, than it has been since 1971. Current cars can go farther on a gallon of gas than ever before. Between 2005 and 2014, U.S. consumption of motor gasoline fell 2.6 percent despite population growth of 7.6 percent and gross domestic product growth of 13.0 percent. Additionally, as a result of changes in economic structure and conditions and policies to promote energy efficiency, U.S. electricity consumption was flat over that 10-year period and total energy use declined by 1.9 percent.^a

The composition of the Nation's energy supply has also started to shift: petroleum consumption is flat and coal consumption is declining, while the use of natural gas and renewables is growing. In 2014, renewable energy sources accounted for half of new installed electric-generation capacity, and natural gas units made up most of the remainder. Electricity generation from wind grew 3.3-fold between 2008 and 2014, and electricity generation from solar energy grew more than 20-fold.

The focus of U.S. energy policy discussions has shifted from worries about rising oil imports and high gasoline prices to debates about how much and what kinds of U.S. energy should be exported, concerns about the safety of transporting large quantities of domestic crude oil by rail, and the overriding question of what changes in patterns of U.S. energy supply and demand will be needed—and how they can be achieved—for the United States to do its part in meeting the global climate change challenge.

^a The figures in this and the succeeding paragraph are from: Energy Information Administration. "Monthly Energy Review." March 2015. www.eia.gov/totalenergy/data/monthly/pdf/mer.pdf. However, the population data are from: Census Bureau. "Population Estimates." www.census.gov/popest/. Accessed April 5, 2015.

In the “Climate Action Plan” unveiled by President Obama in June 2013, he directed his Administration to initiate an interagency Quadrennial Energy Review (QER) to help ensure, in this dramatically changing energy landscape, that Federal energy policy is appropriately matched to the Nation’s economic, security, and climate goals. The approximately annual installments of the QER over the ensuing 4 years are to focus on different components of the Nation’s energy system—resource extraction and processing, energy transport and storage infrastructure, electricity generation, energy end-use—providing findings and recommendations on how Federal energy policy can best complement and incentivize state, local, tribal, and private sector actions so as to meet ongoing and emerging challenges and take advantage of new opportunities.

This first installment of the QER addresses infrastructures for energy transmission, storage, and distribution (TS&D), broadly defined as *infrastructures that link energy supplies, carriers, or by-products to intermediate and end users*. This focus was chosen because the dramatic changes in the U.S. energy landscape have significant implications for TS&D infrastructure needs and choices. Well-informed and forward-looking decisions that lead to a more robust and resilient infrastructure can enable substantial new economic, consumer service, climate protection, and system reliability benefits. Good decisions on TS&D infrastructure can also provide flexibility in taking advantage of new opportunities to achieve our national energy objectives.

This summary follows the organization of the main report, starting with an introduction to TS&D infrastructure issues (corresponding to Chapter I, Introduction, in the main report) and continuing with sections on the following:

- Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure (Chapter II)
- Modernizing the Electric Grid (Chapter III)
- Modernizing U.S. Energy Security Infrastructures in a Changing Global Marketplace (Chapter IV)
- Improving Shared Transport Infrastructures (Chapter V)
- Integrating North American Energy Markets (Chapter VI)
- Addressing Environmental Aspects of TS&D Infrastructure (Chapter VII)
- Enhancing Employment and Workforce Training (Chapter VIII)
- Siting and Permitting of TS&D Infrastructure (Chapter IX).

The main report’s treatment of the QER analytical and stakeholder process (Chapter X, Analytical and Stakeholder Process) and its appendices on technical details of TS&D infrastructure for liquid fuels, natural gas, and electricity are not covered here.

Introduction to TS&D Infrastructure Issues

The United States has one of the most advanced energy systems in the world, supplying the reliable, affordable, and increasingly clean power and fuels that underpin every facet of the Nation’s economy and way of life. The energy TS&D infrastructure that links the components of that system with each other and with users is increasingly complex and interdependent. It includes approximately 2.6 million miles of interstate and intrastate pipelines; about 640,000 miles of transmission lines; 414 natural gas storage facilities; 330 ports handling crude petroleum and refined petroleum products; and more than 140,000 miles of railways that handle crude petroleum, refined petroleum products, liquefied natural gas, and coal. The components of the Nation’s TS&D infrastructure considered in this report are listed in Table SPM-1.

The requirements that this TS&D infrastructure must meet are extensive and demanding. It must handle a diverse and evolving mix of energy sources and energy products; link sources, processors, and users across immense distances; match demands that vary on multiple time scales; co-exist with competing uses of the

same systems (e.g., ports and railways); and perform 24 hours a day, 365 days a year with high reliability, which in turn requires both low susceptibility to disruptions and the resilience to recover quickly from whatever disruptions nonetheless occur. The longevity and high capital costs of energy TS&D infrastructure, moreover, mean that decisions made about how to locate, expand, and otherwise modify this infrastructure today will be influencing—either enabling or constraining—the size and composition of the national energy system for decades to come.

Challenges of TS&D Infrastructure Management and Policy

Much of the TS&D infrastructure is owned and operated by the private sector, and a significant portion of the related legal, regulatory, and policy development and implementation occurs at state and local levels. At the same time, the Federal Government controls and operates substantial TS&D infrastructure assets of its own, including inland waterways, thousands of miles of transmission lines, and strategic oil and product reserves. Some of the infrastructure elements owned by others are federally regulated with respect to aspects of siting, safety, environment, and reliability. A number of emergency authorities bearing on TS&D infrastructure are also vested in the Federal Government.

A further complexity affecting the TS&D infrastructure management and policy is that these infrastructures often reach across state and even international boundaries, thus affecting large regions and making multi-state and sometimes multi-national coordination essential for modernization, reliability, resilience, and flexibility. In addition, the large capital costs, scale, and “natural monopoly” characteristics of much TS&D infrastructure tend to perpetuate the role of incumbent providers; these circumstances constrain innovation and add to the usual litany of market failures—public goods, externalities, information deficits, perverse incentives—generally understood to warrant intervention through government policy when the proposed remedy is expected to have sufficient net benefits to overcome predictable ancillary and unintended consequences.

Table SPM-1. Components of TS&D Infrastructure Considered in this Installment of the QER

Fuel/Energy Carrier	TS&D Infrastructure Element/System
Electricity	Transmission lines and substations
	Distribution lines and distributed generation
	Electricity storage
	Other electric grid-related infrastructure
Natural Gas	Natural gas gathering lines
	Transmission pipelines
	Natural gas storage facilities
	Processing facilities
	Distribution pipelines and systems
Coal	LNG production/storage facilities (including export terminals)
	Rail, truck, barge transport
	Export terminals
Crude Oil/ Petroleum Products	Crude oil pipelines
	Crude oil and products import and export terminals
	Rail, truck, barge transport
	Oil refineries
	Strategic Petroleum Reserve & Regional Petroleum Product Reserves
	CO ₂ pipelines (including EOR)
Biofuels	Transport of feedstock and derived products, biorefineries

Chapter 1, Table 1-1.

Given the complexity of this policy landscape, it should be obvious that Federal policies to encourage and enable modernization and expansion of the Nation’s TS&D infrastructure must be well coordinated with state, local, tribal, and (sometimes) international jurisdictions. Full consideration must be given to the interaction of policy at all levels of government with private sector incentives and capabilities and include attention to opportunities for well-designed, purpose-driven, public-private partnerships.

Current Trends Affecting TS&D Infrastructure Choices

A number of changes in the U.S. energy landscape over the last decade were previously mentioned—dramatic changes in the pattern of domestic coal, petroleum, and natural gas production; a drastically altered outlook for energy imports and exports; large increases in electricity generation from wind and sunlight; and an increased priority on moving rapidly to reduce greenhouse gas (GHG) emissions from the energy sector. All of these trends have significant implications for the Nation’s TS&D infrastructure. So does another trend that has been building for decades, which is lack of timely investment in refurbishing, replacing, and modernizing components of that infrastructure that are simply old or obsolete. These trends are elaborated briefly in the subsections that follow.

Aging Infrastructure and Changing Requirements

More than a decade ago, a Department of Energy (DOE) report pronounced the U.S. electricity grid “aging, inefficient, congested, and incapable of meeting the future energy needs of the information economy without significant operational changes and substantial public-private capital investment over the next several decades.”¹ Although significant improvements have been made to the grid since then, the basic conclusion of the need to modernize the grid remains salient. The Edison Electric Institute estimated in 2008 that by 2030 the U.S. electric utility industry would need to make a total infrastructure investment of \$1.5 trillion to \$2.0 trillion, of which transmission and distribution are expected to account for about \$900.0 billion.²

Modernization of the grid has been made all the more urgent by the increasing and now virtually pervasive dependence of modern life on a reliable supply of electricity. Without that, navigation; telecommunication; the financial system; healthcare; emergency response; and the Internet, as well as all that depends on it, become unreliable. Yet the threats to the grid—ranging from geomagnetic storms that can knock out crucial transformers; to terrorist attacks on transmission lines and substations; to more flooding, faster sea-level rise, and increasingly powerful storms from global climate change—have been growing even as society’s dependence on the grid has increased.

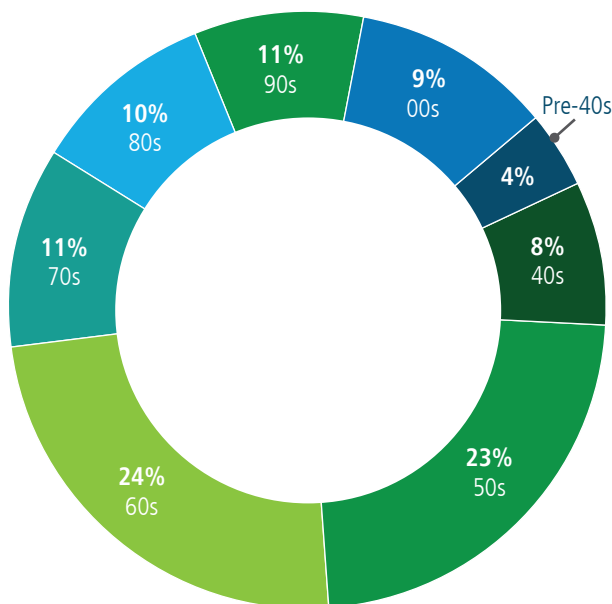
In addition, technology is altering expectations of what the grid should do. Once satisfied with a simple arrangement where utilities provided services and consumers bought power on fixed plans, individual consumers and companies increasingly want to control the production and delivery of their electricity, and enabling technology has become available to allow this. These trends, coupled with flat or declining electricity demand, could dramatically alter current utility business models, and they are already making it more important to appropriately value and use distributed generation, smart grid technologies, and storage.

Natural gas and oil TS&D infrastructures likewise face aging and obsolescence concerns. These infrastructures have not kept pace with changes in the volumes and geography of oil and gas production. The Nation’s ports, waterways, and rail systems are congested, with the growing demands for handling energy commodities increasingly in competition with transport needs for food and other non-energy freight. Although improvements are being made, much of the relevant infrastructure—pipelines, rail systems, ports, and waterways alike—is long overdue for repairs and modernization.

One compelling example is the infrastructure for moving natural gas. Close to 50 percent of the Nation’s gas transmission and gathering pipelines were constructed in the 1950s and 1960s—a build-out of the interstate pipeline network to respond to the thriving post-World War II economy (see Figure SPM-1). Analyses conducted for the QER suggest that natural gas interstate pipeline investment will range between \$2.6 billion and \$3.5 billion per year between 2015 and 2030, depending on the overall level of natural gas demand. The total cost of replacing cast iron and bare steel pipes in gas distribution systems is estimated to be \$270 billion.^b

^b The American Gas Association reports that the total cost of replacing all cast iron pipe in the United States would be about \$83 billion in 2011 dollars. American Gas Association. “Managing the Reduction of the Nation’s Cast Iron Inventory.” 2013. www.aga.org/managing-reduction-nation%E2%80%99s-cast-iron-inventory. Accessed January 16, 2015. According to Pipeline and Hazardous Materials Safety Administration data, cast iron pipes represent approximately 30 percent of the total leak-prone pipe in the United States. Therefore, assuming other pipe replacement has similar costs, the total cost for replacement of all leak-prone pipe is roughly \$270 billion.

