QUADRENNIAL ENERGY REVIEW:

ENERGY TRANSMISSION, STORAGE, AND DISTRIBUTION INFRASTRUCTURE

April 2015

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Preface

In June 2013, through the President's "Climate Action Plan" and in response to a 2011 recommendation by the President's Council of Advisors on Science and Technology, President Obama initiated a quadrennial cycle of energy reviews to provide a multi-year roadmap for U.S. energy policy. In a Presidential Memorandum released on January 9, 2014 (see page iii for full text), President Obama directed his Administration to conduct a Quadrennial Energy Review (QER) and identified infrastructure as the focus of its first installment:[1]

> "This first-ever review will focus on infrastructure challenges, and will identify the threats, risks, and opportunities for U.S. energy and climate security, enabling the Federal Government to translate policy goals into a set of analytically based, clearly articulated, sequenced and integrated actions, and proposed investments…."

The President also announced the formation of a White House Task Force—co-chaired by the Director of the Office of Science and Technology Policy and the Special Assistant to the President for Energy and Climate Change from the Domestic Policy Council and comprised of 22 Federal agencies with equities in energy—to develop the QER. The Task Force is directed to deliver a report to the President that includes the following:

- Provides an integrated view of, and recommendations for, Federal energy policy in the context of economic, environmental, occupational, security, and health and safety priorities, with attention in the first report given to the challenges facing the Nation's energy infrastructures.
- Reviews the adequacy of existing executive and legislative actions and recommends additional executive and legislative actions as appropriate.
- Assesses and recommends priorities for research, development, and demonstration programs to support key energy innovation goals.
- Identifies analytical tools and data needed to support further policy development and implementation.

The President further directed the Department of Energy (DOE) to provide analytical support for the QER and to help manage the interagency process through a secretariat at DOE. This is consistent with DOE's missions and statutory responsibilities. DOE has undertaken periodic reviews and analyses of the energy sector (including in the "National Energy Strategy" of 1991 and the "Comprehensive Energy Strategy" of 1998) and contributed to the work of the National Energy Policy Development Group led by the Vice President in 2001, but the last national energy policy report was published nearly 14 years ago, and the U.S. energy system has changed very significantly over that period. The Presidential Memorandum on the QER recognizes that such a review is overdue and the high value of the White House as the convener of such an effort. It also reinforces the equities that multiple agencies have in Federal energy policy.

As directed by the President, the QER is envisioned as a focused, actionable document designed to provide policymakers, industry, investors, and other stakeholders with unbiased data and analysis on energy challenges, needs, requirements, and barriers that will inform a range of policy options, including legislation. Each installment of the QER will analyze and make recommendations for a key component of the energy value chain.

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[1] The White House. "Obama Administration Launches Quadrennial Energy Review." January 9, 2014. https://www.whitehouse.gov/the-press-office/2014/01/09/presidential-memorandum-establishing-quadrennial-energy-review. Accessed January 15, 2015.

Presidential Memorandum

The White House
January 09, 2014

Presidential Memorandum -- Establishing a Quadrennial Energy Review
MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security. Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders. To help the Federal Government better meet this responsibility, I am directing the undertaking of a Quadrennial Energy Review.

The initial focus for the Quadrennial Energy Review will be our Nation's infrastructure for transporting, transmitting, and delivering energy. Our current infrastructure is increasingly challenged by transformations in energy supply, markets, and patterns of end use; issues of aging and capacity; impacts of climate change; and cyber and physical threats. Any vulnerability in this infrastructure may be exacerbated by the increasing interdependencies of energy systems with water, telecommunications, transportation, and emergency response systems. The first Quadrennial Energy Review Report will serve as a roadmap to help address these challenges.

The Department of Energy has a broad role in energy policy development and the largest role in implementing the Federal Government's energy research and development portfolio. Many other executive departments and agencies also play key roles in developing and implementing policies governing energy resources and consumption, as well as associated environmental impacts. In addition, non-Federal actors are crucial contributors to energy policies. Because most energy and related infrastructure is owned by private entities, investment by and engagement of the private sector is necessary to develop and implement effective policies. State and local policies; the views of nongovernmental, environmental, faith-based, labor, and other social organizations; and contributions from the academic and non-profit sectors are also critical to the development and implementation of effective energy policies.

An interagency Quadrennial Energy Review Task Force, which includes members from all relevant executive departments and agencies (agencies), will develop an integrated review of energy policy that integrates all of these perspectives. It will build on the foundation provided in my Administration's Blueprint for a Secure Energy Future of March 30, 2011, and Climate Action Plan released on June 25, 2013. The Task Force will offer recommendations on what additional actions it believes would be appropriate. These may include recommendations on additional executive or legislative actions to address the energy challenges and opportunities facing the Nation.

Therefore, by the authority vested in me as President by the Constitution and the laws of the United States of America, I hereby direct the following:

Section 1. Establishing the Quadrennial Energy Review Task Force.

(a) There is established the Quadrennial Energy Review Task Force (Task Force), to be co-chaired by the Director of the Office of Science and Technology Policy and the Director of the Domestic Policy Council, which shall include the heads of each of the following, or their designated representatives:

(i) the Department of State;

(ii) the Department of the Treasury;

(iii) the Department of Defense;

(iv) the Department of the Interior;

(v) the Department of Agriculture;

(vi) the Department of Commerce;

(vii) the Department of Labor;

(viii) the Department of Health and Human Services;

(ix) the Department of Housing and Urban Development;

(x) the Department of Transportation;

(xi) the Department of Energy;

(xii) the Department of Veterans Affairs;

(xiii) the Department of Homeland Security;

(xiv) the Office of Management and Budget;

(xv) the National Economic Council;

(xvi) the National Security Staff;

(xvii) the Council on Environmental Quality;

(xviii) the Council of Economic Advisers;

(xix) the Environmental Protection Agency;

(xx) the Small Business Administration;

(xxi) the Army Corps of Engineers;

(xxii) the National Science Foundation; and

(xxiii) such agencies and offices as the President may designate.

(b) The Co-Chairs may invite independent regulatory agencies with energy-related responsibilities, including the Federal Energy Regulatory Commission and the Nuclear Regulatory Commission, to participate in the Task Force, as determined to be appropriate by those agencies.

(c) The Co-Chairs shall regularly convene and preside at meetings of the Task Force and shall determine its agenda. Under the direction of the Co-Chairs, the Task Force shall:

(i) gather ideas and advice from State and local governments, tribes, large and small businesses, universities, national laboratories, nongovernmental and labor organizations, consumers, and other stakeholders and interested parties; and

(ii) coordinate the efforts of agencies and offices related to the development of the Quadrennial Energy Review Report, as described in sections 1 and 2 of this memorandum.

(d) The Secretary of Energy shall provide support to the Task Force, including support for coordination activities related to the preparation of the Quadrennial Energy Review Report, policy analysis and modeling, and stakeholder engagement.

(e) The Task Force shall submit a Quadrennial Energy Review Report to the President every 4 years beginning with a report delivered by January 31, 2015. Intermediate reports and other material may be prepared by the Task Force as required by the President.

Sec. 2. The Quadrennial Energy Review Report.

The Task Force shall establish integrated guidance to strengthen U.S. energy policy. Building on the Blueprint for a Secure Energy Future and the Climate Action Plan, and taking into consideration applicable laws and regulations, the Task Force shall prepare a Quadrennial Energy Review Report that:

(a) provides an integrated view of, and recommendations for, Federal energy policy in the context of economic, environmental, occupational, security, and health and safety priorities, with attention in the first report given to the challenges facing the Nation's energy infrastructures;

(b) reviews the adequacy, with respect to energy policy, of existing executive and legislative actions, and recommends additional executive and legislative actions as appropriate;

(c) assesses and recommends priorities for research, development, and demonstration programs to support key energy-innovation goals; and

(d) identifies analytical tools and data needed to support further policy development and implementation.

Sec. 3. Outreach.

In order to gather information and recommendations and to provide for a transparent process in developing the Quadrennial Energy Review Report, the Task Force shall engage with State and local governments, tribes, large and small businesses, universities, national laboratories, nongovernmental and labor organizations, and other stakeholders and interested parties. The Task Force shall develop an integrated outreach strategy that relies on both traditional meetings and the use of information technology.

Sec. 4. General Provisions.

(a) This memorandum shall be implemented consistent with applicable law and subject to the availability of appropriations.

(b) Nothing in this memorandum shall be construed to impair or otherwise affect:

(i) the authority granted by law to any agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(c) Nothing in this memorandum shall be construed to require the disclosure of confidential business information or trade secrets, classified information, law enforcement sensitive information, or other information that must be protected in the interest of national security or public safety.

(d) This memorandum is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

(e) The Director of the Office of Science and Technology Policy is authorized and directed to publish this memorandum in the Federal Register.

BARACK OBAMA

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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. 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 in the Summary for Policymakers.

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; more than 640,000 miles of high-voltage 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
	LNG production/storage facilities (including export terminals)
Coal	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 for enhanced oil recovery)
Biofuels	Transport of feedstock and derived products, biorefineries

Source: 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 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.

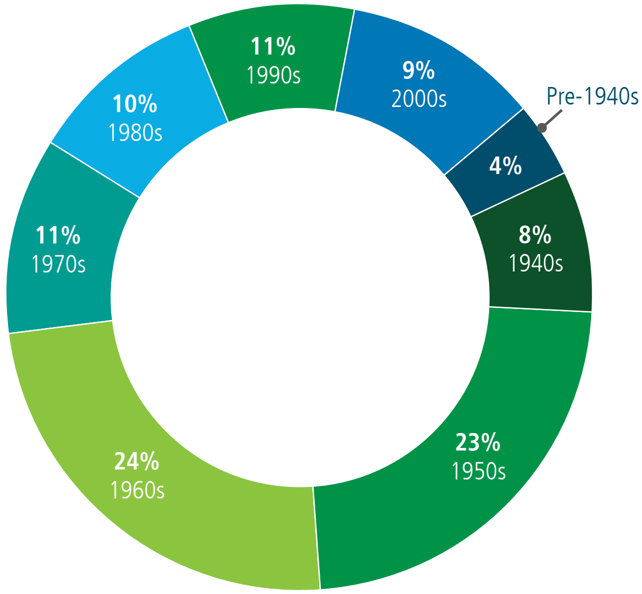
In addition, technology is altering expectations of what the grid should do. Once satisfied with a simple arrangement where utilities provided services and consumers bought power on fixed plans, individual consumers and companies increasingly want to control the production and delivery of their electricity, 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



Source: 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.

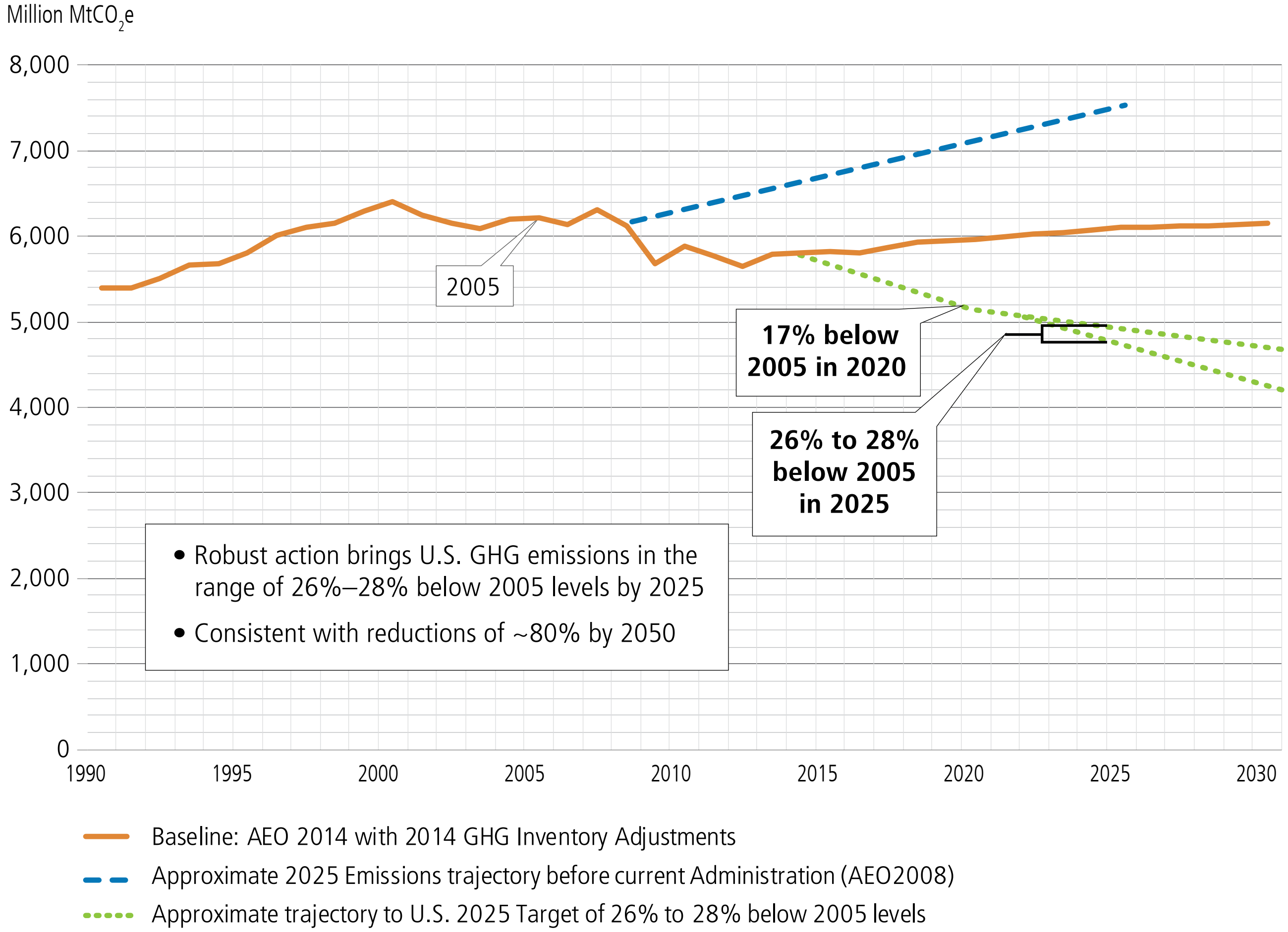
The key relevant conclusions from climate science—as embodied in the most recent reports of the Intergovernmental Panel on Climate Change, the National Academy of Sciences (jointly with the Royal Society of London), and the Third National Climate Assessment of the Global Change Research Program[3, 4, 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 are 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 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.

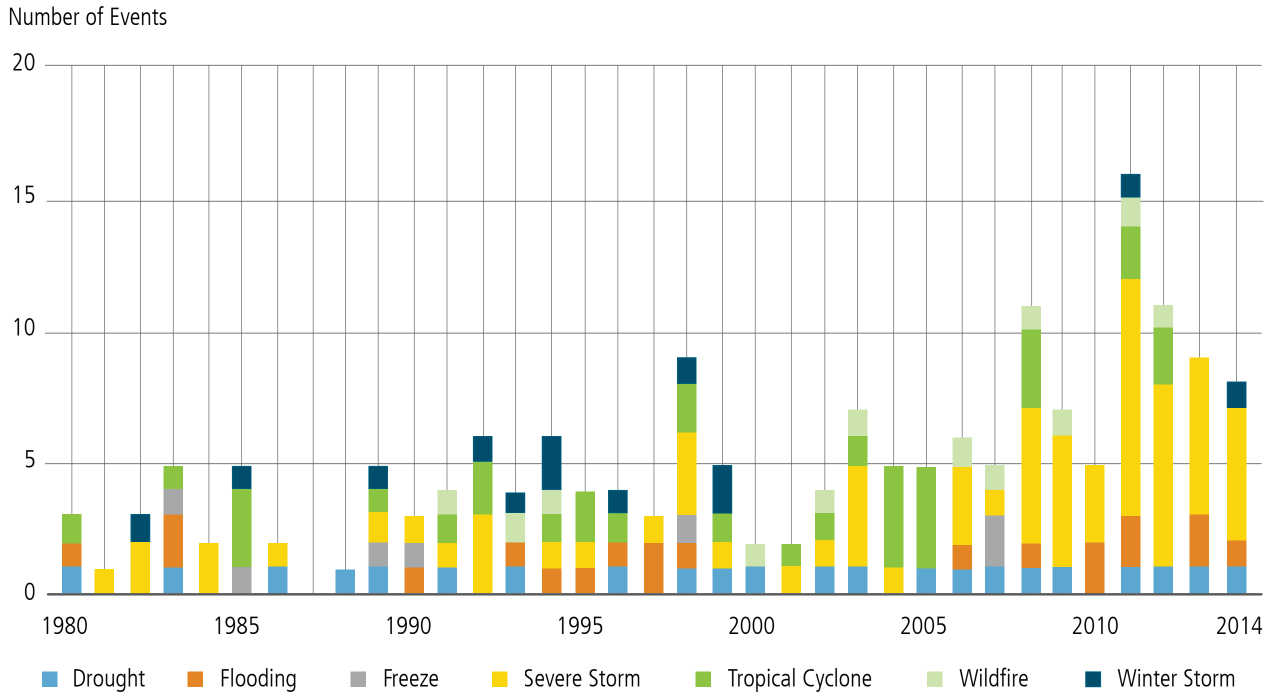
Figure SPM-2. Historic and Projected U.S. GHG Emissions under Obama Administration Targets



Source: 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



Source: 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:

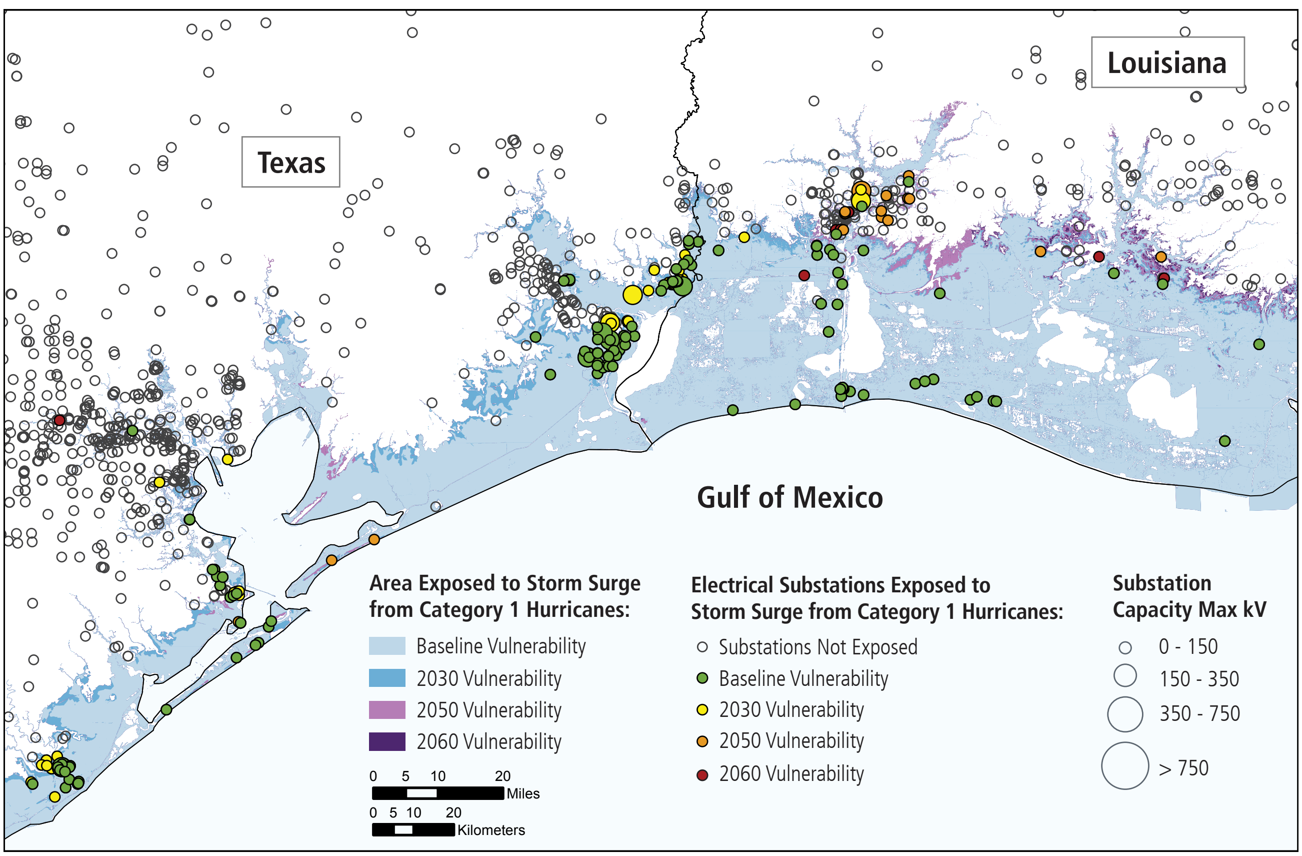
- Promoting environmental responsibility in developing, managing, and updating TS&D infrastructure, including reducing emissions from infrastructure that could contribute to climate change
- Developing and training the workforce needed for a 21st century energy infrastructure
- Expediting the siting 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 competiveness, 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 to Storm Surge under Different Sea-Level Rise Scenarios



Source: 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), limiting 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 pipeline 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 directed 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.

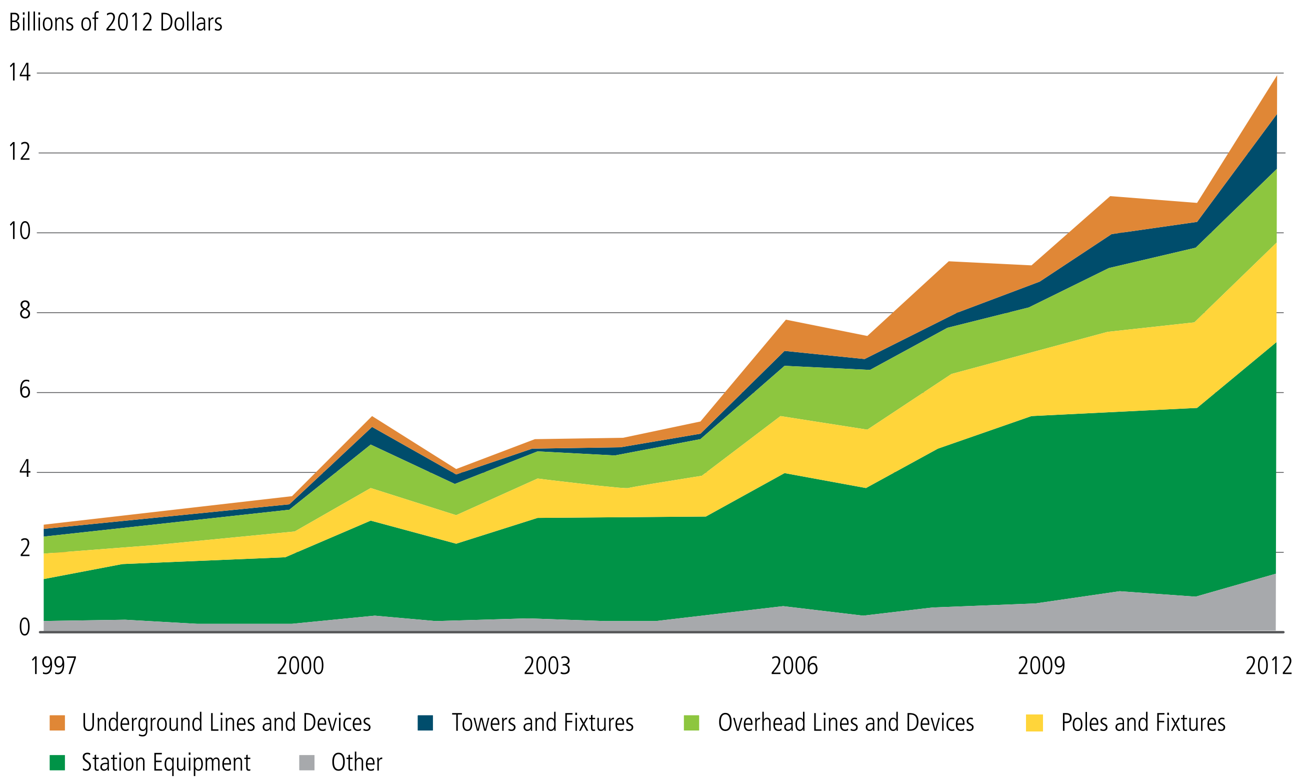
Modernizing the Electric Grid

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



Source: 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 needed 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 where delivery is 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 a more 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 growing 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 wear 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 gain 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 mid-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 Renewal, 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, DOE and other relevant agencies 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 can enable 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; it will also improve 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 reduce 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 (CO_2) 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 independent microgrid operations.
- **Pursuing a Caribbean Energy Security Initiative.** In 2014, Vice President Biden announced the Caribbean Energy Security Initiative, which recognizes the diversity of Caribbean nations' 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. The United States, Canada, and Mexico 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 CO_2 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.

Understanding the potential positive and negative effects of TS&D infrastructure 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 CO_2 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 CO_2 transportation pipelines that can be a critical component of a low-carbon future. The pipelines mostly transport naturally occurring CO_2, but new projects are increasingly linking captured CO_2 from electric power plants and other industrial sources to a productive use in oil fields (through CO_2 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 new methane reduction technologies
  - 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 CO_2 pipelines. Building on successful state models for CO_2 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 CO_2 pipelines or that may have CO_2 pipeline projects proposed within their borders in the future.

Enact financial incentives for the construction of CO_2 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 CO_2.

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 Strategy Council.** DOE has created a new Jobs Strategy 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 Strategy 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) NEPAnode;

(2) the Fish and Wildlife Service Information, Planning, and Conservation Tool; (3) EPA's NEPAssist; (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 Table SPM-2).

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	Shared Transport Infrastructures Improvement
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			

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. Figure SPM-6 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

Smart Grid of the Future

- Grid Modernization* ($3.5B)
- Grants for state and multi-state grid reliability planning* ($300-$350M)

Modernizing Global Energy Security Infrastructures

- SPR modernization and life extension ($1.5-$2B)
- G-7 Collective Energy Security Initiative

Resiliency, Recovery, Safety and Asset Recovery

- Implementation Grants for Energy System Hardening ($3-$5B)
- Rate Mitigation for accelerated NG distribution pipe replacement ($2.5-$3.5B)
- State Energy Assurance/Resiliency Planning Grants* ($350-$500M, depending on 2 or 3 year cycle)
- Strategic Transformer Reserve

Improvements to Shared Infrastructure

- ASSETS grants for energy-intensive connector projects ($2-$2.5B)

Integrating North American Energy Markets

- Enhance North American energy integration through cooperative measure with Canada and Mexico
- Caribbean Renewables/LNG project planning support

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.

Endnotes

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Chapter I

INTRODUCTION

This chapter provides a general introduction to transmission, storage, and distribution (TS&D) infrastructure issues and to the report. It describes why TS&D infrastructure is important to the U.S. energy system. It then covers a set of trends and issues affecting the current U.S. TS&D infrastructure and the demands it will need to meet going forward. Finally, the chapter briefly describes the objectives that informed the study's development and the architecture of the report that resulted.

The Character of the Nation's TS&D Infrastructure

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—defined here as *the infrastructure that links energy supplies, energy carriers, or energy by-products to intermediate and end users*—is large, complex, and interdependent. It includes approximately 2.6 million miles of interstate and intrastate pipelines; 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 (LNG), and coal. The electrical component of the Nation's TS&D infrastructure links more than 19,000 individual generators with a capacity of 1 megawatt or more (sited at more than 7,000 operational power plants), with more than 642,000 miles of high-voltage transmission lines and 6.3 million miles of distribution lines.[1, 2]

The critical importance of these infrastructure facilities is not only in linking energy system components with each other and with end users across the Nation; they also link the U.S. energy system to the rest of the world. The TS&D infrastructure elements considered in this report are listed in Table 1-1.

Table 1-1. Elements of TS&D Infrastructure Considered in this Installment of the QER[3]

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
	LNG production/storage facilities (including export terminals)
Coal	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 for enhanced oil recovery)
Biofuels	Transport of feedstock and derived products, biorefineries

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.

Much of the TS&D infrastructure is owned and operated by the private sector, and a significant portion of the legal, regulatory, and policy development and implementation around such infrastructure 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. Additionally, a number of emergency authorities bearing on TS&D infrastructure are 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 predicable ancillary and unintended consequences.

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 and with full consideration of the interaction of policy at all levels of government with private sector incentives and capabilities, to include attention to opportunities for well-designed, purpose-driven, public-private partnerships.

Trends Affecting TS&D Infrastructure Choices

The U.S. energy landscape is in a time of transition. The relevant trends include 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 a lack of timely investment in refurbishing, replacing, and modernizing components of that infrastructure that are simply old or obsolete. These trends and their implications for TS&D infrastructure 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."[4] Although significant improvements have been made to the grid since then, the basic conclusion of the need to modernize the grid remains valid. The Edison Electric Institute estimated in 2008 that by 2030 the U.S. electric utility industry will need to make a total infrastructure investment of between $1.5 trillion and $2.0 trillion, of which transmission and distribution investment is expected to account for about $900.0 billion.[5]

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, changes in the expectations and desires of businesses and individual consumers have been altering what the grid is expected to do. Once satisfied with a simple arrangement where utilities provided services and consumers bought power on fixed plans, now individuals and companies want to control the production and delivery of their electricity, and technology has become available to implement those wishes. 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 pose aging and obsolescence concerns. These infrastructures simply 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 increasing in competition with transport needs for food and other non-energy freight, and much of the relevant infrastructure—pipelines, rail systems, ports, and waterways alike—is long overdue for repairs, not to mention 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 1-1). Analyses conducted for the Quadrennial Energy Review (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.[a]

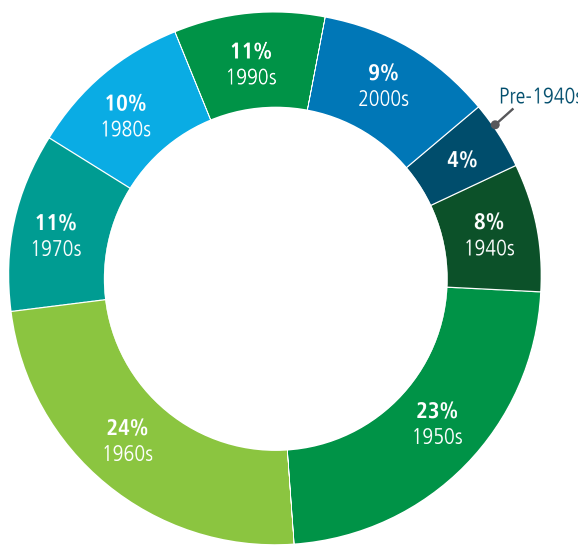


Figure 1-1. Age by Decade of U.S. Gas Transmission and Gathering Pipelines[6]

Nearly 60 percent of U.S. natural gas transmission and gathering lines are at least 45 years old, and 35 percent are 55 years old or older.

[a] 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.

Increases in U.S. Oil and Natural Gas Production and Proved Reserves

The United States is the world's largest combined producer of petroleum and natural gas. In just 2 years, U.S. oil production increased by 35 percent from 2011 to 2013.[7] U.S. proved reserves[b] of crude oil and lease condensates increased each year from 2009 through 2013 and now total more than 36 billion barrels—a level not seen for almost four decades.[8] Some of this increased production has been in locations that did not have sufficient pipeline capacity to accommodate it. For example, proved reserves of crude oil and lease condensate in North Dakota recently surpassed those of the Federal waters in the Gulf of Mexico, ranking North Dakota second only to Texas among U.S. oil-producing states.[9]

Industry has responded to the infrastructure gap by expanding pipeline capacity where it can; reversing flow direction on other pipelines; converting natural gas lines to oil; and seeking new "workaround" solutions to transportation bottlenecks by moving increasing amounts of oil by truck, barge, and rail.

The profile for U.S. natural gas production and reserves is similar. Between 2005 and 2013, U.S. production increased by 28 percent, and in 2013, proved natural gas reserves in the United States hit 354 trillion cubic feet—a new record.[10] In 2013, shale gas was 38 percent of U.S. production and 47 percent of proved gas reserves;[11, 12] between 2010 and 2013, shale gas production increased by 114 percent.[13] The geography of gas production and reserves has also changed dramatically. Seventy percent of net increases in proved gas reserves are in just two states: Pennsylvania and West Virginia.[14] This production is also occurring in locations where natural gas has not been produced in the past, changing movement of product flows and placing demands on the infrastructure to move this product to consumers.

Decreases in Oil Consumption

At the same time that U.S. oil production has been growing markedly, U.S. oil consumption, and particularly consumption of a major refined product (gasoline), has been falling.[15] A number of factors have led to the decrease in oil consumption. The Administration has set historic fuel economy standards for light and heavy vehicles in recent years, which are already having an impact. In October 2014, a record was set for new light-duty vehicle efficiency in the United States, reaching 24.1 miles per gallon.[16] By 2025, passenger and light-duty trucks are expected to be more than twice as efficient, reaching an average of 54.5 miles per gallon.[17] Many of these vehicles are hybrid or electric; widespread deployment of hybrid vehicles could substantially reduce oil demand, and wide-scale deployment of electric vehicles would require changes to the United States' current infrastructure. An increase in natural gas heavy-duty vehicles is projected; this is unlikely to make a significant difference in TS&D infrastructure requirements.[18]

The Energy Information Administration (EIA) forecasts show a slight drop in oil demand by 2040 as a result of these standards; this is a significant change from previous forecasts, which anticipated increases in fuel demand in 2040.[19] The Renewable Fuel Standard also requires that a mandated volume of renewable fuels (such as ethanol and biodiesel) to be blended into U.S. transportation fuels. In 2012, ethanol consumption reached nearly 10 percent of U.S. gasoline demand by volume.[20] After decades of growth, U.S. vehicle miles traveled dropped between 2007 and 2008 and have been relatively flat since.[21] Specifically, from 1971 through 1995, average vehicle miles traveled growth was approximately 3 percent per year; this growth rate dropped to about 2 percent per year from 1996 through 2007 and has been close to 0 percent from 2008 to 2012. Vehicle miles traveled *per capita* actually peaked a few years earlier in 2004 and has continued to decline.[22] Finally, a proportion of the decline in fuel consumption is the result of reduced demand during the contraction of the economy in 2008 to 2009.

[b] Proved reserves are estimated volumes of hydrocarbon resources that analysis of geologic and engineering data demonstrates with reasonable certainty are recoverable under existing economic and operating conditions. Reserve estimates change from year to year as new discoveries are made, existing fields are more thoroughly appraised, existing reserves are produced, and prices and technologies change. See: Energy Information Administration. "U.S. Crude Oil and Natural Gas Proved Reserves." December 19, 2014. www.eia.gov/naturalgas/crudeoilreserves/.

Reductions in Net Oil Imports

As a consequence of both increased oil production and decreased oil consumption, net petroleum imports to the United States have declined steadily and significantly in recent years. The United States is currently less dependent on foreign oil than it has been in over 40 years. In 2005, net U.S. imports of crude oil and petroleum products averaged about 12.5 million barrels per day (million bbl/d) of a total of 20.8 million bbl/d of product supplied; by year-end 2014, net imports of crude oil and petroleum products exceeded 5.0 million bbl/d of a total of 19.6 million bbl/d.[23, 24, 25] This decrease in net petroleum imports has improved the energy and economic security of the United States. The United States remains, however, a large crude oil importer and petroleum product exporter;[26] these links into the global market also link the United States to global oil prices and oil price volatility. Continued attention to infrastructure (e.g., the Strategic Petroleum Reserve) that addresses those vulnerabilities is needed.

Increases in Petroleum Product and Natural Gas Exports

U.S. exports of crude oil and petroleum products have increased dramatically. In 2005, the United States exported 1.2 million bbl/d of crude oil and petroleum products (gasoline, distillate, jet fuel, petroleum coke, and hydrocarbon gas liquids); by October 2014, this amount grew to around 4.0 million bbl/d of crude oil and petroleum products.[27] Almost 92 percent of total exports are refined products from oil; only 8 percent of the total is crude oil.[28] Many of these refined products are produced or shipped from the Gulf of Mexico, which has increased the flow of petroleum and petroleum products in TS&D infrastructure flowing in that direction.

In addition, the United States is positioned to become a major exporter of natural gas just 10 years after an accelerated development of significant import capacity. Rising supplies and falling natural gas costs in the United States opened a price gap with other parts of the world and eliminated most of the need to import LNG. In response, developers have started to repurpose previously constructed LNG import terminals to allow exports. Approved LNG export permits to Free Trade Agreement and non-Free Trade Agreement countries are about 40 billion cubic feet per day (Bcf/d) and 5.74 Bcf/d, respectively. Total capacity of natural gas pipelines to Mexico was 6.5 Bcf/d in 2008,[29, 30] and by 2016, EIA projects that the United States will be exporting more than 1 trillion cubic feet of natural gas to Mexico annually.[31] This additional capacity is meant to serve anticipated growing demand from Mexico's electric power sector.[32]

Onshoring of Energy-Intensive Industries

According to the Congressional Budget Office, without shale gas, U.S. natural gas prices would be 70 percent higher than projected prices by 2040.[33] The availability of lower-cost natural gas and natural gas liquids (NGL) provides an advantage for U.S. manufacturers using natural gas or NGL for heat, power, or feedstocks. As NGL costs have decreased, process costs for U.S. petrochemical manufacturing, which commonly uses NGL as a feedstock, have also decreased. This has enabled some U.S. petrochemical facilities to gain an export advantage over other parts of the world.[34] As a result, many expansions and additions to the U.S. petrochemical manufacturing sector have been announced. The industrial sector as a whole has also taken advantage of abundant natural gas. U.S. industrial consumption of natural gas has increased 15 percent from 2007 to 2014.[35] The 2014 Annual Energy Outlook Reference case projects industrial consumption of natural gas and petroleum to increase substantially from 2014 levels by 2025 and NGL and petrochemical feedstock consumption to increase 44 percent from 2014 levels by 2025.[36] Many of these increased operations will require access to, and be sited near, natural gas and NGL TS&D infrastructure. As a result, in 2014, renewable energy (including hydropower) made up almost 13 percent of U.S. electricity generation.[37]

Increased Deployment of Renewable Energy for Power Generation

Renewable energy deployment in the United States is rising. From 2008 to the end of 2013, the amount of electricity generated from wind energy has more than tripled, and the amount from solar has increased by more than tenfold.[38] Renewable energy systems, including hydropower, wind, biomass, geothermal, and solar, generated 523 million megawatt-hours of electricity in the United States in 2013.[39] According to EIA, in the first 6 months of 2014, 26 percent of the 4,396 megawatts of new utility-scale installed generating capacity that came online were solar additions and one-sixth were wind. Solar additions were up 67 percent over the same time period in 2013 and wind more than doubled.[40]

One important driver of increased renewable energy generation for electricity has been falling costs. Photovoltaic solar modules cost about 1 percent of what they did 35 years ago.[41] Analysis by the National Renewable Energy Laboratory has found that the average cost for a utility-scale photovoltaic project in the United States dropped from about $0.21 per kilowatt-hour in 2010 to $0.11 per kilowatt-hour at the end of 2013.[42] A second driver for increased renewable electricity generation has been state-level Renewable Portfolio Standards. Thirty-eight states have Renewable Portfolio Standards or some kind of preference or goal for renewables.[43] Almost all states have met their targets for 2013.[44] A third important driver has been the Production Tax Credit.

The increase in renewable electricity has changed demands on TS&D infrastructure. Some significant renewable resources are located far from population centers, and construction of adequate TS&D infrastructure is key to accessing those resources. Another element of TS&D infrastructure—energy storage—may also become more important as a means of integrating higher amounts of intermittent renewables into the electric grid. At present, though, the many options for managing and operating the grid have lessened demand for long-distance transmission, though this could strand some high-value resources in both the midcontinent and offshore, particularly where there is no nearby demand. Power companies have multiple options for meeting state Renewable Portfolio Standards, and depending on how they choose to comply, there will be more or less need for additional transmission and distribution systems, particularly interstate TS&D infrastructure. For example, Texas requires the use of indigenous renewable resources for power generation to meet its standard. While it is the only state to do so explicitly, 17 other states offer a range of preferences for in-state renewable generation sources, including rebates or upfront cash incentives, income or franchise tax incentives, property or sales tax incentives, Property Assessed Clean Energy or low-interest financing, grant programs, feed-in tariffs, and bond funding.[45] With respect to energy storage, while it is an important enabler for variable renewables, the lack of available energy storage is not yet a limiting factor for expansion of renewable electricity generation.

Increased Use of Natural Gas for Power Generation

Abundant natural gas supply and comparatively low prices have also affected the economics of electric power markets. Additionally, recent environmental regulations at the local, state, regional, and Federal levels have encouraged switching to fuels with lower emissions profiles, including natural gas and renewables. Natural gas demand for power generation grew from 15.0 Bcf/d in 2005 to 21.4 Bcf/d in 2013, and it is projected to increase by another 6.2 Bcf/d by 2030.[46, 47, c] Electricity generation from natural gas rose by 85 percent nationally from 2000 to 2013—from 601 terawatt-hours in 2000 to 1,114 terawatt-hours in 2013.[48] To better understand the scale of natural gas use, total U.S. natural gas consumption in 2013 was 71.6 Bcf/d.[49]

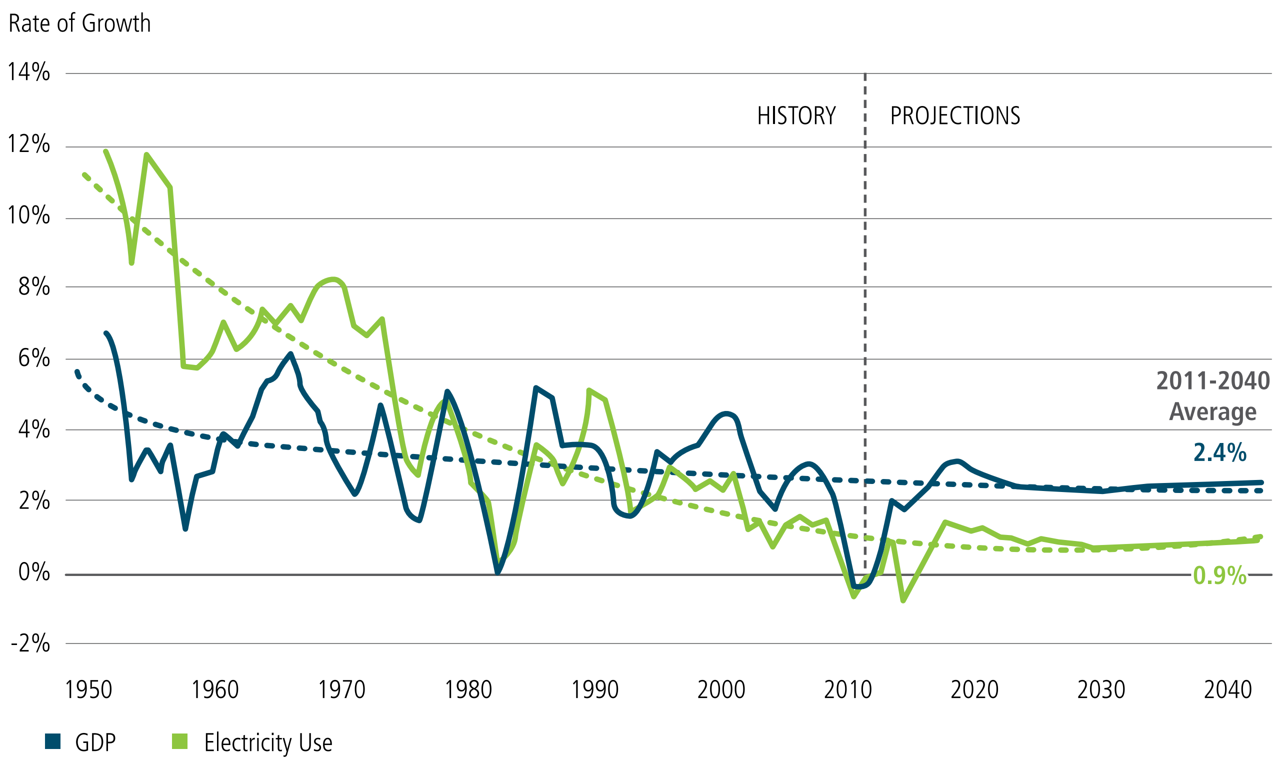
[c] Note that the EIA 2030 projection made does not include laws and policies not enacted or finalized at the time of the projection.

Natural gas-fired power plants accounted for just more than 50 percent of new utility-scale generating capacity added in 2013.[50, d] Natural gas-fired capacity continued to expand in 2014.[51] Infrastructure changes may be needed to accommodate future growth in natural gas use for power, including repurposing and reversals of existing pipelines; laterals[e] to gas-fired generators;[52] more looping and compression to the existing network; potential new pipelines (although, this could be regionalized); and additional processing plants and high-deliverability storage. Under multiple scenarios, the pace of these changes for the interstate natural gas pipeline system through 2030 is projected to be comparable to or less than historical build rates.

Slowing Rate of Electricity Demand Growth

Growth in U.S. electricity demand is at its lowest level in decades (as illustrated in Figure 1-2), driven most significantly by policies that promote energy efficiency, supply/demand balance, and the shift in the economy to less energy-intensive industry.[53] It is important to note, at the same time, that while there is low demand growth nationally, there is wide variation in the amount of load growth across states and regions (see Figure 1-3).

Figure 1-2. U.S. Electricity Use and Economic Growth (3-Year Compound Growth Rate), 1950–2040[54]

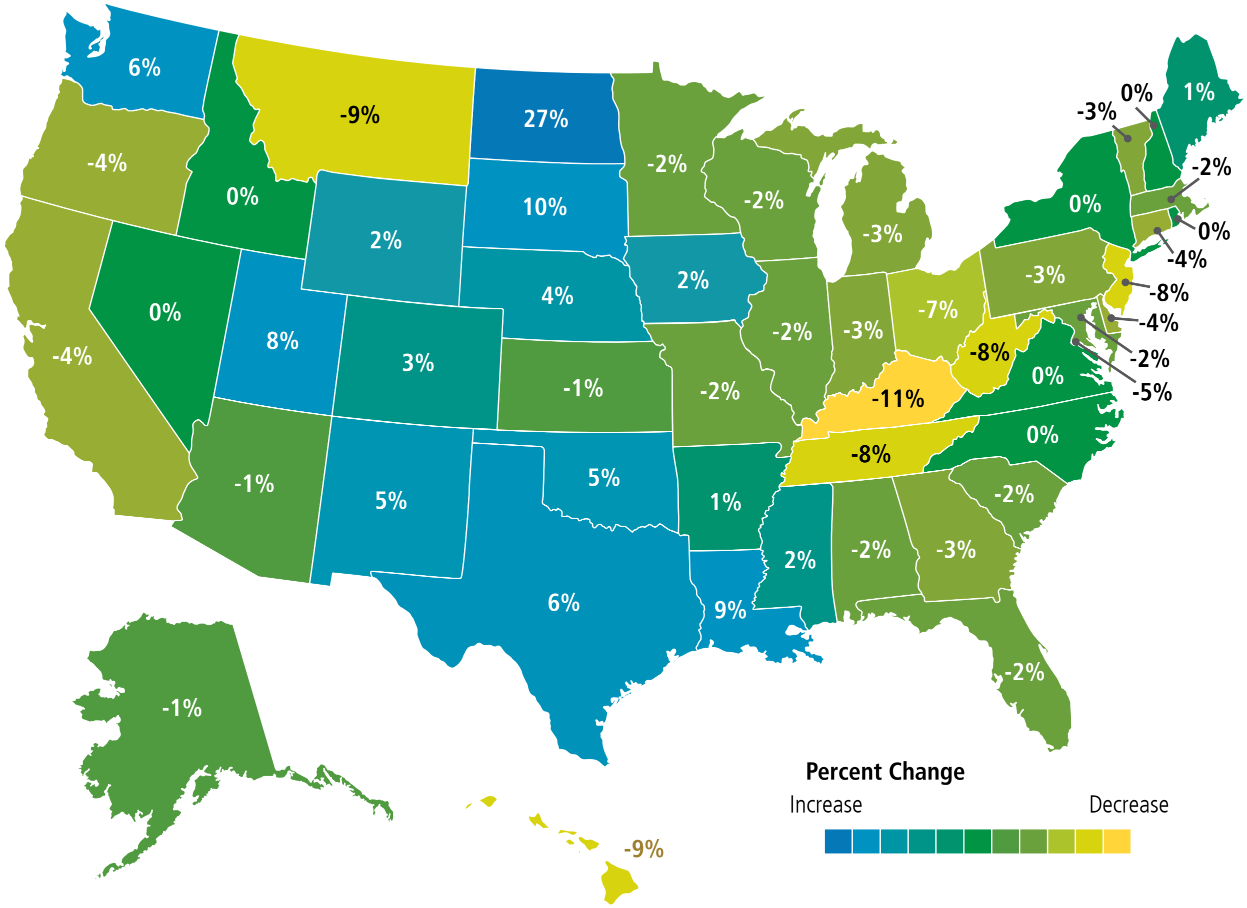


The rate of growth in electricity use has declined since 1950, while the rate of growth in gross domestic product has stayed relatively constant. The slower electricity growth rate is a result of several factors, including a decline in energy-intensive industries, increasing energy efficiency, and the slow recovery from the recent recession.

[d] Representative capacity factors by technology are: coal 85 percent, conventional combined cycle 87 percent, conventional combustion turbine 80 percent, nuclear 90 percent, wind 35 percent, solar photovoltaic 25 percent.

[e] Small segments of pipelines designed to link gas-fired power plants to the natural gas pipeline system.

Figure 1-3. Percent Change in Retail Electricity Sales (kilowatt-hours), 2008–2013[55]



There is a considerable variation in electricity retail sales among states and by region, ranging from an increase of 27 percent in North Dakota to a decrease of 11 percent in Kentucky; these variations are due in part to changes in load growth.

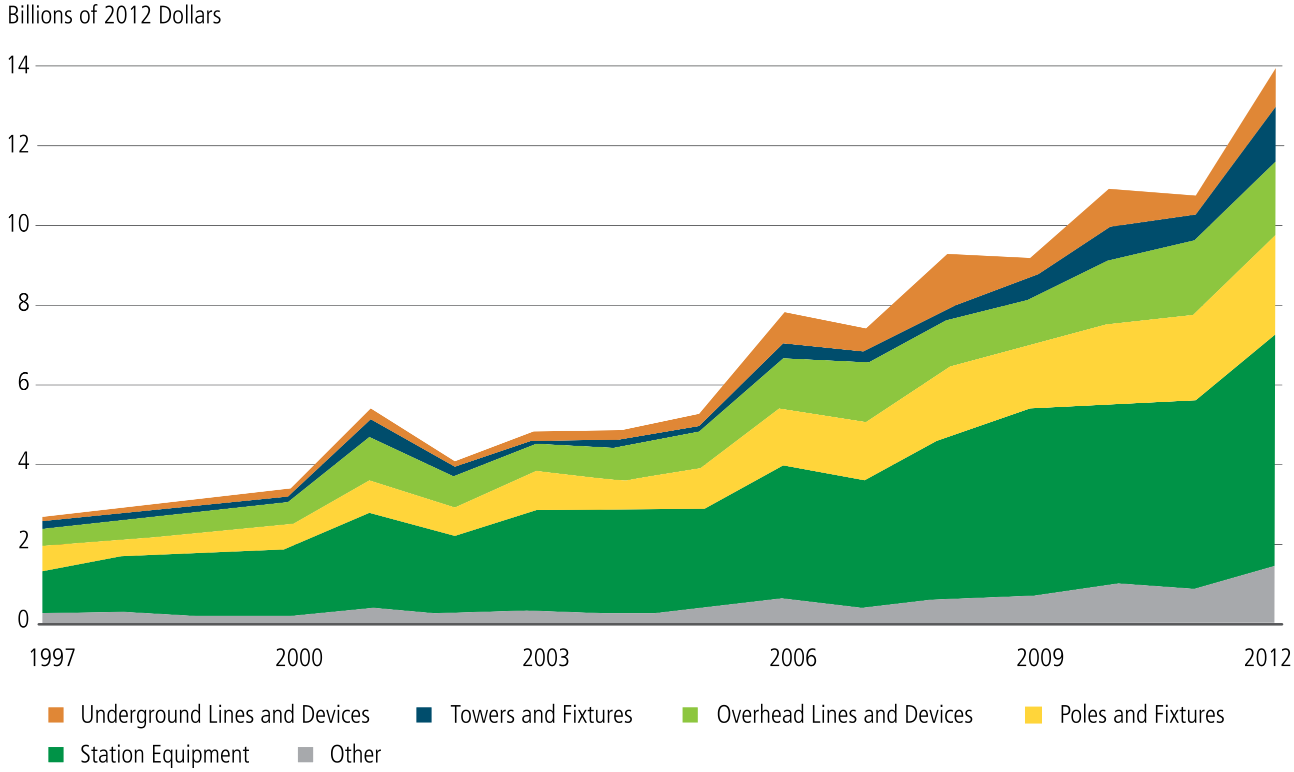
Power Plant Retirements

Since October 2012, utilities have announced the retirement of five nuclear reactors in California, Wisconsin, Florida, and Vermont; Oyster Creek in New Jersey is also slated for retirement.[56] U.S. electricity providers are announcing the retirement of a number of coal-generating assets. EIA forecasts 49.4 gigawatts of retirements between 2013 and 2020.[57] Changes in baseload generation will affect transmission infrastructure needs. Market-related factors driving coal retirements include declining growth in electricity demand, lower natural gas prices, and changing coal prices. Due to rising international demand and declines in domestic mining productivity, EIA projects steady price increases for coal through 2040;[58] meanwhile, market prices for coal have increased by roughly 70 percent since 2000.[59] Coal generation retirements will vary by region, based on the amount of existing coal generation, with regionally varying implications for transmission and bulk power system's operations and reliability. Retirements are also affecting the nuclear power industry, with closures announced in 2012–2013 of five nuclear reactors, the first since 1998. Nuclear power supplied nearly 19.0 percent of U.S. electricity in 2013—all of it carbon free—yet only accounts for 10.0 percent of total installed capacity, with 2014 preliminary data showing a record average 90.9 percent capacity factor for the Nation's 100 nuclear units.[60] The loss of these plants could lead to a shift in power flows across the transmission system.

Rising Investment in Electric Transmission

According to EIA, between 1997 and 2012 electric transmission investments by private companies and investors increased fivefold in real terms (2012 dollars), growing from $2.7 billion in 1997 to $14.1 billion in 2012—reversing a three-decade decline (see Figure 1-4).[61] Reasons for increased investment include reliability enhancement, connecting to renewables, demand shifts, cost increases, and market reforms that created more options for independent generators.

Figure 1-4 Investment in Transmission Infrastructure by Investor-Owned Utilities, 1997–2012[62]



Spending on transmission Infrastructure has increased fivefold since the late 1990s.

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.

Some key aspects of the climate change picture are summarized here as a prelude to the discussion in later chapters of how decisions about TS&D infrastructure will likely be influenced by this and other environmental issues.

Climate Science

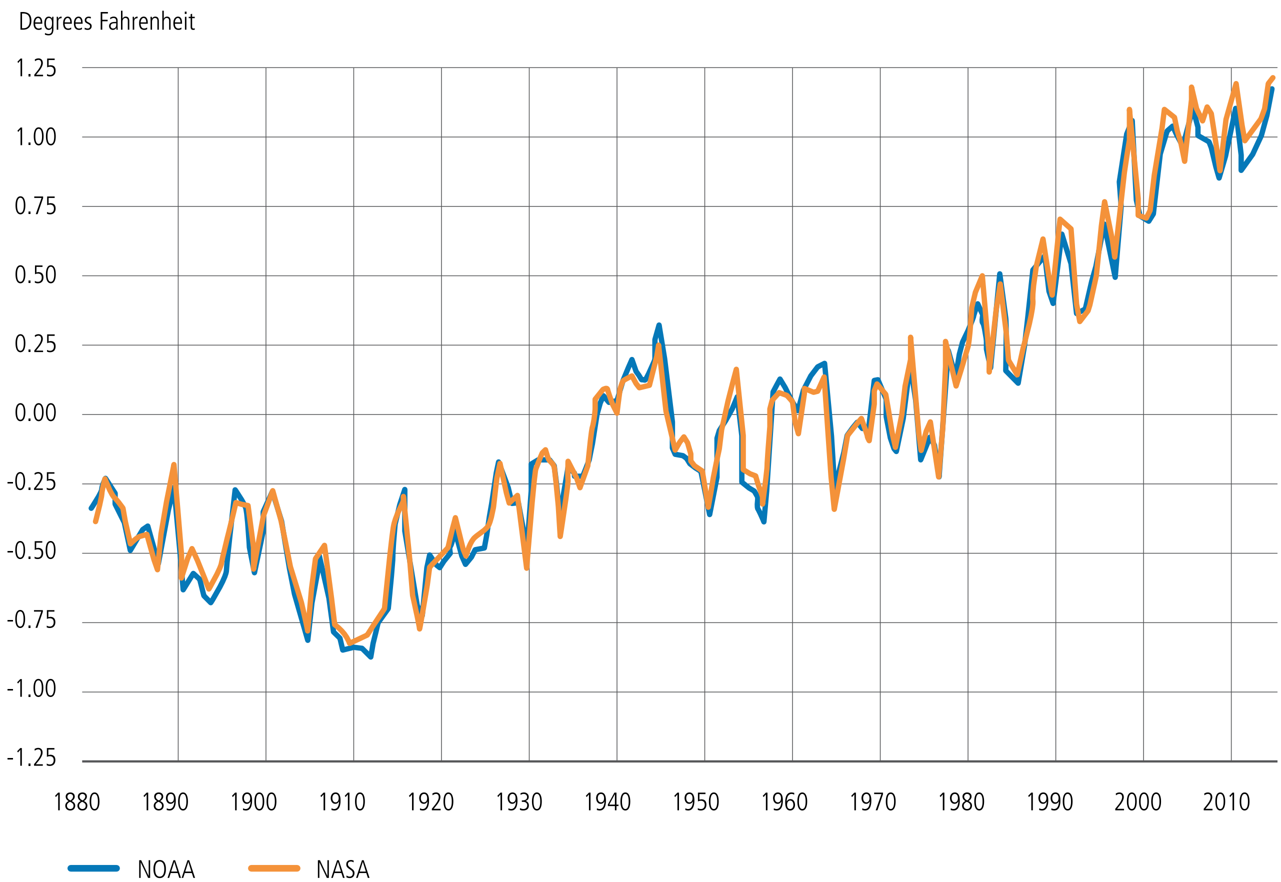
The key conclusions from climate science—as embodied in the most recent reports of the Intergovernmental Panel on Climate Change,[63] the National Academy of Sciences (jointly with the Royal Society of London),[64] and the Third National Climate Assessment of the U.S. Global Change Research Program[65]—are 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.

Climate Trends

The annually and globally averaged air temperature near Earth's surface has been directly computable from thermometer measurements around the world since the late 19th century; determinations of this average over the period 1880–2014 by the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration are shown in Figure 1-5. According to the best estimates of both organizations, 2014 was the hottest year since 1880, 2010 the second hottest, and 2005 the third hottest.

The increase in the average temperature, amounting to about 1.4 degrees Fahrenheit for the world and 1.6 degrees Fahrenheit for the United States, is not *per se* the essence of the climate change problem, however. These average temperatures, like the temperature of the human body, are simply indices pointing to the overall state of a very complex system. In the case of climate, the state of the system includes not just the averages, but the spatial and temporal variations of temperature, humidity, clouds, winds, rainfall and snowfall, and tropical and extratropical storminess, as well as such closely related factors as sea level; sea-ice cover; ocean currents; the stability of permafrost; and the amount of water stored in groundwater, snowpack, and mountain glaciers.

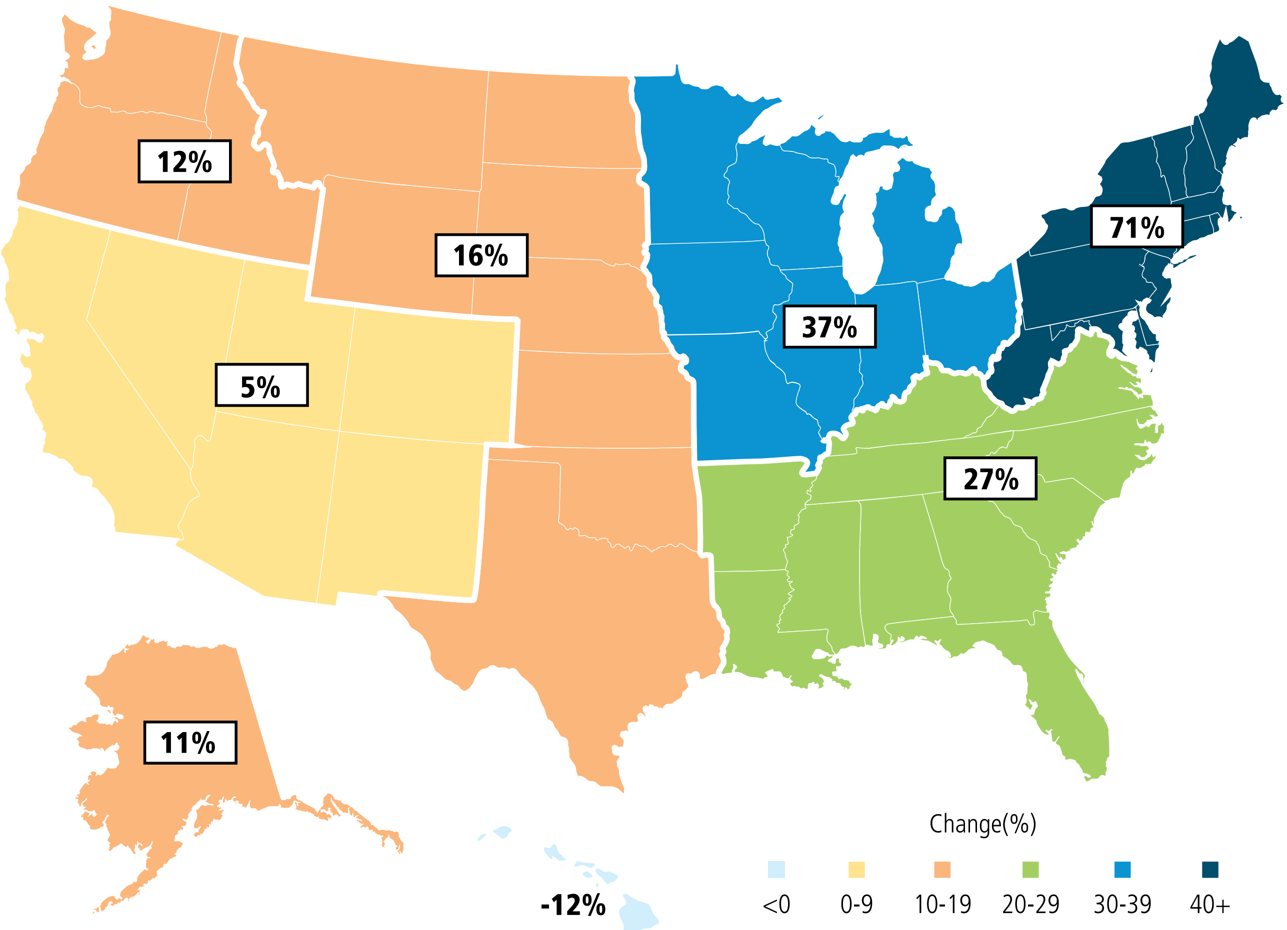
Figure 1-5. Global Average Surface Air Temperature Relative to the 1951–1980 Average[66]



Climate Change Impacts

A number of the manifestations of global climate change are particularly relevant to the TS&D focus of this report. These include dramatic increases in very hot days and heat waves in many regions; a higher fraction of rain falling in downpours in most regions (see Figure 1-6); increases in the intensity of droughts, wildfires, and the most powerful storms in some; the shrinkage of sea ice and the thawing of permafrost in the far North; and the rise of mean sea level.

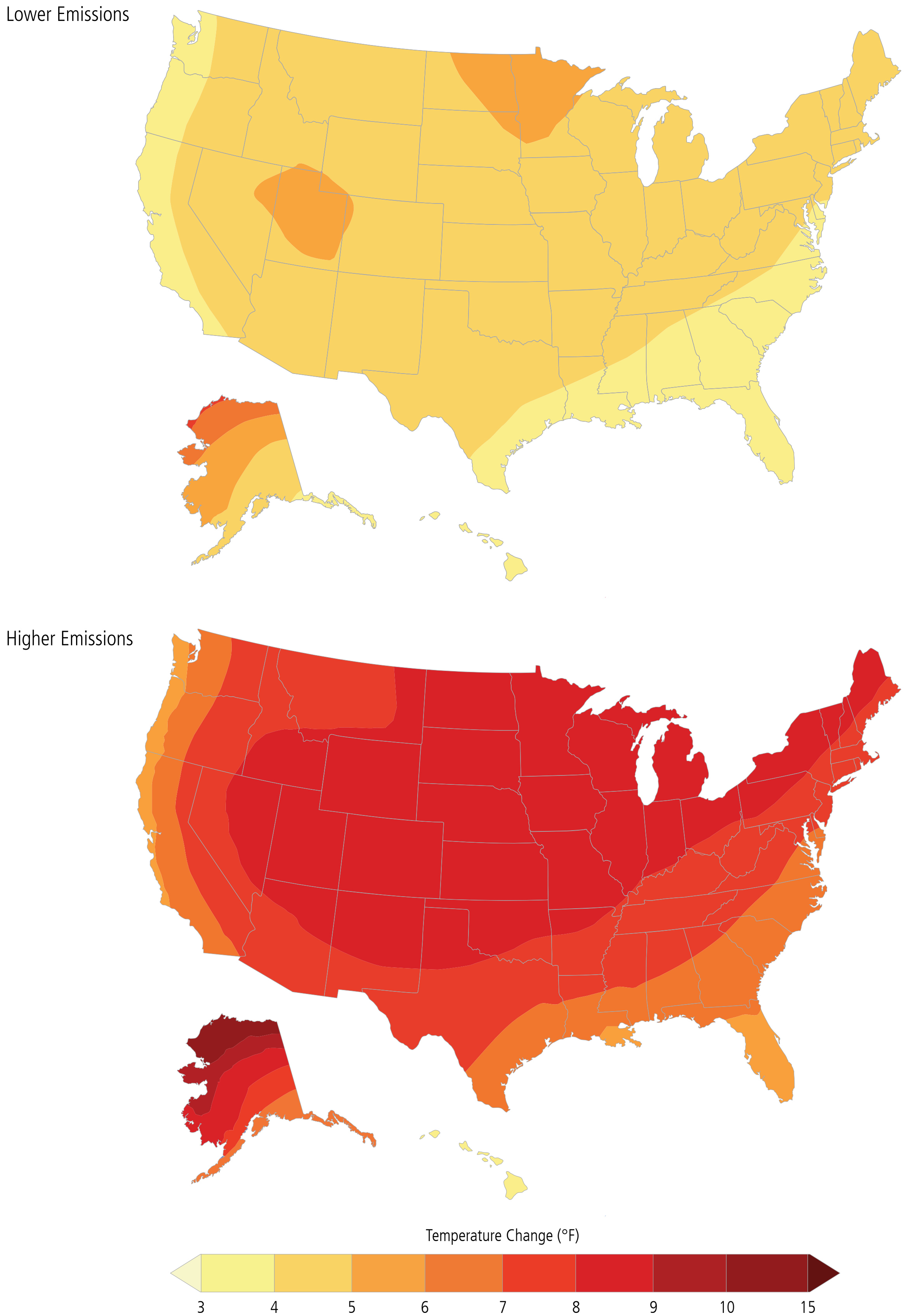
Figure 1-6. Observed Change in Very Heavy Precipitation[67]



Intense precipitation events are becoming more frequent, particularly in the northeastern United States. The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1 percent of all daily events) from 1958 to 2012 for each region of the United States.

It is these kinds of changes that have brought climate change home to a large proportion of the world's population, including in the United States. Additionally, because of these manifestations of climate change beyond average warming, their impacts on life and property and livelihoods, and the prospect of their continuing to worsen going forward, in proportion to the size of future emissions (see Figure 1-7), that many policymakers, many leaders of business and civil society, and large majorities of publics around the world have concluded that it is time to take action both to reduce those emissions and to increase preparedness for and resilience against whatever further changes in climate materialize.

Figure 1-7. Change in Average Temperature in the Later Part of this Century (2071-2099; 20-year average) Relative to the Late Part of Last Century (1970-1999) under Low- and High-Emission Scenarios for Global GHGs[68]



Human Causes of Climate Change

The most important of the anthropogenic emissions driving global climate change are those of CO_2, methane, and particulate black carbon. Of the total warming influences exerted by anthropogenic emissions since the nominal start of the Industrial Revolution in 1750, 42 percent came from CO_2 emissions, 24 percent from methane emissions, and 16 percent from particulate black carbon emissions; the remainder was divided almost equally among emissions of halocarbons, nitrous oxide, and carbon monoxide (which converts to CO_2 in the atmosphere).[69] The relative importance of CO_2 emissions compared to those of the other heat-trapping substances has been growing over time, moreover. Based on integrated warming influence over the next 100 years, U.S. emissions of CO_2 in 2013 accounted for more than 82 percent of the impact of all U.S. GHG emissions combined for that year.[70] The share of CO_2 as a proportion of all global GHG emissions in the same year, calculated on the same basis, was about the same.[71]

The main sources of the anthropogenic additions of CO_2 to the atmosphere over the course of the industrial revolution have been fossil fuel burning (including flaring of natural gas), cement production, and land-use change. By 2013, the fossil fuel and cement contribution accounted for 92 percent of the total.[72] U.S. CO_2 emissions from fossil fuels and cement in 2013 amounted to about 17 percent of the world total and came from oil burning (40 percent), coal burning (30 percent), useful natural gas burning (25 percent), non-energy uses of fossil fuels (3 percent), cement manufacturing and other non-fossil-fuel industrial activities (1 percent), and gas flaring (1 percent).[73]

In recent years, the main contributors to global emissions of methane from human activities have been the fossil fuel system (30 percent of human-caused emissions), livestock (27 percent), landfills (21 percent), biomass/biofuels burning (11 percent), and rice cultivation (11 percent).[74] In the United States, which accounts for about 8 percent of anthropogenic methane emissions worldwide, the role of the energy system in methane emissions has been larger; the main contributors in 2013 were the fossil fuel system (43 percent), livestock and manure management (34 percent), and landfills and other waste management (20 percent).[75]

TS&D systems are responsible for only a small fraction of overall U.S. emissions. There are nonetheless opportunities to reduce emissions from this sector—for example, through halting methane leakage from natural gas pipelines and processing facilities. And, of course, the expanded implementation of no- and low-CO_2 energy technologies being undertaken to reduce the energy system's GHG emissions overall will place additional demands on TS&D in some cases (e.g., to link remote renewable energy sources with demand centers and to move captured CO_2 from fossil-fueled (and, possibly biomass-fueled) power plants through pipeline networks to sites for productive use or geologic storage).

The U.S. Response to the Climate Change Challenge

The Obama Administration has addressed the growing threat from climate change through a comprehensive set of energy and environmental strategies to cut GHG emissions domestically and through sustained diplomacy to spur global action.

The Administration's First Term

First term actions include $80 billion of investments in a cleaner, more efficient U.S. energy future through the American Recovery and Reinvestment Act of 2009, as well as additional funding through 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.

Other actions to deploy low-carbon solutions included creation of the TIGER program (i.e., the Transportation Investment Generating Economic Recovery program), which combines Federal, private, state, and local funding to advance public transportation; the public-private Better Buildings Initiative to boost the energy efficiency of commercial and industrial buildings; and promulgation of the first-ever national fuel efficiency and GHG emissions standards for heavy-duty trucks and buses.

The Administration also invested in clean energy technology leadership through increases in DOE funding for research and development on clean energy and energy efficiency; creation of five Energy Innovation Hubs linking academia, industry, and government in a concerted effort to overcome barriers to the development and commercialization of a variety of cleaner and more efficient energy technologies; and the launch of the Transportation Electrification Initiative to accelerate market adoption of advanced electric vehicles.

These domestic initiatives contributed to a number of the trends affecting TS&D infrastructure that were mentioned previously in this chapter, such as decreases in oil consumption, increased deployment of renewable energy for power generation, and slowing the rate of electricity demand growth.

The Climate Action Plan

In June 2013, the President announced a comprehensive "Climate Action Plan," with three pillars:[76]

- **Additional measures to reduce domestic GHG emissions and bolster land-sector carbon sinks**, including CO_2 emission standards for existing and new fossil-fueled electric power plants, an interagency strategy to reduce methane emissions, and further commitments to clean energy and increased energy efficiency.
- **Measures to increase domestic preparedness for and resilience against changes in climate that can no longer be avoided**, including directing Federal agencies to incorporate climate change preparedness and resilience into their missions and policies, establishing interagency and state/local/tribal task forces on preparedness and resilience to advise on and implement additional steps, developing strategies and partnerships for managing floods and droughts, and mobilizing science and data to support these efforts.
- **Leading international efforts to address climate change**, including not just leading by example, but also bilateral and multilateral engagement on emission reduction targets and technologies (focusing particularly on the largest-emitting nations), assistance on building preparedness and resilience (focusing particularly on developing countries), and mobilizing clean energy and preparedness finance.

As noted in the Preface, the "Climate Action Plan" also mandated the production of an interagency QER, of which this report is the first installment.

Among the actions subsequently taken under the "Climate Action Plan,"[77] those with the greatest potential relevance for the future of TS&D infrastructure (and thus most germane to the focus of this report) include the following:

- **On domestic emissions**, changes to TS&D infrastructure will play a role in achieving the interagency strategy to reduce methane emissions nationwide, in the acceleration of permitting for new renewable energy projects on public lands and military installations, and in the implementation of 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.
- **On preparedness and resilience**, an Executive Order in November 2013 established both an interagency Council on Climate Preparedness and Resilience to coordinate the Federal Government's activities in this domain and a State, Local, and Tribal Leaders Task Force on Climate Preparedness and Resilience to advise the President and the council on needs on the ground. A climate data initiative was

launched in March 2014 to make available, in convenient form, all of the relevant data held by Federal departments and agencies; the "Third U.S. National Climate Assessment" (providing information tailored to regional and sectoral preparedness and resilience needs, including the needs of the energy sector) was released in May 2014, and the first version of a user-friendly U.S. Climate Resilience Toolkit was released to the public in November 2014. Among the benefits of these initiatives is better data and insight for TS&D infrastructure owners, regulators, and other stakeholders concerning the potential effects on that infrastructure of climate-driven phenomena such as sea-level rise.

- **On international engagement**, in November 2014, in a joint announcement with Chinese President Xi, President Obama announced a new U.S. target for post-2020 GHG emission reductions: 26 percent to 28 percent below 2005 levels by 2025. At that event, the Chinese government made the unprecedented commitment that Chinese emissions would peak by around 2030 and that China would boost its economy-wide share of non-fossil-fuel energy to about 20 percent by that time. Since then, the United States has worked with other countries, including Mexico, to secure ambitious climate change and clean energy commitments from those two countries, as well. Improvements to TS&D infrastructure will play a role in facilitating the achievement of the U.S. target and in increasing clean energy trade and market integration with Mexico.

Results of the Administration's Energy and Climate Policies

Between 2008 and 2014, the U.S. economy grew by 8.5 percent while total energy use and electricity generation both fell by 0.6 percent. That means the energy efficiency and electricity efficiency of the U.S. economy—real gross domestic product per quadrillion British thermal unit of total energy and real gross domestic product per billion kilowatt-hours of electricity—both grew during this period by 9.1 percent, an average of about 1.5 percent per year.[78] U.S. GHG emissions in 2013 were 7.0 percent below the 2008 level and 9.2 percent below the 2005 level used as a reference point for U.S. emissions reduction targets.[79]

A large part of these recent emissions reductions have come from the electric power sector, where emissions from coal burning declined 21.3 percent and emissions from all fossil fuel combustion in power plants declined 15.4 percent between 2005 and 2014.[80] Key factors contributing to this trend have included a reduction in demand growth; fuel switching from coal and petroleum to lower-carbon natural gas; and the previously mentioned growth in generation from wind and solar energy.[81] In addition, a combination of state and Federal policies, plus industry actions that include improved gas infrastructure equipment, contributed to a 13 percent decline in methane emissions in natural gas systems between 2005 and 2012.[82]

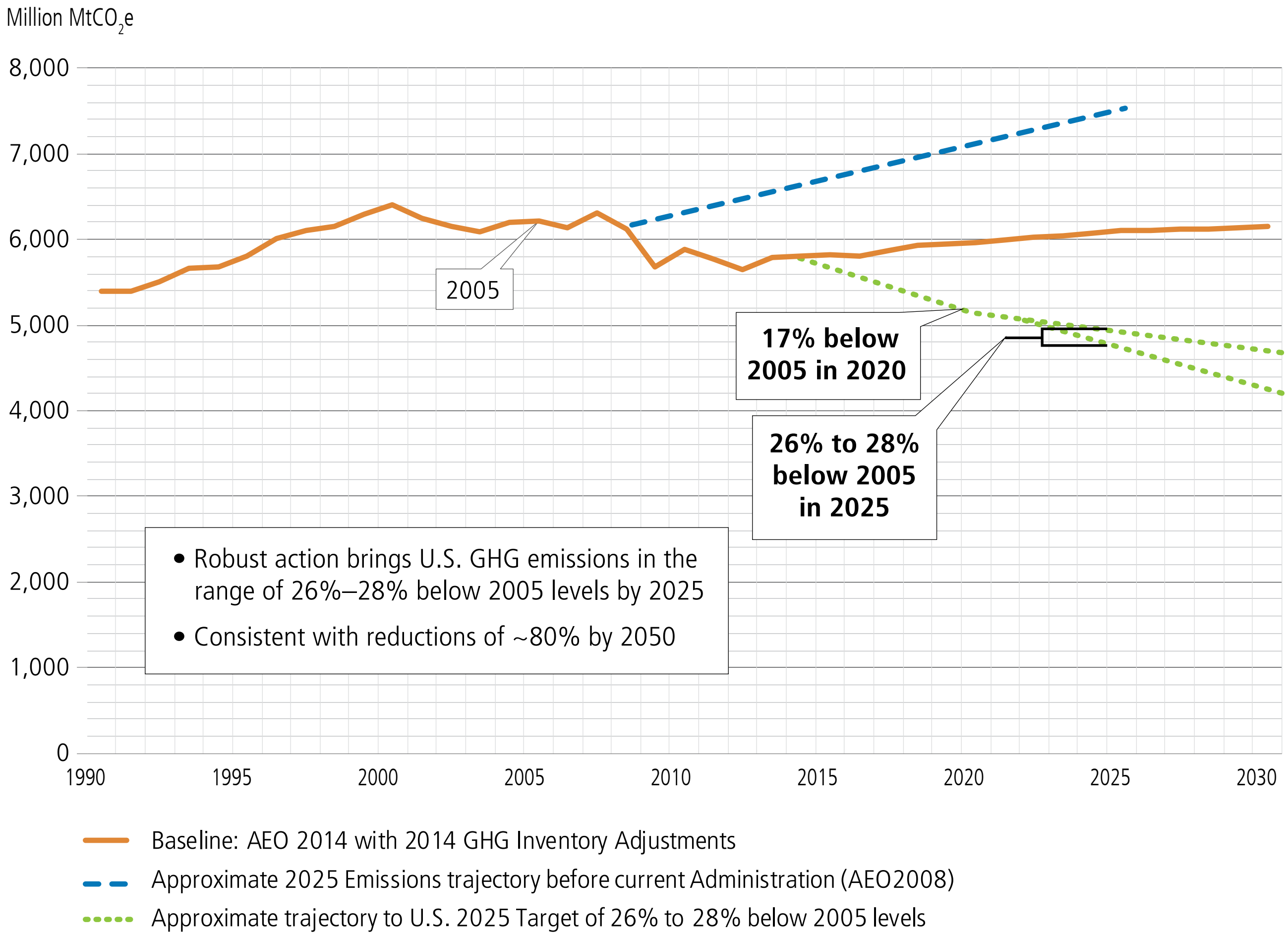
The Path Forward

As noted above, the Obama Administration committed formally in 2009 to a target of reducing U.S. GHG emissions to a level in the range of 17 percent below the 2005 value by 2020, and it committed further, in November 2014, to a level 26 percent to 28 percent below the 2005 value by 2025. Historic and projected U.S. emissions under these targets, to 2025, are shown in Figure 1-8.

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. According to the "U.S. Climate Action Report 2014" submitted by the Administration to the UN Framework Convention on Climate Change, U.S. emissions reductions by 2020 under the "Climate Action Plan," compared a 2012 Policy Baseline scenario,[f] could amount to 485 million metric tons to 800 million metric tons in energy sector CO_2, 100 million metric tons to 135 million metric tons of CO_2 equivalent in hydrofluorocarbons reductions under the Montreal Protocol, and 25 million metric

[f] The 2012 Policy Baseline Scenario assumes no additional measures beyond those in place in 2012 are implemented.