Figure SPM-1. Age by Decade of U.S. Gas Transmission and Gathering Pipelines



Chapter 1, Figure 1-1.

The Nation’s Strategic Petroleum Reserve (SPR) also requires attention. The design of the SPR and the infrastructure for utilizing it were determined in 1975, when domestic oil production was in decline, oil price and allocation controls separated the U.S. oil market from the rest of the world, there was no global commodity market for oil at all, and there were no hedging mechanisms to manage risk. The SPR requires updating in light of changed circumstances, including significant maintenance and upgrades to enhance its distribution capability.

Climate Change

Energy TS&D infrastructure has always been shaped not only by the mix of energy supply technologies and end-use patterns, but also by the characteristics of the environment where the infrastructure must operate, including, for example, terrain, vegetation, soil and seismic conditions, and climate. It has long been true, as well, that choices about TS&D infrastructure have had to take into account the need to limit that infrastructure’s adverse impacts on the environment.

By far the most important environmental factor affecting TS&D infrastructure needs now and going forward is global climate change. Sea-level rise, thawing permafrost, and increases in weather extremes are already affecting TS&D infrastructure in many regions. The need to mitigate global climate change by reducing GHG emissions, moreover, is accelerating changes in the mix of energy supply options and end-use patterns, and over time, it is likely to become the dominant such influence. Reducing GHG emissions from TS&D infrastructure, including methane emissions from the transmission and distribution of natural gas, will be increasingly important in this context.

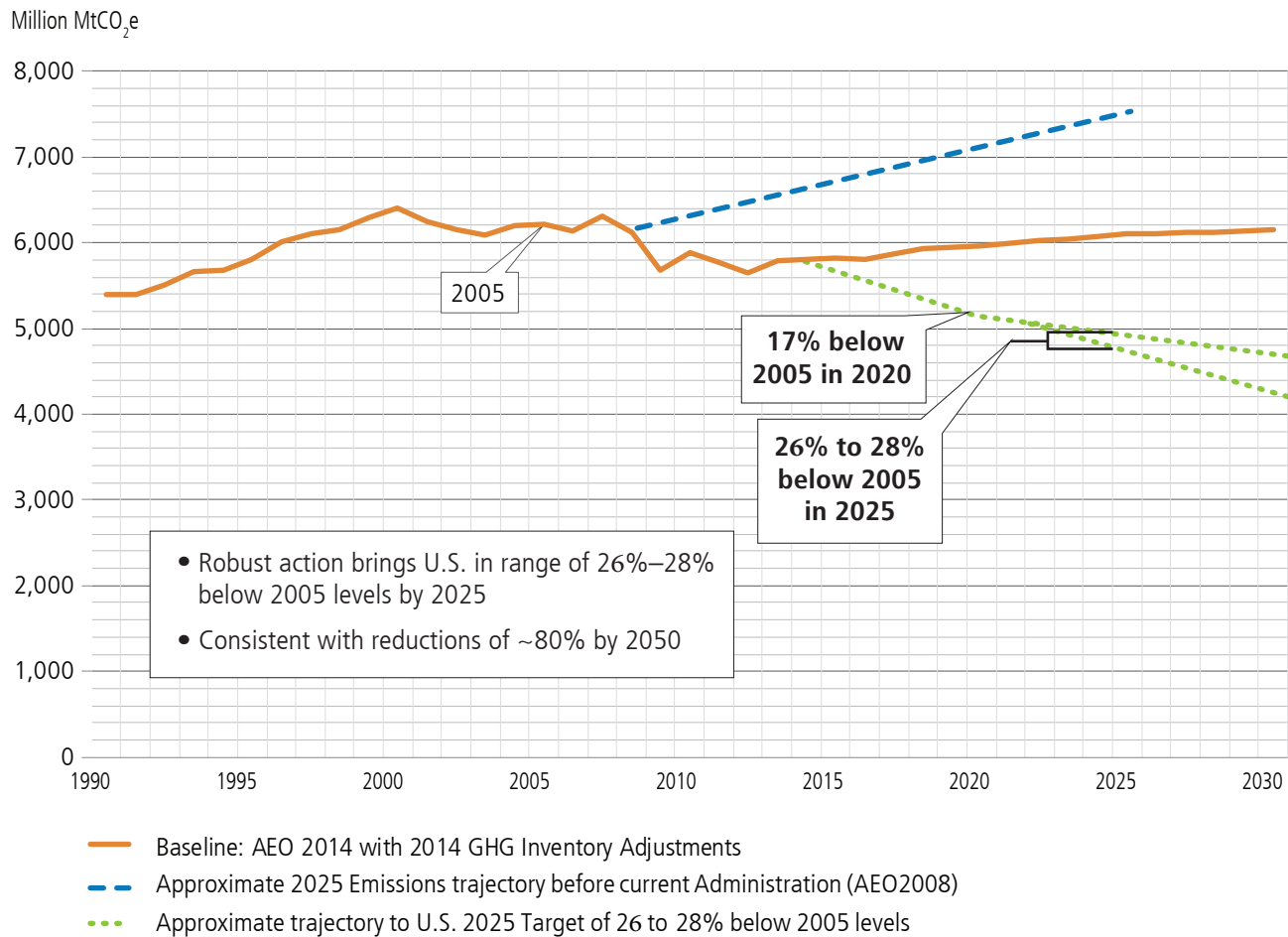
The key relevant conclusions from climate science—as embodied in the most recent reports of the Intergovernmental Panel on Climate Change, the National Academy of Sciences (jointly with the Royal Society of London), and the Third National Climate Assessment of the Global Change Research Program^{3, 4, 5}—are that GHGs emitted by civilization’s energy system are the dominant cause of changes in climate being observed across the globe; that the changes not just in average conditions, but in extremes, are already causing harm to life, health, property, economies, and ecosystem processes; and that deep reductions in GHG emissions will be required if an unmanageable degree of global climate change is to be avoided.

Actions taken in the first term of the Obama Administration in response to the climate change challenge included major investments in a cleaner, more efficient U.S. energy future in the American Recovery and Reinvestment Act of 2009 and subsequent Presidential budgets; the promulgation of the first-ever joint fuel economy/GHG emission standards for light-duty vehicles and new, more stringent energy efficiency standards for commercial and residential appliances; and the announcement of a U.S. emissions reduction target in the range of 17 percent below the 2005 level by 2020. These steps were followed in the second term by the President's announcement, in June 2013, of a new "Climate Action Plan" with three pillars: reducing U.S. emissions of GHGs, increasing domestic preparedness for and resilience against the changes in climate that can no longer be avoided, and engaging internationally to encourage and assist other countries in taking similar steps.^{6,7}

Among the actions subsequently taken under the "Climate Action Plan," those with potential relevance for the future of TS&D infrastructure include a new Strategy for Reducing Methane Emissions nationwide; acceleration of permitting for new renewable energy projects on public lands and military installations; Executive Orders requiring that Federal departments and agencies—including those with responsibilities relating to TS&D infrastructure—take climate change into account in all of their policies and programs; and the announcement, in November 2014, of a post-2020 U.S. GHG emissions reduction target of 26 percent to 28 percent below the 2005 level by 2025.

The Administration's actions under the "Climate Action Plan" put the United States on a path to meet the Administration's 2020 and 2025 targets through several means, including the establishment of carbon emission standards for the power sector that will drive further shifts to low- and zero-carbon fuels, cleaner electricity generation technologies, and continuing improvements in end-use efficiency. Historic and projected U.S. emissions under these latest targets are shown in Figure SPM-2. While the Administration's 2020 and 2025 targets are ambitious, it is clear that continued reduction in GHG emissions will be needed beyond 2025 in the United States and globally. These reductions will continue to drive significant changes in TS&D infrastructure in the longer term.

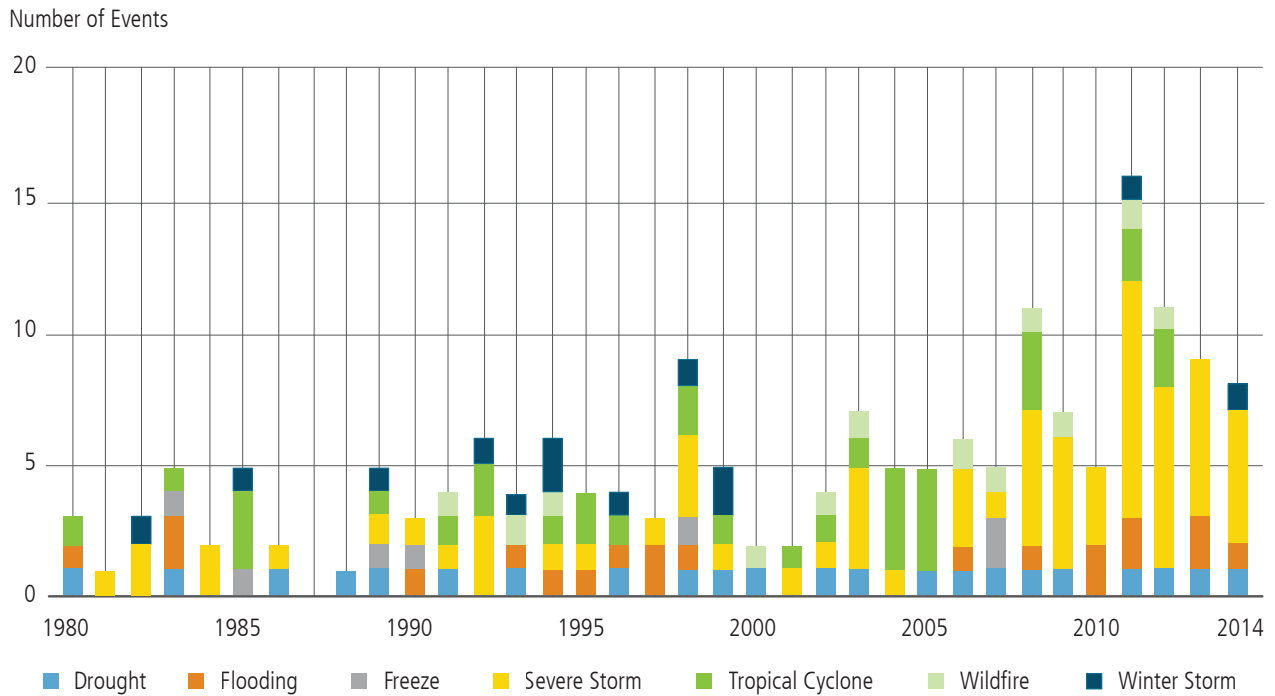
Figure SPM-2. Historic and Projected U.S. Emissions under Obama Administration Targets



Chapter 1, Figure 1-8.

Meanwhile, the ongoing impacts of global climate change have already been stressing energy TS&D infrastructure in a variety of ways. Extreme weather events with high societal costs have been increasing (see Figure SPM-3), a trend expected to intensify under continuing climate change. This means greater vulnerabilities for TS&D infrastructure from hurricanes, drought, extreme temperatures, wildfires, more intense precipitation events, and flooding. Climate change is also driving sea-level rise, which interacts with storm surge and heavy downpours to intensify coastal flooding, and it has been thawing large areas of permafrost in the far North, with impacts on pipelines, roads, and other energy-linked infrastructure.

Figure SPM-3. Billion-Dollar Disaster Event Types by Year



Chapter 2, Figure 2-2.

Goals for TS&D Infrastructure Policy

This first installment of the QER analyzes how to leverage authorities, expertise, and resources to help modernize and transform the extensive, interlocking, capital-intensive networks constituting the national energy TS&D system so as to meet, in a complex jurisdictional environment, the evolving set of requirements and challenges just described. This report presents a set of findings and recommendations, organized around the high-level goals of energy security, economic competitiveness, and environmental responsibility, in the context of a set of analytically derived objectives that reflect an integrated assessment of the adequacy of existing TS&D infrastructures to meet these goals. These objectives include the following:

- Enhancing TS&D infrastructure resilience, reliability, safety, and asset security
- Modernizing the electric grid
- Modernizing the segments of TS&D infrastructure essential for collective energy security
- Improving the increasingly stressed TS&D infrastructures that are shared by energy and other goods and commodities.

These objectives are also informed and affected by an additional set of crosscutting needs and requirements, namely the following:

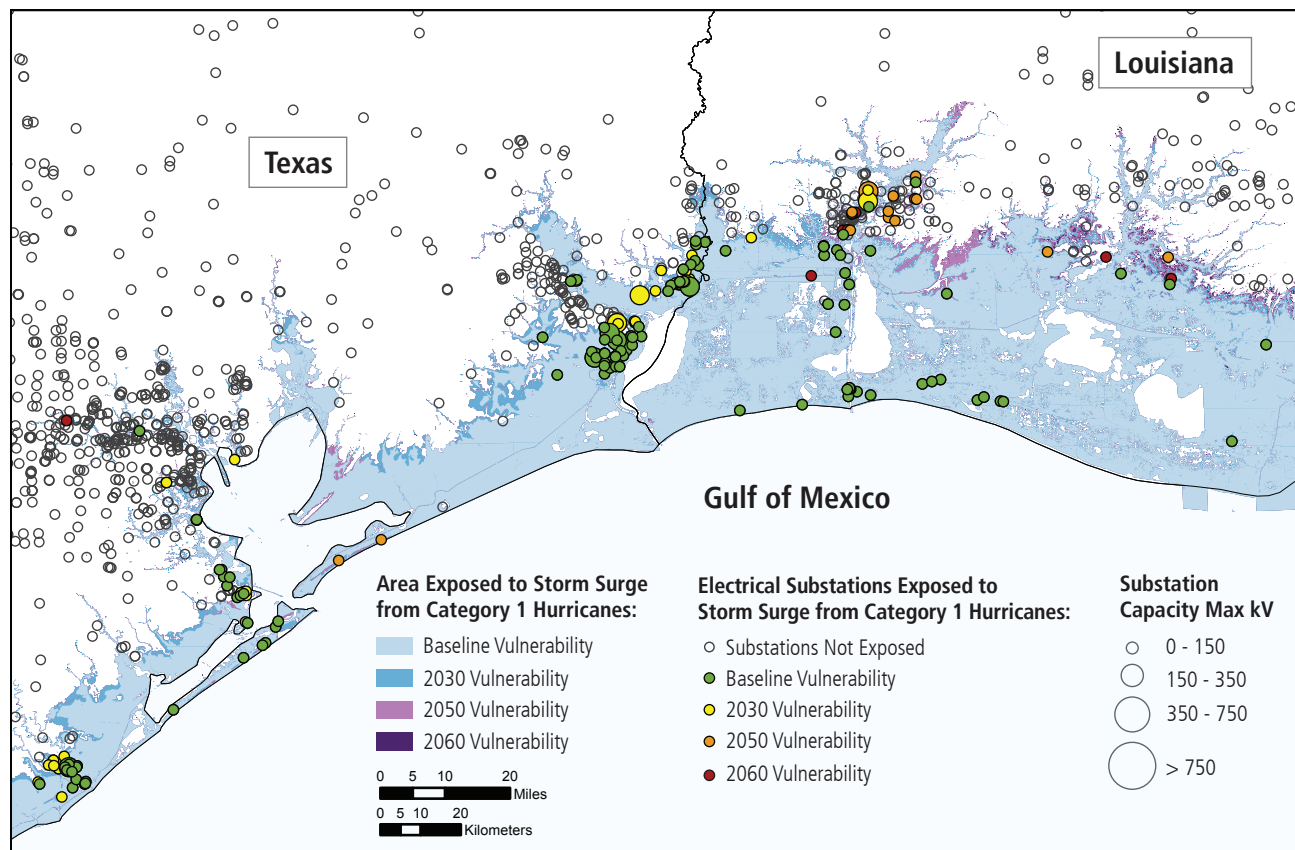
- Promoting environmental responsibility in developing, managing, and updating TS&D infrastructure, including reducing emissions from infrastructure that could contribute to climate change
- Developing and training the workforce needed for a 21st century energy infrastructure
- Expediting the siting of critical TS&D infrastructures to meet a range of energy needs and policy objectives
- Enhancing North American energy market integration.

Modernizing the Nation’s TS&D infrastructures will also help enhance U.S. competitiveness in a global economy, and it will support jobs—approximately 1 million people were employed in energy transmission and distribution jobs in 2013, or almost 0.75 percent of U.S. civilian jobs; modernization will increase those numbers.

Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure

Ensuring the resilience, reliability, safety, and security of TS&D infrastructure is a national priority and vital to American competitiveness, jobs, energy security, and a clean energy future. The imperative for TS&D infrastructure in the United States, going forward, is to maintain the high performance of existing systems; to continue to accommodate significant growth in domestic energy supplies; and to manage and adapt to new technologies, threats, and vulnerabilities in cost-effective ways. For example, severe weather is the leading source of electric grid disturbances in the United States. In fact, between 2003 and 2012, an estimated 679 widespread power outages occurred due to severe weather, costing the U.S. economy \$18 billion to \$33 billion each year between 2003 and 2013. This risk is growing; the number of Gulf Coast electricity substations exposed to inundation caused by storm surge from Category 1 storms is projected to increase from 255 to 337 by 2030 due to sea-level rise (see Figure SPM-4). TS&D infrastructures are becoming increasingly interconnected and interdependent, so disruptions from climate change, natural disasters, and cyber and physical incidents can have serious consequences beyond the specific TS&D infrastructure system that is directly affected.

Figure SPM-4. Gulf Coast Electricity Substation Facilities Exposure under Different Sea-Level Rise Scenarios



Chapter 2, Figure 2-4.

Key Findings

Mitigating energy disruptions is fundamental to infrastructure resilience. Mitigating energy disruptions is particularly important because other critical infrastructures rely on energy services to operate, and these interdependencies are growing. Should disruptions occur, it is essential to have comprehensive and tested emergency response protocols to stabilize the system and begin recovery.

TS&D infrastructure is vulnerable to many natural phenomena. These include hurricanes, earthquakes, drought, wildfires, flooding, and extreme temperatures. Some extreme weather events have become more frequent and severe due to climate change, and this trend will continue. Sea-level rise resulting from climate change, coupled with coastal subsidence in the Mid-Atlantic and Gulf Coast regions, increases risks and damages to coastal infrastructure caused by storm surge.

Threats and vulnerabilities vary substantially by region. In many cases, a particular natural threat or infrastructure vulnerability will be region specific (e.g., Gulf Coast hurricanes threatening refineries), dampening the utility of national, one-size-fits-all solutions for reliability and resilience. Regional solutions are essential.

Recovery from natural gas and liquid fuel system disruptions can be difficult. Although liquid fuels and natural gas disruptions are less likely than electricity disruptions, it is relatively more difficult to recover from disruptions to these systems than electric systems. Recovery from natural gas disruptions is particularly difficult because of the need to locate and repair underground breakages.

Cyber incidents and physical attacks are growing concerns. Cyber incidents have not yet caused significant disruptions in any of the three sectors, but the number and sophistication of threats are increasing, and information technology systems are becoming more integrated with energy infrastructure. There have been physical attacks; while some physical protection measures are in place throughout TS&D infrastructure systems, additional low-cost investments at sensitive facilities would greatly enhance resilience.

High-voltage transformers are critical to the grid. They represent one of its most vulnerable components. Despite expanded efforts by industry and Federal regulators, current programs to address the vulnerability may not be adequate to address the security and reliability concerns associated with simultaneous failures of multiple high-voltage transformers.

Assessment tools and frameworks need to be improved. Research has focused more on characterizing vulnerabilities and identifying mitigation options than on measuring the effects of best practices for response and recovery. In addition, assessment tools and frameworks tend to characterize the impacts of disruptions on system performance, but are less able to examine impacts on national or regional consequences like economic loss or loss of life.

Shifts in the natural gas sector are having mixed effects on resilience, reliability, safety, and asset security. The addition of onshore shale gas infrastructure benefits natural gas resilience by decreasing the percentage of infrastructure exposed to storms. The Energy Information Administration (EIA) reports that the Gulf Coast percentage of natural gas production went from 18 percent in 2005 to 6 percent in 2013. On the other hand, overall reliance on gas for electricity has gone up, creating a new interdependence and grid vulnerability. Furthermore, additional export infrastructure resulting from the natural gas boom would increase vulnerabilities to coastal threats, such as sea-level rise.

Dependencies and interdependencies are growing. Many components of liquid fuels and natural gas systems—including pumps, refineries, and about 5 percent of natural gas compressor stations—require electricity to operate. The interdependency of the electricity and gas systems is growing as more gas is used in power generation.

Aging, leak-prone natural gas distribution pipelines and associated infrastructures prompt safety and environmental concerns. Most safety incidents involving natural gas pipelines occur on natural gas distribution systems. These incidents tend to occur in densely populated areas.

Selected Recent Federal Government Actions

The Federal Government, the states, and the private sector all play crucial roles in ensuring that energy infrastructures are reliable, resilient, and secure. In 2013, President Obama released Presidential Policy Directive-21, *Critical Infrastructure Security and Resilience*, establishing national policy on critical infrastructure security and resilience and refining and clarifying the critical infrastructure-related functions, roles, and responsibilities across the Federal Government, as well as enhancing overall coordination and collaboration. The directive applies to all critical infrastructures, but calls out energy infrastructures as being *uniquely* critical due to the enabling functions they provide across all other critical infrastructures. Other recent Federal Government actions include the following:

- **Creating the Build America Investment Initiative.** The Administration has created this initiative—an interagency effort led by the Departments of Treasury and Transportation—to promote increased investment in U.S. infrastructure, particularly through public-private partnerships.
- **Enhancing grid resilience to geomagnetic storms.** In June 2014, the Federal Energy Regulatory Commission adopted a new reliability standard to mitigate the impacts of geomagnetic disturbances on the grid. In November 2014, the Administration established an interagency Space Weather Operations, Research, and Mitigation Task Force to develop a National Space Weather Strategy, to include mitigation of grid vulnerability.
- **Improving safety of natural gas transmission pipelines.** The Pipeline and Hazardous Materials Safety Administration of the Department of Transportation (DOT) is currently developing a proposed rule on integrity management for natural gas pipelines. In addition, the Federal Energy Regulatory Commission has issued a policy statement that will allow interstate natural gas pipelines to recover certain expenditures made to modernize pipeline system infrastructure in a manner that enhances system reliability, safety, and regulatory compliance.
- **Developing and operating regional refined petroleum product reserves.** DOE created the Northeast Gasoline Supply Reserve in 2014 and continues to manage the Northeast Home Heating Oil Reserve.
- **Enhancing emergency preparedness.** The National Petroleum Council, in response to a request from the Secretary of Energy, recently completed an Emergency Preparedness Study to help industry and government achieve a more rapid restoration of motor fuel supplies after a natural disaster.

Recommendations in Brief

To continue to drive progress toward addressing these TS&D infrastructure challenges, we recommend taking the following additional actions:

Develop comprehensive data, metrics, and an analytical framework for energy infrastructure resilience, reliability, safety, and asset security. DOE, in collaboration with the Department of Homeland Security and interested infrastructure stakeholders, should develop common analytical frameworks, tools, metrics, and data to assess the resilience, reliability, safety, and security of energy infrastructures.

Establish a competitive program to accelerate pipeline replacement and enhance maintenance programs for natural gas distribution systems. DOE should establish a program to provide financial assistance to states to incentivize cost-effective improvements in the safety and environmental performance of natural gas distribution systems through targeted funding to offset incremental costs to low-income households and funding for enhanced direct inspection and maintenance programs.

Support the updating and expansion of state energy assurance plans. DOE should undertake a multi-year program of support for state energy assurance plans, focusing on improving the capacity of states and localities to identify potential energy disruptions, quantify their impacts, share information, and develop and exercise comprehensive plans that respond to those disruptions and reduce the threat of future disruptions.