Figure 1-8. Historic and Projected U.S. GHG Emissions under Obama Administration Targets[83]



tons to 90 million metric tons of CO_2 equivalent in methane reductions under the "Climate Action Plan's" Methane Strategy.[84] The report indicates that these and a combination of smaller reductions from other sectors of the economy would bring total U.S. emissions in 2020 down to the range of 17 percent below 2005 levels.

Steepening of the downward trend after 2020, as Figure 1-8 shows, will be required in order to reach the target of 26 percent to 28 percent below the 2005 level by 2025. This is to be accomplished through several means, including implementation 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. Improvements in TS&D infrastructures will assist in meeting these goals. 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.

Energy Finance for TS&D Infrastructure

Significant investment by both the private and public sectors will be required to meet energy objectives and reduce vulnerabilities to disruptive events, but capital and cost of capital issues will be less challenging in the near term than regulatory or market structure barriers. Although most energy TS&D assets are privately or non-federally funded and owned, significant elements of the Nation's shared transport infrastructure, increasingly important for energy commodities, are federally funded and owned.

Private Sector Financing for Infrastructure

As an investment class, infrastructure generally is considered to be a long-term investment with relatively low risk, and most energy TS&D infrastructure projects fall into this category. Capital generally is available for projects that have a predictable revenue stream, have stable cash flows, and are based on proven technologies.[g, 85] These may include distribution infrastructure investments, where the rate base and rate of allowed return on investment have been established for the utility by the public service commission through the rate case process, or investments by a natural gas midstream pipeline company that have signed long-term contracts with suppliers or shippers. These stable, predictable returns are attractive to capital markets, including institutional investors, many of whom are looking for lower-risk, longer-duration assets to match long-dated liabilities.[86, h]

Barriers to investment tend to arise from unfavorable market fundamentals or regulatory challenges, rather than from constraints related to access or cost of capital (although, this may change if interest rates rise or risk spreads change). These barriers include lack of full market valuation (e.g., for grid ancillary services, including storage) and lack of information for decision makers (e.g., to inform an appropriate level of resiliency upgrades). Additionally, market externalities, such as climate change impacts due to GHG emissions, are not addressed. Additional public financing mechanisms may help support investment; for example, by de-risking projects that incorporate innovative technology, as well as ameliorating near-term affordability issues such as rate shock to customers from infrastructure modernization (further discussed in Chapter II, Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

Public Sector Financing for Infrastructure

The Federal Government funds and owns key elements of the Nation's energy systems, such as the Strategic Petroleum Reserve for liquid fuels and the Power Marketing Administrations for electricity. The government also plays a role in demonstrating and deploying first-of-a-kind technologies at scale, such as through the DOE Loan Program. In addition, the Department of Agriculture's Rural Utility Service provides support for TS&D infrastructure. In addition, energy TS&D infrastructure investments have been supported by Federal tax credits and structures, such as master limited partnerships for natural gas and liquid fuels transmission, tax-exempt municipal bonds for public utilities, and investment tax credit for storage associated with renewable power.

Large segments of shared infrastructure, such as highways, water transportation, and ports, are supported by public funds.[87] For example, water transport infrastructure, including canals, shipping channels, and locks, are constructed and maintained by the Army Corps of Engineers through Federal appropriations. In many cases, as discussed in Chapter V (Improving Shared Transport Infrastructures), these assets serve a vital and increasing role in the transport and distribution of energy supplies, which have been underfunded for many years.

This installment of the QER and the analysis supporting its recommendations suggests the need for substantial additional private and public sector investment. Targeted Federal investments will be needed in areas such as the Strategic Petroleum Reserve, ports, and waterways, as well as other areas of traditional government responsibility, and to incentivize the mobilization of private sector capital. Appropriately designed Federal investments will pay significant dividends for the Nation's competitiveness, energy security, and the transition to a clean energy future. As disruptive events to energy infrastructure become more prevalent, the Federal

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[g] For example, one panelist at the QER Finance Stakeholder meeting in New York City commented that today's market has a "tremendous amount of capital" chasing "a dearth of [financeable] projects." See: Department of Energy. "Summary of Presentations and Comments at the Quadrennial Energy Review Stakeholder Meeting #13." p. 2. October 6, 2014.

[h] Additionally, global total capital for all mutual fund and institutional investors is estimated at approximately $75 trillion, with approximately $20 trillion in U.S. pension funds alone, although only a fraction of this capital is currently dedicated to the infrastructure asset class. See: Ceres. "Investing in the Clean Trillion: Closing The Clean Energy Investment Gap." www.ceres.org/resources/reports/investing-in-the-clean-trillion-closing-the-clean-energy-investment-gap/view.

Government can build and incentivize the capacity of states, tribes, and localities for greater reliability, resiliency, and recovery through energy assurance plans and grants.

Energy Infrastructure Data and Information

Policymakers and companies rely on energy data to understand the status and evolution of national energy systems and associated implications for markets, resilience, environment, safety, and other issues. One of the major goals of policymakers is to forecast potential trends or disruptions to the system, identify vulnerabilities, accurately characterize and quantify the scale of externalities, and then direct the response that is in the national interest. Good decision making by public and private entities alike on energy investments and policies requires accurate, accessible data and analysis. There are three overlapping areas around data that need to be improved in order for the Federal Government to accomplish its energy policy goals: data gaps, analytical methodology, and modeling/visualization tools.

Many national-level data gaps in liquid fuels, natural gas, and electricity infrastructure need to be filled, particularly for environmental and safety issues and energy-related transport. In many cases, current data is either outdated, sporadically collected, privately held, not coordinated in definitions or formats, "siloed" in different databases, or simply not collected. For example, information of railway congestion related to energy product transportation is severely outdated, with data often lagging by 2 years or more (see Chapter V, Improving Shared Transport Infrastructures).

Energy stakeholders also need improved, commonly accepted analytical methodologies to define, measure, verify, and evaluate options in order to make more accurate and timely decisions regarding infrastructure. For example, frameworks and tools for assessing energy infrastructure resilience to disruptions vary widely across industries and government agencies and may be well-tailored for specific industries and sectors, but are not designed to aid policymakers and regulators in understanding current vulnerabilities; in deciding where to focus efforts and investment to increase resilience; or in determining what level of resilience is needed to protect consumers, safety, and the economy.

Finally, as the quality and consistency of data improve, models available to the Federal Government must be adapted to utilize that data effectively and to address key emerging policy questions. For example, models cannot fully address issues of electric grid congestion at a national scale. Further, while many energy-sector-specific modeling and visualization tools already exist, these often are likely to ignore critical interdependencies or operate with low temporal resolution. Gaps also exist in high-quality modeling and visualization tools in specific subsectors, such as electricity distribution, natural gas production, bulk gas transmission, and the liquid fuels network.

TS&D Infrastructure Goals and Architecture of the Study

This report's integrated assessment of the emerging threats, risks, and opportunities for TS&D energy infrastructure in the United States was guided by three high-level goals:

Economic competitiveness: Energy infrastructure should enable the Nation to, under a level playing field and fair and transparent market conditions, produce goods and services that meet the test of international markets while simultaneously maintaining and expanding jobs and the incomes of the American people over the longer term. Energy infrastructures should enable new architectures to stimulate energy efficiency, new economic transactions, and new consumer services.

Environmental responsibility: Energy infrastructure systems should be developed and managed in an environmentally responsible manner, taking into consideration the imperatives of climate change and the societal costs and benefits of reducing or avoiding pollution and land-use impacts on a lifecycle basis in order to minimize their environmental footprint while enabling better environmental performance for the energy system more broadly. It is also important for policies to promote equity and avoid disproportionate impacts to any particular populations.

Energy security: Vulnerabilities resulting from disruptions to energy infrastructure should be minimized from disruptions in supply and mitigate impacts of disruptions, including economic impacts. If disrupted, the U.S. energy infrastructure should be able to recover quickly. Energy security should support overall national security and encompass a collective approach to U.S. allies, other friendly nations, and trading partners.

The "Desirable Infrastructure Characteristics" box provides a longer list of characteristics that U.S. TS&D infrastructures should embody (in varying degrees) by 2030. The overall structure of the study and its recommendations is depicted in Figure 1-9.

Desirable Infrastructure Characteristics

In addition to the high-level goals of competitiveness, energy security, and environmental responsibility, this report focuses on how to enhance a more granular set of desirable characteristics that transmission, storage, and distribution infrastructures should, in varying degrees, embody by 2030:

Reliability. The ability of a system or its components to operate within limits so that instability, uncontrolled events, or cascading failures do not result if there is a disturbance, whether the disturbance is a disruption from outside the system or an unanticipated failure of system elements. Reliability also means that a system's components are not unexpectedly failing under normal conditions.

Resilience. The ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions. To the extent that actions improve a system's ability to withstand disruptions, they might be characterized as enhancing reliability, or resilience, or both. The ability to recover from a disturbance, however, is specific to resilience.

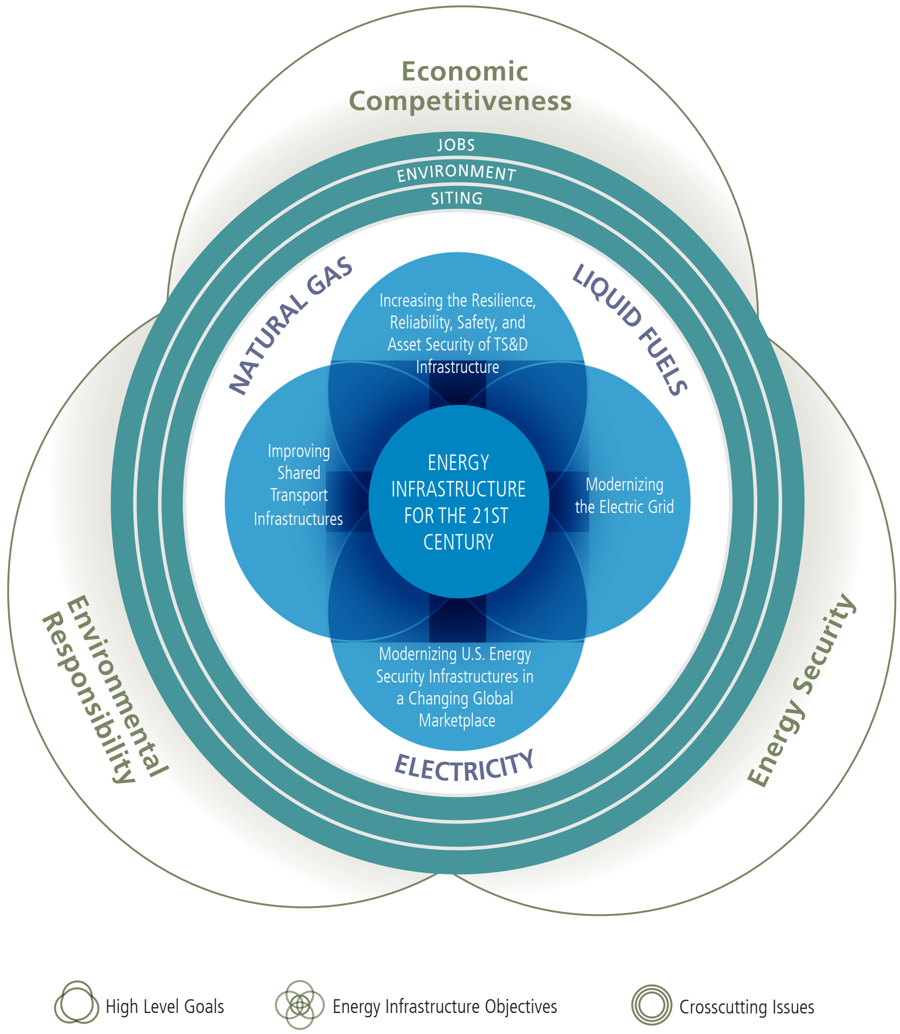
Safety. Achieving an acceptably low risk to life and health in the design, construction, operation, and decommissioning of a system. That level of risk is determined by taking into account the magnitude of potential consequences, the probability of those consequences occurring, and the costs of risk mitigation.

A minimal environmental footprint. Energy systems should be efficient and designed, constructed, operated, and decommissioned in a manner that minimizes carbon pollution. They should have a minimal impact on air quality and water quantity and quality, have a minimal land-use footprint, have a low impact on biological resources, and have minimal toxic emissions.

Flexibility. Energy infrastructure should be flexible enough to accommodate change in response to new, expected, or unexpected internal or external system drivers. Flexibility could include extensibility, the ability to extend into new capabilities beyond those required when the system first becomes operational; interoperability, the ability to interact and connect with a wide variety of systems and subsystems, both in and outside of the energy sector; and optionality, which provides infrastructures or features of infrastructures that would allow users to maximize value under future unforeseen circumstances. Distributed generation, for example, could include these characteristics.

Affordability. Ensures that at both the system and component levels, costs and defined needs (or requirements) of users are balanced with their ability to pay and consider the value created by the energy goods or services for the users or the system.

Figure 1-9. Objectives, Goals, and Organization of the QER[88]



This figure shows the comprehensive set of interactions and overlapping objectives and goals of energy TS&D infrastructure, and of the corresponding organization of the QER.

Figure Notes:

1. Analyses were conducted with high-level national goals as the guideposts: (1) energy security, (2) environmental responsibility, and (3) economic competitiveness.
2. Central to the QER is a set of four analytically derived objectives that represent an integrated approach to assessing the adequacy of our TS&D energy infrastructures for supporting these high-level goals. These objectives are: (1) increasing TS&D resilience, reliability, safety, and asset security; (2) modernizing the electric grid; (3) modernizing U.S. energy security infrastructure; and (4) improving shared transport infrastructures.
3. The QER also provides more conventional sector-level analyses of three infrastructures that represent key fuels/energy carriers: (1) liquid fuels, (2) natural gas, and (3) electricity. Each of these is described in detail in Appendices A, B, and C. Finally, the figure shows a host of additional crosscutting government and private sector mechanisms/tools that enable or impede energy infrastructures in achieving the objectives; these are represented in the surrounding circles and include jobs and training, environment, and siting. Other crosscutting issues are embedded in the integrated analysis.

Assessing Trends Using Scenario Analysis

The QER used scenario analyses to assess the impact of many of the factors previously described on the need for liquid fuels, natural gas, and electricity transmission infrastructure between 2014 and 2030. The scenarios explored infrastructure changes and TS&D investments that might be required under a range of possible future conditions, including changes in policy. Factors analyzed included, among others, an economy-wide cap on CO_2 emissions driving a 40-percent reduction in 2030, decreases in renewable generation costs, increased natural gas prices, and dramatic expansions of LNG export capacity (see Table 1-2). Each of these scenarios was run individually, and some were run in combination. The scenarios were defined to be "stressing" as they were not those considered most likely, but were those that might require the greatest amount of change in existing infrastructure. Each scenario was compared to the Annual Energy Outlook 2014 Reference case. Scenario outputs included the amount of additional transmission and storage infrastructure built, GHG emissions, and energy costs.

Table 1-2. QER Scenarios

Scenarios	Model
Base Case: Annual Energy Outlook 2014 Reference Case	
Natural Gas • High domestic gas demand • High world gas supply • High U.S. exports	**Deloitte (MarketPoint)** • Coupled gas infrastructure and electricity market models • Outputs include major pipeline capacity expansions and new pipeline builds
Electricity • Low wind cost • Low solar cost • Low-cost storage • High/low electricity demand • High natural gas prices • 40-percent economy-wide greenhouse gas reduction by 2030 • High penetration of distributed generation (photovoltaic) • High natural gas use • No new transmission	**National Renewable Energy Laboratory (Renewable Energy Deployment System, ReEDS)** • Electricity generation capacity expansion model • Outputs include transmission capacity expansion, generation, electricity costs, etc.
Liquid Fuels • Low/high oil resource • Revisit oil export ban/keep intact • Low oil demand	**Energy Policy Research Foundation, Inc. (Ponderosa Crude Flow Model)** • Pipeline flow and refinery model allocates domestic and foreign crude oil based on refinery demand and margin optimization **Oak Ridge National Laboratory/Jacobs Model** • Detailed refinery modeling (Jacobs) informs simplified refinery, crude distribution model (Oak Ridge)

The natural gas scenario analysis results indicated that even under conditions of high domestic gas demand or high U.S. gas exports, the amount of new gas transmission infrastructure needed is lower than or commensurate with historical build rates. More new infrastructure is needed for the high U.S. exports case than for the high domestic demand case because new pipelines would be needed, especially in the Gulf region. The electricity scenarios similarly showed that transmission needs through 2030 do not significantly exceed historical build rates under a wide range of renewable energy deployments, under a GHG cap, and under accelerated retirements. Certain scenarios do, however, produce different regional transmission needs; for example, more transmission is required in the Great Lakes region relative to the base case if wind costs drop by about 15 percent. Finally, liquid fuels scenarios showed that very little liquid fuels transmission infrastructure will be built even under high-demand conditions.

In parallel with the QER, DOE is conducting a Quadrennial Technology Review examining energy research, development, demonstration, and deployment opportunities. Unlike the QER, which assesses the entire energy sector, the QTR is more directly focused on DOE's internal research and technology priorities. The first QTR was issued in 2011, and the box below describes the 2015 QTR effort.

The Quadrennial Technology Review

The Quadrennial Technology Review (QTR) is a report issued by the Department of Energy (DOE) that examines the most promising research, development, demonstration, and deployment (RDD&D) opportunities across a broad spectrum of energy supply and end-use technologies. The first QTR was issued in 2011; DOE is anticipating the release of the second review in mid-2015. While the Quadrennial Energy Review (this report) is focused on infrastructure and policy issues across the public sector, the QTR is primarily focused on DOE-supported RDD&D to meet national energy challenges and goals. The two reviews are parallel to and complementary with each other.

The 2011 QTR defined a framework for understanding and discussing energy system challenges; established a set of priorities for DOE; and explained to stakeholders the roles of DOE and its national laboratories, the broader government, the private sector, academia, and innovation in energy transformation.

The 2015 edition of the QTR will describe the Nation's energy technology landscape and the dramatic changes that have taken place since the first report in 2011. The 2015 QTR will approach the analysis from a systems perspective to explore the integration of science and technology. It will include chapters on the following:

- Advancing systems and technologies to produce cleaner fuels
- Enabling modernization of electric power systems (grid)
- Advancing clean electric power technologies (generation)
- Increasing efficiency of building systems and technologies
- Innovating clean energy technologies in advanced manufacturing
- Advancing clean transportation and vehicle systems and technologies
- Enabling capabilities for energy science and technology.

As with the 2011 QTR, the 2015 QTR will inform DOE's strategic planning through detailed technology assessments that examine potential RDD&D pathways and their impacts out to 2030 and beyond.

More information on the QTR can be found at www.energy.gov/qtr.

Organization of the Remainder of the Report

The analysis conducted for the QER identified four major integrated objectives that address near-, mid-, and long-term energy infrastructure needs and challenges, which are covered in Chapters II through V:

- **Chapter II. Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure**, focusing on the range of vulnerabilities and growing threats for TS&D infrastructures and ways to decrease those vulnerabilities, including hardening them to make them less vulnerable, more reliable and resilient, or safer.
- **Chapter III. Modernizing the Electric Grid**, enabled through infrastructures, policies, technologies, and other mechanisms.
- **Chapter IV. Modernizing U.S. Energy Security Infrastructures in a Changing Global Marketplace**, including physical, market, and geopolitical recommendations.
- **Chapter V. Improving Shared Transport Infrastructures**, focusing on rail, waterways, ports, and roadways—transportation modes shared by other commodities and products that are seeing significant increases in use for the transportation of energy commodities.

The report also focused on crosscutting areas of inquiry that are important to the integrated analyses, as well as the analyses of the physical energy infrastructures in Chapters VI through IX:

- **Chapter VI. Integrating North American Energy Markets** summarizes how an integration of the North American energy market could enhance energy security, reliability, resiliency, and competitiveness policies affecting cross-border infrastructures.
- **Chapter VII. Addressing Environmental Aspects of TS&D Infrastructure** focuses on ways to cut carbon pollution and protect the environment.
- **Chapter VIII. Enhancing Employment and Workforce Training** focuses on enhancing jobs, competitiveness, and training for modernizing energy infrastructures.
- **Chapter IX. Siting and Permitting of TS&D Infrastructure** focuses on promoting siting and permitting policies that expedite infrastructure build-out while protecting the environment and communities.

The processes through which the findings and recommendations emerged are described in:

- **Chapter X. Analytical and Stakeholder Process** describes how the QER analysis was informed by the stakeholder outreach effort and provides details on the systems analysis commissioned to support the QER.

Sector-specific analyses of the following physical infrastructures (listed in more detail in Table 1-1) were also completed and accompany this report as appendices, as does a summary of Federal emergency authorities germane to recovery of TS&D infrastructure after disasters:

- **Appendix A. Liquid Fuels**
- **Appendix B. Natural Gas**
- **Appendix C. Electricity**
- **Appendix D. Federal Emergency Authorities.**

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ROAD CLOSED
TO
THRU TRAFFIC

Chapter II

INCREASING THE RESILIENCE, RELIABILITY, SAFETY, AND ASSET SECURITY OF TS&D INFRASTRUCTURE

This chapter addresses a broad range of challenges to the resilience, reliability, safety, and asset security of transmission, storage, and distribution (TS&D) and shared infrastructures. The challenges vary among different types of TS&D infrastructure and among different regions of the United States. First, the electric grid is examined. The grid is especially vulnerable to extreme weather events. It also is vulnerable to low-probability/high-consequence events. Natural gas is the second TS&D infrastructure discussed. Here, in addition to the examination of vulnerabilities and interdependencies, is a discussion of safety issues. The third major section of this chapter addresses the resilience, reliability, and asset security of TS&D infrastructure for liquid fuels. This chapter concludes by presenting a series of major recommendations, a number of which cut across and address multiple infrastructures and challenges.

FINDINGS IN BRIEF:
Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure

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.

Transmission, storage, and distribution (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 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.

The Importance of Resilient, Reliable, Safe, and Secure TS&D Infrastructure

Building a resilient, reliable, safe, and secure energy infrastructure is a national priority and vital to American competitiveness, jobs, energy security, and a clean energy future. President Obama highlighted the importance of energy infrastructure in Presidential Policy Directive-21, in which energy infrastructures were described as "uniquely critical."

Presidential Policy Directive-21[a]

In February 2013, the President broadened the national effort to strengthen and maintain secure, functioning, and resilient critical infrastructure by issuing Presidential Policy Directive-21, *Critical Infrastructure Security and Resilience*. 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. This document goes on to define resilience as "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents." Threats may include natural or human-made hazards, such as hurricanes or physical threats. The consequences of these hazards to infrastructure broadly affect social welfare. They go beyond the ability of a system to operate and address the vitality of our national safety, prosperity, and well-being.

[a] The White House Office. "Presidential Policy Directive 21 - Critical Infrastructure Security and Resilience." February 12, 2013. http://www.whitehouse.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil. Accessed February 2, 2015.

TS&D infrastructures—key components of the Nation's energy systems—include approximately 2.6 million miles of interstate and intrastate pipelines, 142 operable refineries, about 642,000 miles of high-voltage transmission lines, and almost 6.3 million miles of electricity distribution lines.[1] These vast energy TS&D networks reliably deliver electricity, transportation fuels, and heat to more than 300 million American consumers daily and provide industry with feedstocks for a large range of products. The U.S. bulk electric power transmission system, for example, had high availability (97–98 percent) during the period from 2008 to 2013.[2] In less than one decade, the U.S. natural gas and oil TS&D infrastructures have successfully connected significant new sources of supply to processing facilities and consumers. In addition, in just a few short years, ethanol has moved from a niche fuel to 10 percent of the Nation's gasoline supply, supported by a TS&D system that has been flexible enough to accommodate this growth.

The imperative for resilient TS&D infrastructures going forward is to maintain the high performance of the existing systems; to continue to accommodate significant growth in domestic supplies; and to manage and adapt to new technologies, threats, and vulnerabilities in cost-effective ways. These vulnerabilities are growing and exacerbated by climate change.

In addition, TS&D infrastructures are becoming increasingly interdependent and interconnected. These extremely complex systems consist of physical TS&D facilities (such as transmission lines, pipelines, and storage facilities); cyber-dependent communications or control networks; roadways, railways, and waterways; and human decision makers (such as consumers, legislators, investors, and CEOs).[3,4] A key interdependency (and vulnerability) for *all* sectors and critical infrastructures is reliance on electricity, making its reliability a fundamental need and requirement economy-wide.

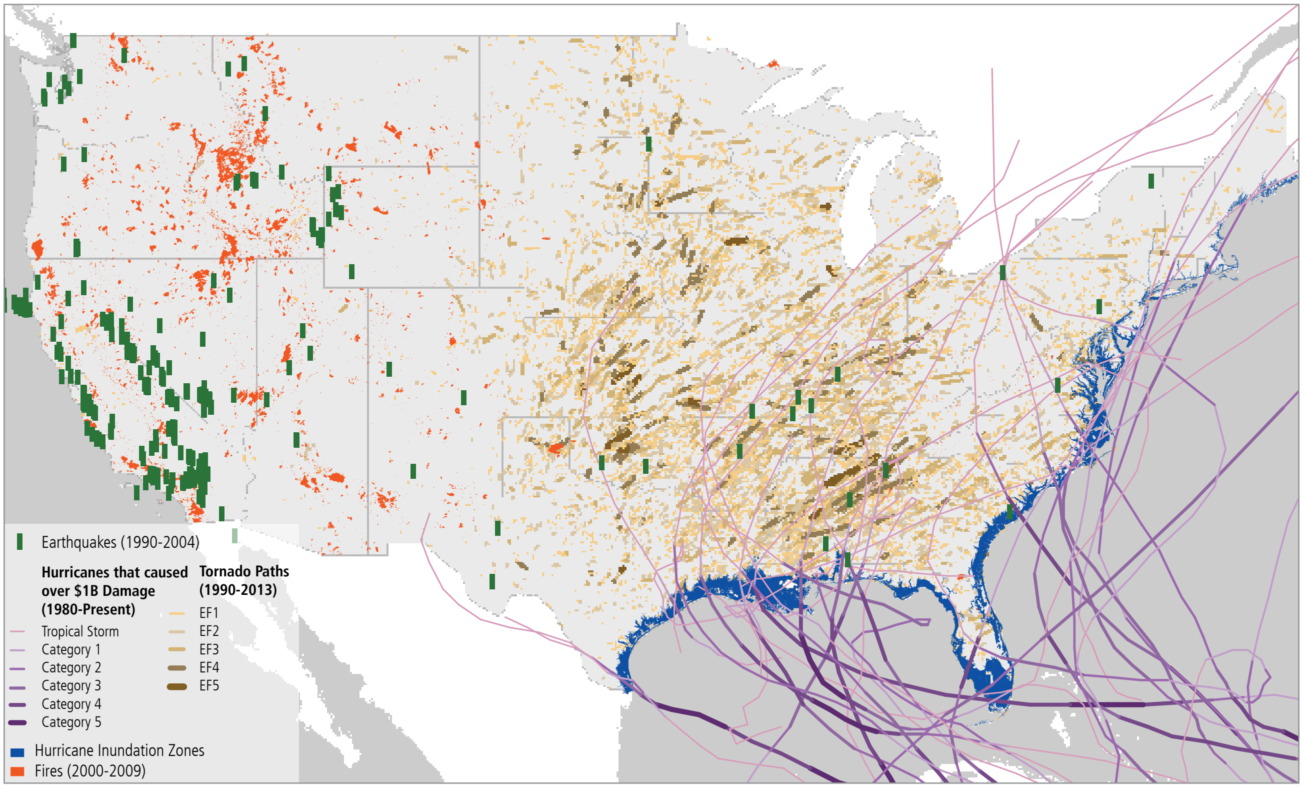
The private sector, states, and Federal Government all play crucial roles in ensuring that TS&D infrastructures are reliable, resilient, and secure. Responsibility for resilience, reliability, and safety of privately held TS&D infrastructure lies mostly with the state public utility commissions and other state energy regulators, but also with Federal regulators such as the Federal Energy Regulatory Commission, the Nuclear Regulatory Commission, and the Department of Transportation's Pipeline and Hazardous Materials Safety Administration. Given the national significance of these infrastructures to interstate commerce and the economy, the Federal Government regulates aspects of their operation and has other emergency authorities that it exercises in the public interest. Communication, coordination, and cooperation among all of these entities, in the exercise of their respective responsibilities, is essential. Key Federal emergency responsibilities relevant to energy infrastructure are highlighted in Appendix D.

- **Reliability** refers to the ability of a system or its components to operate within limits so that instability, uncontrolled events, or cascading failures do not result if there is a disturbance, whether the disturbance is a disruption from outside the system or an unanticipated failure of system elements. Reliability is also used by industry to mean that a system's components are not unexpectedly failing under normal conditions.
- **Resilience** refers to the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions. To the extent that actions improve a system's ability to withstand disruptions, they might be characterized as enhancing reliability, or resilience, or both. The ability to recover from a disturbance, however, is specific to resilience.
- **Safety** refers to achieving an acceptably low risk to life and health in the design, construction, operation, and decommissioning of a system. That level of risk is determined by taking into account the magnitude of potential consequences, the probability of those consequences occurring, and the costs of risk mitigation.
- **Security** refers specifically to the ability of a system or its components to withstand attacks (including physical and cyber incidents) on its integrity and operations. It overlaps, in part, with the concepts of reliability and resilience.

The Impacts of Disruptions on Energy TS&D Infrastructures

Disruptions of TS&D infrastructures have serious consequences for the Nation and many regions of the country. Extreme weather and climate change is a leading environmental risk to this infrastructure. Low-probability, extremely high-consequence events, such as geomagnetic distrubances, must also be anticipated and managed. Figure 2-1 shows the regional distribution of various natural disasters in the contiguous 48 states.

Figure 2-1. Illustration of Tornado and Hurricane Tracks, Wildfires, Earthquakes, and Coastal Inundation[5]



This figure maps the regional distribution of major natural disasters to help visualize regional vulnerabilities. This visualization shows the lower 48 states, but analysis was also completed on Alaska and Hawaii.

Energy Infrastructure Damage from Hurricane Sandy[b]

Hurricane Sandy made landfall in New Jersey and New York, as a post-tropical cyclone, on October 29, 2012. The storm destroyed neighborhoods along the coast and directly or indirectly killed at least 159 people. At its peak, it knocked out power to 8.66 million customers from North Carolina to Maine and as far west as Illinois and Wisconsin. Sandy's impact on the region's petroleum infrastructure was severe, with flooding and power outages at refineries, pipelines, and petroleum terminals in the New York Harbor area, leading to depressed petroleum product supply in the Northeast and stock drawdowns and temporary price increases. Nearly 2 weeks after the storm, product deliveries (outflows) from petroleum product terminals in the New York Harbor had returned to only 61 percent of their pre-storm levels. Breaks in natural gas lines caused fires in some locations, resulting in the destruction of many residences. The supply issues at New York Harbor terminals, combined with power outages at retail fueling stations, led to widespread gasoline shortages in the New York City area in the weeks after landfall. This was largely caused by flooding damage to major terminals and docks in the Arthur Kill area of New Jersey. As a result, portable generators sat unused and lines at fueling stations were long and problematic, while consumers struggled to identify which gas stations had power and were operational. Significantly, these fuel shortages delayed first responders and other response and recovery officials.

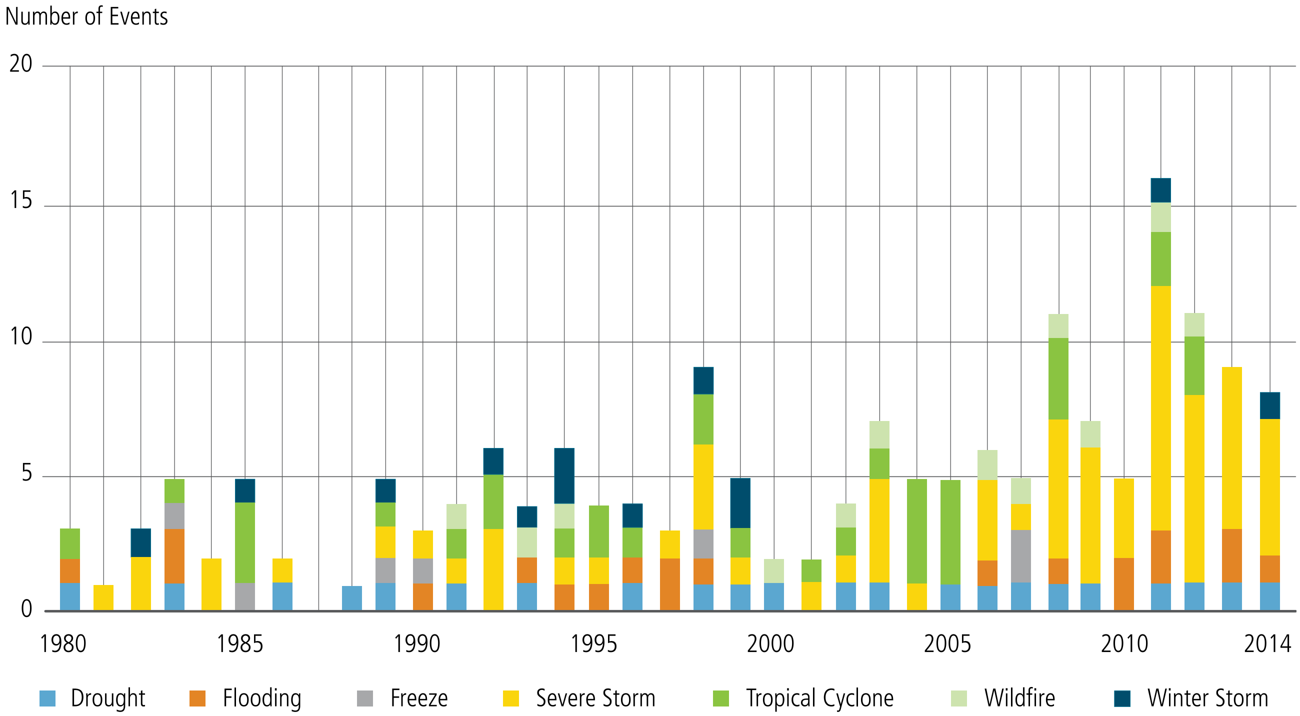
[b] Department of Housing and Urban Development. "Hurricane Sandy Rebuilding Strategy." p. 24. Hurricane Sandy Rebuilding Task Force. http://portal.hud.gov/hudportal/documents/huddoc?id=hsrebuildingstrategy.pdf.

Natural disasters, equipment and maintenance failures, and physical attacks come at a significant cost. A National Research Council study looking at the 2003 blackout that affected the Midwest, the Northeast, and Canada concluded that "the economic cost of the 2003 blackout came to approximately $5 per forgone kilowatt-hour, a figure that is roughly 50 times greater than the average retail cost of a kilowatt-hour in the United States."[6] Data suggest that electricity system outages attributable to weather-related events are increasing, costing the U.S. economy an estimated $20 billion to $55 billion annually.[7]

In the United States, there were 11 *individual* weather disasters costing $1 billion in 2012, second only to 2011 for the most on record.[8] Insurance data identifies almost $22 billion in *total* losses from a range of weather events in 2013, excluding self-insured losses.[9]

Extreme weather events resulting in more than $1 billion in damages are increasing, as seen in Figure 2-2. The damages represented in this figure are broader than energy infrastructure; these trends, however, must be considered in future energy infrastructure policy.

Figure 2-2. Billion-Dollar Disaster Event Types by Year[10, c]



Costly weather-related disasters have been increasing in frequency over the past decade.

Extreme weather has a range of impacts on TS&D infrastructure. The severity of hurricane impacts on all energy infrastructure is highlighted in Table 2-1. Heat waves—also extreme weather events—affect electric TS&D infrastructure in several ways, including reducing the efficiency of electric transmission and distrubution circuits; increasing the load on the grid associated with additional demand for air conditioning; and reducing the efficiency of cooling at thermal power plants that can result in lower power plant output.[11] Drought and extreme cold pose challenges to TS&D infrastructure by, for example, impeding barge transport of energy products. Drought also decreases the water available for natural gas processing.[12]

[c] Data from all original events were adjusted for inflation (using the Consumer Price Index, to 2014 dollars), prior to identifying events that exceeded $1 billion in damages. Caution should be used when interpreting long-term trends; data quality improves over time.

Continued increases in extreme weather can cause multiple stresses to energy systems more broadly, exacerbating direct effects on TS&D infrastructures. Sequential or compounded extreme weather events, such as Hurricanes Katrina and Rita, can result in significant nationwide economic and safety consequences that also affect TS&D infrastructures.

Table 2-1. Probability and Severity of Hurricane Damage to Liquid Fuels and Natural Gas Infrastructure[13, d]

Infrastructure	Tropical Storm (39-73 MPH)		Hurricane Cat 1-2 (74-95 MPH, 96-110 MPH)		Hurricane ≥ Cat 3-5 (111-129 MPH, 130-156 MPH, >157 MPH)	
	Probability of Damage	Severity of Damage	Probability of Damage	Severity of Damage	Probability of Damage	Severity of Damage
Loss of Electrical Power	Med	Significant	Med-High	Major	High	Catastrophic
Gulf of Mexico Platforms	Low	Insignificant	Med-High	Major	Med-High	Major
Pumping/Compressor Station	Low	Insignificant	Med	Significant	Med-High	Major
Pipelines	Low	Insignificant	Low-Med	Interrupting	Med-High	Major
Rail	Low	Insignificant	Low-Med	Interrupting	Med-High	Major
Ports	Low	Insignificant	Med-High	Major	High	Catastrophic
Crude Tank Farm	Low	Insignificant	Low-Med	Interrupting	Med	Significant
Refineries	Low	Insignificant	Med	Significant	Med-High	Major
Natural Gas Plants	Low	Insignificant	Med	Significant	Med-High	Major
Product Storage Terminals	Low	Insignificant	Low-Med	Interrupting	Med-High	Major
Propane Tanks	Low	Insignificant	Low	Insignificant	Low	Insignificant
Underground Storage	Low	Insignificant	Low	Insignificant	Low	Insignificant
LNG Terminals	Low	Insignificant	Med	Significant	Med-High	Major
Local Gas Distribution	Low	Insignificant	Med	Significant	Med-High	Major
Filling Stations	Low	Insignificant	Med	Significant	Med-High	Major
SPR/NEHHOR	Low	Insignificant	Low-Med	Interrupting	Med	Significant

This table is an example of infrastructure damage from natural disasters (here showing tropical storms and hurricanes). For three ranges of intensity of tropical storms and hurricanes, the severity of probable damage was rated qualitatively using a 5-point scale (i.e., insignificant, interrupting, significant, major, and catastrophic) and probability also on a 5-point scale (i.e. low, low-medium, medium, medium-high, high). These ratings were based on the extensive review of impacts from past events and judgment of industry experts.

[d] Damage severity is defined by ease of recoverability. Infrastructure damage categorized as insignificant includes damage that can be resolved with no outside help (i.e., clearing downed trees). Interrupting damage is associated with damage that probably requires outside assistance to repair. Recovery from significant damage is problematic and causes minor delays. Major damage requires replacements to resolve and causes major delays. Damage defined as catastrophic disrupts infrastructure for months, in addition to requiring rebuilding.

As a result of greater awareness of the direct and indirect effects of climate-change-related extreme weather, there has been growing interest in understanding and reducing the impacts of disruptions. There is evidence that pre-disaster hardening of critical energy infrastructures could help save lives and reduce economic losses to individuals, businesses, insurers, states, and the Federal Government. A statistical study of 5,500 Federal Emergency Management Agency mitigation grants awarded between 1993 and 2003, while not specific to energy, found that the benefit-cost ratio for mitigation investments was about 4:1.[14] In order to spend investment dollars more wisely, it is essential to focus on modernizing TS&D infrastructures at the same time that they are being hardened.

A barrier to progress on understanding and reducing the impacts of disruptions on TS&D infrastructures is that frameworks, tools, and metrics for assessing and prioritizing energy infrastructure resilience, reliability, and security actions and investments vary widely across industries and government agencies.[15, e] While resilience measures may be well-tailored for specific industries and sectors, they are not designed to aid policymakers and regulators in understanding current vulnerabilities; in deciding where to focus efforts and investment to increase resilience, reliability, and security; or in determining degrees of resilience that are needed. At the regional level, the lack of commonly used analytical methods for determining the appropriate level of resilience, as well as what resilience projects are prudent, can lead to difficulty in determining which resilience projects should be recoverable in rates.

The sections that follow analyze the vulnerabilities to disruption of each major TS&D infrastructure sector—electricity, natural gas, and liquid fuels—as well as the dependencies and interdependencies that could magnify the effect of any given disruption. There is substantial variability in the impact of natural threats on TS&D infrastrcutures, depending on the region in which they are located and on vulnerabilities inherent in the infrastructures of each sector.

Resilience, Reliability, Safety, and Asset Security for the Electric Grid: Analysis of Vulnerabilities

Resilience and reliability of the electric grid is essential to the economy and our way of life. Electricity transmission is vulnerable to many of the same types of threats as electricity distribution, but each sector also comes with discrete risks. Differences in risk arise from the purpose of the equipment, from technological differences, and from regulatory aspects of transmission versus distribution systems. Analysis to inform the Quadrennial Energy Review (QER) identified components of four categories of electricity TS&D[16] that are particularly vulnerable to hazards and ranked the vulnerabilities from low to high:

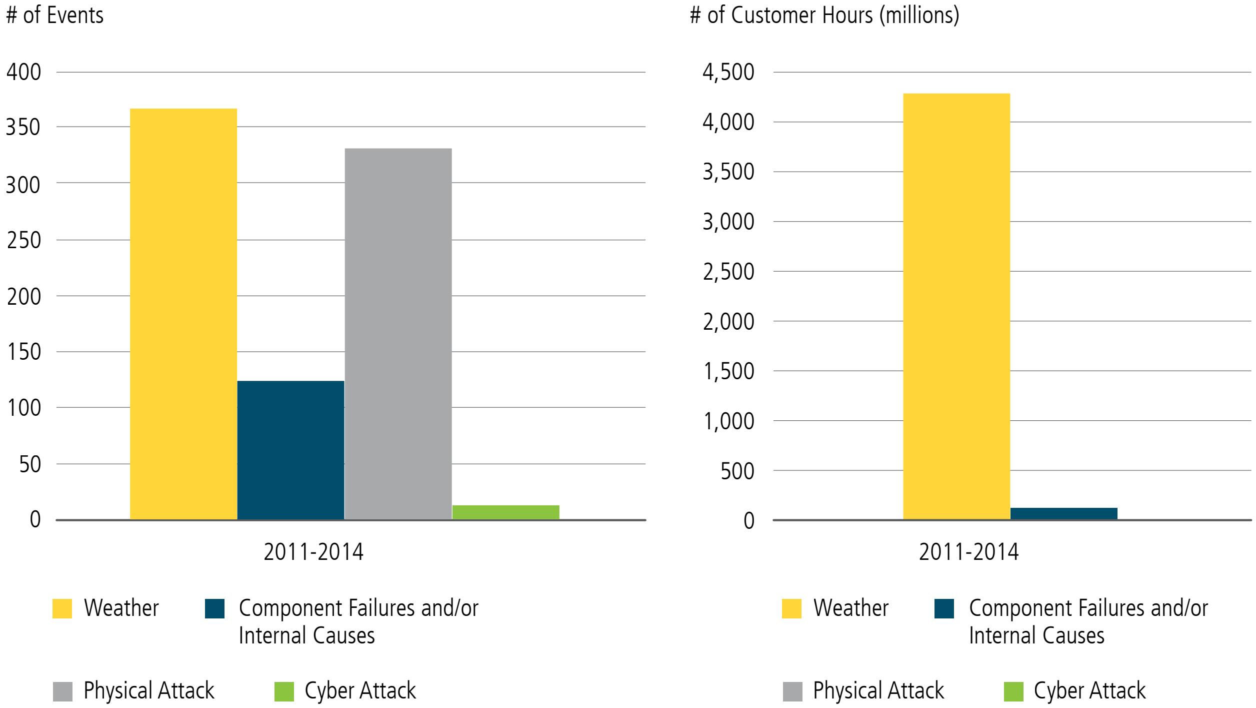
- **Electricity Transmission:** High vulnerability to physical attacks and wind; medium-high vulnerability to earthquakes, wildfires, snow and ice, extreme heat, and geomagnetic storms.
- **Electricity Substations:** Medium-high vulnerability to cyber and physical attacks and geomagnetic storms—large power transformers (LPTs) in such substations are a particular concern. A common vulnerability for substations is flooding, and flood vulnerability has a relatively high probability.
- **Aboveground Electricity Distribution:** High vulnerability to wind; medium-high vulnerability to earthquakes, physical attacks, wildfires, and snow and ice.
- **Control Centers:** Medium-high vulnerability to cyber and physical attacks.

[e] RAND documented 172 resilience metrics in peer-reviewed literature, and many others exist outside the literature, specific to single industries or even individual companies. There appear to be fewer metrics for liquid fuels and natural gas infrastructure than for electricity—this literature review found 105 metrics specifically related to electricity systems and only 67 for natural gas and oil. Existing metrics appear abundant for assessing resilience at the facility or system levels, but RAND found only 30 assessing regional or national resilience, many of which dealt with market factors rather than system performance. RAND also found that most metrics related to elements of disruption mitigation rather than system outcomes.

Weather-Related and Other Reliability Vulnerabilities

Historically, weather-related disturbances are the leading source of grid outages. For a 5-year period from 2008 to 2012, estimated costs of weather-related power outages ranged from $107 million to $202 billion.[17] Weather-related disturbances have a far greater impact on grid reliability—measured in terms of customer interruption hours—than component failures, physical attacks, and cyber incidents combined (see Figure 2-3).

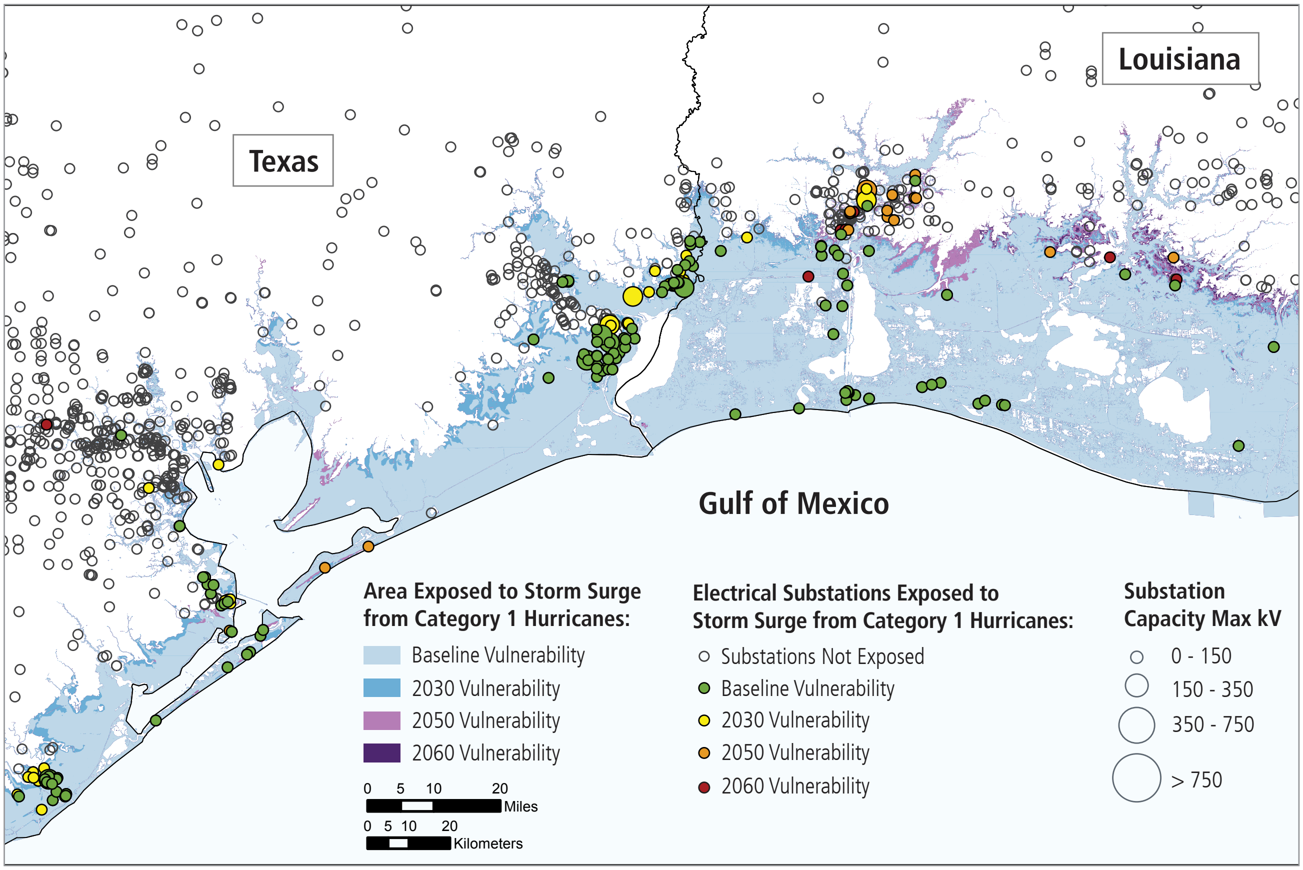
Figure 2-3. Left Figure: Electric Disturbance Events, January 2011–August 2014; Right Figure: Customer Hours Affected by Electric Disturbance Events, 2011–August 2014[18]



While weather was responsible for less than half of all reported incidents, weather accounted for the vast majority of customer interruption hours from 2011 to 2014. Not all reported events (shown on the left), such as voltage reductions and public appeals, result in actual customer outages (shown on the right).

The frequency and severity of certain types of extreme weather events have led to greater vulnerabilities for electric transmission and distribution systems.[19] Recent Department of Energy (DOE) analysis[20] examining the effects of climate change on infrastructure exposure to storm surge and sea-level rise found that vulnerabilities are likely to increase for many energy sector assets, including electricity. Figure 2-4 illustrates that, under the highest sea-level rise scenario from the National Climate Assessment,[21] by 2030 the number of electricity substations in the Gulf of Mexico exposed to storm surge from Category 1 hurricanes could increase from 255 to 337. Projected sea-level rise by 2050 would increase the number to roughly 400. Any significant increase in hurricane intensities in a warmer climate would greatly exacerbate exposure to storm surge and wind damage. Another important factor is current and projected development patterns, which is expected to have a larger effect on energy infrastructure vulnerability than rising sea levels, particularly in regions where energy distribution infrastructure is being built to serve growing populations in exposed coastal areas.[22]

Figure 2-4. Gulf Coast Electricity Substation Facilities' Exposure to Storm Surge under Different Sea-Level Rise Scenarios[23, 24, f, g]



Sea-level rise increases the vulnerability of electricity substations to inundation caused by hurricane storm surge. Future vulnerabilities correspond with a high-end sea-level rise scenario of 10 inches in 2030, 23 inches in 2050, and 32 inches in 2060. The baseline vulnerability corresponds with sea levels in 1992.

Other extreme weather events that are projected to increase with climate change and have regional and possibly national-scale impacts include extreme heat waves, droughts, and wildfires that can damage electricity infrastructure or reduce transmission efficiency. U.S. temperatures are projected to continue rising in the coming decades.[25] Electricity transmission and distribution systems carry less current and operate less efficiently when ambient air temperatures are higher.[26] Case studies indicate that sudden, extreme heat can cause transformers to malfunction or stop working.[27] Increasing temperatures also will likely increase electricity demand for cooling, which could increase utilization of transmission and distribution systems during peak demand periods. Increasing air and water temperatures also reduce the efficiency of power plant cooling, which increases the risk of partial or full shutdowns of generation facilities and loss of the grid services that they provide during heat waves.[28]

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[f] The Platts Electric Substation data contains point features representing a total of 55,819 electric transmission, sub-transmission, and some distribution substations in North America. These substations can be located on the surface within fenced enclosures, within special purpose buildings, on rooftops (in urban environments), or underground.

[g] Areas inundated by hurricane storm surge do not account for local land subsidence, which will further increase the exposure of infrastructure in this region. Note that 2030, 2050, and 2060 vulnerabilities correspond with 10 inches, 23 inches, and 32 inches of sea-level rise, respectively. Zero sea-level rise corresponds with sea levels in 1992.

Drought is also problematic. In 2014, California experienced its third driest year in 119 years of record keeping.[29] As a consequence, California hydroelectric generation—and the use of hydroelectric power for load leveling and energy storage—was significantly reduced. In June 2014, California hydroelectric generation was only 59 percent of the June average of the preceding 10 years.[30] In addition, annual temperature profiles can impact the timing of water availability.[31] A rapid spring thaw of the snowpack can overload reservoir capacity and lead to lost energy. Increasing frequency and severity of wildfires (also linked to droughts), particularly in the West, may damage electricity transmission and distribution infrastructure (such as utility poles, lines, transformers, and substations) and lead to power outages.[32]

Physical Attacks, Geomagnetic Disturbances, and Cyber Incidents: High-Consequence, Low-Probability Events

In addition to the impacts of severe weather and climate change, the electric grid is vulnerable to other events, including malevolent acts—such as physical attacks and cyber incidents—and geomagnetic disturbances.

Large Power Transformers Vulnerable to Attacks

LPTs can weigh hundreds of tons, are expensive, and are typically custom made with procurement lead times of 1 year or more.[33] In addition, due to their size and weight, moving LPTs presents logistical challenges requiring specialized equipment, permits, and procedures (see Chapter V, Improving Shared Transport Infrastructures, for more discussion of logistics challenges).

The loss of critical LPTs can result in disruptions to electricity services over a large area. Such a loss could be due to the customized nature of the components and the associated manufacturing requirements, as well as physical attacks (such as the Metcalf incident), natural hazards (such as geomagnetic disturbances, discussed below), or extreme weather (such as floods, salt water corrosion, and sudden heat waves). In the Metcalf attack on a substation in California, "multiple individuals outside the substation reportedly shot at the [high-voltage] transformer radiators … causing them to leak cooling oil, overheat, and become inoperative."[34]

The United States has never experienced simultaneous failures of multiple high-voltage transformers, but such an event poses both security and reliability concerns. The Edison Electric Institute, seeking to manage such vulnerabilities, has established a Spare Transformer Equipment Program, enabling utilities to stockpile and share spare transformers and parts. The inventory under this program is not large enough, however, to respond to a large, coordinated attack. Transformer design variations and the logistical challenges associated with their movement pose additional challenges to maximizing the effectiveness of the program. A National Research Council study referring to this effort noted that "... The industry has made some progress toward building an inventory of spares, but these efforts could be overwhelmed by a large attack" and that "it alone is not sufficient to address the vulnerabilities that the United States faces in the event of a large physical attack."[35]

The National Research Council study further included as its number one recommendation that the Department of Homeland Security (DHS) should work with DOE and industry to "develop and stockpile a family of easily transported high-voltage recovery transformers and other key equipment." The study acknowledged that the costs and benefits are hard to estimate, but noted that the benefits of such a stockpile would be "many times [the] cost" if available to respond to an event.[36] The Western Area Power Administration proposed a strategic transformer reserve pilot program and included a calculation of costs. Under this program, the Federal Government would purchase 110 large transformers at a cost of $324 million to provide backup units for the roughly 20,000 LPTs nationwide in emergency events. The Federal Government could mitigate the cost of the program by sharing the burden with industry. The benefits would accrue to the entire national grid (valued at more than $1 trillion) and directly to the U.S. economy by avoiding outages.

Large Power Transformers: Lack of "Off-the-Shelf" Options Could Impact Reliability[h]

Sometimes the challenge of completing infrastructure investment is dependent on the time and schedule associated with the manufacturing of large power transformers. The Western Area Power Administration experienced this situation with its most recent transformer procurement and installation. Scheduled delivery of this transformer was planned to be 1 year ahead of a critical deadline. In December 2013—13 months before the deadline—the transformer failed during testing in the factory. This resulted in an initial 4-month delay to the expected delivery date. The transformer was rebuilt and delivered to the site, but was compromised due to contamination. This required returning the transformer to the factory for further inspection and corrective measures. In the factory, the transformer was refurbished and ultimately passed factory testing 10 months after the original delivery date. Delivery to the site, final assembly, and onsite testing and commissioning was completed 1 year after the original scheduled in-service date. While the deadline for commercial operation was ultimately met, there was no room for error and significant uncertainty in the ability to meet the critical service deadline. The lack of off-the-shelf transformer options and industry practice of as-needed manufacturing is an ongoing concern.

[h] Email communication between Western Area Power Administration and Department of Energy, Office of Energy Policy and Systems Analysis staff. March 26, 2015.

The use of smaller, less-efficient, temporary replacement transformers may be appropriate for emergency circumstances. In 2006, the Electric Power Research Institute suggested building compact "restoration transformers" that would fit on large cargo aircraft and trucks.[37] Since then, DHS's Recovery Transformer Program has developed and tested a flexible transformer that is transportable by truck and can be installed within several days of an incident. These technologies could help address logistical concerns with moving large transformers in the event of disruptions.

Geomagnetic Disturbances

Geomagnetic storms are another high-consequence hazard for the electric grid that presents concerns due to the increasing reliance of many critical infrastructures on grid functions. These storms arise when charged particles and magnetic fields ejected from the Sun interact with Earth's magnetic field. The resulting geomagnetically induced currents create a significant threat to the reliability of the interconnected grid across North America. Though the probability of an extreme geomagnetic storm is relatively low in any given year, the occurrence is almost inevitable at some point in the future. Geomagnetic storms have the potential to damage transformers and other critical grid assets over large geographical areas. A geomagnetic storm in 1989 resulted in a blackout in Montreal and most of the Province of Quebec. In October 2003, an intense geomagnetic storm caused a blackout in Malmo, Sweden, and damaged several transformers in South Africa. Economic and societal costs attributable to impacts of geomagnetic storms could be very large. A 2013 Lloyds of London report indicated that geomagnetic disturbances could cost the economy as much as $2.6 trillion and take 1 to 2 years for a full recovery[38] (to put this in perspective, the Northeast blackout in 2003 was estimated to have cost between $4 billion and $10 billion).

Cyber Incidents

As seen in Figure 2-3, from 2011 through 2014 there were few reported cyber incidents on the electric grid and none reported that resulted in system outages. Cyber threats to critical infrastructure, though, are increasing. More than half of the cyber incidents to which DHS's Industrial Control Systems Cyber Emergency Response Team responded in 2013 related to energy installations.[39] Cyber events have the potential to cause significant and far-reaching problems on the power system.[40] Administration actions on cybersecurity are discussed in greater detail on page 2-37.

Electricity TS&D Vulnerabilities Vary by Region

While all regions of the country are susceptible to certain weather-related disruptions, grid TS&D infrastructure in three regions is expected to be particularly vulnerable to climate change and extreme weather events:[41]

Southeast: Due to increasing temperatures, heat waves, and humidity, the Southeast is expected to require the steepest growth in electricity transmission and distribution to meet cooling demand.[42] The region also is exceptionally vulnerable to sea-level rise and hurricanes (see Figure 2-4); challenges that are exacerbated by growing coastal populations.[43]

Southwest: Climate changes pose particular challenges for the Southwest, which is expected to get hotter and significantly drier; the regional population also is expected to increase 68 percent by 2050, further increasing electricity transmission and distribution load to meet higher cooling demands.[44, 45] The increased frequency and severity of wildfires are expected to have significant impacts on electricity transmission and distribution in the Southwest. In 2007, due to a wildfire, San Diego Gas & Electric and Southern California Edison had to reduce their electrical loads by 500 megawatts, nearly 80,000 customers lost power, and more than two dozen transmission lines were out of service with damage to 35 miles of wire.[46]

Atlantic and Gulf Coasts: Due to land subsidence, rising sea levels and shifts in ocean currents, heavier downpours, and the potential for more intense hurricanes in the future, coastal infrastructure in these regions is increasingly exposed to erosion, flooding, storm surge, and damage from high winds. Coastal development patterns that do not take these trends into account increase the vulnerabilities in these regions. Hurricanes Katrina and Rita combined downed more than 85,000 utility poles, 800 distribution substations, and thousands of miles of transmission and distribution lines, leaving more than 3.5 million customers along the Gulf Coast (especially in Louisiana, Mississippi, Florida, and Texas) without power at the height of the disruptions.[47] As another example, 75 percent of the net annual power generation in the New York City metropolitan region comes from 27 power stations that lie in the Federal Emergency Management Agency 100-year flood zone, a vulnerable position for a vast proportion of the region's energy infrastructure.

Dependencies of the Electricity Grid on Other TS&D Systems

As noted, all critical infrastructures depend on electricity; the electric grid also depends on other energy and related infrastructures within the scope of the QER. Coal, natural gas, and, to a limited extent, petroleum are used as fuels for power generation; the systems that move these fuels to generators are critical to the grid. Natural gas demand for power generation is expected to grow 30 percent by 2030, making electricity generation increasingly dependent on natural gas supply and transmission systems.[48] Generation from petroleum was only 0.6 percent of the total in 2013, but dual-fueled (natural gas and petroleum) plants in the Northeast increased electricity reliability in the winter of 2013-2014 when the extreme cold of the polar vortex threatened to constrain natural gas supplies. Power generation from coal is dependent on shared transportation infrastructures, especially rail; this dependency is discussed in greater detail in Chapter V (Improving Shared Transport Infrastructures).

Other key dependencies of the electric power sector include the following:

- The use of liquid fuels to power vehicles to repair and service transmission and distribution lines.
- Road, barge, and rail transportation networks used to deliver fuels, including liquefied natural gas for peaking facilities, and equipment supplies to generation stations.
- Transportation of LPTs, challenging because their large dimensions and heavy weight pose unique requirements to ensure safe and efficient transportation. Water is used for cooling and to reduce emissions.
- Natural gas, propane, and diesel to provide fuel for microgrids.
- Supervisory control and data acquisition and energy management systems that are essential to operations.

Actions for Managing Grid Vulnerabilities

Options for managing the vulnerabilities of the electric grid span a wide range of technological sophistication. To date, activities and investments have been primarily at the lower end of the technology range, focused on bulk changes in physical infrastructure, such as building physical barriers or moving equipment, building backup systems, building non-wooden or reinforced poles, and burying lines underground.[49] Reliability and resilience projects have also included operations and maintenance activities, such as aggressive vegetation management. While it might be considered low-tech, vegetation management is an essential activity; both the 1996 West Coast and 2003 East Coast-Midwest power outages started from trees along transmission lines.

A growing number of options for managing grid vulnerabilities to extreme weather use new technologies like smart meters and automated switching devices that allow for much quicker recovery times from disruptions. Microgrids and distributed generation technologies also provide options for improved resilience during storms.[50]

Incorporation of newer technologies is happening slowly. For example, about 90 percent of recent resilience project funds, in response to Hurricane Sandy, were spent on bulk infrastructure changes and additional operations and maintenance activities rather than on upgrading infrastructure components with advanced smart grid technologies.[51] Some utilities are doing more than bulk infrastructure changes. After Hurricane Sandy took out ConEdison's substation on the lower East Side, helping to throw lower Manhattan into darkness, for example, the utility's plan of action included construction of walls and barriers; installation of pumping equipment and submersible network equipment; and the deployment of smart grid tools to enhance network flexibility in emergencies.[52]

Barriers to Managing Electric Grid Vulnerabilities

As an integral part of risk management, utilities have proposed and completed projects to harden their infrastructures against wind and flood damage for many years; several state public utility commissions have issued rulemakings and other regulatory instructions related to electricity infrastructure resilience and hardening since 2005.[53] Yet, in some cases, procedural barriers to cost recovery for addressing vulnerabilities remain.

Rate-based cost recovery for repair of damages already incurred by storms and for future long-term investment programs remains the most common mechanism for paying for these damages. The criteria, process, and timing of this cost recovery vary widely between states. For example, states such as Oklahoma, New Hampshire, and Connecticut allow resilience project cost recovery through surcharges or other rate-adjustment mechanisms that allow utilities to immediately rate base their expenditures rather than waiting for the next rate case. Many states, however, have prohibitions against single-issue ratemaking, meaning that a utility that does not have a general rate case scheduled in the near future would have no recourse to recover its costs for resilience measures, perhaps for years.[54] Investments in efficiency and distributed generation are increasingly recognized as viable strategies for improving energy system resilience (see Chapter III, Modernizing the Electric Grid); for example, the New York State Department of Public Service recently approved such projects as part of a broader rate case focused on hardening and resilience.[55]

Beyond procedural barriers, there are problems with inadequate information and tools with which to manage for resilience. Quantitative measures of adequacy of resilience investments, or even a commonly accepted method for determining the appropriate level of resilience at either the transmission or distribution level, do not exist. For example, while the North American Electric Reliabilty Corporation develops and enforces mandatory reliability standards applicable to the bulk electric system (subject to Federal Energy Regulatory Commission review, approval, and independent enforcement authority) and, more recently, physical security and geomagnetic disturbance standards, there are no mandatory standards in place that speak directly to grid resilience against natural disasters. In addition, there is no common, generally accepted analytical method of determining whether it is prudent to implement alternative resilience projects.[56]

Distribution hardening projects are separately planned on a utility-by-utility basis; data are not systematically reported, which makes any central coordination difficult in the event of a large-scale regional or national problem. Resilience project metrics and analysis methods typically are defined on a locality-by-locality basis, starting with risk-assessment modeling of, for example, flooding or wind damage. The analysis may incorporate specific critical infrastructure, population, vulnerability, and duration to quantify the risk reduction and economic cost-benefit of alternative resilience projects.[57] Methods for analyzing the potential economic impact of weather-related damage is a topic of ongoing development,[58] and data for performing this analysis can be insufficient.[59]

The power industry's resilience-related risk assessments largely focus on physical and cybersecurity—rather than extreme weather and climate change—and currently rely on information from the Federal Government. Incomplete or ambiguous threat information may lead to inconsistency in physical security among grid owners, inefficient spending of limited security resources at facilities (e.g., to address overestimated threats), or deployment of security measures against the wrong threat. For example, while physical barriers could protect against one particular type of attack, incorporation of better communication technologies could simultaneously reduce vulnerabilities to multiple forms of risks, such as physical and cyber threats, geomagnetic disturbances, electromagnetic pulses, and natural disasters.[60] The Federal Government can fill gaps in creating data sets, tools, and assessments that provide a more complete and robust analytical approach to measuring resilience needs and investments. It can also step in where the utility industry is not well-positioned to make significant investments—such as where new, innovative technologies can be introduced, but they face barriers to cost recovery in the rate base.

Administration Initiatives on Electric Grid Resilience

The Build America Investment Initiative. This initiative is an interagency effort led by the Departments of Treasury and Transportation to promote increased investment in U.S. infrastructure, particularly through public-private partnerships. The Department of Energy has participated in the effort and included several recommendations related to resilience of the electricity sector that focus on data, information, and analytical tools. The initiative establishes an electricity resilience information portal at the Department of Energy to provide data, tools, and best practices to support investment in resilient electricity infrastructure; improve electricity sector data availability and data standardization; develop analytical tools to evaluate the potential impacts of climate change in assessments of electricity resilience investments; create standard metrics to account for the benefits of resilience in electricity infrastructure investment decisions; and establish a resilience course to educate state and local stakeholders on robust decision making related to new infrastructure.

Coordination and Outreach to Reduce Vulnerabilities of the Grid to the Loss of Large Power Transformers. The Administration has made it a priority to work with industry to identify challenges and create solutions for increasing the security and resilience of the electric grid, including the development of an integrated national plan to mitigate challenges pertaining to aging power transformers, the cyber and physical security of transformers, and the vulnerabilities of large power transformers. The Administration is working with trade association leadership and the private sector to improve the coordination of existing and planned transformer-sharing programs and to identify solutions for transformer replacement capabilities as part of its efforts to enhance the resilience of the Nation's electric grid. These efforts will be part of a formal national strategy (planned for release in 2015) for strengthening the security and resilience of the entire electric grid for threats and hazards. In its Recovery Transformer Program, the Department of Homeland Security's Science and Technology Directorate has developed, tested, and demonstrated a prototype rapidly deployable extra high-voltage transformer that is transportable by road and can quickly be installed within several days of an incident.

Enhancing Grid Resilience to Geomagnetic Storms. Ensuring that the United States is prepared to respond to and recover from severe space weather storms is a priority for the Administration. In November 2014, the Administration established an interagency Space Weather Operations, Research, and Mitigation Task Force. The Task Force is developing a National Space Weather Strategy with high-level strategic goals for improving forecasting, evaluating impacts, and enhancing national preparedness (protection, mitigation, response, and recovery) across all economic sectors to a severe space weather event.

Administration Initiatives on Electric Grid Resilience (continued)

In addition, a Space Weather Action Plan, coordinated across numerous Federal departments and agencies, will establish actions, timelines, and milestones for implementation of the national strategy. Both the strategy and the action plan will be complete in 2015. In addition to this work, the President's Fiscal Year 2016 Budget requests $10 million to conduct research to better understand the risks that ground-induced currents from geomagnetic storms or electromagnetic pulses could have on large power transformers. Also, in June 2014, the Federal Energy Regulatory Commission adopted the new reliability standard (EOP-010-1) developed by the North American Electric Reliability Corporation to mitigate the impacts of geomagnetic disturbances that can have potentially severe, widespread effects on the operations of the U.S. power system. The standard specifically addresses implementation of operating plans and procedures to mitigate effects of geomagnetic disturbances for reliability coordinators and transmission operators. This standard is in response to the Federal Energy Regulatory Commission's May 2013 final rule (Order No. 779) in which it directed the North American Electric Reliability Corporation to develop geomagnetic disturbances vulnerability standards in two phases. The second phase of pending standards will provide more comprehensive protections by requiring applicable entities to protect their facilities against a benchmark geomagnetic disturbance event.

Resilience, Reliability, Safety, and Asset Security of Natural Gas TS&D Infrastructure: Analysis of Vulnerabilities

The physical or operational vulnerabilities of natural gas TS&D infrastructures to threats vary among infrastructure components. Though generally less vulnerable than electric power infrastructure, the natural gas TS&D sector contains several components that could be ranked high in terms of their vulnerability to damage and failure from a given hazard. These high-ranking components include natural gas transmission pipelines, compressor stations (which provide the pressure needed to move gas through pipelines), and distribution systems. Disruptions of these components could result in significant infrastructure outages.

Pipeline and Storage Vulnerabilities

The vulnerability of natural gas pipelines is dependent on the type of pipeline. Offshore pipelines, from the perspective of natural threats, are most vulnerable to damage to platforms and risers from storms; during Hurricanes Katrina and Rita, the majority of the offshore pipeline damage occurred at or near platform interfaces. Onshore pipelines are vulnerable to landslides and earthquakes. Extreme cold temperatures adversely affect natural gas well production and the associated infrastructure; for example, when extreme cold in the southwestern United States in early February 2011 curtailed more than 7 billion cubic feet per day of natural gas production due to well freeze-offs (see more discussion of this on page 2-25).[61]

Another area of concern is aboveground pipelines in Alaska, which are becoming increasingly vulnerable to climate change and its associated temperature increases. This is contributing to the thawing of the permafrost, affecting the foundations of infrastructure, contributing to pipeline displacements, and increasing requirements for operations and maintenance.[62] Permafrost thawing could have serious implications for Alaska's energy infrastructure, such as the Trans-Alaska Pipeline System, transmission lines, fuel storage tanks, generators, and other large energy infrastructure. It is estimated that permafrost thaw could add between $3.6 billion and $6.1 billion (10 percent to 20 percent) to current costs of maintaining public infrastructure—such as buildings, pipelines, roads, and airports—over the next 20 years.[63]

Although pipelines above and below ground represent a highly dispersed element of the energy system that, like electric transmission lines, are difficult to protect, the underground portion of pipelines generally are difficult for non-professionals to locate; this reduces the possibility of physical attacks. The exception for pipeline systems is aboveground compressor stations. In addition, depending on their severity, earthquakes could have a major or catastrophic impact on both transmission and distribution pipelines (discussed later in this chapter; see Table 2-5).

There have been cyber incidents on natural gas systems, notably between February and March of 2013.[64] During this time period, there were brute force attacks (i.e., efforts to obtain passwords and personal identification numbers) on a natural gas compressor station, resulting in a warning from DHS to gas system and other critical infrastructure operators. This alert prompted reports of similar activities, broadly from gas system operators in the Midwest and the Plains. These attacks, while unsuccessful, continued for over 2 weeks. Vulnerabilities affecting natural gas resilience and reliability likely will grow given the increasing reliance of natural gas infrastructure on electricity and other electricity-dependent infrastructures, such as telecommunications.

In 2012, there were 414 underground natural gas storage sites in the United States.[65] Three-hundred-eighty of the facilities were primarily used to meet seasonal winter demand; the remaining facilities are high-deliverability facilities used to inject and flexibly withdraw large natural gas volumes over short periods.

In general, natural gas underground storage is minimally susceptible to natural hazards. Underground gas storage facilities are well protected from accidents or malicious acts and generally insensitive to natural events, such as earthquakes, owing to the depth of underground storage and the design of the systems connecting the storage to the surface.[66] However, the U.S. natural gas profile could change the economics of gas storage. Shale gas production has increased and gas price volatility has decreased; this may diminish economic incentives for storage.

Enhancing Natural Gas Transmission and Distribution Pipeline Safety

There were approximately 315,000 miles of transmission and gathering pipelines and a transmission capacity of approximately 443 billion cubic feet per day in the U.S. natural gas pipeline network in 2011. They form the backbone of the gas transmission infrastructure system and deliver natural gas directly to many high-volume customers, such as industrial plants and gas-fired electric generation. In 2013, the United States had 1,437 distribution systems comprised of more than 2.1 million miles of distribution lines, delivering gas from high-pressure pipelines to more than 68 million residential and 5 million commercial customers.[67]

Transmission Pipeline Safety

Operators of transmission pipelines and gathering lines have fewer requirements than distribution lines to ensure pipeline integrity and safety through damage prevention programs, routine inspection, leak detection, and the development of integrity management plans.[68] While there are industry standards, for example, for instrumentation, safety equipment, and metering, there are no comparable industry standards or industry-led systematic research program for external sensor-based leak detection.[69] Such a program and standards would be useful.

Administration Initiatives on Pipeline Safety

Transmission pipeline safety. The Obama Administration's Department of Transportation and the Pipeline and Hazardous Materials Safety Administration first responded to concerns about transmission pipeline safety by issuing a "call to action" on pipeline safety in 2011. Congress also responded to the same concerns by passing the Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011.[i] This act directed the Department of Transportation to reexamine many of its requirements, including the expansion of integrated management plans for transmission pipelines.[j] In addition, in 2011, the National Transportation Safety Board recommended that the Pipeline and Hazardous Materials Safety Administration require all operators of transmission and distribution natural gas pipelines to equip their pipeline monitoring systems with tools to assist in recognizing and pinpointing the location of leaks.[k] The Pipeline and Hazardous Materials Safety Administration is currently developing a proposed rule on integrity management for natural gas pipelines. Also, it continues to conduct and support research to provide the technical and analytical foundation necessary for planning, evaluating, and implementing its pipeline safety program. In addition, the Federal Energy Regulatory Commission has issued a policy statement[l] 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.

Distribution pipeline safety. The Department of Energy, as part of the President's Strategy to Reduce Methane Emissions, convened a series of roundtable discussions with stakeholders (e.g., utilities, environmental groups, state officials, and academics) in 2014 focused on reducing methane emissions from gas transmission and distribution systems. Some stakeholders commented that it was both necessary and feasible to make further progress through additional efforts to modernize natural gas infrastructure in ways that improve safety and reduce emissions. For example, replacement programs for leak-prone pipelines achieve multiple benefits; they enhance safety, reduce methane emissions, and create jobs. One barrier to public utility commission approval of surcharges for infrastructure modernization is that consumer advocates typically oppose these mechanisms for cost recovery.[m,n] Some stakeholders noted that infrastructure replacements could be more cost effective and expeditious when state agencies and municipalities coordinate pipeline replacement with other public works projects (i.e., in conjunction with water and telecommunications modernization efforts). At the final stakeholder roundtable meeting, the Department of Energy announced a series of new initiatives that will help improve pipeline safety. Among them is a new partnership with the National Association of Regulatory Utility Commissioners to provide technical assistance for gas.distribution system modernization and a clearinghouse for related information on effective technologies and policy strategies.

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i Department of Transportation, Pipeline and Hazardous Materials Safety Administration. "Pipeline Replacement Updates: Call To Action." http://opsweb.phmsa.dot.gov/pipeline_replacement/action.asp.

j Regulatory Certainty and Job Creation Act of 2011, Public Law No. 112-90, 125 Stat. 1904 (2012).

k National Transportation Safety Board and Department of Transportation, Pipeline and Hazardous Materials Safety Administration. "Recommendation P-11-10." 2011. http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_54F297878A5472F8CDF692407F40A9AC8A530300/filename/NTSB%20Reply%20to%20P-11-8%20thru%20-20.pdf.

l Federal Energy Regulatory Commission. "Cost Recovery Mechanisms for Modernization of Natural Gas Facilities." FR Doc. 2014–28015. 2014. http://www.federalregister.gov/articles/2014/11/26/2014-28015/cost-recovery-mechanisms-for-modernization-of-natural-gas-facilities.

m Popowsky, S. "Testimony before the House Consumer Affairs Committee of Pennsylvania; Regarding Special Session House Bill 40 and House Bill 41 Natural Gas Issues." November 9, 2007. http://www.oca.state.pa.us/Testimony/2007/00096290.PDF.

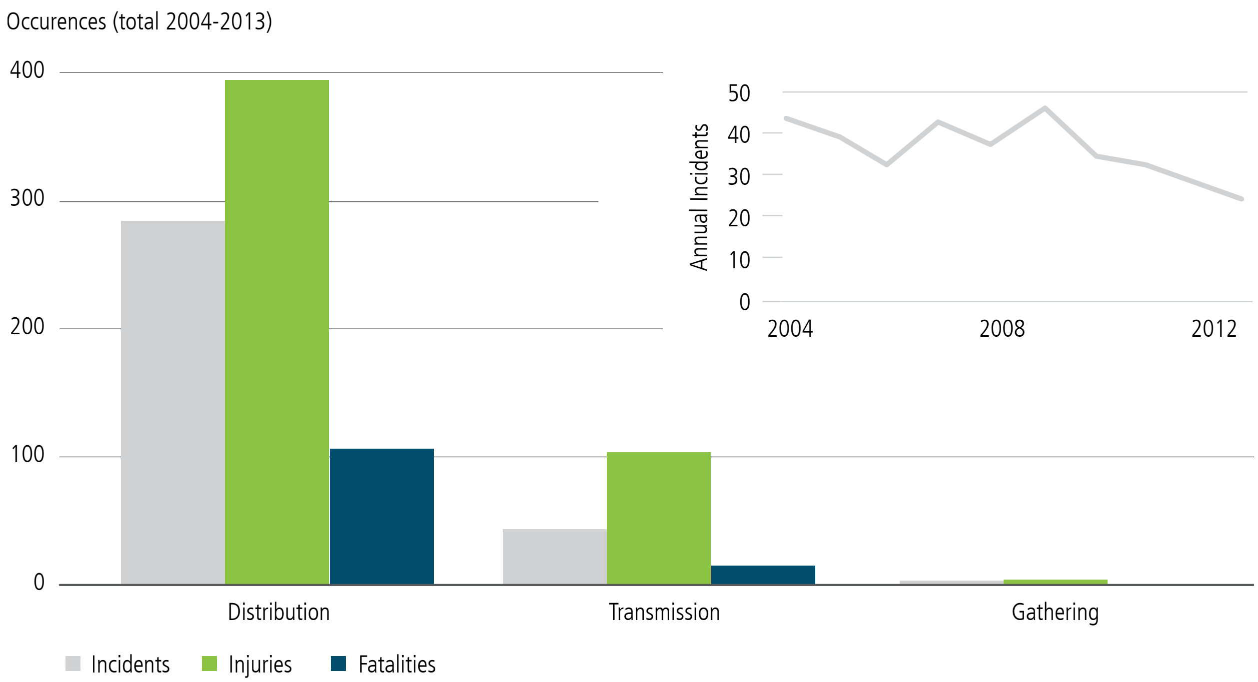
n Department of Transportation, Pipeline and Hazardous Materials Safety Administration. "Pipeline Safety: Safety of Gas Transmission Pipelines - Advanced Notice of Proposed Rulemaking (ANPRM)." Docket No. PHMSA-2011-0023. 76 Fed. Reg. 5308. August 25, 2011. http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=3d7248c521dd1310VgnVCM1000001ecb7898RCRD&vgnextchannel=2dd0d95c4d037110VgnVCM1000009ed07898RCRD.

Safety and Methane Emissions from Gas Distribution Systems

Natural gas distribution systems represent roughly 20 percent of all methane leaks from gas systems. Emissions from local distribution systems come largely from two sources—leak-prone pipelines and meters and regulators at city gates. Together, these two sources represent 70 percent of methane emissions from distribution systems.

Most safety incidents involving natural gas pipelines occur on the natural gas distribution system, as shown in Figure 2-5. These incidents tend to occur in densely populated areas. Excavation damage is the leading cause of serious incidents along natural gas pipelines; although, significant and preventable contributors also include equipment failure, incorrect operation, and pipeline corrosion.[70] Incidents are relatively infrequent, but increase as systems age.