Establish a competitive grant program to promote innovative solutions to enhance energy infrastructure resilience, reliability, and security. DOE should establish a program to provide competitively awarded grants to states to demonstrate innovative approaches to TS&D infrastructure hardening and enhancing resilience and reliability. A major focus of the program would be the demonstration of new approaches to enhance regional grid resilience, implemented through the states by public and publicly regulated entities on a cost-shared basis.

Analyze the policies, technical specifications, and logistical and program structures needed to mitigate the risks associated with loss of transformers. As part of the Administration's ongoing efforts to develop a formal national strategy for strengthening the security and resilience of the entire electric grid for threats and hazards (planned for release in 2015), DOE should coordinate with the Department of Homeland Security and other Federal agencies, states, and industry on an initiative to mitigate the risks associated with the loss of transformers. Approaches for mitigating this risk should include the development of one or more transformer reserves through a staged process.

Analyze the need for additional or expanded regional product reserves. DOE should undertake updated cost-benefit analyses for all of the regions of the United States that have been identified as vulnerable to fuel supply disruptions to inform subsequent decisions on the possible need for additional regional product reserves.

Integrate the authorities of the President to release products from regional petroleum product reserves into a single, unified authority. Congress should amend the trigger for the release of fuel from the Northeast Home Heating Oil Reserve and from the Northeast Gasoline Supply Reserve so that they are aligned and properly suited to the purpose of a product reserve, as opposed to a crude oil reserve.

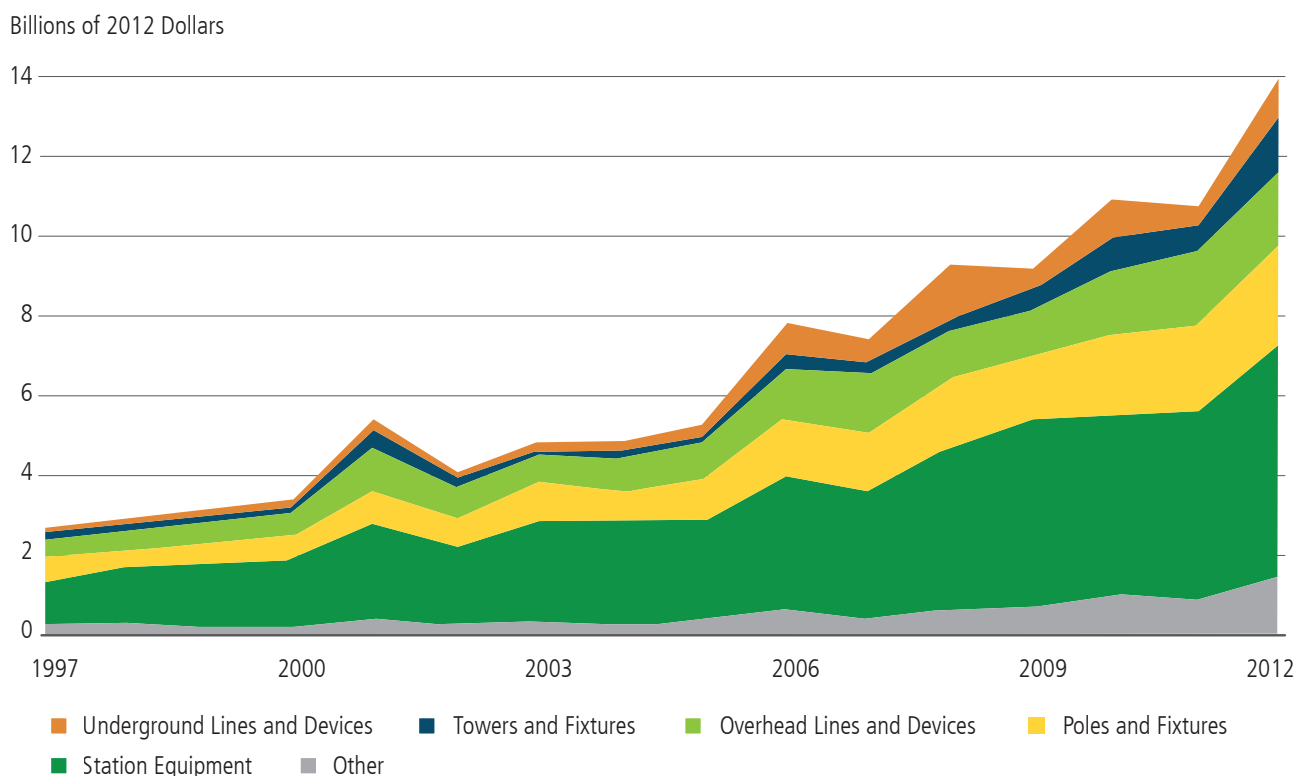
Modernizing the Electric Grid

Electricity is central to the well-being of the Nation. The United States has one of the world’s most reliable, affordable, and increasingly clean electric systems, but the U.S. electric system is currently at a strategic inflection point—a time of significant change for a system that had had relatively stable rules of the road for nearly a century. The U.S. electricity sector is being challenged by a variety of new forces, including a changing generation mix; low load growth; increasing vulnerability to severe weather because of climate change; and growing interactions at the Federal, state, and local levels. Innovative technologies and services are being introduced to the system at an unprecedented rate—often increasing efficiency, improving reliability, and empowering customers, but also injecting uncertainty into grid operations, traditional regulatory structures, and utility business models. Modernizing the grid will require that these challenges be addressed.

Key Findings

Investments in transmission and distribution upgrades and expansions will grow. It is anticipated that in the next two decades, large transmission and distribution investments will be made to replace aging infrastructure; maintain reliability; enable market efficiencies; and aid in meeting policy objectives, such as GHG reduction and state renewable energy goals. Recent increases in investment in transmission infrastructure by investor-owned utilities are shown in Figure SPM-5.

Figure SPM-5. Investment in Transmission Infrastructure by Investor-Owned Utilities, 1997–2012



Chapter 3, Figure 3-3.

Both long-distance transmission and distributed energy resources can enable lower-carbon electricity. The transmission network can enable connection to high-quality renewables and other lower-carbon resources far from load centers; distributed energy resources can provide local low-carbon power and efficiency.

The potential range of new transmission construction is within historic investment magnitudes. Under nearly all scenarios analyzed for the QER, circuit-miles of transmission added through 2030 are roughly equal to those needed under the base case, and while those base case transmission needs are significant, they do not appear to exceed historical yearly build rates.

Flexible grid system operations and demand response can enable renewables and reduce the need for new bulk-power-level infrastructure. End-use efficiency, demand response, storage, and distributed generation can reduce the expected costs of new transmission investment.

Investments in resilience have multiple benefits. Investments in energy efficiency, smart grid technologies, storage, and distributed generation can contribute to enhanced resiliency and reduced pollution, as well as provide operational flexibility for grid operators.

Innovative technologies have significant value for the electricity system. New technologies and data applications are enabling new services and customer choices. These hold the promise of improving consumer experience, promoting innovation, and increasing revenues beyond the sale of electric kilowatt-hours.

Enhancing the communication to customer devices that control demand or generate power will improve the efficiency and reliability of the electric grid. For example, open interoperability standards for customer devices and modified standards for inverters will improve the operation of the grid.

Appropriate valuation of new services and technologies and energy efficiency can provide options for the utility business model. Accurate characterization and valuation of services provided to the grid by new technologies can contribute to clearer price signals to consumers and infrastructure owners, ensuring affordability, sustainability, and reliability in a rapidly evolving electricity system.

Consistent measurement and evaluation of energy efficiency is essential for enhancing resilience and avoiding new transmission and distribution infrastructure. Efficiency programs have achieved significant energy savings, but using standard evaluation, measurement, and verification standards, like those recommended by DOE's Uniform Methods Project, is key to ensuring that all the benefits of efficiency are realized, including avoiding the expense of building new infrastructure.

States are the test beds for the evolution of the grid of the future. Innovative policies at the state level that reflect differences in resource mix and priorities can inform Federal approaches.

Different business models and utility structures rule out “one-size-fits-all” solutions to challenges. A range of entities finance, plan, and operate the grid. Policies to provide consumers with affordable and reliable electricity must take into account the variety of business models for investing, owning, and operating grid infrastructure.

Growing jurisdictional overlap impedes development of the grid of the future. Federal and state jurisdiction over electric services are increasingly interacting and overlapping.

Selected Recent Federal Government Actions

In addition to resilience-related activities aimed at the electric grid (e.g., large power transformer) discussed in the Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure), the Administration has undertaken the following activities aimed at creating the electric grid of the future:

- **Promoting grid modernization.** DOE has made a comprehensive grid modernization proposal in the President's Fiscal Year (FY) 2016 Budget request. The crosscutting proposal supports strategic DOE investments in foundational technology development, enhanced security capabilities, and greater institutional support and stakeholder engagement, all of which are designed to provide the tools necessary for the evolution to the grid of the future. Specific elements include the following:

- A new State Energy Reliability and Assurance Grants program for grants to states, localities, regions, and tribal entities for electricity TS&D reliability planning.
- A program directed at research and development (R&D) on transformer protection from geomagnetic fields.
- Increases directed at improved controls, sensors, power electronics, and connection to energy storage.
- Increases in the Smart Grid program to develop next-generation distribution management system and controls to accommodate new end-use technologies and develop microgrid systems.
- Increases in R&D to improve building control system interoperability with new grid control systems and improve building internal controls to adapt to efficient and improved grid connectivity.
- Increases to link plug-in electric vehicle systems to building and grid systems.

Recommendations in Brief

The Administration and Congress should support or incentivize investment in electricity infrastructure reliability, resilience, and affordability through the development of tools, methods, and new funding for planning and operating the grid of the future. Accordingly, we recommend the following:

Provide grid modernization R&D, analysis, and institutional support. DOE should continue to pursue a multi-year, collaborative, and cost-shared research and development, analysis, and technical assistance program for technology innovation that supports grid operations, security, and management; and for analyses, workshops, and dialogues to highlight key opportunities and challenges for new technology to transform the grid.

Establish a framework and strategy for storage and grid flexibility. DOE should conduct regional and state analyses of storage deployment to produce a common framework for the evaluation of benefits of storage and grid flexibility, and a strategy for enabling grid flexibility and storage that can be understood and implemented by a wide range of stakeholders.

Conduct a national review of transmission plans and assess barriers to their implementation. DOE should carry out a detailed and comprehensive national review of transmission plans, including assessments on the types of transmission projects proposed and implemented, current and future costs, consideration of interregional coordination, and other factors. A critical part of this review should be to assess incentives and impediments to the development of new transmission.

Provide state financial assistance to promote and integrate TS&D infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection. In making awards under this program, DOE should require cooperation within the planning process of energy offices, public utility commissions, and environmental regulators within each state; with their counterparts in other states; and with infrastructure owners and operators and other entities responsible for maintaining the reliability of the bulk power system.

Coordinate goals across jurisdictions. DOE should play a convening role to bring together public utility commissioners, legislators, and other stakeholders at the Federal, state, and tribal levels to explore approaches to integrate markets, while respecting jurisdictional lines, but allowing for the coordination of goals across those lines.

Value new services and technologies. DOE should play a role in developing frameworks to value grid services and approaches to incorporate value into grid operations and planning. It should convene stakeholders to define the characteristics of a reliable, affordable, and environmentally sustainable electricity system and create approaches for developing pricing mechanisms for those characteristics. The goal should be to develop frameworks that could be used by the Federal Energy Regulatory Commission, state public utility commissions in ratemaking proceedings, Regional Transmission Organizations in their market rule development, or utilities in the operation and planning of their systems.

Improve grid communication through standards and interoperability. In conjunction with the National Institute of Standards and Technology and other Federal agencies, DOE should work with industry, the Institute of Electrical and Electronics Engineers, state officials, and other interested parties to identify additional efforts the Federal Government can take to better promote open standards that enhance connectivity and interoperability on the electric grid.

Establish uniform methods for monitoring and verifying energy efficiency. Through its Uniform Methods Project, DOE should accelerate the development of uniform methods for measuring energy savings and promote widespread adoption of these methods in public and private efficiency programs.

Modernizing U.S. Energy Security Infrastructures in a Changing Global Marketplace

Until recently, the concept of energy security has focused on “oil security” as a proxy for “energy security.” It is clear, however, that energy security needs to be more broadly defined to cover not only oil, but other sources of supply, and to be based not only on the ability to withstand shocks, but also to be able to recover quickly from any shocks that do occur. In addition, security is not exclusively domestic; it is dependent on interactions in the interconnected global energy market. U.S. energy security and the infrastructure that supports it should be viewed in the context of this new, broader, more collective definition of energy security.

Key Findings

Multiple factors affect U.S. energy security. These include U.S. oil demand; the level of oil imports; the adequacy of emergency response systems; fuel inventory levels; fuel substitution capacity; energy system resilience; and the flexibility, transparency, and competitiveness of global energy markets.

The United States has achieved unprecedented oil and gas production growth. Oil production growth has enabled the United States to act as a stabilizing factor in the world market by offsetting large sustained supply outages in the Middle East and North Africa and, later, contributing to a supply surplus that has reduced oil prices to levels not seen since March 2009. The natural gas outlook has also changed tremendously. Just 10 years ago, it was projected that the United States would become highly dependent on liquefied natural gas imports, whereas the current outlook projects that the United States will have enormous capacity and reserves and could become a major liquefied natural gas exporter.

The United States is the world’s largest producer of petroleum and natural gas. Combined with new clean energy technologies and improved fuel efficiency, U.S. energy security is stronger than it has been for over half a century. Nonetheless, challenges remain in maximizing the energy security benefits of our resources in ways that enhance our competitiveness and minimize the environmental impacts of their use.

The network of oil distribution (“the midstream”) has changed significantly. Product that had historically flowed through pipelines from south to north now moves from north to south, and multiple midstream modes (pipelines, rail, and barges) are moving oil from new producing regions to refineries throughout the United States.

The SPR’s ability to offset future energy supply disruptions has been adversely affected by domestic and global oil market developments coupled with the need for upgrades. Changes in the U.S. midstream (for example, competing commercial demands and pipeline reversals) and lower U.S. dependence on imported oil have created challenges to effectively distributing oil from the reserve. This diminishes the capacity of the SPR to protect the U.S. economy from severe economic harm in the event of a global supply emergency and associated oil price spike.

Increasing domestic oil production has focused attention on U.S. oil export laws established in the aftermath of the 1973–1974 Arab Oil Embargo. There are now concerns that the U.S. oil slate may be too light for U.S. refineries; although, recent Department of Commerce clarifications that liquid hydrocarbons, after they have been processed through a crude oil distillation tower, are petroleum products, and therefore eligible for export, will help avoid adverse production impacts.

An extensive network of pipelines, electric transmission lines, roads, rail, inland waterways, and ports link the United States with Mexico and Canada. These systems provide not only economic value to all three nations, but also enhance continental energy security and improve system reliability.

Biofuel production in the United States has increased rapidly over the last decade, enhancing energy security and reducing emissions of GHGs from transportation. This growth has been driven in part by the Renewable Fuel Standard. Ethanol now displaces approximately 10 percent of U.S. gasoline demand by volume; biodiesel, advanced, and cellulosic biofuel production volumes have also been growing. Continued growth in ethanol use will depend in part on investment in additional distribution capacity; growth in the use of other biofuels, such as “drop-in” fuels, will depend on continued investment in research, development, demonstration, and deployment.

Selected Recent Federal Government Actions

- **Testing the capabilities of the SPR.** In March 2014, DOE conducted a test sale to demonstrate the drawdown and distribution capacity of the SPR. This test sale highlighted changes in the distribution infrastructure in the Gulf Coast region.
- **Addressing SPR deferred maintenance backlogs.** The President’s FY 2016 Budget Request provided \$257 million for the development, operation, and management of the SPR, including funding to address the backlog of deferred maintenance on the SPR.
- **Addressing changes in propane TS&D infrastructure.** DOE has responded to changes in TS&D infrastructure for propane and other natural gas liquid by adding capability at the EIA to monitor propane inventories on a more granular, state-by-state basis.

Recommendations in Brief

Update SPR release authorities to reflect modern oil markets. Congress should update SPR release authorities to allow the SPR to be used more effectively to prevent serious economic harm to the United States in case of energy supply emergencies.

Invest to optimize the SPR’s emergency response capability. DOE should analyze appropriate SPR size and configuration, and, after carrying out detailed engineering studies, DOE should make infrastructure investments to the SPR and its distribution systems to optimize the SPR’s ability to protect the U.S. economy in an energy supply emergency.

Support other U.S. actions related to the SPR and energy security infrastructures that reflect a broader and more contemporary view of energy security. The United States should continue to consult with allies and key energy trading partners on energy security issues, building on the G-7 principles on energy security.

Support fuels diversity through research, demonstration, and analysis. DOE and the Department of Defense should continue research and demonstration activities to develop biofuels that are compatible with existing petroleum fuel infrastructure, especially in aviation and for large vehicles. DOE should provide technical support to states, communities, or private entities wishing to invest in infrastructure to dispense higher-level ethanol blends. DOE should ensure adequate support for data collection and analysis on fuels, like propane, that play an important role in the Nation’s diverse energy mix and are challenged by changing TS&D infrastructures.

Undertake a study of the relationship between domestic shipping and energy security. The relevant agencies should conduct a study of the economic, engineering, logistics, workforce, construction, and regulatory factors affecting the domestic shipping industry’s ability to support U.S. energy security. The Secretary of Transportation should ensure that the National Maritime Strategy includes a consideration of the energy security aspects of maritime policy in its discussion and recommendations.

Improving Shared Transport Infrastructures

Changes in U.S. energy production and use are stressing and transforming the way that energy and other commodities are transported in the United States. Some energy commodities, such as coal and ethanol, have traditionally relied on rail and barge transport to move from suppliers to distribution points and end users. Their use of transportation modes (e.g., rail, barge, and truck transport) that are also shared by agricultural and other major commodities is being joined by significant growth in the use of these transport modes by crude oil, refined petroleum products, and petrochemicals. Increasingly, the shipment of oil from the wellhead to a refinery may employ a combination of trucks, pipelines, railcars, barges, and other marine vessels—giving oil transportation in the United States an increasingly multi-modal character. Since these transportation modes have been, and continue to be, used for transporting other commodities, they are considered in the QER to be “shared transport infrastructures” for energy commodities. The increased utilization of rail, barge, and truck for oil transport, as well as for other energy supplies and materials, exacerbates underlying issues in these shared transport infrastructures and underscores the need for an expanded infrastructure investment as proposed by the Administration.

Key Findings

Rapid crude oil production increases have changed the patterns of flow of North American midstream (pipelines, rail, and barge) liquids transport infrastructure. Pipelines that previously delivered crude oil from the Gulf of Mexico to Midcontinent refineries have now changed direction to deliver domestic and Canadian oil to the Gulf of Mexico. In addition, oil produced in North Dakota is now being shipped to refineries on the East and West Coasts of the United States. As a result, modes of transport other than pipelines are being employed to move crude oil, including a significant increase in crude oil unit trains and barge shipments.

Limited infrastructure capacities are intensifying competition among commodities, with some costs passed on to consumers. Until new additional capacity becomes available, the competition among commodity groups for existing capacity will intensify. The proximity of Bakken crude oil movements and Powder River Basin coal movements, along with agricultural shipments in the region, affect Midwest power plants and the food industry. Typically, rail and barge service are the most cost-effective shipping methods available for moving grain and other relatively low-value, bulk agricultural commodities, and the Department of Agriculture has indicated that disruptions to agricultural shipments caused by recent unexpected shifts in supply and demand for rail services exceed even those caused by Hurricane Katrina.

Rail, barge, and truck transportation are crucial for ethanol shipment. Ethanol production in the United States has increased over the last few decades. Ethanol is typically shipped from production plants by rail and then delivered by truck (or directly by rail or barge) to petroleum product terminals. Ethanol is likely to rely on shared infrastructure for its transport for the foreseeable future.

The ability to maintain adequate coal stockpiles at some electric power plants has been affected by rail congestion. The Surface Transportation Board (STB) recently acted to require weekly reports of planned versus actual loadings of coal trains.

Funding for the U.S. freight transportation system is complex and involves a combination of Federal, state, local, and private investments. Railroad infrastructure is primarily owned and maintained by the private sector. The marine transportation infrastructure involves a mix of Federal, state, local, and private investments, and roadways are owned and maintained by a range of Federal, state, local, and—in some cases—even private entities.

Navigable waterways are essential for the movement of energy commodities, equipment, and materials, especially petroleum and refined petroleum products. Investments in construction, rehabilitation, and maintenance of this infrastructure must be balanced against other investments, including other water resource investments, such as flood and coastal storm damage reduction projects and aquatic ecosystem restoration.

Increased transportation of crude oil by rail and barge has highlighted the need for additional safeguards. For rail transport, in particular, the Federal Government has a number of efforts underway, including a rulemaking on improving the safety of rail transport of crude oil, including more robust tank car standards and operational requirements, to address these concerns.

Multi-modal shared transportation infrastructure is stressed by increased shipments of energy supplies, materials, and components. Wind turbine blades, for example, have more than tripled in length since the 1980s. Transporting components of this size (and others of significant weight and size, such as large power transformers) creates a range of challenges, including stress on roads, many of which are rural; the need to coordinate movement through ports, tunnels, overpasses, and turning areas; and additional permitting and police escort requirements.

Selected Recent Federal Government Actions

The stresses on shared transport infrastructures as a result of changes in energy production have resulted in a series of responses and initiatives across the Administration, including both regulatory initiatives on the part of responsible agencies for specific infrastructures and broader initiatives to provide new resources to help the modernization of these shared infrastructures. These include the following:

- **Addressing congestion and service for rail transport of commodities.** In light of the problems of rail congestion affecting shipments of key commodities, STB, an independent regulatory body in DOT, has taken a number of actions. Starting in October 2014, STB has required all major (Class I) railroads to publicly file weekly data reports regarding service performance of unit trains carrying coal, crude oil, ethanol, and grain. In December 2014, STB initiated a formal notice and comment rulemaking proceeding for weekly performance data reporting by the Class I railroads and also the freight railroads serving the Chicago gateway. STB has two ongoing proceedings on rail business practices aimed at helping shippers to have competitive access to railroads and be protected against unreasonable freight rail transportation rates.
- **Improving safe shipment of crude oil by rail.** DOT and other Federal agencies have been taking action to respond to heightened awareness and concern over rail shipments of crude oil from the Bakken and ethanol. DOT issued a proposed rule in August 2014 containing comprehensive proposed standards to improve the rail transportation safety of flammable liquids, including unit trains of crude oil and ethanol. A final rule is anticipated to be issued in May 2015. DOE, in cooperation with the Pipeline and Hazardous Materials Safety Administration, is supporting studies on the properties (including behavior in fires) of crude oil. The Federal Emergency Management Agency has assessed training needs and requirements in 28 states with oil rail routes identified by DOT. The interagency National Response Team Training Subcommittee launched Emerging Risks Responder Awareness Training for Bakken Crude Oil to help responders better prepare for these incidents.

- **Doubling the size of the Inland Waterways Trust Fund.** This fund currently pays 50 percent of the Federal cost for construction, replacement, rehabilitation, and expansion costs for inland and intracoastal waterways. In December 2014, Congress authorized an increase in the fuel tax supporting this fund from the current \$0.20 per gallon to \$0.29 per gallon, which took effect April 1, 2015. In addition, the President's Fiscal Year 2016 Budget proposes a new per-vessel user fee that will raise \$1.1 billion over the next 10 years, effectively doubling the level of resources available in the Fund.
- **Helping ports through the DOT Maritime Administration StrongPorts initiative.** This program is developing tools and initiatives helpful to port authorities that are pursuing modernization projects, including those interested in public-private partnerships. While the StrongPorts initiative does not provide direct financial assistance, the recently released guide provides an additional resource regarding financing for ports.
- **Creating a multi-modal freight grant program through the GROW AMERICA Act.** The Administration has proposed the GROW AMERICA Act, which includes \$18 billion over 6 years to establish a new multi-modal freight grant program to fund innovative rail, highway, and port facilities that will improve the efficient movement of goods across the country. The Generating Renewable, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities throughout America Act (GROW AMERICA Act) also will give shippers and transportation providers a stronger role in working with states to collaborate and establish long-term freight strategic plans.
- **Expanding funding for the DOT TIGER grant program.** The Transportation Investment Generating Economic Recovery (TIGER) program is a competitive grant program that funds state and local transportation projects across the United States. The Administration's GROW AMERICA Act proposal will provide \$7.5 billion over 6 years to the TIGER grant program, more than doubling it.