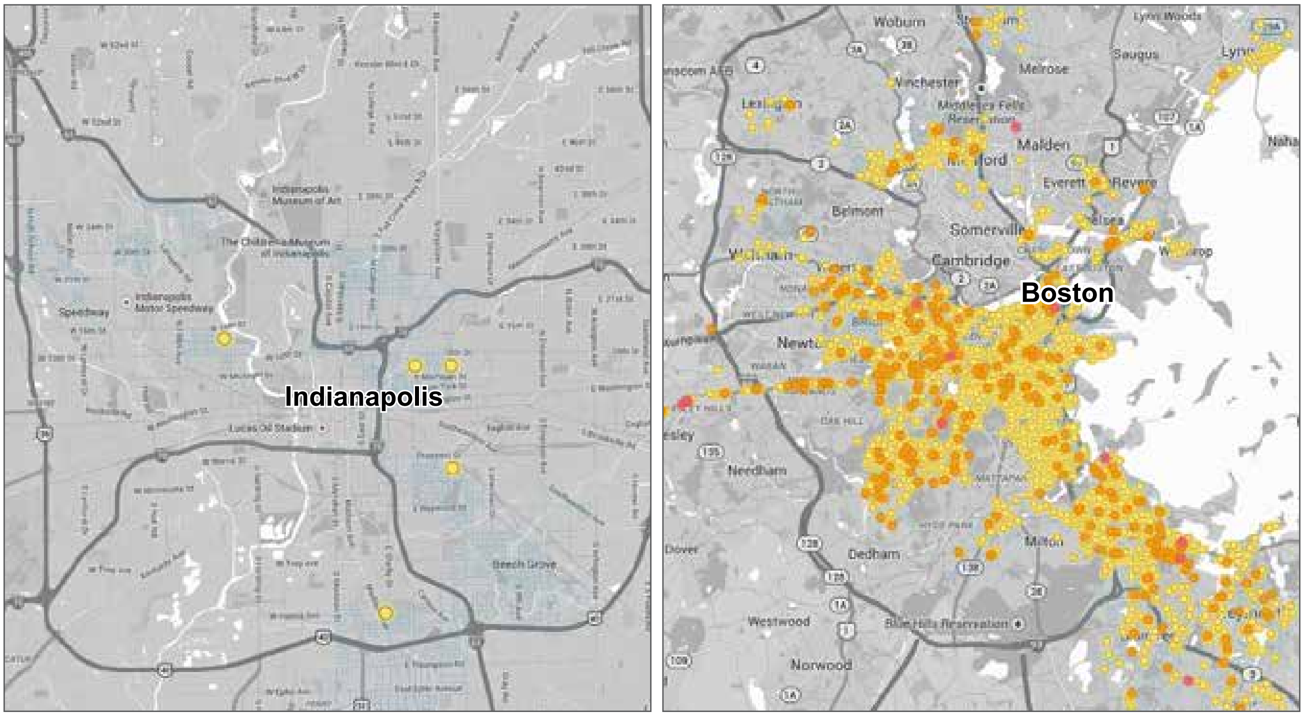
Figure 2-5. Total Incidents, Injuries, and Fatalities Associated with U.S. Natural Gas Pipelines, 2004–2013[71, o]



The majority of natural gas pipeline-related incidents involve distribution pipelines. The annual number of incidents associated with U.S. natural gas pipelines (shown in inset) declined between 2004 and 2013.

[o] Note that only a small portion of gathering lines are subject to reporting requirements; therefore, the Pipeline and Hazardous Materials Safety Administration data likely represent a significant underestimate of incidents on gathering lines.

Figure 2- 6. Methane Emissions from Natural Gas Distribution Systems in Indianapolis and Boston, 2013[72, p, q]



Emissions Rate

- **Low** (The same near-term climate impacts as driving a car between 100 and 1,000 miles everyday. Rate: 700 to 9,000 liters/day.)
- **Medium** (The same near-term climate impacts as driving a car between 1,000 and 9,000 miles everyday. Rate: 9,000 to 60,000 liters/day.)
- **High** (The same near-term climate impacts as driving a car more than 9,000 miles everyday. Rate: More than 60,000 liters/day.)

After a pipeline explosion in Indianapolis, Indiana, in the 1980s, the city began a program to replace leak-prone natural gas pipelines. Massachusetts has more recently started a replacement program.

Many companies, states, and localities have taken action to improve safety by accelerating distribution pipeline replacement. After a natural gas explosion in the early 1980s, Citizens Energy Group, the local distribution company for Indianapolis, initiated an aggressive pipeline replacement program that reduced the proportion of pipeline-miles made from cast iron and steel from 16 percent in 1990 to less than 1 percent in 2013.[73, 74] Massachusetts ranks seventh in the Nation for leak-prone iron and steel gas system mains (see Table 2-2). The state has taken proactive measures to reduce these risks. In 2009, the Massachusetts Department of Public Utilities established a Targeted Infrastructure Recovery Factor to incentivize the accelerated replacement of leak-prone natural gas distribution infrastructure and to support "… benefits to public safety, service reliability, and the environment."[75] The agency subsequently approved a Targeted Infrastructure Recovery Factor mechanism for National Grid's Boston Gas in 2010.[76] While Boston's leak rates were higher than

[p] The study authors use isotopic analysis to confirm that the methane measured in this study are from fossil sources (i.e., not biologically produced). The methodology used to convert measurements of methane concentration into flux estimates is described in: Environmental Defense Fund. "Methodology: How the data was collected." www.edf.org/climate/methanemaps/methodology. Accessed February 27, 2015.

[q] While fixing and repairing pipeline leaks is critical for increasing public safety, it is important to note that not every leak is dangerous; effective safety programs take many factors into consideration.

Indianapolis' in 2013 (see Figure 2-6), the proportion of pipeline-miles made from cast iron and steel in Boston Gas has reduced from 60 percent in 2008 to 51 percent in 2013.[77] To further expedite pipeline replacement, Massachusetts recently enacted a law requiring utility classification and prioritization of pipeline leaks for replacement or repair.[78]

The most leak-prone distribution pipeline materials are cast iron and bare steel, accounting for approximately 9 percent of distribution pipes in the United States[79] and resulting in roughly 30 percent of methane emissions from natural gas distribution systems.[80] All regions of the country have some leak-prone distribution pipeline networks. Table 2-2 presents the top 10 states with the most miles of leak-prone distribution mains.[r] The magnitude of investment needed to replace all leak-prone distribution mains nationwide is more than $270 billion.[s]

Table 2-2. 10 States with the Most Miles of Leak-Prone Distribution Mains[81]

Rank	State	Leak Prone Iron Mains (mi)	Leak Prone Steel Mains (mi)	Total Leak Prone Mains (mi)	Total Leak Prone Mains (% of pipes in state)
1	PA	3,300	8,600	11,900	25%
2	NY	4,200	7,500	11,700	25%
3	OH	570	9,500	10,070	18%
4	CA	29	8,200	8,229	8%
5	NJ	4,900	2,200	7,100	21%
6	MA	3,600	2,600	6,200	30%
7	TX	820	5,000	5,820	6%
8	MI	3,000	2,300	5,300	9%
9	WV	13	3,000	3,013	29%
10	AL	1,200	820	2,020	7%

Of the 10 states with the most miles of leak-prone natural gas mains, nine have infrastructure modernization acceleration initiatives.

Despite progress in many states to help the replacement of leak-prone pipes in distribution networks,[82] some have limitations; many place caps on the magnitude of investments eligible for cost recovery and/or on the size of rate increases. Even with such special cost-recovery mechanisms,[83] at least one dozen utilities will require two decades or more to replace their leak-prone pipeline. Table 2-3 shows replacement time frames for select distribution systems.

[r] Distribution mains are pipelines that serve as a common source of supply for more than one service line. Source: 49 CFR § 192.3. In: Department of Transportation, Pipeline and Hazardous Materials Safety Administration. "Glossary." www.phmsa.dot.gov/staticfiles/PHMSA/Pipeline/TQGlossary/Glossary.html#main. Accessed March 9, 2015. Generally, these are gas pipelines running underground along streets, connecting to service lines that run to individual buildings.

[s] The American Gas Association reports that the total cost of replacing all cast iron pipe in the United States is $82,682,696,844 in 2011 dollars. 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. Assuming other pipe replacement has similar costs, the total cost for replacement of all leak-prone pipe is roughly $270 billion. Source: 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.

Table 2-3. Expected Replacement Horizons for Select Utilities for Leak-Prone Mains[84]

Utility Company	Service Territory	State	Forecasted Timeframe (years)
Philadelphia Gas Works	Philadelphia, PA	PA	84
ConEd	New York, NY	NY	35
PECO	Greater Philadelphia, PA	PA	33
PSE&G	Newark, NJ	NJ	30
Pensacola Energy	Pensacola, FL	FL	30
Baltimore Gas Company	Baltimore, MD	MD	30
UGI	Rural Pennsylvania	PA	27
Consumers Energy	Detroit, MI	MI	25
DTE	Detroit, MI	MI	25
National Grid	New York, NY	NY	25
Dominion Hope Gas Co.	Ohio	OH	20
Yankee Gas Services Company	Rural Connecticut	CT	20
Peoples Gas	Chicago, IL	IL	20
National Grid - Niagra Mohawk	Rhode Island	RI	19
Peoples TWP	Southwestern Pennsylvania	PA	19
Peoples Natural Gas Co.	Southwestern Pennsylvania	PA	17
National Grid - Niagra Mohawk	Syracuse, NY	NY	16
Columbia Gas of Pennsylvania	Southwestern Pennsylvania	PA	15
Northern Utilities	Maine	ME	13
CenterPoint	Arkansas	AR	12

Projected pipeline replacement rates (from a select group of utilities) vary considerably and can range from about one decade to more than 80 years. Key factors affecting projected time frames include remaining miles of pipeline made of leak-prone materials (e.g., cast iron and unprotected steel) and the scale of existing replacement programs.

Another leading source of leaks is from meters and regulators at "city gate" station facilities that connect long-distance interstate transmission pipelines to local distribution networks. These account for 40 percent of methane emissions from natural gas distribution systems.[85] A recent study found that in cases where companies had invested in upgrades, emissions from city gate stations in 2013 declined to a fraction of emission levels measured at the same stations in 1992. Conversely, the one station that had not invested in upgrades over this 20-year period saw a 40-percent increase in estimated emission levels, illustrating the environmental benefits of such investments.[86] The Environmental Protection Agency's Natural Gas STAR program encourages voluntary actions to address these losses through directed inspection and maintenance programs that include leak detection and repair measures. Installing state-of-the-art measurement technologies could assist in leak management. In addition, it is estimated[87] that quarterly leak detection and repair, which requires little capital investment and could be scaled up quickly, could reduce emissions from city gate stations by 60 percent.

Natural Gas Infrastructure Dependencies

As noted, the electricity sector is increasingly reliant on natural gas as a fuel for power generation. On the flip side, many physical and operational components of natural gas TS&D infrastructures depend on electricity for key functions. In addition, other key sectors, such as industry and natural gas vehicles, depend on reliable and robust natural gas TS&D systems for a range of applications.

Gas System Dependencies on Electricity

Most pumps and compressors along natural gas gathering and transmission pipelines are fueled with gas flowing through the station,[88] with only about 5 percent of installed compression horsepower on interstate pipelines nationwide requiring electricity to run.[89,90] In some areas of the Nation where there are concerns about emissions and the increased speed of permitting of electric compressors, there is significantly greater reliance on electric compressors.[91,92] Pennsylvania, Ohio, and California, for example, have a higher percentage of compressors powered by electricity than the national average.[93] On the flip side, increased reliance on electricity-powered compressors could increase the vulnerability of the gas transmission system to power outages. During the 2011 "Big Chill" in the Southwest (see box), for example, rolling blackouts contributed to natural gas production outages (primarily affecting compressors on gathering lines), which in turn led to power generation curtailments.[94]

While compression facilities for underground natural gas storage generally are fueled by offtake gas, they may still require electric power.[95] Electricity is needed for dehydration of underground stored gas. Pipeline-quality natural gas is pumped into underground formations for storage; when the gas is withdrawn, it requires processing to remove water from the natural gas and to filter the gas all over again.

Also, most of the Nation's liquefied natural gas facilities store this gas for periods of peak demand or pipeline gas supply interruption. Cryogenic liquefaction of natural gas allows large volumes of gas to be stored and transported over long distances that cannot be technically or economically served by pipelines, and this process requires large amounts of electricity. These facilities are distributed across the Nation and generally are found near electric power stations.[96]

Centralized gas control stations monitor the flow of natural gas and collect, assimilate, and manage data received from compressor stations all along the pipeline. These control systems can integrate gas flow and measurement data with other accounting, billing, and contract systems. The data are transmitted through a communications network that could consist of company-owned, fiber-optic lines; leased telephone lines; ground- or satellite-based microwave; or radio communication systems.[97] The total loss of communications could result in manual operations of the affected pipeline. Many systems in the oil, gas, and alternative fuels infrastructures are increasingly monitored and controlled remotely through cyber networks that are also powered by electricity.[98]

Dependencies of Other Sectors on Natural Gas TS&D Systems

Dependencies of other infrastructures on the natural gas TS&D sector include the following:

- Supply of natural gas liquids for petroleum refining. Growth in production of natural gas liquids has stimulated renewed interest in petrochemicals production where ethane and propane are key feedstocks (see Chapter V, Improving Shared Transport Infrastructures, for a more detailed discussion).
- Natural gas as a transportation fuel. Compressed natural gas vehicles also rely on natural gas. Although there are only about 120,000 compressed natural gas vehicles in the United States today, the Energy Information Administration forecasts increases in natural gas vehicles over the next decades, especially in heavy-duty vehicles.[99]
- Industrial consumption of natural gas. Given low natural gas prices over the past several years and forecasts of abundant supplies at moderate prices in the future, there has been a resurgence of natural gas use in industrial applications in the United States, as seen in Table 2-4.

Table 2-4. Projected Incremental Natural Gas Demand for Select U.S. Industrial Sector Projects, 2015–2020[100]

Planned Operations Date	Chemical		Metals		Petroleum		Other Industrial		Total Demand	
Year	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects	MMcf/d	# Projects
2015	246	57	118	54	355	21	24	179	743	311
2016	317	13	62	5	488	10	58	27	926	55
2017	261	5	79	3	325	3	2	8	668	19
2018	265	5	1	1	747	5	0	4	1,010	15
2019	-	-	-	-	1,350	4	-	-	1,350	4
2020	-	-	-	1	-	-	-	-	-	1
Project dates not announced*	179	6	2	3	872	5	-	-	1,050	14
Total	1,090	80	261	64	3,260	43	86	218	4,700	405

* Not announced at time of this analysis, 6/2014

Natural gas supply is projected to stimulate additional industrial construction and demand growth.

Natural Gas – Electricity Interdependencies

Nationally, natural-gas-fired power generation has increased by more than 40 percent since 2005, and carbon dioxide regulations may increase its use even further.[101] The increasing absolute demand for natural gas in the power sector has heightened the interdependence between gas and electric systems. In addition, fast-ramping requirements of natural-gas-fired generation, especially in response to the need to firm renewable generation, has increased the need for scheduling coordination between the gas and electricity sectors.

Gas Pipeline Transmission Capacity and Power Generation

An important question regarding natural gas transmission infrastructure is whether the existing gas transmission infrastructure can reliably accommodate increased use of natural gas in electric power generation, resulting from significant shifts in fuel utilization in the power sector. A recent DOE study for this QER on the adequacy of the national natural gas transmission system (there may be regional differences and needs, as discussed in the next section) to accommodate increased demand for natural gas[102] concluded the following:

- Higher utilization and repurposing of existing interstate natural gas pipeline infrastructure will reduce the need for new transmission pipelines. Pipeline flow patterns have already evolved with changes in supply and demand. Given the cost of building new pipelines, finding alternatives that utilize available existing pipeline capacity, such as adding compression to existing pipelines or reversing flow, is often less costly than building new pipeline capacity.

- The changing geography of natural gas supply, where diverse sources are now found closer to demand centers, is reducing the need for additional long-distance interstate natural gas pipeline infrastructure. There will be a need for expanded natural gas pipeline capacity as a result of new and expanded production of natural gas from shale formations and growth in natural gas demand, but it is lower than would be expected if the increased production were concentrated in traditional gas-producing regions.
- Incremental interstate natural gas pipeline infrastructure needs, even in a future that includes a national carbon policy, are projected to be modest. While a future carbon policy may significantly increase natural gas demand from the electric power sector, the projected incremental increase in natural gas pipeline capacity additions is modest relative to the reference case used in the analysis, which is based on projections from the 2014 Annual Energy Outlook. The rate of pipeline capacity expansion in the scenarios considered by the analysis is lower than the rate of natural gas pipeline capacity expansion that hs historically taken place.

The Big Chill: A Disruptive Event Made Worse by Infrastructure Interdependencies[t]

The "Big Chill" of 2011 illustrates the complicated relationship between natural gas and electric power, which had compounding effects during a period of extreme weather.

During the first week of February 2011, the U.S. Southwest was hit by an arctic cold front that was unusually severe in terms of its low temperatures, gusting winds, geographic extent, and duration. From January 31 to February 4, temperatures in Texas, New Mexico, and Arizona were the coldest experienced within the region since 1971. Dubbed the "Big Chill" in the media, it overwhelmed the routine preparations for cold weather that had been put in place by electric generators and natural gas utilities located in those states.

Within the Electric Reliability Council of Texas (ERCOT) Interconnection, starting in the early morning hours of February 2, the cold temperatures and wind chill caused a significant number of outages at generating plants, with approximately one-third of the total ERCOT generating fleet unavailable at the lowest point of the event. With electricity demand soaring because of the cold weather, ERCOT and some utilities in New Mexico instituted rolling blackouts to prevent collapse of their electric systems. For the Southwest as a whole, 67 percent of electric generator failures (by megawatt-hour) were due directly to weather-related causes, including frozen sensing lines, frozen equipment, frozen water lines, frozen valves, blade icing, and low-temperature cutoff limits on equipment.

Gas producers and pipelines were also affected in Texas, New Mexico, and Arizona. Natural gas production was diminished due to freeze-offs and the inability to reach gas wells (due to icy roads) to remove produced water and thereby keep them in operation. When rolling electricity blackouts hit gas producers and gas pipelines, it had the effect of causing further losses to natural gas supply. The ERCOT blackouts or customer curtailments caused or contributed to 29 percent of natural gas production outages in the Permian Basin and 27 percent of the production outages in the Fort Worth Basin, principally as a result of shutting down electric pumping units or compressors on gathering lines. As a result of all these factors, natural gas deliveries were affected throughout Texas and New Mexico. More than 30,000 customers experienced natural gas outages at some point during this period.

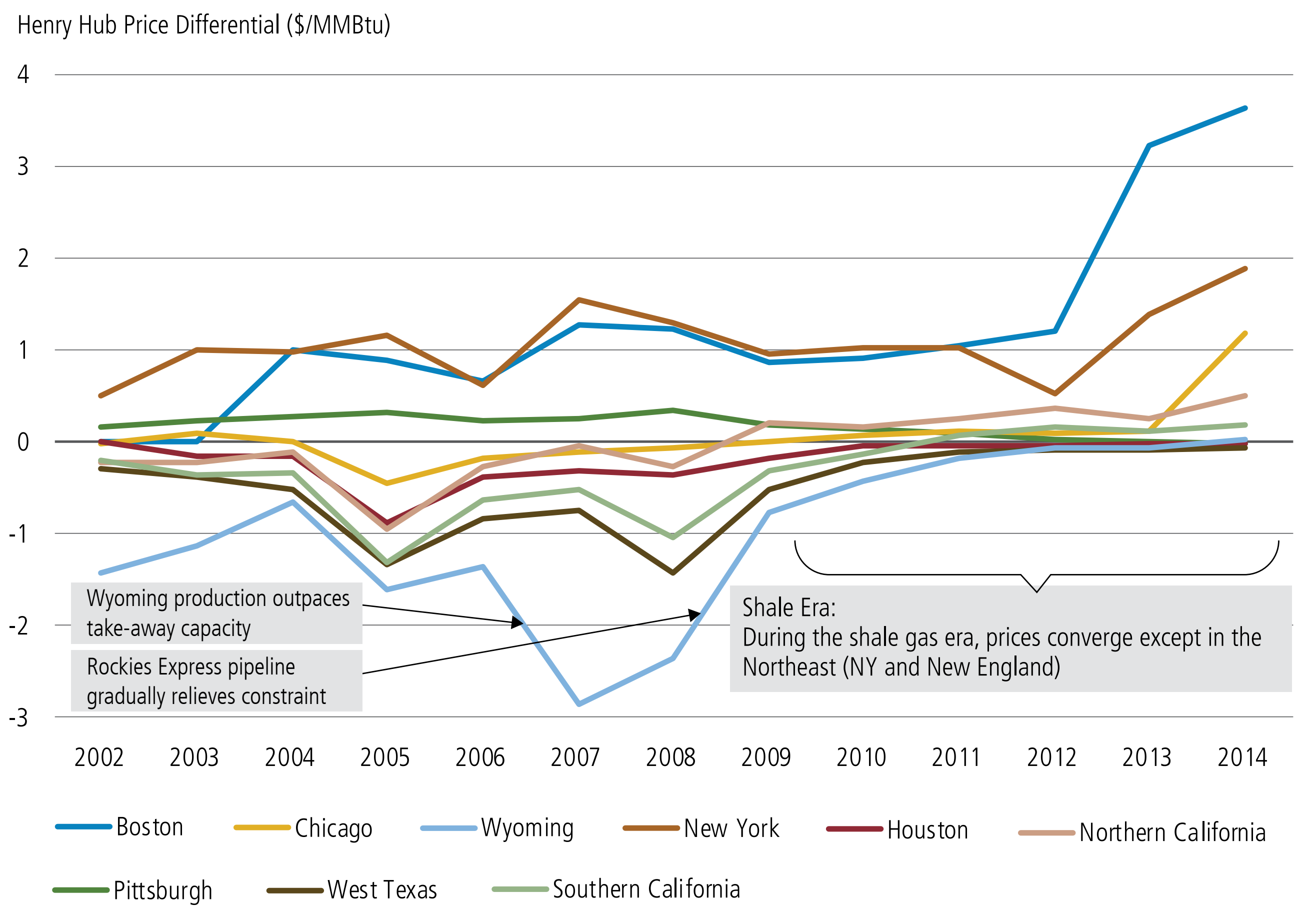
The majority of the problems experienced by the many generators that tripped, had their power output reduced, or failed to start during the event were attributable, either directly or indirectly, to the cold weather itself. However, at least another 12 percent of these problems were attributed afterward to the interdependencies between gas and electricity infrastructures (such as lost electricity generation due to natural gas curtailments to gas-fired generators and difficulties in fuel switching).

[t] Federal Energy Regulatory Commission and North American Electric Reliability Corporation. "Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011: Causes and Recommendations." August 2011. http://www.ferc.gov/legal/staff-reports/08-16-11-report.pdf. Accessed February 2, 2015.

Natural Gas Infrastructure Constraints in the Northeast

The Northeast represents a region of the country where natural gas transmission constraints have caused price differentials to rise during periods of peak demand.[103] While, in the past few years, construction of natural gas pipelines in other parts of the country have caused natural gas price differentials to decrease in those regions, the Northeast has seen its price differentials increase (see Figure 2-7). Much of the northeastern Atlantic region (New England, New York, and—to some extent—the Mid-Atlantic States) continues to see natural gas supply constraints due to gas transmission capacity limits, especially during cold winter periods. However, the actions undertaken by the Independent System Operators, Regional Transmission Organizations, and market participants, such as PJM's Cold Weather Preparation Guidelines and the continuation of Independent System Operator New England's Winter Reliability Program for a second winter, have improved operational performance and moderated prices.[104]

Figure 2-7. Natural Gas Price Differentials between Henry Hub and Key Trading Points[105, u]



Basis differentials reflect regional gas infrastructure constraints and the price signal that spurs infrastructure investment. These constraints persist in New England and New York.

The Northeast region is located at the end of major pipeline routes from traditional natural gas producing areas. Its supplies of natural gas have tended to be constrained during winter peak periods, allowing prices to rise much higher in this region than in the rest of the country in recent years.[106] For example, natural gas prices

[u] The 2014 increase in Chicago city gate prices relative to Henry Hub is attributable to cold winter weather and deep drawdowns of gas in storage, rather than systemic infrastructure constraints, and is less likely to persist.

rose to greater than $34 per million British thermal unit during cold snaps in the winter of 2012-2013 and increased to more than $73 per million British thermal unit during the southward shifts in the polar vortex in the winter of 2013-2014.[107] These capacity constraints are being exacerbated by a large increase in the use of natural gas in the electric power sector in New England. Despite large volumes of new unconventional gas resources available from the Marcellus Shale in nearby Pennsylvania, pipeline constraints have not allowed sufficient supplies of this gas to reach New England, resulting in upward pressure on prices at gas delivery points in the region.[v] The New York metropolitan area, by contrast, has alleviated some of the winter congestion it had faced by adding new pipeline capacity.

The underlying issues affecting natural gas prices and reliability in New England are caused by several complex factors. One area of concern has been the role of capacity markets in the challenges associated with assuring access to adequate fuel supplies. Independent System Operator New England has taken a number of steps to address this issue, including implementing changes to its capacity markets to enhance generator performance and adopting winter reliability measures designed to address this concern.[108, 109] Another issue has been public acceptance of new pipelines, especially in New England, which presents a substantial challenge to natural gas pipeline development.[110] Several pending pipeline projects would alleviate infrastructure constraints into New England. In addition to the capacity market changes by Independent System Operator New England described above, the New England governors are formulating proposals to pay for new natural gas pipeline and electric transmission capacity and services.

Resilience, Reliability, and Asset Security of Liquid Fuels TS&D Infrastructure: Analysis of Vulnerabilities

The U.S. liquid fuels system is diverse, robust, and resilient. In 2014, it produced an average of 8.7 million barrels per day (million bbl/d) of crude oil and 3.0 million bbl/d of natural gas liquids, as well as imported an average of 7.3 million bbl/d of crude oil.[w, 111] In 2014, this system refined an average of 15.8 million bbl/d of crude oil into products in 142 operable refineries. While refining is concentrated on the Gulf Coast, the remainder is well-distributed between the East and West Coasts and the Upper Midwest and supplemented by product imports that enter through both coasts and from Canada. Its TS&D infrastructure consists of both dedicated pipelines and facilities and infrastructures shared with other major commodities.

Liquid Fuel Vulnerabilities Vary by Region

Despite the robustness of the system, the Nation's liquid fuel infrastructure has vulnerabilities. These vulnerabilities are determined by the types of natural disasters that occur in a region, as well as by the types of infrastructure within the region. Regions have supply vulnerabilities if they are dependent on fuel supplies from outside the region. This section describes the relationship between the functions of the liquid fuel infrastructure in a given region and the geographically based vulnerabilities that it faces for regions defined by Petroleum Administration for Defense District (PADD) groupings, a subdivision of the petroleum sector that is commonly used by the Energy Information Administration and other energy analysts.[112] The following are profiles of liquid fuel systems and vulnerabilities by PADD.[113]

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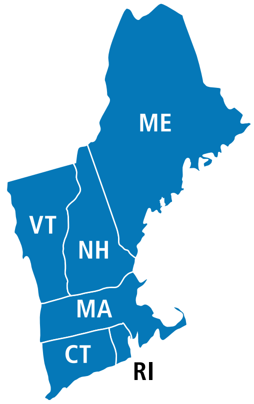
[v] For a more detailed discussion of infrastructure constraints in the New England area, see the documents relating to the April 21, 2014, Quadrennial Energy Review Stakeholder Meeting, "New England Regional Infrastructure Constraints:" energy.gov/epsa/downloads/qer-public-meeting-providence-ri-hartford-ct-new-england-regional-infrastructure.

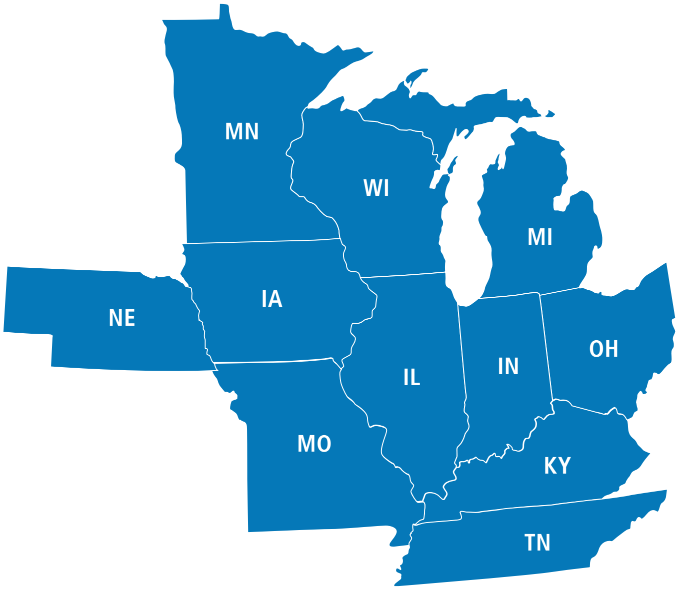
[w] Data are based on cumulative daily averages through December 26.



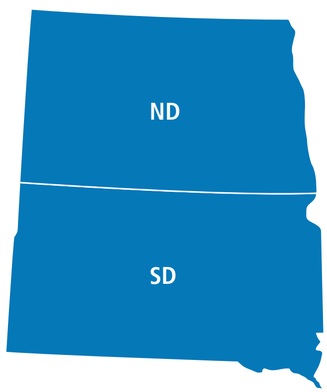
Atlantic Coast-North (PADD I, Subdistrict A): This region (the Atlantic Coast north of New York) has no crude oil production or refining capacity and is not served by large pipelines from the Gulf Coast. The region predominantly receives its supply of liquid fuels by waterborne transport. It is consequently susceptible to weather disruptions of ports. Infrastructure in this region is also susceptible to extreme cold.

Atlantic Coast-Central (PADD I, Subdistrict B): This region has only a small amount of capacity for producing or refining crude oil, relative to its consumption. It is heavily dependent on receiving water shipment of crude oil and refined products at coastal ports and on pipeline shipments of refined products from the Gulf Coast on the Colonial and Plantation pipeline systems. It has a relatively high level of storage for refined products. Liquid fuels shipments are susceptible to weather disruption of ports, flooding of coastal refineries and terminals, and disruptions to flows on Colonial and Plantation pipelines. During the past century, land subsidence has contributed to rising relative sea levels along the Mid-Atlantic Coast as high as 5.0–10.0 millimeters per year (mm/yr), which is more than twice the global average (1.7 mm/yr).[114]

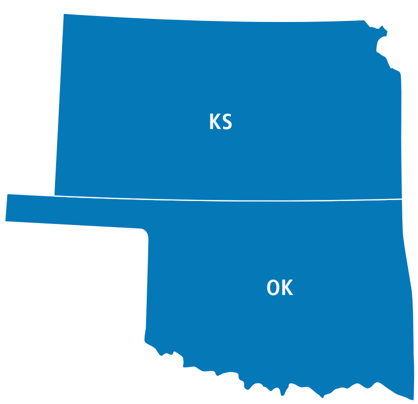
Atlantic Coast-South (PADD I, Subdistrict C): The southern part of this region (Florida and the coastal regions of Georgia, South Carolina, and North Carolina) has very little crude production or refining capacity and is not served by the large pipelines from the Gulf Coast. All coastal areas are supplied by waterborne deliveries, and Florida is heavily dependent on receiving water shipments of refined products. The interior portions of Georgia, South Carolina, North Carolina, and Virginia are dependent on pipeline shipment of refined products from the Colonial and Plantation pipeline systems. The region is susceptible to weather disruptions of receiving ports, pipeline shipments, as well as events that disrupt loading and departures of barges from the Gulf Coast. Over the past century, sea levels have increased by as much as 3–6 mm/yr in the Atlantic Coast-South region.[115]



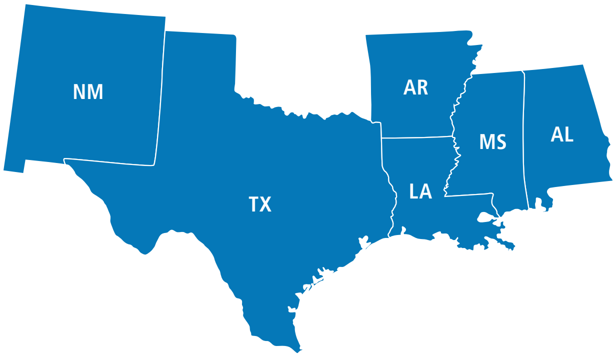
Great Lakes/Midwest Region (Part of PADD II): Refineries in this region have historically relied on crude oil shipped via pipeline from the Gulf Coast. Now almost all oil moved to refineries in the region comes from more recently developed supplies of Midcontinent and Canadian crude oil. This shift has diminished the need for pipelines to deliver crude oil from the Gulf of Mexico to the region, and many have been reversed to move additional Midcontinent and Canadian oil supplies south to the Gulf Coast (PADD III) refining complex. Weather events are less likely to affect multiple refineries in the Midwest compared to, for example, the refineries concentrated along the Gulf of Mexico. An earthquake in the New Madrid Seismic Zone could disrupt product deliveries, but it would be less likely now to disrupt crude oil supplies into the region than 5 years ago. Extreme cold can hinder refining and distribution.



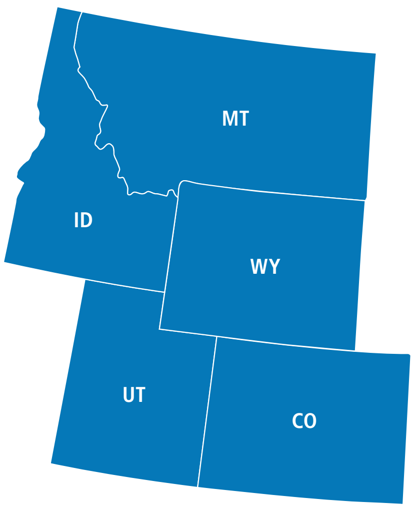
Williston Basin (Part of PADD II): Recent development of technology to produce oil from shale formations (in this case, the Bakken formation) has made the Williston Basin an important producing area. The area is not highly susceptible to natural disasters, but is susceptible to extreme cold. The East and West Coasts and the Gulf Coast rely on this region for rail transport to bring its crude to their refineries.



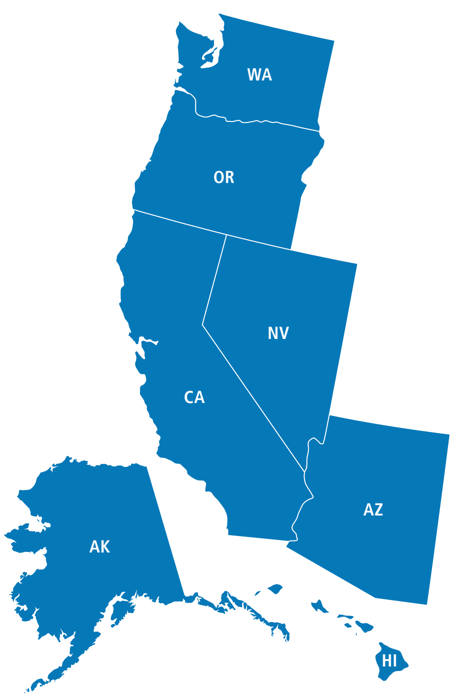
Oklahoma/Kansas (Part of PADD II): This region is a relatively large producer of crude oil and, more importantly, a national hub for trading, storing, and transporting crude oil. One of the largest oil storage and pipeline junction centers in the world is located near Cushing, Oklahoma. Tornados likely are the highest-impact hazard that could strike this area.



Gulf Coast (PADD III): This region is a major center for onshore and offshore production, refining, and loading and unloading of water shipments of crude oil and refined products. Fifty-two percent of the Nation's operable refinery capacity is in PADD III. It is susceptible to tropical storms and hurricanes, flooding, and sea-level rise. During the past century, land subsidence in the Gulf Coast region has caused relative sea levels to rise by 5–10 mm/year, which is more than the twice the global average. The highest rates of land subsidence within the Gulf Coast region are estimated to be in the vicinity of the Mississippi River Delta.[116]



Northern Rocky Mountain Region (PADD IV): This region consumes fuels from refineries in the Salt Lake and Denver areas that mainly process crude oil produced from within the region. The main hazards are earthquakes and perhaps tornados. It is susceptible to extreme cold. Pipelines networks are less dense in the less populated regions of PADD IV. This leads to cities that are far from refining centers often being served by long dedicated pipelines. These cities are more dependent on the operation of single pipelines than typically is the case in regions of the country with higher-density populations. An example in PADD IV is Boise, Idaho, which is dependent on a single pipeline from Salt Lake City.



West Coast Region (PADD V): Although this region still produces much of the crude oil processed in its refineries, it increasingly depends on receiving shipments by water from other regions and from ports within PADD V, including Alaska. PADD V is not well-connected to other PADDs by pipeline, but it does receive an increasing amount of its oil by rail. The level of imports to PADD V is stable. This region is susceptible to earthquakes and wildfires. Cities that are on the downstream edge of supply from West Coast refineries and depend on long dedicated pipelines include Phoenix, Arizona; Las Vegas, Nevada; and Reno, Nevada. During the past century, sea levels along the West Coast have generally risen at or below the global average rate.[117]

Vulnerability of Fuel Supply Disruptions from Gulf Coast Hurricanes

As noted, the Gulf Coast region is home to more than 50 percent of the Nation's refining capacity. Damage to liquid fuels infrastructure in this region can lead to significant impacts on much of the rest of the country, as the Gulf supplies oil products to the Northeast, Midwest, Mid-Atlantic, and South Atlantic regions.[118] Many U.S. regions are vulnerable to severe weather in the Gulf of Mexico or other threats to infrastructure in the Gulf of Mexico or on the Gulf Coast. Land subsidence also is a widespread issue throughout the Gulf Coast (and Mid-Atlantic coastal areas). During the past century, global sea-level rise has averaged about 1.7 mm/yr, though the rate in the Gulf has been faster (at 5–10 mm/yr, in part due to subsidence).[119] Between now and 2030, the average global sea-level rise could accelerate to as much as 18 mm/yr in worst-case scenarios.[120]

Gulf Coast refineries in the path of a major hurricane typically shut down in advance of a storm and restart after the storm has passed. While an undamaged refinery is likely to return to operation within 1 week of hurricane landfall, a severely damaged refinery might take several months to recover. Hurricanes Katrina and Rita provide examples of such impacts. The combined consequences of these two hurricanes in 2005 caused refinery outages of more than 4.5 million bbl/d. More than 20 refineries were shut down on the worst day, representing a loss of 67 percent of the Gulf's capacity and 28 percent of national refinery capacity. While the refineries recovered, the outage was still 2 million bbl/d 3 weeks after Rita's landfall and remained at 1 million bbl/d for over 2 months. This caused a sharp, temporary increase in regional and national gasoline and diesel fuel prices.[121]

In response to these hurricanes, 30.0 million bbl of crude oil from the Strategic Petroleum Reserve (SPR) were offered to the market and 20.8 million bbl were ultimately sold; it took 20 days for the first oil to move. While the International Energy Agency, in a coordinated effort, released petroleum product stocks to assist with the U.S. supply disruption, these supplies were not easily distributed to the Southeast region; truck deliveries to the Southeast region were made hundreds of miles from ports on the Atlantic Coast.

Similar petroleum product outages occurred in 2008 as a result of Hurricanes Gustav and Ike, leading to significant increases in motor fuel prices in all regions of the United States. In these instances, no SPR emergency release or International Energy Agency coordination action was taken.[x] In 2012, Hurricane Sandy caused numerous fuel supply and distribution problems in New York and New Jersey, involving refineries, marine terminals, petroleum product terminals, and retail service stations. As with the 2005 and 2008 hurricanes, an SPR crude oil release would have provided little remedy to the fuel supply problems. Also, all four U.S. facilities are located in the Gulf Coast region and may be exposed to hurricane damage, including inundation caused by storm surge.[122] In September 2008, for example, the Big Hill and West Hackberry sites sustained significant damage caused by Hurricane Ike.[123]

Industry has taken actions to harden Gulf Coast infrastructures after hurricanes in 2005 and 2008. Aboveground product storage tanks represent a particular vulnerability in hurricanes as they can float off their foundations and spill product, creating environmental and supply concerns. At least four companies surveyed by DOE in 2010[124] indicated that they had "taken steps to ensure a minimum volume of product is in their storage tanks before a storm arrives." The refinery and pipeline operators interviewed for this study all confirmed that they maintain confidential hurricane preparedness plans. State public utility commissions also have responded in a variety of ways, initiating studies of and rulemakings for storm hardening. On the power side, the actions of Entergy during Hurricane Gustav in 2008 provide an example of the efforts by utilities to maintain service to customers. Entergy's use of grid sensors enabled it to identify and warn of islanding conditions[y] in order to manage their impacts on its systems in four states. Entergy's success during Gustav provides a replicable example for the effective use of technologies to manage storm impacts.[125]

[x] Some SPR sites sustained significant damage. While the SPR was able to conduct a test exchange of 5.4 million bbl of crude in response to requests for supplies from several refiners, it took weeks to restore SPR sites to their pre-storm levels of mission capability.

[y] Islanding is an unsafe situation for utility workers, where a distributed generator, when not appropriately monitored or understood, continues to provide power when electricity from the utility is cut off.

Vulnerabilities to Non-Weather-Related Refined Product Disruptions

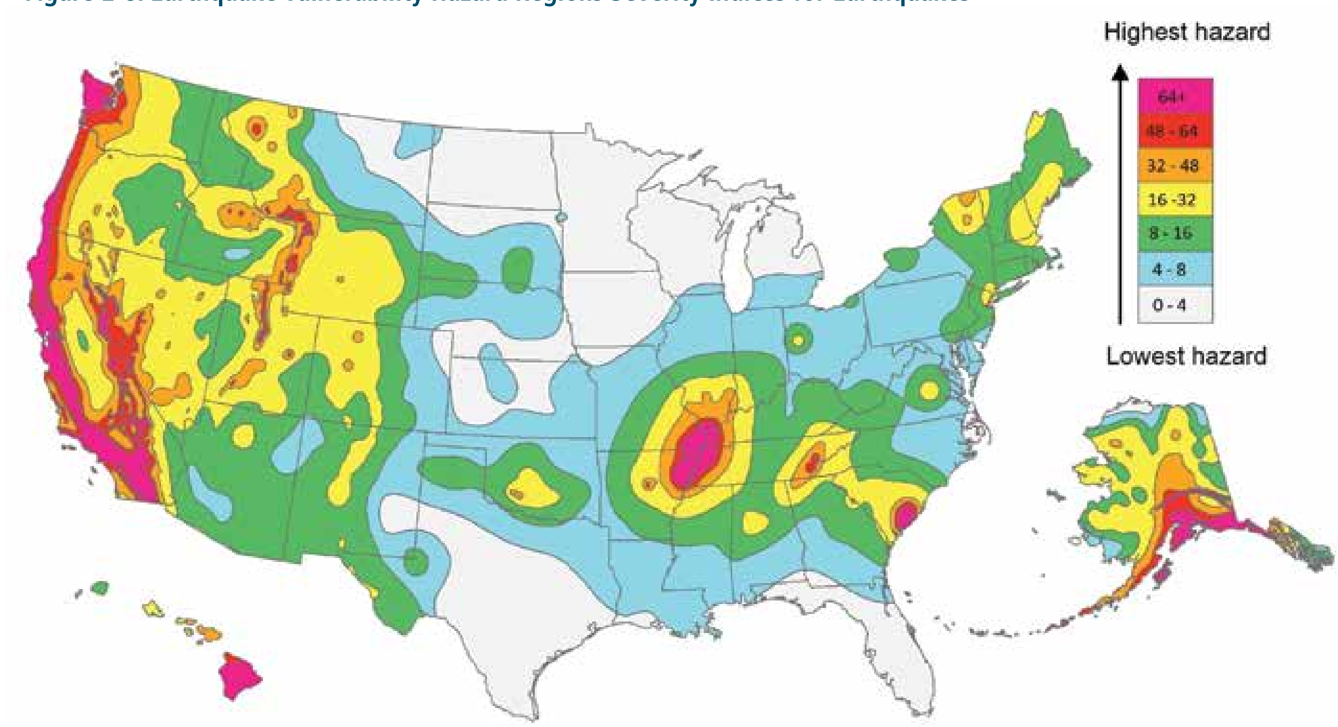
In addition to storms on the East and Gulf Coasts, other natural disasters can cause interruptions of petroleum products. While the U.S. West Coast is not as vulnerable to hurricanes, a severe earthquake in the Los Angeles Basin or San Francisco region would cause significant disruptions of fuel supplies. For example, Table 2-5 and Figure 2-8 show (1) the potential impacts of severe earthquakes on a variety of energy infrastructures, and (2) regions that are prone to damaging earthquakes. The greatest infrastructure risks occur when the probability of damage and severity of damage are high, the risk of the event is high, and the infrastructure involved is critical. Western pipelines and refineries are both at risk in major earthquakes.

Table 2-5. Probability and Severity of Earthquake Damage to TS&D Infrastructure[126]

Infrastructure	Magnitude<5		Magnitude >5	
	Probability of Damage	Severity of Damage	Probability of Damage	Severity of Damage
Loss of Electrical Power	Med	Significant	High	Catastrophic
Gulf of Mexico Platforms	Low-Med	Interrupting	Med	Significant
Pumping/Compressor Station	Low-Med	Interrupting	Med	Significant
Pipelines	Low-Med	Interrupting	Med-High	Major
Rail	Low	Insignificant	Med	Significant
Ports	Low	Insignificant	Med-High	Major
Crude Tank Farm	Low	Insignificant	Med	Significant
Refineries	Low	Insignificant	Med-High	Major
Natural Gas Plants	Low	Insignificant	Med	Significant
Product Storage Terminals	Low	Insignificant	Med	Significant
Propane Tanks	Low	Insignificant	Med	Significant
Underground Storage	Low	Insignificant	Low-Med	Interrupting
LNG Terminals	Low	Insignificant	Med	Significant
Local Natural Gas Distribution	Low	Insignificant	High	Catastrophic
Filling Stations	Low	Insignificant	Med	Significant
SPR/NEHHOR	Low	Insignificant	Low	Insignificant

For two magnitudes of earthquake intensity, the severity of probable damage was rated qualitatively using a five-point scale (i.e., insignificant, interrupting, significant, major, and catastrophic) and probability also on a 5-point scale (i.e., low, low-medium, medium, medium-high, and high).

Figure 2-8. Earthquake Vulnerability Hazard Regions Severity Indices for Earthquakes[127, z]



Analyzing the impacts of earthquake on TS&D infrastructure involved a review of the probability of damage and severity of damage on infrastructure components (Table 2-5) and the probability of an event occurring in a region. Comparing this to the types and amounts of energy infrastructure in the region (e.g., limited liquid fuels pipelines in the Rocky Mountain region) identified regional TS&D infrastructure vulnerabilites.

Responding to Liquid Fuels Disruptions

There is a range of actions that could be taken to address the vulnerabilities outlined in the previous section. One is to develop strategic and regional stockpiles of oil and refined petroleum products to help respond to shortfalls caused by breakdowns in the liquid fuel infrastructure, regardless of cause. Another is additional hardening. Hardening can consist of flood protection (e.g., berms, eves, and floodwalls), self-sufficient electric power (e.g., a generator sited at a facility that is configured to operate in a safe "island mode" disconnected from the local electricity grid to supply that facility with electricity during a local grid blackout[aa]), and other measures. A combination of these actions may provide the most cost-effective approach to avoid the loss of fuel supplies after a natural disaster, recognizing that government and industry (refiners, pipeline companies, utilities, power providers, the Army Corps of Engineers, and DOE) have different roles in implementing different measures.

[z] For a range of intensities of the event (e.g., earthquakes with a magnitude less than 5), the likely damage was rated on a qualitative 1–5 score (i.e., minor, interrupting, significant, major, and catastrophic). These ratings were based on the extensive review of impacts from past events and judgment of industry experts.

[aa] "Island" facilities are used at facilities such as hospitals, office buildings, and sometimes individual's homes; they can operate independently from the grid to provide electricity during a power outage.

Administration Activities for Liquid Fuels Resilience, Reliability, Safety, and Asset Security

Operations of Regional Oil Product Reserves. The President's Fiscal Year 2016 Budget requests $7.6 million to continue operation of the Northeast Home Heating Oil Reserve. The Northeast Gasoline Supply Reserve will continue to be funded out of prior-year balances.

Southeast Refined Product Reserve Cost-Benefit Analysis. In 2011, the Department of Energy (DOE) carried out a cost-benefit study of the establishment of a Southeast Refined Product Reserve. This study estimated that such a Refined Petroleum Product Reserve would reduce the average gasoline price rise by 50 percent to 70 percent in the weeks immediately after a hurricane landfall, resulting in consumer cost savings.[ab] DOE is updating this study to reflect recent economic research and to examine whether currently available analyses of refinery hardening and climate change alter the study's estimates of the likelihood of Gulf Coast refinery outages.

West Coast Regional Refined Product Reserve Cost-Benefit Analysis. DOE has launched a Refined Petroleum Product Reserve study for Petroleum Administration for Defense District (PADD) V (the West Coast, Alaska, and Hawaii). It will review current and projected oil and refined product demand in southern California, northern California, Arizona, Nevada, Washington, Oregon, Hawaii, and Alaska. It also will describe storage capacities; how and where stocks are stored; and how refined products move from refinery, to storage, to end-use markets. The study will evaluate the physical and market vulnerabilities that could cause a supply disruption or shortage to PADD V markets and estimate the probability of the occurrence of natural events at various locations within PADD V. The potential impacts on crude oil and petroleum product supplies from events of various intensity or duration will be estimated. The physical vulnerabilities to be considered will include earthquakes, tsunamis, and storms. Refined Petroleum Product Reserve configurations that could provide a relatively effective fuel supply relief, in light of the estimated likelihood of fuel supply interruptions, will be evaluated using a cost-benefit methodology similar to that used in DOE's 2011 study,[ac] but will be updated to reflect recent economic research, especially concerning the impact of sudden increases of petroleum product prices on the U.S. economy.

Emergency Preparedness Study. The National Petroleum Council, in response to a request from the Secretary of Energy, recently completed an Emergency Preparedness Study. This study will help industry and government achieve a more rapid restoration of motor fuel supplies after a natural disaster.

[ab] Department of Energy, Office of Fossil Energy and Office of Policy and International Affairs. "Refined Petroleum Product Reserve, Assessment of Energy Security Needs, Costs and Benefits." September 2011.

[ac] Department of Energy. "Regional Petroleum Product Reserve: Assessment of Energy Security Needs, Costs, and Benefits." September 2011.

The United States has created two regional petroleum product reserves (RPPRs) during the last 15 years—the Northeast Home Heating Oil Reserve (NEHHOR) and the Northeast Gasoline Supply Reserve. NEHHOR is a 1-million-barrel reserve of ultra-low sulfur diesel, stored at terminals in Connecticut and Massachusetts. It is intended to provide a buffer to compensate for interruptions in heating oil supplies during severe winter weather. NEHHOR has a trigger mechanism established by the Energy Act of 2000 that requires a 60 percent price differential over the 5-year average price of heating oil, that the differential be sustained for 7 days, and that it continues to increase thereafter. A second authority for a release from NEHHOR is available to the President for a "regional supply shortage of significant scope and duration."[128] These release authorities have never been used. After Hurricane Sandy, however, NEHHOR distillate was provided to the Department of Defense. The Defense Logistics Agency distributed this fuel to support emergency operations and other priorities.

Also, the Northeast Gasoline Supply Reserve currently contains about 1 million barrels of gasoline in five locations in New Jersey, Massachusetts, and Maine to serve consumers in the northeastern United States. This gasoline reserve operates under the same release authorities as the SPR, but under different authorities than the NEHHOR; depending on the nature and degree of the emergency, the threshold for use of these facilities in concert could prove difficult to reach.

Liquid Fuel TS&D Dependencies on Electricity

In 2013, U.S. refineries consumed a total of 46 million megawatt-hours of purchased electricity in their operations. One of the biggest vulnerabilities for Gulf Coast and East Coast refineries can be the lack of electricity supply. Without power, refineries cannot continue to operate, and petroleum products cannot be moved through pipelines. A number of refineries have invested in portable generators; however, the majority has only established plans for leasing generators in advance of the hurricane, and even the largest 2-megawatt mobile generators cannot provide enough electricity to operate a refinery. During electrical outages, these generators provide electricity to critical facilities—the data control center, critical information technology facilities, and the water pumps required to remove storm water from the plant and refinery equipment. The high probability of electricity outages after hurricanes has caused refiners to initiate controlled shutdowns in advance of landfalls to avoid "cold shutdowns" that result in refinery damages.

Crude oil and refined product pipelines also rely on electricity to move petroleum products, such as gasoline, through their systems. As noted, power outages from Hurricane Katrina caused the complete shutdown of three major pipelines for 48 hours and forced these pipelines to operate at reduced capacities for an additional 2 weeks.[129] In 2006, Colonial Pipeline responded to the need to keep pipelines operating during emergencies by installing trailer-mounted portable generators, some transformers, and additional cables. The generators are staged at a site in Mississippi and can be moved to any of Colonial's pump stations depending on emergency needs.[130]

Even these actions, however, have limitations, as they assume uninterrupted supplies of product from refineries and terminals. Evidence suggests this is problematic, as transmission pipelines depend on many independent and interconnected pipelines and terminals for delivery of supplies; the overall network feeding major transmission pipelines may not be able to meet supply needs in the event of a disruption. Also, this intermediary infrastructure is often co-owned by refineries; if a refinery is disrupted and vulnerable, so too are the interconnecting pipelines and ultimately the transmission pipelines that move product to consumers.[131]

Refineries, pipelines, and distribution systems also rely on electricity to power supervisory control and data acquisition and other monitoring systems that ensure that their operations are efficient, safe, and secure. Finally, the loss of electricity can have a significant impact on retail gasoline distribution (see the Hurricane Sandy box on page 2-5).

Vulnerabilities of Shared Transportation Infrastructures

Transportation infrastructure (such as railroads, barges, tankers, and ports) that liquid fuels and coal share with other commodities also face resilience challenges from extreme weather and climate change. As noted, extreme weather events are increasing. Intermodal crossing points, such as grade crossings and waterway-railroad trestle intersections, will be vulnerable, as will stretches of rail far removed from observational networks.[132]

Rail Vulnerabilities Associated with Extreme Weather

Railroads are vulnerable to structural damage and track misalignment where the roadbed has been affected by extreme weather. Railroad operations also are affected by weather conditions such as snow, flash floods, heat waves, and extreme wind. Extreme heat, for example, causes materials to expand, leading highways and roads to buckle and rails to kink (see Figure 2-9). A 1,800-foot section of rail can expand by a foot with an 80-degree temperature change.[133] These kinks can be highly dangerous and require vigilant track inspections. Some rail operators also issue "heat orders" during high temperatures that require trains to slow their speed along the tracks.[134]

Barge and Tanker Transport Are Affected by Extreme Weather

More than 4,500 tank barges transport liquid fuels and coal nationwide.[136, 137] They are vulnerable to damage by storm surge, as well as river flow fluctuations (e.g., on the Mississippi River) that can impede traffic or reduce barge fuel carrying capacity. During Hurricane Katrina, the Coast Guard closed parts of the Lower Mississippi River to traffic for more than a week as inspectors surveyed the river obstructions. More than 300 barges along the river were set adrift, sunk, or damaged, posing further risks to navigation.[138] Increased storm surge and flooding could interrupt barge navigation by flooding inland marine transportation infrastructure and increasing the velocity of flow on rivers, forcing channels to shutdown intermittently. In the long term, increased incidents of storm surge and coastal flooding may cause sand formations to build up in channels, forcing operators to shutdown channels that have become too shallow.

Figure 2-9. Rail Thermal Misalignment[135]

Track buckling is typically caused by a combination of high compressive forces due to temperature stresses, weakened track conditions, and mechanical stress from train braking and rolling friction. Safety and operations are therefore impacted by both extreme high and low temperatures, by causing track creep, and by making track more susceptible to the mechanical stresses that cause buckling.

Flooding by itself can have an impact on pump stations, control rooms, oil tanks, well pads, and barges or tankers travelling on flooded navigable waterways, such as the Mississippi River. High water conditions can disrupt barge and tanker traffic by, for example, barring navigation under bridges. In addition, if port and terminal facilities were flooded and shutdown, barge shipments that require loading or unloading at the terminals would be delayed.[139]

Drought can also affect some port facilities and some navigation channels that are inland, such as the Great Lakes. If water levels are too low, barges risk running aground, causing either disruptions to liquid fuel transport or lower draft limits. This forces barges to carry lighter loads, thereby reducing available supply.[140] Low water levels also can be caused by freezing temperatures upstream, leaving less water available downstream.[141] Climate change is expected to cause more frequent and severe weather in the future, which in some regions will lead to droughts and floods that may create further vulnerabilities for barge transport.

Vulnerabilities of Energy TS&D and Shared Infrastructures to Physical Attack

The lack of controlled standoff distances[ad] or adequate barriers for a range of oil and gas transmission and distribution facilities and infrastructures makes them especially vulnerable to physical attacks. Much of the liquid fuel TS&D infrastructure in the central Atlantic Coast region, for example—including gas production, ports and terminals, and processing and refining facilities—is geographically concentrated, visible, and potentially accessible from major and ancillary transportation routes, making it vulnerable to intentional damage.[142] Physical attacks on this type of infrastructure could have outsized impacts because of the concentration of refining and product storage facilities that serve other domestic markets.

[ad] "Controlled standoff distance" refers to the distance maintained between an asset and a potential detonation site.

Results from an Argonne National Laboratory analysis of DHS survey data[ae] on critical infrastructure energy facilities showed that at many facilities vehicles may pose a risk by being placed (legally or illegally) inside a safe standoff perimeter.

Increasing standoff distance is an effective way to mitigate potential consequences of certain types of threats. Other measures include fencing, barriers, access control points, and security personnel. Notably, only a portion of energy facilities has barriers in place sufficient to limit vehicle access and approach. The DHS critical infrastructure survey also assessed the existence of security forces at facilities. The prevalence of security forces is highly dependent on the energy subsector. Refineries generally have a security force, but liquid fuel product transport facilities tend to have less security.

Improving Cybersecurity in the U.S. Energy Sector

This installment of the Quadrennial Energy Review did not carry out original analysis of cyber threats to energy infrastructure because significant work is being done elsewhere. It is noted, however, that cyber threats to energy delivery systems are growing and evolving. In 2013, there were 151 cyber incidents involving the energy sector that were reported to the Department of Homeland Security's Industrial Control System Cyber Emergency Response Team. Cybersecurity is a shared responsibility among Federal, state, local, tribal, and territorial entities, as well as public and private owners and operators of critical infrastructure.

In February 2013, President Obama issued Executive Order No. 13636, *Improving Critical Infrastructure Cybersecurity*, and Presidential Policy Directive-21, Critical Infrastructure Security and Resilience. These policies reinforce the need for holistic systems thinking about security and risk management in the energy sector. In February 2014, the Obama Administration launched the Cybersecurity Framework to assist organizations in enhancing critical infrastructure cybersecurity.

While the Department of Homeland Security coordinates the overall Federal effort to promote the security and resilience of the Nation's critical infrastructure, in accordance with Presidential Policy Directive-21, the Department of Energy serves as the day-to-day Federal interface for sector-specific activities to improve security and resilience in the energy sector. This Quadrennial Energy Review report does not go into detail about cybersecurity; the U.S. government and others have activities underway to improve cybersecurity of critical infrastructure. Improving security and resilience includes accelerating progress in the following areas relevant to the Quadrennial Energy Review:

Build robust information-sharing architecture across the energy sector. Robust information sharing between government and industry (including owners and operators) is critical for addressing cyber threats. Information Sharing and Analysis Centers help propagate information on cyber threats, vulnerabilities, incidents, and solutions in the energy sector.

Expand implementation of best practices and sound investments by owners and operators. The Cybersecurity Capability Maturity Model, developed by the Department of Energy in partnership with industry and others, can identify and assess various practices for energy sector cybersecurity. In many cases, there is an opportunity for owners and operators of critical infrastructure to invest more in people, processes, and technology that can improve security and resilience. The model can assist those responsible for overseeing cybersecurity decisions.

Develop and deploy cutting-edge technical solutions. Experience indicates that proactive measures taken on the basis of advanced research and development can provide a defensive edge. The Department of Energy has partnered with energy sector owners, operators, and vendors since 2006 to research, develop, and deploy cybersecurity solutions according to a set of near-, mid-, and long-term objectives outlined in the "Roadmap to Achieve Energy Delivery Systems Cybersecurity," which was developed through government-industry partnership.

Build a strong incident management capability. Government and industry are developing a strong capability to respond to serious cybersecurity incidents in the energy sector. Incident response plans need to be developed, vetted, and tested through progressively challenging exercises, culminating in a capstone-type exercise like GridEx, which is hosted by the North American Electric Reliability Corporation. Future exercises could address the interdependency between the electricity subsector and the oil and gas subsector.

[ae] DOE's Office of Energy Policy and Systems Analysis requested that Argonne National Laboratory's Infrastructure Assurance Center conduct an analysis of the protection and resilience information collected through DHS's Enhanced Critical Infrastructure Program Initiative, which conducts facility site visits and surveys. The primary objective of this analysis was to identify gaps in preparedness and rapid recovery measures for surveyed energy facilities. The analysis was conducted on 273 energy facilities (170 electricity, 45 liquid fuels, and 15 natural gas) using data collected from January 2011 through September 2014.

QER Recommendations

This chapter has laid out a broad range of crucial issues and questions relating to improving the resilience, reliability, security, and safety of energy TS&D infrastructures. To continue to drive progress toward improving these key energy infrastructures, we recommend taking the following additional actions:

Develop comprehensive data, metrics, and an analytical framework for energy infrastructure resilience, reliability, and asset security: Multiple gaps in federally accessible data impede decision making on policies and investment related to resilience, reliability, and security. These data are critical for understanding the extent to which our existing energy infrastructure is resilient and for better informing resilience investments. DOE, in collaboration with DHS and interested infrastructure stakeholders, should develop common analytical frameworks, tools, and metrics to assess the resilience, reliability, and security of energy infrastructures. The purpose of this work will be to help inform, coordinate, set priorities for, and justify expenditures across Federal agencies to increase the resilience, reliability, and security of energy infrastructure.

Establish a competitive program to accelerate pipeline replacement and enhance maintenance programs for natural gas distribution systems: The proposed DOE program would provide Federal competitive financial assistance to states to incentivize cost-effective improvements in the safety and environmental performance of natural gas distribution systems. Specifically, it would target transitional assistance (for a 3- to 4-year period) to help low-income households absorb initial rate increases related to these activities; it would also provide incentives to accelerate the reduction of methane emissions through repairs of other system components. This includes programs to accelerate the rate of replacement and repair of pipelines made of leak-prone materials and direct inspection and maintenance to reduce emissions from regulators and meters at city gate facilities. Providing rate assistance to low-income customers could incentivize states to expand current special regulatory cost-recovery programs, which in turn would facilitate increased private investment in infrastructure modernization. (See additional discussion on employment and workforce training in Chapter VIII, Enhancing Employment and Workforce Training).

The program would be implemented through financial assistance to states awarded on a nationwide competitive basis. State applicants would be required to demonstrate how the proposed financial assistance would be integrated with rate-setting programs that would ensure that the funds are applied to the targeted beneficiaries. Applications could be prioritized for funding based on estimated net benefits of the proposal, considering factors such as enhancement of public safety, magnitude of methane emission reduction, innovation in technical and policy approaches, number of beneficiaries, and overall cost effectiveness. DOE would establish specific guidelines for each of the evaluation criteria.

The estimated cost for this program is $2.5 billion to $3.5 billion over 10 years.

QER Recommendations (continued)

Support the updating and expansion of state energy assurance plans: DOE began a State Energy Assurance Planning Initiative in 2009 with funding from the American Recovery and Reinvestment Act of 2009. The President's Fiscal Year 2016 Budget proposes $35 million to establish a State Energy Assurance grant program to finance state, local, and tribal governments to continue this important task. DOE should continue 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, and develop comprehensive plans that respond to those disruptions and reduce the threat of future disruptions.

- The specific objectives of this initiative should be as follows:
    1. Strengthen and expand state, local, and tribal energy assurance planning and resilience efforts by incorporating innovative technologies and measures to improve resilience.
    2. Build state in-house energy assurance expertise.
    3. Build regional energy assurance capability to allow states, localities, and tribes to better identify the potential for energy disruptions, quantify the impacts of those disruptions, and develop comprehensive mitigation and response plans.
    4. Address the disproportionate impacts of potential energy disruptions on vulnerable or underserved communities.
- Energy assurance plans funded under this recommendation should be continually updated to reflect changing conditions and new threats and should be tested for adequacy in simulations or exercises to maintain staff capacity to implement the plans.
- As part of updating the state energy assurance plans, states would be encouraged to work with industry and each other to identify locations where energy infrastructure is particularly vulnerable to disruption (e.g., by physical attack) and craft effective strategies to reduce vulnerability and coordinate preparedness and response plans.
- As part of these plans, states should also assess needs for backup electricity at retail gasoline stations along emergency evacuation routes.
- DOE should encourage strong intergovernmental coordination to ensure state and local energy assurance plans interface with one another, as well as with Federal and private sector disaster and emergency response plans.
- Having a state energy assurance plan that meets a threshold of completeness and rigor should be an eligibility requirement for other kinds of Federal funding related to energy infrastructure.
- This program should be supported on either a 2-year or 3-year cycle.

On a 3-year cycle, the estimated support needed for this program over 10 years is $350 million. On a 2-year cycle, the estimated support needed for this program over 10 years is $500 million.

QER Recommendations (continued)

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, incorporating lessons learned from new data, metrics, and resilience frameworks.

- An example of such a project is the NJ TRANSITGRID, which incorporates renewable energy, distributed generation, and other technologies to provide resilient power to key NJ TRANSIT stations, maintenance facilities, bus garages, and other buildings. Through a microgrid design, NJ TRANSITGRID will also provide resilient electric traction power to allow NJ TRANSIT trains on critical corridors, including portions of the Northeast Corridor, to continue to operate even when the traditional grid fails.[143] This project received $410 million from the Department of Transportation in late 2014 and partnered with DOE on project design.
- The Department of Housing and Urban Development's National Disaster Resilience Competition, which supports innovative resilience projects at the local level, could also serve as a model for types of projects to be funded, with a specific focus on energy.
- The grant program should also include incentives to establish mandatory resilience standards and codes. States, tribes, and local governments with resilience standards in place would be eligible to receive cost-shared grant funding. Approved state energy assurance plans could also be a criterion for eligibility.

The estimated cost for this program is $3 billion to $5 billion over 10 years.

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 lead—in coordination with DHS and other Federal agencies, states, and industry—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.

- The staged process should begin with an assessment of technical specifications for reserve transformers, where transformers would be located and how many would be needed, how transformers would be secured and maintained, how transformers might be transported, and whether new Federal regulatory authorities or cost share are necessary and appropriate. These reserves may include smaller, deployable transformers.
- The analysis under this process should both recognize significant efforts already underway by industry to share transformers and parts, including planning for surge manufacturing and long-term standardization of transformer designs, and build on policy work already underway by Federal regulators.

QER Recommendations (continued)

Analyze the need for additional or expanded regional product reserves: The benefits of an RPPR derive from its ability to replace lost product supplies in emergency situations and mitigate sharp increases in petroleum product prices. DOE should undertake updated cost-benefit analyses for all regions of the United States that have been identified as vulnerable to fuel supply disruptions. Additional or expanded RPPRs could be supported, depending on the outcome of these studies.

Integrate the authorities of the President to release products from RPPRs into a single, unified authority: Congress should amend the trigger for the release of fuel from NEHHOR 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.

RECOMMENDATIONS IN BRIEF:
Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure

Develop comprehensive data, metrics, and an analytical framework for energy infrastructure resilience, reliability, safety, and asset security. The Department of Energy (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 transmission, storage, and distribution (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—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 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.

Endnotes

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Chapter III

MODERNIZING THE ELECTRIC GRID

This chapter examines how the electricity grid of the future can provide affordable and reliable clean electricity, while minimizing further human contributions to climate change. After an introduction to the structure of the U.S. electrical grid, the chapter lays out a vision for its transformation and describes the drivers of change toward the future grid. These major drivers cover challenges and opportunities that affect transmission and distribution grids, involve new technologies and services, and require careful consideration of the diverse institutions and business models currently involved in managing the grid. After discussion of a policy framework for the grid of the future, the chapter concludes by presenting a series of recommendations, divided into three major categories: (1) research and development, analysis, and other studies; (2) state and regional planning and managing across jurisdictions; and (3) appropriate valuation, standards, and measurement methods to facilitate the introduction of new technologies and practices to improve the grid.

FINDINGS IN BRIEF:
Modernizing the Electric Grid

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 greenhouse gas reduction and state renewable energy goals.

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 Quadrennial Energy Review, 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 the Department of Energy'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.

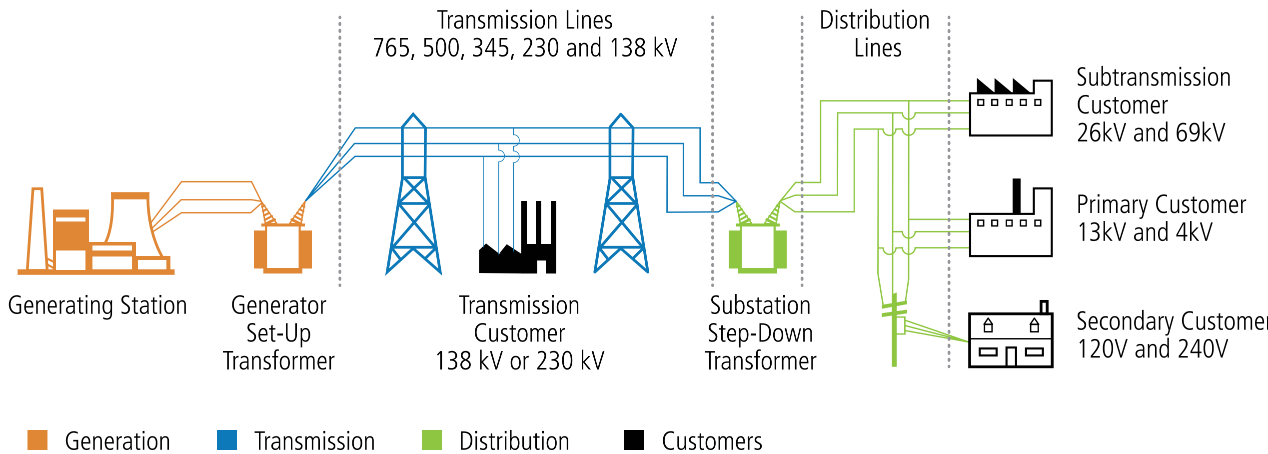
Growing jurisdictional overlap impedes development of the grid of the future. Federal and state jurisdiction over electric services are increasingly interacting and overlapping.

The Electric Grid in Transition

The United States has one of the world's most reliable, affordable, and increasingly clean electric systems—a system that powers its economy and provides for the well-being of its citizens. The U.S. electric system is at a strategic inflection point—a time of significant change for a system that has had relatively stable rules of the road for nearly a century.

The structure of today's U.S. electric grid grew organically over the course of the last century (see Figure 3-1). Historically, it was geographically based—with one-way flows of energy from central station generators, over transmission networks, through substations to distribution systems, and over radial distribution circuits to end-use customers.

Figure 3-1. The Electric Grid[1]



Six components comprise the grid: four physical components, including generation, transmission, distribution, and storage; the information infrastructure to monitor and coordinate the production and delivery of power and operate the grid; and customer demand—the driver of power system operation and investment. New storage technologies could be deployed throughout the power system in the future.

The U.S. electricity sector is influenced by a variety of new forces, some of which will affect the future growth and management of the grid. Current drivers of change within the electricity sector include the growing use of natural gas to power electricity generation; low load growth; increasing deployment of renewable energy and the retirement of coal and nuclear generation; severe weather and climate change; and growing jurisdictional interactions at Federal, state, and local levels. Innovative technologies and services are being introduced to the system at an unprecedented rate, often increasing efficiency, reliability, and the roles of customers, but also injecting uncertainty into grid operations, traditional regulatory structures, and utility business models.

The changing nature of grid operations, the implications of demand response and distributed generation deployment at increasing scale, the introduction of other new technologies, and growing consumer interaction with the grid are putting pressure on the regulatory boundaries that have evolved over the past century. Resolving the institutional, regulatory, and business model issues that could enable the grid of the future will help the United States take full advantage of the range of available energy sources and technologies that will help meet its climate change goals. These sources and technologies include energy efficiency; energy storage; carbon capture, utilization, and storage; electric vehicles; microgrids and other distributed technologies; and nuclear, natural gas, and renewable energy generation. A positive resolution of these issues will also help mitigate the growing vulnerabilities of the grid to cyber, physical, and climate change threats, as well as ensure the grid's reliability under its current institutional structures.

The Electric Grid: Complex, Highly Engineered, Essential for Modern Life

At the core of the electricity system is the grid—a complex, highly engineered network that coordinates the production and delivery of power to customers. There are six elements that make up the grid (see Figure 3-1)—four physical components of the electric system (generation, transmission, distribution, and storage); the information infrastructure to monitor and coordinate the production and delivery of power and operate the grid; and demand—the driver of power system operation and investment. Transmission, storage, and distribution (TS&D) provide the backbone of the grid, with storage increasingly deployed throughout the power system.

Today, the U.S. transmission and distribution system is a vast physical complex of interlocked machines and wires, with a correspondingly complex set of institutions overseeing and guiding it through policies, statutes, and regulations. The U.S. grid delivers approximately 3,857 terawatt-hours[2] of electrical energy from electric power generators to 159 million residential, commercial, and industrial customers.[a] This is accomplished via 19,000 individual generators at about 7,000 operational power plants in the United States with a nameplate generation capacity of at least 1 megawatt (MW).[3] These generators send electricity over 642,000 miles of high-voltage transmission lines and 6.3 million miles of distribution lines.[4] Together with its electric generation component, the grid is sometimes referred to as the world's largest machine; in 2000, the National Academy of Engineering named electrification as the greatest engineering achievement of the 20th century.[5]

Transmission is the high-voltage transfer of electric power from generating plants to electrical substations located near demand or load centers. As shown in Figure 3-1, step-down substations are the boundary between the transmission system and the distribution system that serve retail customers. High-voltage transmission lines can more easily accommodate two-way flows of electricity than the distribution network. High-voltage transmission lines have a range of voltage classes—mostly alternating current with some direct current. Transmission lines are primarily owned by investor-owned utilities and public power and cooperative-owned utilities within each interconnection. New forms of ownership of transmission assets, including independent transmission companies and "pure-play" merchant transmission firms, are beginning to emerge. For the new transmission-focused utilities, the core business and potential source of profits is based on acquiring, developing, building, and operating transmission.

Distribution is the delivery of power from the transmission system to the end users of electricity. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage. This medium-voltage power is carried on primary distribution lines, and after distribution transformers lower the voltage, secondary distribution lines carry the power to customers. Larger industrial customers may be connected directly at the primary distribution level. The poles supporting distribution lines, meters measuring usage, and related support systems are also considered to be part of the distribution system.

A Vision for the Grid of the Future

Today's grid—where power typically flows from central station power plants in one direction to consumers—is fundamentally different from the grid of the future, where two-way power flow will be common on both long-distance, high-voltage transmission lines and the local distribution network.

The grid of the future will be an essential element in achieving the broad goals of promoting affordable, reliable, clean electricity and doing so in a manner that minimizes further human contributions to climate change. To do this, the grid of the future will have to accommodate and rely on an increasingly wide mix of

[a] Here, a "customer" is defined as an entity that is consuming electricity at one electric meter. Thus, a customer may be a large factory, a commercial establishment, or a residence. A rough rule of thumb is that each residential electric meter serves 2.5 people.

resources, including central station and distributed generation[b] (some of it variable in nature), energy storage, and responsive load. It should support a highly distributed architecture that integrates the bulk electric and distribution systems. It should enable the operation of microgrids that range from individual buildings to multi-firm industrial parks and operate in both integrated and autonomous modes.

New technologies for the grid, including storage, will alter the traditional real-time requirements for grid operations and the nature of production, transmission, and distribution of power—opening up new avenues for flexible and cost-effective operation of the grid.

The grid of the future should be supported by a secure communication network—its information backbone—that will enable communication among all components of the grid, from generation to the customer level, and protect the system from cyber intrusions. This communication network will support the ability to monitor and control time-sensitive grid operations, including frequency and voltage; dispatch generation; analyze and diagnose threats to grid operations; fortify resilience by providing feedback that enables self-healing of disturbances on the grid; and evaluate data from sensors (such as phasor measurement units[c]) that enable the grid to maximize its overall capacity in a dynamic manner.

In short, the grid of the future should seamlessly integrate generation, storage, and flexible end use. It should promote greater reliability, resilience, safety, security, affordability, and enable renewable energy, while achieving better economic and environmental performance, including reductions in greenhouse gas (GHG) emissions. It will require business models and regulatory approaches that sustain grid investment and continued modernization while at the same time allow for innovation in both technologies and market structures.

The Department of Energy's (DOE's) Quadrennial Technology Review summarizes the technology challenges and research, development, and demonstration requirements for transforming the grid and achieving this vision. The Quadrennial Energy Review (QER) therefore focuses on the institutional, regulatory, and business model barriers to achieving the grid of the future.

Emerging Architecture of the Grid

The architecture of the grid is a new, emerging concept that defines the grid as not just a physical structure, but one that encompasses a range of actors and needs.[6] This new, broader concept of a grid architecture considers information systems, industry, regulators, and market structures; electric system structure and grid control frameworks; communications networks; data management structure; and many elements that exist outside the utility but interact with the grid, such as buildings, distributed energy resources, and microgrids. The grid's architecture is shaped by public policy, business models, historical and even cultural norms of practice, technology, and other factors. Analyses conducted for the QER (see box on page 3-6) focused on the complex interactions of these players and qualities, with the goal of suggesting recommendations to help drive toward a vision of actively shaping the grid of the future, as opposed to passively allowing the grid to evolve in a bottom-up manner and waiting to see the form that emerges. Analyses carried out for the QER also considered the drivers of change and how those drivers affect both today's grid and the future grid.

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b There are a variety of options for distributed generation, including photovoltaics, wind, low-head hydropower, combined heat and power, and fuel cells.

c Phasor measurement units operate by the simultaneous measurement and comparison of an important electrical property of large-scale alternating current transmission networks known as "phasor angles," thus the name "phasor measurement units." This will provide valuable real-time early warning of potential grid problems, including over very large geographic regions, when the technology is fully deployed and related tools to use the information are implemented.

Electricity Transmission Scenario Analysis

Quadrennial Energy Review scenario analysis used the Regional Energy Deployment System model to determine the impact of varying 10 input assumptions, individually and in combination, on U.S. transmission needs (see Chapter I, Introduction, Table 1-2 for the complete list of cases). The majority of cases characterized clean energy futures, in which renewable energy costs (such as solar and wind) dropped dramatically, or a greenhouse gas cap drove low- and carbon-free electricity generation deployment. An accelerated nuclear retirement case looked at the effect of the rapid loss of baseload capacity and is discussed in depth in the Electricity Appendix. The Quadrennial Energy Review focused on these cases as most likely to "stress" the transmission system, as they would produce significant changes in the electricity sector, and thus large potential changes in transmission needs.

Under the Annual Energy Outlook 2014 Reference case, installed megawatt-miles of transmission infrastructure grew by 0.3–1.5 percent per year and 6 percent total through 2030. While there was a range of new installed transmission across the scenarios, none of the scenarios appeared to require additional buildout beyond that already anticipated in the 2030 timeframe, nor did rates in any scenario exceed recent historical transmission investment levels.

Drivers of Change for the Grid of the Future: Transmission and Distribution

While the architecture of the grid of the future extends well beyond the physical structure of the system, a discussion of the drivers of change for the grid of the future should start with a consideration of the changes that will likely affect both transmission and distribution systems. Both systems may continue to grow in physical size to meet new needs, including demands for lower carbon electricity, but investments to facilitate flexible operations and resilience can enable smart growth, so both transmission and distribution systems can serve customer needs more effectively and economically.

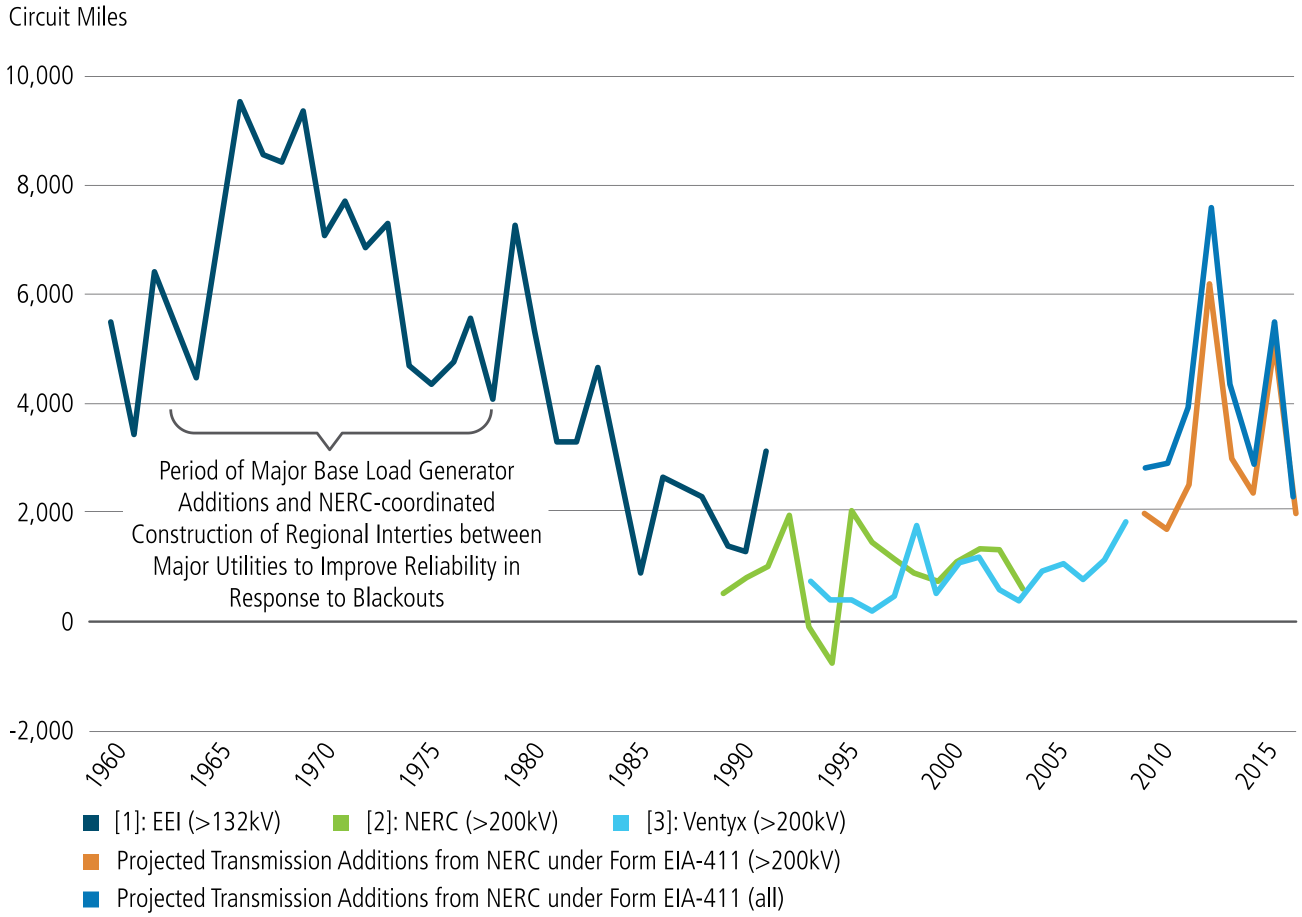
Investments in Transmission Are Expected to Grow

Transmission development and planning activity has been on the rise since the early 2000s, reversing a decades-long decline following the historic build-out of the transmission system in the mid-20th century. As an asset class, transmission attracts significant investment from utilities, financial investors, and project developers. Investor-owned utilities spent a record high of $16.9 billion on transmission in 2013,[7] up from $5.8 billion in 2001.[8] The number of circuit miles added to the Nation's transmission networks has also been on the rise in recent years (see Figure 3-2), but new line construction accounts for just slightly more than half of total investments.[9] Non-line investments—including station equipment, fixtures, towers and undergrounding lines—were increasing even during the lowest period of circuit miles construction from 1997 to 2012 (see Figure 3-3).

Drivers of recent investment increases include new technologies for improved system reliability; development of new infrastructure to ease congestion; interconnection of new sources of generation, including renewable resources; and support for production of natural gas. These investments have very distinct regional characteristics based on the different resources and constraints of each region.[10, 11] The largest increase in transmission spending over the last 15 years occurred in the Western Electricity Coordinating Council, with much of the transmission expansion happening in southern California to relieve constraints and connect to renewable resources.[12]

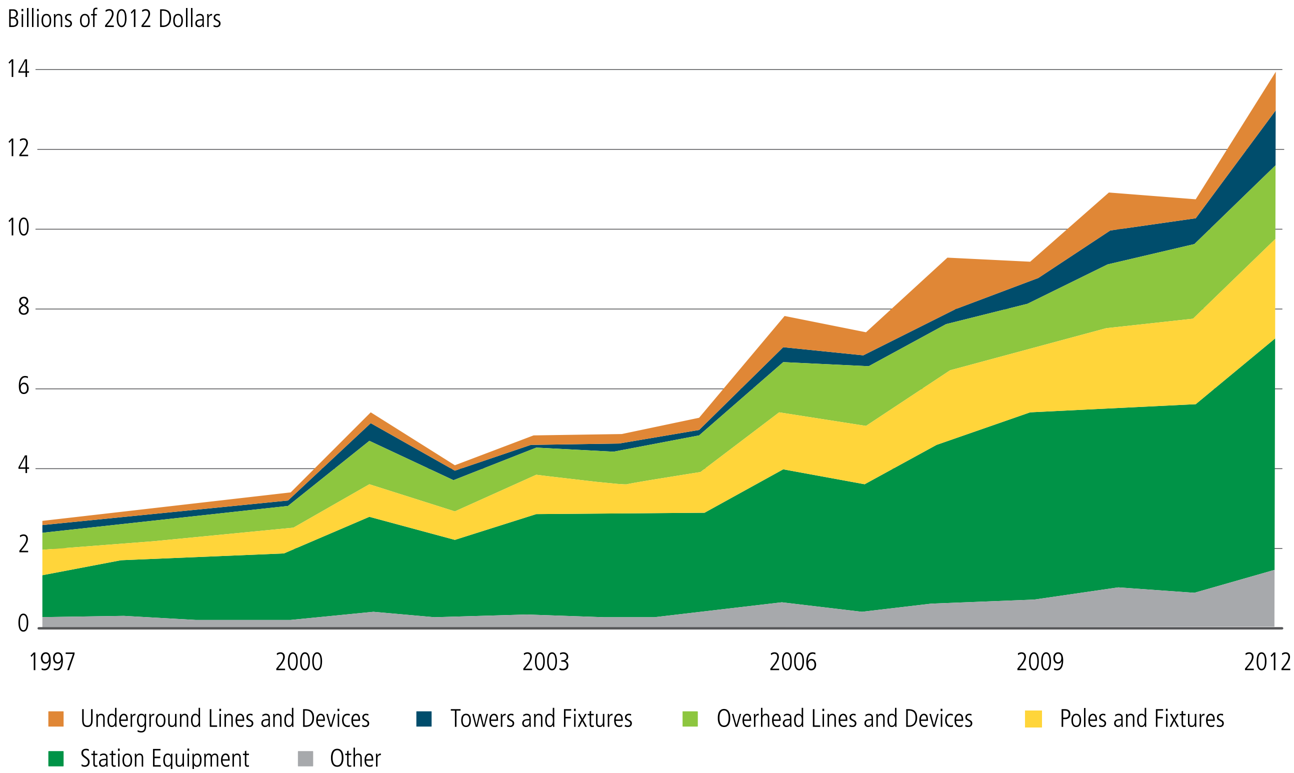
Looking forward over the next several years, a high level of transmission investment is expected to replace aging infrastructure; maintain system reliability; facilitate competitive wholesale power markets; and aid regions in meeting their public policy objectives, such as GHG reduction and renewable energy goals.[13] How much new transmission capacity is built in the future depends on a number of factors, including the amount of transmission necessary to connect high-quality wind, solar, and other energy resources to load centers; uncertainty about state and Federal incentives like the Production Tax Credit; flat or declining electricity demand; and the costs of alternative generation and demand-side resources. For renewables, an additional uncertainty is whether time of permitting or the costs of additional transmission facilities may lead to the development of wind or solar resources that are of lower quality but closer to load (Appendix C, Electricity, includes a more in-depth discussion of transmission). Nevertheless, there are a number of long-distance interregional transmission lines now in various stages of market development.[14, 15]

Figure 3-2. Historic and Projected Expansion of Net Transmission Circuit Miles[16]



Addition of new circuit miles to the Nation's transmission system has increased in recent years after over a decade of lower build-out. This increase has been driven by investments to replace aging infrastructure; maintain system reliability; facilitate competitive wholesale power markets; and support public policy objectives, such as GHG reduction and renewable energy goals. Circuit miles constructed in a year vary more than total transmission infrastructure spending, which has had an upward trend since the late 1990s. Note that historical values are year to year reported net changes in total circuit miles.

Figure 3-3. Investment in Transmission Infrastructure by Investor-Owned Utilities, 1997–2012[17]



Spending on the various components of transmission infrastructure has steadily increased since the late 1990s, driven by factors ranging from the need to replace aging materials, to the development of new technology for increased reliability, to requirements to connect new generation.

Both Long-Distance Transmission and Distributed Energy Resources Can Enable Lower-Carbon Electricity

Both bulk and distributed technologies have the potential to supply low-carbon electricity, enhance system reliability, and operate at a reasonable cost for all consumers. High-quality renewable energy sources suitable for utility-scale generation facilities are often located in remote areas. New long-distance transmission lines may be necessary in the future to connect these resources to demand centers. Conversely, other factors, such as extensive deployment of distributed energy resources, could potentially reduce the need for additional long-distance transmission build-out in the future.

The analyses conducted for the QER examined transmission capacity needs in 2030 under a variety of scenarios (this analysis did not consider distribution line needs). One scenario considered in QER analyses modeled transmission capacity necessary to accommodate high deployment of low-cost distributed energy resources using low-cost solar photovoltaic (PV) as a proxy for all types of distributed generation. The results of scenario modeling show that changes in transmission requirements through 2030 for a high-distributed PV case vary by region. In most regions, 2030 transmission needs are similar to those for a scenario based on the Annual Energy Outlook 2014 Reference case—high deployment of very low-cost distributed energy resources does not eliminate the need for additional transmission capacity. In fact, transmission requirements in the Upper Midwest and Great Lakes regions increase slightly under the distributed PV scenario in order to optimize remaining baseload resources.

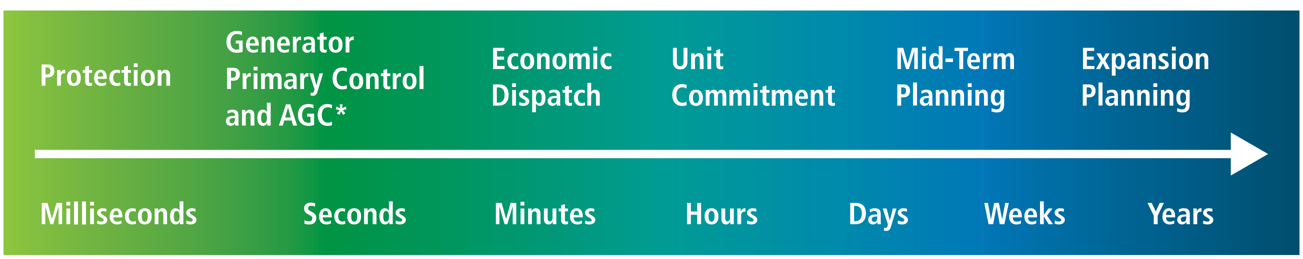
In the Southwest, transmission build-out requirements do, however, drop somewhat with expanded distributed PV because less utility-scale PV would be built in that region. This same effect is seen to a smaller extent in other Western regions. A review of three DOE-funded interconnection-wide studies, performed with American Recovery and Reinvestment Act of 2009 grants from 2012 to 2014, showed that scenarios combining high levels of end-use efficiency, demand response, and distributed generation can reduce the expected costs of new transmission investment. One 20-year scenario modeled in the Western Interconnection resulted in a reduction of $10 billion in transmission capital costs (or 36 percent below the base case).[18]

There are multiple technology innovations that could provide new long-distance transmission options. A serious physical challenge of high-voltage transmission lines is that the physics and safety factors require certain distances between the conducting wires and the ground and persons. Opponents of new transmission lines have called the resulting towers unsightly, intrusive, or "visual pollution." Ways to reduce additional issues with siting include the use of existing transmission line corridors, as well as technology fixes, such as higher-capacity-conducting materials, high-voltage underground lines, and even superconducting cables (also underground). Encouraging progress has been made on higher-capacity conductors that can be restrung on existing towers and on underground high-voltage direct current cables. These technologies should be considered and used when appropriate.

Flexible Grid System Operations and Demand Response Enable Variable Renewables and Reduce Need for New Infrastructure

All power systems have been designed with some level of flexibility to accommodate variable and uncertain load and contingencies related to network and conventional power plant outages. Flexibility is the ability of a resource—whether it is a component or a collection of components of the power system—to respond to the scheduled or unscheduled changes of power system conditions at various operational timescales (see Figure 3-4 for the timescale of different grid operations and planning functions).[19]

Figure 3-4. Transmission Operation and Planning Functions Shown by Timescale[20]



*Automatic Generation Control

Reliable and affordable electricity from the grid requires a continuum of operating, planning, and investment decisions over a wide-time horizon.

Grid operators must respond to trends affecting load patterns across a range of timescales, such as decreased demand growth, the changing demand patterns across the day, increased variable renewables, power plant retirements, and more extreme weather events. Many recent analyses lay out options for flexible electric systems.[21] Increased electric system flexibility can come from a portfolio of supply- and demand-side options, including grid storage, more responsive loads, changes in power system operations, larger balancing areas, flexible conventional generation, and new transmission.[22, 23]

Power Marketing Administrations: Valuable Federal Transmission Assets

Designed to provide customers access to electricity generated by Federal hydroelectric dams, the four Federal Power Marketing Administrations, along with the Tennessee Valley Authority, have a significant footprint within the North American grid. Today, in varying degrees, the operation, maintenance, and improvements to these Federal transmission assets are funded by revenues from and investments by preference customers. Honoring this unique customer-provider relationship, Congress has established two programs that build on the expertise of the Power Marketing Administrations. One is the Section 1222 program established by the Energy Policy Act of 2005 that authorizes the Department of Energy, through the Southwestern and/or Western Area Power Administrations, to partner with third parties to build transmission projects. There is one applicant proposing a line from wind resources in Oklahoma to Tennessee.[d] The other program is the Transmission Infrastructure Program established by the American Recovery and Reinvestment Act of 2009. The program allows the Western Area Power Administration to provide loans to and partner on transmission projects within its service area that support the development of renewable resources. The first Transmission Infrastructure Program project, the Montana to Alberta Tie Line, created 300 megawatts (MW) of transmission capacity specifically for renewable energy.[e] The project immediately enabled 189 MW to be deployed from the Rim Rock wind farm in Montana to markets.[f] The second project to be completed is Electrical District 5 – Palo Verde Hub. In this solar-rich area, the Electrical District 5 – Palo Verde Hub adds up to 410 MW of bi-directional capacity to the electric grid, including 254 MW of capacity connecting to the vital Palo Verde market hub that serves markets in Arizona, southern California, and Nevada.[g]

[d] Department of Energy. "Proposed Project: Plains and Eastern Clean Line." http://energy.gov/oe/services/electricity-policy-coordination-and-implementation/transmission-planning/section-1222-0. Accessed February 1, 2015.

[e] Enbridge. "Montanar-Alberta Tie-Line." http://www.enbridge.com/DeliveringEnergy/Power-Transmission/Montana-Alberta-Tie-Line.aspx. Accessed February 1, 2015.

[f] NaturEner. "Rim Rock Wind Farm." http://www.naturener.us/rimrock. Accessed February 1, 2015.

[g] Western Area Power Administration. "Electrical District No. 5 - Palo Verde Hub Project." http://ww2.wapa.gov/sites/western/transmission/tip/project/pages/ed5pvh.aspx. Accessed February 1, 2015.

Demand Response

Demand response improves flexibility by enabling consumers to participate in load control; it could also reduce the need for new infrastructure. Demand response mechanisms can include automated load control, smart grid and smart metering, real-time pricing, and time-of-use tariffs. Demand response can be a cost-effective grid resource; though, it requires strict regulations for response time, minimum magnitude, reliability, and verifiability of demand-side resources. Experience in the Texas wholesale electricity system and, more recently, in California shows that market designs that include demand response participation can markedly improve system flexibility. For example, industrial customers supply a significant portion of the Electric Reliability Council of Texas's responsive (spinning) reserves and have demonstrated the ability to effectively respond within minutes to a dramatic change in wind output.[24]

Energy Storage

Energy storage technologies, including pumped hydro storage, thermal storage, hydrogen storage, and batteries provide valuable system flexibility. Storage is unique because it can take energy or power from the grid, add energy or power to the grid, and supply a wide range of grid services on short (sub-second) and long (hours) timescales. It can supply a variety of services simultaneously. For example, concentrating solar power paired with highly efficient thermal storage becomes a dispatchable resource (meaning grid operators can control the power output) available throughout the day. Many storage technologies (e.g., batteries, flywheels, and supercapacitors) have fast response rates (seconds to minutes) available over a short time frame; other storage technologies, such as compressed air energy storage, are better suited to offer flexibility in the time frame of hours to days. Pumped hydro storage is usable on a timescale from seconds to days.

Pumped hydro storage currently represents the largest share of storage in the United States, with 42 pumped hydro storage plants totaling about 22 gigawatts of installed capacity, which is equivalent to about 2 percent of U.S. electricity generation capacity.[25] There are currently an additional 37 gigawatts of projects that are in some stage of licensing at the Federal Energy Regulatory Commission (FERC).[26] The original pumped hydro storage plants were built to store power to release at peak demand. New technology (such as variable speed pumps) enable pumped hydro storage to provide ancillary services (i.e., functions that maintain the reliability of the grid); integrate variable renewables; and provide other services, such as restarting down generators during an outage. Under current market structures, options such as dispatchable natural gas are cheaper and faster to permit than pumped hydro storage. FERC has a pilot project underway to test a shorter 2-year licensing process for pumped hydro storage.

Federal and State Activities to Promote Storage

Department of Energy (DOE) support for valuation, early deployment, and education has contributed to storage adoption. For example, Federal Energy Regulatory Commission Order 755 cited a DOE lab study showing that "energy storage resources (such as flywheels and batteries) could be as much as 17 times more effective than conventional ramp-limited regulation resources" for providing frequency regulation.[h] The order requires payment for frequency regulation resources based on a resource's speed and accuracy,[i] resulting in significant growth of storage installations in markets such as PJM.[j] The recent DOE Energy Storage Safety Strategic Plan addresses institutional barriers to enhance the safety and reliability of storage.[k]

States have built on these advances to bring storage benefits to closer to the mainstream. California, home to multiple DOE-funded storage demonstrations,[l, m, n] has been aggressive with policies to promote storage, first with a program to incentivize behind-the-meter storage, and then with its storage mandate, which will require the state's three utilities to deploy 1,325 megawatts of storage by 2020.[o] In Hawaii, recent wind installations in Maui and Oahu have been paired with energy storage,[p] and Hawaiian Electric Company opened a solicitation for up to 200 MW of storage "to meet its goal of adding more renewable generation to the O'ahu grid."[q] Other states, including Arizona[r] and New York,[s] have approved or are actively encouraging their utilities to consider storage.

[h] Makarov, Y.V. et al. "Assessing the Value of Regulation Resources Based on Their Time Response Characteristics." Pacific Northwest National Laboratory. June 2008. In: 137 FERC 61,064. p. 35. 2011.

[i] Federal Energy Regulatory Commission. "Frequency Regulation Compensation in the Organized Wholesale Power Markets." 137 FERC 61,064. 2011.

[j] PJM Independent Market Monitor. "2013 State of the Market Report for PJM." p. 305. 2013.

[k] Department of Energy. "Energy Storage Safety Strategic Plan." December 2014. http://energy.gov/sites/prod/files/2014/12/f19/OE%20Safety%20Strategic%20Plan%20December%202014.pdf.

[l] Department of Energy. "Fact Sheet: Borrego Springs MicroGrid." September 2013. http://www.sgiclearinghouse.org/sites/default/files/projdocs/1650.pdf.

[m] Department of Energy. "Fact Sheet: Wind Firming EnergyFarm." August 2013. http://energy.gov/sites/prod/files/Primus.pdf.

[n] Department of Energy. "Fact Sheet: Tehachapi Wind Energy Storage Project." May 2014. http://energy.gov/sites/prod/files/Tehachapi.pdf.

[o] Maui Electric Company. "Contract with Auwahi Wind Energy LLC." 2011.

[p] Hawaiian Electric Company. "Request for Proposal (RFP# 072114-01) for 60 to 200 MW of Energy Storage for Oahu." April 30, 2014. http://www.hawiianelectric.com/portal/site/heco/menuitem.508576f78baa14340b4c0610c510blca/?vgnextoid=03ebf219fe9a5410VgnVCM10000005041aacRCD&vgnextchannel=a595ec523c4ae010VgnVCM1000005c011bacRCRD&appInstanceName=default.

[q] California Public Utilities Commission. "Order Instituting Rulemaking Pursuant to Assembly Bill 2514 to Consider the Adoption of Procurement Targets for Viable and Cost-Effective Energy Storage Systems." Decision 13-10-040. October 17, 2013.

[r] Arizona Public Service Company and Residential Utility Consumer Office. "APS AND RUCO JOINT REQUEST FOR REVIEW." DOCKET NO. L-00000D-14-0292-00169, Case No. 169. 9 26, 2014.

[s] Consolidated Edison Company of New York. "Petition for Approval of Brooklyn Queens Demand Management Program." 14-E-0302. 2014.

Traditionally, power generation must meet consumer demand in real time. Storage provides a buffer between generation and volatility of customer demand. FERC Order 755, adopted in 2011, recognizes the ability of storage to contribute to frequency regulation on the grid faster than centralized generators. The box on page 3-11 provides more examples of Federal support for storage development and deployment.

The impact of storage can be location-dependent, so grid operators and regulators need new planning tools and procedures to make use of storage as a standard grid component and to optimize storage location and size. Changes in the way the United States values ancillary services can also help make the services provided by storage a competitive option. In the future, distributed storage (e.g., grid-connected electric vehicles) could be a transformative technology.

Changes to Power System Operations

Changes to power system operations and markets can provide significant existing flexibility, often at lower economic costs than building new transmission infrastructure. Operations examples include more frequent dispatch (which reduces the time frame over which a generator must follow a specified output level), smart network technologies, and increased plant cycling.

Smart network technologies and advanced network management practices minimize bottlenecks and optimize transmission usage. They provide unprecedented, real-time visibility across the energy system. Transmission and distribution planners and operators can use this information to employ the most reliable and cost-effective flexibility options. They can consider building new generation and transmission alongside other options like demand response or bigger balancing areas.

Forecasting and planning are low-cost ways of accessing system flexibility. System operators increasingly require variable renewable energy generators to forecast power output to improve the ability of system operators to commit, dispatch resources, deploy reserves, and improve situational awareness.[27] Integrating these data, along with wind and solar plant outage data, into market operations helps variable renewable energy plants participate in electricity markets.

Market Signals

Market signals can enable flexibility. Establishing short-term market products for flexible capacity (e.g., the California Independent System Operator (ISO) and Midcontinent ISO's proposed fast-ramping products) can also incentivize resources to respond to imbalances over the minutes-to-hours time frame. In market structures that more comprehensively value services provided to the grid, demand-side resources and storage could provide low-cost grid services, allowing more efficient grid operations and avoiding generation or transmission investments.[28] Cost savings to the power system attributable to demand response and energy storage can be much larger than the revenue they can receive in current market structures.[29]

Investments in Reliability and Resilience Can Have Multiple Benefits

North American Electric Reliability Corporation standards (subject to FERC review, approval, and independent enforcement authority) require the bulk electric system to withstand certain disruptive events, including most single contingencies and some multiple contingencies, with no interruption to transmission service or major customer outages. Some outages, or "non-consequential load losses," are tolerated in the case of extreme events, where multiple facilities are taken out of service simultaneously. The North American Electric Reliability Corporation requires bulk power system owners and operators to have plans in place to contain extreme events to prevent cascading outages to other regions.[30]

Resilience investments can require a substantial change in physical infrastructure, including building physical barriers or moving equipment, building backup systems, building non-wooden or reinforced poles, and burying lines underground.[31] Resilience investment also includes additional operations and maintenance activities, which primarily means more thorough tree trimming.[32]

Many energy sector investments to mitigate climate change can have co-benefits that make the grid more resilient to climate change impacts and extreme weather. Investments in energy efficiency, smart grid technologies, storage, and distributed generation can also contribute to enhanced resilience from environmental threats.[33] For example, DOE-funded demonstrations of distribution automation systems enabled a utility to restore power 17 hours faster following an outage, while other utilities have experienced marked improvements in outage interruption frequency and duration indices.[34] In addition to providing added redundancy, transmission can also provide the operational flexibility to adapt to long-term changes, such as an increase in the peak-to-average energy demand and water constraints on energy production.[35]

Drivers of Change for the Grid of the Future: New Technologies and Services

A second dimension of the emerging architecture for the grid of the future has to do with new or emerging technological innovations in grid operations. Many of the characteristics that customers desire in the grid of the future—affordability, reliability, sustainability, and an improved customer experience—will be facilitated by new technologies. The challenges to speeding the adoption of these technologies include developing network designs and open standards so they can communicate and operate seamlessly with other elements of the grid, as well as determining the value of the benefits that they bring to customers.

Innovative Technologies Have Significant Value for the System

An array of new technologies and data applications are enabling new electricity-related services, customer control choices, and investments that hold the promise of greatly improving electric consumer experience, as well as promoting a new ecosystem of innovation and revenues beyond the sale of electric kilowatt-hours.

Distributed generation systems provide consumers a number of benefits. According to a 2007 DOE study,[36] these benefits include increased electric system reliability; reduction of peak power requirements; provision of ancillary services, including reactive power; improvements in power quality; reductions in land-use effects and rights-of-way acquisition costs; and reduction in vulnerability to terrorism and improvements in infrastructure resilience.

A revolution in information and communication technology is changing the nature of the power system. The smart grid is designed to monitor, protect, and automatically optimize the operation of its interconnected elements, including central and distributed generation; transmission and distribution systems; commercial and industrial users; buildings; energy storage; electric vehicles; and thermostats, appliances, and consumer devices.[37] Smart grid technologies include a host of new and redesigned technologies, such as phasor measurement units or advanced metering infrastructure, that provide benefits such as increased reliability, flexibility, and resiliency.[38, 39, 40]

Within the delivery portion of the electric grid, smart grid technology is enabling sizable improvements in distribution and transmission automation. Many of these new technologies are "behind-the-meter," involving end-use management or generation on the consumers' premises; these end-use technologies are not directly germane to this installment of the QER. Nevertheless, as parts of an integrated electricity system, with growing effects on TS&D, behind-the-meter technologies do affect and interact with the systems that are the focus of this QER. For example, engineers will need to design and install components of the grid, such as safety interlocks, since two-way power flow, introduced by distributed generation, may pose a danger to line workers.

Emerging technologies on the distribution grid (whether digital communications, sensors, control systems, digital "smart" meters, distributed energy resources, greater customer engagement, etc.) present both technical and policy challenges and opportunities for the delivery of energy services. Power grids evolved organically in a bottom-up manner, as opposed to a centrally coordinated master plan. This build-up has led to large-scale legacy investments that require significant operating margins to maintain system stability, as opposed to more refined margins enabled by the rapid and precise control offered by new and emerging technologies.

These changes have injected uncertainties into a utility business model that typically has relied on continued load growth, steady economic returns, and long payback horizons.[41] While regulators, utilities, and the Federal Government are all engaged in addressing these uncertainties, developing appropriate rate structures for the benefits these technologies provide to the customer and the grid can be difficult, resulting in either over-investment or under-investment and higher costs to consumers.

Another key element in the development and use of information technologies on the grid relates to network coordination. The grid of the future would benefit from overall network architectures that allow for specific grid elements to be aligned in ways that allow them to contribute to solving problems that affect multiple grid components. Whole-grid coordination, in which these distributed elements are made to cooperate to solve a common problem (i.e., overall grid stability), is a key challenge and opportunity for new information and network technologies and approaches.

There are many other opportunities to infuse advanced technology into key operating elements of the grid. Some notable opportunities are shown in Table 3-1.

Table 3-1. Examples of Key Technologies for the Grid of the Future[42]

Grid Component/Opportunity	Description
AC/DC power flow controllers/converters	Technologies that adjust power flow at a more detailed and granular level than simple switching.
Advanced multi-mode optimizing controls	Controls capable of integrating multiple objectives and operating over longer time horizons, to replace simple manual and tuning controls, or controls that operate based only on conditions at single points in time.
Bilaterally fast storage	Energy storage in which charge and discharge rates are equally fast and thus more flexible.
Control frameworks	New hybrid centralized/distributed control elements and approaches.
Management of meta-data, including network models	New tools for obtaining, managing, and distributing grid meta-data, including electric network models.
Synchronized distribution sensing	Synchronization of measurements in order to provide more accurate snapshots of what is happening on the grid.
Transactive buildings	Buildings with controls and interfaces that connect and coordinate with grid operations in whole-grid coordination frameworks.
"X"-to-grid interface and integration	Interface technologies, tools, and standards for the general connection of energy devices to power grids; includes integrated mechanisms for coordinating those devices with grid operations in whole-grid coordination frameworks.
Distribution System Operation	Structure for clear responsibility for distributed reliability.

Innovation will introduce new grid components that are increasingly digitized, can provide new services for customers and grid operators, and continue to produce and reliably deliver affordable electricity to customers.

Communication with Customer Devices Will Improve Efficiency and Reliability of the Grid

The evolving role of the modern-day electricity customer is transforming into a more dynamic, transactive role in which customers are also becoming participants in electric system operations. Customers can create value to the electric system in two ways: as both suppliers of responsive demand and producers of distributed power. As suppliers of responsive demand, customers can provide capacity resources to the system that helps maintain reliability and affordable prices. As distributed producers of power, customers can provide power that could reduce total GHG emissions, increase resilience, and forestall infrastructure investments.

Three impediments to realizing customer value are related to communications. First, comprehensive communication and data standards need to be developed.[43] Competing, proprietary systems inhibit the adoption of technologies and control strategies and drive up the cost of deployment. Second, there is no uniform approach to characterizing the grid services that end-use devices can provide. Third, the communication and control interface devices between the customer as a distributed generator and the distribution system limit the types of service that the distributed generator can provide. In general, the lack of regulatory structures and standards are impeding the full utilization of information technology to enhance the efficiency and reliability of the grid.

Low-cost sensors and controls in buildings, distributed generation, electric vehicle charging, end-use storage, and other innovations make it increasingly important to integrate building devices and control systems with utility distribution systems to fully enable the development of new value propositions. Customer applications in residential and commercial buildings could potentially have economic benefits worth $59 billion (in 2009 dollars) by 2019, including packages of pricing, in-home displays, smart appliances, and information portals that would serve to reduce both energy demand and overall use.[44] Well-designed control systems also can increase building efficiency.[45]

Capturing these benefits requires building communication networks, allowing the components to interoperate and respond to a facility-wide control. One impediment to fully realizing the benefits of information technology is the balkanized structure of regulation. Early information technology adoption was accomplished by vertically integrated utilities that used computers as a tool to enhance their ability to perform existing functions. New information technology enables new behaviors, market mechanisms, and monitoring and operating procedures. While the reliability and efficiency of the system can be improved in the long run, these changes pose a threat to the status quo and have potentially significant unintended consequences and ambiguous benefits for utilities. As a consequence, there is a general caution associated with the wide-scale deployment of new information technology infrastructures and devices.

Speeding the adoption and accrual of potential benefits will require coordination of open standard development and clear business models that enable the benefits to be widely shared. An open standard for energy devices would be analogous to the voluntary industry USB standard developed in the mid-1990s, which allowed simple plug-and-play between smart phones, tablets, computers, chargers, printers, games, and many other peripheral devices. Its existence greatly expanded both the usability and types of all these personal electronic devices. Similar standards are emerging but not settled for the much newer set of information technology-enabled grid devices, leading to an ongoing lack of interoperability.

Implications of Electric Vehicle Penetration for the Grid

Battery-electric vehicles run on electricity and plug-in hybrid electric vehicles run on a combination of electricity and gasoline. In 2013, there were about 70,000 battery-electric vehicles and 104,000 plug-in hybrid electric vehicles—small numbers compared to the approximately 226 million registered vehicles in the United States. Total U.S. sales of plug-in electric vehicles (PEVs) have increased rapidly in recent years, but still represent only about 0.7 percent of new vehicle sales in 2014 (albeit up from 0.6 percent in 2013 and 0.4 percent in 2012). California is home to almost half of all of the Nation's PEVs, but only about 5 out of every 1,000 registered California vehicles are PEVs.[t]

There has also been a rapid recent increase in the numbers of charging stations. From 2011 to 2014, the numbers of public electric vehicle charging outlets grew from fewer than 4,000 to more than 25,000.[u] Various business models for developing new charging stations have emerged, as installation costs can be high.[v, w] For each infrastructure upgrade, utilities and regulators must assess costs (e.g., installation) and benefits (e.g., ancillary services).

According to the National Academy of Sciences in its 2013 report on electric vehicle deployment,[x] *"The existing electric infrastructure does not present a barrier to the expansion of PEV technology in the United States given the projected growth of PEV use in the next decade."* In addition, the report states that *"As PEVs account for a more significant share of total electricity consumption, the committee sees no barriers to provision of generation and distribution capacity to accommodate the growth through the normal processes of infrastructure expansion and upgrades in the electric utility industry."*

The National Academy of Sciences concludes that existing U.S. generation and transmission capacity could accommodate 5 million to 50 million PEVs. However, the report also suggests that if large numbers of PEVs were to be charged at the same time as residences also see peak loads, there could be potential for overloading elements of the local distribution system and thus a need for local upgrades. Furthermore, the National Academy of Sciences notes that concentrations of fast-charging stations, dense clustering of private PEV owner charging, or fleet-charging facilities could require grid upgrades. An assessment prepared for the Independent System Operator/Regional Transmission Organization Council noted that smart grid enhancements could allow electric vehicles to provide services to the grid, particularly related to demand response and load balancing.[y] Furthermore, smart grid developments could enable a shift in charging to off-peak periods and help avoid additional generation requirements.[z]

[t] Energy Information Administration. "California leads the nation in the adoption of electric vehicles." Today in Energy. December 10, 2014. http://www.eia.gov/todayinenergy/detail.cfm?id=19131.

[u] Department of Energy, Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center. "Alternative Fueling Stations by Fuel Type." http://www.afdc.energy.gov/data/10332. Accessed January 16, 2015.

[v] Rocky Mountain Institute. "Pulling Back the Veil on EV Charging Station Costs." RMI Outlet. April 29, 2014. http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs. Accessed January 16, 2015.

[w] Greene, D.L. "Alternative Transportation Refueling Infrastructure in the U.S. 2014: Status and Challenges." University of Tennessee Knoxville. March 31, 2015.

[x] National Research Council. "Overcoming Barriers to Electric-Vehicle Deployment: Interim Report." 2013. http://www.nap.edu/download.php?record_id=18320.

[y] KEMA and Taratec Corporation. "Assessment of Plug-in Electric Vehicle Integration with ISO/RTO Systems." Produced for the ISO/RTO Council. 2010. http://www.rmi.org/Content/Files/RTO%20Systems.pdf. Accessed January 27, 2015.

[z] Hadley, S.W. "Impact of Plug-in Hybrid Vehicles on the Electric Grid." Oak Ridge National Laboratory. 2006. http://web.ornl.gov/info/ornlreview/v40_2_07/2007_plug-in_paper.pdf.

In addition to interoperability, safe and improved connectivity is important to the deployment of new technologies to the grid. For example, there are voluntary industry standards for the interconnection of distributed generation of all types that connect customer-owned generation to the local distribution network. The majority of state public utility commissions use a voluntary standard issued in 2003 by the Institute of Electrical and Electronics Engineers (IEEE) known as the IEEE 1547 interconnection standards. These standards set technical guidelines for the interconnection of distributed resources less than 10 MW in size with the electric grid, including requirements relevant to the performance, operation, testing, safety considerations, and maintenance of the interconnection. These standards are now in revision, with a goal of completion by 2018. Modifications are taking into account impacts on grid reliability; new technologies that offer two-way communications and intelligent controls; and dispatchability of some types of distributed generation plus extension to demand response, storage, and microgrids.

Updated standards will both improve grid safety and better use distributed energy resources in maintaining overall system reliability. In particular, as large fossil-fueled generators with spinning turbines retire, the system is losing the inertia that has helped maintain grid frequency and thus grid reliability. Properly configured with appropriate communications, inverters used with distributed generation or storage can provide frequency regulation services to the grid to fill this gap. Conversely, improper connections or protocols could lead to simultaneous disconnection of all distributed energy resources under particular circumstances. While there is an existing process underway to update the IEEE 1547 interconnection standards, finding ways to accelerate the update of these standards will provide increased benefits to both customers and the reliability of the system.

Appropriate Valuation of New Services, Technologies, and Energy Efficiency

Ultimately, the electric system exists to serve load—or the demand for electric services—from the residential, commercial, industrial, and transportation sectors. There is a suite of services that the grid provides to meet real-time changes in load and supply, among other things. A better understanding of the full costs and benefits of those services would allow regulators, utilities, and customers to develop more fair and equitable pricing structures.

These services and a range of other important societal goals are enabled by new technologies. Distributed energy and smart grid technologies offer the potential to help meet America's changing energy needs, minimize the environmental impact of electricity generation, strengthen economic growth, and improve the reliability of the Nation's electrical infrastructure. As noted, the full spectrum of existing and emerging technologies includes new intelligent grid (smart grid) delivery technologies, energy efficiency, combined heat and power, fuel cells, gas turbines, rooftop PV, distributed wind, plug-in hybrid and all-electric vehicles, distributed storage, demand response, and transactive building controls.

At high penetrations, many of these new technologies could challenge current distribution systems and the functional integrity of the current electricity system. New investments and changes to existing regulatory, policy, financial, and business structures may be necessary to fully realize the benefits of these technologies. Regulators and policymakers will need to address the operational issues associated with new technologies, as well as longer-term concerns, such as how the loss of revenue (and a utility's ability to cover fixed costs) and load resulting from increasing numbers of some installations of distributed energy resources could challenge utilities' financial health under current business models.

A key element for addressing the operational and business model concerns posed by new technologies centers on valuation (i.e., "What are the benefits of new services and technologies to the grid?" and conversely, "What is the cost of the services the grid provides to customers?"). There is no agreement on the answers, though, as answers depend on the situation. This issue has been examined in numerous valuation studies in the public domain. These studies do not consider the same set of impacts from one study to the next. For example, not all studies explicitly consider impacts on transmission and distribution, such as capacity avoidance, grid support services, or external impacts like avoided GHGs. The monetized estimates that different studies assign to a given service or impact (capacity, energy, system losses) can range by a factor of as much as five or more.

There currently are no transparent, broadly accepted methods that can be used by stakeholders to determine the costs and benefits associated with integrating new services and technologies into the grid.[46] Clearer valuation methods would empower legislators and regulators in their efforts to address their local needs as they formulate strategies and plans to provide a portfolio of electricity options that meet their state-specific goals for reliable, affordable, and clean electricity. It is also important for policymakers to understand that, as they work to value services on both sides of the meter, there is the potential for stranded assets (i.e., assets for which investments have been made but cannot be recovered) on both sides; valuation policies must take these issues into consideration as well.

Net Metering

The challenges associated with integrating new technologies into the current electricity grid system are illustrated by the variety of opinions on net metering. Net metering is a system for paying for generation located on customer facilities—typically, although not exclusively, small residential solar generators. Currently, 45 states have Net Energy Metering programs that credit customers in some way for the energy they produce onsite.[47] The most common type of Net Energy Metering customer today owns or leases a rooftop PV system, but current regulations often apply to other distributed energy technologies, such as gas-fired turbines and combined heat and power. With rapid solar PV market penetration, controversies among utilities, consumer groups, solar businesses, and other stakeholders have arisen in several states over how to account for the full cost of grid services, placing pressure on legislators and regulators to understand conflicting positions and analyses supporting them.

Valuing Ancillary Services

Ancillary services are defined by the North American Electric Reliability Corporation as "those services that are necessary to support the transmission of capacity and energy from resources to loads while maintaining reliable operation of the transmission system in accordance with good utility practice."[48] Types of ancillary services include ramping, voltage support, and frequency support, all of which are furnished by a combination of generation and transmission facilities. Ultimately, the system operator is responsible for ensuring that there are adequate ancillary services at all times to maintain reliability. The ability to provide ancillary services, such as frequency support, is changing with the transformation of the electric generation system. As the electric system continues to evolve, system planners and grid operators will need to value and integrate the services that new technologies can provide to maintain system stability and reliability. New payments, or changes to existing payment methods (both to generation owners and to other potential ancillary service providers), may be necessary to ensure continued provision of needed ancillary services to maintain grid reliability.

Consistent Measurement and Evaluation of Energy Efficiency

The evaluation, measurement, and verification of energy efficiency savings are critical as efficiency becomes increasingly important as a mechanism to meet a variety of goals, including reducing the need to build additional generation and GHG reduction. Many entities have made progress toward standardizing the evaluation of energy efficiency. These methods can help regulators understand the opportunities energy efficiency creates for infrastructure avoidance.

Ratepayer-funded efficiency programs run by utilities and third parties, energy service companies' projects, codes and standards, and other efficiency programs have achieved significant energy savings over the last three decades.[49] These programs have developed in different ways across the country, along with some state variation in protocols and procedures for measuring and verifying savings. While inconsistencies can complicate efforts to compare measured savings across jurisdictions, a number of important standardization efforts have emerged in recent years at the state and regional levels that have started to address these issues. These include efforts led by the Northwest Regional Technical Forum and the Northeast Energy Efficiency Partnership that include development of regional databases of energy savings. Building on this momentum, DOE's voluntary Uniform Methods Project for Determining Energy Efficiency Program Savings has convened policy stakeholders and technical experts to develop a set of protocols for determining savings from energy efficiency measures and programs. Over the last 2 years, the Uniform Methods Project has issued more than 20 protocols for common residential, commercial, and crosscutting energy efficiency measures. The Energy Information Administration has also tracked energy efficiency program evaluations.

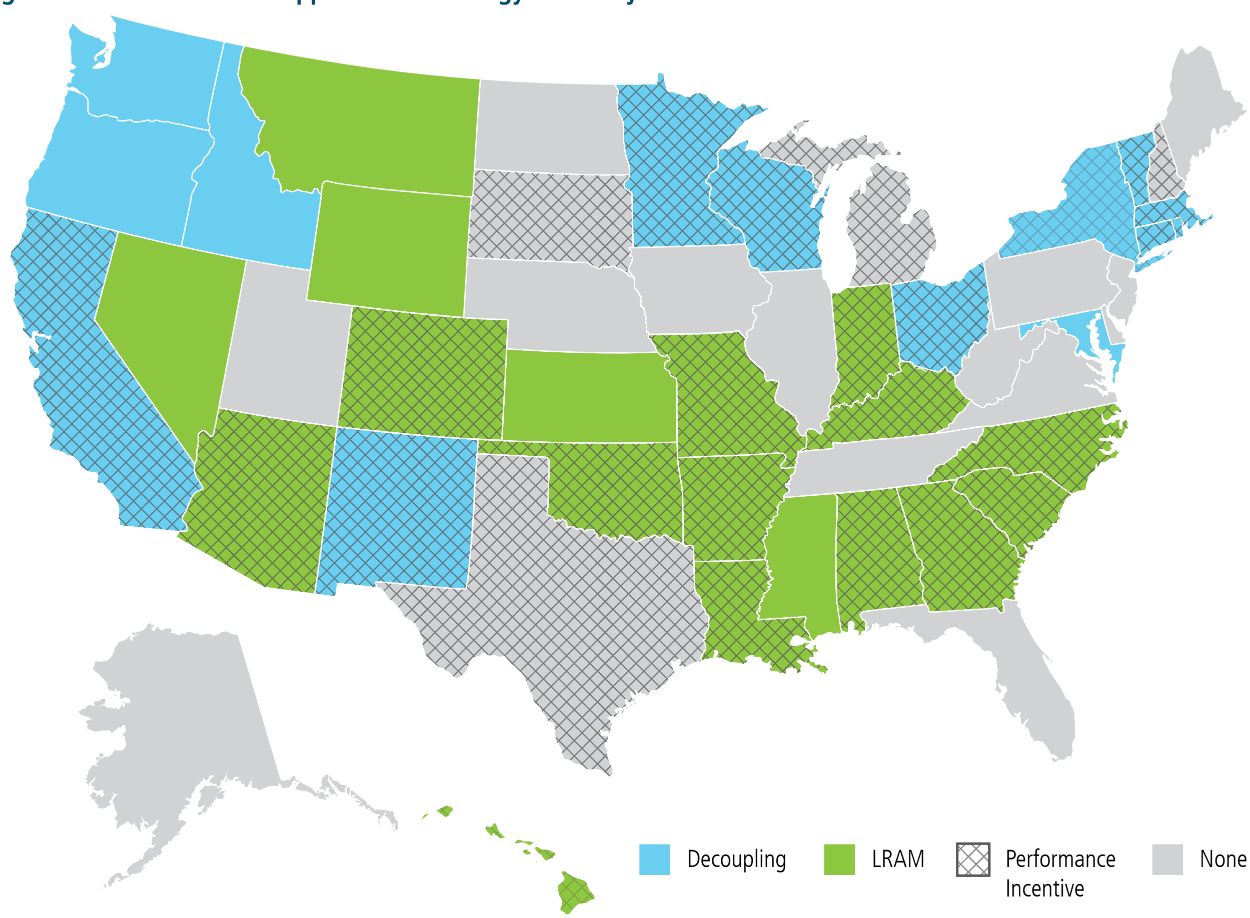
Drivers of Change for the Grid of the Future: Institutions and Utility Business Models

A third dimension of the architecture for the grid of the future encompasses all the actors involved in managing the grid, including in industry and regulatory bodies (at all levels of government). These businesses and institutions shape the operation, management, and regulation of the grid. Incorporation of the new technologies and services will require an evolution in these businesses and institutions.

States Are the Test Beds for the Evolution of the Grid of the Future

States have the primary role in regulating the retail provision of electricity (see Figure 3-5), as well as the siting of transmission and generation. Due to this primacy, states are at the forefront of managing the transition to the grid of the future. Historically, states have been the laboratories for developing policies that reflect their individual and regional situations, and in the electricity sector, state policies reflect differences in resource mix, priorities, geography, economies, and even culture.

Figure 3-5. Different State Approaches to Energy Efficiency[50]



Thirty-six states have adopted regulatory approaches to promote utility investment in energy efficiency: decoupling, lost-revenue adjust mechanisms ("LRAM"), or performance incentives.

As the complexity of the grid increases, states are working to develop policies that incorporate new services and technologies in a manner that maintains affordability and reliability. The unique circumstances of each state have resulted in a diverse set of responses across a range of issues confronting the electricity sector. For example, many states have adopted policies to support utility investments in energy efficiency. There are at least three different regulatory approaches being used: decoupling, lost revenue adjustment mechanism, and a broad set of methods to allow performance incentives (see Figure 3-5). These efforts create a regulatory model that rewards utility shareholders for effective energy efficiency efforts that lower ratepayer bills in the long term. Another example of state innovation is the cost-allocation scheme member states in the Midcontinent ISO and Southwest Power Pool negotiated among themselves for the funding of large region-wide transmission upgrades for each of their regions, which was then approved by FERC.[51, 52]

Different Industry Structures and Business Models Rule Out "One-Size-Fits-All" Solutions to Challenges

The grid is financed, planned, and operated by numerous entities that cross states, regions, and countries. It provides valuable services and includes a variety of industry types and a range of business models that often reflect regional differences in resource mix.

Policies designed to provide consumers with affordable and reliable electricity in the future must take into account the variety of business models for investing, owning, and operating grid infrastructure. The nature of the entities that comprise the grid has changed and will continue to do so. The earliest model of electric service delivery was the investor-owned, vertically integrated utility, namely the Edison Illuminating Company that used the New York City Pearl Street Station generator in 1882 to begin serving customers. Following, in the late 1880s and 1890s, was the establishment of public power utilities, which were also vertically integrated, in small towns to also serve local loads with generation. Now, as shown in Table 3-2, the basic functions of the vertically integrated utility are performed by a wide variety of entities with different ownership structures, pursuing different functions.

The variety of ownership and scope of the entities that comprise the grid leads to a complex set of motivations and decision drivers. The reliable operation of the grid is a testament to the integration of these different interests. There are five different predominant ownership types: (1) investor owned; (2) cooperatively owned, owned by their member customers; (3) publicly owned, such as by municipalities, states, public utility districts, and irrigation districts; (4) Federally owned; and (5) merchant companies that are competitive entities in generation, transmission, or retail supply.

Table 3-2. Taxonomy of Utility Business Models (examples, ownership, and scope)[53]

	State-Regulated IOUs	Cooperatively Owned	Publicly Owned	Federally Owned	Merchant
Vertically Integrated (T,D,G)*	Oklahoma Gas & Electric	None	Los Angeles Dept. of Water & Power	None	None
Transmission and Distribution	Pepco	Southern Maryland Electric COOP (SMECO)	Clallam County Public Utility District	None	None
Generation and Transmission	None	Basin Electric G&T	New York Power Authority	Tennessee Valley Authority	LS Power
Generation and Distribution	DTE Energy; Consumers Energy	Fox Island (ME) Electric	Lansing (MI) Board of Water & Light	None	NRG
Transmission	None	Upper Missouri Power Cooperative	Transmission Agency of Northern Calif.	Western Area Power Adminstration, Bonneville Power Administration, Southwestern Power Administration	ITC; Hudson Transmission; Transource Energy; Clean Lines Energy Partners
Distribution	Mt. Carmel Public Utility Co.	Kenergy	Nashville Electric Service	None	None
Generation	None	Oglethorpe Power Corporation	Wyoming Municipal Power Agency	Bureau of Reclamation	Calpine; BP Energy; Tenaska;

* (T,D,G= Transmission, Distribution, and Generation)

There is a diversity of ownership structures in the U.S. electricity sector. Such diversity often precludes one-size-fits-all policies.

Although all utilities may invest in demand response and energy efficiency, each ownership pattern engenders different interests in performance of service, investment, and market structure. For example, cooperatives have been innovative in their use of direct load control to modify peak load conditions,[54] while publicly owned utilities have been leaders in energy efficiency.[55] Because investor-owned utilities earn a return on capital expenses, and without special incentives, do not earn a return on cost-saving operational expenses, this class of utilities tends to lead in the development of new service through capital-intensive assets.

Investor-owned companies have fiduciary obligations to increase shareholder value. Regulated entities that earn profit based upon a return on invested capital lack a strong incentive (absent explicit requirements and incentives) to invest in energy efficiency practices. In contrast, public power and cooperative utilities are motivated to keep customers' bills down and, as such, can optimize the provision of service by using both capital-intensive options and less capital-intensive alternatives (e.g., energy efficiency).

Merchant generators whose profits are the residual revenues after expenses are paid (including return on capital) are motivated to maximize revenue. The Federal Power Marketing Administrations, such as the Western Area Power Administration and the Bonneville Power Administration, must follow the dictates of their statutory authorities. The balancing authorities, some of which are Regional Transmission Organizations or ISOs, in turn, are concerned about maintaining reliability while operating the bulk power system.

Fragmented and Overlapping Jurisdictions Threaten to Impede Development of the Grid of the Future

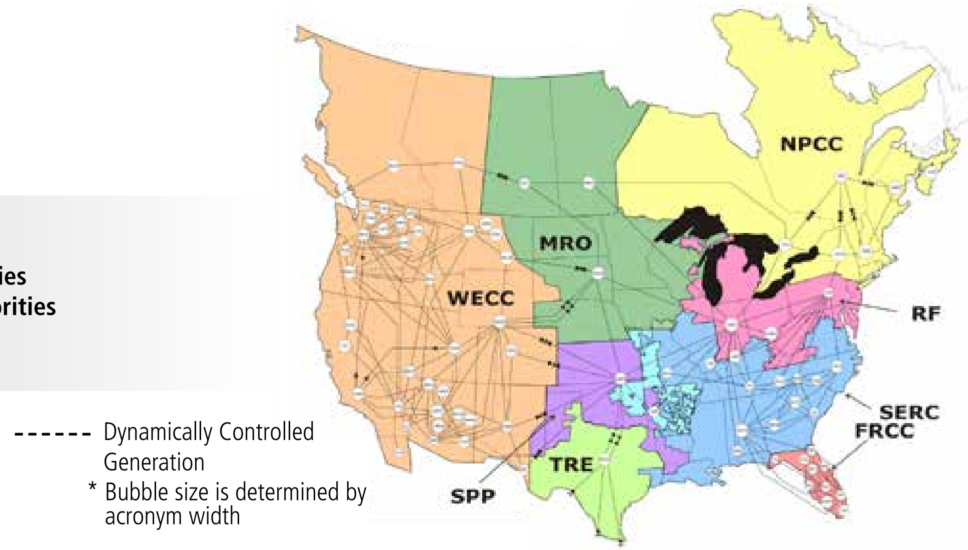
Federal, regional, and state institutions and regulatory structures that have evolved over decades to manage the electric grid are increasingly interacting and overlapping. The geographical boundaries of the institutions are not coincident with the flow of electrons on the physical system. The increasing physical complexity of the grid will only complicate governance and analysis. Policymaking to address regulatory and operational challenges of the evolving grid is more difficult because models used to analyze the physical flows of electricity do not align with the institutional and regulatory structures (see Figure 3-6).

The current Federal-state regulatory boundary dates back to the 1930s, when the Federal Power Act substantially expanded the responsibilities of the Federal Power Commission (the predecessor to FERC) and created Federal oversight of wholesale sales of electricity and of transmission of electricity in interstate commerce, as well as state oversight of retail sales and distribution of electricity. In recent decades, organized wholesale markets have spread geographically and incorporated a greater variety of products with a broader set of market participants. This trend—coupled with the increased ability of end-use consumers to supply distributed generation, demand response, and other services—has and will continue to raise questions about the dividing line between state and Federal jurisdiction.[56]

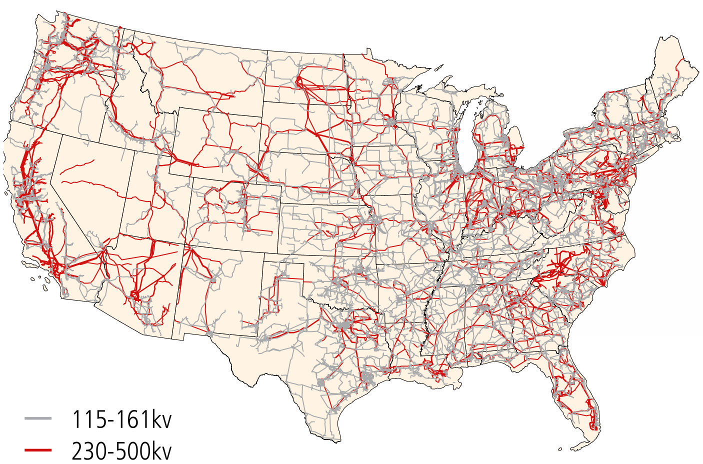
This threatens to impede the development of markets that efficiently integrate both utility-scale and small-scale participants. While FERC and the National Association of Regulatory Utility Commissioners have engaged in a collaborative dialogue on a range of topics (smart grid, demand response, enforcement, and others) since 2006,[57] Federal and state regulators should seek new ways to coordinate goals across their respective jurisdictions, without which the Nation will not be able to take full advantage of the efficiencies offered by emerging technologies and the grid of the future.[58]

Figure 3-6. Select Electricity Jurisdictions[59]

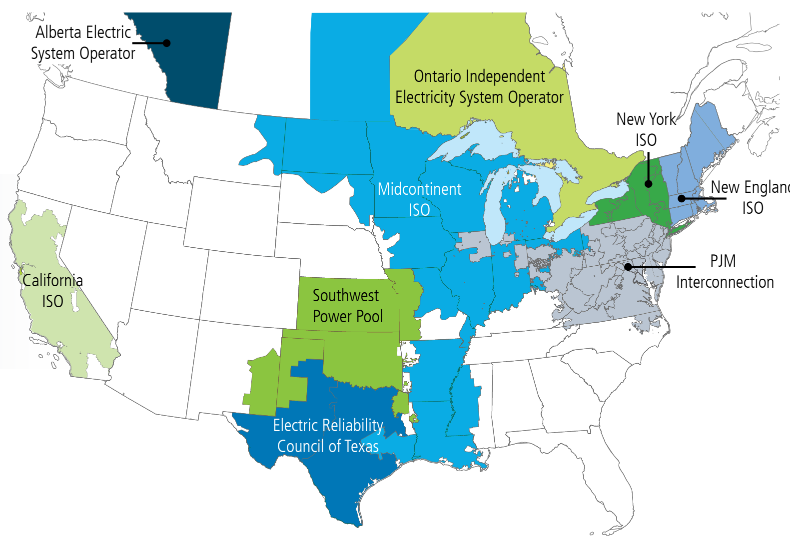
NERC Regional Entities and Balancing Authorities



Federally Regulated Power Lines



Regional Transmission Organizations (RTOs)/Independent System Operators (ISOs)



Transmission lines, which are regulated at the Federal level, cross state boundaries and connect the regional organizations that manage and operate the bulk power electricity grid. In contrast, states regulate the distribution of electricity to end-use customers for entities under their jurisdiction, as well as the siting of transmission on non-Federal lands. Further, in most states, local appointed or elected governing boards handle the regulation of distribution for their publicly or cooperatively owned electric utility. This diversity of institutions and differences in jurisdictional boundaries create challenges in grid governance (given that changing the grid in one location can alter electricity dynamics over a large area).

Policy Framework for the Grid of the Future

The transition from today's existing grid to the grid of the future will be challenging. The electric grid is highly complex, has significant regional variability, and should be managed to accommodate a range of possible futures. The vision of the future electric grid described earlier in this chapter was developed after a year-long QER process of analyses and stakeholder engagement. The recommendations that follow are guided by five key policy principles that emerged from this work.

- The future grid should encourage and enable energy efficiency and demand response to cost effectively displace new and existing electric supply infrastructure, whether centralized or distributed. The policies, financial tools, and pricing signals that enable customers to save money and energy while enhancing economic growth should be preserved and strengthened as business models evolve.

- The future grid should provide balanced support for both decentralized power sources and the central grid. As the costs of decentralized power sources and storage continue to fall, there will be increased opportunities for end users to partially or completely supply their own electricity. At the same time, the vast majority of American homes and businesses will continue to rely on the power grid for some or all of their electricity. It is essential, then, that investment in both centralized and decentralized systems occur in a balanced manner, preserving high-quality service for all Americans while simultaneously enabling new options and services that may reduce energy costs or climate impacts. Similarly, access to renewable energy, energy efficiency improvements, and new energy-related services should not be limited to isolated customer groups, but rather become an integral part of the universal service that both decentralized and centralized grid customers enjoy.

- In the future grid, new business and regulatory models must respect the great regional diversity in power systems across the United States, as well as the critical roles played by state, local, tribal, and regional authorities, including state public service commissions and regional grid operators. The drivers of change in the power system cut across the traditional boundaries of state and Federal regulation and thereby introduce new challenges in designing and overseeing new business and regulatory models. An unprecedented amount of consultation and collaboration will be necessary to ensure that national objectives are met alongside complementary state policies in power systems that are inherently regional in their scope and technology.

- Planning for the future grid must recognize the importance of the transmission and distribution systems in linking central station generation—which will remain an essential part of the U.S. energy supply for many years to come—to electricity consumers. Transmission and generation both benefit from joint, coordinated planning. Transmission can allow distant generation—where there may be excess capacity—to supplement local supply and avoid the need to build new plants. New generation sometimes requires new transmission, especially remotely sited renewables or new nuclear plants. Utility and Regional Transmission Organization planning processes and tools should continue to evolve to evaluate transmission, generation (both central and distributed), and demand-side resources holistically.

- Finally, the careful combination of markets, pricing, and regulation will undoubtedly be necessary in all business and regulatory models of the future grid. While the precise nature and scope of the market structures in the future grid may vary considerably, there is little doubt that markets in one form or another will be an important means of providing access to new technologies and services. Even in settings where prices are regulated, novel approaches can allow beneficial new pricing and service structures. Moreover, both new and traditional financing options provided by capital markets will be an important element in the future industry landscape.

QER Recommendations

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 research and development, analysis, and institutional support: A modernized 21st century grid will require a governing framework that values and optimizes the benefits from new technologies and services, as well as a physical infrastructure that maintains reliability, resilience to disruption, cost effectiveness, and flexibility to adapt to these changes. Early and strategic investments by DOE in foundational technology development, enhanced security capabilities, and institutional support and stakeholder engagement provide decision makers with a common set of tools that balances electric industry and consumer interests. Though small relative to the size of the industry, DOE's investment is significant compared to utilities' limited spending on innovation, which stems from an investor-owned business model where profits are based on return on capital expenditures, as well as public- and consumer-owned power's requirement for lowest feasible rates. The President's Fiscal Year 2016 Budget requests $356 million for DOE's Grid Modernization Initiative.

To reflect the rapidly shifting grid landscape, DOE should continue to pursue a multi-year, collaborative, and cost-shared research and development, analysis, and technical assistance program:

- Technology innovation resulting from research and development coordinated among DOE offices, creating new tools and technologies in areas such as the following:
  - Design and planning tools to model emerging needs
  - System control and power flow to optimize for new grid capabilities
  - Grid sensing and measurements for determining changes in variable generation markets and infrastructure conditions
  - Devices and integrated systems testing for evaluation and validation of new technologies in a systems context
  - Grid security and resilience efforts to protect, prevent, analyze, and respond to threats by developing physical and cybersecurity technology and standards
  - Risk management, including integrated demonstration of promising new technologies with new institutional approaches.
- Institutional support and alignment, including analyses, workshops, and dialogues to highlight key policy and market challenges and options for grid transformation.

The cost of this program is estimated to be $3.5 billion over 10 years.

Establish a framework and strategy for storage and flexibility: Energy storage is a key functionality that can provide flexibility, but there is little information on benefits and costs of storage deployment at the state and regional levels, and there is no broadly accepted framework for evaluation of benefits below the bulk system level. DOE should conduct regional and state analyses of storage deployment to produce a strategy for flexibility and storage. The strategy will integrate the findings from these analyses and make them easy for all types of stakeholders, including regional and state leaders, to understand and implement where appropriate. It will also establish a common framework for exploring means, methods, and technologies that can enhance grid flexibility, regionally, in states, and load-serving entities.

QER Recommendations (continued)

The national energy system storage strategy will address a suite of approaches that enable flexibility, including integrated planning methods, system operations and markets, demand and storage, conventional and variable renewable generation, and interconnected transmission networks.

Conduct a national review of transmission plans and assess barriers to their implementation: Transmission is critical both to ensuring reliability, as well as to connecting generation to load. While DOE has funded interconnection-level analyses of transmission needs and specific studies of transmission needs for renewable generation, a more detailed and comprehensive national review of transmission plans is warranted. DOE should carry out such a review to include assessments on the types of transmission projects proposed and implemented, current and future costs, consideration of interregional coordination, and other factors. Synthesizing this information at a national level would better inform and guide the development of transmission, including opportunities for additional regional or interregional coordination. In conjunction with such a review, it will be critical to assess incentives and impediments to the development of new transmission. Such an assessment should include a review of existing Federal incentives, implementation of Section 1222 of the Energy Policy Act of 2005 to enable third-party transmission projects partnered with the DOE Western and Southwestern Power Administrations, implementation of the $3.25 billion Western Area Power Administration Transmission Infrastructure Program, siting constraints, and other incentives and impediments that may exist at both the national and local levels.

Provide state financial assistance to promote and integrate TS&D infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection with a focus on regional coordination: States are the test beds for the evolution of the electric power system. DOE should provide competitive funding for states to promote and integrate TS&D infrastructure investment plans for electricity reliability, affordability, efficiency, lower carbon generation, and environmental protection (including climate mitigation).

- As described in this chapter, states can play an important role in promoting grid reliability as new technologies, including distributed generation, are added to the grid, and consumers demand more services from the electric power system. The increasing interdependency of natural gas and electricity systems creates additional planning requirements, as does climate change and extreme weather events.
- States have historically established separate agencies for reliability and environmental regulation of the electric power sector that operate independently of each other. The actions required to meet the goals of an affordable, resilient, reliable, and cleaner electricity sector are, however, becoming increasingly interdependent. States can provide innovative ways to address new trends that allow the electric sector to reliably provide services that meet environmental, resilience, and efficiency goals. 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.

The estimated support for this program is about $300 million to $350 million over 5 years.

QER Recommendations (continued)

Coordinate goals across jurisdictions: Technology is indifferent to state-Federal boundaries and jurisdictions; technology users cannot be. Both Federal and state governments need to play constructive and collaborative roles in the future to ensure that consumers and industry are able to maximize the value of new technologies to enhance resilience and reliability and mitigate climate change. While the notions of retail versus wholesale have, in some respects, become blurred, the states still have a strong and important role in electricity regulation. The variety and strength of state policies on energy efficiency, storage, renewable energy, smart grid, and even GHG regulation demonstrates the undiminished importance of the power sector to state leaders, notwithstanding technological change. At the same time, portions of the electric power sector have an important role to play in improving the efficiency of the wholesale markets overseen by FERC at the Federal level. 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: Efficient characterization and valuation of services provided to the grid by existing and new technologies is important for maintaining reliability and affordability of the rapidly evolving electricity system and providing clear price signals to consumers. Existing methods for establishing values and rates should appropriately compensate new technologies, with the potential to more effectively provide grid services reliably, affordably, and in compliance with environmental regulations. The Federal Government can play a role in developing frameworks to value grid services and approaches to incorporate value into grid operations and planning.

- DOE 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 ability of distinct grid components to provide grid services should be evaluated, and options for increasing the viability of components to provide grid services should be reviewed—this would allow market operators and regulators to have a more complete understanding of the range of technologies and strategies that can provide grid services.
- DOE should also work with stakeholders to develop a framework(s) for identifying attributes of services provided to the grid by electricity system components, as well as approaches to incorporate the valuation of grid service attributes in different regulatory contexts (e.g., pricing or incorporation in planning processes).
- The convening efforts recommended here will build on past DOE workshops on the value of storage and distributed energy resources (discussed in Chapter X, Analytical and Stakeholder Process). The frameworks developed through this process could be used by FERC, 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.

QER Recommendations (continued)

Improve grid communication through standards and interoperability: A plethora of both consumer-level and grid-level devices are either in the market, under development, or at the conceptual stage. When tied together through the information technology that is increasingly being deployed on electric utilities' distribution grids, they can be an important enabling part of the emerging grid of the future. However, what is missing is the ability for all of these devices to coordinate and communicate their operations with the grid, and among themselves, in a common language—an open standard. One analogy is the voluntary industry USB standard developed in the mid-1990s that allows simple plug-and-play between smart phones, tablets, computers, chargers, printers, games, and many other peripheral devices, and whose existence has greatly expanded both the usability and types of all these personal electronic devices. Similar standards are emerging but not settled for the much newer set of information technology-enabled grid devices (i.e., a lack of interoperability exists). The Department of Commerce's National Institute of Standards and Technology (NIST) was very active in working with industry and other interested parties to develop several generations of voluntary standards to bring interoperability to grid-connected devices. NIST's efforts have now transitioned to the industry-based Smart Grid Interoperability Panel. DOE is supporting efforts by IEEE to develop next-generation standards for inverters used by distributed generation. While the Federal Government lacks authority to mandate standards in these areas, it can take additional steps. In conjunction with NIST and other Federal agencies, DOE should work with industry, IEEE, 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: The measurement and verification of energy efficiency savings will be increasingly important as efficiency continues to become not just a source of revenue, but a mechanism by which the utility can meet its GHG reduction goals. Regulators need ways to understand, validate, and value savings from energy efficiency practices, including understanding the value of infrastructure avoidance as a result of efficiency investments. Through its Uniform Methods Project, DOE should accelerate the development of uniform methods for measuring energy savings and promote adoption of these methods in public and private efficiency programs.

RECOMMENDATIONS IN BRIEF:
Modernizing the Electric Grid

Provide grid modernization research and development, analysis, and institutional support. The Department of Energy (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, as well as 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 transmission, storage, and distribution 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.

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Chapter IV

MODERNIZING U.S. ENERGY SECURITY INFRASTRUCTURES IN A CHANGING GLOBAL MARKETPLACE

This chapter addresses the role of infrastructure in ensuring U.S. energy security in a global marketplace. It first describes the evolution of the concept of U.S. energy security in response to interconnected global energy markets. It then discusses the security benefits of both increased domestic production and increasingly efficient use of energy. The chapter then examines four sets of infrastructures and provides associated recommendations at the end of each discussion. First, it looks at modernizing the Strategic Petroleum Reserve (SPR), analyzing both its physical facilities and the legal authorities governing its use. Second, the chapter examines changes affecting infrastructures for delivering propane and alternative fuels—two important contributors to a diverse U.S. energy supply. Third, it looks at the need to reinvigorate the U.S.-flagged shipbuilding industry, given the importance of marine transport of energy commodities to U.S. security. The chapter concludes with a discussion of the U.S. energy infrastructures that are shared with Canada and Mexico. This discussion is related to the broader issues of North American energy market integration that are covered in Chapter VI (Integrating North American Energy Markets).

FINDINGS IN BRIEF:
Modernizing U.S. Energy Security Infrastructures in a Changing Global Marketplace

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 also has 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 Strategic Petroleum Reserve'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 Strategic Petroleum Reserve 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 determinations 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 not only provide 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 greenhouse gases 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.

A Broad and Collective View of Energy Security

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.

Acknowledging the need for a modern and collective definition of energy security, last May in Rome the G-7[a] Energy Ministers adopted a set of seven core principles for energy security,[1] several of which are particularly relevant to energy infrastructures:

- Development of flexible, transparent, and competitive energy markets, including natural gas markets.
- Diversification of energy fuels, sources, and routes and encouragement of indigenous sources of energy supply.
- Reducing our greenhouse gas emissions and accelerating the transition to a low-carbon economy as a key contribution to enduring energy security.
- Enhancing energy efficiency in demand and supply and demand response management.
- Promoting deployment of clean and sustainable energy technologies and continued investment in research and innovation.
- Improving energy systems resilience by promoting infrastructure modernization and supply and demand policies that help withstand systemic shocks.
- Putting in place emergency response systems, including reserves and fuel substitution for importing countries, in case of major energy disruptions.

U.S. energy security and the infrastructures that support it, both physical and geopolitical, should be viewed in the context of this new, broader, more collective definition of energy security. This chapter—and the Quadrennial Energy Review (QER) more widely—addresses each of these elements. Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure) considers various actions that the government and private sector can take to promote a more rapid and effective response to energy shocks, including those from weather, supply disruptions, and physical attacks. This chapter, as well as Chapter VI (Integrating North American Energy Markets), speaks to the increasing diversification of U.S. energy supply, with safe, secure, and economically efficient energy coming from Canada and Mexico through pipelines, over interconnected transmission networks, and via barge and tanker. The discussions in Chapter V (Improving Shared Transport Infrastructures) address issues related to the diversification of fuel supplies and routes, as well as the dynamics of better managing the distribution of the increasing production of domestic energy supplies.

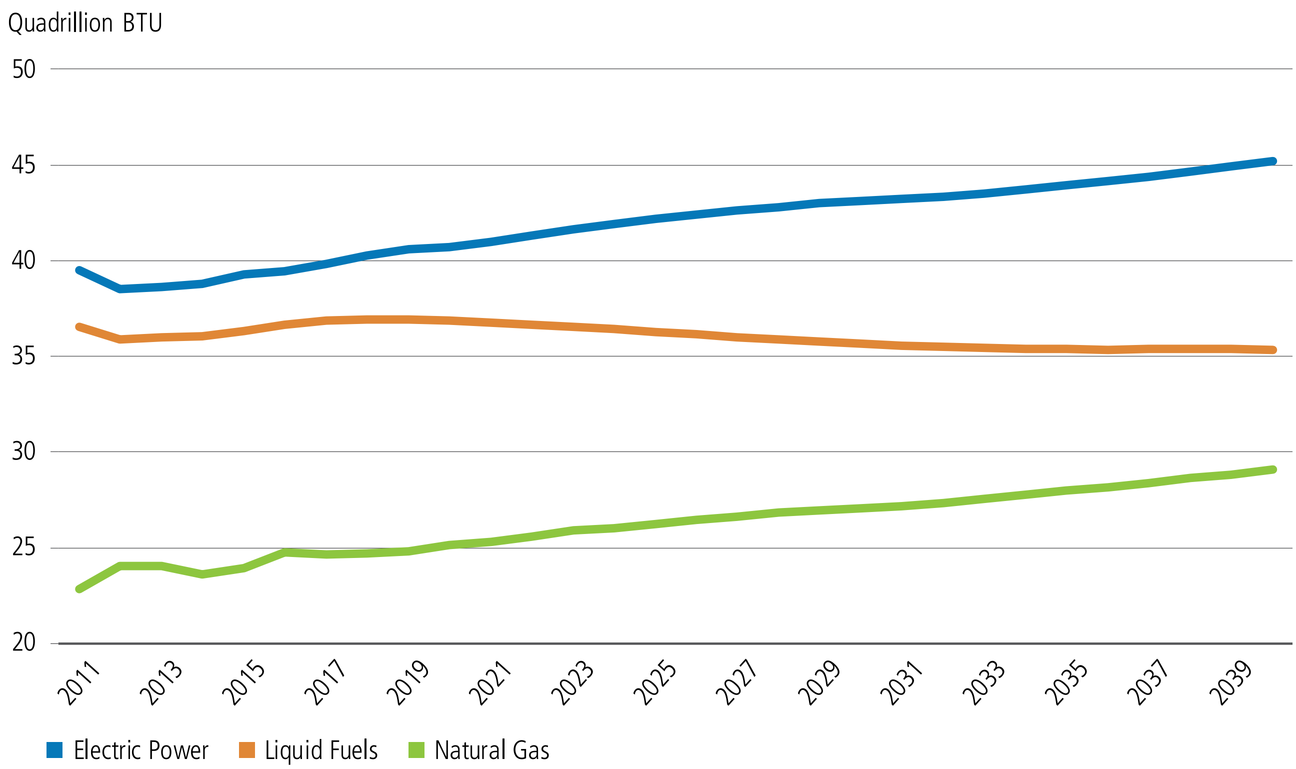
Energy security issues need to be considered in light of future supply growth projections, fuel switching, shifting consumption patterns, and their implications for both U.S. and world energy security. Irrespective of the recent global crude oil price drop, near-term projections from the Energy Information Administration (EIA) and other expert energy market forecasters indicate global supply growth will continue for some time and that potential oil price recovery—when and by how much—remains uncertain for the foreseeable future.

Finally, the discussion of energy security would not be complete without addressing the demand side. While issues of energy conservation, energy efficiency, and demand reduction are largely out of scope for this installment of the QER, they are nonetheless relevant for energy security. Figure 4-1 shows U.S. energy

[a] The G-7 countries include the United States, Canada, France, Germany, Italy, Japan, and the United Kingdom.

demand as projected by EIA through 2040. These projections indicate that U.S. liquid fuel demand is expected to grow through 2018 and then begin a slow decline for the remainder of the period. In contrast, EIA projects a steady growth through the projection period for both electricity and natural gas. However, it should be noted that EIA's projections do not consider regulations that are not yet finalized. Thus, EIA projections do not account for electricity supply and demand changes likely to occur from implementation of the Environmental Protection Agency's "Clean Power Plan," because it has not yet been finalized. Should demand decline in any of these sectors (particularly, if the infrastructure and resources remained in place to manage higher levels of supply), the energy system's ability to withstand supply disruption would increase. Of course, over the longer term, it is to be expected that a new equilibrium would be reached, and supplies and demand would again be in balance, suggesting that supply disruptions could still create insecurities in the energy system even with lower overall levels of energy flows.

Figure 4-1. Trends in U.S. Use of Petroleum, Natural Gas, and Electricity, 2011–2040[2]



EIA projections indicate that through 2040, natural gas and electric power demand will steadily increase, while liquid fuels demand will increase until 2018 and then slightly decline through 2040.

U.S. Energy Security, Changed Production Profile, and Infrastructure Needs

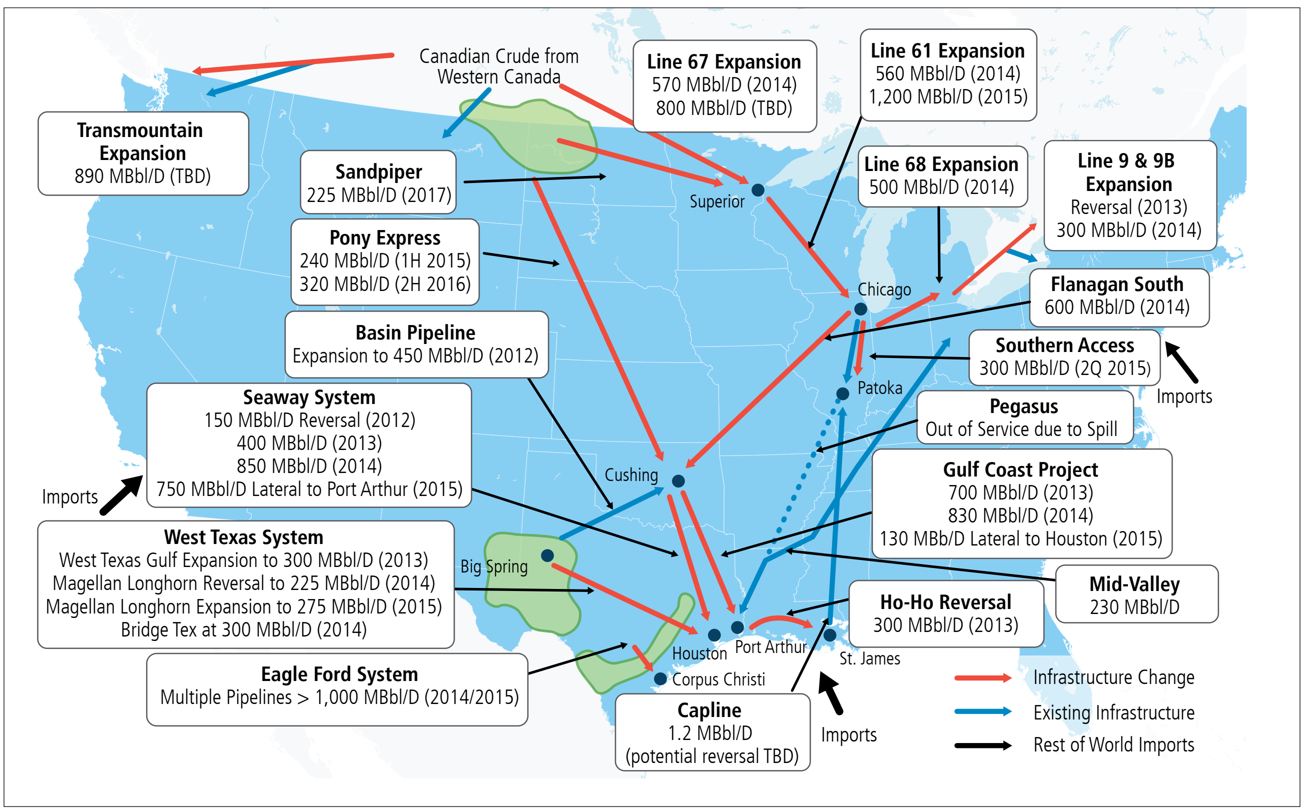
As discussed in Chapter I (Introduction), there have been striking changes in U.S. oil production over the last 5 years, as well as changes in supplies of natural gas, natural gas liquids (NGL), and biofuels. The unprecedented oil and gas production growth in the United States has made it the world's largest producer of combined petroleum and natural gas. Growth in oil production 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, more recently, contributing to a supply surplus that has reduced oil prices to levels not seen since March 2009.[3] The natural gas outlook also has significantly changed. Just 10 years ago, the United

States was forecast to become highly dependent on liquefied natural gas imports; however, the current outlook projects that the United States will have enormous capacity and will likely become a major liquefied natural gas exporter.[4] 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.

This production of oil and natural gas is occurring in new locations often removed from areas of historical production. As a consequence, the flow of both raw energy commodities and their refined products is changing, placing demands on the infrastructure that moves them to intermediate users and consumers.

Historically, oil and oil products in the United States have tended to flow from south to north to inland refineries. Now, this generally has been reversed, with oil from the Bakken field in North Dakota and Montana moving from the north toward the Gulf of Mexico, as well as to East and West Coast refineries. Significant new quantities of crude oil from the Eagle Ford and Permian shale basins also are moving to Gulf Coast refineries. To accommodate these changes in the volume and geography of U.S. crude oil production, there have already been substantial pipeline additions and some reversals,[5,6] as shown in Figure 4-2.There have also been significant increases in barge, rail, and truck transport of crude oil, crude oil products, petrochemicals, and ethanol. This build-out of infrastructure has improved U.S. energy security. Without it, the United States could not have reduced its reliance on imports of liquid fuels to the extent that it has.