Recommendations in Brief

Enhance the understanding of important safety-related challenges of transport of crude oil and ethanol by rail and accelerate responses. Key activities at DOE and DOT should be strongly supported.

Further analyze the effects of rail congestion on the flow of other energy commodities, such as ethanol and coal. DOE, STB, and the Federal Energy Regulatory Commission should continue to develop their understanding of how rail congestion may affect the delivery of these energy commodities.

Analyze the grid impacts of delayed or incomplete coal deliveries. In assessing these issues, the Federal Energy Regulatory Commission and DOE should examine whether a minimum coal stockpile for electricity reliability should be established for each coal-fired unit.

Address critical energy data gaps in the rail transport of energy commodities and supplies. Congress should fund the President's FY 2016 Budget Request for the EIA to address critical energy transportation data gaps and continued data sharing with the STB.

Support alternative funding mechanisms for waterborne freight infrastructure. The Administration should form an ongoing Federal interagency working group to examine alternative financing arrangements for waterborne transportation infrastructure and to develop strategies for public-private partnerships to finance port and waterway infrastructure.

Support a new program of competitively awarded grants for shared energy transport systems. A new grant program—Actions to Support Shared Energy Transport Systems, or ASSETS—should be established and supported at DOT, in close cooperation with DOE. This program should be dedicated to improving energy

transportation infrastructure connectors. A Federal investment in ASSETS would likely mobilize additional and significant non-Federal investment, based on typical TIGER cost shares.

Support public-private partnerships for waterborne transport infrastructure. Developing a set of shared priorities for investment ensures that public and private sector needs are met.

Coordinate data collection, modeling, and analysis. DOE should lead an interagency effort with DOT, the Department of Agriculture, the Army Corps of Engineers, and the Coast Guard—in cooperation with other relevant agencies with data regarding marine, rail, and other energy transport modes—to improve and coordinate their respective data collection, analytical, and modeling capabilities for energy transport on shared infrastructures.

Assess the impacts of multi-modal energy transport. DOE, working with DOT and the Army Corps of Engineers, should conduct a one-time comprehensive needs assessment of investment needs and opportunities to upgrade the Nation's energy-related shared water transport infrastructure.

Assess energy component transportation. DOE, in coordination with relevant agencies, should examine routes for transportation of energy system-related equipment, materials, and oversized components. The assessment would include the capacity of the Nation's transportation infrastructure systems to safely accommodate more frequent and larger shipments where analyses indicate such transport will be required.

Integrating North American Energy Markets

The United States, Canada, and Mexico, as well as other North American neighbors, benefit from a vast and diverse energy TS&D network that has enabled the region to achieve economic, energy security, and environmental goals. Continued integration of the North American energy markets will increase those benefits and address structural changes and constraints that have arisen since new production, processing, consumption, and policies have taken effect.

Energy system integration is in the long-term interest of the United States, Canada, and Mexico, as it expands the size of energy markets, creates economies of scale to attract private investment, lowers capital costs, and reduces energy costs for consumers. There is already a robust energy trade between the United States and Canada (more than \$140 billion in 2013) and the United States and Mexico (more than \$65 billion in 2012).

The scope and magnitude of the existing and ongoing energy integration among the United States, Canada, and Mexico goes far beyond any one particular infrastructure or project, and continuing to foster this integration is an enduring interest on the part of each country. While a smaller market, there are also needs and opportunities for greater energy trade and integration with individual nations and islands in the Caribbean.

The North American Arctic region, including Alaska and U.S. territorial waters in the Bering, Chukchi, and Beaufort Seas, as well as Canada and its territorial waters, is experiencing rapid changes on land and at sea due to the changing climate. These changes have important implications for TS&D infrastructure in this region. Warming in the North American Arctic is resulting in increased risk of land subsidence from thawing permafrost, which threatens TS&D infrastructure. It also leads to a reduction in late-summer sea ice extent, which will affect offshore energy and mineral exploration and extraction in U.S. and Canadian waters.

Key Findings

The United States has significant energy trade with Canada and Mexico, including oil and refined products, gas, and electricity. Canada is the largest energy trading partner of the United States, with energy trade valued at \$140 billion in 2013. Mexican energy trade was valued at \$65 billion in 2012. Both countries are reliable sources of secure energy supplies.

Greater coordination will improve energy system efficiency and build resiliency to disruptions of the North American energy market, data exchanges, and regulatory harmonization.

The electricity systems of the United States and Canada are fully interconnected. There are currently more than 30 active major transmission connections between the United States and Canada, trading approximately \$3 billion worth of electricity in 2014. If the transmission projects filed with DOE in the last 5 years are constructed, they would add approximately 4,100 megawatts of additional hydropower to the U.S. electricity mix.

Canadian natural gas production is expected to slightly outpace consumption with exports rising slowly over the projection period. Oil production is anticipated to continue to grow over the next 30 years.

Mexico has reformed its energy sector. Mexico amended its constitution and reformed its energy sector in 2013, retaining government control over its assets while opening oil and gas resources to private sector exploration and development. These reforms provide an opportunity for increased trade with the United States.

Increasing U.S. natural gas exports may help Mexico generate more gas-fired electricity and achieve its environmental goals.

Changing climate conditions in the Arctic are expected to continue with the melting of permafrost and reduced sea ice extent, which will affect increasing energy development that is underway. This presents both an opportunity for greater cooperation between the United States and Canada, but also a need for both countries to undertake risk mitigation.

There is an opportunity to lower Caribbean electricity costs and emissions. The Caribbean is largely reliant on foreign sources of oil with little energy resources of its own. Energy demand is driven largely by electricity generation, mostly from fuel oil. A 30 percent decrease in carbon dioxide (CO₂) emissions could be achieved by displacement of fuel oil by natural gas—and even more if this were combined with renewable energy.

Selected Recent Federal Government Actions

Recognizing the importance of North American energy, the Administration has been undertaking a number of activities to promote market integration and to address the challenges we share in the North American Arctic region, including the following:

- **Improving data exchange.** The United States, Canada, and Mexico are creating a framework for the sharing of publicly available information and data on their respective energy systems. This initiative was formalized in a memorandum of understanding (MOU) signed by DOE, Canada's Ministry of Natural Resources, and Mexico's Ministry of Energy on December 15, 2014. The President's FY 2016 Budget Request provides an increase of \$1 million to the EIA for the purpose of carrying out this collaboration.
- **Leading the Arctic Council.** In April 2015, the United States assumed the chairmanship of the Arctic Council for a 2-year period. This will provide the United States with the opportunity to implement increased international collaboration in such areas as addressing the impact of climate change and Arctic Ocean stewardship and scientific research. In addition to this leadership role in Arctic policy, there is an opportunity for increased and enduring cooperation between the United States and Canada on issues such as Arctic energy infrastructure and climate and ocean science as an important future dimension to the U.S.-Canadian energy relationship.

- **Partnering with remote communities to develop renewable energy.** DOE's National Renewable Energy Laboratory, in partnership with the Department of the Interior, has developed the Remote Communities Renewable Energy partnership to develop, demonstrate, and deploy smaller-scale technologies for remote communities, such as in the Arctic, to utilize local renewable energy resources, reduce diesel fuel dependence and distribution requirements, and create an independent microgrid operation.
- **Pursuing a Caribbean Energy Security Initiative.** In 2014, Vice President Biden announced the Caribbean Energy Security Initiative, which recognizes the diversity of Caribbean nation economies, natural resources, and energy constraints. Led by the State Department, in coordination with the U.S. Overseas Private Investment Corporation, DOE, and other agencies, the initiative seeks to improve energy sector governance, to increase access to affordable finance, and to improve communication and coordination among regional governments and their development partners.

Recommendations in Brief

Continue advances that have been made in the North American energy dialogue. All three countries should encourage further business exchanges and regular minister-level engagement.

Increase the integration of energy data among the United States, Canada, and Mexico. Provide resources for the EIA to collaborate with its Canadian and Mexican counterparts to systematically compare their respective export and import data, validate data, and improve data quality. In addition, efforts should be taken to better share geographic information system data to develop energy system maps and review forward-looking assessments and projections of energy resources, flows, and demand.

Undertake comparative and joint energy system modeling, planning, and forecasting. Enhance comparative and joint modeling, planning, and forecasting activities among U.S., Canadian, and Mexican energy ministries and related governmental agencies. The current scale of activities has aided bilateral and individual goals; however, increasing trilateral engagement on planning, modeling, or forecasting activities would capture greater efficiencies and enhance each country's ability to reach economic, security, and environmental goals. DOE's Offices of Energy Policy and Systems Analysis and International Affairs would lead modeling workshops with their Canadian and Mexican counterparts to share methodologies and collaborate on North American analysis.

Establish programs for academic institutions and not-for-profits to develop legal, regulatory, and policy roadmaps for harmonizing regulations across borders. In partnership with universities, qualified not-for-profits, and relevant U.S. energy regulatory authorities, state/provincial, local, and national energy regulations will be compared to identify gaps, best practices, and inconsistencies with regulations in Canada and/or Mexico with the goal of harmonization.

Coordinate training and encourage professional interactions. This should involve the technical staff in government agencies of the three North American countries that share similar responsibilities to evaluate and implement cross-border energy projects.

Partner with Canada and the Arctic Council on Arctic energy safety, reliability, and environmental protection. Joint work should emphasize research and information sharing on the effects of spills and the effectiveness of countermeasures, the identification and mobilization of the resources necessary to mitigate the effects of a pollution incident, and the development of international guidelines for preparedness and response in this logistically challenging region.

Partner with Canada and the Arctic Council on energy delivery to remote areas. This should be done through promoting and disseminating the work of the Remote Community Renewable Energy partnership.

Promote Caribbean energy TS&D infrastructure. As part of a larger Caribbean strategy, the United States should support the diversification of energy supplies, including actions to facilitate the introduction of cleaner forms of energy and development of resilient energy TS&D infrastructure in the Caribbean.

Addressing Environmental Aspects of TS&D Infrastructure

Energy TS&D infrastructure affects the environment in a variety of ways. While it is important to address the direct environmental impacts and vulnerabilities of TS&D infrastructure, this infrastructure also has enormous potential to enable better environmental performance for the energy system more broadly. Key examples include CO₂ pipeline infrastructure to enable carbon sequestration, smart grid technologies to enable energy efficiency, and long-distance transmission to enable utilization of remote renewable resources. Energy efficiency also reduces the need for new infrastructure with all of its attendant challenges.

Understanding the potential positive and negative effects of TS&D infrastructure, then, on the achievement of overall environmental goals—including climate mitigation—is key to siting, constructing, operating, and maintaining TS&D infrastructure in an environmentally responsible manner. Many QER recommendations in other chapters touch on actions that will enhance the ability of the United States to achieve its environmental goals. This chapter focuses on those that relate specifically to the environmental impacts posed by TS&D infrastructure itself.

Key Findings

TS&D infrastructure can serve as a key enabler for—or barrier to—better environmental outcomes.

Certain types of TS&D infrastructure enable improvements in system-wide environmental performance at lower cost, such as electric transmission and distribution infrastructure to access renewable energy resources and interstate natural gas pipelines which can facilitate CO₂ emission reductions from the electric power sector.

TS&D infrastructure contributes a relatively small share of total air and water pollution from the energy sector. TS&D infrastructure covered by this installment of the QER contributes to nearly 10 percent of U.S. GHG emissions. Many of the environmental issues related to TS&D infrastructure are subject to rules established by existing statute and regulation.

Energy infrastructure can have direct, indirect, and cumulative land-use and ecological impacts. The nature and magnitude of those impacts depend on a number of factors, including whether construction of a facility will affect endangered species or sensitive ecological areas, or cause land-use impacts such as top-soil erosion or habitat fragmentation.