Figure 4-2. Highlighted Liquid Fuels Pipeline Reversals and Expansions Accommodating Increased Domestic and Canadian Supply (existing or in construction by end 2014)[7]



There have been substantial pipeline additions and some reversals of pipeline product flows to accommodate the changes in domestic production regions and the volumes of product that are being transported.

Natural Gas and Liquid Fuels Scenario Analyses

Quadrennial Energy Review scenario analysis used the Deloitte MarketPoint model (www.deloittemarketpoint.com) and several oil infrastructure models to examine oil and gas transmission pipeline needs between 2014 and 2030. Several cases were run to evaluate different oil and gas production and demand profiles (see Chapter I, Introduction, Table 1-2 for the complete list of cases). Even under conditions where natural gas and liquid fuels demand increases dramatically, pipeline infrastructure requirements do not exceed recent historical industry build rates. The recent build-out to integrate new shale gas supplies has added substantial optionality to the interstate natural gas pipeline system. Options include utilizing excess pipeline capacity in some regions, as well as the potential for additional looping, compression, and pipeline reversals. These options dampen the need for new gas infrastructure; even when new gas capacity is regionally concentrated, as it would be in the Gulf if gas exports were to increase significantly, annual rates of investment are at or below historical levels.

The analysis also incorporated expansion of the transportation and distribution infrastructure currently underway along with expansion of this infrastructure to accommodate forecasted growth in crude production. Crude by rail remained an important mode of transport for moving midcontinent crudes to coastal refineries. In addition, crude oil pipelines from north to south and west to east continued to expand in the midcontinent and west Texas, respectively.

Many U.S. Gulf Coast refineries have been largely configured to use a greater share of heavy crude oils, whereas nearly all of the recent incremental U.S. crude oil production is light oil. To date, U.S. refiners have been able to absorb increasing amounts of light crude oil by displacing imported light and medium crudes. The natural gas boom has not only reduced gas imports and enabled liquefied natural gas exports, but it has also reduced costs for U.S. refiners who use natural gas for process fuel. They are now more competitive in international markets, leading to more highly refined product exports.[8]

As a result of the renaissance of U.S. oil and natural gas production, the U.S. Gulf Coast marine facilities serving the SPR are operating at high capacities. This has implications for the distribution capacity of the SPR, the infrastructures that support it, and the degree to which it can protect the U.S. economy from oil disruptions.

The U.S. Strategic Petroleum Reserve: Oil Security Infrastructure

The SPR is a Federal facility that consists of a network of 62 salt caverns at 4 geographically dispersed storage sites in Louisiana and Texas. It currently holds 691 million barrels of crude oil. The SPR caverns are connected to three distribution networks—Seaway, Texoma, and Capline—that distribute SPR oil through a network of pipelines and marine terminals to Gulf Coast refineries, inland refineries, and refineries on the East and West Coasts. The SPR has a design drawdown capacity of 4.4 million barrels per day from its caverns into its distribution networks.[9] During an SPR release, an auction determines which U.S. refineries will receive SPR oil. The ability to *deliver* oil to the refineries is the SPR's distribution capacity and depends on the SPR's network of pipelines and marine terminals.

The SPR is an important insurance policy for the U.S. economy in the event of serious oil supply disruptions and the associated price increases in domestic petroleum and petroleum products. Sharp increases in fuel prices and declines in gross domestic product growth have consistently followed previous oil supply disruptions. In spite of the changes in the U.S. oil profile, the U.S. economy will remain vulnerable to future international oil supply disruptions without the protection afforded by the SPR.[10]

Changing Global and Domestic Oil Markets Underscore the Need to Modernize the SPR

U.S. and global oil markets have evolved since the 1970s, changing the environment in which the SPR operates. When the SPR was established, U.S. oil production was in decline, oil price and allocation controls separated the U.S. oil market from the rest of the world, and a truly global commodity market for oil, as we know it today, did not exist. The Energy Policy and Conservation Act of 1975's (EPCA's) 1970's-era goal was focused on avoiding "national energy supply shortages"—a loss of supply to U.S. refineries—rather than on the impacts of an overall disruption of global oil markets—a less important concern given the existence of domestic price controls that aimed to separate domestic and foreign prices.

Regardless of the levels of U.S. oil imports, in today's global oil markets, a severe global market disruption would have the same effect on domestic petroleum product prices whether or not U.S. refineries import crude oil from the disrupted countries.[b, 11] EPCA's definition of a "severe energy supply interruption" should expressly include criteria focused specifically on disruptions in the global oil market, regardless of whether they resulted in a loss of oil imports to the United States.

Another change that would increase the effectiveness of the SPR involves the adequacy of the anticipatory authorities in EPCA, which articulate the process and criteria for an SPR release *before* domestic petroleum price increases. In 1990, Section 161(h) was added to authorize an SPR release in anticipation of a severe increase of petroleum product prices; that authority is limited to a release of no more than 30 million barrels of oil and for no more than 60 days. In today's fast-moving and globalized energy markets, the President should not have to wait until higher fuel prices have already damaged the U.S. economy before the SPR can be used without restrictions. The authority to anticipate an economy-damaging price increase as a result of a severe energy supply interruption should be added to the President's broader Section 161(d) release authorities to more closely conform to other EPCA goals of preventing "a severe increase in the price of petroleum products" that "is likely to cause an adverse impact on the national economy."

Further Enhancing the SPR's Value in Today's Oil Markets

In the event of a serious international oil supply disruption, offsetting a significant share of lost supplies with SPR oil, in concert with other countries that hold strategic reserves, would help reduce the sharp increase of international oil prices that would otherwise occur. When SPR oil is sold to domestic refineries, foreign oil shipments that would have been processed by U.S. refineries are freed up for use elsewhere, effectively increasing global oil supplies. The more oil the SPR is able to distribute to U.S. coastal refineries (inland refineries are now well supplied by domestic production and Canadian imports), the more oil will be added to global markets. This will mitigate the increase in international and domestic fuel prices and reduce harm to the U.S. economy. These diversions of foreign oil that would have been used by U.S. refineries are illustrated by the 2011 Libyan Collective Action.[c] At that time, the United States imported about 1 million barrels per day of oil from Nigeria. As a result of the June 2011 SPR release, significant Nigerian supplies were redirected to foreign refineries. The SPR oil sold to domestic refineries caused a corresponding increase of oil into the global market.

In recent years, the changing geography of U.S. oil production has led to major changes in the domestic oil and natural gas pipeline system. New patterns of oil supply and demand among U.S. oil producers and refineries, along with associated changes in the U.S. midstream, have significantly reduced the ability of the SPR to distribute *incremental* volumes of oil during possible future oil supply interruptions. Moving SPR oil to Midwest refineries—a historical pattern—would be of no value during a petroleum supply disruption as non-Canadian imports and Gulf Coast

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[b] Domestic petroleum product prices are determined by international oil prices.

[c] In June 2011, the United States, as part of an International Energy Agency "Collective Action," released 30 million barrels of SPR oil in response to the loss of Libyan oil production as a result of the Libyan civil war (February 2011) and subsequent loss of Libyan oil exports.

supplies into this refining complex have essentially disappeared. The U.S. pipeline distribution system, along with other modes of oil transport, is instead moving large volumes of oil to the Gulf Coast, especially from U.S. tight oil plays and Canada.[d] This new geography of U.S. oil production and energy exports has also increased commercial traffic at U.S. Gulf Coast marine loading facilities.

While the SPR can commandeer dock space at certain leased locations, doing so might cause a corresponding reduction in commercial traffic. The changing patterns of U.S. oil imports[e] mean that the location of an international oil supply disruption can affect the disposition of an SPR oil auction and the capacity of the SPR to deliver oil to its customers.[f] If the SPR cannot load oil onto barges and tankers without disrupting commercial shipments, SPR sales could be offset by a corresponding decrease in domestic crude oil shipments or exports of domestically produced petroleum products. For all of these reasons—the evolution of global oil markets, the participation of the United States in those markets, the changed geography and volume of U.S. oil supplies, reduced oil imports, and congestion of commercial facilities in the SPR's distribution region—an effective SPR release will increasingly depend on the ability to load *incremental* SPR oil onto barges and tankers.[12]

SPR facilities are also aging. Investment has not kept pace with need. Some SPR infrastructure is nearing the end of its design life. Life-extension investments will be needed in the near future to ensure the SPR's reliability for the next several decades. The Department of Energy (DOE) is working to address SPR-deferred maintenance issues within the regular budget process. The more costly long-term investments in life extension will need to be addressed separately.

Administration Activities and Plans

In March 2014, the Secretary of Energy ordered the Strategic Petroleum Reserve office to conduct a test sale to demonstrate the drawdown and distribution capacity of the Strategic Petroleum Reserve in the two locations served by its Texoma distribution network. This test sale highlighted changes in the distribution infrastructure in the Gulf Coast region. During the test sale, purchasers had problems getting capacity on one major pipeline for preferred deliveries and had to make adjustments by shipping crude oil to a different terminal and placing the oil into temporary storage until pipeline capacity became available.[g]

The President's Fiscal Year 2016 Budget provides $257 million for the development, operation, and management of the Strategic Petroleum Reserve. This is an increase over fiscal year 2015 enacted levels of more than $54 million. This additional funding includes more than $8.5 million for the operations and cavern integrity program, $17 million to improve distribution flexibility and reliability at the Big Hill site, and more than $26 million to reduce the backlog of deferred maintenance projects and address maintenance issues.

[g] Department of Energy. "Strategic Petroleum Reserve Test Sale 2014: Report to Congress." p. 16. 2014. http://energy.gov/sites/prod/files/2014/11/f19/2014%20SPR%20Test%20Sale%20Final%20Report.pdf. Accessed February 12, 2015.

[d] For example, the SPR's distribution capacity has been affected by reversals of the Seaway and Ho-Ho pipelines. New pipeline capacity has been built to move oil stored at the Cushing, Oklahoma, terminal to the Gulf Coast, or to bypass Cushing by shipping oil from new tight oil plays directly to Gulf Coast refineries.

[e] Besides the virtual disappearance of non-Canadian imports to Midcontinent refineries, Gulf Coast refineries are using more heavy oil from Latin America and less oil from the Middle East, while West Coast and East Coast refiners continue to import Middle Eastern and other light/medium grade crudes.

[f] The maximum distribution rate during an oil supply interruption depends on the location of the oil-exporting nation(s) that has (have) been disrupted, the type of oil that has been disrupted, and whether the United States imports oil from that nation (and, if so, how much and to what refining region). Additionally, due to increased U.S. tight oil production, the three SPR distribution systems will, in the future, rely more on marine distribution of SPR oil than inland pipelines. The pipeline network will remain important, though, especially for disruptions of oil that the Gulf Coast refineries rely on (such as oil from Venezuela, Mexico, or Columbia). Supply disruptions from these sources may result in less congestion for moving SPR oil on its pipeline system.

QER Recommendations

SPR MODERNIZATION

An effective modernization program for the SPR should reflect changed global oil markets and U.S. market conditions. It should be undertaken, as should all recommendations in this chapter, with a more up-to-date appreciation of the nature of energy security in an interconnected world. It should also focus both on physical infrastructure and an updated statutory trigger for the use of the SPR. Addressing both physical and statutory issues will ensure that high volumes of incremental barrels of oil will be able to move rapidly to U.S. refineries in case of a global market disruption, thereby increasing supplies in global markets and maximizing the value of the SPR for meeting the Nation's strategic energy needs. Specific recommendations include the following:

Update SPR release authorities to reflect modern oil markets: Congress should update the SPR release authorities in EPCA so that (1) the definition of a severe energy supply interruption includes an interruption of the supply of oil that is likely to cause a severe increase in the price of domestic petroleum products, and (2) the requirement that a severe increase in the price of petroleum products ***has resulted*** from such emergency situation is changed to a requirement that a severe price increase ***will likely result*** from such emergency situation.

Invest to optimize the SPR's emergency response capability: DOE should make investments to optimize the ability of the SPR to protect the U.S. economy in an energy supply emergency. It is anticipated that $1.5–$2.0 billion is needed to increase the incremental distribution capacity of the SPR by adding dedicated marine loading dock capacity at the Gulf Coast terminus of the SPR distribution systems, as well as undertaking a life extension program for key SPR components, including surface infrastructure and additional brine-drive caverns. This work should be preceded by DOE analyzing appropriate SPR size and configuration and carrying out detailed engineering studies.

Support other U.S. actions related to energy security infrastructures that reflect a broader and collective view of energy security: The United States should continue to consult with allies and key energy trading partners on energy security issues, as well as support actions related to energy infrastructures that are consistent with U.S. interests and G-7 principles on energy security.

Infrastructure Supporting Energy Security through Fuel Diversity

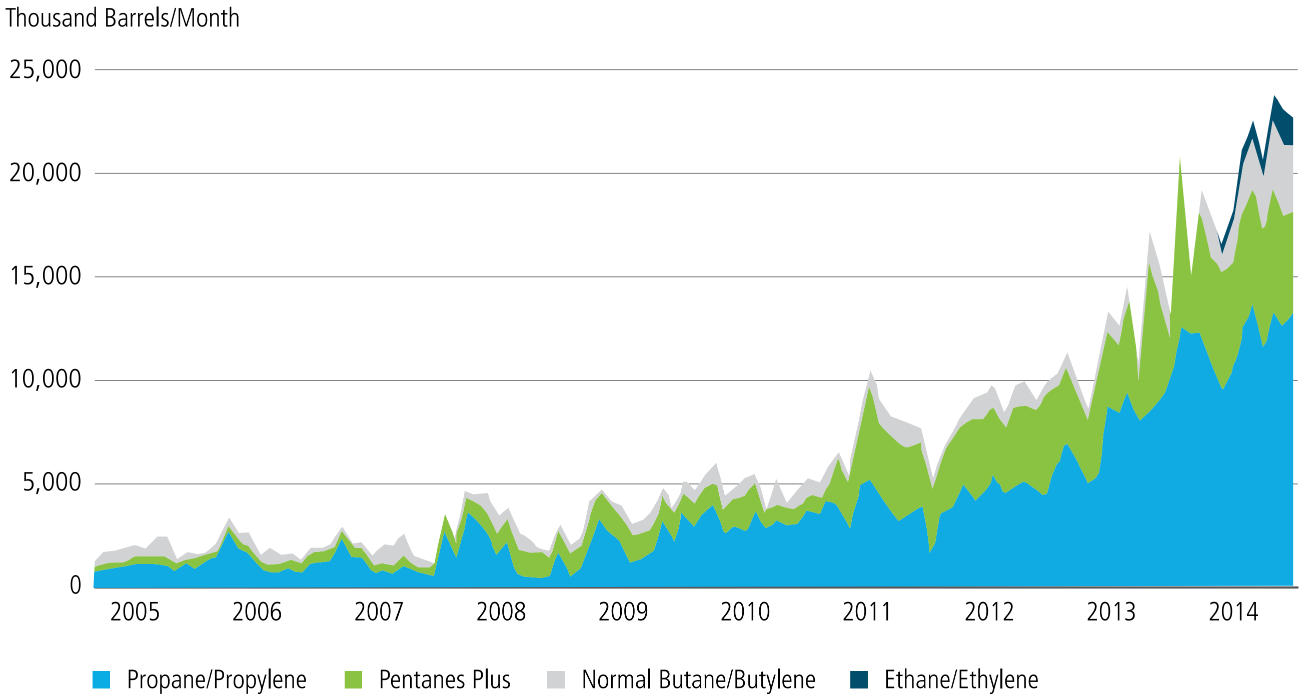
Transmission, storage, and distribution (TS&D) infrastructure has an important role to play in meeting another one of the long-term energy security core principles adopted by the G-7: diversifying energy fuels, sources, and routes and encouraging indigenous sources of energy supply. Two challenges in recent years related to maintaining a diverse supply of energy fuels—in the face of overall TS&D infrastructure changes that have been occurring—relate to the use of propane and biofuels.

Changes in NGL Infrastructure and Exports Could Have Propane Customer Impacts

Propane is a hydrocarbon gas liquid produced in gas plants and refineries. Propane is primarily used in industry, but during the winter, propane is an essential fuel for heat and is especially important in rural areas. The infrastructure connecting the producers of propane with distribution points for customers has changed dramatically in the last few years. As other geographies of energy supply have changed, infrastructure once used to transport propane to these distribution points (particularly those that serve agricultural users predominantly in the Upper Midwest) has been converted to other purposes. One of the major changes in this regard has been the reversal, by Kinder Morgan, of the Cochin pipeline, which originally transported propane from a storage site in Edmonton, Canada, to serve markets throughout the Midwest. In early 2014, the company reversed the pipeline's flow to deliver NGL to Edmonton, cutting off a major supply source of propane for Midwest markets.

Although propane storage has increased along with recent increasing levels of NGL production, a growing portion of propane is being exported. Propane exports are seasonal, however, reflecting tighter markets during the winter when domestic demand is high and greater surplus during the summer. In addition, rapidly increasing exports of propane and other NGL, as shown in Figure 4-3, are competing with the supply needs of users of propane in the agricultural, residential, and petrochemical sectors. This changing interplay of NGL use was highlighted during the fall and winter of 2013–2014 when propane users encountered severe regional shortages and price spikes in some regions across the country.

Figure 4-3. U.S. Hydrocarbon Gas Liquid Exports[13, h]



Since 2009, U.S. hydrocarbon gas liquid exports have risen substantially due to increased domestic production and wide international price spreads.

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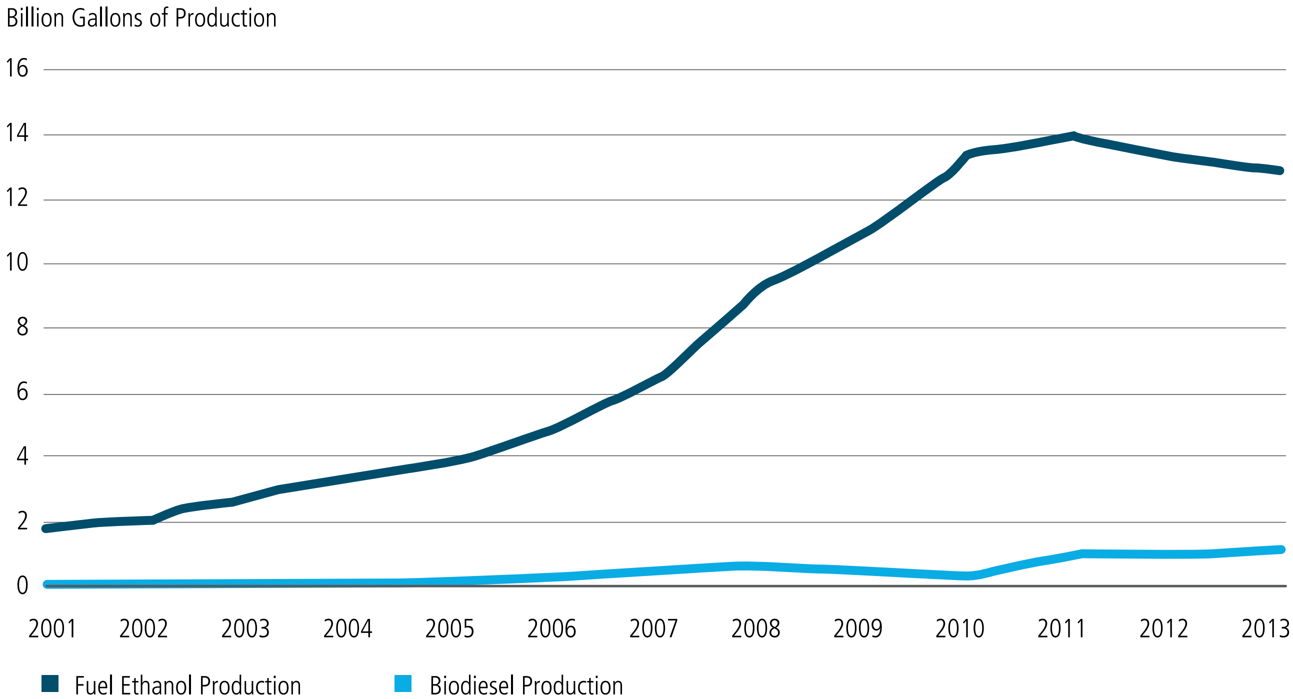
[h] Hydrocarbon gas liquids: A group of hydrocarbons, including ethane, propane, normal butane, isobutane, and natural gasoline, and their associated olefins, including ethylene, propylene, butylene, and isobutylene. As marketed products, hydrocarbon gas liquids represent all NGL and olefins.

Biofuels and TS&D Infrastructure Issues

Ethanol production in the United States has increased steadily over the last few decades, driven by tax credits, the oxygenate standard,[i] the Renewable Fuel Standard,[j] and the lower cost of ethanol relative to other gasoline additives. By 2012, ethanol production reached nearly 10 percent of U.S. gasoline demand by volume. As shown in Figure 4-4, further growth in ethanol production has flattened since then. Increased use of ethanol requires either growing gasoline consumption or higher-level blends (E15, with 15 percent ethanol, or E85, with up to 85 percent ethanol). However, the demand for gasoline is not expected to grow significantly (due to projected improvements of fuel economy and demographic trends). Continued growth in ethanol use will depend in part on private sector investment in additional distribution capacity of higher-level blends.

Figure 4-4. Yearly Ethanol and Biodiesel Production, 2001–2013[14]



Yearly production of ethanol increased between 2001 and 2011 and has declined slightly through 2013.

Ethanol shipments from production plants typically occur by rail, which accounts for approximately 70 percent of ethanol transport.[15] Ethanol is then delivered by truck (or directly by rail) to petroleum product terminals that blend ethanol with unfinished gasoline for delivery by truck to retail outlets. It is difficult to move ethanol shipments by pipeline because ethanol absorbs water and can therefore degrade the specifications of petroleum products, which would follow it in the pipeline.

Other biofuels have chemical properties more similar to gasoline and other hydrocarbons, enabling more ready distribution through existing TS&D infrastructure. Upstream biofuels involve biofuels that could be blended into the petroleum product supply chain at the refinery and then transported with the petroleum product

[i] The oxygenate standard for reformulated gasoline, introduced by the Clean Air Act Amendments of 1990, required a minimum level of oxygen in complying gasoline. The oxygen content of gasoline is typically increased by blending ethanol or methyl tertiary butyl ether into gasoline. The oxygenate standard was repealed in the same legislation that established the Renewable Fuel Standard (Energy Policy Act of 2005).

[j] The Renewable Fuel Standard was enacted as part of the Clean Air Act by the Energy Policy Act of 2005 and amendments in 2007. The Renewable Fuel Standard requires a minimum level of qualifying biofuels, including ethanol, to be blended into U.S. motor fuels.

through its normal infrastructure. These alternatives include oil from the pyrolysis of biomass, hydrocarbons derived from applying the Fischer-Tropsch process to mixtures of carbon monoxide and hydrogen produced in biomass gasifiers, oil derived from algae, and fatty acid methyl esters.[16] Drop-in biofuels, such as biobutanol and renewable diesel, can use existing oil and gasoline infrastructure and be "dropped in" at points along the supply chain without infrastructure modification. Future research on both types of biofuels can support energy security through fuel diversity without posing additional infrastructure challenges.

Administration Activities and Plans

Propane. The Administration has taken a series of actions to respond to the changes in transmission, storage, and distribution infrastructure for propane and other natural gas liquids. The Energy Information Administration has added capability to monitor propane inventories on a more granular, state-by-state basis, greatly enhancing the ability of industry, consumers, and policymakers to monitor possible shortages or distribution issues. Because propane storage in customer tanks can provide an additional margin of supply security, the Federal Government supported public education campaigns to encourage consumers to fill their propane storage early for the 2014–2015 winter season. As of January 2015, propane inventories were above the 5-year average, and the Propane Education and Research Council's market research shows the campaign contributed to these increases.[k,l]

Department of Energy (DOE) alternative fuels programs. DOE has supported research and development on the compatibility of higher-level ethanol blends with distribution infrastructure and vehicles. DOE grants and loans helped initial commercial cellulosic ethanol refineries come online. DOE has active research programs on drop-in fuels, and small amounts are already entering the commercial markets.[m] DOE also has robust research, development, demonstration, and deployment programs using electricity and hydrogen in vehicles, and use of these fuels in transportation is increasing.

Department of Defense alternative fuels programs. The Air Force's 2013 "U.S. Air Force Energy Strategic Plan" includes a goal to use cost-competitive alternative drop-in fuels for half of "non-contingency" operations by 2025. The Navy's 2010 report, "A Navy Energy Vision for the 21st Century," sets a goal of 50 percent of Naval energy use afloat to be derived from alternative fuels by 2020. The Navy designated an aircraft carrier task force built around the USS Nimitz as "the great green fleet," which is intended to operate using biofuels by 2016. In support of these objectives, the Department of Defense has an active program of research and development and testing alternative fuels for use in a range of aircraft and ships, including Fischer-Tropsch synthetic biofuels and small amounts of algal biofuels. The Department of Defense also purchases alternative fuels for research and testing purposes.

[k] Propane Education & Research Council. "Results of the 2014 Consumer Safety Preparedness Campaign." February 2015. http://www.propanecouncil.org/uploadedFiles/Council/Campaigns/ConsumerCampaignPresentationResults.pdf. Accessed March 4, 2015.

[l] Energy Information Administration. "This Week in Petroleum: Propane stocks (million barrels) and days of supply." http://www.eia.gov/petroleum/weekly/propane.cfm. Accessed February 25, 2015.

[m] Department of Energy. "Bioenergy Frequently Asked Questions." http://www.energy.gov/eere/bioenergy/bioenergy-frequently-asked-questions. Accessed February 25, 2015.

QER Recommendations

TS&D INFRASTRUCTURE RELATED TO FUEL DIVERSITY

To address TS&D infrastructure issues related to promoting U.S. energy security through fuel diversity, we recommend the following:

Continue research, development, and deployment of drop-in biofuels and support work related to higher-level ethanol blends: DOE and the Department of Defense should continue to fund research and demonstration activities on drop-in jet fuel and diesel. These applications are important given the challenges of electrifying airplanes and other large vehicles. Most production is in the pilot or demonstration phase, and, beginning in 2011, some commercial flights in Europe and the United States have flown with 50-50 biofuel blends. Despite this, biofuels for aviation and large vehicle applications still face considerable challenges in penetrating these markets. In addition, DOE should provide technical support to states, communities, or private entities wishing to invest in infrastructure to dispense higher-level ethanol blends.

Continue to monitor propane storage, use, and exports: Given the changes occurring in propane TS&D infrastructure, DOE should ensure adequate support for EIA's data collection and analysis relative to domestic propane storage and use, as well as propane exports, going forward.

Infrastructure Supporting Energy Security through Marine Transport

The marked increase in inland, coastal, and offshore maritime traffic stemming from the recent boom in U.S. oil and gas production and the resulting investment in the petrochemical complex highlights the need for new energy transport vessels in the United States.

Trends in U.S. Shipbuilding

American shipyards are experiencing a surge in construction orders for patrol boats, tugs, barges of all sizes, ferries, and other vessels. In 2012 alone, U.S. shipbuilders delivered 1,260 vessels[17] and have since seen a spike in orders for large ocean-going vessels. Today, there are more than 30 large, self-propelled, ocean-going Jones Act-eligible tankers, articulated tug-barge units, and container ships either under construction or on order at U.S. shipyards. The Maritime Administration has noted that U.S. shipyards are experiencing the greatest volume of shipbuilding activity in more than three decades.[18]

An understanding of the history of the decline of U.S. commercial shipbuilding capacity is instructive. Until 1981, the U.S. policy was to actively support its merchant marine fleet and the Nation's domestic shipbuilding industry, recognizing its critical role in supporting national defense.[19] U.S. international shipping companies received an operating subsidy, a condition for which was to buy U.S.-built ships. Subsidized shipping companies received a construction subsidy to make up the difference between the prices of less expensive foreign built ships and the prices charged by U.S. shipyards. In 1981, operating and construction differential subsidies were halted under the theory that the domestic industry would be supported by construction of naval vessels.[20] When construction of naval vessels actually declined, the effect was a significantly diminished capacity for domestic shipbuilding.[21] Prior to the 1980s, U.S. shipbuilders produced nearly 100 commercial ships per year. Orders for commercial ships dropped to zero in the mid-1980s and have averaged just seven ships per year since.[22]

U.S. shipyards traditionally focused on orders from U.S. shipping companies.[23] South Korea, Japan, and China have aggressively sought export business and subsidized their shipping industries.[24] Currently, South Korea and China dominate the shipbuilding industry[25] and benefit from technical learning, capital investment, and improving economies of scale and purchasing advantages. As a result, these nations now operate at much lower costs than competitors, including the United States.[26] Despite accounting for about 20 percent of the global seaborne trade, the United States builds less than 1 percent of the world's merchant vessels.[27] Aside from lost commercial opportunity, some observers believe that reliance on foreign shipyards could have implications for U.S. security and prosperity.

QER Recommendations

MARINE TRANSPORT

The security implications are evident in the inextricable linkage between energy and maritime commerce, as recent changes require moving oil in new ways. Because it is important to have a better understanding of possible energy vulnerabilities associated with the overall decline in U.S. shipbuilding, as well as the competitiveness opportunities associated with enhancing domestic energy shipbuilding, we recommend the following:

> **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. We recommend that the Secretary of Transportation ensure that the National Maritime Strategy includes a consideration of the energy security aspects of maritime policy in its discussion and recommendations.

Energy Security Benefits of North American TS&D Infrastructure

One of the most significant benefits to U.S. energy security is its location; the United States shares the North American continent with two close allies. The United States, Canada, and Mexico are each resource-rich nations; there is an enormous bilateral energy trade; and all three countries have intertwined and increasingly integrated energy markets and infrastructure. Three of the G-7 core principles for energy security have regional implications for the United States and its North American neighbors: the improvement of energy system resilience to disruptions through infrastructure modernization; the development of flexible and competitive energy markets; and the diversification of fuel mixes, sources, and routes.

The TS&D infrastructure across the U.S.-Canadian and U.S.-Mexican borders is diverse and extensive. Currently, there are approximately 85 transboundary pipelines and 35 major electricity transmission lines that transport crude oil, refined products, natural gas, and electricity across the U.S.-Canadian border.[n] To the south, liquid fuels make up the largest share of the energy trade between the United States and Mexico, primarily via shipping in the Gulf of Mexico. Additionally, 17 natural gas interconnections currently span the U.S.-Mexican border, and while minimal, electricity trade does occur between California and Baja California and to a lesser extent between Texas, Tamaulipas, and Chihuahua.[28]

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[n] Additional oil and petroleum products are shipped to Canada.

The United States and Canada share water access through the Great Lakes and St. Lawrence Seaway. The Army Corps of Engineers lists more than 60 commercial harbors on the U.S. Great Lakes coast alone.[29] Rail and trucking routes also span the border, enabling the transfer of energy commodities using several transportation modes. Further development of these interconnections could improve continental security and bring economic benefits. For example, the Electric Reliability Council of Texas has peak electricity demand that exceeds generation in south Texas, and it is using new high-voltage transmission lines to provide power from Mexican generating facilities to Texas. Additional generation is being proposed on the Mexican side of the border that can support Texan power requirements and help avoid power outages.

Chapter VI (Integrating North American Energy Markets) contains a more detailed discussion of the North American energy markets and the benefits of increased integration beyond that of enhanced regional energy security.

RECOMMENDATIONS IN BRIEF:
Modernizing U.S. Energy Security Infrastructures in a Changing Global Marketplace

Update Strategic Petroleum Reserve (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. The Department of Energy (DOE) should analyze appropriate SPR size and configuration, and, after carrying out detailed engineering studies, should make infrastructure investments in 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 on 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 fuel 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 transmission, storage, and distribution 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.

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Chapter V

IMPROVING SHARED TRANSPORT INFRASTRUCTURES

This chapter examines the use—for transporting, storing, and delivering energy—of transportation modes shared by other major commodities. These modes include railroads, highways, waterways, ports, and the intermodal facilities that connect them together. The discussion is divided into four major sections. The first focuses on rail transport of energy commodities, with a consideration of ancillary use of highways. The second focuses on waterways, ports, and their connectors to other transportation infrastructure. The third section addresses conflicts due to the increased transport of energy supplies, materials and components. The final section focuses on gaps in data and analytical methods needed to understand the rapid changes occurring in the use of these transport infrastructures for energy. Each major section concludes with a discussion of major Administration initiatives underway to address the issues—especially in rail transport—and recommendations for further action.

FINDINGS IN BRIEF:
Improving Shared Transport Infrastructures

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 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.

Increased Use of Shared Transport Infrastructures for Energy

Changes in the U.S. energy marketplace are stressing the Nation's infrastructures that move energy from where it is produced to both processing and demand centers, particularly in the case of oil where the rapid increase in U.S. tight oil production is transforming conventional patterns and modes of petroleum transport in North America.

While pipelines traditionally have been the preferred mode for transporting large amounts of oil and refined products within the United States, expanded development in regions distant from refineries, where existing petroleum infrastructure is minimal, has increasingly shifted energy products to other modes of transportation. The movement of 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 alternatives have been, and continue to be, used for transporting other commodities, they are considered in the Quadrennial Energy Review (QER) to be "shared transport infrastructures" for energy commodities.

The increased utilization of rail, barge, and truck for oil transport, as well as other energy supplies and materials, is contributing to increased competition among commodities on these shared transport infrastructures. This has contributed to delays in the delivery of other commodities, such as crops, fertilizers, and chemicals.[1] The same constraints have recently affected the delivery of coal to electric generators.[2]

While modal shifts are responsible for a share of the energy sector's impact on the shipment of goods around the Nation, the dramatic increases in shale oil and gas production have put additional pressure on transportation infrastructure in other ways as well. For example, developing a single well pad in the Marcellus Shale region is estimated to require roughly between 1,600 and 4,900 truck trips,[3] resulting in $13,000 to $23,000 in roadway maintenance costs per well.[4] Likewise, most of the nearly fivefold growth in rail shipments of industrial sand since 2009 can be attributed to sand used for hydraulic fracturing.[5] Drilling operations in the Marcellus region also produce significant quantities of wastewater. Disposal of this wastewater close to production sites is hindered by factors such as inappropriate geology and lack of capacity at local municipal and industrial wastewater facilities to treat adequately the high level of total dissolved solids in wastewater generated from Marcellus wells. As a result, there has been a shift to the use of underground injection wells to dispose of this wastewater, with most of those injection wells located in Ohio.[6] Truck and rail transport are options for transporting wastewater, but higher costs for those modes and the ability to move large volumes of wastewater by barge have made waterborne transport of wastewater attractive to the natural gas industry.[7] The Coast Guard is considering regulations to allow barge operators to carry produced wastewater from drilling operations.[8]

This chapter explores the impact of these changes, particularly on railroads and waterborne infrastructure (including ports). The rapid shifts in the use of shared infrastructure also raise new questions about system resilience and environmental impacts. These have been addressed in the broader discussions of those topics in Chapters II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure) and VII (Addressing Environmental Aspects of TS&D Infrastructure).

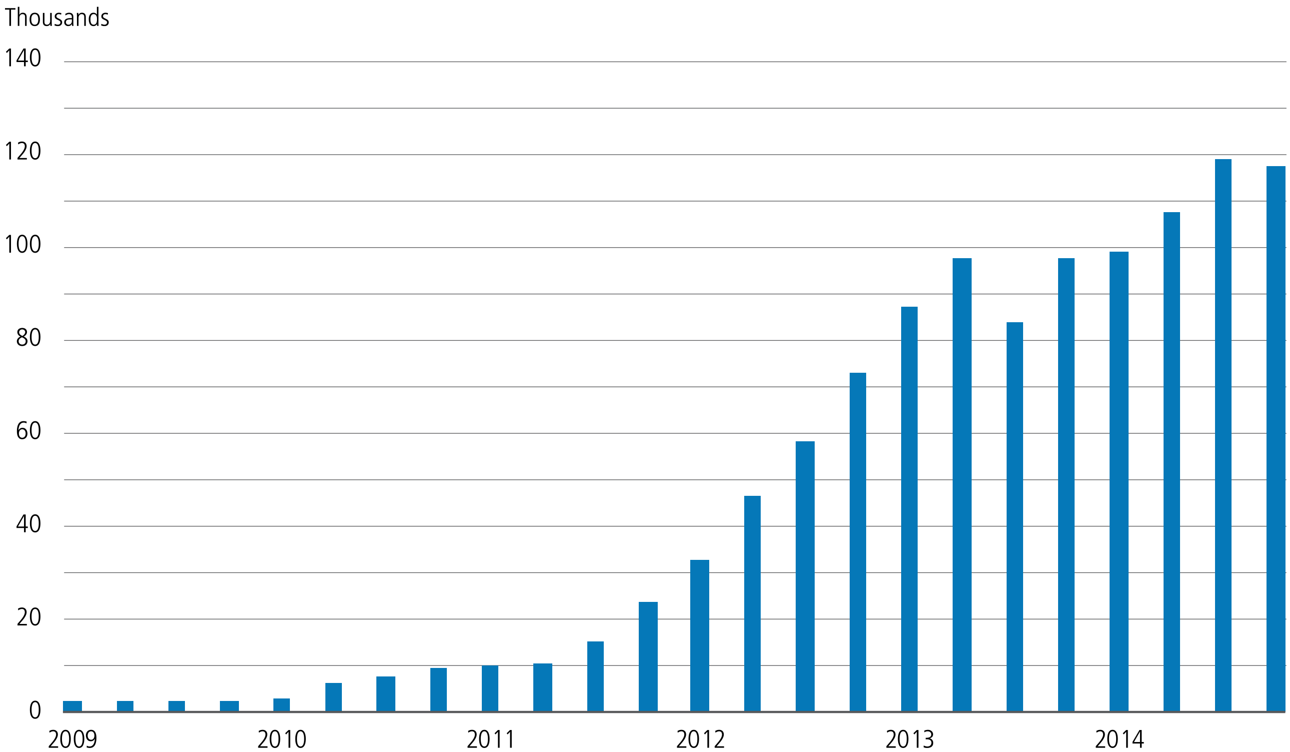
Rail Transport of Liquid Fuels: Status and Trends

Among all the shared freight transport infrastructures, the rail network may have experienced the most significant changes in the past several years. Increases in oil transport by rail are occurring on an existing system—a $60 billion plus freight rail industry that includes 140,000 rail miles operated by 7 large national (Class I) railroads,[a] 21 regional railroads, and 510 local railroads.[9]

Growth in Rail Transportation of Crude Oil

The dramatic increases in the use of rail to transport oil over the last four years can be seen in the volume of shipments, as represented by number of originated railcars carrying crude oil. In 2009, roughly 10,800 carloads of crude oil originated on U.S. Class I railroads.[10] By 2014, the volume of rail shipments had grown to more than 493,000 originated carloads of crude oil[11]—an increase of roughly 4,400 percent in 5 years (see Figure 5-1). The Energy Information Administration (EIA) estimates that, on average, more than 1,022,000 barrels of domestic and Canadian crude were moved in the United States by rail per day in 2014.[12,13]

Figure 5-1. Originated Class I Railcars of U.S. Crude Oil (2009–2014, Quarterly)[14]



The rapid increase in crude by rail is a function of the growth in new source of new oil production, particularly in North Dakota, as well as limited pipeline capacity for moving this oil to refiners on the East and West Coasts.

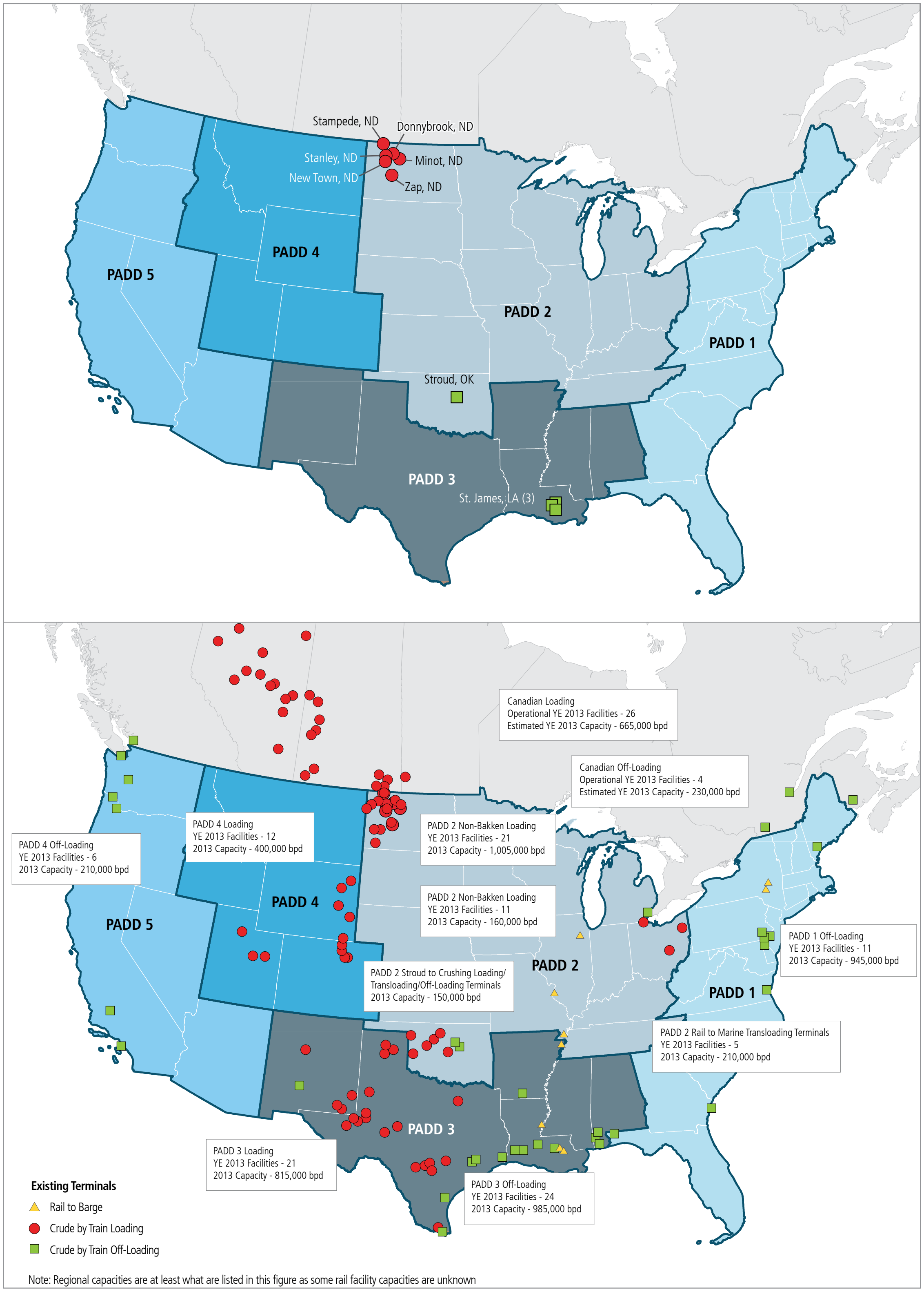
[a] Class I railroads are the Nation's largest railroads. For purposes of the accounting and reporting requirements of the Surface Transportation Board, railroads are divided into three classes. Class I is defined as those railroads with annual operating revenues (after being adjusted to compensate for inflation by a railroad revenue deflator formula) of more than $250 million. There are seven Class I railroads in the United States: Union Pacific Railroad, BNSF Railway, CSX Transportation, Norfolk Southern Railway, Canadian Pacific Railway, Canadian National Railway, and Kansas City Southern Railway.

There are several reasons for this phenomenal growth in such a short time. Railroads have an extensive existing track infrastructure, so new movements of crude oil by rail generally require only the construction of crude loading and unloading terminals and the expansion of the tank car fleet. This can be done relatively quickly compared to the time required to build or expand a pipeline. Rail also uses shorter-term contracts than the multi-year commitments required for pipeline construction, increasing the attractiveness of rail for oil producers and refiners who value such flexibility. While pipeline transport has substantially expanded to ship Midcontinent oil to the Gulf of Mexico, recent light oil production in Texas (where there has been an even larger increase than that of North Dakota) is competing for the available Gulf Coast refining capacity. Thus, East and West Coast refiners have become increasingly important customers for North Dakota oil, and this oil can travel by rail and barge to those destinations. Given these and other factors, as well as the difficulty and expense of pipeline build-out, crude by rail has become an important new component of the U.S. oil midstream, and it is anticipated that this new modal shift will have a place in the industry in the long-term.[15]

Rail shipment of oil has increased in most U.S. production areas, but it has been of particular importance for the Bakken Formation in North Dakota. As of mid-2014, rail accounted for more than 60 percent of total oil shipments from the Bakken and 100 percent of Bakken-to-West-Coast deliveries (from North Dakota to Washington State and then by barge to California).[16]

As a result of these factors, the number of crude oil loading, unloading, and barge transfer points in the United States and Canada has grown markedly in the past few years (see Figure 5-2). In 2010, there were only six rail loading facilities for oil, and no barge loading facilities. Three years later, in 2013, there were more than 60 rail loading facilities and a host of new barge loading facilities—an enormous change.

Figure 5-2. Crude Oil by Train Loading, and Offloading, and Rail-to-Barge Facilities for 2010 and 2013[17]



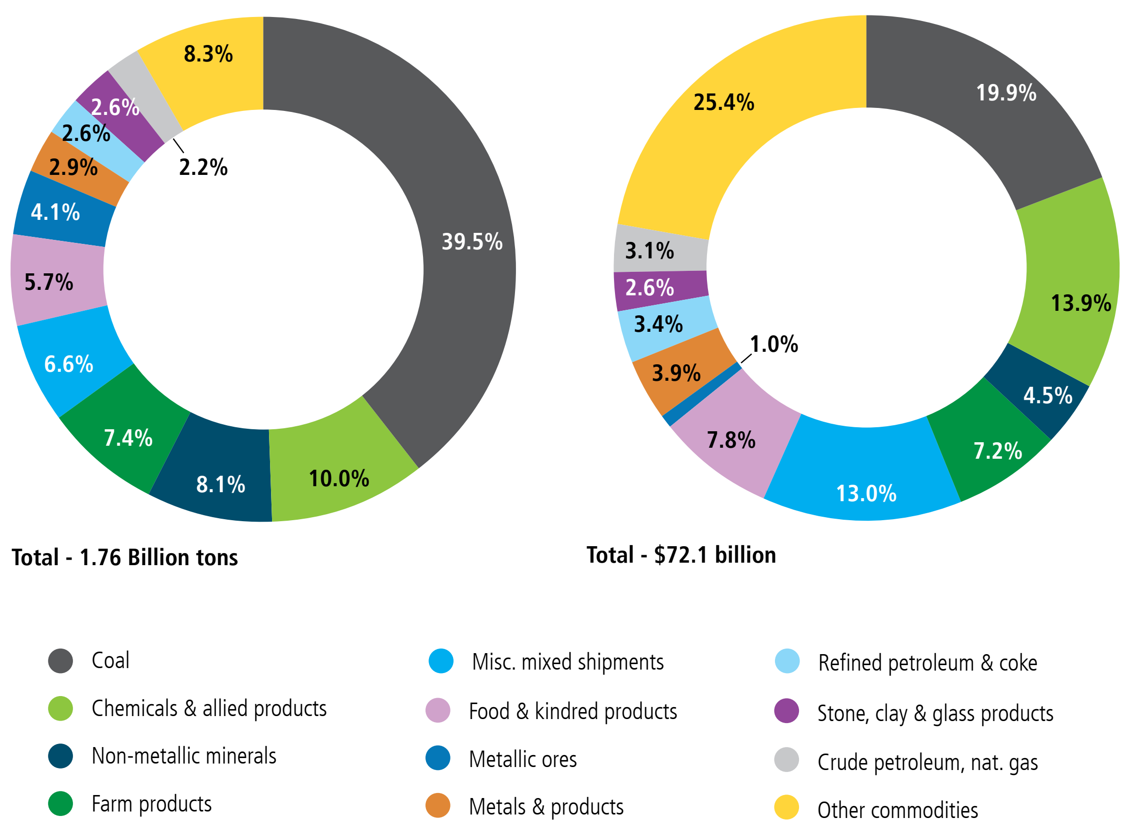
In 2010, the United States and Canada had six rail loading facilities for crude oil and four offloading facilities. By year-end 2013, crude oil by rail capacity had grown to include 65 loading facilities in Petroleum Administration Defense Districts II, III, and IV. Rail-to-barge facilities also increased.

Congestion and Competition among Commodities

This rapid increase in rail usage to transport oil has exacerbated existing capacity constraints in the rail systems, which are determined by multiple factors, including the throughput on the rails themselves, the operation of loading and unloading facilities, the number of locomotives and rail cars, train speed, and the availability of qualified employees.

The overlap of crude oil movements from the Bakken with coal moving out of the adjacent Powder River Basin, along with high volume of rail shipments of agricultural commodities from the region, present a singular set of challenges. Just as crude oil is transported to major ports for refining and export, so too are other commodities. Figure 5-3 shows the range of commodities shipped by rail in 2013, by percent of tonnage and revenue. The shipments of a number of these (such as crude petroleum, petroleum products, and sand used in hydraulic fracturing for oil and gas production, known as frac sand) have been influenced strongly by increased shale oil production in the West and development of natural gas resources in the East. For every new well, the Nation's railroads move approximately 40 rail cars of drilling material.[18] While most of the sand transported by rail is used for cement production, road building, and other construction purposes,[19] industrial sand, which includes frac sand, makes up about one-third of total carloads in this category, and this subcategory is growing about twice as fast as other sand and aggregate cargoes.[20] Frac sand makes up the bulk of this increase.[21] The need to move frac sand and other drilling inputs is a significant factor in the multi-year backlog of the production of various types of rolling stock—with back orders reaching 124,000 rail cars as of late 2014, an increase of 25 percent between June and December 2014.[22]

Figure 5-3.Class I Railroad Commodities, Percentage by Weight and Gross Revenue (2013)[23, 24]



Energy commodities and associated products account for a large portion of rail traffic. Crude oil has grown to 3 percent of national (Class I) rail revenues and more than 2 percent of tonnage. Transport of crude oil and petroleum products, chemicals, crushed stone, sand, and gravel, all of which are strongly influenced by shale oil production growth, are more significant on a regional basis, and, in those regions, tend to perturb both other energy and non-energy commodity movements on a constrained rail network.

While crude by rail may be a relatively small part of the national rail picture, on a regional basis, the constrained capacity created by oil movements emerges as a more significant issue. BNSF Railway is the largest rail carrier for both Bakken crude oil and Powder River Basin coal. BNSF currently carries about 75 percent of Bakken oil moving by rail.[25] Meanwhile, BNSF also is a major carrier for coal. More than 90 percent of coal carried by BNSF originates in the Powder River Basin.[26]

Economic Effects of Capacity Constraints

Agricultural product shippers have expressed concern that oil and coal shipments will crowd out their commodities on the already constrained rail network through the Plains States.[27] Rail service is particularly important for U.S. agriculture, as it is often the most cost-effective shipping mode available for moving grain and other relatively lower-value, bulk agricultural commodities from production areas to markets or transfer points for waterborne transportation.[28] Grain and oilseed shippers in Montana and North Dakota are particularly dependent on rail transportation because of their distance to inland waterways and the prohibitive cost of hauling grain long distances to markets by truck.[29]

In 2013 and 2014, the demand for rail service increased for most commodities, including coal, oil, intermodal containers, sand, and gravel. Near-record harvests in those years of corn, soybeans, and wheat in the Northern Plains States (Minnesota, Montana, North Dakota, and South Dakota) put additional stress on the rail transportation system, which was already operating with limited excess capacity.[30] The 2013 harvest was followed shortly by a severe winter, compounding the rail service interruptions grain shippers were experiencing. Smaller harvests in 2014 were met by improved rail service in the region.[31]

Many shippers, unable to pay the additional premiums for service, diverted more grain into storage or used alternative transportation at a higher-than-normal cost.[32] The growing imbalance between supply and demand for rail service was manifested as backlogged grain shipments and higher-than-average prices for empty grain cars sold in the secondary auction markets.[33] Based on an analysis of these markets, the Department of Agriculture's (USDA's) Agricultural Marketing Service concluded in October 2014 that "The past year was marked by both higher than anticipated demand for service and rail service disruptions….The current rail service problems have exceeded previous events in terms of both magnitude and duration, including Hurricane Katrina, which caused major disruptions throughout the entire agricultural transportation network."[34]

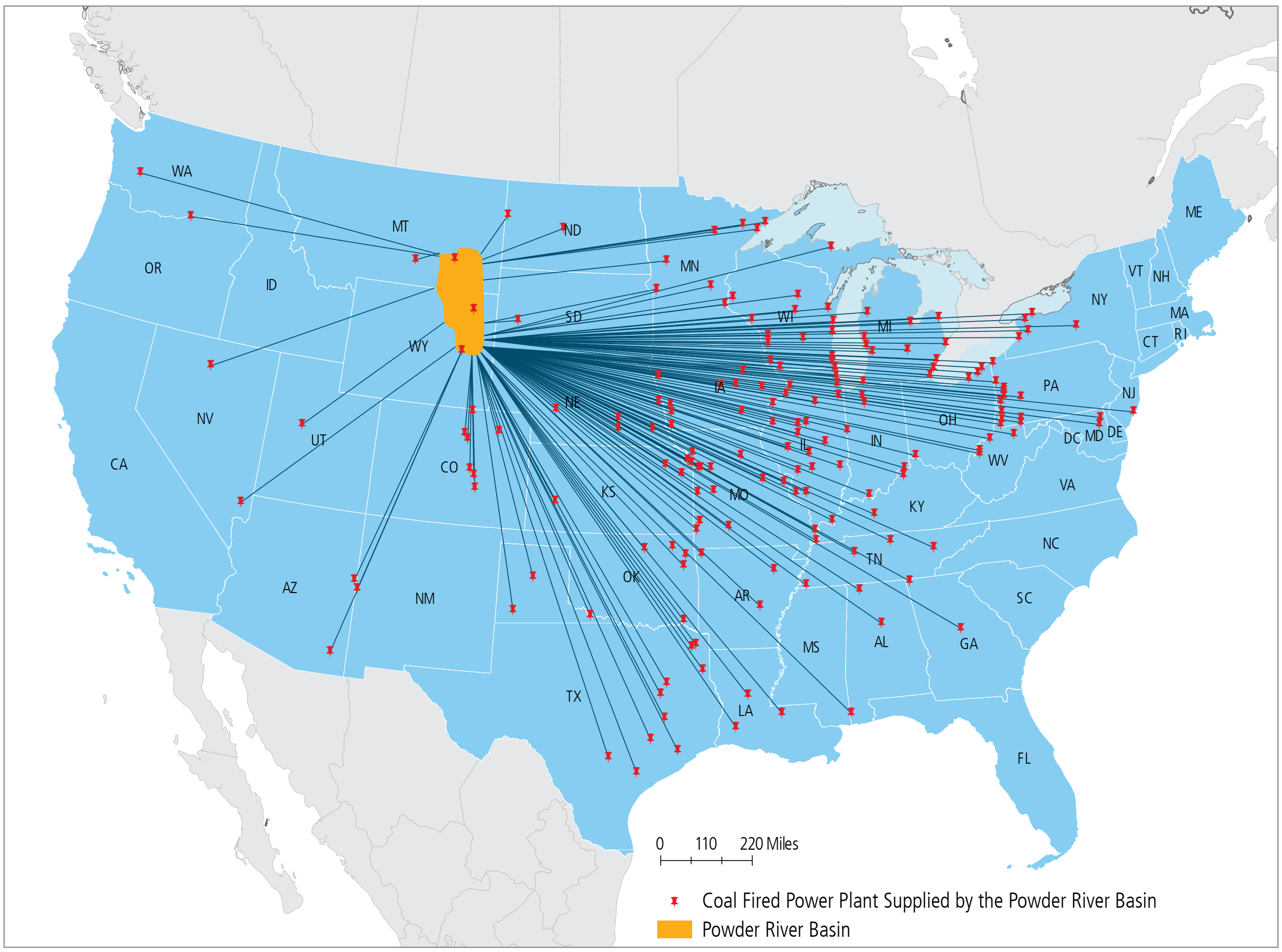
Prompted mainly by the financial struggles of U.S. railroads in a heavily regulated, economically inefficient environment, Congress passed the Staggers Rail Act in 1980. The Staggers Act has been successful in improving the financial health of the railroads, in part because carriers have become more efficient, eliminating excess capacity and redundancy and streamlining operations. Over the last 30 years (from 1980 to 2011), the number of ton-miles transported by rail has doubled, while Class I revenues per ton-mile have declined almost 40 percent in real terms.[35, 36]

The last several years, however, tell a different story. According to USDA, "Even though a recession started in December 2007, railroads continued to raise rail rates, partly to support record railroad capital investments and higher costs. Average real rail rates per ton-mile for all commodities increased 36 percent between 2004 and 2011. Real rail costs adjusted for railroad productivity increased 29 percent during the same. This indicates that most of the increase in rail rates was due to increased rail cost, but the increased rail rates also contributed to record rail profits. In comparison, real truck rates have increased 27 percent since 2004."[37] Protecting rail consumers from service disruptions is another prime factor in passage of the Staggers Act; a more streamlined rail system with limited excess capacity can, however, become overburdened when demand spikes, as it did in 2013 to 2014, which can leave shippers vulnerable to service deficiencies.

Coal Transportation by Rail

Coal represents 39.5 percent of total tonnage moved by rail and 19.9 percent of total revenues for the railroad industry, and it is viewed by many in the industry as its most important single commodity.[38] Sixty-eight percent of coal used to generate electricity is delivered to power plants by rail. Approximately 40 percent of all U.S. coal is produced in Wyoming, which is more than is produced by the next three highest-producing states combined.[39] The vast majority of Wyoming's coal is sent to power plants in 34 states, almost all of this by rail. Eight states obtain more than 90 percent of their domestic coal from Wyoming,[40] giving these states an enormous interest in ensuring reliable rail deliveries of coal. Figure 5-4 illustrates the reach of transport from the Powder River Basin to coal-fired units across the Nation.

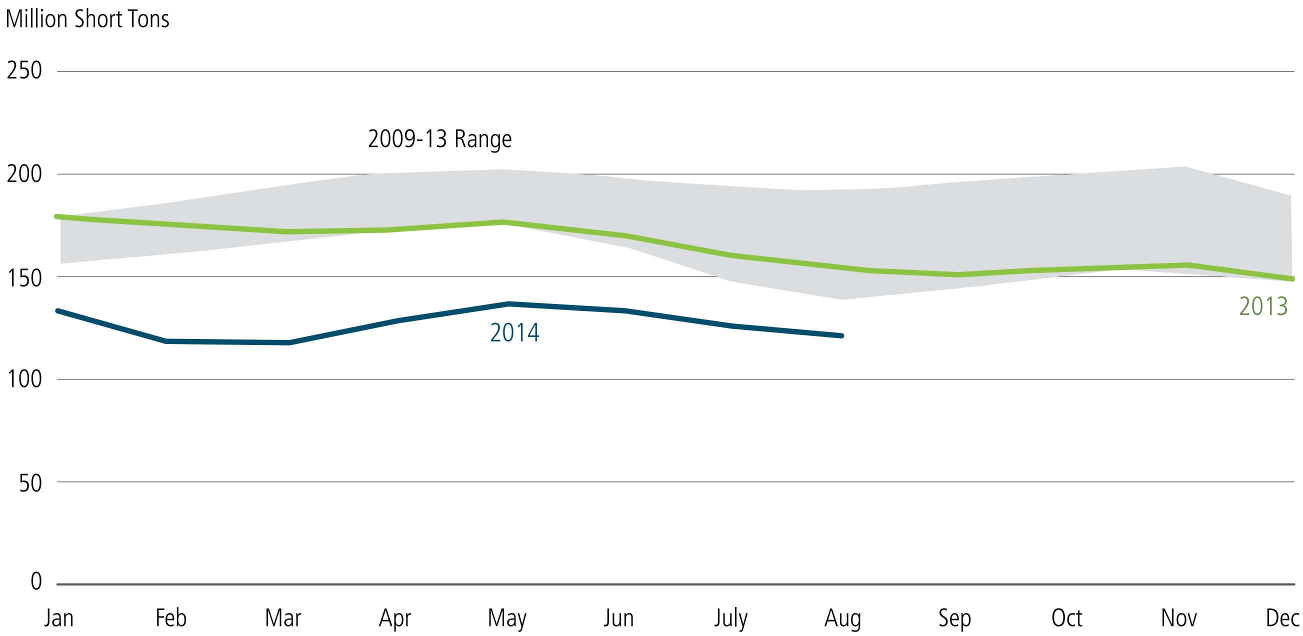
Figure 5-4. Coal-Fired Power Plants Supplied by the Powder River Basin[41]



The vast majority of Powder River coal is sent out of Wyoming to power plants in 34 other states.

The EIA's recent analysis of coal stockpile levels at electric power plants (see Figure 5-5)[42] confirms that stockpiles are low in both absolute levels and days of burn compared to recent norms—both nationally and regionally (particularly in the Upper Midwest where rail congestion has been problematic). The EIA attributes this to several causes, including record grain harvests and transport of crude oil.

Figure 5-5. Monthly U.S. Coal Stockpile Levels at Electric Power Plants, 2009–2014[43]



Stockpiles of coal at power plants in 2013 and 2014 were either at the lower end of, or below, the 5-year range of stockpile levels from 2009 to 2013.

Of those coal-fired plants served by rail, most are served by only one Class I railroad (these plants are referred to as "captive" to the single railroad).[b] The power producers that own these plants have been concerned for decades about service and rate problems based on this lack of competition. The issue of coal delivery shortfalls in some regions has recently become more pronounced as Bakken crude and other rail traffic has increased.[44] There have been numerous instances where coal-fired units have been left with a week's worth of coal or less.[45] Four small plants in Minnesota shutdown in fall 2014 to conserve coal stocks; grid operators were able to dispatch from non-coal units for use during the peak winter demand period,[46] demonstrating the value of diersity to reliable energy systems.

> In recognition of the importance of ensuring adequate coal reserves for electricity, on December 30, 2014, the Surface Transportation Board issued a decision on Docket No. EP 724: "The Board directs BNSF Railway Company to submit a detailed description of the contingency plans the carrier would use to help mitigate an acute coal inventory shortage at one or more generating stations in a region."

The railroad companies are aware of the issues concerning adequate service and have responded to service performance issues. Some of the steps they are taking to address these issues include significant orders for additional rolling stock and double tracking in some locations. On November 20, 2014, BNSF Railway announced plans for record capital spending in 2015 of $6 billion for rail updates, track replacements, and expansion projects. "Nearly $500 million of that expansion work will occur in the Northern region, which is where BNSF is experiencing the fastest growth. That region primarily serves agriculture, coal, crude oil, and materials related to crude oil exploration and production."[47]

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b Many agricultural shippers are also captive to one railroad. According to the Department of Agriculture, "only about five percent of grain elevators are served by more than one railroad." See: Department of Agriculture and Department of Transportation. "Study of Rural Transportation Issues." April 2010. ntl.bts.gov/lib/32000/32800/32855/STELPRDC5084108.pdf.

Ethanol Transportation by Rail

Ethanol production in the United States has increased steadily over the last few decades, reaching a historically high level in 2011. By 2012, ethanol displaced approximately 10 percent of U.S. gasoline demand by volume. Ethanol production is primarily located in the Midwest where most of the corn feedstocks are grown.[48] Ethanol blending into gasoline takes place at petroleum product distribution terminals across the country, so large amounts of ethanol must be transported from production plants to the distribution terminals. These shipments from production plants to distribution terminals typically occur by rail, which accounts for around 70 percent of ethanol transport,[49] with the final product then delivered by truck to retail outlets.

Roads, rail, and waterborne infrastructures are used extensively for ethanol transport because fuel quality specifications, ethanol's water-absorbing properties, and the complications presented by multiple owners of pipelines prevent the transport of ethanol in the same pipelines as petroleum products. Ethanol is likely to rely on shared infrastructure for its transport for the foreseeable future. Attempts to construct dedicated transportation infrastructure have not been successful—a $4-billion ethanol pipeline project from the Midwest to the Northeast was explored by POET and Magellan Midstream Partners, but the project was abandoned in 2012 after it was determined to be economically infeasible.

Safety of Rail Transport of Liquid Fuels

Rail safety has become a key issue as rail transport of liquid fuels has grown. Several high-profile crude-by-rail accidents occurred since 2013, the most devastating of which killed 47 people in Lac-Mégantic, Quebec. Others, such as those in Aliceville, Alabama; Casselton, North Dakota; Lynchburg, Virginia; and Mount Carbon, West Virginia, resulted in significant environmental and property damage after tank cars derailed, ruptured, and the oil caught fire. Similar accidents involving ethanol rail shipments have also raised concerns about the safety of rail tank cars and the shipment of these flammable hazardous commodities across the United States. These accidents have highlighted the need for additional monitoring, enforcement, and inspection, as well as setting new safety design requirements for tank cars.[50]

The rail transport infrastructure for liquid fuels also faces reliability and resilience challenges, which are described in more detail in Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

Administration Activities and Plans

The Surface Transportation Board (STB) is an independent entity within the Department of Transportation that is the successor to the Interstate Commerce Commission. It is charged with resolving railroad rate and service issues and rail restructuring transactions (such as mergers, line sales, line construction, and line abandonments). The Pipeline and Hazardous Materials Safety Administration at the Department of Transportation (DOT) regulates the transportation of hazardous materials by all modes, including rail, while the Federal Railroad Administration is responsible for rail safety.

Congestion and service. In light of the problems of rail congestion affecting shipments of key commodities:

- STB issued a decision requiring all Class I railroads to publicly file weekly data reports regarding service performance of unit trains carrying coal, crude oil, ethanol, and grain. Railroads began filing performance data in October 2014 in addition to reports on coal, grain, and intermodal trains.
- STB has begun informal interactions with the Energy Information Administration to share data and insights on overall energy flows among major U.S. regions.
- On December 30, 2014, STB issued a decision directing the BNSF Railway Company "to submit a detailed description of the contingency plans the carrier would use to help mitigate an acute coal inventory shortage at one or more generating stations in a region."[c]
- On December 30, 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. The purpose of the reporting requirements, in part, is to give both STB and shippers/stakeholders greater transparency into railroad operating conditions.
- STB has two ongoing proceedings on rail business practices. EP 711 concerns competitive access in the railroad industry and whether to revise agency rules governing shipper requests for competitive access to another railroad. EP 665 would ensure that STB's rate complaint procedures are accessible to grain shippers and provide effective protection against unreasonable freight rail transportation rates.

Safety. 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.

- To raise awareness of local emergency responders to oil/rail accident, in July 2014 DOT released a "Lessons Learned Roundtable Report," providing key findings from a meeting of DOT and Virginia's Department of Fire Programs to affected fire chiefs and emergency management officials.
- The Federal Emergency Management Agency assessed training needs and requirements in 28 states with oil rail routes identified by DOT. Eight of these states indicated a need for training, and the Federal Emergency Management Agency is working with these states to prioritize and ensure their participation in currently available programs.
- The Pipeline and Hazardous Materials Safety Administration issued a Notice of Proposed Rulemaking on August 1, 2014, which contains 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 mid-2015.[d]
- The Pipeline and Hazardous Materials Safety Administration and the Department of Energy have entered into an agreement to conduct research and development on the properties (including behavior in fires) of unconventional crudes.
- 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.[e] The training is available online.

* Average coal unit train loadings versus planned loadings, by coal production region.

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[c] Department of Transportation, Surface Transportation Board. "United States Rail Service Issues." p. 1. Docket No. EP-724. December 30, 2014. http://www.stb.dot.gov/decisions/readingroom.nsf/WebDecisionID/43733. Accessed February 22, 2015.

[d] 79 Fed. Reg. 45016. "Hazardous Materials: Enhanced Tank Car Standards and Operational Controls for High-Hazard Flammable Trains." August 1, 2014. http://www.gpo.gov/fdsys/pkg/FR-2014-08-01/pdf/2014-17764.pdf. Accessed April 1, 2015.

[e] National Response Team. "Emerging Risks Responder Awareness Training: Bakken Crude Oil." 2015. http://www.nrt.org/production/NRT/NRTWeb.nsf/AllPagesByTitle/SP-EmergingRisksResponderAwarenessTrainingBakkenCrudeOil%282015%29?Opendocument. Accessed March 17, 2015.

QER Recommendations

RAIL TRANSPORT

In light of the significant activity undertaken by the Administration in recent years, and the fact that some of these proceedings and relevant interagency research projects are still in progress, additional major recommendations should await finalization of these initiatives before next steps can be determined. In the interim, recognizing the crucial role that rail will continue to play in energy commodity transport, we recommend continued focus on the following:

Enhance the understanding of important safety-related challenges of transport of crude oil and ethanol by rail and accelerate responses: The cooperative work of the Department of Energy (DOE) and the Pipeline and Hazardous Materials Safety Administration, as well as the forward movement of strengthened safety regulations at the Department of Transportation (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, the Surface Transportation Board, 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, DOE, in coordination with relevant Federal agencies, should examine the role of freight rail in utility operations, the growing complications created by freight infrastructure constraints on multiple energy products and other bulk commodities, and 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: This should include data on monthly movements of crude by rail. The Surface Transportation Board and the EIA should continue their cooperative work to share data and insights to improve the ability of both agencies to better understand the changes underway in energy shipments by rail. Congress should provide the EIA with the funding increase requested in the President's Budget Request for Fiscal Year 2016 to support this activity.

Waterways, Ports, and Connectors: Status and Trends

The greater Mississippi Basin and Intracoastal Waterways have more miles of navigable internal waterways than the rest of the world combined, and the U.S. Atlantic Coast has more major ports than the rest of the Western Hemisphere. The Nation's coastal ports and inland waterways are part of a larger waterborne transportation network, sometimes called the Marine Transportation System (MTS).[f] The MTS includes 25,000 miles of navigable channels and related infrastructure, such as publicly and privately-owned marine terminals, intermodal connections, shipyards, and related repair facilities.[g]

[f] Connecting land-side infrastructure includes more than 174,000 miles of rail in the 48 contiguous states, as well as Canada and Mexico; more than 45,000 miles of interstate highway, supported by more than 115,000 miles of other roadways; and more than 1,400 designated intermodal connections. Source: DOT.

[g] The 25,000 miles of navigable channels includes 12,000 miles of inland waterways (including two intracoastal waterways) with 229 lock chambers at 187 sites; and 926 coastal and inland ports (including the ports of the Great Lakes) with 13,000 miles of channels and 12 locks (not including the locks of the St. Lawrence Seaway).

Waterborne transportation of commodities and other goods is critical to international trade and the U.S. energy economy. The Nation's coastal ports and inland waterways handle almost 2.3 billion tons of commerce annually. According to DOT, coastal deep-water ports alone handle 70 percent of our Nation's imports and exports by weight. The expected growth over the next 30 years in the volume of imports and exports transported by sea will have "dramatic implications for America's ports and transportation system and will lead to greater congestion at America's coastal ports."[51]

Unlike railways or pipelines, much of the waterway infrastructure is federally maintained; landside port and connector infrastructure used in conjunction with these waterways is often operated by state and local governments and private industry. The Army Corps of Engineers (USACE) is responsible for managing and maintaining most of the Inland Marine Transportation System, including navigation locks and dams. Some locks are federally owned and maintained by DOT's Saint Lawrence Seaway Development Corporation in cooperation with the Canadian government.

Energy commodities make up the largest proportion of U.S. waterborne cargo traffic, and waterborne commerce is essential to the energy sector. In 2012, crude oil, refined petroleum products, and coal were 55 percent of all U.S. waterborne cargo traffic by weight. Nearly 15 percent of all petroleum products consumed in the United States are shipped on inland waterways.[h] Sixty percent of the oil Americans consume arrives in a U.S. port, including all of Alaska's crude.[52]

Growth in Waterborne Transport of Energy

Similar to the trends in rail transport, new domestic energy production is spurring rapid growth in the waterborne transport of energy commodities and related products, increasing the demands on the existing system. Shippers of those commodities seeking options for low-cost, high-volume transport are turning to the Nation's network of navigable costal ports and inland waterways.[53] In the near future, additional drivers of waterborne transport of energy commodities will likely include the exports of liquefied natural gas, the expansion of existing refineries, and the development of new petrochemical plants. Some estimates show greater than $125 billion in planned petrochemical plant investments, most of which will occur along the Gulf Coast and other U.S. waterways.[54]

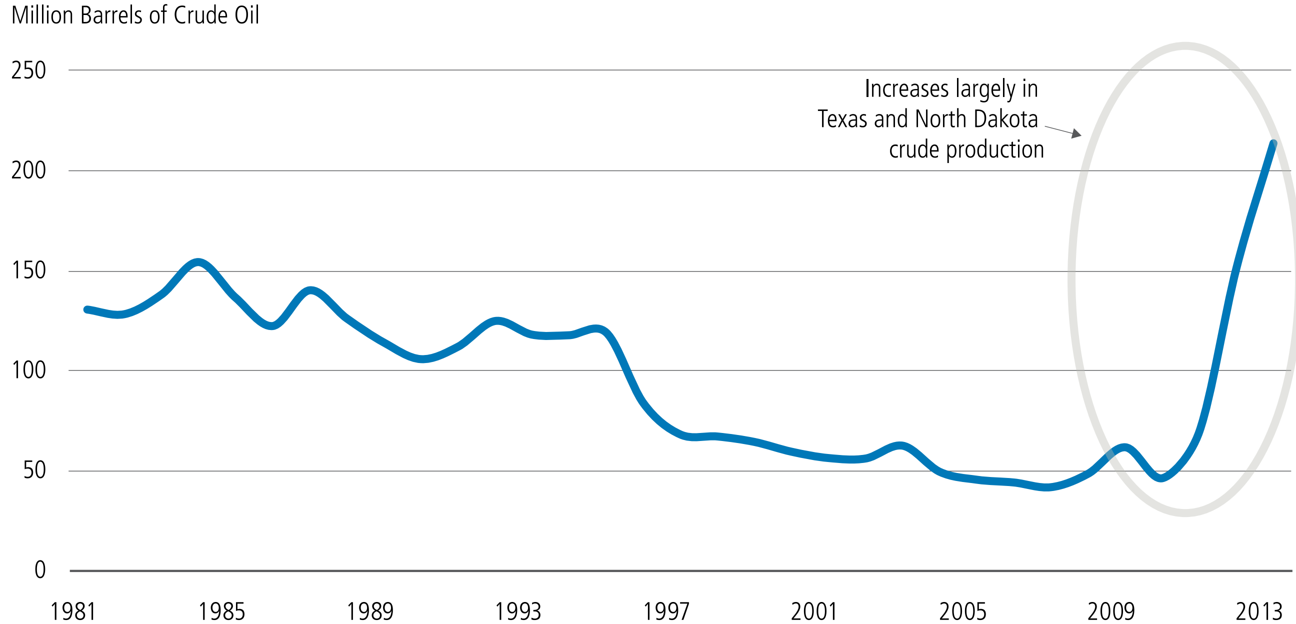
U.S. ports and inland waterways transported nearly 7 billion barrels of crude and petroleum products in 2012.[55] Of that total, 2.5 billion barrels were transported on barges on the inland waterways from port to port along the coast or on the Great Lakes—or in intra-port transfers.[i] Utilization of barges for petroleum transport has risen dramatically, as shown by the sharp increase in refinery receipts by barge from 46 million barrels of domestic crude in 2010 to more than 210 million barrels in 2013 (see Figure 5-6). Despite a decrease in oil imports, barge deliveries of foreign crude have risen more than 60 percent since 2011.[56] Barge transport of oil typically is inter-modal, where oil may travel by pipeline or rail to a terminal and then be dispatched on barges to cover the last segment of the trip to refineries.[j] This configuration is particularly important for refineries without rail access.

[h] Calculated based on 2012 data. The total petroleum products consumed are 18,000 to 19,000 barrels per day. Source: Energy Information Administration. "US Weekly Product Supplied." www.eia.gov/dnav/pet/pet_cons_wpsup_k_w.htm. Accessed January 21, 2015. The total petroleum products moved on inland waterways in 2012 was 111,129 tons. Source: Army Corps of Engineers. "Waterborne Commerce of the United States: Calendar Year 2012." Table 2-1. November 20, 2013. OMB No. 0704-0188. www.navigationdatacenter.us/wcsc/pdf/wcusnatl12.pdf. Conversion from tons to barrels based on an average product density of 8 barrels per ton.

[i] Domestic shipments by barrel were estimated using data on domestic shipment by short ton reported by the Army Corps of Engineers. Based on the composition of petroleum products in domestic shipments, average densities from the Energy Information Administration (www.eia.gov/cfapps/ipdbproject/docs/unitswithpetro.cfm) were used to estimate an average conversion of 7.0–7.5 barrels per short ton.

[j] Therefore, while refinery-receipts-by-mode is a useful metric for showing utilization of a specific mode over the last miles traveled to the refinery, it is not necessarily accurate for cross-modal comparisons.

Figure 5-6. Annual Refinery Receipts of Domestic Crude Oil by Barge[57]



Refinery receipts of crude oil by barge have increased by more than 300 percent since 2010.

Expanded use of inland waterways for the transportation of energy commodities and a corresponding increase in rail transport of many of those same products is one of the factors in the increased rates for barge shipments of grain and other commodities.[k] While barges have the lowest per-ton prices, they are geographically limited by access to navigable waterways and seasonal availability. Also, timeliness is a critical variable; it can, for example, take 11 days to move grain by barge from Minneapolis, Minnesota, to New Orleans, Louisiana, by barge but only 4 days by rail.[58]

Total domestic movements of crude oil, including coastal ocean shipping, have also risen in recent years.[59] Most of the Nation's refining capacity is located near a coastline. This allows refineries to receive, via waterborne transport, crude from foreign sources, domestic offshore production, and other port facilities, as well as to export refined products. Coastal barges and tankers, while less direct options than rail, could soon play a bigger role in moving domestic oil to East Coast or West Coast refineries.[60] The cost of using domestic port-to-port transport routes is subject to the Jones Act.[l] Utilization rates of Jones Act tankers and barges are reported to now range from 90 percent to near the maximum achievable rate of 95 percent.[61]

[k] The Mississippi River and the Illinois Waterway are the primary inland waterways for moving agricultural products by barge. They are especially important for transporting bulk grains and oilseeds from the Midwest to export ports in the New Orleans region. Other important waterways for agriculture include the Columbia River in the Pacific Northwest. Source: Department of Agriculture. "Study of Rural Transportation Issues." December 2010. Alternative overland routes by rail to ports are also available and heavily used, with shippers choosing depending on price and distance to a commercial waterway.

[l] The Jones Act refers to the Merchant Marine Act of 1920, which states that merchandise shipped between U.S. ports must be on a ship that was built in the United States, is flagged as a U.S. ship, and is owned and operated by U.S. citizens. Waivers have been issued for certain provisions of the act during national emergencies (e.g., Hurricane Katrina, Hurricane Sandy, etc.). The Jones Act also applies to merchandise transport on the Great Lakes.

The 10 U.S. ports and port systems with the most energy-related commodity shipments (coal, crude oil, and petroleum products), measured by tonnage, are shown in Table 5-1.[m]

Table 5-1. Top 10 Port Systems by Total Energy Commodity Shipments, 2013 (millions of short tons)[62]

Port Channel System	Crude and Petroleum Products	Coal	Total Energy	Energy as a Percent of Shipments
Lower Mississippi (LA)	161	47	208	48
Houston/Galveston (TX)	200	3	203	69
Beaumont/Port Arthur (TX)	115	0	115	89
Port of NY/NJ	80	<1	80	59
Delaware River	62	0	62	82
Corpus Christi (TX)	58	0	58	77
Port of Virginia	2	50	52	66
Lake Charles (LA)	49	0	50	88
LA and Long Beach (CA)	46	2	47	33
Huntington - Tristate (WV)	8	32	41	87

Energy shipment is concentrated on the Gulf Coast, but half of the 10 ports moving the most energy commodities are found elsewhere in the United States. The inland waterways are also important to the shipment of energy commodities to and from coastal ports.

The changes in energy commodity traffic are occurring as waterborne cargo volumes are increasing at some ports, a trend that will continue as the completion of the Panama Canal expansion project brings even larger "Post-Panamax"[n] cargo vessels to U.S. harbors.[63] Overall marine freight by tonnage through coastal ports is expected to increase domestically between 2010 and 2020,[64] while over the next 20 years, the total volume of imports and exports through U.S. ports could double.[65]

Future Investments in Waterborne Transportation Infrastructure

These relatively recent and rapid increases in energy-related demands for waterborne transport have brought a new focus on the Nation's port and related infrastructure. DOT's "Beyond Traffic 2045" report[66] concludes that "Looking to the future, several critical trends will have a major impact on the performance of critical marine links in our transportation systems." They include the following:

- Increasing imports and exports and containerized freight will lead to greater congestion on America's coastal and inland ports.
- Investment in ports, harbors, and waterways will be essential to meet the demand of increased trade and competition."