Energy transport, refining, and processing infrastructure contribute to emissions of criteria air pollutants that pose risks to public health and the environment. Ports and rail yards with high densities of vehicles and congestion often have high concentrations of pollutants and increase risks to nearby urban communities. Reducing emissions of particulate matter from aircraft, locomotives, and marine vessels would have public health benefits. Low-income and minority households are two to three times more likely to be affected by freight-based diesel particulate pollution than the overall U.S. population.

Transportation of crude oil by pipeline, rail, and waterborne vessels has safety and environmental impacts. The Federal Government has a number of efforts underway to mitigate these impacts, including a rulemaking on rail transport of crude oil.

The United States currently has a network of more than 4,500 miles of CO₂ transportation pipelines that can be a critical component of a low-carbon future. The pipelines mostly transport naturally occurring CO₂, but new projects are increasingly linking captured CO₂ from electric power plants and other industrial sources to a productive use in oil fields (through CO₂ enhanced oil recovery) and safe storage in deep saline formations.

Selected Recent Federal Government Actions

In addition to the efforts to improve natural gas pipeline safety discussed under Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure), which will have environmental benefits, the Administration is undertaking a number of other initiatives to reduce methane emissions and address environmental effects of TS&D infrastructure. They include the following:

- **Setting a national goal to reduce methane emissions.** Building on the 2014 interagency Strategy to Reduce Methane Emissions, in January 2015, the President announced a national goal to reduce methane emissions from the oil and gas sector by 40 percent to 45 percent from 2012 levels by 2025.
- **Establishing standards for methane emissions from new and modified sources.** The Environmental Protection Agency (EPA) has initiated a rulemaking to set standards for methane and volatile organic compound emissions from new and modified oil and gas production sources and natural gas processing and transmission sources. EPA will issue a proposed rule in the summer of 2015, and a final rule will follow in 2016.
- **Modernizing natural gas transmission and distribution infrastructure.** Following on its methane roundtables, DOE is taking steps to encourage reduced GHG emissions, including the following:
 - Issuing energy efficiency standards for natural gas and air compressors
 - Funding was proposed in the FY 2016 Budget to advance R&D to bring down the cost of detecting leaks and to improve estimates of methane emissions from midstream natural gas infrastructure for incorporation into EPA's Greenhouse Gas Inventory
 - Implementing an Advanced Natural Gas System Manufacturing Research and Development Initiative
 - Partnering with the National Association of Regulatory Utility Commissioners to help modernize natural gas distribution infrastructure
 - Issuing an Advanced Fossil Energy Projects Solicitation inviting applicants to apply for developing a clearinghouse of information on effective technologies, policies, and strategies.
- **Working cooperatively with industry to reduce methane emissions.** EPA is working to expand on its successful Natural Gas STAR Program by launching a new partnership in collaboration with key stakeholders later in 2015. EPA will work with DOE, DOT, and leading companies—individually and through broader initiatives, such as the One Future Initiative and the Downstream Initiative—to develop and verify robust commitments to reduce methane emissions.
- **Reducing other air pollution from TS&D infrastructure systems.** A number of Administration initiatives are reducing air pollution from TS&D infrastructure. Examples of this include the EPA's guidelines to states to reduce ozone precursors from oil and gas systems; DOE's work to improve the energy efficiency of equipment powering natural gas transmission systems and other TS&D infrastructure; DOT's Federal Highway Administration funding of state and local programs that reduce air emissions through its Congestion Mitigation and Air Quality Improvement program; and funding of the National Clean Diesel Campaign, which issues grants to eligible entities for projects to reduce emissions from existing diesel engines, which are pervasive in TS&D infrastructure.

Recommendations in Brief

Improve quantification of emissions from natural gas TS&D infrastructure. Congress should approve the \$10 million requested in the FY 2016 Budget to help update Greenhouse Gas Inventory estimates of methane emissions from natural gas systems. DOE and EPA should undertake a coordinated approach, building on stakeholder input, to ensure that new research and analysis is targeted toward knowledge gaps unaddressed by other researchers.

Expand R&D programs at DOE on cost-effective technologies to detect and reduce losses from natural gas TS&D systems. DOE should leverage its R&D efforts in this area to facilitate broader air quality benefits.

Invest in R&D to lower the cost of continuous emissions monitoring equipment. To further improve safety and reduce emissions from natural gas systems, additional R&D—as proposed in the FY 2016 Budget—is needed to reduce costs and enable deployment of continuous emissions monitoring technologies.

Support funding to reduce diesel emissions. To protect workers and nearby communities through further reductions in diesel particulate matter emissions from ports and rail yards, the Administration proposed, and Congress should provide, funding for the Diesel Emissions Reduction Act and other related programs.

Collaborate on R&D on the beneficial use and/or disposal of dredging material. The Army Corps of Engineers and other appropriate Federal agencies should undertake collaborative R&D on treating and then either beneficially using or disposing of dredging material.

Improve environmental data collection, analysis, and coordination. DOE should work with other Federal agencies to improve data and analysis on the environmental characteristics and impacts of TS&D infrastructures.

Work with states to promote best practices for regulating and siting CO₂ pipelines. Building on successful state models for CO₂ pipeline siting, DOE, in cooperation with Federal public land agencies, should take a convening role to promote communication, coordination, and sharing of lessons learned and best practices among states that are already involved in siting and regulating CO₂ pipelines or that may have CO₂ pipeline projects proposed within their borders in the future.

Enact financial incentives for the construction of CO₂ pipeline networks. Congress should enact the Administration's proposed Carbon Dioxide Investment and Sequestration Tax Credit, which would authorize \$2 billion in refundable investment tax credits for carbon capture technology and associated infrastructure (including pipelines) installed at new or retrofitted electric generating units that capture and permanently “sequester” CO₂.

Enhancing Employment and Workforce Training

The workforce needed to build, maintain, and operate energy infrastructures will continue to evolve and, in many cases, grow significantly. The heavy investment in new U.S. energy infrastructure that is anticipated over the next few decades, combined with the maintenance needed by current infrastructure systems and the looming retirement of a significant fraction of this sector's labor pool, will stimulate the creation of a wide range of new job opportunities for skilled workers. This will pose an increasing challenge for workforce development and job training strategies.

Key Findings

Approximately 1 million people were employed in energy transmission and distribution jobs in 2013. This represented almost 0.75 percent of U.S. civilian jobs. An additional 900,000 jobs were indirectly supported by energy transmission and distribution activity.

Projections indicate that, by 2030, the energy sector overall, including the TS&D segment, will employ an additional 1.5 million workers. Most of these jobs will be in construction, installation and maintenance, and transportation, and approximately 200,000 more workers with computer and mathematics skills will be in demand.

Changes in the electricity sector, in particular, affect the number and types of energy jobs. New technologies are changing the skill sets in demand in the electricity workforce, creating opportunities that include utility management positions for smart grid programs, meter installers and service providers, intelligent transmission and distribution automation device producers, communications system products and services providers, and software system providers and integrators.

Accelerating methane abatement actions in the natural gas TS&D system is projected to support a significant number of jobs. One study projects that an accelerated replacement timeline along with other measures could support 313,000 jobs throughout the economy.

New job-driven training strategies, reflecting a broader range of needed skills, will be required to meet the challenges of the future. Whether it is by expanding training curricula to use the latest educational tools and techniques, moving to a competency-based system of evaluating educational and training outcomes, or engaging new pools of potential talent (such as veterans), innovation in methods to attract and train the TS&D infrastructure workforce of the future will be required.

Defining priorities in the area of jobs and workforce training and establishing effective programs requires good data. It is challenging both to define and quantify jobs in the energy industry because of how employment data in the United States are organized and published. The lack of information is especially critical in job categories experiencing high growth and rapid technological change, such as those dealing with infrastructure associated with the solar industry.

Selected Recent Federal Government Actions

The activities of the Federal Government to respond to changes in employment and workforce for TS&D infrastructures exist in a broader context of initiatives to train a competitive domestic energy workforce that are being undertaken by the energy industry, labor organizations, colleges, trade schools, and state and local governments. Some recent Federal actions and initiatives that are aimed at supporting and partnering with these broader efforts include the following:

- **Expanding existing efforts.** The Administration's Ready to Work Initiative and the passage of the Workforce Innovation and Opportunity Act have led to several important efforts in the energy sector. In addition to the significant investments in energy and advanced manufacturing workforce training, the newly formed Skills Working Group, an interagency task force of 13 Federal agencies chaired by the Secretary of Labor, has focused on the energy sector as one of six key opportunity areas for expanding apprenticeships, building career pathways to the middle class, and initiating place-based initiatives to expand opportunities to underserved communities.
- **Providing financial assistance for training.** The Department of Labor has granted \$450 million in Trade Adjustment Assistance Community College and Career Training grants to nearly 270 community colleges across the country. Also, in December 2014, the Department of Labor announced the American Apprenticeship Grants Competition—a \$100-million grant program to launch apprenticeship models in high growth fields, such as energy, and expand apprenticeship models that work.
- **Creating an energy Jobs Council.** DOE has created a new Jobs Council, which brings together the diverse energy programs of the Department with its laboratories and technology resources to accelerate job creation across all energy sectors in partnership with other Federal agencies, the private sector, and state and local governments.

- **Developing curricula and certification standards.** DOE has been deeply engaged with both traditional and new energy sectors, developing curricula and/or certification standards for the solar, unconventional natural gas extraction, and building energy efficiency industries, for instance. In addition, through DOE's Office of Economic Impact and Diversity and its new Jobs Council, the Department's programs have focused on driving energy opportunities to traditionally underserved communities and to veterans and other specific populations.

Recommendations in Brief

Support an energy-job skills training system through the interagency Skills Working Group. The training system should include new curricula, apprenticeship programs, industry-based credentialing standards, and innovative online learning systems.

Expand support for an open-source learning community to develop, facilitate, and expand use of state-of-the-art courses in energy-related fields. These efforts should work to maintain and improve the National Training and Education Resource platform.

Coordinate efforts to accelerate the development of high-quality energy and manufacturing curricula and apprenticeship programs. DOE should coordinate with existing Department of Labor and National Science Foundation programs.

Facilitate national credentials for energy occupations. DOE should support and facilitate an industry-led process of defining needed skills in a number of emerging occupations.

Facilitate the transition of military veterans into the energy sector. DOE should work with the Departments of Labor and Defense and stakeholders to standardize the applicability of Military Occupation Codes to civilian jobs in energy sectors.

Establish an interagency working group to reform existing energy jobs data collection systems. DOE should convene a group with the Departments of Labor and Commerce to provide complete and consistent definitions and quantification of energy jobs across all sectors of the economy.

Siting and Permitting of TS&D Infrastructure

The trends affecting TS&D infrastructure are discussed in this report—including major increases in oil and gas production, expanding production of renewable energy, changing requirements for what is expected of energy infrastructure, climate change, and steps to maintain electricity grid—are shaping and driving demand for new TS&D infrastructure. Over the last decade, there has been a growing awareness of the gap between the times typically needed to permit new generation and production sources of energy and the much longer times needed for TS&D infrastructure. This discrepancy in permitting time frames affects everything from transmission planning to utility procurement and project finance decisions—making it more challenging to plan, site, permit, finance, and construct energy infrastructure projects. Given these challenges, it is essential to promote more timely permitting decisions while protecting our Nation's environmental, historic, and cultural resources.

Key Findings

The involvement of multiple jurisdictions adds time to siting, permitting, and review of infrastructure projects. As major infrastructure projects are proposed, Federal, state, local, and tribal governments must work to consider and minimize potential impacts on safety and security, as well as environmental and community resources (e.g., air, water, land, and historic and cultural resources). These entities often have overlapping and sometimes conflicting statutory responsibilities for siting and permitting projects. The interplay among the diverse sets of participants and statutorily defined responsibilities is challenging, and for particularly large and complex infrastructure projects, multiple permits and approvals can lead to inefficiencies and delay.