[m] For this analysis, Port Channel Systems refer to a group of ports on a single Federal navigation channel. Houston/Galveston comprises Houston, Galveston, Texas City, and Victoria. Lower Mississippi comprises New Orleans, Baton Rouge, Plaquemines, and the Port of South Louisiana. Port of New York/New Jersey comprises New York City; Albany; and Newark, New Jersey. Delaware River comprises Philadelphia; Marcus Hook, Pennsylvania; Paulsboro, New Jersey; Camden-Gloucester, New Jersey; New Castle, Delaware; and Wilmington, Delaware. Port of Virginia comprises Newport News and Norfolk Harbor.

[n] Post-Panamax ships are those that cannot fit through the current size of the Panama Canal. Expansion of the canal now underway will significantly increase the size of ships that can pass through it.

Funding mechanisms for maintaining or improving coastal ports, inland waterways, and related infrastructure is a shared responsibility. The available funding sources depend in part on the nature of the investment and the type of infrastructure involved.[67]

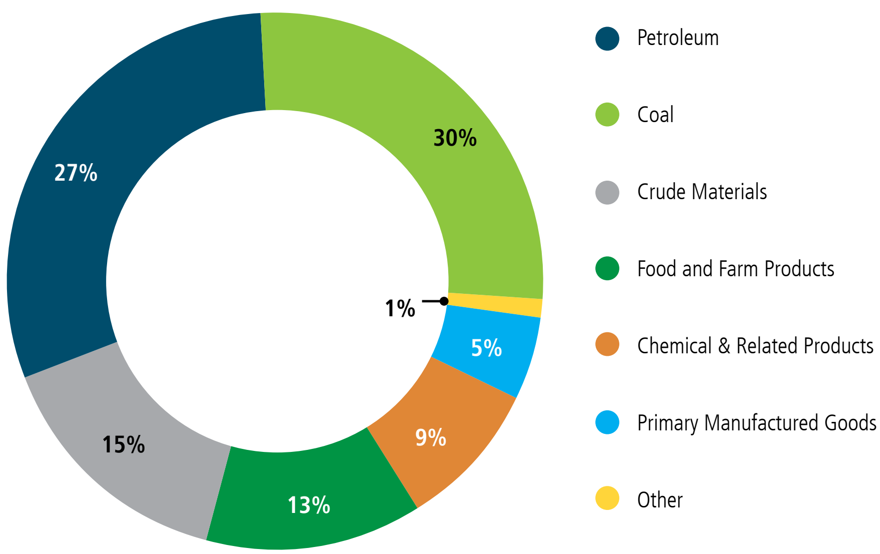
Under current law, the Federal Government is authorized to pay all operations and maintenance costs for inland waterways and generally for half the cost of the construction, replacement, rehabilitation, and expansion of locks and dams on these waterways. The other half is paid for with an excise tax on diesel fuel used on the 27 fuel-taxed inland waterways, which in effect is deposited in the Inland Waterways Trust Fund.[68]

The Federal Government is authorized to pay 100 percent of the cost of eligible operations and maintenance at coastal ports for all work at depths up to 50 feet depth. For channels at coastal ports, the Federal Government provides a 50 percent to 90 percent cost share for new construction (this varies by channel depth needs and contributions by sponsors).[69] There are two port channel systems in use or under construction that exceed 50 feet depth—Los Angeles/Long Beach and Seattle/Tacoma—both of which have limited needs for maintenance dredging. Additional ports have been authorized to depths greater than 50 feet and may require non-Federal maintenance dredging expenditure, but construction has not yet begun.

Improving Inland Waterways

The largest categories of tons of commodities shipped on U.S. inland waterways are coal and petroleum (by tonnage). Together, these energy commodities were 57 percent of goods transported on inland waterways in 2012.[70] In addition, a significant proportion of chemicals and crude materials shipped on inland waterways are energy related (see Figure 5-7).

Figure 5-7. Inland Waterborne Shipments by Commodity, 2012 (by weight)[71]

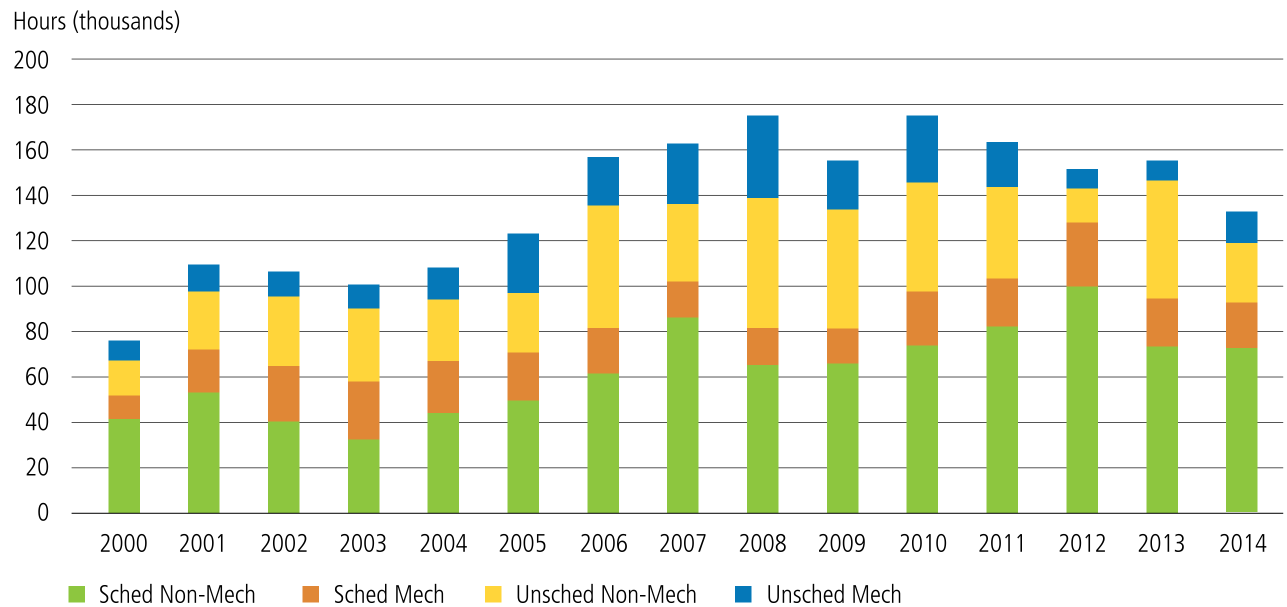


Energy commodities are the dominant commodity group in U.S. waterborne cargo traffic. In 2012, crude oil, refined petroleum products, and coal were 56 percent of all shipments by weight on U.S. inland waterways. Energy commodities were a similarly large portion by weight of all domestic and international waterborne shipments in the United States.

Inland locks and dams are a critical component of the Nation's inland waterways system. More than 55 percent of the navigation lock chambers were built in the 1960s or earlier, yet almost half of the overall tonnage moving on the inland system passes through them.[72] According to a joint USDA/DOT study, "Although aging, the locks and dams on the river system are generally reliable. As locks age, however, repairs and maintenance becomes more extensive and expensive."[73] The Corps gives priority to the structures that support the most commercial traffic, and invests heavily in their maintenance and periodic rehabilitation. Maintaining the locks and dams of the inland waterways is becoming more costly over time, due primarily to two factors – the condition of some of the components, as well as cost increases in the broader economy.

The Administration has made progress in reducing time losses from lock closures in recent years. Due in part to Federal investment, the number of main lock chamber closures on high and moderate commercial use waterways (those that carry at least 1 billion ton-miles of traffic annually) due to preventable mechanical breakdowns and failures lasting longer than 1 day and lasting longer than 1 week has decreased significantly since fiscal year 2010. Non-mechanical failures—such as weather, drought, floods, ice, and current conditions—also create unscheduled lock outages, so impacts from climate change may play a role in inland waterway availability in the future (see Figure 5-8).

Figure 5-8. Hours of Lock Unavailability on U.S. Inland Waterways, 2000–2014[74]



Progress in reversing the trend of increasing outages due to unscheduled mechanical breakdown must continue for the inland waterways to remain a reliable and affordable transportation option for shippers.

A typical round trip from New Orleans to the Upper Midwest and back on the inland waterways can take up to 30 days. Although shippers expect to encounter occasional delays due to weather and equipment related conditions, according to USACE, "Shippers recognize that the inland waterways are a low-cost method of transportation...they will encounter a delay on some trips due to a weather or equipment related conditions but they remain uneasy about the reliability of this system, noting observed trends in availability. To the extent that system outages disrupt waterborne service, shippers and carriers will experience additional, sometimes unexpected, costs."[75] In spite of these risks, shippers move roughly 600 million tons of cargo annually on the inland waterways.

Inland shippers that want to move a product more quickly over long distances generally have the option to use rail. However, strong demand for rail due to increased oil, petroleum products, sand, ethanol, and more recently, coal (after a decline coal transport is on the upswing again), combined with track delays and rail speed reductions, has reduced rail transport options. According to USDA, in 2013–2014, "rail service in the United States is currently operating near full capacity as the United States recovers from the recession and production of ethanol and unconventional oil and gas are near record highs. Because railroads are operating near full capacity, transportation disruptions (e.g., adverse weather conditions or an unexpected sudden surge in demand) are likely to cause performance problems for rail transport. In addition, routine track maintenance by an individual railroad may result in longer-than-anticipated disruptions in certain areas and can lead to delays that spill over to the larger parts of the connected rail system."[76]

On the principal inland waters, which carry 90 percent of the traffic, additional capital investment beyond current funding levels will be needed to maintain the current level of performance into the future. To address this concern, the Administration has proposed legislation to reform the way that the Federal Government finances capital investment on these waterways.[77] Funding for water infrastructure is split between Federal and users of these waterways. The changing domestic energy landscape presents an opportunity for Federal and private sector investment to accommodate new needs that are not reflected in current project plans.

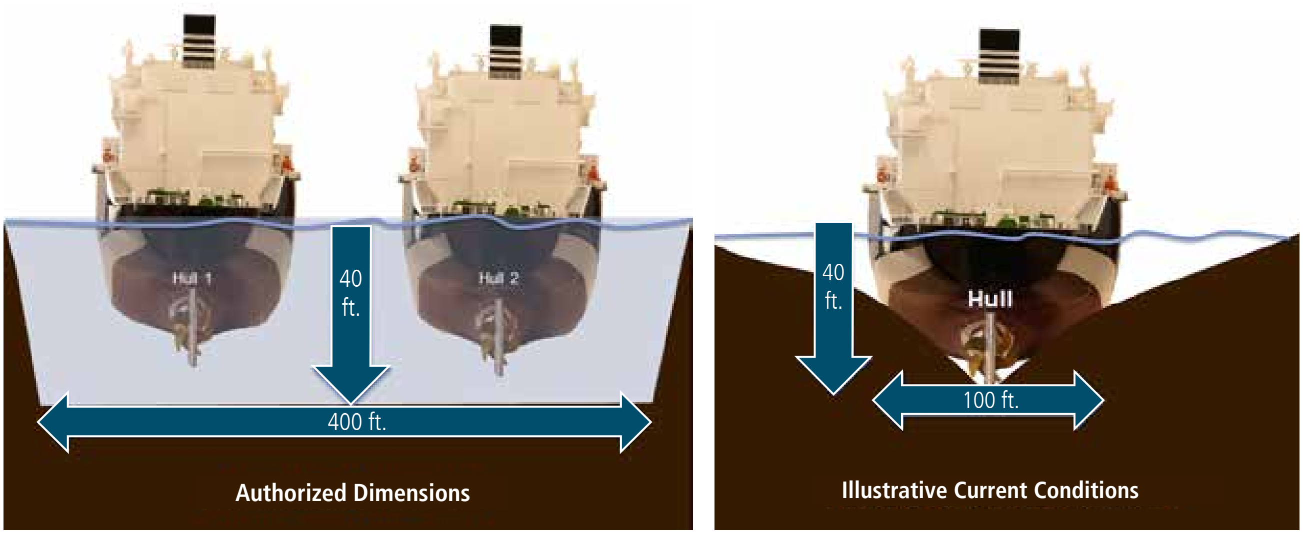
Port and Harbor Infrastructure Investments

On November 12, 2014, Vice President Biden issued a call to action for greater investment in U.S. port facilities, noting, "We are investing less than 1 percent of our gross domestic product in transportation infrastructure... ranking 28th in the world among advanced nations. That is simply unacceptable...we need to do everything we can to ensure that the whole infrastructure system is connected, especially to our ports."

Large ports generally are able to successfully handle today's levels of cargo at the current funding levels for harbor maintenance and related work, although, as noted, port traffic is expected to grow over the next decades. However, some carriers may need to proceed more slowly due to hazards, or to light load their vessels, or offload some cargo to smaller vessels. Depending on the channel conditions, tankers or other vessels may encounter arrival or departure delays (e.g., until another ship has moved through that section of the channel, or until high tide) or restrictions that reduce the recommended vessel draft (which can affect how much cargo some ships can hold).

An example can be found in Louisiana's Calcasieu Ship Channel, which provides access to the Port of Lake Charles—the 13th largest deep sea port in the Nation and an important maritime hub for the U.S. energy industry—and could be used in the near future by liquefied natural gas tankers to access federally approved gas export terminals. In 1968, USACE deepened and otherwise improved the Calcasieu River and Pass to the current authorized Federal dimensions of the channel, which are 400 feet wide and 40 feet deep. USACE dredges the most critical reaches of the channel annually, but shoaling reduces the channel to less-than-authorized dimensions (see Figure 5-9). To help address reduced depths and channel narrowing, which reduces the efficiency of commercial operations, the Calcasieu River and Pass Federal navigation project received $27.7 million of fiscal year 2015 Operation and Maintenance funds, which will allow the Corps to dredge the most vital portions of the channel to optimize safety and efficiency.

Figure 5-9. Calcasieu River Ship Channel, Illustration (not to scale) of Authorized Dimensions and Example Conditions Where Shoaling Occurs[78]



Inadequate dredging can lead to shoaling and narrowing of channels, forcing tankers and other large vessels to reduce cargos, idle until high tide, or be subjected to one-way traffic restrictions.

Another example of the role of maintenance dredging is the main channel of the lower Mississippi River between Baton Rouge and the Gulf of Mexico. In 2011, shoaling in some areas led those who are responsible for vessel operation to place restrictions on certain parts of the river, until USACE addressed the concern by performing additional maintenance dredging.[79]

USACE is working to develop better analytical tools to help determine the appropriate spending level for harbor maintenance and related work at coastal ports, based on the economic and safety return, as well as a comparison with other potential uses of available funds. The sufficiency of a channel for commercial navigation depends upon the economic and safety return from an additional potential increment of maintenance work, which in turn is a function of actual traffic utilization patterns, the condition of the channel, and other factors.

Dredging varies from port to port. Due to geographic differences, Gulf Coast ports generally silt in more quickly—and thus require much more maintenance dredging—than many ports on the East Coast or West Coast.[80] Ports in the Great Lakes region also require significant maintenance and account for a major portion of the Corps' dredging activities. Regardless of where a port is located, the proper placement of dredged material can be a significant portion of the total cost of dredging. A discussion of the environmental aspects of dredging materials is contained in Chapter VII (Addressing Environmental Aspects of TS&D Infrastructure).

Port Connector Infrastructure Improvement

Getting crude oil from the wellhead to refineries or terminals on the coasts has become increasingly multi-modal, often utilizing a combination of pipe, truck, rail, barge, and tanker transport. These infrastructure systems already play a major role in moving petroleum products, coal, biofuels, wind components, and other energy-related materials and equipment through the Nation's system of public and private ports and related facilities. In addition to the navigation-related maintenance and construction, the landside port connector infrastructures that provide largely "first and last mile" access between ports and the national freight network need investment to accommodate the increased intermodal movement of domestic petroleum. Because of the variety of infrastructures involved, however, stewardship of port connectors is complex, with improvements that may be funded through a combination of Federal, state, local, and private investments.

DOT reports that connecting roads to ports had twice the percent of mileage with deficient pavement than other non-interstate Federal highway routes, and connectors to rail terminals had 50 percent more mileage in the deficient category.[81] In a recent survey of port authorities, more than one-third of respondents said that intermodal connector congestion over the last 10 years has caused port productivity to decline by 25 percent to 50 percent.[82]

Port Connector Congestion[o]

The head of the American Association of Port Authorities recently described road congestion at the Port of Baltimore.

"In Baltimore, thousands of cargo-laden trucks annually travel an extra 5.3 million miles over some of the city's most congested roads and release an extra 175,000 tons of carbon dioxide to move cargo from the Maryland Port Administration's busy Seagirt and Dundalk marine terminals. These extra miles and emissions could be eliminated after construction of the proposed Broening Highway Corridor Improvement Project that would replace the city's Colgate Creek Bridge and create a new primary transportation link between the port and Interstate 95. The project's price tag is estimated at $32 million."

[o] Nagle, K. "Port Intermodal Connections Crucial to Supply Chain Logistics Flow." Travel & Industry Development. November 4, 2014. http://www.tradeandindustrydev.com/industry/logistics-warehousing-distribution/port-intermodal-connections-crucial-supply-chain-l-9738.

The surge in waterborne and rail shipments of crude may be a factor in delays at some inland and coastal ports. For example, freight traffic through the Port of Albany has experienced delays, reportedly due largely to a new influx of trains carrying domestic crude oil.[83] Port congestion in Baltimore is increasing the time that vessels, trains, and trucks idle, thus exacerbating air quality conditions in the area.[84] While the situation in Baltimore appears to be temporary (the port has plans to address the concern[p]), these examples show how the condition of port and related infrastructure can sometimes compromise public safety and air quality or degrade natural environments.

A more efficient system of port connectors could help address these and other problems and is discussed in the recommendations for this chapter. Funding for better emissions control technologies and strategies in ports is discussed in Chapter VII (Addressing Environmental Aspects of TS&D Infrastructure).

Economic Return from Investments in Coastal Ports, Inland Waterways, and Connectors

The Nation's coastal ports, inland waterways, and related infrastructure are part of the national freight transportation network and contribute to the economy. The condition of this infrastructure can affect the competitiveness of the U.S. economy, including the energy sector. As the level of traffic in waterborne commerce has increased, the Federal Government, states, local governments, local port authorities, and the private sector have made investments to maintain and improve the performance of this infrastructure, promoting economic efficiency. However, external analyses have found that delays due to inadequate infrastructure in inland waterways and ports have impacts on business sales and jobs; these losses are expected

[p] See, for example, the Broening Highway Corridor Improvement Project. archive.baltimorecity.gov/Government/AgenciesDepartments/Transportation/TIGER/BroeningHighwayCorridorImprovementProject.aspx.

to increase absent a focus on reversing the deterioration of inland waterways and ports.[q] Targeted high-return investments in this part of the national freight transportation network could strengthen the overall U.S. economy.

In addition, an assessment of the state of waterborne infrastructure also raises concerns about its reliability and resilience, which are described in more detail in Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

The analysis of potential investments can change due to several factors. For example, USACE will need to consider the changing domestic energy landscape in some of its project plans, such as where an increase in energy-related commodities through one or more of the ports, locks, and dams has occurred that may be large enough to affect an investment decision; also, energy is only one of many factors to consider when making decisions about infrastructure investments.

Opportunities for Public-Private Partnerships in Ports and Waterways

In his call to action, Vice President Biden noted that after years of underinvestment, more than $90 billion in improvements are needed to prepare for a significant increase in shipping over the next several years, saying that "Ports can expect to ship 50 percent more cargo by 2020 than they do now, and that's probably a low estimate." He also highlighted the opportunity that ports have to deliver projects through public-private partnerships.[85]

As noted, there is a distinction between responsibilities for landside and waterside facilities at ports. Landside facilities at ports are generally under the control of local port authorities. The Federal Government, however, has substantial responsibility for many waterside activities, in particular, for maintenance of the authorized Federal portion of the main channels and associated features such as turning basins, and for related work. The National Research Council, in a study of USACE funding for water projects, found that "Future Corps water resources activity will be less dedicated to construction of major new civil works, and more heavily focused on operating, maintaining, rehabilitating, and upgrading existing infrastructure…[and] deferred costs for maintaining… commercial navigation are considerable."[86] Some cases of deferred maintenance, however, reflect decisions to perform channel maintenance dredging when the incremental costs are lower with more material to dredge, or when a channel's traffic levels do not justify use of limited funds over other potential uses at that time.

Increasing demands by the users and others for more Federal investment in coastal ports, inland waterways, and related infrastructure highlight the need for additional and innovative funding mechanisms and public-private partnerships. The National Research Council's analysis of these and other issues concludes, among other things, that "The modern context for water resources management involves smaller budgets, cost sharing, an expanded range of objectives, and inclusion of more public and private stakeholders in management decisions. Two important implications of these conditions are (1) given current budget realities, the Nation may have to consider more flexible, innovative, and lower-cost solutions to achieving water-related objectives; and (2) USACE will by necessity work in settings with more collaboration and public and private partnerships than in the past."[87]

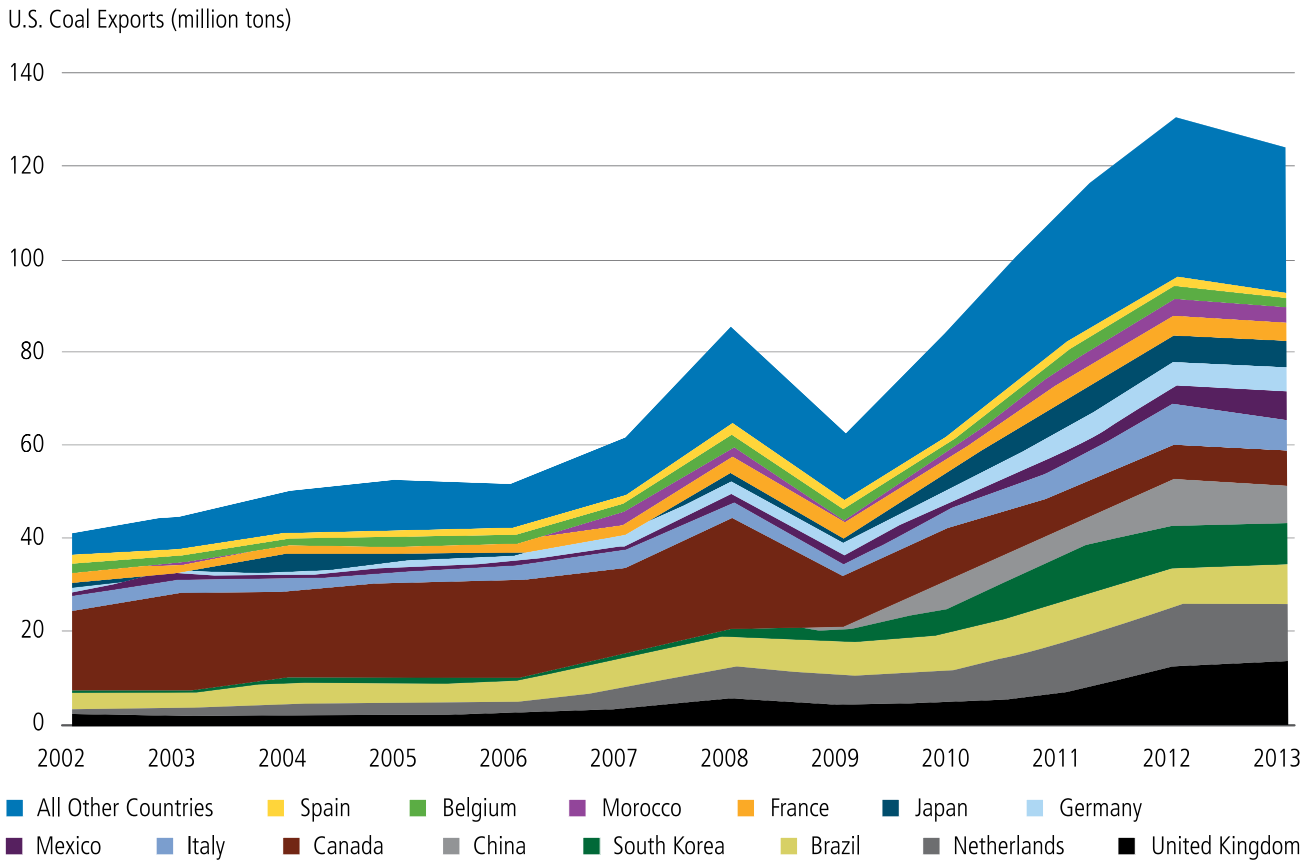
[q] A report prepared for the American Society of Civil Engineers estimated that waterborne shipping delays due to inadequate infrastructure in inland waterways and ports imposed $33 billion in costs on U.S. products in 2010; the report projected those costs (in constant 2010 dollars) to increase to nearly $49 billion in 2020 and $68 billion in 2040. Further, the report calculated that by jeopardizing the U.S. ability to provide the low-cost transportation needed to remain competitive in a global economy, the cumulative economic shortfall from deterioration of the inland waterways and ports will result in $1.3 trillion in lost business sales from 2012 to 2020; $270.0 billion in lost exports from 2012 to 2020; almost $2.0 trillion in lost exports from 2012 to 2040; 738,000 fewer jobs by 2020; and 1.4 million fewer jobs by 2040.

Uncertainty in U.S. Coal Exports

U.S. coal exports peaked in 2012;[88] in that record year, East Coast ports alone shipped 68 million tons, which was only about 65 percent of potential export capacity.[89] Exports have declined since then, dropping in the last seven quarters ending in Quarter 3 of Calendar Year 2014.[90] Notwithstanding this decrease in exports (and currently low global coal prices), companies that own and manage export terminals continue with long-range plans for expansion, focused on the potential for continued demand in Europe, Asia, and South America.[91]

Shifts in coal export destinations have produced associated shifts in the locations of ports serving the international coal trade. As shown in Figure 5-10, exports to Canada have sharply declined since 2008, which has reduced coal tonnage passing through Great Lakes customs districts (including Duluth, Detroit, and Cleveland),[92] while rising exports to Europe and the Far East have increased tonnage through Norfolk, Baltimore, New Orleans, and Seattle.[93]

Figure 5-10. U.S. Coal Exports by Destination[94]



Overall export volumes of U.S. coal have declined from recent record levels, despite growth in coal exports to countries in Europe and Asia.

Impact of Energy and Energy Component Transport on Multi-Modal Systems

The introduction of unprecedented levels of domestic and Canadian crude into interconnected pipeline, rail, barge and tanker, and roadway systems not only provides flexibility to shippers, but it has also introduced new intermodal stresses on the freight system and associated regulatory bodies.

Roadways, Short Hauls, and Energy Production

The domestic energy production boom is increasing roadway traffic for transport of both energy products and the materials and tools required to produce those energy products. For instance, a typical Bakken well completion requires roughly 2,300 drilling-related truck trips for machinery, sand, and injection fluids.[95] Trucks are also used for short-haul drayage of crude oil from the wellhead to gathering pipelines or rail loading terminals for long-distance transport. In North Dakota, well drilling has outstripped the development of gathering systems, leaving about 40 percent of Bakken production to be delivered to pipeline and rail terminals by truck. Demand for trucks has also increased downstream of production, as illustrated by the threefold increase from 2004 to 2013 in refinery receipts of crude oil by truck,[96] a substantial portion of which—because of the location of refineries—occurs on roads and highways near ports and waterways.

As a result of this new demand, trucking firms have reported a shortage of trained drivers, and firms in non-energy producing regions of the country are losing experienced drivers to the higher wages available in producing areas.[97] Trucks fill a very specific role that other transport modes are not well-suited to fill. According to the American Association of State Highway and Transportation Officials, "Local and regional cargo mostly moves by truck, since trucks are generally more efficient at short distances and provide door-to-door service to almost all freight shippers and receivers. At longer distances, typically beyond 400 to 600 miles, intermodal rail becomes increasingly more competitive and can be used as a substitute for long-haul trucking."[98] While port-related truck traffic may represent a low-share of total truck traffic in a region, it tends to be highly concentrated on certain corridors and highly visible, and—unlike rail and waterborne transport—trucks share the infrastructure with the general public, thus making it of particular importance to adjacent communities.

Another example of multi-modal stress from transporting energy supplies is found in transporting large quantities of sand for oil and gas production. In one county in Wisconsin alone, a 2012 forecast suggested that supplying sand to meet oil and gas production demand could require transport of 5 million tons to 7 million tons of sand by truck and rail, compared to 137,000 tons just 4 years earlier; 7 million tons translates into 280,000 one-way truck trips and 500 unit trains.[99] The impact of such traffic on roads, rail crossings, and tracks is significant.

Moving Large Energy Components on Shared Infrastructure

Shared infrastructure systems are also strained by movement of large components associated with other energy resources beyond petroleum, ethanol, and coal. An example is found in transport of wind turbine components. Large wind components are both domestically manufactured and imported; in 2012, 40 percent of the total value of component imports moved through the Houston-Galveston area alone,[100] placing additional burdens on the port facilities and connectors that are responsible for moving these very large components. In 2012, an estimated 689 truckloads, 140 railcars, and 8 vessels were required to carry the turbines, blades, and related components needed to complete a moderately sized 150-megawatt (MW) wind project.[101]

Turbines have increased in size to maximize generation capacity, raising a range of complications for transportation and logistics.[102] Typical turbine blade lengths in the 1980s were 5 meters to 15 meters. In the last several years, typical turbine blades have grown to 38 meters to 50 meters in length for generating capacities of 1.5 MW to 2.5 MW,[103] and many blades deployed today exceed this length. Figure 5-11 shows the transport of an 80-meter blade bound for a 7-MW offshore test turbine in Scotland. The limits of the existing transportation infrastructures are now constraining component designs as manufacturers try to balance optimal energy production with transportability.[104]

Figure 5-11. Transport of Large Wind Turbine Blade[105]

As wind turbines continue to grow in size, project developers will face greater challenges in transporting components. This 80-meter blade is being transported to a 7-MW test turbine in Scotland.

Transporting components of this size requires coordination of movement through ports, tunnels, overpasses, and turning areas,[106] and often puts significant stress on small and rural roads. The larger and more complex wind projects become, the more developers will be challenged by Federal vehicle weight limits[r] and differing state and local requirements for issuing permits for oversize and overweight vehicles. Nacelles[s] for new turbines can weigh more than 80 tons[107] and, according to the American Wind Energy Association, "A truck carrying a tower section must be able to support a load ... that is over 30 meters long and weighs over 150,000 pounds."[108] In addition to limited availability of specialized trailers for blade transport, projects are also challenged by the availability of the large mobile cranes capable of lifting the very heavy components onto tall towers, and the cranes alone may require more than 100 semi-tractor trailers to move between projects.[109]

The National Energy Renewable Laboratory has underscored these logistical concerns, noting that "The challenges and costs associated with transporting taller towers and very long blades with wide chord lengths also affects wind plant deployments and will become more constraining as wind turbines increase in size and height. Similarly, trucking heavy nacelles and blades with larger root diameters could become challenges meriting additional attention."[110] Increasingly complex logistical challenges are requiring shippers to use a variety of land transportation methods and modes, resulting in increased project costs of up to 10 percent of capital costs for some projects.[111]

[r] Federally mandated maximum weights for the National System of Interstate and Defense Highways and reasonable access thereto (23 C.F.R. § 658.17): 80,000 pounds gross vehicle weight; 20,000 pound single axle weight; 34,000 pound tandem axle weight.

[s] A nacelle is the box-like component that sits atop the tower that contains the majority of the approximately 8,000 components of the wind turbine, such as the gearbox, generator, main frame, etc.

There are similar logistical issues associated with moving large power transformers. Like wind turbine components, transformers require special permits for transport over highways. Though trailers for road transport are generally only around 70 feet long, large transformer units can weigh up to 400 tons.[112] Transport via rail requires a specialized car of which only roughly 30 are available in North America.[113] Estimates suggest that transportation and logistics costs represent 3 percent to 20 percent of the total cost of a large transformer.[114]

Administration Activities and Plans

New per-vessel user fee to double the size of the Inland Waterways Trust Fund. This fund currently pays 50 percent of the Federal cost for construction, replacement, rehabilitation, and expansion for inland waterways (the other 50 percent is derived from the General Fund of the Treasury). Inland Waterways Trust Fund funding is derived from a fuel tax on commercial transportation on most of the inland waterways. In December 2014, Congress authorized an increase in the fuel tax from the current $0.20 per gallon to $0.29 per gallon, to take effect after March 31, 2015. The President's Fiscal Year 2016 Budget proposes a new per-vessel user fee that will raise an additional $1.1 billion over the next 10 years from the users, effectively doubling the level of resources available in the Waterways Trust Fund. These increased resources are allocated through annual Appropriations acts (and would be matched by General Fund revenues). As such, the level of investment in inland waterways infrastructure can continue to be expanded to the extent that it is matched by appropriations from the General Fund.

Department of Transportation/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. StrongPorts initiatives include a Port Planning and Investment Toolkit that provides port authorities with a how-to guide for performing due diligence and developing an investment-grade project; a new "PortTalk" initiative aimed at helping ports to integrate these projects into state transportation department and metropolitan planning organizations' transportation infrastructure planning and funding processes; and direct technical assistance to ports interested in taking advantage of Federal grant assistance. While the StrongPorts initiative does not provide direct financial assistance, the recently released guide provides an additional resource regarding financing for ports. More information can be found at www.marad.dot.gov/ports_landing_page/StrongPorts/StrongPorts.htm.

GROW AMERICA Act multi-modal freight grant program. The Administration's Fiscal Year 2016 Budget includes a new transportation Infrastructure financing proposal—the Generating Renewal, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities throughout America Act (GROW AMERICA Act). This proposal 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 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.

Expanded funding for the Department of Transportation 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. TIGER'S broad eligibility criteria make it ideal for multi-modal, multi-jurisdictional projects, such as landside infrastructure for ports and waterways, which can be difficult to fund under state block grants. Since 2009, Congress has dedicated $4.2 billion for TIGER projects, of which $400 million has gone to port-related projects. However, TIGER is currently oversubscribed; in its most recent funding round, only 72 of 797 eligible applications were funded, and 15 times the available $600 million was requested. The Administration's GROW AMERICA Act proposal will provide $7.5 billion over 6 years, more than doubling the TIGER competitive grant program.

QER Recommendations

PORTS, HARBORS AND CONNECTORS

The shared infrastructures in inland waterways and ports that are important for waterborne transport of energy commodities need to be strengthened, both to accommodate the increased use of waterborne, rail, and road transport to move energy commodities and to recognize the key role these infrastructures play in domestic commerce, generally. Accordingly, we recommend the following:

Support alternative funding mechanisms for waterborne freight infrastructure: Recognizing that no one entity or program can fully address the scale and diversity of investment requirements, the Administration should examine alternative financing arrangements for waterborne transportation infrastructure. The working group should develop strategies for public-private partnerships to finance port and waterway infrastructure. It should also coordinate and integrate Federal investment programs through DOT and USACE and consider new user fee arrangements that better allocate costs to beneficiaries, as well as potential tax incentives. The Administration should also work to encourage non-Federal involvement in ports and inland waterways, targeting the beneficiaries of infrastructure investment identified in the needs assessment. Options would be informed by findings of the one-time comprehensive energy needs assessment for coastal ports, inland waterways, and connectors, which would establish the foundation for providing additional support for projects at energy-intensive port and harbors.

Support a new program of competitively awarded grants for shared energy transport systems: Reducing congestion from additional movement of energy commodities to and from coastal ports and inland waterways, improving air quality, and enhancing public safety in and around ports and waterways will help meet competiveness, environmental, and security goals. The DOT Transportation Investment Generating Economic Recovery (TIGER) program has successfully targeted investment in port connectors but it is not specific to energy and is heavily oversubscribed; only 10 percent of past TIGER awards have gone to port connectors. A similar grant program—Actions to Support Shared Energy Transport Systems, or ASSETS—should be established and supported at DOT, operated in close cooperation with DOE; this program would be dedicated to improving energy transportation infrastructure connectors. The ASSETS program could provide significant benefits as a stand-alone measure while a new, more comprehensive infrastructure investment framework takes shape.

The estimated scale of ASSETS investment could be on the order of $2.0 billion to $2.5 billion over the next 10 years, which would likely mobilize $4.0 billion to $5.0 billion in non-Federal investment, based on typical TIGER cost shares.

Support public-private partnerships for waterborne transport infrastructure: The U.S. freight transport system is a complex blend of Federal, state, and local government and private sector assets, as well as operation and maintenance investments. Developing a set of shared investment priorities can ensure that both public and private needs are met.

Data, Modeling, and Analysis

Policymakers, investors, managers, and users of shared transportation systems require better information in order to plan new infrastructure investments and optimize current operations to minimize the cost of congestion, limit environmental impacts, and ensure safety. However, the increase in multi-modal transport of energy and other commodities presents new complexities in understanding the interplay among rail, highway, and waterborne freight transportation. Furthermore, significant gaps exist in the data collected by various Federal agencies and, even where the data is collected, there are often long lags between commodity movements and the publication of data.

As one example, the most granular source of multi-modal commodity, route, and origin and destination data now available is the Freight Analysis Framework.[115] However, as a mechanism for understanding energy commodity flows, the framework has significant limitations. For instance, it is based on the Commodity Flow Survey, a joint effort of the Bureau of Labor Statistics and the Department of Commerce's Census Bureau.[116] The survey is derived from data collected every 5 years—a frequency that does not adequately capture the rapid changes in the energy sector.

QER Recommendations

MODELING, ANALYSIS, AND DATA COLLECTION

Coordinate data collection, modeling, and analysis: DOE should lead an interagency effort with DOT, USDA, USACE, 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. For example, DOE, leveraging the technical resources and expertise of the national laboratories, should work with DOT and USACE to develop new modeling and analytical tools to establish a more comprehensive systems framework for analysis of MTS infrastructure issues. This modeling and analysis effort should apply the improvements in data on shared transportation systems recommended elsewhere in the QER and the ongoing efforts of the Committee on the MTS to improve maritime data. A concerted effort should also be made to improve the data in the Freight Analysis Framework and the Commodity Flow Survey and make this tool more useful as a mechanism for understanding energy commodity flows. This effort will enable better informed investment decisions by both government and industry through a better understanding of energy-related supply chain issues.

Assess the impacts of multi-modal energy transport: DOE, working with DOT and USACE, should conduct a one-time comprehensive needs assessment of investment needs and opportunities to upgrade the Nation's energy-related shared water transport infrastructure. The assessment should take advantage of the new analytics and modeling tools previously recommended to assess and prioritize investments from a systems perspective, taking into account the dramatic changes and projections of future use of shared water transport infrastructures due to changes in domestic energy markets, increases in vessel size, and other factors. The infrastructure investment analysis should identify the costs and benefits (including beneficiaries) in order to guide capital investment planning and identify equitable partnerships among the Federal Government, state and local governments, and the private sector infrastructure users.

QER Recommendations (continued)

MODELING, ANALYSIS, AND DATA COLLECTION

Assess energy component transportation: DOE, in coordination with relevant agencies, should examine logistical challenges in the transportation of oversized or high-consequence energy materials, equipment, and components. The study will assess the capacity of infrastructure systems, such as roadways, waterways, and railroads, to safely accommodate more frequent and larger shipments where energy analyses indicate such transport will be required. The study will also examine opportunities for coordination of Federal, state, and local permitting and other regulatory processes along affected transportation routes, as well as the role of private sector infrastructure owners and users in enhancing the safety and reliability of transporting certain energy-related materials components.

RECOMMENDATIONS IN BRIEF:
Improving Shared Transport Infrastructures

Enhance the understanding of important safety-related challenges of transport of crude oil and ethanol by rail and accelerate responses. Key activities at the Department of Energy (DOE) and Department of Transportation (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, the Surface Transportation Board, 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, DOE and other relevant Federal agencies 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 Fiscal Year 2016 Budget request for the Energy Information Administration to address critical energy transportation data gaps and continued data sharing with the Surface Transportation Board.

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. The estimated scale of ASSETS investment should be on the order of $2.0 billion to $2.5 billion over the next 10 years, which would likely mobilize $4.0 billion to $5.0 billion in 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 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.

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Chapter VI

INTEGRATING NORTH AMERICAN ENERGY MARKETS

This chapter takes a broader look at the current energy trade and the continuing integration of energy markets and infrastructure in the North American region. Its discussion includes cross-border infrastructure with Canada and Mexico, impacts of climate change on energy infrastructure in the Arctic, and the evolving energy needs of the Caribbean region. For each major geographic focus of this chapter, the status of Administration initiatives is discussed and recommendations for further action are presented.

FINDINGS IN BRIEF:
Integrating North American Energy Markets

Overall North American 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.**

Findings on Canada

- **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 the Department of Energy 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.

Findings on Mexico

- **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.

Findings on the Arctic

- **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.

Findings on the Caribbean

- **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 emissions could be achieved by displacement of fuel oil by natural gas—and even more if this were combined with renewable energy.

Benefits of North American Energy System Integration

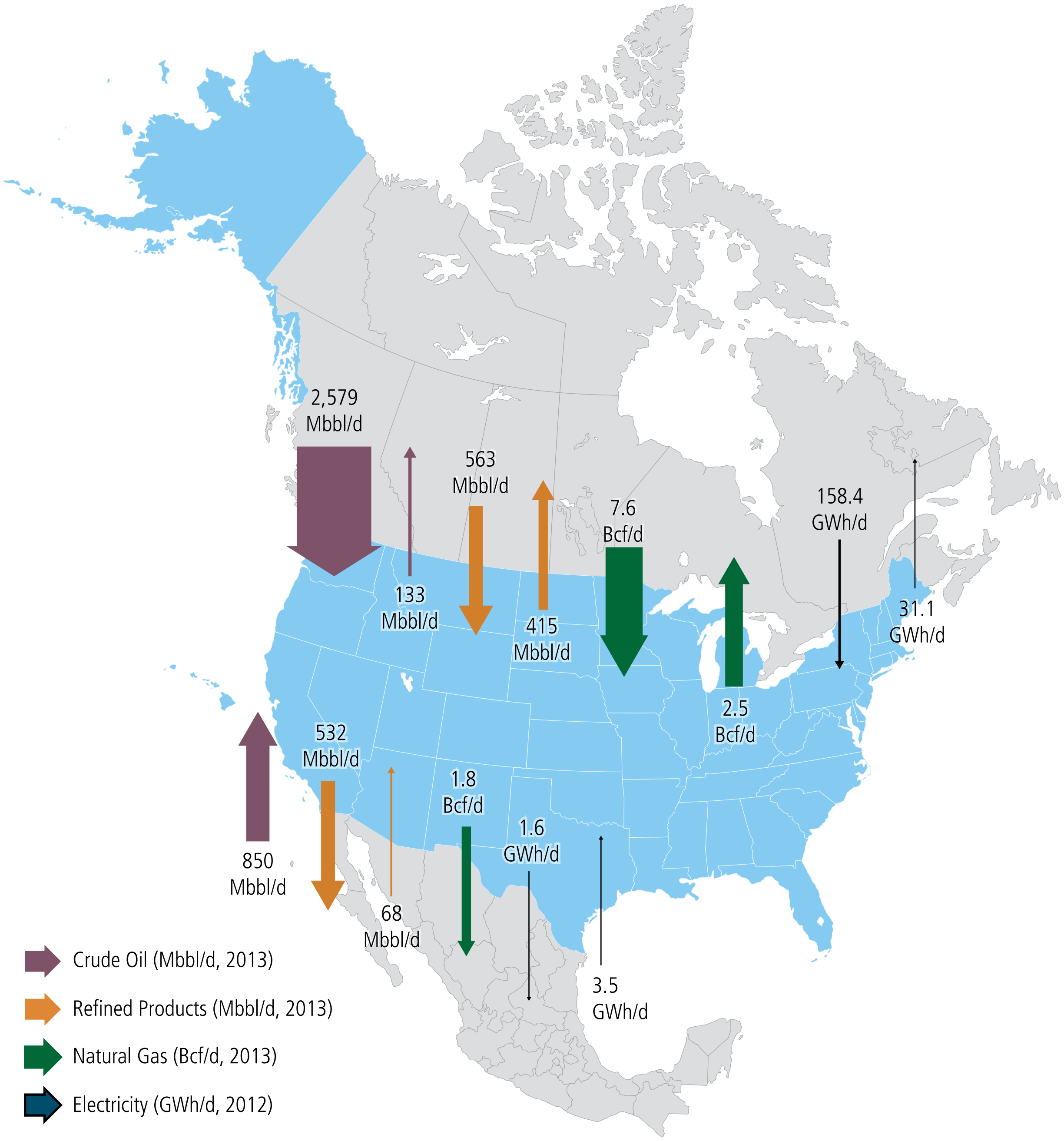
The United States has a robust energy trade with both Canada and Mexico and the potential to increase its energy trade with the Caribbean region. Policymakers throughout North America understand and value the benefits derived from our common energy market, our shared environmental and security goals, and the infrastructure that undergirds our economies. Individual projects and policies will continue to be evaluated by each government. This chapter considers the role of transmission, storage, and distribution (TS&D) infrastructure as part of a broader discussion of past energy trade relationships; current developments and trends in both Canadian and Mexican energy systems; ongoing initiatives for better market integration; and future challenges and opportunities, especially in the Arctic and the Caribbean.

Energy trade in North America has a long history. The first recorded international electricity interconnection crossed the U.S.-Canada border near Niagara Falls in 1901.[1] For several decades, the United States largely has been a recipient of energy resources (whether for internal consumption or for refining and re-export). Developments in energy production, processing, and consumption in the past 10 years have dramatically altered North American energy flows. At the same time, U.S. electricity demand has fallen, and all three countries have begun implementing policies to reduce greenhouse gas emissions from their energy sectors. This changing North American energy landscape presents opportunities for increased integration of markets and policies to further energy, economic, and environmental objectives.

In 2013, energy trade between the United States and Canada reached approximately $140 billion,[2, 3] and energy trade with Mexico exceeded $65 billion in 2012.[4] Electricity, liquid fuels, and natural gas cross U.S. borders with Canada and Mexico at many points and in large quantities on an annual basis (see Figure 6-1).

The 1994 implementation of the North American Free Trade Agreement—which prohibits most import and export restrictions, including those placed on energy commodities—did not apply to Mexico for energy commodities due to its constitutional provisions.[5] As a result, while the North American Free Trade Agreement has promoted U.S. and Canadian energy market integration, it has been less successful in achieving energy market integration between the United States and Mexico. Recent regulatory reforms undertaken by Mexico in both the hydrocarbon and electricity sectors are anticipated to open its energy market to foreign investment, to present an opportunity for increased integration with the broader North American energy system, and to elevate the importance of its energy commodities in trade with the United States and Canada via the North American Free Trade Agreement.[6]

Figure 6-1. North American Energy Flows[7]



Energy trade between Canada and the United States dominates the North American market, but Mexico's reforms provide an opportunity for increased integration and trade. The size of the arrows is roughly equivalent to the quads of energy of the imports or exports.

Energy system integration is in the interest of all North American countries, 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. Expanding energy systems may also allow for the development of a more diverse mix of energy resources (including renewable energy), processing facilities, and end uses—all of which increase energy security.

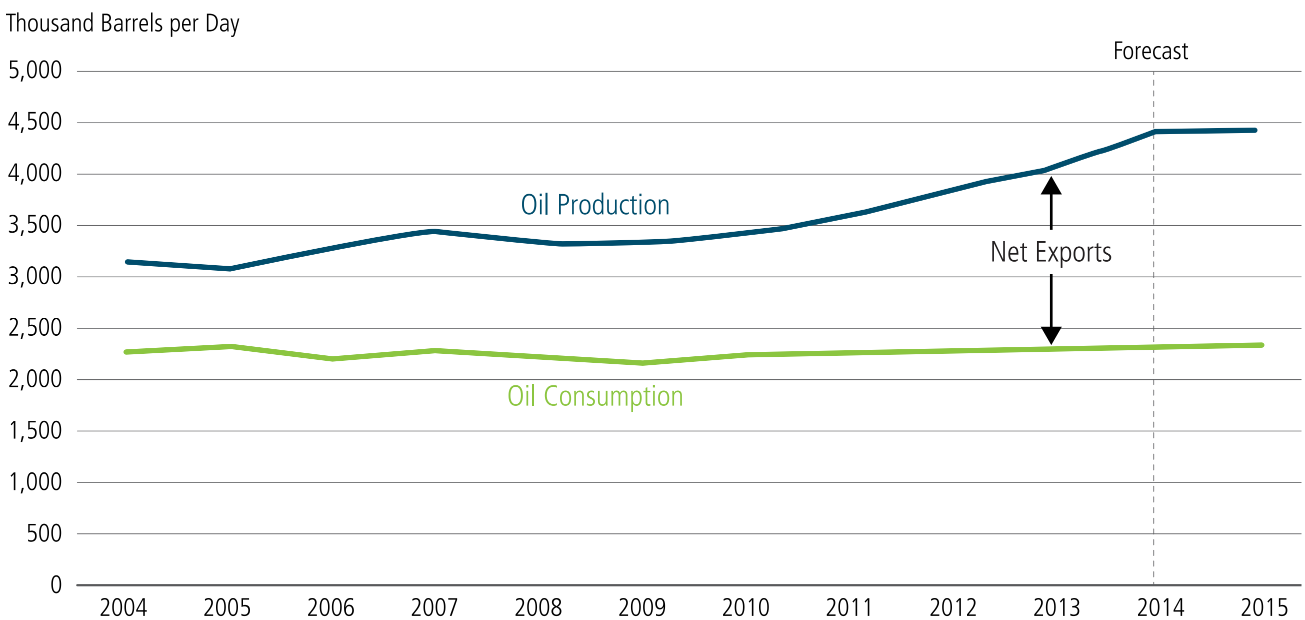
TS&D infrastructure already plays an important role in integration of North American energy markets. This infrastructure allows these markets to operate more efficiently and with greater resilience to disruptions. For example, the integration of the U.S. and Canadian electric reliability systems considerably enhances performance and resilience. Bilateral and trilateral collaboration among the U.S., Canadian, and Mexican governments, as well as each country's participation in multilateral energy initiatives, has also contributed to establishing and harmonizing the policies and programs most useful to the efficiency and resilience of the North American energy system.

Energy Trade with Canada

The energy relationship between the United States and Canada is highly intertwined. For many purposes, the energy sectors of the two countries are considered as one market. There are more than 80 transboundary pipelines and more than 30 electricity transmission lines (69 kilovolts or greater) that transport crude oil, refined products, natural gas, and electricity across the border.[8, 9] Although the predominant flow of trade is from north to south, it is not entirely one-sided. Canada is an overall net exporter of energy to the United States, but the roles are reversed in certain regions, particularly where there are infrastructure constraints.

The Energy Information Administration (EIA) reported Canadian production of petroleum and other liquid fuels grew to more than 4 million barrels per day in 2013, an increase of more than 930,000 barrels per day from a decade ago (see Figure 6-2) and including 3.3 million barrels per day of crude oil and a small amount of lease condensate.[10] Canada is the largest supplier of crude oil and refined products to the United States, exporting 3.1 million barrels per day in 2013.[11] EIA's 2014 International Energy Outlook forecasts that Canada's petroleum production will experience 2.1 percent annual growth between 2010 and 2040, which would lead to a 51 percent growth by 2030.[12]

Figure 6-2. Canadian Oil Production and Consumption, 2004–2015[13]

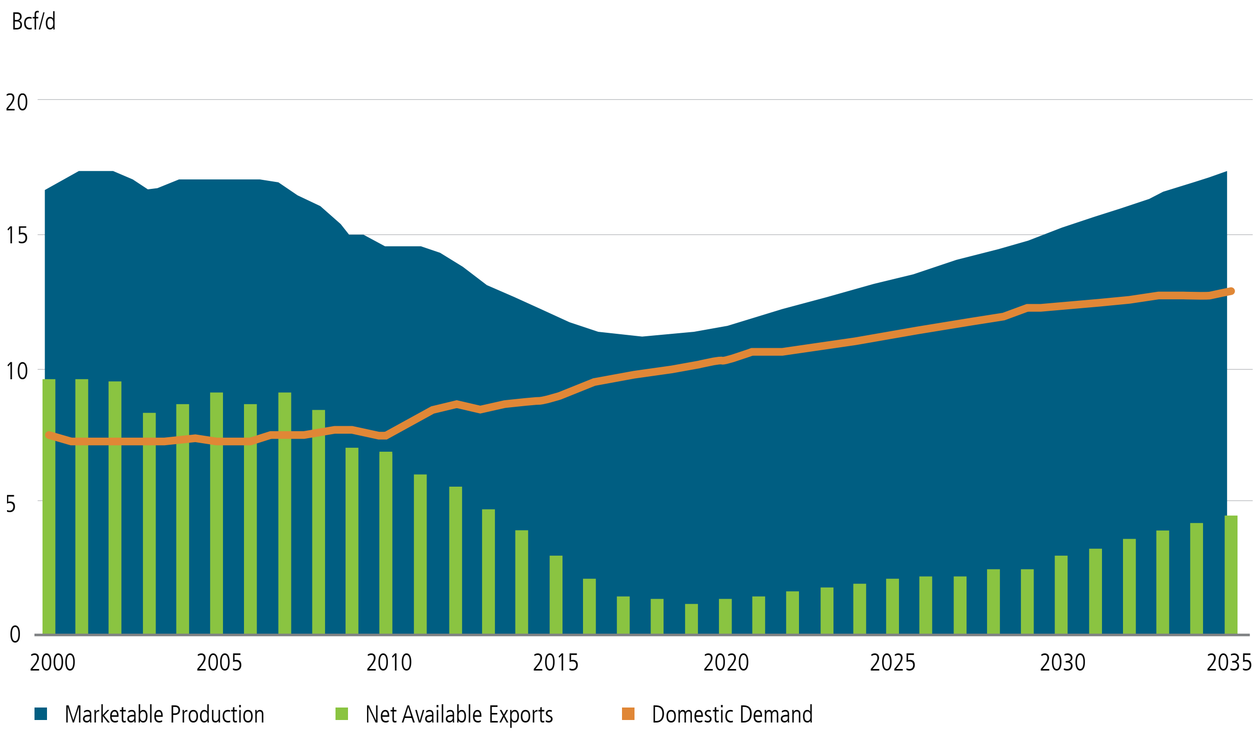


With production growing and consumption flat, Canada's exports have increased over the last several years. Canada is the largest supplier of foreign oil to the United States.

Canada's National Energy Board projects that, starting in 2017 and continuing through the forecast period, natural gas production and consumption will closely track one another (see Figure 6-3).[14] However, the price for U.S. gas may influence this; according to some analysts, the low cost and increasing supply of Marcellus production could price western Canadian gas out of the market.[15] EIA projects that net pipeline imports from Canada will drop 80 percent in the next 15 years, from 2.0 trillion cubic feet in 2012 to 0.4 trillion cubic feet in 2030.[16] This in turn could limit the need for new transborder natural gas pipeline development between the United States and Canada.

The Dawn Hub, located in southeastern Ontario, illustrates the multiple benefits of U.S.-Canadian regional natural gas system integration. Able to store supplies from western Canada, the U.S. Northeast, Midwest, and Gulf Coast, the underground storage facilities in the Dawn area held 221.9 billion cubic feet in December 2014,[17] and they are used to balance seasonal peak demand in Ontario and supply downstream markets in the United States.[18]

Figure 6-3. Canadian Natural Gas Production, Domestic Demand, and Net Available Exports through 2035[19]



While Canadian natural gas production and demand are roughly equivalent in the 2017 to 2022 time frame, natural gas available for exports increases steadily after that through 2035.

Both the United States and Canada benefit from a relatively seamless border that allows grid managers to optimize electricity generation assets on both sides of the border in order to improve electric reliability and efficiency. Currently, there are more than 30 active major transmission connections (69 kilovolts or greater) between the two countries, trading approximately $3 billion (U.S. dollar) of electricity in 2013.[20, 21] Three of eight North American Electric Reliability Corporation regions span the U.S.-Canadian border, coordinating among and setting standards for U.S. and Canadian utilities and regulators to assure electric reliability.[22] Most Canadian electricity exports to the United States go to New England, New York, and the Upper Midwest, mainly from Quebec, Ontario, and Manitoba.[23] Most U.S. electricity exports to Canada (about 75 percent) go to British Columbia, but U.S. exports made up only 18 percent of electricity trade between the two countries in 2014.[24] Applications filed with the Department of Energy (DOE) in the last 5 years for Presidential permits for electric transmission facilities crossing the U.S.-Canada border suggest an increased interest in utilizing Canadian hydropower to meet demand in the United States. If these projects were to be constructed, they would add approximately 4,100 megawatts of additional hydropower to the U.S. electricity mix.[a, 25] This carbon-free generation has the potential to help the United States achieve its long-term greenhouse gas reduction goals.

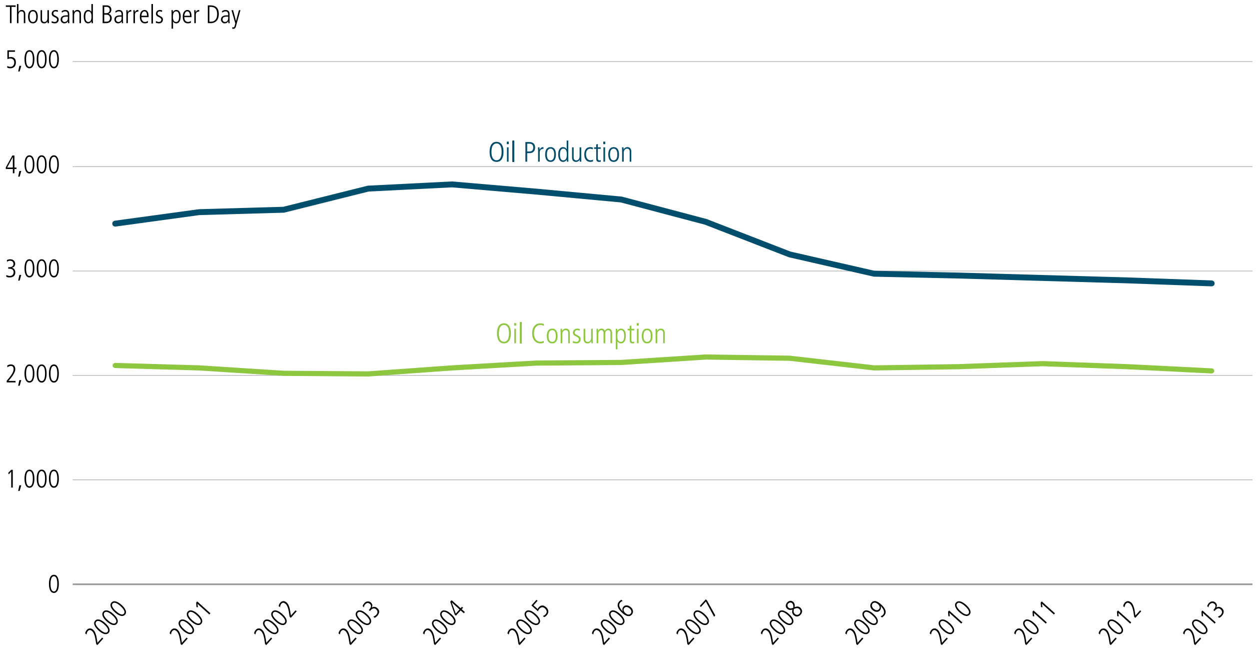
As noted, the United States and Canada share one of the world's great inland lake and waterway systems in the Great Lakes and St. Lawrence Seaway. The Army Corps of Engineers lists more than 60 commercial harbors on the U.S. Great Lakes coast alone.[26] In 2013, nearly one-quarter of all shipments in and out of U.S. ports in the Great Lakes system were energy commodities moving between the United States and Canada. In that year, 7.4 million tons of coal and petroleum products moved across the Great Lakes.[27] U.S. coal exports to Canada have fallen approximately two-thirds between 2003 and 2013, even as overall U.S. coal exports have grown more than 170 percent—in part as a result of Canadian energy policies limiting coal use in the power sector. Imports of Canadian coal have also fallen by approximately one-half, from more than 2 million short tons in 2003; although, their share of total U.S. coal imports has grown from 8 percent to 13 percent over the same time period.[28]

Energy Trade with Mexico

In December 2013, Mexico amended its constitution and reformed its energy sector. The principal factors driving these decisions were, in part, Mexico's declining oil production over the past decade (see Figure 6-4), as well as its interest in promoting economic growth. Mexico's reforms retain government control and ownership of assets while opening oil and gas resources to private exploration and development. They also include new governance structures for Petróleos Mexicanos and the Federal Electricity Commission and four new contract structures for oil development that align with international standards. The reforms establish Independent System Operators to manage electricity transmission. The reforms also will gradually adjust the retail fuel market. In August 2014, the Mexican Ministry of Energy announced "Round Zero" fields that Petróleos Mexicanos will retain, as well as "Round One" in which foreign companies will be allowed to participate for bidding through July 2015.[29]

[a] Recent Presidential Permit applications received by DOE's Office of Electricity Delivery and Energy Reliability, National Electricity Delivery Division, indicate certain companies' intentions to import hydropower from Canada. Specifically, Champlain Hudson Power Express, Northern Pass Transmission, and New England Clean Power Link would each deliver electricity from Hydro Quebec facilities. Great Northern Transmission Line would deliver electricity from Manitoba Hydro.

Figure 6-4. Mexico's Oil Production and Consumption[30]

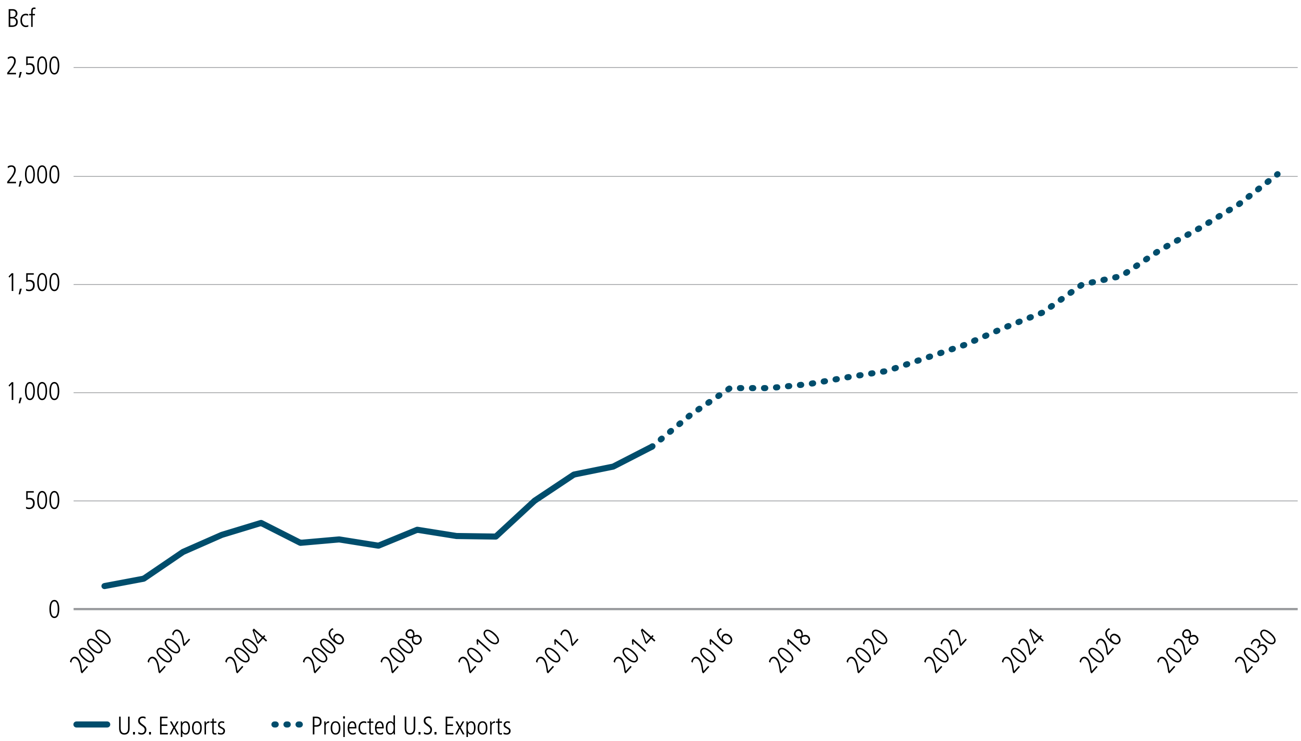


Recent trends in Mexican oil production and consumption indicate a decline in production and largely stable consumption. The Mexican energy reforms seek, in part, to reverse these declines in production.

Mexico's energy reforms present an opportunity to increase energy trade with the United States and enhance energy security for the region.

The main cross-border infrastructure needs, particularly over the last decade, have been natural gas pipelines. Since 2000, U.S. exports of natural gas have increased six-fold and are projected to continue to increase through 2030 (see Figure 6-5).[31, 32] More than 5 billion cubic feet per day of new pipeline export capacity has been added during this time period, with about half that amount in the form of expansions of existing pipelines.[33] By 2016, EIA projects that the United States will be exporting more than 1 trillion cubic feet of natural gas to Mexico annually, and, by 2030, that amount is expected to almost double.[34] This growth will be driven by continued increases in the use of natural gas for electric power generation, by demand for natural gas from Petróleos Mexicanos, and from consumers switching to natural gas when the infrastructure is in place to deliver additional volumes of natural gas.

Figure 6-5. U.S. Natural Gas Exports to Mexico[35, 36]



Mexican demand for U.S. natural gas is projected to grow through 2030, in large part driven by continued increases in the use of gas for electric power generation and residential use.

If Mexico's energy reforms achieve the goal of reversing the decline in its oil production, it is possible that Mexico will serve as a larger source of U.S. oil imports in 2030. Alternatively, if Mexico's refinery capacity expands, more of its oil may stay in the country, and Mexico may export refined petroleum products instead of crude oil—most likely overseas.

U.S. coal exports to Mexico have doubled between 2003 and 2013, but their share of total U.S. coal exports remained below 5 percent throughout this period.[37]

Currently, there is very little cross-border electricity trade between the United States and Mexico. Between southern California and Baja California, electricity is imported from a few power plants on the Mexican side to supply demand in the San Diego area, and a small portion of the grid in Baja California, Mexico, participates in the Western Electric Coordinating Council. At even lower voltage levels, a few ties connect southern and western Texas with the Mexican States of Tamaulipas and Chihuahua. Here, the transmission systems on either side operate independently, and trade mainly occurs during periods of constrained supply.[38]

There is potential for greater exchange of electricity between the United States and Mexico, particularly from natural gas-fired or renewable generation on both sides of the border.

TS&D Infrastructures: Cooperation among the United States, Canada, and Mexico to Achieve Common Objectives

Going forward, enhanced system integration holds the potential to advance several objectives, including more efficient and smoothly integrated markets and protection of the environment.

Enhanced coordination on energy data, which is important for the proper function of energy markets, including the planning, construction, and operation of TS&D infrastructure, requires that market participants and policymakers have reliable, transparent, and comparable data on the overall energy system. The benefits of integration would be greatly enhanced by harmonizing and improving the availability of relevant energy data.

In addition, there are opportunities to build on past collaboration involving regulatory and industry counterparts to promote harmonization of relevant regulations, both with respect to energy overall and with respect to infrastructure specifically. Opportunities for further regulatory harmonization with both Canada and Mexico exist across different resources, types of infrastructure, modes of transport, market structures, energy security, and environmental protection. Engagement on these topics may be particularly important on regional and local levels, where it has been limited in the past. Regulatory harmonization benefits regulated parties by eliminating duplicative requirements and generating savings in time or cost. It benefits consumers by lowering costs and making products available in both countries. It benefits regulators by enabling joint approaches to common risks.

The near-seamless integration of the U.S.-Canadian electricity grid has occasionally resulted in blackouts spanning the border, but in regional crises, cooperation among Federal, state, provincial and local governments, utilities, and regulators has provided benefits and enabled faster recoveries. Cross-border assistance for emergency response happens regularly in the electric sector.

Superstorm Sandy (2012) stands out among recent examples of North American cross-border emergency response to power outages and other extreme weather impacts on energy infrastructure. Due to the storm, 2.7 million customers were left without power in New Jersey alone.[39] Approximately 800 Canadian utility workers traveled to New Jersey to help restore power in the aftermath of Superstorm Sandy. New Jersey Governor Chris Christie declared December 6, 2014, "Canadian Utility Workers Appreciation Day" in response to their volunteered support.[40]

In late January 2015, Hydro-Quebec dispatched 180 employees and 75 trucks to the Boston area to assist with power outages due to the snowfall there in response to mutual aid requests coordinated through the North Atlantic Mutual Assistance Group (NAMA).[41] The group includes 21 utilities among 13 states, the District of Columbia, and 4 Canadian provinces, and it represents 1 of 7 Regional Mutual Assistance Groups organized by the Edison Electric Institute.[42]

Emergency response to electrical outages includes wheeling power through the grid to cover outages. A recent example of this practice occurred when Mexico supplied electricity to Texas to support Texas system operators threatened by blackouts.[43]

In addition to collaboration on preparedness and resilience, there are significant opportunities for the United States, Canada, and Mexico to cooperate on multiple initiatives, projects, and in international fora that promote clean energy and environmental responsibility. As Mexico develops its natural gas resources, better coordination of actions to mitigate methane emissions from natural gas systems, including TS&D infrastructures, could address climate concerns on both sides of the border. Similarly, to the extent that transmission projects enable access to new, existing, or expanded hydropower projects, the use of Canadian hydroelectric generation and pumped hydropower storage could help achieve U.S. clean energy goals by providing a low-cost addition to current state Renewable Portfolio Standard programs and by smoothing variable supply from renewable energy.[44, 45] A 2014 Argonne National Laboratory study indicated that advanced pumped hydropower storage could provide a range of grid management and cost reduction services to the Western Interconnection, including the Canadian provinces of British Columbia and Alberta and some areas of northern Mexico.[46]

Such initiatives have precedent: the Columbia River Treaty, ratified in 1964, has for more than 50 years provided coordinated operational benefits for the U.S. Federal Columbia River Power System and the Province of British Columbia hydro system. The reservoir storage authorized by the treaty allows the United States and Canada to optimize clean, renewable hydroelectric power generation.[47] More recently, the Western Area Power Administration approved financing a portion of the Montana-Alberta Tie Line project—a 300-megawatt, 230-kilovolt electrical transmission line allowing the movement of power between Montana and Alberta, Canada. The 214-mile (345-kilometer) line ties into the Alberta grid at a new substation located 9 miles (15 kilometers) northeast of the City of Lethbridge. The project supports ongoing development of a rich wind-powered generation resource and allows much-needed energy to flow in both directions, ensuring increased availability of supply of electricity into the U.S. Pacific Northwest and Alberta. Northern Montana and southern Alberta are home to some of the best wind energy sources in North America.[48]

In addition to specific projects and regional programs, the United States, Canada, and Mexico have active governmental bilateral and trilateral engagements. At the 2014 North American Leaders Summit, leaders affirmed that energy is a trilateral priority and directed the three Energy Ministers to meet in 2014. Under a bilateral agreement between DOE and the Canadian Ministry of Natural Resources, signed September 18, 2014, one of the five areas of cooperation between the two agencies is "safe and modern infrastructure, including cyber security." Cooperative activities the agencies agreed to pursue are "sharing knowledge and exploring options to enhance reliability and security of the North American energy infrastructure." Under the U.S.-Mexico High-Level Economic Dialogue, the United States and Mexico agreed to enhance communication and collaboration between our energy agencies and improve data and information sharing on U.S.-Mexico energy flows. In March 2015, the United States and Mexico also launched a high-level bilateral clean energy and climate policy task force to further deepen policy and regulatory cooperation and coordination.

This cooperation is further extended through participation in multilateral efforts. The United States, Canada, and Mexico also participate in the Energy and Climate Partnership of the Americas, a flexible mechanism through which governments in the Western Hemisphere cooperate to accelerate clean energy development and deployment, advance energy security, meet climate challenges, and reduce poverty in the region. Mexico will host the second Energy and Climate Partnership of the Americas Ministerial on May 25–26 and chairs the Energy Efficiency Working Group. Canada chairs the Heavy Oil Working Group.

In May 2015, Mexico will host the sixth Clean Energy Ministerial (CEM) in Mérida.[49] CEM is a high-level forum of the world's major and forward-leaning countries working together to promote policies and share best practices to accelerate the transition to a global clean energy economy. Mexico participates in nine CEM initiatives, and through that work, it has developed voluntary standards for cool (reflective) roofs, including a national study on the energy savings potential of cool roof deployment across the country,[50] and it has drawn on international expertise on power system transformation to support its energy reform agenda. The CEM Clean Energy Solutions Center Ask-An-Expert service, which provides policymakers in emerging economies with up to 40 hours of free technical assistance from policy experts in CEM countries, has assisted Mexico with developing appliance standards and labeling programs, building certification rating incentives, and developing a clean energy policy database. Canada and Mexico have participated in CEM initiatives advancing efficiency through municipal lighting system replacements and the International Smart Grid Action Network, which has gathered and shared in-depth case studies on advanced metering infrastructure and demand-side management. All three countries have collaborated on CEM-led initiatives to support implementation of the ISO 50001 International Energy Management Systems Standards.

Canada and Mexico also participate in the Carbon Sequestration Leadership Forum, a Ministerial-level international initiative focused on developing improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term storage. Canada currently participates in eighteen projects, including the completed Alberta Enhanced Coal-Bed Methane Recovery Project, which aimed at demonstrating the feasibility of coal-bed methane production and simultaneous carbon dioxide storage in deep unmineable coal seams.[51]

The United States, Canada, and Mexico also cooperate in other fora, including the Asia-Pacific Economic Cooperation, the Major Economies Forum, and the International Partnership for Energy Efficiency Cooperation.

Administration Activities and Plans

Engagement on further integration of U.S., Canadian, and Mexican energy systems has led to a number of concrete outcomes, including the following:

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 the Department of Energy, Canada's Ministry of Natural Resources, and Mexico's Ministry of Energy on December 15, 2014. The trilateral MOU covers data, information, maps, and statistics that are publicly available (it excludes any information considered confidential, strategic, or fundamental for national security and sovereignty reasons). Areas of cooperation include comparing energy-flow data between countries; geospatial information related to infrastructure; projections for cross-border flows of natural gas, electricity, crude oil, and refined products; and sector terminology. The MOU is expected to facilitate further dialogue, comparisons, and joint and individual work products on each country's energy outlooks and information.[b]

The President's Fiscal Year 2016 Budget provides an increase of $1 million to the Energy Information Administration for the purpose of collaboration with Canada and Mexico to increase the quality, transparency, and integration of energy-related data.

DIALOGUE WITH CANADA AND MEXICO ON THE QER

Development of the Quadrennial Energy Review (QER) has provided an opportunity to engage Canada and Mexico in a deeper dialogue on the integrated nature of North American energy systems—including transmission, storage, and distribution infrastructure. This engagement included contacts with energy ministries in Canada and Mexico, invitations to public entities in those countries to submit comments through the QER process, and two formal dialogues: one with the Ministry of Natural Resources of Canada (September 19, 2014) and the other with the Ministry of Energy of Mexico (December 4, 2014). The formal dialogues with Canada and Mexico included participation from multiple relevant government agencies, industry, non-governmental organizations, and academic institutions. The input received from these sessions and through the formal public comment process (as described in Chapter X, Analytical and Stakeholder Process) has been considered in developing this section of the QER.

Secretary Moniz, Secretary Joaquín Coldwell, and Minister Rickford met on December 15, 2014, in response to the call of the North American Leaders. They discussed in depth a strategic vision for North America's energy sector and signed a trilateral memorandum of understanding. Key topics included public energy data and statistics collaboration; Mexico's energy reform, its vision, perspectives, and opportunities for trilateral cooperation; and creating resilient infrastructure for North America.

[b] Department of Energy. "Memorandum of Understanding among the Department of Energy of the United States of America and the Department of Natural Resources of Canada and the Ministry of Energy of the United Mexican States Concerning Cooperation on Energy Information." December 2014.

QER Recommendations

NORTH AMERICAN ENERGY MARKET INTEGRATION

There are opportunities to build on past accomplishments in further enhancing North American energy integration. Accordingly, we recommend that all three countries carry out the following:

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 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: All three countries should enhance comparative and joint modeling, planning, and forecasting 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 should lead modeling workshops with their Canadian and Mexican counterparts to share methodologies and collaborate on North American analysis.

Establish collaborative programs in each country 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 technical dialogue: This coordinated training and enhanced dialogue of technical staff in government agencies of the three North American countries that share similar responsibilities to evaluate and implement cross-border energy projects.

Energy Security and the Arctic

Energy delivery to remote areas in the Arctic—including diesel fuel for electricity generation and heating in remote communities, industrial uses in mining and other industrial operations, and military installations—increases costs due to the broadly dispersed market and challenges of transporting energy products. Through its Power Cost Equalization program for rural communities, the Alaska Energy Authority reported serving more than 190 remote or rural communities, which used nearly 28 million gallons of diesel for electricity generation at an average price of $4.21 per gallon in fiscal year 2014.[52]

Impacts of Climate Change on TS&D Infrastructure in the Arctic

The entire Arctic is undergoing rapid changes on land and at sea due to the changing climate. Climate change is specifically affecting TS&D infrastructure in 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. Warming in the Arctic region is resulting in increased risk of land subsidence from thawing permafrost, which threatens infrastructure.[53] It also leads to a reduction in late-summer sea ice extent, which increases opportunities for offshore hydrocarbon and mineral exploration and extraction. The combination of these effects will likely affect Alaska and Canadian Arctic energy infrastructure onshore and offshore over the next several decades.[54] These changes are becoming more significant as both the United States and Canada increase energy production in the region. Cooperation between the United States and Canada on a range of issues from Arctic energy infrastructure to climate and ocean science may become an important new dimension to the U.S.-Canadian energy relationship.

Climate impacts—including primarily land subsidence caused by thawing permafrost, but also coastal impacts—are estimated to add between $3.6 billion and $6.1 billion (10 percent to 20 percent) to current costs of maintaining public infrastructure in Alaska over the next 20 years. Road, harbor, and airport maintenance comprise 57 percent of these projected additional maintenance costs through 2030.[55] The design of the Trans-Alaska Pipeline System illustrates the challenges posed by building on permafrost. Elevated above the tundra for approximately 400 miles with supports that allow for extensive vertical and horizontal movement to prevent damage from seismic or subsidence incidents, the Trans-Alaska Pipeline System cost $8 billion to build in 1977—a sum that indicates the expense that such adaptive measures entail. A 2008 U.S. Geological Survey study estimated that major disruptions caused by subsidence activity requiring replacement of the Trans-Alaska Pipeline System pipeline sections could result in $1.25 million per kilometer in repair costs.[56]

Climate changes affect energy exploration, development, and infrastructure for access to resources. It also creates more unpredictable work seasons and transportation conditions. For example, since the 1970s, permafrost changes have led to a 50-percent decrease in the length of time during which oil and gas exploration on tundra is allowed.[57] As transmission and storage facilities and vessels are increasingly employed to access Arctic energy resources, safety and spill and leak-prevention standards or regulations will also need to be tailored to the region given its changing climate and harsh conditions.

Administration Activities and Plans

The Administration is committed to taking a thoughtful and balanced approach to oil and gas leasing and exploration in the Arctic, recognizing its substantial oil and gas potential, as well as the marine and coastal resources that Native communities depend on for subsistence and the unique and sensitive ecosystems that it harbors. In early 2015, the Department of the Interior took steps to resolve judicial concerns that had prevented a final decision on whether to award leases in the Chukchi Sea under a 2008 oil and gas lease sale[c] and released a Proposed 5-Year Plan for additional offshore oil and gas exploration that solicited comment on three additional lease sales in waters offshore Alaska during the 2017 to 2022 period.[d] The Administration also moved to protect some sensitive undersea areas in the Beaufort and Chukchi Seas by withdrawing them from future leasing for oil or gas exploration and development.[e] The Administration's policy is to develop scientific information and stakeholder feedback to proactively determine, in advance of any potential offshore lease sale, which specific areas offer the greatest resource potential while minimizing potential conflicts with environmental, subsistence, and multiple use considerations.[f]

[c] Department of the Interior. "Department Releases Updated Assessment for Chukchi Sea Lease Sale." February 12, 2015. http://interior.gov/news/pressreleases/interior-department-releases-updated-assessment-for-chukchi-sea-lease-sale.cfm. Accessed February 26, 2015.

[d] Department of the Interior, Bureau of Ocean Energy Management. "2017–2022 Outer Continental Shelf Oil and Gas Leasing Draft Proposed Program." January 2015. http://www.boem.gov/2017-2022-DPP/. Accessed February 26, 2015.

[e] The White House. "Presidential Memorandum – Withdrawal of Certain Areas of the United States Outer Continental Shelf Offshore Alaska from Leasing Disposition." January 27, 2015. http://www.whitehouse.gov/the-press-office/2015/01/27/presidential-memorandum-withdrawal-certain-areas-united-states-outer-con. Accessed February 6, 2015.

[f] Department of the Interior, Bureau of Ocean Energy Management. "2017–2022 Outer Continental Shelf Oil and Gas Leasing Draft Proposed Program." p. S-6. January 2015. http://www.boem.gov/2017-2022-DPP/. Accessed February 26, 2015.