Close collaboration with tribal, state, and local governments is critical to siting, permitting, and review of infrastructure projects. Most infrastructure siting and permitting decisions are made at the state and local levels; some also require consultation with affected Indian Tribes. The bulk of Federal review and permitting responsibilities are also handled at regional offices rather than agency headquarters. The local nature of decision making requires close interaction between local and tribal governments and Federal agencies, as well as appropriate knowledge of resource concerns to be addressed in the permitting process.

Robust public engagement is essential for the credibility of the siting, permitting, and review process. Major infrastructure projects, such as high-voltage transmission lines and pipelines, are likely to trigger potentially conflicting stakeholder interests and have the potential to produce significant impacts on local communities and the environment due to their complexity and scale. Robust stakeholder engagement is necessary to avoid, minimize, and mitigate these potential impacts and is likely to reduce delays in reaching a decision.

Siting timetables vary widely, and processes for siting energy infrastructure differ by sector. Major infrastructure projects typically involve multi-year design, development, and construction timelines with complex approval processes. Timelines and processes for approval vary depending on the scope and type of project.

Selected Recent Federal Government Actions

The Obama Administration has taken steps within and across Federal agencies to modernize the Federal permitting and review process for major infrastructure projects to reduce uncertainty for project applicants, to reduce the aggregate time it takes to conduct reviews and make permitting decisions by half, and to produce measurably better environmental and community outcomes. These include the following actions:

- **Coordinating project review.** The Interagency Steering Committee established under Executive Order 13604 and the Interagency Infrastructure Permitting Improvement Team housed at DOT are currently developing a Policy for Coordinated Review of infrastructure project applications among Federal agencies and with project sponsors.
- **Developing pre-application procedures and cost recovery for project reviews.** In 2013, DOE—through the Council on Environmental Quality and the Administration’s Rapid Response Team for Transmission—developed a proposed Integrated Interagency Pre-Application Process for onshore electric transmission lines. DOE is now considering issuing a revised regulation under Section 216(h) of the Federal Power Act that would incorporate that process. In September 2014, the Bureau of Land Management issued a proposed rule that would require all applicants for rights of way across public lands for electric transmission lines of 100 kilovolts or greater and pipelines 10 inches or more in diameter to hold pre-application meetings to coordinate with appropriate Federal and state agencies and tribal and local governments. It would also require proponents to pay reasonable or actual costs associated with the pre-application process.
- **Expanding online project tracking and developing metrics.** The Administration launched a Federal Infrastructure Project Permitting Dashboard to track designated infrastructure project schedules. The dashboard also hosts a “Permit Inventory”—a searchable database of required permits and approvals—as well as National Environmental Policy Act (NEPA) reviews and milestones relating to major infrastructure projects.
- **Expanding availability and sharing of data and geographic information system tools.** The Administration has identified a number of actions and policies to facilitate adequate collection, integration, and sharing of the best available data to assist project sponsors in siting projects in order to minimize resource impacts and to support Federal decision making, including (1) NEPA node;

(2) the Fish and Wildlife Service Information, Planning, and Conservation Tool; (3) EPA's NEPAAssist; (4) the Eastern Interconnection States Planning Council Energy Zones Mapping Tool; (5) the Army Corps' Federal Support Toolbox; (6) the Western Governors' Associations' Crucial Habitat Assessment Tool; and (7) the National Oceanic and Atmospheric Administration's Social Vulnerability Index.

- **Designating corridors for pipelines, electric transmission lines, and related infrastructure.** The Department of the Interior and the Department of Agriculture are conducting a periodic review of the Western energy rights-of-way corridors designated in 2009. As directed in the June 2013 Presidential Memorandum, DOE issued two reports—one for assessing potential corridors in the West, as proposed by the Western Electricity Coordinating Council, and one for the rest of the United States that looks at current and potential crossings for transmission lines and oil and gas pipelines on federally protected national trails.
- **Undertaking landscape- and watershed-level mitigation and conservation planning.** Federal land management agencies have begun to implement mitigation and conservation planning at the landscape, ecosystem, or watershed level. For example, in March 2014, the Department of the Interior released the Solar “Regional Mitigation Strategy for the Dry Lake Solar Energy Zone,” and in April 2014, Secretary Jewell issued the “Strategy for Improving the Mitigation Practices of the Department of the Interior.”

Recommendations in Brief

Allocate resources to key Federal agencies involved in the siting, permitting, and review of infrastructure projects. Federal agencies responsible for infrastructure siting, review, and permitting have experienced dramatic appropriations cuts and reductions in staff. Many of the components of the overall effort to improve the Federal siting and permitting processes have been stymied in recent years by appropriations shortfalls. Congress should fully fund these priorities.

Prioritize meaningful public engagement through consultation with Indian Tribes, coordination with state and local governments, and facilitation of non-Federal partnerships. Early and meaningful public engagement with affected residential communities, nonprofit organizations, and other non-Federal stakeholders through the NEPA process and other forums can reduce siting conflicts. Federal agency coordination with state and local governments and government-to-government consultation with affected Indian Tribes should remain a Federal Government priority. When possible, Federal agencies should co-locate energy infrastructure environmental review and permitting staff from multiple Federal agencies' regional and field offices.

Expand landscape- and watershed-level mitigation and conservation planning. When adverse impacts to the Nation's landscape cannot be avoided or minimized any further, Federal agencies should seek innovative approaches to compensate for adverse project impacts commensurate with the scope and scale of the project and effects to resources. Through mitigation planning at a landscape, ecosystem, or watershed scale, agencies can locate mitigation activities in the most ecologically important areas.

Enact statutory authorities to improve coordination across agencies. Congress should authorize and fund the Interagency Infrastructure Permitting Improvement Center in DOT, as set forth in Section 1009 of the Administration's draft legislation for the GROW AMERICA Act.

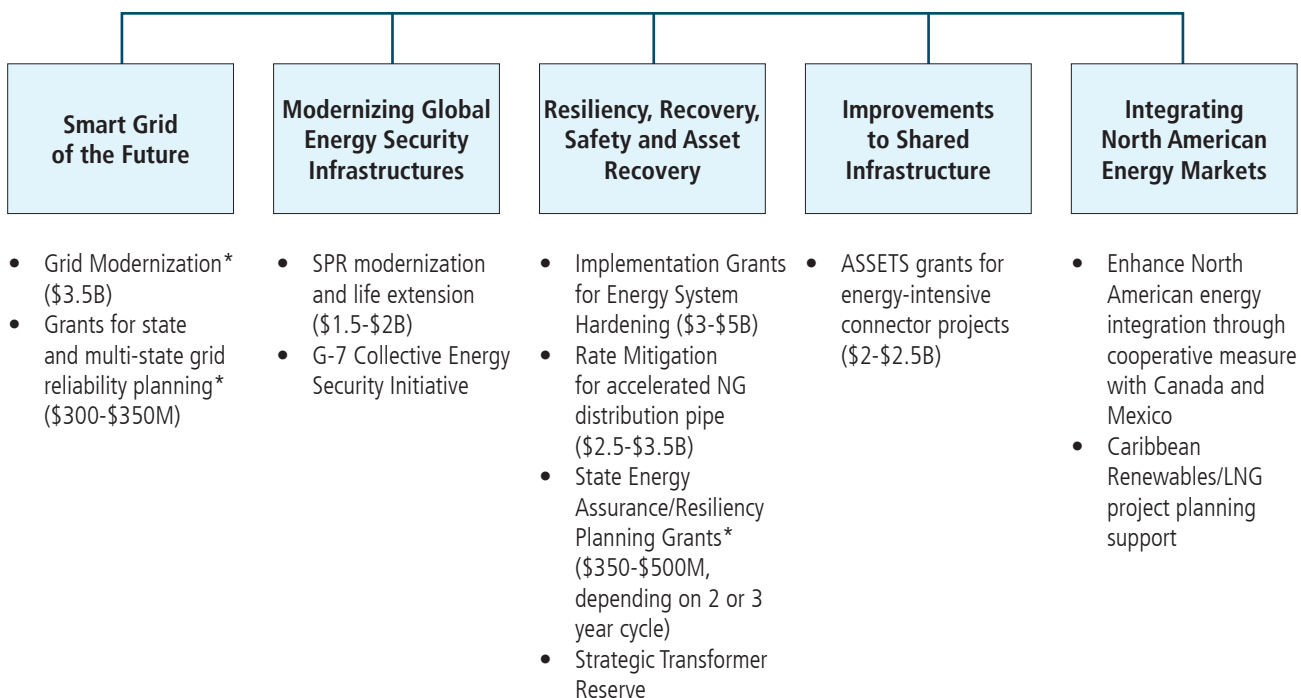
Adopt Administration proposals to authorize recovery of costs for review of project applications. Consistent with the proposal in the President's FY 2016 Budget Request, additional flexibility for certain agencies to accept funds from applicants would be appropriate and could expedite the Federal permitting and review process.

Investing in Energy Infrastructure

The replacement, expansion, and modernization of dedicated and related energy infrastructure require major investment over an extended period of time. Most of the resources will come from the private sector—sometimes as approved costs under Federal and state-regulated rate structures for energy delivery to consumers and businesses. Nevertheless, a significant number of the infrastructure recommendations put forward in this QER call for Federal funds, either for direct investment or for stimulating and incentivizing other investments. The desirability of Federal engagement comes in large part from classic market failures of a variety of kinds, above all public goods and negative externalities. As noted in a 2012 report by the Department of the Treasury and the President’s Council of Economic Advisers, moreover, there is a large body of evidence showing significant private sector productivity gains from public infrastructure investments, in many cases with higher returns than private capital investment.⁸

The QER calls for increased Federal investments, targeted both at areas of traditional Federal responsibility and at new approaches to inform, incentivize, and leverage the investment decisions of state and local governments and the private sector that reinforce overarching economic, security, and environmental objectives (see Figure SPM-6). Some of these investments were already proposed in the President’s FY 2016 Budget Request. The recommendations that were not proposed in the FY 2016 Budget, both on the mandatory and discretionary side, will be subject to the President’s Budget process, including, for example, identification of revenue sources or other offsets. Other recommendations would require new authorizing legislation and were not proposed in the FY 2016 Budget. Table SPM-2 summarizes the recommendations that will require further legislative authorization, together with initial order-of-magnitude cost estimates. More precise cost estimates will depend upon more detailed program design and final statutory language. The Administration looks forward to working with Congress to advance these recommendations.

Figure SPM-6. Recommendations Requiring Legislative Authorization



Note: Most funding is over 10 years and would be incremental to agency baseline budgets. Programs identified with an asterisk would require incremental funding over a shorter time period.

Table SPM-2. Examples of Federal Mechanisms/Tools Applied to Each Energy Infrastructure Objective

Objectives Mechanisms/Tools	Resilience, Reliability Safety and Security	Electricity Grid Modernization	Energy Security and Supporting Infrastructures	Administration Chair
Direct Federal Infrastructure Investments	Provide competitive, cost-shared implementation grants to harden and enhance the resilience of electricity TS&D infrastructures	Provide competitive grants for State and multi-State reliability planning to meet environmental, resilience, and efficiency goals	De-bottleneck Strategic Petroleum Reserve (SPR) distribution capability through marine terminal enhancements	Provide cost sharing for investments in shared energy transportation systems
Research, Development and Analysis	Develop and demonstrate cost-effective technologies to detect and reduce GHG losses from natural gas transmission and distribution systems	Assess flexibility and value of electricity storage	Enhance research on Arctic energy safety and accident prevention	Support research on disposal of dredging materials
Data Collection and Information Management	Develop a framework and metrics for modeling and measuring resiliency	Institutionalize energy efficiency evaluation, measurement, and verification	Increase the integration of EIA energy data with Canada and Mexico	Improve data collection on shared energy transportation infrastructure
Federal Regulation	Enhance safety standards for gas transmission pipelines	Develop grid connectivity and interoperability standards to enhance safe and reliable grid operation	Revise legal, regulatory, and policy roadmaps for harmonizing regulations for energy emergency response	Eliminate regulatory impediments to ensure adequate power plant fuel reserves.
Workforce Development	Develop curricula, training programs, and industry-based credentialing standards to expand energy sector workforce			

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