Administration Activities and Plans (continued)

On February 20, 2015, the Department of the Interior released proposed regulations to ensure that future exploratory drilling on the U.S. Arctic Outer Continental Shelf is conducted safely and responsibly, guided by the highest operational standards. The proposed rule for Arctic standards focuses solely on the Beaufort Sea and Chukchi Sea Planning Areas. The regulations seek to ensure that operators take the necessary steps to plan and safely operate through all phases of offshore exploration in the Arctic environment, including mobilization, drilling, maritime transport, and emergency response. The enhanced regulatory framework would ensure that operators and their contractors are appropriately prepared for Arctic conditions and that operators have developed an integrated operations plan to cover all operations. The proposed regulations released incorporate some of the lessons learned from Shell's 2012 operations and recommendations from the Department's review.

In addition to these steps, at the request of Secretary of Energy Moniz, the National Petroleum Council undertook a study on Arctic research requirements and the technology constraints that must be addressed to ensure prudent oil and gas resource development, advance U.S. energy and economic security, and ensure environmental stewardship there. The study focused on technology constraints for offshore oil and natural gas liquids development, primarily in shallow depths.[g]

In response to energy needs in Arctic communities, the Department of Energy's National Renewable Energy Laboratory, in partnership with the Department of the Interior, developed the Remote Communities Renewable Energy partnership, which aims to develop, demonstrate, and deploy smaller-scale, hybridized, modular platforms to harvest energy from local renewable energy resources, reduce diesel fuel dependence and distribution requirements, and create an independent microgrid operation.[h]

Beginning in April 2015, the United States will assume the chairmanship of the Arctic Council for a 2-year term and will propose collaborative initiatives for the council to implement in such areas as addressing the impact of climate change and Arctic Ocean stewardship and scientific research. In advance of the chairmanship, President Obama issued an Executive Order on January 21, 2015, establishing an Arctic Executive Steering Committee led by the Director of the White House Office of Science and Technology Policy.[i, j]

Within the U.S. Arctic Council agenda under the Sustainable Arctic Communities pillar, the State Department has proposed a suite of renewable energy programming to address region-specific barriers to project deployment and convening best practices. These projects include constructing a high-penetration wind-diesel hybrid system based on the Remote Community Renewable Energy partnership design in a rural Arctic community. The Arctic Council's Sustainable Development Working Group is also sponsoring an Arctic Energy Summit in Fairbanks, Alaska, this September that will address energy challenges including renewables, oil and gas development, remote and rural heat and power, and energy transmission and transportation. The State Department also plans to sponsor an Arctic Renewable Energy business plan challenge through our Arctic embassies.

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[g] National Petroleum Council, Committee on Arctic Research. "Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources." March 31, 2015. http://www.npcarcticpotentialreport.org/pdf/AR_Exec_Summary.pdf. Accessed April 2, 2015.

[h] National Renewable Energy Laboratory. "Remote Community Renewable Energy Partnership." 2014. http://alaskarenewableenergy.org/wp-content/uploads/2010/09/HighPenetrationModularSystem_BrianHirsch_NREL.pdf. Accessed February 26, 2015.

[i] Executive Order No. 13,689. "Enhancing Coordination of National Efforts in the Artic." 80 Fed. Reg. 4191. January 26, 2015. http://www.gpo.gov/fdsys/pkg/FR-2015-01-26/html/2015-01522.htm.

[j] The member states of the Arctic Council are Canada, Denmark, Finland, Iceland Norway, the Russian Federation, Sweden, and the United States. Other countries have observer status on the council. Recent U.S. and European Union sanctions may affect coordination with Russia over the next few years.

QER Recommendations

ARCTIC ENERGY TS&D INFRASTRUCTURE

Through the U.S. chairmanship of the Arctic Council and in partnership with Canada, the U.S. government should provide leadership on energy safety, reliability, and environmental protection in Arctic regions, and on improving energy availability in remote areas, through the following:

Partner with Canada and the Arctic Council on Arctic energy safety, reliability, and environmental protection: DOE, the Department of the Interior, the Coast Guard, and the State Department should partner with Canada and other Arctic Council members, including the Arctic Regulators Forum, to 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: Additionally, under the Arctic Council, and domestically, DOE, the Department of the Interior, and the State Department should promote the Remote Community Renewable Energy partnership: first by developing, testing, and demonstrating its proposed modules in the United States and second by seeking avenues to deploy small-scale, hybridized conventional fuel-renewable generation platforms in other Arctic Council countries.

Infrastructures for Diversification of Caribbean Energy Supply

The Caribbean energy market is not large, but, given its proximity to the North American markets and energy systems, it could be a beneficiary of the North American energy renaissance. Current dependence on high-cost fuel imports for transportation and electricity generation is a major challenge for Caribbean islands, has local environmental and affordability impacts, and raises regional energy security and market concerns. Several strategies have emerged throughout the Caribbean to address the economic, environmental, and energy security issues associated with reliance on oil imports for electricity and transportation there.

The principal cause of high energy prices for electricity and transportation is the reliance of many Caribbean islands on oil imports. Currently, much of the Caribbean's oil imports come from Venezuela through its Petrocaribe organization, financed in part by deferred payment structures.[k] From June 2005 through the first quarter of 2009, Venezuela delivered approximately 90.5 million barrels of crude oil and refined products at an estimated $14 per barrel price reduction from market price among receiving countries.[58] Recently, Venezuela has been cutting the oil it supplies under these terms, which, in some cases, is leading to supply shortages on the islands.

[k] On June 29, 2005, 14 Caribbean and Central American nations signed the Energy Cooperation Agreement, establishing Petrocaribe during the First Energy Meeting of Heads of State/Government of the Caribbean on Petrocaribe. Presently, the now 18-member energy alliance consists of Antigua and Barbuda, the Bahamas, Belize, Cuba, Dominica, the Dominican Republic, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Saint Lucia, Suriname, and Venezuela.

Risk and Resilience in the Caribbean

Recent history has illustrated the potentially devastating consequences of natural disasters in the Caribbean. Small Island Developing States, including many Caribbean nations, face high risks and potential losses due to their size, location, economic characteristics, capital stock, and investment ability. For example, the United Nations reported that climate change leads to an additional $1.4 billion in the expected average annual losses associated with wind damage alone in the Caribbean through 2055.[l]

Apart from volatile energy prices, which affect Caribbean electricity generation and transportation, Caribbean islands face climate impacts to their energy infrastructure. Changes in precipitation may impact water availability on larger islands, including Jamaica, Haiti, and the Dominican Republic, for hydroelectric and thermal plants. Additionally, sea-level rise projections indicate greater impacts in the Caribbean due to gravitational and geophysical factors, and these impacts may affect coastal facilities, including power plants, oil refineries, and port facilities that receive oil and gas deliveries. Tropical storms represent a current and significant threat to Caribbean islands, and recent storms have resulted in the damage to energy production and distribution infrastructure, including damage to offshore platforms, pipelines, railways, roads, and bridges. Given the region's current reliance on oil for electricity generation, disruptions to transportation infrastructure also impact energy reliability.[m]

Since its establishment in 2007, the Caribbean Catastrophe Risk Insurance Facility (CCRIF), the world's first multi-country risk pool, has made nine payouts for extreme weather events (tropical cyclones, excess rainfall, and trough systems), totaling nearly $27 million to six member countries.[n, o, p] The CCRIF also performs regional tropical cyclone risk modeling in order to produce country profiles for its members. For example, using historic data, exposure assessment, and tropical cyclone risk modeling, the CCRIF profile of the Bahamas estimates a national loss of nearly $2.5 billion for a tropical cyclone with a 20-year return period.

[l] United Nations International Strategy for Disaster Relief. "Making Development Sustainable: The Future of Disaster Risk Management, Global Assessment Report on Disaster Risk Reduction." 2015. http://www.preventionweb.net/english/hyogo/gar/2015/en/home/GAR_2015/GAR_2015_1.html. Accessed March 26, 2015.

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[n] Caribbean Catastrophe Risk Insurance Facility. "Annual Report 2013-2014." October 2014. http://www.ccrif.org/sites/default/files/publications/CCRIF_Annual_Report_2013_2014.pdf. Accessed March 26, 2015.

[o] Caribbean Catastrophe Risk Insurance Facility. "About Us." January 2015. http://www.ccrif.org/content/about-us. Accessed March 26, 2015.

[p] Current members include Anguilla, Antigua and Barbuda, the Bahamas, Barbados, Belize, Bermuda, Cayman Islands, Dominica, Grenada, Haiti, Jamaica, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Trinidad and Tobago and Turks and Caicos Islands

Opportunities for Clean Energy Supplies for Caribbean Nations and Territories

Recognizing the need for tailored approaches to energy infrastructure in the region, the United States (with a delegation led by Vice President Biden) and several Caribbean partners developed the Caribbean Energy Security Initiative, which promotes and finances clean energy technologies in the region (see box on Current Administration Activities and Plans).

Recent increases in U.S. natural gas production—as well as longstanding natural gas production in Trinidad and Tobago[q]—may also provide opportunities to export liquefied natural gas (LNG) to Caribbean islands. This could lower energy costs, address the variability of renewable electricity generation resources, and reduce emissions from existing fuel oil-fired electricity generation.[59] Making natural gas a viable fuel source in the

[q] Trinidad and Tobago is unique among the Caribbean island nations in its significant fossil energy resource base. It has long been an oil and gas producer, and it exports significant quantities of LNG—approximately 675 billion cubic feet of LNG in 2012.

Caribbean would require the TS&D infrastructure associated with LNG imports. To date, Caribbean demand has been too small to justify the expense of the necessary infrastructure. However, a 2014 study commissioned by the Inter-American Development Bank determined that establishing a natural gas supply chain in the Caribbean (based on small-scale LNG transport and floating regasification infrastructure) presented an economical method of displacing fuel oil as a method for energy delivery to eight Caribbean region nations.[r, 60] The study estimated a 30 percent decrease in carbon dioxide emission by 2032, resulting from the displacement of fuel oil by natural gas in current generation.[61]

Other proposals to displace fuel oil have gained traction, including the use of propane, other liquid fuels, and renewable sources for electricity generation. In July 2013, the U.S. Virgin Islands Water and Power Authority began the process to design and construct propane TS&D infrastructure for two electricity generation units in St. Croix and St. Thomas. To produce the same amount of electricity as the fuel oil plants they are replacing, the propane generators will emit on average 96 percent less sulfur dioxide, 84 percent less coarse particulate matter, 85 percent less carbon monoxide, 24 percent less nitrogen oxide, and 17 percent less greenhouse gases.[62]

Administration Activities and Plans

U.S.-CARICOM Summit—Deepening Energy Cooperation. In April 2015, President Obama met with Caribbean leaders in a U.S.-CARICOM Summit in Kingston, Jamaica, to reaffirm the importance of our relationship with the region and the United States' commitment to partner with Caribbean countries to advance economic development, security, and good governance. Leaders discussed a broad range of issues, from our important trade and investment linkages to security cooperation, including the importance of improving energy security, reducing energy costs, and fighting climate change. This follows robust engagement on these issues over the last year, including the White House Caribbean Energy Security Summit hosted by the Vice President in January 2015 and the launch of the Caribbean Energy Security Initiative (CESI) coordinated by the State Department. The United States is deepening this collaboration through a Clean Energy Finance Facility for the Caribbean and Central America; an Energy Security Task Force, driving clean energy finance to support renewable energy and clean energy technology collaboration to promote energy efficiency and storage; spurring a clean energy transition; greening tourism through a new Clean Energy Program to establish the pre-conditions for clean energy development, optimize renewable energy integration, and accelerate private-sector clean energy investment.

Caribbean Energy Security Initiative. In 2014, Vice President Biden announced CESI, 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, CESI 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. CESI also is aimed at the full spectrum of the Caribbean energy sector, from production and generation through transmission, storage, and distribution to end uses. This scope is broader than the transmission, storage, and distribution focus of this Quadrennial Energy Review, but infrastructure will play a key role in the success of the projects under CESI.

On January 26, 2015, the Vice President, Energy Secretary Moniz, Deputy Secretary of State Blinken, and other senior Administration officials joined Caribbean heads of government, multilateral development banks, and other international partners in a Caribbean Energy Security Summit in Washington, D.C. The summit highlighted ongoing CESI efforts, such as improved governance of the energy sector, and recognized the continuing need for legal and regulatory reforms to introduce a broad range of clean energy technologies into the Caribbean. A variety of other commitments to promote and finance clean energy projects were announced. Administration engagement to promote energy security in the Caribbean, including through support for the necessary transmission, storage, and distribution infrastructure, will continue to be a priority.

[r] The Inter-American Development Bank study discussed the Bahamas, Barbados, Belize, the Dominican Republic, Guyana, Haiti, Jamaica, and Suriname.

QER Recommendations

CARIBBEAN ENERGY TS&D INFRASTRUCTURE

The Department of Energy recommends that, 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 the development of resilient energy infrastructure in the Caribbean.

RECOMMENDATIONS IN BRIEF:
Integrating North American Energy Markets

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 Energy Information Administration 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. The Department of Energy'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 transmission, storage, and distribution 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 the development of resilient energy transmission, storage, and distribution infrastructure in the Caribbean.

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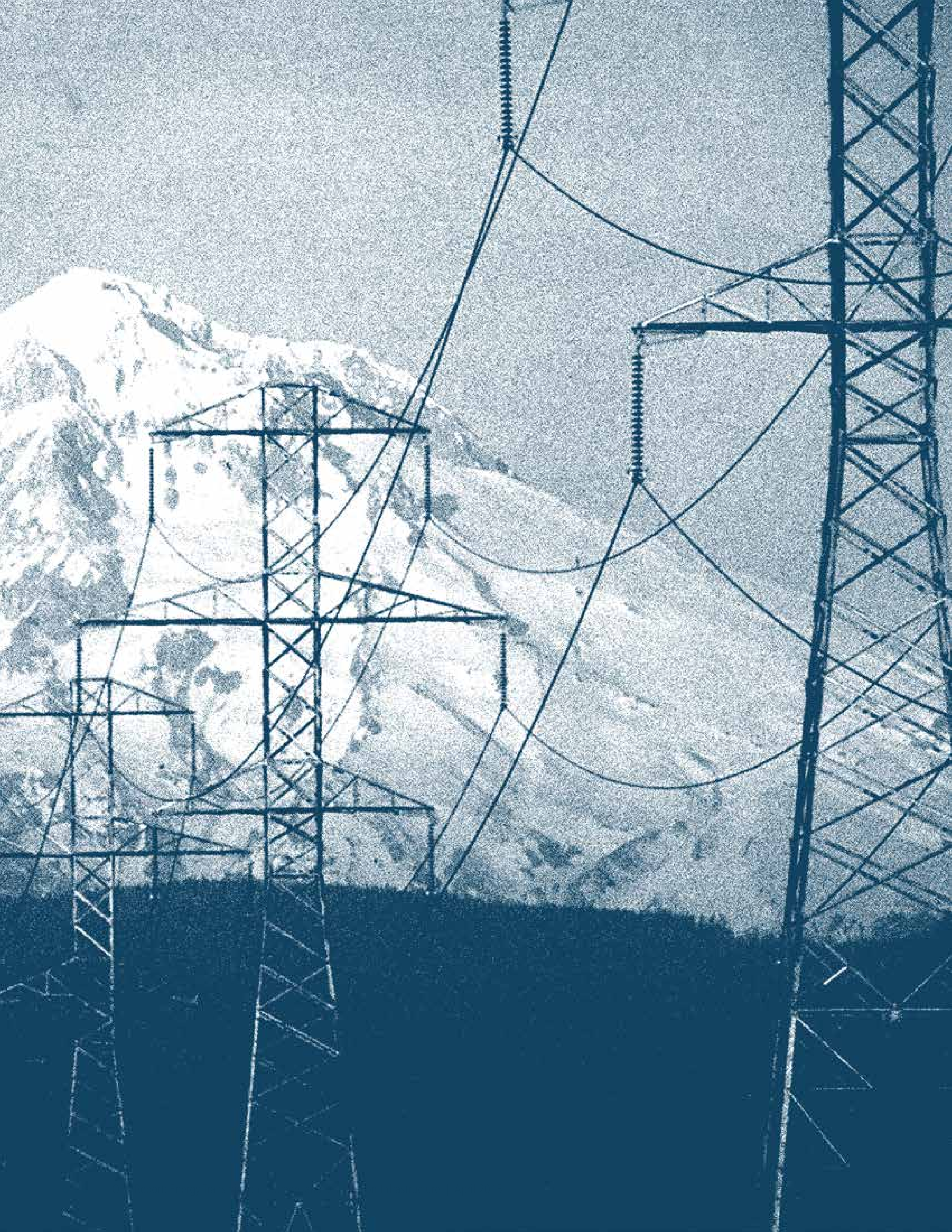

Chapter VII

ADDRESSING ENVIRONMENTAL ASPECTS OF TS&D INFRASTRUCTURE

This chapter focuses on the impacts of transmission, storage, and distribution (TS&D) infrastructure on the environment, complementing the discussion in Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure) of the effect of the environment on TS&D infrastructure. After a brief introduction discussing the range of environmental effects of TS&D infrastructure, the chapter briefly discusses land-use and ecosystem issues that commonly arise in connection with constructing and maintaining TS&D infrastructure. Actions to improve the siting and permitting processes that address these issues are discussed in greater detail in Chapter IX (Siting and Permitting of TS&D Infrastructure). The next two sections discuss air pollution from TS&D infrastructure, first focusing on greenhouse gas (GHG) emissions and then discussing conventional air pollutants. The following section deals with other environmental issues associated with TS&D infrastructure, including liquid fuel spills, water use, dredging, and the need for better data and analyses on environmental impacts of TS&D infrastructure. The final section of the chapter discusses how carbon dioxide (CO_2) pipelines can help enable the reduction of GHG emissions. The sections on GHG emissions, conventional air pollution, other environmental issues, and CO_2 pipelines each conclude with recommendations for further action.

FINDINGS IN BRIEF:
Addressing Environmental Aspects of TS&D Infrastructure

Transmission, storage, and distribution (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 carbon dioxide (CO_2) 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 Quadrennial Energy Review contributes to nearly 10 percent of U.S. greenhouse gas 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 carbon dioxide (CO_2) transportation pipelines that can be a critical component of a low-carbon future. The pipelines mostly transport naturally occurring CO_2, but new projects are increasingly linking captured CO_2 from electric power plants and other industrial sources to a productive use in oil fields (through CO_2 enhanced oil recovery) and potentially safe storage in deep saline formations.

The Range of Environmental Effects Associated with TS&D Infrastructure

Energy TS&D infrastructure affects the environment in a variety of ways. On the positive side, TS&D infrastructure can often enable better environmental performance of the overall energy system by providing access to cleaner energy supplies.

There is also the potential for harmful environmental effects, though, which need to be addressed. On a nationwide basis, siting, constructing, and maintaining TS&D infrastructure may have negative land-use and ecosystem impacts—especially habitat fragmentation—that are significant. While TS&D infrastructures are relatively minor sources of total air and water pollution compared to energy production and end use (which are not being addressed in this installment of the Quadrennial Energy Review [QER]), air and water pollution from TS&D infrastructure can be significant on a regional and local basis. For example, some vehicle engines used in energy transport produce particulate matter, posing local and regional public health concerns. Existing statutes and regulations address these concerns, in part. Some TS&D infrastructures also contribute to GHG emissions. Addressing leakage and venting of methane—a powerful GHG—requires a range of additional actions, including prudent regulation; research, development, and demonstration; and public-private partnerships to reduce methane emissions, promote efficiency, and improve safety. Many of these actions are underway as part of the President's "Climate Action Plan,"[1] including the Strategy to Reduce Methane Emissions.[2]

Land-Use and Ecosystem Impacts of Constructing and Maintaining TS&D Infrastructure

Given their size and complexity, many major TS&D infrastructure projects have unavoidable direct and indirect impacts on the Nation's landscapes and natural and cultural resources. The magnitude of these potential environmental impacts of TS&D infrastructure depend on a number of factors, including whether the proposed location of the facility will affect endangered species, involve sensitive ecological areas, impact cultural or historic resources, give rise to visual or aesthetic concerns, or open new areas to development. As energy infrastructures continue to expand, there is an opportunity to address these issues by improving how TS&D infrastructure is sited, built, and maintained, particularly infrastructure that enables better environmental performance.

Some of the most common land-use and ecosystem impacts of TS&D infrastructure described in this section are analyzed as part of the environmental and historic preservation review processes for energy infrastructure siting. They include those effects most often considered in the context of the National Environmental Policy Act of 1969 (NEPA) and its framework for assessing environmental impacts during the planning process before a Federal agency decides whether to fund, conduct, permit, or otherwise approve proposed TS&D infrastructure.[a] In its analysis, the permitting agency must consider mitigation requirements that may be imposed as conditions for unavoidable environmental harms.[3]

[a] Under NEPA and the Council on Environmental Quality Regulations Implementing the Procedural Provisions of the National Environmental Policy Act, any TS&D infrastructure proposal requiring a Federal agency to take an action (such as funding, permitting, or otherwise approving a pipeline or electricity transmission project) requires preparation of an environmental review that considers the environmental impact of the proposed action and any reasonable alternatives prior to the agency proposed action (42 U.S.C. §§ 4321–4347 and 40 C.F.R. §§ 1500–1508).

Cultural Resources

Cultural resources generally include important archaeological, historic, and architectural sites; structures; or places with important public and scientific uses. Section 106 of the National Historic Preservation Act requires Federal agencies to consider the effects on historic properties of projects, activities, or programs (referred to in the act as undertakings) that they carry out, assist, permit, license, or approve.[4] Resources considered as part of compliance with Section 106 are those that meet the criteria for listing on the National Register of Historic Places, which can include properties of traditional and religious importance to an Indian tribe.[5] The presence of cultural resources can present challenges for the siting of new energy transmission infrastructure.[b] Impacts are typically related to the project footprint and altered access to the area. Surveys must be conducted to identify potential archaeological and historic sites.[c] The identification of cultural resources within a proposed right of way may require moving the proposed route to avoid such resources or mitigation measures to address potential impacts to such resources.[6]

Special Status Wildlife, Fish, and Plant Species

Special status species include threatened or endangered plants or animals, the presence of which may pose a barrier to siting.[7] They also may include non-listed wildlife, fish, and plants that require special management consideration.[8, 9] The potential for impacts on threatened and endangered species of construction and operation of energy transport systems within corridors are related to the amount of land disturbance, the duration and timing of construction periods, and the habitats crossed by the corridors. In order to comply with NEPA and the Endangered Species Act, agencies may conduct inventories to ensure that they have sufficient information available to adequately assess the effects of proposed actions on special status species.

Habitat Fragmentation/Land Cover

Ecological habitats (including rangeland, forests, woodlands, wetlands, lakes, reservoirs, riparian areas, and fishable streams) may become fragmented when crossed by transmission lines or pipelines that divide the continuous natural habitat into smaller patches. Even though physical barriers are not normally erected along the majority of transmission corridors, fragmentation occurs when the habitat or land cover type in the transmission corridor is altered from its surroundings. By changing the habitat, land cover change can alter the species makeup of the local ecosystem—favoring some species and disadvantaging others.[10]

Environmental Justice

Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.[11] The responsibility of Federal agencies to consider environmental justice is set out in Executive Order No. 12898[12, 13] and typically implemented in conjunction with NEPA review, as described in the Council on Environmental Quality guidance for environmental justice.[14]

Seismic Hazards

Significant risk of ground shaking can pose a threat to human health and safety in areas where energy transmission infrastructure—particularly natural gas pipelines—exists. This risk can pose a barrier to siting new transmission. Seismic hazards include earthquakes; ground faulting; and secondary effects, such as

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[b] New transmission facility proposals initiate agency collaboration to determine an Area of Potential Effect (APE). The APE may be hundreds of feet wide or many miles wide depending on the resources, potential impacts, and decisions under consideration. Once the APE is established, the agencies review existing data and collect new data, as appropriate, within the APE.

[c] A low number of National Register of Historic Places sites for a proposed corridor may seem to indicate few siting challenges, but if only a small percent of the corridor has been surveyed, this low number of sites may not be indicative of the actual number of cultural resources present.

liquefaction and related slope failures.[15] Measurement of seismic risk depends on the chosen intensity and probability thresholds for a damaging event.[d]

Visual Resources, Specially Designated Areas, and Recreation

Negative impacts to the visual surroundings of specially designated Federal areas can create barriers to the siting of energy transmission facilities nearby (even if the proposed right of way does not intersect the designated area).[16] These specially designated areas can include, but are not limited to, national parks, national monuments, national recreation areas, national conservation areas, national park service areas, national natural landmarks, national historic landmarks, national scenic trails, national historic trails, national scenic highways, national scenic areas, national scenic research areas, national wild and scenic rivers, and national wildlife refuges. Numerous state-designated areas that are sensitive to visual disturbance also exist.

Aviation

NEPA analyses consider overhead electrical transmission wires, as they pose a threat to the low-level flight activity.[17] Special-use airspace is established in Federal regulations[18, 19] and can also involve low-altitude flight. When less than 200 feet above ground level, electric transmission lines often do not require marking or lighting, thus posing a particular hazard to aviation in areas where low-altitude flight is expected.

Cumulative Impacts

Under NEPA, cumulative impact is defined as the impacts on the environment that result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.[20] Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.[21] Guidance issued by the Council on Environmental Quality specifies how to carry out cumulative effects analysis for identified impacts.[22] Cumulative effects should be considered for all environmental impacts in an assessment.

Additional Considerations

Additional considerations under NEPA that can create challenges for siting of TS&D infrastructure or require mitigation, minimization, or compensation for impact include Native American concerns; acoustics; air quality; land use; paleontological resources; proximity to hazardous materials; proximity to Department of Defense operations and facilities; socioeconomics; soils and geologic resources; waste management areas; and water resources, including groundwater, waterbody crossings, and wetlands. Water quality can also be affected by excavations that lead to erosion.[23] Additionally, herbicides applied to maintain clearings can have adverse effects on aquatic life.[24]

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[d] An event with a peak acceleration of 0.18 g or higher is considered potentially damaging. See: Wald, D.J. et al. "Shake Map® Manual — Technical Manual, Users Guide, and Software Guide." U.S. Geological Survey. June 19, 2006. The area of TS&D infrastructure where there is a moderate or higher potential for damage from seismic activity is defined as a 2 percent risk of a ground-shaking event exceeding 0.18 g peak acceleration in the next 50 years). See: Petersen, M.D. et al. "Documentation for the 2008 Update of the United States National Seismic Hazard Maps: Open-File Report 2008–1128." U.S. Geological Survey. 2008. pubs.usgs.gov/of/2008/1128/. Accessed February 25, 2015. See also: Federal Energy Regulatory Commission. "Final Environmental Impact Statement on Ruby Pipeline Project (Docket No. CP09-54-000): Chapter 4." p. 4–16. January 10, 2010. www.ferc.gov/industries/gas/enviro/eis/2010/01-08-10.asp. Accessed March 9, 2015.

Mitigation of Environmental Impacts

Decades of experience with siting energy infrastructure have resulted in the development of various measures and methods for offsetting impacts to affected communities and ecosystems, including avoidance, minimization, and compensation.[e] Mitigation is an important mechanism for agencies to use to avoid, minimize, rectify, reduce, or compensate the adverse environmental impacts associated with their actions.[25, 26] Federal agencies typically rely upon mitigation to reduce environmental impacts through modification of proposed actions and consideration and development of mitigation alternatives during the NEPA process.[f]

Resource-specific mitigation measures can be applied to avoid or minimize impacts from a pipeline or an electric transmission project. In order to identify and implement appropriate mitigation measures, first the potential impacts of a project on a specific resource must be assessed. Then, project-specific and site-specific factors must be evaluated to determine whether the impact can be avoided or mitigated, what action can be taken, how effective the mitigation measure will be, and the cost effectiveness of the measure.[27]

Mitigation is of particular importance to Federal agencies that manage hundreds of millions of acres of public lands, which comes with a responsibility to sustain a vast array of resources, values, and functions. For example, public lands contain important wildlife habitat and vegetative communities—in addition to recreational opportunities and ecosystem services, cultural resources, and special status species. These lands are managed for the use and enjoyment of present and future generations. The location, construction, and maintenance of energy infrastructure should avoid, minimize, and, in some cases, compensate for impacts to these public resources, values, and functions. Mitigation is also of critical importance to those agencies responsible for protecting the Nation's waters.[28] Applying this mitigation hierarchy early in the planning for TS&D infrastructure will help provide better outcomes for the impacted resources, values, and functions.[29]

The issues described in this section are not the only factors considered during the environmental and historic preservation review processes for energy infrastructure development. A more detailed description of the siting, permitting, and review process for infrastructure projects and approaches for avoiding, minimizing, or compensating for potential impacts of those projects is found in Chapter IX (Siting and Permitting of TS&D Infrastructure).

Emissions from TS&D Infrastructure

Air pollution can be associated with all stages of construction and operations of TS&D infrastructure; however, the severity of the pollution—both in type of pollutant and overall environmental load—differs significantly across the scope of infrastructure covered in the QER. Certain components within the TS&D infrastructure are sources of both conventional air pollutants and GHG emissions. The following discussion is not intended to be a comprehensive catalog of air pollution impacts from energy TS&D infrastructure, but rather a discussion of areas where actions could lead to emissions reductions. For example, analyses for the QER on GHG emissions focused on natural gas TS&D systems because there are opportunities for relatively low-cost emissions reductions, and this infrastructure is expanding significantly.

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[e] This mitigation hierarchy of "avoid, minimize, and compensate" has been developed through implementation of both NEPA (40 C.F.R. § 1508.20) and the Clean Water Act (33 U.S.C. §§ 1251–1387). See: "Memorandum for Heads of Federal Departments and Agencies." February 18, 2010. ceq.doe.gov/nepa/regs/Mitigation_and_Monitoring_Draft_NEPA_Guidance_FINAL_02182010.pdf. The final step in the hierarchy seeks to repair, rehabilitate, or restore the affected environment or resource and ultimately to compensate for, or offset, any impacts that remain. This is typically described as "compensatory mitigation."

[f] The Council on Environmental Quality's NEPA regulations require agencies to identify in their Record of Decision any mitigation measures that are necessary to minimize environmental harm from the alternative selected (40 C.F.R. § 1505.2(c)). The NEPA analysis can also consider mitigation as an integral element in the design of the proposed action. The regulations further state that a monitoring and enforcement program shall be adopted where applicable for any mitigation (40 C.F.R. § 1505.3).

TS&D infrastructure covered by this installment of the QER[g] contributes to nearly 10 percent of U.S. GHG emissions.[30] For conventional air pollutants, the TS&D systems considered in the QER are also relatively small contributors to national pollutant loads, but may have significant local and regional impacts on air quality. The facilities of the greatest concern include petroleum refineries; ethanol plants; natural gas and natural gas liquids processing plants; and natural gas compressor stations, which are located along transmission and gathering pipelines. The transportation of energy commodities also leads to air pollution, particularly in transportation hubs like ports and rail yards.

GHG Emissions from Natural Gas Systems

The two primary GHGs emitted from natural gas systems[h] are CO_2 and methane. Emissions of methane throughout the natural gas system have been declining,[31] but are expected to increase if additional action is not taken.[32] As discussed in this section, analysis for the QER identified significant opportunities for reducing these emissions in the coming decades. Methane—the primary component of natural gas—is a potent GHG, with an atmospheric lifetime of only 10 to 12 years. When integrated over 100 years, methane is more than 25 times more effective than CO_2 at trapping heat in the atmosphere.[33, i] The Environmental Protection Agency's (EPA's) national Greenhouse Gas Inventory (GHGI) estimates that, in 2012, methane contributed to roughly 10 percent of gross GHG emissions (on a CO_2-equivalent basis) from U.S. anthropogenic sources, nearly one-quarter of which were emitted by natural gas systems.[34]

While 80 percent of GHG emissions from natural gas occur at the end-use stage (from combustion by consumers),[35, 36, 37] significant methane and CO_2 emissions occur throughout natural gas infrastructures (not including end use) in almost equal amounts on a CO_2-equivalent basis. As shown in Figure 7-1, 155 million metric tons of CO_2 equivalent of methane were emitted in 2012 through routine venting,[j] as well as inadvertent leakage.[k] In the same year, a roughly equal amount of CO_2 (approximately 164 million metric tons of CO_2 equivalent) was emitted at production, processing, transmission, and storage facilities, primarily from the combustion of natural gas that is used as a fuel for compression, but also when non-hydrocarbon gases are removed during the processing stage, as well as from flaring. Figure 7-1 shows these emissions in detail from natural gas infrastructures; GHG emissions that are in scope for the QER include only those from processing, transmission and storage, and distribution segments. Methane emissions from the petroleum sector are not covered in this installment of the QER because they are almost entirely from production-stage operations.

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[g] Sources of GHG emissions that are in scope for the QER include petroleum refineries; biofuel refineries; liquid fuel pipelines; natural gas processing plants; natural gas pipelines; natural gas compressor stations; and the transport of energy by pipeline, truck, rail, and marine vessel.

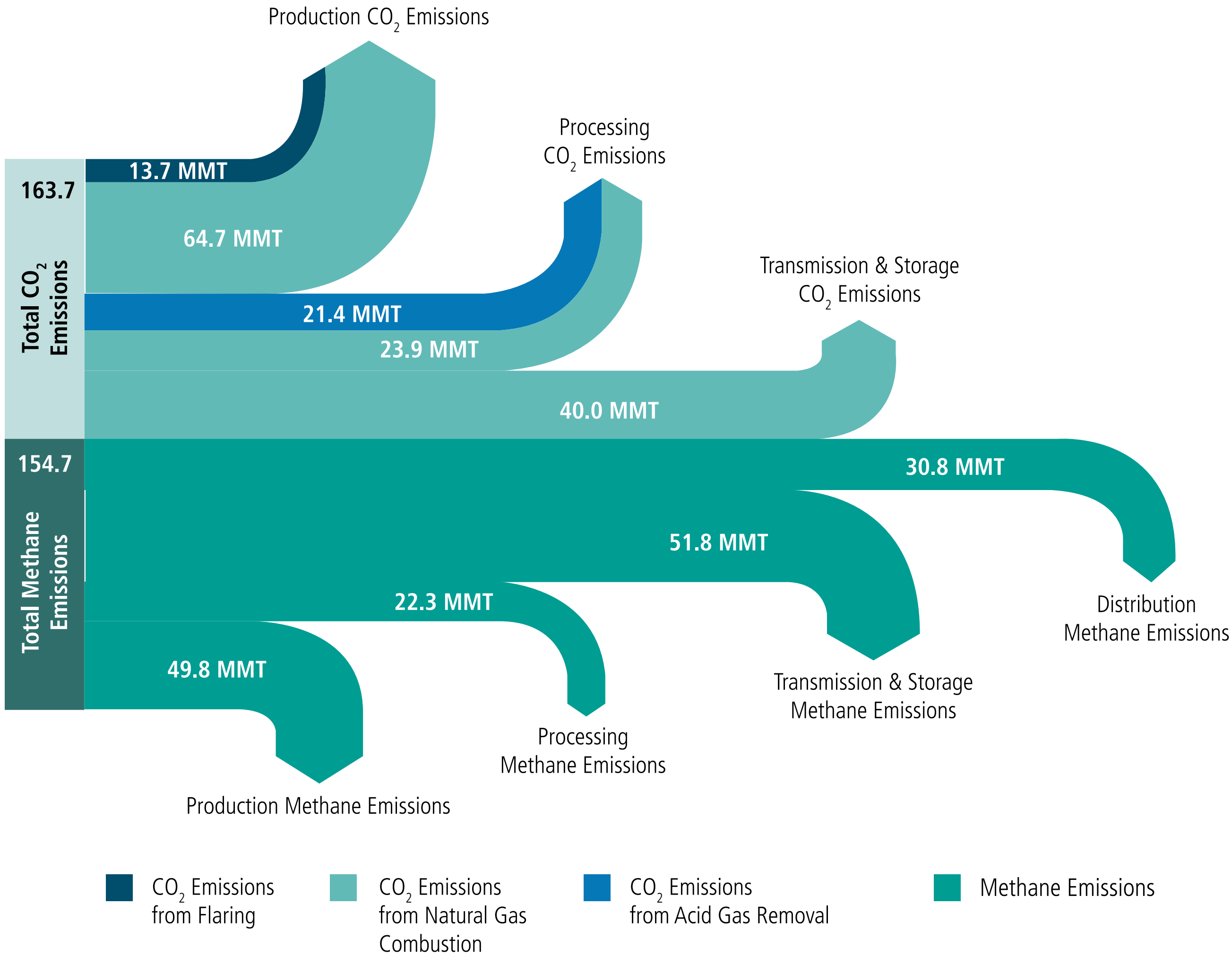
[h] Throughout this chapter, the term "natural gas system" refers broadly to natural gas production, processing, transmission, storage, distribution, and end-use consumption; the term "natural gas infrastructure" refers to all aspects of the natural gas system except for end-use consumption.

[i] Considering these impacts over such a period leads to what is called the Global Warming Potential (GWP) of a GHG. The 100-year GWP for methane from the "Intergovernmental Panel on Climate Change Fourth Assessment Report" is 25. A 20-year GWP can be used to measure the shorter-term impacts of methane emissions. GWPs compare GHGs by equating the warming potential of gases other than CO_2 to the equivalent amount of CO_2 emissions needed to achieve the same warming.

[j] Examples of routine "venting" include blowdowns (when gas is evacuated from a section of pipeline for the purpose of conducting tests, repairs, or maintenance). Natural gas is vented by a number of sources, including pneumatic devices, which operate natural gas-driven controllers and natural gas-driven pumps, both of which are used extensively throughout the oil and natural gas industry—emitting natural gas as a function of routine operation.

[k] Natural gas "leakage," also commonly referred to as "fugitive emissions," includes those emissions that occur inadvertently as a result of malfunctioning equipment (e.g., damaged seals, cracked pipelines).

Figure 7-1. 2012 GHG Emissions from Natural Gas Production, Processing, Transmission, Storage, and Distribution[38]



Both CO_2 (top of diagram) and methane (bottom of diagram) are emitted in roughly equal amounts from various sources and processes upstream of end-use consumers. Eighty percent of the GHG emissions from the natural gas system result from consumer end use of natural gas. However, these emissions are omitted from this figure to enable a more detailed picture of emissions from natural gas infrastructure.

Data from the Energy Information Administration[39] indicate that fuel use—and therefore CO_2 emissions—by natural gas processing and transmission[l] increased by 35 percent between 2005 and 2013. As natural gas infrastructure continues to expand, the Energy Information Administration projects that natural gas fuel use by TS&D systems will continue to increase in the coming decades,[40] leading to greater CO_2 and potentially other combustion-related air emissions from these facilities. Methane emissions from natural gas processing, transmission, and storage have increased by 13 percent from 2005 to 2012,[41] which is slower than increases in fuel use because new infrastructure is less prone to leakage.

Opportunities to Reduce GHG Emissions from Gas Systems

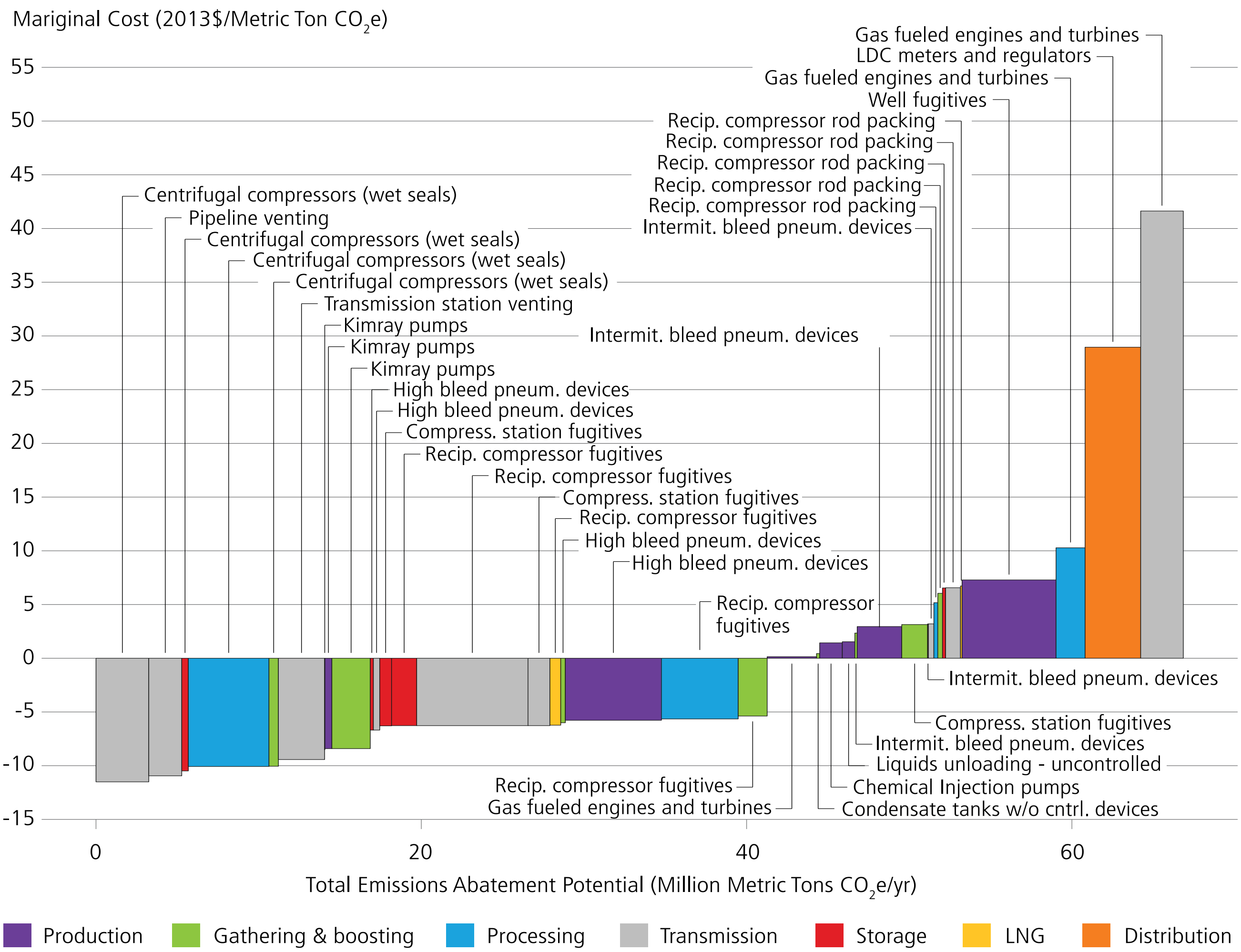
CO_2 emissions from processing, transmission, and storage facilities stem primarily from natural gas fuel consumed by compressor units during natural gas transport.[42] Most methane emissions from the processing, transmission, and storage of natural gas result from leakage and venting by compressor stations.[43] Methane emissions from natural gas distribution result mainly from leaks in meters, regulators, and distribution

[l] This includes U.S. natural gas "plant fuel consumption" and "pipeline and distribution use."

pipelines.[44] Examples of cost-effective options for reducing methane emissions from the natural gas system include (1) changing operations and maintenance practices, (2) increasing leak detection and repair, and (3) upgrading equipment (see Figure 7-2).[45, 46, 47]

There are economic, environmental and safety benefits associated with modernizing the natural gas TS&D system. Policies are needed to ensure that private companies can recover costs of such investments to improve safety and reduce emissions.[48] In addition, while a number of actions may not have net benefits when only accounting for the monetary value of conserved gas, some of these can be cost effective if the climate change and safety benefits are taken into account. To achieve these societal benefits, there is an important role for government—often in partnership with industry—to advance new technologies and encourage investments. A combination of ongoing Administration actions and QER recommendations meet this need for Federal action.

Figure 7-2. Total Emissions Abatement Potential (million metric tons CO_2-equivalent per year)[49, m]



Assuming full revenue recovered from the sale of captured natural gas, an estimated 40 million metric tons CO_2-equivalent of methane emissions abatement could be achieved at a negative marginal cost; under this scenario, at a marginal cost below the Social Cost of Carbon, all segments of natural gas infrastructure have potential opportunities for cost-effective methane abatement. Acronyms: intermittent (intermit.); pneumatic (pneum.); local distribution company (LDC); liquefied natural gas (LNG); reciprocating (recip.).

[m] The social cost of carbon is a metric that monetizes the societal benefits and costs of emitting an additional ton of carbon. The social cost of carbon at a 3 percent discount rate in year 2015 and in 2015 dollars is $43 per ton CO_2. Source: Interagency Working Group on Social Cost of Carbon, 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis – Under Executive Order 12866. May. U.S. Government.

GHGI and Methane Measurement

The White House's Strategy to Reduce Methane Emissions calls for the U.S. government to assess current emissions data and address identified data gaps.[50] The U.S. natural gas profile has dramatically changed in the last 10 years. Ongoing efforts to update the data used to calculate GHGI emissions estimates are being privately and federally funded and carried out by several researchers, including large multi-stakeholder efforts.[51] Under the 2014 "Climate Action Plan" Strategy to Reduce Methane Emissions, EPA will continue to update and enhance the data published in its annual GHGI as new scientific evidence and data sources emerge.

Improving the efficiency of equipment operating along the natural gas supply chain, especially compressors, would reduce GHG emissions and other combustion-related emissions of criteria air pollutants and ozone precursors. Additional opportunities for technical efficiency improvements include pipeline operations, sizing, layout, cleaning, and interior coatings, as well as opportunities for waste heat recovery. While the greatest opportunities for efficiency improvement lie in new systems, options do exist for improving the efficiency of existing systems as well.[52]

Reducing GHG Emissions from Refineries and Energy Transport

Petroleum refineries are among the most energy-intensive manufacturing facilities in the United States,[53] which results in substantial CO_2 emissions—both onsite and offsite of these facilities. Onsite emissions of CO_2 from petroleum refineries accounted for more than 30 percent of CO_2 emissions from U.S. manufacturing[54] and 4 percent of total CO_2 emissions from fossil energy combustion.[n] The combination of all other TS&D infrastructure—including biofuel refineries,[55] liquid fuel pipelines, and vehicles that transport energy[56] directly or indirectly (i.e., through the use of electricity)—contribute to CO_2 emissions in relatively smaller amounts. The primary means for reducing CO_2 emissions from refineries is through efficiency improvements. Analysis has also consistently found that there remain opportunities for additional efficiency improvement.[57, 58]

Administration Activities and Plans to Reduce Greenhouse Gas Emissions from Transmission, Storage, and Distribution Infrastructures

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 40–45 percent from 2012 levels by 2025, as well as a set of actions to put the United States on a path to achieve this ambitious goal. These goals include the following:

Common-sense standards for methane emissions from new and modified sources. The Environmental Protection Agency (EPA) will initiate a rulemaking effort 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.

New guidelines to reduce volatile organic compounds. EPA will develop new guidelines to assist states in reducing ozone-forming pollutants from existing oil and gas systems in areas that do not meet the ozone health standard and in states in the Ozone Transport Region—an added benefit will be methane emissions reductions.

Enhancing leak detection and emissions reporting. EPA will continue to promote transparency and accountability for existing sources by strengthening its Greenhouse Gas Reporting Program to require reporting in all segments of the industry. In addition to finalizing updates to the program, by the end of 2015, EPA will explore potential regulatory opportunities for applying remote-sensing technologies and other innovations in measurement and monitoring technology to further improve the identification and quantification of emissions and improve the overall accuracy and transparency of reported data in a cost-effective manner.

[n] This compares direct CO_2 emissions from refineries in 2012 (210 million metric tons) with the Energy Information Administration's estimate of total CO_2 emissions from fossil fuels in 2012 (5,255 million metric tons). More information can be found on the Energy Information Administration's Environment website at www.eia.gov/environment/.

Administration Activities and Plans to Reduce Greenhouse Gas Emissions from Transmission, Storage, and Distribution Infrastructures (continued)

Leading by example on public lands. The Department of the Interior's Bureau of Land Management will update decades-old standards to reduce wasteful venting, flaring, and leaks of natural gas—primarily methane—from oil and gas wells. These standards, to be proposed in spring of 2015, will address both new and existing oil and gas wells on public lands.

Reducing methane emissions while improving pipeline safety. The Department of Transportation's Pipeline and Hazardous Materials Safety Administration will propose natural gas pipeline safety standards in 2015. While the standards will focus on safety, they are expected to lower methane emissions as well.

Modernizing natural gas transmission and distribution infrastructure. Following on its methane roundtables, the Department of Energy will continue to take steps to encourage reduced greenhouse gas emissions, including the following:

- Issuing energy efficiency standards for natural gas and air compressors
- Advancing research and development to bring down the cost of detecting leaks
- 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
- Providing loan guarantees for new methane reduction technologies
- Developing a clearinghouse of information on effective technologies, policies, and strategies

Industry actions to reduce methane emissions. Several voluntary industry efforts to address these sources are underway, including EPA's plans to expand on the successful Natural Gas STAR Program by launching a new partnership in collaboration with key stakeholders later in 2015. EPA will work with the Department of Energy, the Department of Transportation, 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.

Other Federal actions. The Federal Energy Regulatory Commission has issued a policy statement that will allow interstate natural gas pipelines to recover certain investments made to modernize pipeline system infrastructure in a manner that enhances system reliability, safety, and regulatory compliance. Also, in December 2014, the Council on Environmental Quality released revised draft guidance for public comment that describes how Federal departments and agencies should consider greenhouse gas emissions and climate change in their National Environmental Policy Act reviews.

QER Recommendations

REDUCING GHG EMISSIONS

Reducing GHG emissions from TS&D infrastructure includes a number of win-win opportunities from climate change and public safety perspectives. Among these are opportunities for modernizing natural gas distribution infrastructure, as discussed in Chapter II (Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure). In addition to the measures already put in place, to further reduce methane emissions from TS&D infrastructure, we recommend the following:

Improve quantification of emissions from natural gas TS&D infrastructure. An effective strategy to significantly improve methane emission estimates in the GHGI requires additional Federal funding for new measurements to update emission factors and activity data. That is why the President's Fiscal Year 2016 Budget Request proposes $10 million to launch a Research and Analysis Program at the Department of Energy (DOE) to enhance the quantification of emissions from natural gas infrastructure to include in the national GHGI in coordination with EPA.

QER Recommendations (continued)

Specific research areas for consideration that are downstream of natural gas production include emission estimates from pneumatic devices, leaks, and the natural gas gathering and boosting sectors. Congress should approve this funding. DOE and EPA should undertake a coordinated approach, building on stakeholder input, to ensure that new research and analysis is targeted toward knowledge gaps that are not already addressed by existing databases or other ongoing measurement studies.

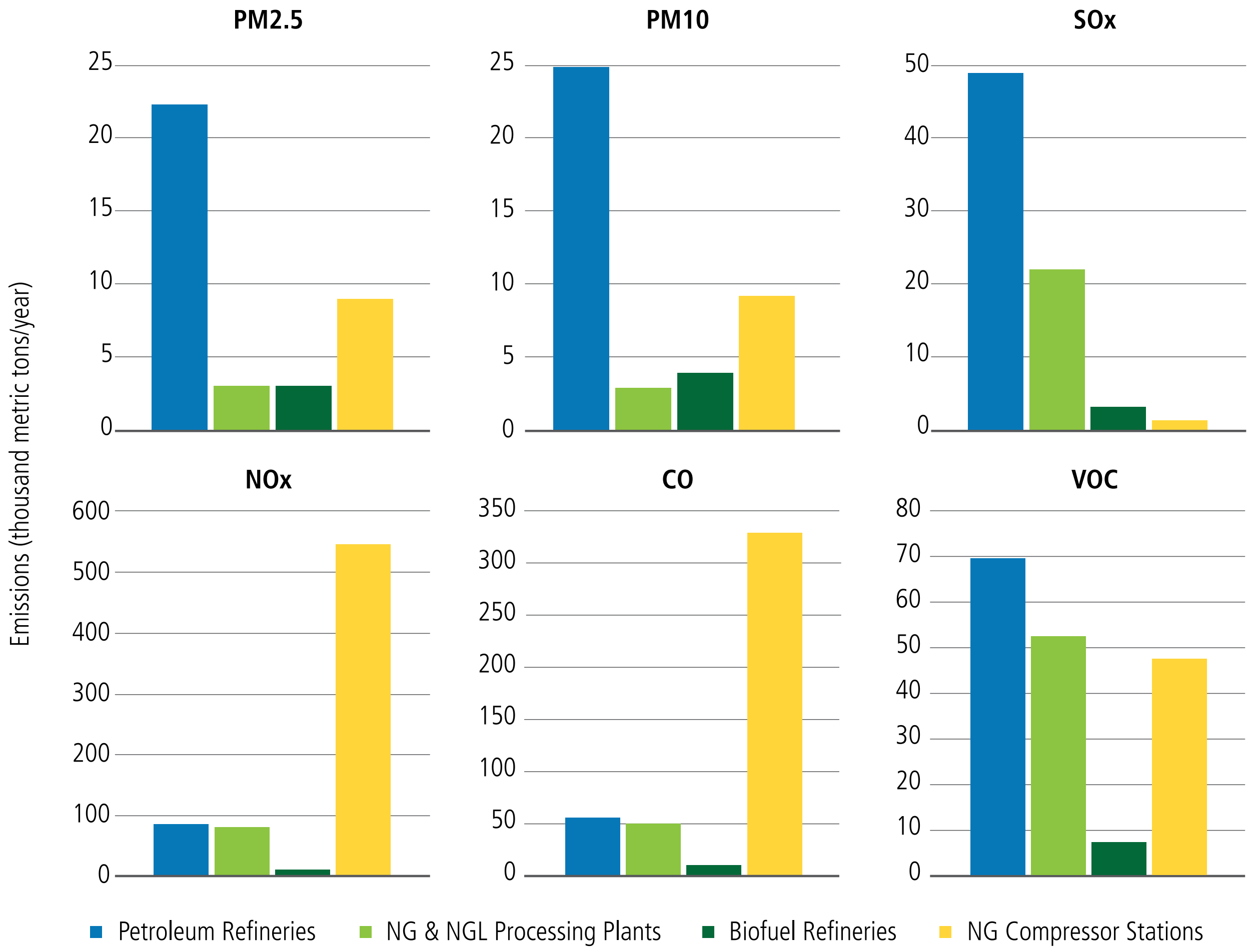
Expand natural gas transmission and distribution research and development programs. DOE should continue to develop and demonstrate cost-effective technologies to detect and reduce losses from natural gas transmission and distribution systems. The President's Fiscal Year 2016 Budget Request proposes $15 million in funding for DOE's midstream natural gas infrastructure subprogram to focus on reducing methane leaks and enhancing operational efficiencies of pipelines, storage facilities, and compressor stations, as well as on communicating results to stakeholders to mitigate methane emissions. Congress should approve this funding. DOE should leverage its research and development efforts in this area to facilitate broader air quality benefits—reducing methane losses and improving midstream infrastructure efficiency to reduce nitrogen oxides and other ozone precursors, which will help states to meet national air quality standards.

Invest in research and development to lower the cost of continuous emissions monitoring equipment. Continuous emissions monitoring can be a valuable component of leak detection and repair programs, which serve to improve safety and the operational improvement of natural gas systems. The Advanced Research Projects Agency-Energy's MONITOR program is providing $30 million for breakthrough technologies to measure methane emissions from natural gas systems. DOE should provide the additional funding needed to ensure that the most successful MONITOR projects are field tested and deployed.

Conventional Air Pollution from TS&D Infrastructure

Beyond GHGs, TS&D infrastructure also contributes to conventional air pollutants such as ozone and particulate matter. Overall, air quality in the United States has been improving for decades, and additional improvements are expected in the coming decades as a result of existing and new regulations.[59] However, given that higher temperatures are known to contribute to the formation of ground-level ozone, continued progress will be increasingly challenged by climate change.[60] Persistent challenges remain in certain areas of the country where concentrations of pollutants in the atmosphere exceed national limits set by EPA. In addition, hazardous air pollutants are regulated through different Clean Air Act requirements. Reducing emissions of these air pollutants has significant benefits for human health and the environment across broad regions of the country—particularly in populated, urban areas, where they are found in relatively high concentrations in the lower atmosphere.[61, 62] In 2012, EPA issued standards for volatile organic compounds (VOCs) from the oil and gas industry. These standards, when fully implemented, are expected to annually reduce 190,000 tons to 290,000 tons of emissions of VOCs, which pose risks to public health and the environment.[63]

Figure 7-3. Criteria Air Pollutant and Precursor Emissions from Stationary TS&D Facilities in 2011[64, o]



Refineries are the primary source of particulate matter, sulfur oxide, and VOC emissions, while natural gas compressor stations are the leading source of ozone precursor emissions (nitrogen oxides, carbon monoxide, and VOCs). Nitrogen oxides emissions shown here for refineries and natural gas processing and compression accounted for roughly 30 percent of total nitrogen oxides emissions from all industrial processes and industrial fuel combustion in 2011.

Stationary Sources of Conventional Air Pollutants from TS&D Infrastructure

In the context of emissions from TS&D infrastructure, the facilities of the greatest concern include petroleum refineries, ethanol plants, natural gas and natural gas liquids processing plants, and natural gas compressor stations, which are located along transmission and gathering pipelines. While these sources generally only account for a small portion of total U.S. emissions of each pollutant, they still are significant, particularly for surrounding areas. Nitrogen oxides emissions from these facilities (see Figure 7-3) added up to roughly 30 percent of nitrogen oxides emissions from industrial processes and industrial fuel combustion in 2011.[65] In 2013, more than 53 million people lived in U.S. counties with ground-level ozone levels above the current

[o] Air emissions from each source category were drawn from EPA's National Emissions Inventory as follows: "Petroleum Refineries" (NAICS 324110); "Natural Gas and Natural Gas Liquid Processing Plants" (NAICS 211112); "Biofuel Refineries" (NAICS 325193); and "NG Compressors" (includes emissions from all facilities listed under Pipeline Transport of Natural Gas (NAICS 486210); plus compressor station facilities listed under Natural Gas Distribution (NAICS 221210); plus county total nonpoint compressor engines (source classification codes 2310020600, 23100211(01,02,03), 23100212(01,02,03), 23100213(01,02,03), and 23100214(01,02,03)).

National Ambient Air Quality Standards,[66] and nitrogen oxides, carbon monoxide, and VOCs are all precursors to ozone. Natural gas compressors can be electrified to reduce emissions in regions with air quality problems;[67] to the degree this is done, however, interdependencies and potential vulnerabilities grow as gas transmission becomes more reliant on electricity (see discussion in Chapter II, Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

While overall emissions have been declining for decades, trends are inconsistent across different sectors. For example, though still only 5 percent of the national total, nitrogen oxides emissions from the oil and natural gas sectors[p] have increased by roughly 94 percent between 2005 and 2011.[68] This is particularly striking, as EPA trends data[69] show that vehicle and power plant emissions have declined considerably.[q]

In addition to emissions of criteria air pollutants and their precursors, the petroleum and gas sectors contribute significantly to emissions of hazardous air pollutants. In particular, the petroleum sector is responsible for roughly 5 percent of industrial sources of hazardous air pollutants released annually (according to the Toxic Release Inventory).[70] A proposed rule (Proposed Petroleum Refinery Sector Risk and Technology Review and New Source Performance Standards) was published in the Federal Register[71] for public comment on June 30, 2014.[r] The rule proposes additional emission controls for storage tanks, flares, and coking units, in addition to fence-line air quality monitoring, to ensure standards are being met and that neighboring communities are not being exposed to unintended emissions. If the final rule is identical to the proposed rule and fully implemented (i.e., 3 years from the promulgation of the final rule), EPA estimates that these and other provisions will result in a reduction of 5,600 tons per year of toxic air pollutants and 52,000 tons per year of VOCs.[72]

Air Pollution from the Transport of Energy Commodities

The transportation of energy commodities also contributes to air pollution. Of particular concern is diesel exhaust—a complex mixture of pollutants and a likely carcinogen—which has health effects that include premature mortality, increased hospital admissions, and heart and lung diseases.[73] Oak Ridge National Laboratory estimates[74] that transport of energy products, as a portion of total freight transport, amounts to 28.6 percent of the total ton-miles of freight transported by rail, 5.2 percent of the total ton-miles of freight transported by truck, and 32.4 percent of the total ton-miles of freight transported by vessel. Therefore, emission estimates presented in Figure 7-3 are scaled from national totals, according to these proportions.

Among the primary energy transportation options (other than pipelines), 2011 emissions from marine vessels were higher than from other modes (see Figure 7-4), particularly with respect to nitrogen oxides, sulfur dioxide, and fine particulate matter. This is largely because ocean-going marine vessels have historically used residual (or bunker) fuel,[75] which is a less-refined energy product. Meanwhile, barges propelled by tugboats that operate on inland waterways exclusively use diesel fuel, resulting in less pollution from these vessels than from ocean-going vessels.[76] Emissions from marine vessels overall are rapidly declining, in large part due to new regulations discussed below.

As with stationary sources, while the criteria air pollutant emissions presented in Figure 7-3 generally account for only a small portion of total U.S. emissions of each pollutant, they can contribute significantly to air quality problems in certain regions and localities. For example, diesel exhaust from rail, heavy-duty trucks, and marine vessels are significant contributors to local and regional air quality problems. To help address these issues, EPA

[p] This is based on EPA National Emissions Inventory estimates of nitrogen oxides emissions for the combination of two sectors—"petroleum and related industries" and "storage and transport"—with roughly half of these emissions coming from natural gas compressors.

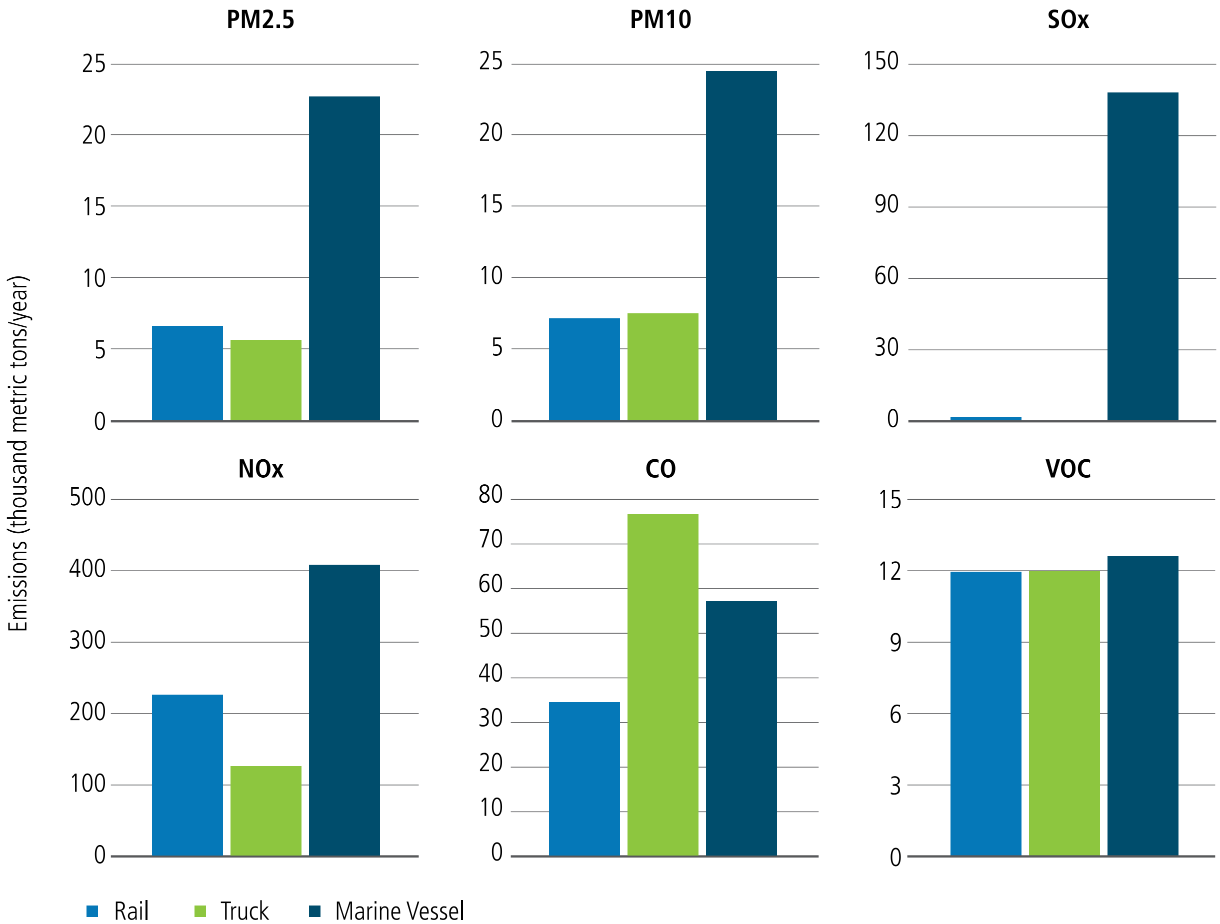
[q] EPA estimates that nitrogen oxides emissions from highway vehicles have declined by 50 percent since 1990, while electric power sector nitrogen oxides emissions are more than 70 percent lower than 1990 levels.

[r] This rulemaking is under consent decree with Air Alliance Houston and several other litigants. The consent decree requires the EPA Administrator to sign the final rule no later than June 16, 2015.

has put in place the SmartWay® Program—a public-private initiative between EPA, large and small trucking companies, rail carriers, logistics companies, commercial manufacturers, retailers, and other Federal and state agencies. Starting in 2004, the program's purpose is to improve fuel efficiency and the environmental performance (reduction of both GHG emissions and air pollution) of the goods movement supply chains. SmartWay-designated tractors and trailers can save upward of 4,000 gallons of fuel each year. To date, SmartWay partners report saving more than 120 million barrels of fuel and eliminating 51.6 million metric tons of CO_2 and almost 740,000 tons of nitrogen oxides through their participation in the program.[77]

In March 2010, the International Maritime Organization officially designated North America and the Caribbean coastal waters as emission control areas.[78] Beginning in 2015, ships are to reduce their emissions of nitrogen oxides, sulfur oxides, and fine particulate matter through use of cleaner fuels or engine technologies (e.g., scrubbers). These standards will dramatically reduce air pollution and deliver substantial air quality and public health benefits that extend hundreds of miles inland.[79]

Figure 7-4. Air Emissions from the Transportation of Coal and Liquid Fuels, by Transport Mode[80, s]

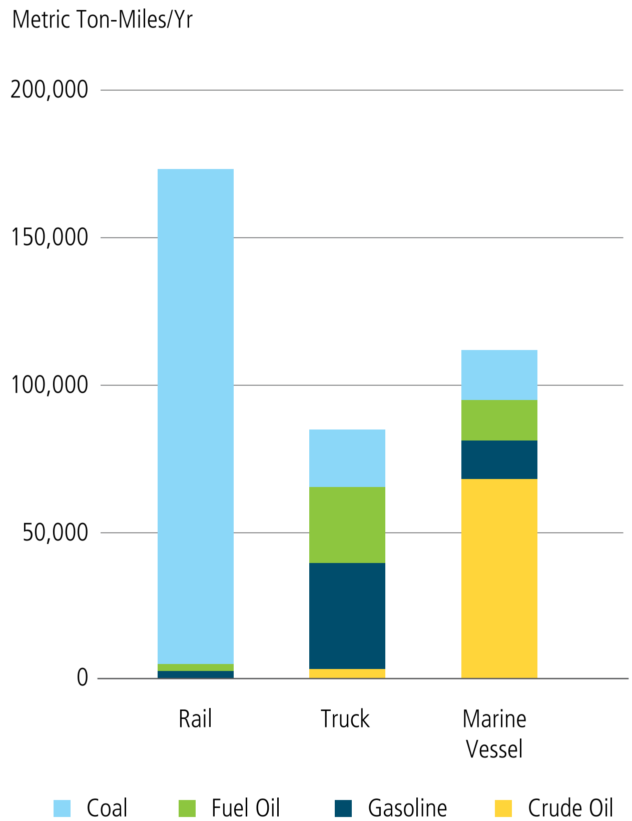


Among the primary energy transportation options (not including pipelines), marine vessels have the highest total emissions, particularly with respect to nitrogen oxides, sulfur oxide, and particulate matter. These emissions are largely the result of ocean-going marine vessels' greater reliance on residual (or bunker) fuel, which is a less-refined energy product. An important caveat is that barge transport via inland waterways can be substantially less polluting than tanker vessels; however, emissions from these two vessel types are not distinguishable in available inventory data.

[s] Since energy products only represent a portion of total freight transported by rail, truck, and marine vessel, emissions data shown here were scaled (on a ton-mile basis) in proportion to the fraction of total freight transport that is represented by energy products (according to the Oak Ridge National Laboratory's "FAF Provisional Annual Data for 2012: Freight Analysis Framework").

Figure 7-5 shows the relative scale of energy transport by vehicle type, accounting for the relative travel distances of each energy product.[t] It does not reflect the observed sharp increase in liquid fuel transport by rail and barge since 2012; it illustrates the relative importance of different transport modes for the movement of different fuel types.

Figure 7-5. Quantities of Energy Transported by Mode (other than pipeline) in 2012, by Fuel Type and Accounting for Distance Traveled (metric ton-miles per year)[81, u]



Freight by rail is the dominant mode for transporting coal within the United States. Energy freight (which does not include pipelines) for liquid fuel products is dominated by truck and marine transport modes.

Another significant area of interest related to air quality and TS&D infrastructure is criteria air pollutants in the vicinity of ports and rail yards, where the density of vehicles leads to high concentrations of pollutants and greater risks to nearby communities.[82] Studies have found that communities living in close proximity to rail yards[83] and ports[84] are exposed to significantly higher concentrations of diesel particulate matter—including fine particulate matter ($PM_{2.5}$)—which is harmful to public health. When compared with the overall U.S. population, research also has found that low-income and minority households are overrepresented in the aggregate affected population, often by a factor of two or three.[85]

[t] Data are presented as metric ton-miles to enable comparison between the relative scale of liquid fuels and coal transport. This is necessary because some energy products are transported over very short distances (e.g., liquid fuels) while others are transported over much greater distances (e.g., coal).

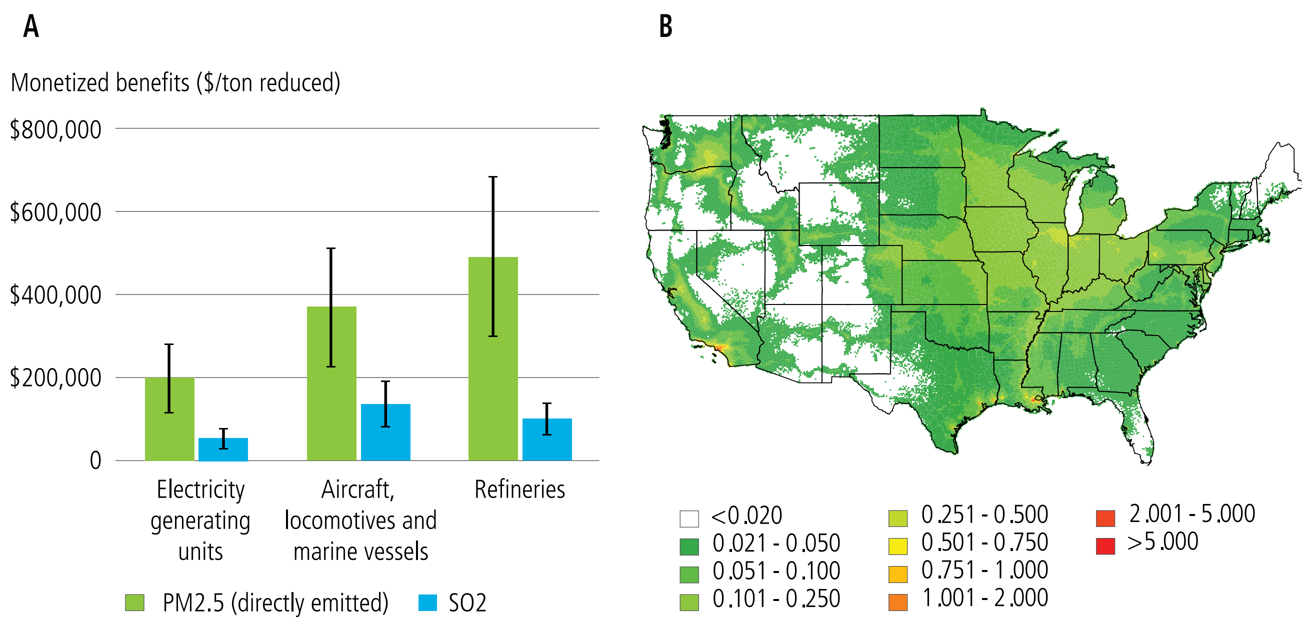
[u] "Gasoline" includes gasoline, aviation turbine fuel, and ethanol. "Fuel oil" include diesel and bunker fuels.

Vehicles that transport energy as freight—primarily coal for electric power generation, but also liquid fuels—include locomotives, as well as truck and marine vessels. Their emissions are primarily due to diesel engine combustion of diesel fuel and residual fuel oil (in the case of marine engines). Health effects from short-term exposures to diesel exhaust, a likely carcinogen, include premature mortality, increased hospital admissions, and heart and lung diseases.[86]

A recent study[87] found that each ton of $PM_{2.5}$ reductions from aircraft, locomotives, and marine vessels yielded very substantial estimated monetized benefits (in comparison to reduction of $PM_{2.5}$ in other sectors). One reason for this is that transportation hubs are often located in relatively close proximity to urban areas; therefore, emission reductions from these sources would have immediate health benefits for onsite workers and neighboring communities (see Figure 7-6).

The California Air Resources Board has issued regulations requiring a 50 percent reduction in berthed ship emissions from large ports by 2014, and an 80 percent reduction by 2018.[88] Most large California ports are implementing shore power projects as a compliance mechanism.[89] Similar regulatory efforts are underway in the European Union, which is expected to encourage retrofitting ships to use shore power.[90]

Figure 7-6. Panel A: Estimated Monetized Benefits of Reductions in $PM_{2.5}$ and $PM_{2.5}$ Precursors. Panel B: Estimated Annual Mean $PM_{2.5}$ Levels Attributable to Aircraft, Locomotives, and Marine Vessels in 2016.[91]



The benefits of reducing a ton of $PM_{2.5}$ or $PM_{2.5}$ precursor sulfur dioxide from certain TS&D sources result in relatively high monetized benefits to society, in part because these pollution sources are commonly close to human populations.

Fuel use and emissions from locomotives could be reduced by improving rail operations and infrastructure and reducing congestion—one of the biggest concerns for rail traffic—as idling and stop-and-go traffic lead to increased fuel consumption.[92] If capacity is not improved by 2035, 25 percent of rail corridors could be running near or at capacity, and 30 percent of rail corridors could be running above capacity, thus leading to increased botlenecks and fuel consumption.[93]

Administration Activities and Plans

A number of Administration initiatives reduce greenhouse gas emissions, as well as other forms of air pollution from transmission, storage, and distribution infrastructure. Examples of this include the Environmental Protection Agency's guidelines to states to reduce ozone precursors from oil and gas systems;[v] the Department of Energy's work to improve the energy efficiency of equipment powering natural gas transmission systems and other transmission, storage, and distribution infrastructure; and efforts to shift to less polluting fuels.[w]

With respect to ports and rail yards, a number of Federal programs provide grant funding for transportation-related projects that can improve air quality in ports and rail yards, including the following:

Congestion Management and Air Quality (CMAQ) program. The Department of Transportation's Federal Highway Administration manages the CMAQ program,[x] which funds state and local programs that reduce air emissions. Under the current transportation bill, the CMAQ program is funded at about $2 billion annually.[y] Typical CMAQ programs include diesel retrofits, diesel idle reduction projects, Intelligent Transportation Systems, alternative fuel vehicle projects, and intermodal freight projects.[z]

Transportation Investment Generating Economic Recovery (TIGER) grants. The Department of Transportation's TIGER program[aa] is a competitive grant program that funds state and local transportation projects across the Nation. TIGER grants have aimed at addressing key national freight rail bottlenecks and reducing truck traffic by funding improved rail access to ports, as well as many other port, rail, and road projects aimed at alleviating freight congestion. Since 2010, annual appropriations for TIGER have ranged from $475 million to $600 million.[ab]

National Clean Diesel Campaign. First authorized by the Diesel Emissions Reduction Act in 2008, the National Clean Diesel Campaign issues grants to eligible entities for projects to reduce emissions from existing diesel engines. The projects meet critical local air quality needs by deploying both proven and emerging technologies much earlier than would otherwise occur.[ac] Past annual appropriations for the Diesel Emissions Reduction Act have ranged from $20 million to $60 million.[ad]

GROW AMERICA Act. The Administration's proposed transportation legislation includes several provisions aimed at increasing investments that will improve freight performance and reduce criteria air pollutant and precursor emissions. These include the following:

- A 6-year, $18-billion competitive grant program targeted at freight infrastructure projects identified by state and local governments and key transportation stakeholders
- A collaborative freight strategic planning process, which will permit the use of formula grant funds for "game-changing" freight transportation projects
- A sharper focus for the CMAQ program on reducing emissions of fine particulates, as well as the criteria pollutants with the greatest impact on human health, and expansion of the TIGER grant program to $1.25 billion per year.

[v] The White House. "Fact Sheet: Administration Takes Steps Forward on Climate Action Plan by Announcing Actions to Cut Methane Emissions." http://www.whitehouse.gov/the-press-office/2015/01/14/fact-sheet-administration-takes-steps-forward-climate-action-plan-anno-1. Accessed March 2, 2015.

[w] Department of Energy. "DOE Launches Natural Gas Infrastructure R&D Program." September 8, 2014. http://energy.gov/fe/articles/doe-launches-natural-gas-infrastructure-rd-program-enhancing-pipeline-and-distribution. Accessed February 27, 2015.

[x] Federal Highway Administration. "CMAQ- Air Quality." http://www.fhwa.dot.gov/environment/air_quality/cmaq/. Accessed February 27, 2015.

[y] Department of Transportation. "Fiscal Year 2014 Apportionments, Allocations and Program Information." March 2014. http://www.fta.dot.gov/printer_friendly/12910_15867.html. Accessed February 27, 2015.

[z] Federal Highway Administration. "CMAQ- Air Quality." http://www.fhwa.dot.gov/environment/air_quality/cmaq/ Accessed February 27, 2015.

[aa] Department of Transportation. "TIGER Discretionary Grants." http://www.dot.gov/tiger. Accessed February 27, 2015.

[ab] Department of Transportation. "TIGER Discretionary Grants." http://www.dot.gov/tiger. Accessed February 27, 2015.

[ac] Environmental Protection Agency. "National Clean Diesel Campaign: Funding Sources." http://www.epa.gov/cleandiesel/grantfund.htm. Accessed February 27, 2015.

[ad] Environmental Protection Agency. "Second Report to Congress Highlights of the Diesel Emissions Reduction Program." http://www.epa.gov/cleandiesel/documents/420r12031.pdf. Accessed February 27, 2015.

While the QER scope is limited to energy freight, expanding any program that reduces freight congestion would achieve emissions reductions from freight transport more broadly, with direct benefits of improved air quality for nearby urban communities and workers.

QER Recommendations

REDUCING CONVENTIONAL AIR POLLUTION

Current Administration activities and proposals before Congress have the potential to broadly benefit both communities and workers affected by conventional air pollution from TS&D infrastructures. In order to build on these ongoing activities, we recommend the following:

Provide funding to programs that reduce diesel emissions. To protect workers and nearby communities through further reductions in diesel particulate matter emissions from ports and rail yards, we recommend providing funding for the successful Diesel Emissions Reduction Act program and other Federal programs that fund complementary activities that reduce diesel emissions. Grant funding should support projects that deploy emissions control technologies, reduce bottlenecks and congestion of freight in the vicinity of these facilities, and use other methods to reduce diesel emissions.

Other Environmental Issues

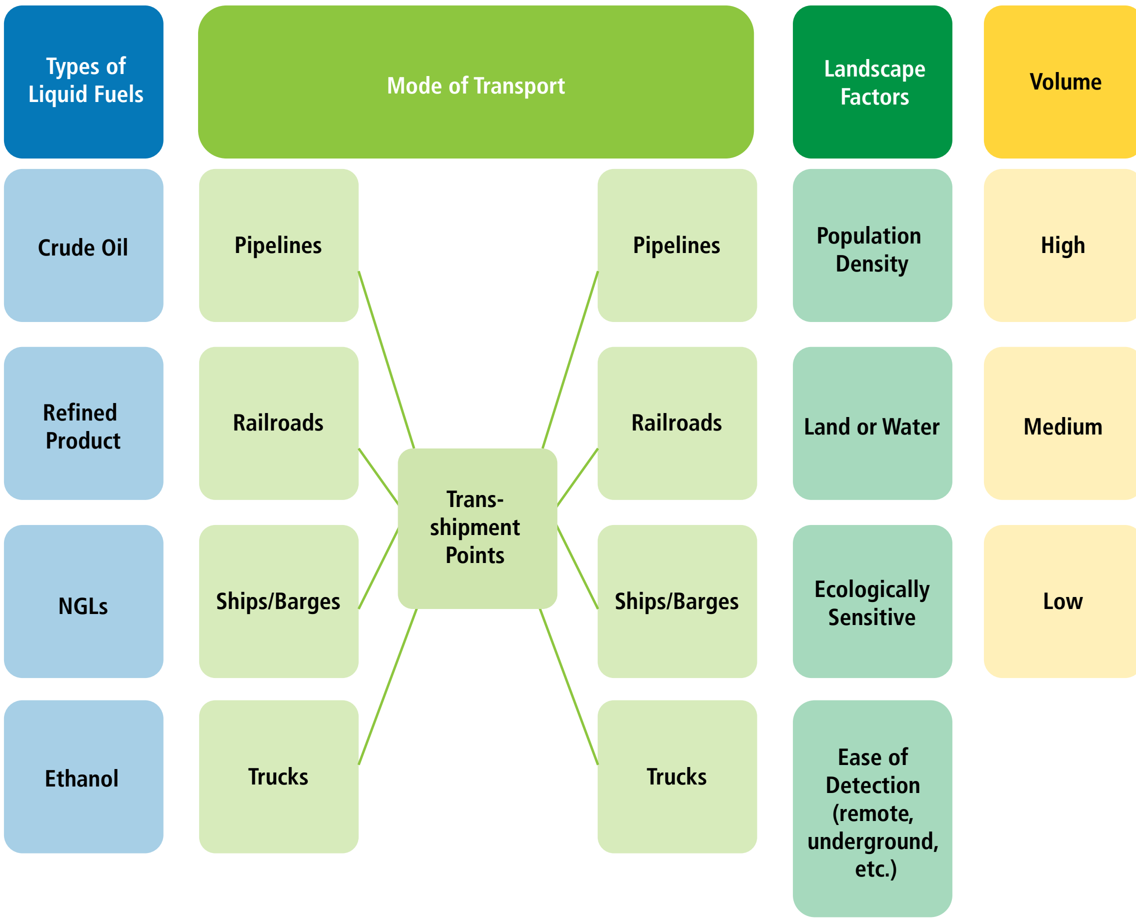
In addition to GHG emissions, conventional air pollution, and land-use issues, there are also other environmental issues related to TS&D infrastructure, such as spills, dredging materials disposal, and CO_2 pipelines.

Liquid Fuel Spills

All forms of TS&D infrastructure for petroleum and refined petroleum products present some risk of spills into the environment. It is challenging to compare marine, rail, truck, and pipeline spill statistics due to several data limitations and inherent differences between modes. For example, there is large interannual variability in the volume of reported releases of crude oil from marine and rail vessels; for rail, it ranges from less than 5 barrels to nearly 25,000 barrels per year—with the increase in shipments of crude by rail, there has been a concomitant increase in oil releases from this mode.[94] In terms of recorded impacts relevant to the environment and public health, the simplest comparative metrics are total reported incidents and volumes of spills. In general, available data indicate that releases from pipelines are relatively more significant than spills from rail transport, and the total oil spilled by pipelines is greater than that from other sources. Between 2004 and 2013, pipelines released an average of 63,069[95] barrels of oil per year. In comparison, for 1998 to 2007, average annual releases of oil by rail (1,400 barrels per year[96]), truck (9,200 barrels per year[97]), and all marine vessels (9,593 barrels per year[98]) were all considerably lower. This comparison is dominated by the fact that each mode transports different total volumes of energy product over different average distances, with pipelines carrying far larger volumes than other modes. Better data on barrels spilled per barrel-miles moved would improve our ability to compare spill statistics across modes on a common basis. This is particularly important for assessing how relative risks are changing during this dynamic period of growing domestic production of crude oil and shifting patterns of energy transport.

The environmental effects of any spill will depend on the vulnerability of the region where the spill takes place and the ease (and therefore speed) of response. Rail and marine spills result in the spill of a relatively small volume, typically aboveground. Pipeline spills, however, can go undetected for relatively long periods of time and result in higher spill volumes, typically underground. Other factors that affect the severity of a spill, both for the environment and public safety, include the season and weather, proximity to densely populated areas and sensitive ecological areas, and the type of liquid involved in the spill (see Figure 7-7).

Figure 7-7. Conditions Affecting Liquid Fuels Spill Severity[99]



Assessing risks associated with oil transport involves the consideration of a number of factors, including the variety of landscapes that could potentially be affected, the vulnerability of those landscapes to damaging impacts, and the type and extent of the incident.

Administration Activities and Plans

Environmental Protection Agency (EPA) Oil Spill Program. The EPA protects U.S. waters by preventing, preparing for, and responding to oil spills in navigable waters. This program is authorized by Section 311 of the Clean Water Act and the Oil Pollution Act of 1990. The oil pollution prevention regulations require each owner or operator of a regulated facility to prepare a Spill Prevention, Control, and Countermeasures Plan that addresses the facility's design, operation, and maintenance procedures established to prevent oil spills, as well as countermeasures to control, contain, cleanup, and mitigate the effects of an oil spill that could affect navigable waters. In addition, high-risk facility owners and operators are also required to prepare Facility Response Plans that identify response actions for discharges of oil that pose substantial harm to the environment. EPA is responsible for inland oil spills that either impact or threaten water. Typically, EPA monitors oil spills to ensure that Responsible Parties take necessary steps to contain and cleanup oil spills. EPA does have authority to direct a Responsible Party's cleanup activities or take oil spill response actions if there is no viable Responsible Party, or if a Responsible Party is unwilling to take appropriate actions. EPA utilizes the Oil Spill Liability Trust Fund to fund its actions.

Administration Activities and Plans (continued)

EPA Superfund Emergency Response and Removal Program. This program trains, equips, and deploys resources in order to contain and remove contaminants. Under the program, EPA personnel respond to or oversee the cleanup by Responsible Parties of thousands of releases, regardless of their cause. EPA manages and/or provides support for a variety of emergency responses, removal assessments, site stabilizations, and cleanup response actions. EPA maintains national and regional response centers for 24-hour reporting of hazardous material or petroleum releases. EPA deploys many advanced technologies and other assets during disaster responses, such as the Chemical, Biological, Radiological, and Nuclear Consequence Management Advisory Team; the portable laboratories; or the airborne sensor platform (which is called ASPECT).

Department of Transportation Proposed Rules. The Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA) is finalizing a proposed rule on Pipeline Safety—Safety of On-Shore Hazardous Liquid Pipelines. This rulemaking would address effective procedures that hazardous liquid operators can use to improve the protection of high-consequence areas and other vulnerable areas along their hazardous liquid onshore pipelines. PHMSA is considering whether changes are needed to the regulations covering hazardous liquid onshore pipelines, whether other areas should be included as high-consequence areas for integrity management protections, what the repair time frames should be for areas outside of the high-consequence areas that are assessed as part of the integrity management program, whether leak-detection standards are necessary, and whether valve spacing requirements are needed on new construction or existing pipelines. PHMSA should extend regulation to certain pipelines currently exempt from regulation. The Department of Transportation also published an Advanced Notice of Proposed Rulemaking on requiring oil spill response plans for high-hazard flammable trains.[ae] This was a companion to a proposed rule setting out comprehensive standards to improve the rail transportation of flammable liquids, including unit trains of crude oil and ethanol, discussed in Chapter V (Improving Shared Transport Infrastructures).[af]

National Oceanic and Atmospheric Administration (NOAA) oil spill programs. NOAA's Office of Response and Restoration is charged with responding to oil spills in coastal and marine environments, and it provides scientific support to the Federal on-scene coordinator. NOAA employs a number of tools to preemptively reduce potential risks from marine oil spills, including providing expertise on oil spill response plans, environmental sensitivity index maps, and trajectory analysis models. In addition, NOAA works with the Bureau of Ocean Energy Management, the Coast Guard, and other Federal and state actors to identify particularly sensitive marine environments in siting of energy facilities and shipping lanes. NOAA also plays a lead role in restoration efforts in the event of a marine spill.

[ae] Department of Transportation. "U.S. DOT Announces Comprehensive Proposed Rulemaking for the Safe Transportation of Crude Oil, Flammable Materials." July 23, 2014. http://www.dot.gov/briefing-room/us-dot-announces-comprehensive-proposed-rulemaking-safe-transportation-crude-oil. Accessed February 19, 2015.

[af] Department of Transportation. "U.S. DOT Announces Comprehensive Proposed Rulemaking for the Safe Transportation of Crude Oil, Flammable Materials." July 23, 2014. http://www.dot.gov/briefing-room/us-dot-announces-comprehensive-proposed-rulemaking-safe-transportation-crude-oil. Accessed February 19, 2015.

Water Use and Wastewater

Petroleum refineries consume the most water and produce the most wastewater discharge of any segment of the energy TS&D infrastructure. Despite data limitations, the relative quantities are known:

- Annual water consumption by petroleum refineries in 2005 was about 1.3 billion gallons per day[100] compared to about 4.3 billion gallons per day of total water consumed by thermoelectric power generation in 2008.[ag]
- Water withdrawals by both petroleum refineries and thermoelectric power generation are substantially greater, meaning that only a fraction of withdrawn water is consumed, while the remainder is discharged to the environment.

[ag] Based on total annual water use of 1,570 billion gallons by thermoelectric power plants in: Averyt, K. et al. "Water use for electricity in the United States: an analysis of reported and calculated water use information for 2008." Environmental Research Letters. 8(1). 2013.

- Fresh water withdrawals by petroleum refineries in 2005 were approximately 6 billion to 19 billion gallons per day,[101] while fresh and saline water withdrawals by thermoelectric power generation in 2011 were approximately 196 billion gallons per day.[102]

Discharges from refineries can also affect water quality (particularly water temperature). Such discharges are subject to EPA permitting requirements under the Clean Water Act, which requires system controls for any direct discharges to surface waters.[103]

Biofuel refineries can also consume large volumes of water. However, the quantity of water consumed during the biorefining processes is modest compared to the water consumed to grow bioenergy feedstocks in cases where irrigation is required.[104] To produce 1 gallon of ethanol, up to 1,000 gallons of irrigation water is consumed, while producing 1 gallon of biodiesel from soybeans consumes up to 750 gallons of irrigation water.[105] Meanwhile, ethanol refineries consume as much as 3 gallons of water to produce 1 gallon of ethanol,[106] which is greater on a per-gallon production basis than petroleum refining. Biodiesel refineries consume less than 1 gallon of water per gallon of biodiesel produced.[107, 108]

Nationally, total water use and wastewater production from processing of natural gas and natural gas liquids is low, although natural gas liquids facilities can have large local water withdrawal impacts. The construction and operation of TS&D infrastructure can also cause significant watershed-level changes in local and regional hydrology.

Dredging Materials

The Army Corps of Engineers oversees 25,000 miles of channels—comprising 13,000 miles of coastal harbors and channels and 12,000 miles of inland and intracoastal waterways—and dredges 225 million cubic yards of material from U.S. harbors, channels, and waterways annually.[109] The proper placement of dredged material is often a significant portion of the total cost of dredging, particularly if dredged material contains contaminants. Dredged material is typically tested, and the method of placement is chosen to minimize costs and environmental impacts. Placement of dredged material in open water is regulated by Section 404 of the Clean Water Act, and placement in ocean waters is regulated by Section 103 of the Marine Protection, Research, and Sanctuaries Act of 1972. Many techniques exist for reusing dredged material or removing potentially hazardous components from it, and dredged material is increasingly being employed for beneficial uses under Section 204 of the Water Resources Development Act of 1992. The Army Corps of Engineers has conducted research and development on treating and beneficially using or placing dredged material since the 1970s. The Corps will continue to conduct research and development on dredging and dredged material placement operations under its Dredging Operations and Environmental Research program.[110]

Environmental Data Related to TS&D Infrastructures

Finally, data that are important for understanding the environmental characteristics and impacts of TS&D infrastructures often are not available or are only available in highly aggregated formats (temporally and spatially). Furthermore, these data are often outdated and sometimes not conducive to identifying trends (e.g., they are only released every 4 years, or methodologies change so that time series are difficult to compile or are of questionable value). These limitations exist with respect to many public health, safety, and environmental quality issues, including oil spills and water use, consumption, and waste. In a 2015 report,[111] the National Transportation Safety Board noted that many types of basic data necessary for comprehensive probabilistic risk modeling of natural gas pipelines are not currently available. The Board's recommendations included the development of better-quality spatial data on pipelines that can be more easily accessed by regulators and operators. Limitations also exist with respect to data on the age of certain equipment (e.g., compressors) and infrastructure (e.g., pipelines), as well as emissions at a granular level (e.g., from different types of vessels—such as barges versus tankers—or from different kinds of compressor motors—such as reciprocating engines versus centrifugal turbines). These latter data are important to have so that appropriate priorities can be set for both research and policy.

QER Recommendations

OTHER ENVIRONMENTAL ISSUES

As noted above, the Administration has a broad range of activities and proposed rules underway in the area of addressing oil spills, so further recommendations in that area are not needed at this time. Similarly, environmental controls on wastewater discharges from TS&D infrastructure are adequate. To continue to make progress on the handling and disposal of dredging materials and to address issues involving environmental data, we recommend the following:

Conduct research needed on dredging materials. The Army Corps of Engineers, in collaboration with other appropriate Federal agencies, should continue to undertake research and development on treating dredged material and then either beneficially using or disposing of it. As efforts continue—by the Federal Government and other stakeholders—to enhance shared infrastructures for energy commodity transport, focusing on waterway and port improvements, the amount of such material may grow substantially and pose a barrier to enhancing waterborne TS&D infrastructure.

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. This work should be designed to fill the host of data gaps on environment, safety, and public health issues with respect to TS&D infrastructure. DOE's activities should take into account the recent recommendations by the National Transportation Safety Board on data gaps related to natural gas pipelines.

CO_2 Pipelines: Enabling Infrastructure for GHG Emissions Reductions

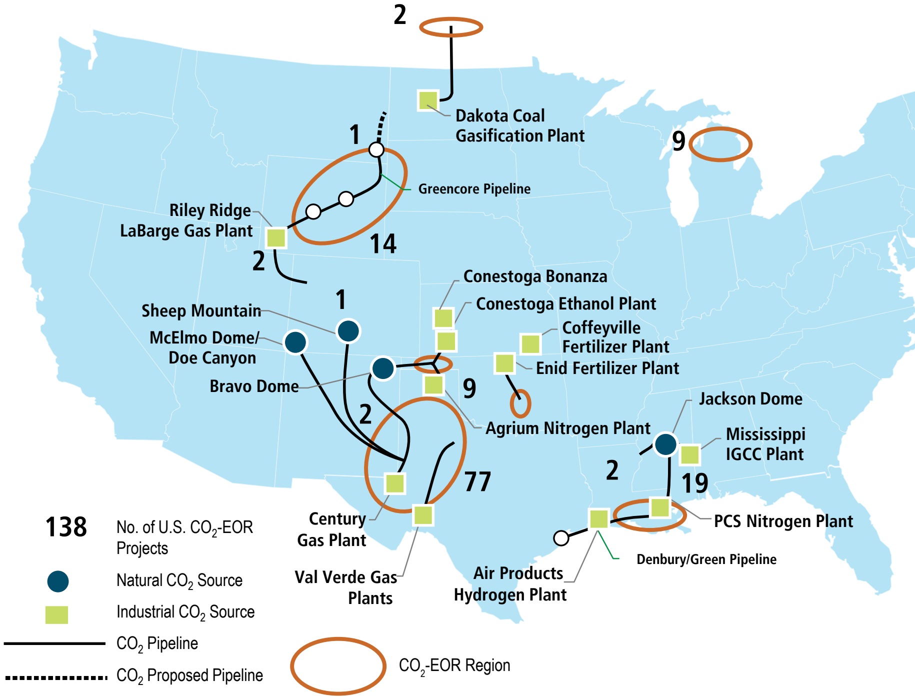
CO_2 pipelines are an important enabling infrastructure for reducing GHG emissions in the future. Carbon dioxide sequestration, particularly in connection with enhanced oil recovery (EOR),[ah] may involve moving CO_2 significant distances from power plants (or other sources) to the sequestration site or EOR field.

Spanning across more than 12 U.S. states and into Saskatchewan, Canada, a safe and regionally extensive network of CO_2 pipelines has been constructed over the past four decades. Consisting of 50 individual CO_2 pipelines, with a combined length of more than 4,500 miles (see Figure 7-8), these CO_2 transportation pipelines represent an essential building block for linking the capture of CO_2 from electric power plants and other industrial sources with its productive use in oil fields and its safe storage in saline formations. The Pipeline and Hazardous Materials Administration (PHMSA)[ai] is responsible for overseeing the safe construction and operation of CO_2 pipelines, which includes technical design specifications and integrity management requirements.

[ah] The injection of CO_2 gas into oil reservoirs at high pressure forces the CO_2 to mix with oil, which reduces the viscosity of the oil and ultimately increases the total cumulative volume of oil produced, thus the percentage of oil-in-place that is recovered.

[ai] While CO_2 is not considered a hazardous material by the Department of Transportation, CO_2 transportation pipelines are regulated under 49 C.F.R. § 195, Transportation of Hazardous Liquids by Pipeline.

Figure 7-8. Current CO_2-EOR Operations and Infrastructure[112]



U.S. regions with large-scale CO_2 pipeline systems currently in operation	Miles of Pipeline
Permian Basin (W. TX, NM, and S. CO)	2,320
Rocky Mountains (N. CO, WY and MT)	810
Gulf Coast (MS, LA and E. TX)	740
Mid-Continent (OK and KS)	480
Other (ND, MI, Canada)	215

The current CO_2 pipeline system has been built to deliver CO_2 for CO_2-EOR to oil fields in the Permian Basin of west Texas and eastern New Mexico. This system spans across more than a dozen U.S. states and into Saskatchewan, Canada.

The vast majority of the CO_2 pipeline system is dedicated to CO_2-EOR[aj] and connects natural and industrial sources of CO_2 with EOR projects in oil fields. In 2014, roughly 1,250 billion cubic feet of CO_2 (or 68 million metric tons) flowed through U.S. pipelines—roughly 80 percent of which is from natural (geologic) sources. In the next few years, several new industrial CO_2-capture facilities[ak] are expected to bring online another 1,100 billion cubic feet of CO_2, with nearly 600 miles of new pipeline by 2020. At that point, the portion of CO_2 from industrial sources would nearly exceed that from natural sources.

Currently, just more than 4 percent of total U.S. crude oil production is produced through EOR, and this is projected to increase to 7 percent by 2030.[113] Additionally, as recent trends[114] in CO_2 pipeline planning and construction have shown, there is considerable potential for low-cost CO_2 capture from ethanol refineries, other industrial facilities, and EOR in nearby oil production basins in regions of the country that do not yet have CO_2 pipeline networks in place. However, given the upfront capital costs associated with pipeline construction and the absence of policy incentives for reducing industrial carbon pollution, financial support would likely be needed to spur private investments in some regions.

A national carbon policy would create investment certainty and spur significant new investment in CO_2 pipeline infrastructure, creating incentives for electric power plants and other industrial facilities to reduce CO_2 emissions through carbon capture technologies and improving the economics for oil production through EOR.

[aj] A small fraction is used for other industrial uses, such as delivering CO_2 to the beverage industry.

[ak] For example, Air Products' PCS Nitrogen plant in Louisiana and Southern Company's integrated gasification combined cycle plant in Kemper County, Mississippi.

In a low-carbon scenario analysis case analyzed for the QER,[115] construction through 2030 would more than triple the size of current U.S. CO_2 pipeline infrastructure through an average annual build rate of nearly 1,000 miles per year.[al]

The regulation of CO_2 pipelines is currently a joint responsibility of Federal and state governments.[116] CO_2 transportation pipelines are subject to Federal safety regulations that are administered by PHMSA.[am] PHMSA directly oversees pipeline safety for all interstate lines, while intrastate pipelines are subject to state agency oversight (as long as the standards are at least as stringent as the Federal rules).[an] The Federal Energy Regulatory Commission and the Surface Transportation Board have determined that CO_2 pipelines are not within their jurisdiction.[117, 118] Otherwise, requirements for siting (including the use of eminent domain), construction, and operations of CO_2 pipelines are largely handled at the state level. If a pipeline crosses Federal land, permits from the relevant Federal agencies (e.g., rights of way) and the accompanying environmental review under NEPA are required prior to siting and construction.[ao]

State laws that are specific to CO_2 pipelines, EOR, and underground storage are varied and generally limited to those regions with CO_2-EOR projects. Texas, for example, has several laws that pertain specifically to CO_2 for EOR and geologic sequestration. A CO_2 pipeline operator in Texas may exercise its right of eminent domain if it has declared itself a common carrier, which deems the CO_2 pipeline open to transport for hire by the public.[ap] Texas also has policy incentives, including a reduction in its severance tax rate by 50 percent for oil produced from EOR using anthropogenic CO_2.[119] The Wyoming Pipeline Authority has begun to plan for and establish corridors for future CO_2 pipelines.[aq] Rather than leave future pipeline planning up to individual operators, the Wyoming Pipeline Authority is seeking to assist pipeline developers through the pipeline construction process by serving as a facilitator and information provider to industry, state government, and the public.[120, 121]

[al] The model projects 11,000 miles of new pipeline construction, which is more than half the scale that would potentially be needed by 2050, to accommodate climate stabilization scenarios modeled by Dooley et al. "Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO_2 Pipeline Networks." Energy Procedia. 1(1). p. 1,595–1,602. February 2009.

[am] While CO_2 is not considered a hazardous material by the Department of Transportation, CO_2 transportation pipelines are regulated under 49 C.F.R. § 195, *Transportation of Hazardous Liquids by Pipeline*. This distinction is made due to the nature of the transportation pipelines, which carries the highly pressurized CO_2 in a liquid phase similar to other hazardous material transportation pipelines. Smaller CO_2 distribution lines, which transport the CO_2 from the trunk line to individual wells, generally are not subject to Federal safety standards.

[an] Other Federal agency requirements, depending upon the area involved, can include threatened and endangered species consultations and permits for wetlands fill. Currently, the Bureau of Land Management regulates CO_2 pipelines under the Mineral Leasing Act as a commodity shipped by a common carrier. See: 30 U.S.C. § 185(r); Buys and Associates, Inc. "Environmental Assessment for Anadarko E&P Company L.P. Monell CO_2 Pipeline Project." Prepared for the Department of the Interior, Bureau of Land Management. February 2003. See also: U.S. Court of Appeals. "970 F. 2d 757 – Exxon Corporation v. Lujan." July 23, 1992.

[ao] Currently, the Bureau of Land Management regulates CO_2 pipelines under the Mineral Leasing Act as a commodity shipped by a common carrier. See: 30 U.S.C. § 185(r); Buys and Associates, Inc. "Environmental Assessment for Anadarko E&P Company L.P. Monell CO_2 Pipeline Project." Prepared for the Department of the Interior, Bureau of Land Management. February 2003. See also: U.S. Court of Appeals. "970 F. 2d 757 – Exxon Corporation v. Lujan." July 23, 1992.

[ap] Texas Natural Resources Code Annotated § 111.019(a) (West); Texas Natural Resources Code Annotated § 111.002(6) (West).

[aq] The Wyoming Pipeline Authority recently announced its application to the Bureau of Land Management for a Wyoming Pipeline Corridor Initiative. See: Wyoming Pipeline Authority. "Wyoming Pipeline Corridor Initiative." www.wyopipeline.com/projects/wpci/. Accessed January 26, 2015. As described by the Wyoming Pipeline Authority, the initiative is a proposed pipeline right-of-way network designed to connect sources of CO_2 to oil fields that are suitable for EOR. The initiative, as proposed to the Bureau of Land Management, would establish 1,150 miles of corridors on Federal lands in Wyoming. The Wyoming Pipeline Authority would be the project proponent receiving the right of way, which would then be assigned to individual project proponents, which would construct and operate pipelines. See: Wyoming Pipeline Authority. "Wyoming Pipeline Corridor Initiative Plan of Development." May 2014. www.wyopipeline.com/wp-content/uploads/2014/06/WPCI_POD_may_2014.pdf. Accessed January 27, 2015.).

QER Recommendations

CO_2 PIPELINES

Meeting U.S. GHG emission goals will require a more concerted Federal policy, involving closer cooperation among Federal, state, and local governments. The development of a national CO_2 pipeline network capable of meeting Federal policy initiatives should build on state experiences, including lessons learned from the effectiveness of different regulatory structures, incentives, and processes that foster interagency coordination and regular stakeholder engagement. To expand current Federal efforts to meet these challenges, we recommend the following:

Work with states to promote best practices for siting and regulating CO_2 pipelines. Improving CO_2 pipeline siting will improve safety and environmental protection. Several states have made substantial progress on this front and provide potential models for other states. 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 CO_2 pipelines, or that may have CO_2 pipeline projects proposed within their borders in the future.

Enact financial incentives for the construction of CO_2 pipeline networks. Expanding and improving CO_2 pipeline infrastructure could enable GHG reductions through carbon capture, utilization, and storage, while promoting domestic oil production through EOR. Providing incentives such as grants or tax incentives will spur activity to link low-cost CO_2 from industrial sources to nearby oil fields and saline storage formations. The President's Fiscal Year 2016 Budget Request proposes the creation of a Carbon Dioxide Investment and Sequestration Tax Credit in order to accelerate commercial deployment of carbon capture, utilization, and storage, as well as to catalyze the development of new carbon capture, utilization, and storage technologies. Specifically, the proposal, part of the President's POWER+ Plan to invest in coal communities, 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" CO_2.[122] Congress should enact this proposed tax credit.

RECOMMENDATIONS IN BRIEF:

Addressing Environmental Aspects of TS&D Infrastructure

(Including environmental recommendations discussed elsewhere in this report)

Improve quantification of emissions from natural gas transmission, storage, and distribution (TS&D) infrastructure. Congress should approve the $10 million requested in the Fiscal Year 2016 Budget to help update Greenhouse Gas Inventory estimates of methane emissions from natural gas systems. The Department of Energy (DOE) and the Environmental Protection Agency 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 research and development (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 Fiscal Year 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 carbon dioxide (CO_2) pipelines. Building on successful state models for CO_2 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 CO_2 pipelines, or that may have CO_2 pipeline projects proposed within their borders in the future.

Enact financial incentives for the construction of CO_2 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" CO_2.

Enhance TS&D resilience to a variety of threats, including climate change and extreme weather (discussed in Chapter II, Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

Enhance natural gas safety, efficiency, and lower emissions by reducing natural gas leakage and improving the efficiency and safety of the natural gas infrastructure through support for innovative programs to upgrade natural gas distribution system performance through targeted funding to low-income consumers (discussed in Chapter II, Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure).

Accelerate current development of uniform methods for measuring energy savings and promote widespread adoption of these methods in public and private efficiency programs (discussed in Chapter III, Modernizing the Electric Grid).

Partner with the Arctic Council on Arctic energy safety, reliability, and environmental protection (discussed in Chapter VI, Integrating North American Energy Markets).

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Chapter VIII

ENHANCING EMPLOYMENT AND WORKFORCE TRAINING

This chapter gives an overview of current and projected employment in and related to the energy sector and discusses programs to assist in meeting the demand for new workers going forward. The first section provides estimates of jobs in energy transmission and distribution and jobs related to energy systems overall, with forecasts out to 2030 for jobs supported by the energy industry. The second section discusses the impact of an aging workforce. The third section discusses specific energy workforce demands related to electricity, natural gas, and shared infrastructures. The remainder of the chapter discusses potential responses to address the demand for new energy workers. A number of data challenges in understanding employment in the energy sector are also discussed. The chapter concludes with a description of current Administration activities and plans, as well as a number of recommendations for further action.

FINDINGS IN BRIEF:
Enhancing Employment and Workforce Training

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 transmission, storage, and distribution 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 transmission, storage, and distribution 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 transmission, storage, and distribution 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. This 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.

Estimates of Transmission and Distribution Jobs

Significant new investment in U.S. energy infrastructure is anticipated over the next few decades. The resulting changes in the transmission, storage, and distribution (TS&D) infrastructure—discussed throughout this report—will create new job opportunities for skilled workers. At the same time, the current TS&D infrastructure will need to be maintained. These factors, expansion of the energy sector, requirements for workers with new skills, and anticipated workforce retirements will create demand for new workers in energy-related jobs.

An analysis of jobs in the TS&D sectors performed to inform the Quadrennial Energy Review (QER) found that approximately 1 million people were employed in direct jobs and 900,000 in indirect jobs (see box for definitions), totaling just over 1 percent of U.S. civilian jobs (see Table 8-1).[1] An additional 2.0 million direct and 1.5 million indirect jobs were supported by the other energy industry sectors.[a, b]

Table 8-1. Total U.S. Direct and Indirect Jobs in Energy T&D in 2013[2]

Sector	Direct	Indirect	Total
Electricity T&D	506,882	441,963	948,845
Fuel T&D	470,204	436,087	906,291
Total Energy T&D Employment	**977,086**	**878,050**	**1,855,136**

Approximately 1 million people were employed in direct jobs and 900,000 in indirect jobs in energy-related sectors considered in the QER analysis, totaling just over 1 percent of U.S. civilian jobs.

Projections indicate that, by 2030, the full energy sector will support 1.5 million additional direct jobs—most of which will be in construction, installation and maintenance, and transportation—and an additional 1.8 million indirect jobs. Due to the technical nature of the energy workforce, a number of these employment opportunities will be open to workers with science and engineering backgrounds. Forecasts suggest that, by 2030, about 200,000 workers with skills in computers and mathematics and roughly an equal number of architects and engineers will be in demand.[3, c]

Direct Jobs: Jobs created from economic activity associated with the investment or operation of the entity under consideration.

Indirect Jobs: Jobs created in directly affected businesses and other supply chain entities as a result of the investment or entity operation.

As with any transformation, employment in some occupations will decline as some infrastructures transition or become obsolete, while new employment opportunities will exist in both more established industries (e.g., oil and gas) and newer industries (e.g., renewable energy and the smart grid).

[a] To obtain the estimate of 1.9 million jobs, the direct jobs were identified through Bureau of Labor Statistics Quarterly Census of Employment and Wages data and Railroad Retirement Board data. The Bureau of Labor Statistics data includes employment in U.S.-based establishments, including, for example, oil rigs in U.S. territorial waters. The indirect jobs were output from the IMPLAN model.

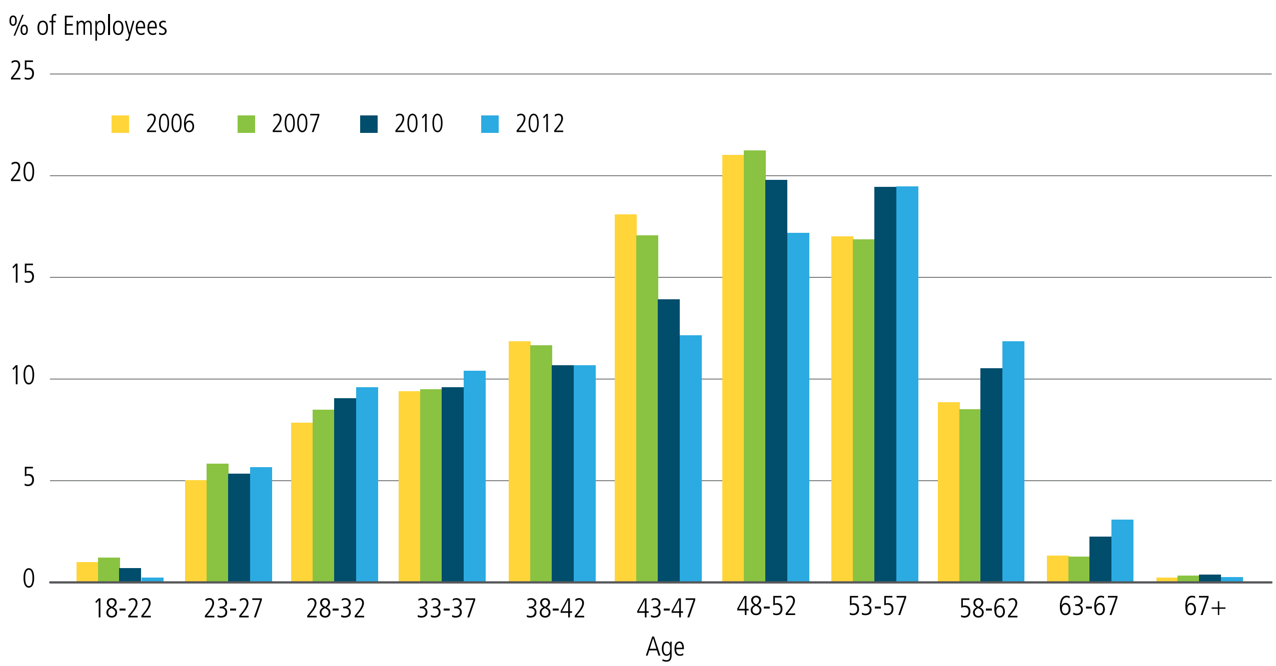
[b] Jobs in energy storage are not as clearly defined, as what encompasses storage is sector and technology dependent. For this reason, this report only examined transmission and distribution jobs.

[c] Due to data and other limitations, these findings are approximations. These estimates cover industries categorized as electricity generation, electricity transmission and distribution, fuels, extraction and production, fuel sales, and fuel transmission and distribution. This is imprecise, as it does not include energy efficiency or emerging industries that are not well covered in existing statistics, and it may include some jobs that do not count as energy jobs. This analysis is also limited by the fact that the skill mix of energy industries is based on historic data. Nonetheless, these data can provide guidance about the need for future training requirements in the energy industry.

Aging and Retiring Energy Workforce

In 2006, a consortium of energy utilities and trade associations created the Center for Energy Workforce Development to "work together to develop solutions to the coming workforce shortage in the utility industry."[4] The Center has developed a set of activities aimed at identifying gaps in the workforce pipeline, including general jobs skills (e.g., interpersonal skills and critical and analytical thinking) and industry-specific technical competencies (e.g., non-nuclear generation). According to a 2013 Center for Energy Workforce Development survey, 38 percent of the employees in the electric and gas utility sector may retire in the next decade (see Figure 8-1), creating demand for skilled technicians and engineers.[5] The oldest group of employees is composed of electric transmission and distribution technicians. The industry has, however, seen an increase in younger employees, especially in line workers and engineers, which the Institute of Electrical and Electronics Engineers credits to progress made in workforce development efforts across the industry.[6] While surveys of all U.S.-based occupations are not available, 38 percent is approximately 1.5 times the percentage reported in a related study for all U.S. occupations.[7]

Figure 8-1. Workforce Age Distribution in the Electric and Natural Gas Utilities by Percentage of Total Employees[8]



The largest percentages of utility employees are in the 48–52 and 53–57 age groups; 38 percent of electric and natural gas employees will be eligible to retire in the next decade.

Energy Sector Workforce Demands

The transformation of the energy economy; the need for enhancing resilience, reliability, and safety; and the need for managing dramatic changes in the current U.S. energy profile are resulting in shifting demands for skills across energy sectors. Some examples are provided in this section.

Electricity

The grid of the future will require a full spectrum of skills, including "utility management positions of smart grid programs (project office leadership, program support, quality assurance, planning, functional support, implementation operations and support, functional specialists), meter installers and service providers, intelligent T&D automation device producers, communications system products and services providers, and software system providers and integrators."[9]

External analyses[10] have identified industry demand for employees with both information technology and operational technology skills. For example, new skills are in demand for distribution-level grid operators to respond to increasing complexity in the networked and information technology-intensive system. Deployment of advanced metering technology in the transmission and distribution system requires two-way communication between the utility and each customer and/or the multitude of intelligent devices that will live on the grid. This, in turn, creates demand for many more network and radio engineers than utilities have employed in the past. Additionally, the resulting 'big data' challenges will create a demand for employees with data management, network management, and cybersecurity skills at the same time that other industries are demanding the same skills.[11]

Maintaining reliability in the electricity sector will also drive demand for skilled workers. The Department of Energy (DOE) Electricity Advisory Committee, in a 2012 memorandum to the DOE Assistant Secretary for Electricity Delivery and Energy Reliability, noted the North American Electric Reliability Corporation's concern that "reliability is at risk if the workforce lacks the necessary skills and knowledge or if workers are overtaxed by their responsibilities."[12]

The modernization of the electricity sector is changing the employment opportunities available. For example, automated metering will vastly reduce the number of meter readers, while the demand for meter technicians will rise. Retraining employees to take higher-skilled positions will be critical.

Oil and Gas

An analysis of employment by IHS in the oil and gas sectors identified 919,000 direct jobs in 2010. The same analysis estimates that the number of jobs in the upstream and midstream oil and gas sectors will grow 11 percent (84,000 jobs) between 2010 and 2020 and 20 percent (155,000) between 2010 and 2030. An additional 227,000 job opportunities were projected due to replacements of existing employees in the upstream, midstream, and downstream oil and gas sectors between 2010 and 2020 and 503,000 opportunities between 2010 and 2030 were projected.[13]

In addition to an increase in the number of employment opportunities, the oil and gas sectors are also experiencing a shift in required skills as the nature of extraction and production becomes more complex and regulatory and technical requirements become more sophisticated. One study[14] identified petroleum engineering faculty retirements as a cause for concern in maintaining a pipeline of qualified engineers over the next 20 years. Notably, a survey of petroleum engineering faculty indicated that approximately 37 percent were over 60 years of age in 2013, while another one-third were between 50 and 59 years old.

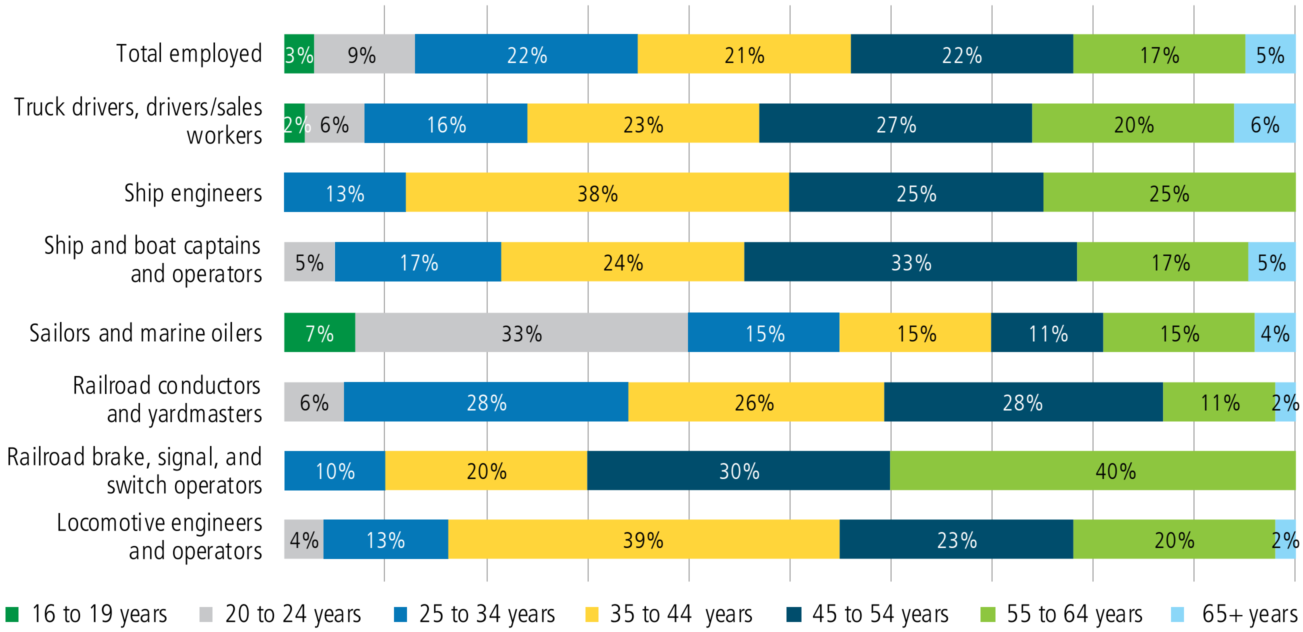
Natural Gas Pipelines

Improving safety and environmental management for natural gas TS&D could support a significant number of jobs. A BlueGreen Alliance analysis on the employment implications of public and private sector investments in methane abatement and infrastructure modernization within natural gas TS&D found that accelerated pipeline replacement (10-year time frame) could support 313,000 jobs throughout the economy. This number is sizable compared to the 63,000 jobs supported in the "business-as-usual" 30-year replacement timeline.

Shared Infrastructures

Employment profiles for shared freight transport modalities—rail, barge, ports, and trucks—are also increasingly important to the energy sector. The Bureau of Labor Statistics (BLS) indicates that 26 percent of the trucking workforce, 20 percent of the rail workforce, and 21 percent of the maritime workforce are aged 55 or older, compared to 22 percent in all U.S. industries (see Figure 8-2); although, individual occupations can have an older workforce.[15] BLS also projects that overall employment in select freight transport occupations[d] will increase by 200,000 from 1.9 million to 2.1 million between 2012 and 2022. Replacing employees that are either exiting the workforce or moving to other occupations would create a demand for approximately 210,000 additional workers in these occupations, according to BLS experimental data and analysis being conducted in coordination with the Departments of Education, Labor, and Transportation.[16]

Figure 8-2. Age Distribution of Select Transportation Workers (2014)[17]



The percentage of transportation workers in rail and maritime positions over 45 years old exceeds the national average; the percentage of workers over the age of 55 in these occupations is comparable to the national average. While age information on tractor-trailer drivers is not available, BLS data indicate that the trucking workforce is older, on average, than other occupations. Numbers may not add to 100 due to rounding.

Workforce Training Strategies

Job-driven training strategies will vary by energy industry sector, but there are a number of common themes, including the following.

Assess Required Skills

In the future, many of the jobs in the energy industry, which include jobs in TS&D systems, will require a much more diverse set of skills than similar jobs in the past. It is difficult to assess exactly what skills will be in demand because new classes of jobs (e.g., smart grid designers and operators, cybersecurity experts, and smart building designers and operators) have not developed nationally accepted certifications. Industry-led skill assessments are critical to ensuring that private and public sector support is targeted to the highest-priority areas.

Expand Training Curricula and "Hands-On" Learning

Better use of the latest educational tools and techniques could assist in the training of new workers. Modern information technology tools enhance teaching methods, allowing individualized training that makes direct connections between abstraction and concrete problems using simulations and other tools. States, in particular, may benefit from access to specialized Federal technical programs and better coordination with Federal economic development resources to deploy these curricula and technologies.

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[d] Select occupation codes are for water transportation, rail transportation, and heavy tractor-trailer truck drivers: 53-3032, 53-4011, 53-4012, 53-4013, 53-4021, 53-4031, 53-5011, 53-5021, and 53-5031.

Move to Competency-Based Evaluations

There is growing interest in defining education and training goals not in terms of inputs (semester hours) but in terms of outputs ("competency-based evaluations"). Information technologies offer powerful new tools for measuring a wide range of skills using simulations and other methods. They also offer interesting opportunities for increasing the efficiency and quality of learning systems, in part, by tailoring instruction to the revealed skills and interests of each student.

Engage Veterans and Facilitate Their Entry into Energy Jobs

At a time when 200,000 veterans are leaving the military annually, recruiting and training them for energy jobs can reduce the skills gap in a critical set of industries. A shift to competency-based credentialing would be particularly useful for veterans because they enter the civilian workforce with a unique set of skills—skills that may not be recognized by civilian certifications (e.g., military time at sea is not recognized toward merchant marine requirements). As a result, veterans are often required to go through courses where they already know a large fraction of what is needed. As certifications and evaluations are developed for new energy skills, veteran engagement needs to be at the forefont.

Data Challenges

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. Employment data in the United States are usually organized and aggregated according to what industries produce or according to individual worker occupations. Even at the greatest possible level of employment data detail, it is not easy or straightforward to identify what portion of jobs in an industry or occupation is involved in energy.

BLS employment data are reported according to the North American Industry Classification System, which represents different types of economic activity. North American Industry Classification System data lack the specificity to identify what portion of jobs fall under an industry or occupation involved in energy. For example, the code for power and communication line and related structures construction includes workers primarily engaged in the construction of power lines and towers; power plants; and radio, television, and telecommunications transmitting/receiving towers.[18] This kind of breadth encompasses multiple skill sets and is insufficiently detailed for jobs planning or workforce training assessments.

The lack of information is especially critical in categories experiencing high growth and rapid technological change. For instance, a recent BLS[19] report counted 4,800 solar installer jobs in the solar industry at a time when the Solar Foundation's annual jobs census identified more than 84,000 solar installers.[20] This large difference results from the fact that solar installation jobs are classified as "construction" under current BLS definitions. Energy generation, distribution, and consumption jobs have become embedded in so many different sectors of the economy and in so many ways that jobs that are primarily energy focused are attributed to the sector where they are housed. As a result, energy jobs are classified with traditional job skills identifiers—making the role that energy is playing in the American economy difficult to measure, understand, and plan for.

The North American Industry Classification System, managed jointly by the United States, Canada, and Mexico, is updated every 5 years to reflect changes in the North American economies. As part of that process, BLS is currently soliciting comments on new classifications for oil and gas production. Future changes may need to be incorporated as the energy sector continues to evolve.

Select Industry and Labor Energy Workforce Training/Development Resources

The fundamental shifts in the Nation's energy landscape extend to the workforce that constructs and operates the energy infrastructure. Changes can be seen in both traditional, direct energy-related fields jobs, as well as in a host of nontraditional energy occupations and sectors, including some where energy had not previously played a major role. A wide range of initiatives to build and train a competitive domestic energy workforce can be found throughout energy-relevant industry and labor organizations, colleges, trade schools, and state and local governments. The following examples are of industry- and labor-sponsored workforce resources:

The Center for Energy Workforce Development is a nonprofit consortium of electric natural gas and nuclear utilities and their associations. Working with contractors, unions, and educational institutions, the Center for Energy Workforce Development focuses on building a skilled workforce pipeline to meet future industry demands. Information can be found at www.cewd.org. The Center for Energy Workforce Development also operates the **Troops to Energy Jobs** websites, which help military veterans map military occupational specialties to energy industry jobs. Information can be found at www.troopstoenergyjobs.com.

The Solar Energy Industries Association's member-led **Installer Safety & Workforce Development Working Group** provides guidance and information to members regarding training opportunities, certifications, and more. Additionally, the Solar Energy Industries Association coordinates with training providers and certification organizations to provide information and guidance to members. Information can be found at www.seia.org/policy/health-safety/workforce-development.

The American Petroleum Institute hosts the **API–U Training** resource, which sponsors training programs and provides continuing education for oil and gas professionals, as well as courses for new entrants into the industry. Information can be found at www.api.org/events-and-training/api-u-training. The American Petroleum Institute has also developed the Oil and Gas Workforce portal to connect applicants with job opportunities in the industry. Information can be found at www.oilgasworkforce.com.

The Institute of Electrical and Electronics Engineers offers an array of education, career, and job-placement resources for technical professionals, as well as an analysis on workforce demands in energy and non-energy fields. Information can be found at www.ieee.org/education_careers.

The Association of American Railroads maintains resources, including videos and profiles of rail employees with military service, job fair listings, job boards, and websites where railroads advertise openings, as well as websites developed by railroads to connect with men and women in the military. Information can be found at www.aar.org/jobs.

Helmets to Hardhats is a nonprofit program that connects military veterans with training and career opportunities in the building trades, most of which are connected to federally recognized apprenticeship programs with trade organizations. Information can be found at www.helmetstohardhats.org.

The Utility Workers Union of America represents workers in the electric, gas, water, and nuclear industries. The Utility Workers Union of America's **Power 4 America Training Trust Fund** is used to recruit and train workers, with an associated online resource center that serves to track training and certification progress and provide access to apprenticeship and continuing education programs. Information can be found at www.power4america.org.

The North America's Building and Construction Trades Unions funds and operates an extensive workforce development, training, and craft apprenticeship infrastructure in a range of energy-related fields. This includes state-of-the-art construction training centers, mobile training centers, and welding booths. Information can be found at www.bctd.org. Members of North America's Building and Construction Trades Unions that also have energy-related workforce training trust funds include the International Brotherhood of Electrical Workers; the Laborers' International Union of North America; the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States, Canada and Australia; and the International Union of Operating Engineers.

Examples of Administration Activities for Energy-Related Employment and Workforce Training

- The Administration's Ready to Work Initiative, led by the Office of the Vice President, and passage in 2014 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 described in this section, 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.
- The President's Fiscal Year 2016 Budget proposed the POWER+ Plan to help these communities adapt to the changing energy landscape and build a better future. The POWER+ Plan invests in workers and jobs, addresses important legacy costs in coal country, and drives development of coal technology. This year, the Administration will make a down payment on the POWER+ Plan by beginning to implement a key part of the effort—the Partnerships for Opportunity and Workforce and Economic Revitalization initiative. The initiative will be a coordinated effort involving multiple Federal agencies, with the goal of effectively aligning, leveraging, and targeting a range of Federal economic and workforce development programs and resources to assist communities negatively impacted by changes in the coal industry and power sector.
- Through First Lady Michelle Obama and Dr. Jill Biden's Joining Forces initiative, businesses have hired nearly 700,000 veterans and military spouses, including energy companies, and 49 states have removed credentialing impediments for separating service members.
- In April 2015, the Department of Energy (DOE), in partnership with the Department of Defense, launched a Solar Ready Vets program at 10 military bases across the country. The program also includes participation from Camp Pendleton in California, Fort Carson in Colorado, and Naval Station Norfolk in Virginia—all of which announced pilot initiatives earlier this year and are serving as models for the Solar Ready Vets program—and Hill Air Force Base in Utah. The program will support DOE in meeting its goal to train 75,000 people to enter the solar workforce by 2020, some of whom will be veterans.
- DOE's technical and financial resources, primarily focused on the development and deployment of energy technology, are playing a significant role in the Skills Working Group. Those activities include identifying new opportunities for apprenticeships and career pathways, such as in the solar industry where DOE's SunShot Initiative worked with the industry to develop the Solar Instructors Training Network. The network created a training curriculum for teaching photovoltaic installation in community colleges and then successfully trained 800 faculty members in 400 institutions who in turn graduated 30,000 students.
- 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, including a concentration on energy and associated advanced manufacturing. Additionally, 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. This initiative to expand "hands-on" learning is part of a broader goal to double the number of apprenticeships in the United States in the next 5 years.
- DOE has created its 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. Along with the SunShot Initiative, other successful programs in this area include the Carbon Fiber Consortium (a partnership of laboratories, materials companies, and educational institutions) and the Clean Energy Manufacturing Initiative (a crosscutting initiative focused on clean energy products and processes), among many others.
- 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. For example, DOE's partnership with the National Institute of Building Sciences is working to establish a common certification for five specific energy management positions by establishing the Better Buildings Workforce Guidelines through the Commercial Workforce Credentialing Council. DOE's National Energy Technology Laboratory, based in Pittsburgh, Pennsylvania, partnered with Westmoreland Community College to develop an industry-specific initiative, ShaleNet, which utilized a three-dimensional simulator for use in training for the natural gas industry. This effort succeeded in graduating and placing thousands of new employees in that rapidly growing industry. 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, as well as to veterans and other specific populations.

QER Recommendations

The challenges facing workforce training for jobs associated with TS&D infrastructure mirror the broader issues facing the energy sector as a whole. For this reason, current Administration activities and the QER recommendations described below have the potential to broadly benefit the entire energy sector beyond their benefits to workers associated with TS&D infrastructure. In order to build on the ongoing Administration-wide activities, we recommend the following:

Support an energy-job skills training system: As part of the interagency Skills Working Group with the Departments of Energy, Labor, and Education, the Administration should support actions for a national job-driven skills training system in the United States by providing new energy and advanced manufacturing curricula; designing new and enhanced apprenticeship programs; establishing industry-based credentialing standards for new technologies; and implementing innovative online learning systems, such as the National Training and Education Resource Web-based learning platform.

Expand support for an open-source learning community: DOE should develop, facilitate, and expand use of state-of-the art courses in energy-related fields through a competition to solicit proposals from organizations that would maintain and continuously improve the National Training and Education Resource. The National Training and Education Resource platform can help colleges lacking sophisticated resources to build and deliver courses using state-of-the-art methods. It can provide a full set of tools, including course authoring, a three-dimensional world builder, a traditional learning and content management system, and support for multiple content types—including images, text, and multimedia—all within a course.

Coordinate efforts to accelerate the development of high-quality energy education programs: DOE should coordinate efforts to accelerate the development of energy and manufacturing curricula and apprenticeship programs with existing Department of Labor or National Science Foundation programs to (1) develop and deliver courses in energy and advanced manufacturing topics; and (2) provide technical support in the form of simulations, visualization tools, cognitive tutoring, and other resources in energy and manufacturing.

Facilitate national credentials for energy occupations: DOE should support and, as necessary, facilitate an industry-led process of defining needed skills in a number of emerging occupations. This would build on DOE's experience in the building retrofit space. These needed skills can be translated into specific certifications, including "stacked credentials" modeled after competency-based education.

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

Reform energy employment data collection systems: DOE should establish an interagency working group—to include the Departments of Labor and Commerce—to reform existing data collection systems to provide consistent and complete definitions and quantification of energy jobs across all sectors of the economy. Because employment data is collected by the State Employment Security Agencies, the success of this initiative will necessarily require their engagement, as well as identifying and mitigating barriers to implementation.

RECOMMENDATIONS IN BRIEF:
Enhancing Employment and Workforce Training

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. The Department of Energy (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.

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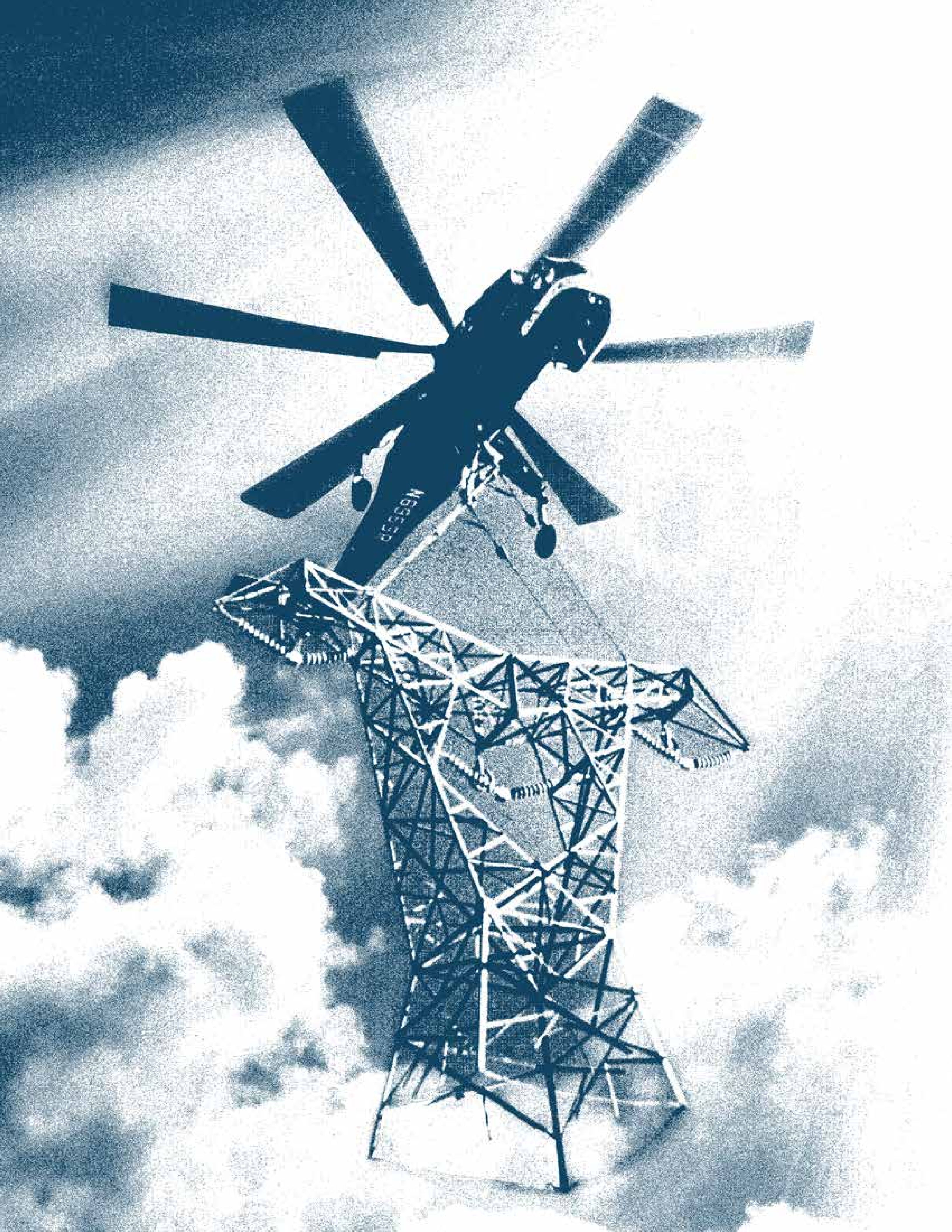

Chapter IX

SITING AND PERMITTING OF TS&D INFRASTRUCTURE

This chapter is devoted to issues surrounding the siting and permitting of transmission, storage, and distribution (TS&D) infrastructure, building on the general identification of those issues in Chapter VII (Addressing Environmental Aspects of TS&D Infrastructure). The first section highlights the multiple jurisdictions involved in permitting. The second section describes the need for close collaboration with governments at a variety of levels. The third section focuses on the need for public engagement on siting issues. The fourth section discusses timetables for siting and permitting. The chapter concludes with a description of current Administration activities and plans and a number of recommendations for further action.

FINDINGS IN BRIEF:
Siting and Permitting of TS&D Infrastructure

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, and 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.

The Federal Government is taking steps to modernize its siting, permitting, and review processes. The complexity and pace of the Federal permitting and review processes for proposed infrastructure projects has been identified as a key challenge to building U.S. infrastructure for transporting, transmitting, and delivering energy. 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.

A New Urgency to Improve Siting and Permitting

The domestic oil-and-gas boom, expanding renewable energy production, actions to mitigate climate change, and ongoing steps to maintain electricity grid reliability are changing our energy infrastructure needs and driving demand for new TS&D energy infrastructure. Actions to expand both renewable and traditional energy production over the past decade have exposed the gap between typical permitting times for generation and production sources and the much longer times for midstream energy infrastructure. The discrepancy in permitting time frames makes it more challenging to plan, site, permit, finance, and construct midstream 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.

While building much of this infrastructure depends on state and local decisions, the Federal Government plays a central role in reviewing and approving applications to site certain projects, including interstate gas pipelines and those that cross Federal lands, or have impacts to wildlife, cultural and historic resources, or waters of the United States. This chapter focuses on that Federal role and the actions taken across the Federal Government to permit and approve energy infrastructure projects and increase the efficiency of the permitting process while improving environmental and community outcomes.

Since 2009, the Department of the Interior's Bureau of Land Management (BLM) has approved 90 major transmission line projects, spanning approximately 3,000 total miles, approximately 1,600 miles of which cross BLM-managed lands. Since that time, BLM also has authorized more than nine major pipeline projects for oil, water, and natural gas, with nearly 1,050 miles on BLM lands. The Federal Energy Regulatory Commission (FERC) has authorized about 4,500 miles of pipeline since 2009, and about 6,200 miles of pipeline have been put in service. Since 2009, the Department of Agriculture's Rural Utilities Service has financed 5,591 total miles of transmission line, 3,316 miles of which are new transmission line and 2,275 miles are line upgrade and improvements. During the same time period, the Department of Agriculture's Forest Service has approved and reauthorized on National Forest System lands 4,921 power line projects covering 31,678 miles; 2,160 natural gas and oil pipelines covering 12,907 miles; and 158 water transmission projects covering 847 miles.

For the vast majority of projects, the environmental review and permitting requirements are accomplished effectively and efficiently. For particularly large and complex infrastructure projects, however, the diverse and often divergent sets of agency permit and decision-making responsibilities can lead to friction and create inefficiencies, as well as extend the time frame for the Federal permitting and review process.

To drive additional progress in Federal reviews of significant midstream infrastructure projects, the Administration launched a government-wide initiative to modernize the Federal permitting and review process. President Obama issued a Presidential Memorandum on August 31, 2011, and an Executive Order on March 22, 2012.[1,2] In those executive actions, the President directed Federal agencies to improve the efficiency and transparency of Federal permitting and review processes for infrastructure projects,[a] as well as to cut through red tape and get more timely decisions, while producing measurably better outcomes for communities and the environment.

Under that initiative, Federal agencies have expedited the review and permitting of more than 50 selected infrastructure projects, including 11 energy projects.[b] Thirty-two of these projects have completed the Federal review process, 29 remain under active Federal review, and 1 project was denied. Estimated time savings range from several months to several years in many cases.

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[a] As defined in the Presidential Memorandum, infrastructure projects include electricity transmission, pipelines, renewable energy infrastructure, water resource projects, ports and waterways, transit systems, broadband Internet, roads, bridges, railways, and airports.

[b] More information about these projects is posted online on the Federal Infrastructure Projects Permitting Dashboard, which was established pursuant to a 2011 Presidential Memorandum on Speeding Infrastructure Development through More Efficient and Effective Permitting and Environmental Review. See: Federal Infrastructure Projects Permitting Dashboard. "Projects Under Active Review." www.permits.performance.gov/projects/active-projects.

SUMMARY OF SELECT TRANSMISSION AND DISTRIBUTION INFRASTRUCTURE SITING, PERMITTING, AND REVIEW AUTHORITIES

Multiple Federal, state, local, and tribal governments have jurisdiction over siting, permitting, and review of proposed transmission, storage, and distribution infrastructure. Projects that involve Federal funds, are proposed on Federal lands, cross Federal land or water, or will affect the air or water quality that is regulated by Federal law are subject to some kind of Federal permitting or review process. The following is a brief summary of some of these legal authorities.

ELECTRIC TRANSMISSION LINES

Federal Jurisdiction:

- The Federal Energy Regulatory Commission has limited siting authority pursuant to Section 216 of the Federal Power Act, under limited circumstances within corridors designated by the Department of Energy. Implementation of this authority has been impacted by court decisions.[c, d]
- The Department of Energy has jurisdiction under Section 216(h) of the Federal Power Act (16 U.S.C. § 824p(h)) to coordinate applicable Federal authorizations and related environmental reviews for transmission projects.
- The Department of Energy has the authority under Section 1222 of the Energy Policy Act of 2005 (42 U.S.C. § 16421) to engage in or to participate with other entities in designing, developing, constructing, operating, maintaining, or owning (1) electric power transmission facilities and related facilities needed to upgrade existing transmission facilities owned by the Western Area Power Administration or Southwestern Area Power Administration, or (2) new electric power transmission facilities and related facilities located within any state in which either operates.
- The Department of the Interior's Bureau of Land Management (BLM) and the Department of Agriculture's Forest Service (USFS) have the authority under the Federal Land Policy and Management Act (43 U.S.C. §§ 1761–1771) to issue rights of way for electric transmission lines crossing their Federal lands.

State Jurisdiction:

- States have primary authority over siting, permitting, and review of electric transmission projects. Each state has different procedures to follow for approving a transmission line. Interstate lines must comply with the legal requirements of each state.

NATURAL GAS PIPELINES

Federal Jurisdiction:

- The Federal Energy Regulatory Commission has jurisdiction under Section 7 of the Natural Gas Act to regulate interstate natural gas pipelines, including siting (15 U.S.C. § 717f(c)). The Federal Energy Regulatory Commission is also required as a lead agency to coordinate the environmental review and processing of all Federal authorizations related to natural gas infrastructure with other Federal agencies (15 U.S.C. § 717n(b)).[e]
- BLM has the authority to issue permits under the Mineral Leasing Act for natural gas pipelines that cross Federal lands (30 U.S.C. § 185). If a proposed pipeline crosses more than one Federal agency's lands, BLM issues the right-of-way permit (30 U.S.C. § 185(c) and 43 C.F.R. § 2882). If the pipeline crosses only USFS lands, USFS issues a special use permit (36 C.F.R. § 251).

State Jurisdiction:

- States have jurisdiction over lines that do not carry gas in interstate commerce.

[c] California Wilderness Coal v. U.S. Dep't of Energy, 631 F.3d 1072 (9th Cir. 2011).

[d] Piedmont Envtl. Council v. FERC 558 F.3d 304 (4th Cir. 2009).

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SUMMARY OF SELECT TRANSMISSION AND DISTRIBUTION INFRASTRUCTURE SITING, PERMITTING, AND REVIEW AUTHORITIES (continued)

OIL PIPELINES

Federal Jurisdiction:

- There is no comprehensive Federal siting and permitting process for interstate or intrastate oil pipelines.
- BLM and USFS authority for oil pipelines crossing Federal lands mirrors that for gas pipelines set forth above (30 U.S.C. § 185).

State Jurisdiction:

- State and local laws govern approval of an oil pipeline route, other than the portions crossing Federal lands. Interstate lines must comply with the legal requirements of each state.

CARBON DIOXIDE PIPELINES

Federal Jurisdiction:

- There is no comprehensive Federal siting and permitting process for interstate or intrastate carbon dioxide pipelines on non-Federal lands.
- BLM regulates carbon dioxide pipelines under the Mineral Leasing Act as a commodity shipped by a common carrier (30 U.S.C. §185(r)).[f, g]

State Jurisdiction:

- Oversight of siting, construction, and operations of carbon dioxide pipelines is largely handled at the state level.[h]

RAIL LINES

Federal Jurisdiction:

- The Surface Transportation Board, created in the 1995 Interstate Commerce Commission Termination Act, regulates construction of rail lines.[i]

State Jurisdiction:

- State and local governments retain the power to protect public health and safety, such as regulating potentially harmful waste disposal, to the extent that regulation does not interfere with the Surface Transportation Board's exclusive jurisdiction over interstate rail operations.[j,k]

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[f] Environmental Assessment for Anadarko E&P Company L.P. Monell CO_2 Pipeline Project.

[g] Exxon Corp. v. Lujan, 970 F.2d 757 (10th Cir. 1992).

[h] Congressional Research Service. "Carbon Dioxide (CO_2) Pipelines for Carbon Sequestration: Emerging Policy Issues." p. 10. January 17, 2008. http://assets.opencrs.com/rpts/RL33971_20080117.pdf. Accessed January 21, 2015.

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[j] See e.g., Norfolk Southern Railway Co. v. City of Toledo, 2015 WL 45537 (N.D. Ohio January 2, 2015).

[k] See e.g., Green Mountain Railroad Corp. v. Vermont, 404 F.3d 638, 643 (2d Cir, 2005).

The Federal Government's Role in Siting, Permitting, and Review of Infrastructure Projects

Permitting and siting of the majority of TS&D infrastructure projects depends on state and local decisions.[3, 4, 5] Federal agencies have siting authority over proposed infrastructure projects that cross Federal land or water; interstate natural gas pipelines; and, to a limited extent, interstate electricity transmission projects. In states where most of the land is Federal land, Federal agencies make the key siting decisions. Federal approval will include environmental protection requirements, as well as required reviews that Federal agencies must follow and which may lead to decisions that ensure the protection of the environment and cultural and historic resources.[l] Applications for pipelines and power lines that cross tribal lands must also be approved by the tribal government and Federal Government.[6]

The number and type of permits and reviews required, as well as the process and the timelines, vary depending on the nature of the project. For example, Congress has granted FERC siting authority over interstate natural gas pipelines.[7, m] In contrast, there is no comprehensive Federal process for obtaining a permit for the routing of an interstate oil pipeline.[n] Rather, state and local laws govern approval of an oil pipeline's route. Similarly, states (with limited exceptions provided under the Energy Policy Act of 2005)[o] have siting authority over electricity infrastructure.[p] The regulation of carbon dioxide (CO_2) pipelines is currently a joint responsibility of Federal and state governments.[q] Four Federal agencies maintain a role in cross-border Presidential permitting and/or export authorization of energy infrastructure that crosses the international borders with Canada or Mexico—the Department of State has delegated authority for oil and refined product pipelines;[8] FERC is the authorizing

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[l] A full inventory of required Federal permits and approvals, as well as National Environmental Policy Act reviews and milestones relating to major infrastructure projects, is available on the Federal Infrastructure Projects Permitting Dashboard. See: Federal Infrastructure Projects Permitting Dashboard. "Permit Inventory." www.permits.performance.gov/permit-inventory.

[m] The Natural Gas Act also provides FERC the authority to grant private companies that transport natural gas in interstate commerce the rights of eminent domain (15 U.S.C. § 717f(c)).

[n] FERC has no oversight authority over construction of interstate oil pipelines, nor does it have jurisdiction over wholly intrastate pipelines. There is also no eminent domain authority for liquid pipelines.

[o] FERC has limited siting authority pursuant to Section 216 of the Federal Power Act, under limited circumstances within corridors designated by the Department of Energy. Implementation of this authority has been called into question in recent court decisions. In the Energy Policy Act of 2005, Congress also added provisions addressing Federal Government jurisdiction over and processes for siting electricity transmission. Under Section 216(h) of the Federal Power Act (16 U.S.C. § 824p(h)), Congress granted DOE authority to coordinate applicable Federal authorizations and related environmental reviews for transmission projects. In 2009, pursuant to Section 216(h)(4)(C), nine Federal agencies signed a memorandum of understanding to expedite the siting and construction of qualified onshore electric transmission infrastructure projects in the United States. See: "Memorandum of Understanding Among the U.S. Department of Agriculture, Department of Commerce, Department of Defense, Department of Energy, Environmental Protection Agency, the Council on Environmental Quality, the Federal Energy Regulatory Commission, the Advisory Council on Historic Preservation, and Department of the Interior, Regarding Coordination in Federal Agency Review of Electric Transmission Facilities on Federal Land." October 23, 2009. www.whitehouse.gov/files/documents/ceq/Transmission%20Siting%20on%20Federal%20Lands%20MOU.pdf. Accessed January 21, 2015.

[p] In almost all states, public utility commissions regulate siting of electricity infrastructure. Each state has different procedures to follow for approving a transmission line. Some states require the developer to demonstrate the necessity of new transmission capacity, and some states require the consideration of non-transmission alternatives. Some states mandate that all types of transmission lines be fully permitted before construction can start, while others only have siting requirements above certain voltage levels.

[q] CO_2 transportation pipelines are subject to Federal safety regulations that are administered by the Department of Transportation's Pipeline and Hazardous Materials Safety Administration (49 C.F.R. § 195). It directly oversees pipeline safety for all interstate lines, while intrastate pipelines are subject to state agency oversight (as long as the standards are at least as stringent as the Federal rules). If a pipeline crosses Federal land, then, prior to construction, permits from the relevant Federal agency and compliance with the National Environmental Policy Act are required. Otherwise, the power of oversight of siting (including the use of eminent domain), construction, and operations of CO_2 pipelines is largely handled at the state level.

agency for natural gas pipelines and liquefied natural gas facilities located onshore and in state waters;[9, 10, r] and the Department of Energy (DOE) is the authorizing agency for cross-border electric transmission lines,[11, 12] exports of electricity,[13] and imports and exports of natural gas.[14, 15] The Department of Commerce exercises export authorities not granted to the preceding agencies.[16]

In all cases, projects that involve Federal funds, are proposed on Federal lands, require passage across Federal lands, or will affect the air or water quality that is regulated by Federal and state law are subject to some kind of Federal and state permitting or review process.[s]

Multiple Jurisdictions for the Siting, Permitting, and Review Process

Large infrastructure siting and permitting in the United States is uniquely challenging in our Federal system of government because it often involves multiple state and Federal agencies and tribal governments with overlapping jurisdictions and different, sometimes conflicting statutory responsibilities. While this interdisciplinary system can help foster appropriate project siting decisions that reduce project impacts, there are often structural and cultural barriers to timely project siting and permitting decisions. Taken together, solely at the Federal level, there are "more than 35 distinct permitting and review responsibilities across more than 18 Federal agencies and bureaus, implemented by staff at headquarters and hundreds of regional and field offices" located across the country.[17]

Federal Collaboration with Tribal, State, and Local Governments

Most infrastructure siting and permitting decisions are made at the state and local levels; some also require consultation with affected Indian Tribes on projects that impact traditional cultural properties and certain other historic and cultural resources.[18, 19] The local nature of permitting decisions requires close stakeholder interaction and appropriate knowledge of local resource concerns to be addressed in the permitting process.[20] Effective collaboration between Federal agency regional leadership and the state, tribal, and local governments that share permitting and review responsibilities for infrastructure projects is essential to moving a project quickly and efficiently from planning to review and permitting. However, cooperation with state and local governments and consultation with tribes requires additional levels of coordination in the context of large, complex infrastructure permitting decisions and can create significant delays in project approval. State agencies can also lack incentives to act on multi-state linear infrastructure projects, especially when the projects' primary beneficiaries are located elsewhere.

[r] Pursuant to the Deepwater Port Act (33 U.S.C. § 1501 et seq.), the Maritime Administration within the Department of Transportation has responsibility for permitting liquefied natural gas terminals located beyond state waters.

[s] Depending on the areas through which a pipeline or transmission line is proposed, there are a variety of Federal permitting or review processes that may apply in addition to state and local permits: Clean Water Act Section 401 water quality certificates (33 U.S.C. §§ 1251–1387), Section 402 National Pollutant Discharge Elimination System Permits (33 U.S.C. § 1342), Section 404 dredge and fill permits from the Army Corps of Engineers (33 U.S.C. § 1344), permits under Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. § 403), Clean Air Act permits (42 U.S.C. § 7401 et seq.), the Endangered Species Act (16 U.S.C. §§ 1531–1544), and the National Historic Preservation Act (16 U.S.C § 470). In addition, compliance with the National Environmental Policy Act is always required when a proposed TS&D infrastructure project necessitates Federal action (such as funding, permitting, or otherwise approving a pipeline or electricity transmission project).

Engagement of the Public in Energy Infrastructure Siting and Permitting

The complexity and scale of 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, which must be addressed and mitigated through avoidance, minimization, or compensation. Under the National Environmental Policy Act (NEPA),[21, 22] and the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA, any Federal action (such as funding or approving a major pipeline or electricity transmission project) requires the responsible official to consider the potential environmental impacts of the proposed action and any reasonable alternatives.[23, 24] Federal agencies work to prepare a categorical exclusion, environmental assessment, or environmental impact statement, which—depending upon the scope and complexity of the project and the intensity of potential impacts on communities and the environment—can take time to address community and environmental impacts. Affected residential communities, nonprofit organizations, and other stakeholders also participate in the NEPA process through public comment opportunities.[25] Public outreach and engagement with diverse sets of stakeholders is essential to reduce the risks associated with uncertainty and potential challenges. Early and robust public engagement is a recognized best practice and can reduce delays and improve projects.[26, 27, 28]

Cross-Border Presidential Permitting and Export Authorities

Four Federal agencies currently maintain a role in cross-border Presidential permitting and/or export authorization of energy commodities. The Department of Energy (DOE) oversees permits for cross-border electric transmission lines, exports of electricity, and imports and exports of natural gas. The Department of State permits cross-border oil and refined product pipelines. The Federal Energy Regulatory Commission permits natural gas pipelines and liquefied natural gas (LNG) facilities. The Department of Commerce exercises export authorities not granted to the preceding agencies. These authorities arise from the following statutes and Executive Orders:

PETROLEUM, PETROLEUM PRODUCTS, COAL, OR OTHER FUELS

Infrastructure: Pipelines, Land Transportation, Other

- Executive Order No. 11423 (1968), Executive Order No. 13337 (2004): Permitting authorities regarding pipelines, conveyor belts, bridges, and border crossings for land transportation, including motor and rail vehicles, delegated to the Secretary of State for a national interest determination.[t, u]

Export Authority

- Energy Policy and Conservation Act (1975): Delegates Presidential authority to restrict exports of coal, crude oil, petroleum products, natural gas, or petrochemical feedstocks, or related materials or equipment, for domestic use to the Secretary of Commerce.[v]

[t] Executive Order No. 10485. "Providing for the Performance of Certain Functions Heretofore Performed by the President with Respect to Electric Power and Natural Gas Facilities Located On The Borders Of The United States." 18 Fed. Reg. 5397. September 9, 1953. http://www.archives.gov/federal-register/codification/executive-order/10485.html. Accessed January 20, 2015.

[u] Executive Order No. 12038. "Relating to Certain Functions Transferred to the Secretary of Energy by the Department of Energy Organization Act." 43 Fed. Reg. 4957. February 7, 1978. http://www.archives.gov/federal-register/codification/executive-order/12038.html. Accessed January 20, 2015.

[v] 42 U.S.C. § 6212.

Cross-Border Presidential Permitting and Export Authorities (continued)

NATURAL GAS

Infrastructure: Pipelines, Onshore or Near-Shore LNG Facilities, Other

- Natural Gas Act Sections 3 and 7 (1938) and DOE Organization Act (1977): Permitting for natural gas pipelines, LNG terminals located onshore and in state waters, and related facilities assigned to Secretary of Energy (subsequently delegated in part to the Federal Energy Regulatory Commission Chair; see below).[w,x]
- DOE Delegation Order No. 00-004.00A (2006): Permitting authority for construction and operation of natural gas import/export facilities delegated to the Federal Energy Regulatory Commission Chair.[y]
- Coast Guard and Maritime Transportation Act of 2012: Responsibility for permitting LNG terminals located beyond state waters assigned to the Maritime Administration within the Department of Transportation.

Export Authority

- Natural Gas Act Section 3 (1938): Permitting authority for exports and imports of natural gas granted to the Secretary of Energy.[z,aa]

ELECTRICITY

Infrastructure and Export Authority

- Federal Power Act (1935) and DOE Organization Act (1977): Permitting and export authority assigned to the Secretary of Energy.[ab]
- Executive Order No. 10485 (1953), Executive Order No. 11423 (1968), Executive Order No. 12038 (1978): Permitting authority for cross-border electric transmission lines delegated to the Secretary of Energy.[ac, ad]

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[w] 42 U.S.C. § 7151(b).

[x] 15 U.S.C. § 717b(a).

[y] Department of Energy. "Delegation Order No. 00-004.00A." 2006. http://www.ferc.gov/industries/electric/indus-act/siting/doe-delegation.pdf. Accessed January 20, 2015.

[z] Executive Order No. 10485. "Providing for the Performance of Certain Functions Heretofore Performed by the President with Respect to Electric Power and Natural Gas Facilities Located On The Borders Of The United States." 18 Fed. Reg. 5397. September 9, 1953. http://www.archives.gov/federal-register/codification/executive-order/10485.html. Accessed January 20, 2015.

[aa] Executive Order No. 12038. "Relating to Certain Functions Transferred to the Secretary of Energy by the Department of Energy Organization Act." 43 Fed. Reg. 4957. February 3, 1978. http://www.archives.gov/federal-register/codification/executive-order/12038.html. Accessed January 20, 2015.

[ab] 16 U.S.C. § 824a(e).

[ac] Executive Order No. 10485. "Providing for the Performance of Certain Functions Heretofore Performed by the President with Respect to Electric Power and Natural Gas Facilities Located On The Borders Of The United States." 18 Fed. Reg. 5397. September 9, 1953. http://www.archives.gov/federal-register/codification/executive-order/10485.html.

[ad] Executive Order No. 12038. "Relating to Certain Functions Transferred to the Secretary of Energy by the Department of Energy Organization Act." 43 Fed. Reg.4957. February 7, 1978. http://www.archives.gov/federal-register/codification/executive-order/12038.html.

Variability in Siting and Permitting Timetables

Large and complex infrastructure projects typically involve multi-year design, development, and construction timelines with complex approval processes. Timelines for approval vary,[29, 30, 31] and hurdles exist across the process. Proposed infrastructure projects that cross state boundaries require the developer to obtain site permits from each state involved, each with its own timeline and process.[32, 33, 34] Some Federal agencies will not begin their approval processes until state and local permitting processes are completed.[35] Schedules are also affected by incomplete applications to the Federal agencies, as well as the multiple agency reviews required at the local, state, and Federal levels.[36, 37] Numerous other risks—such as policy and regulatory uncertainty—and commercial conditions—such as the availability of capital—can jeopardize project timelines and permitting schedules.[38, 39] Project applicants are ultimately responsible for project development and play a critical role in establishing and maintaining project time frames and changes in applicant priorities, or available funding can delay or cancel projects. The interplay among these factors can impact decision making and extend the time frame for the Federal permitting and review process, especially for large and complex infrastructure projects.[40]

Administration Actions to Modernize Siting, Permitting, and Review Processes

Building a 21st century infrastructure in a manner that safeguards our communities and the environment is an important component of President Obama's effort to strengthen our Nation's economy, create new jobs, and improve U.S. competitiveness in the global market. Federal agencies seek to ensure that as these major infrastructure projects are proposed, potential impacts on safety, security, and environmental and community resources, such as air, water, land, and historical and cultural assets, are considered and minimized. Over time, the process and legal requirements for the permitting and review of major infrastructure projects have developed in a siloed and ad-hoc way, creating complex processes that in some cases have taken years or longer to complete. Although there are several reasons why a major infrastructure project may be delayed (including applicant funding uncertainty and state and local reviews), over the past 3 years, the Administration has undertaken an ambitious effort to modernize the Federal Government's role in permitting and review processes.

To ensure his Administration took action to modernize these permitting and review processes, the President signed Executive Order No. 13604, *Improving Performance of Federal Permitting and Review of Infrastructure Projects*, on March 22, 2012, and subsequently a Presidential Memorandum on May 17, 2013, charging an interagency steering committee to lead the development of a plan to turn best practices into standard practice.

To date, agencies have expedited the review and permitting of more than 50 selected major infrastructure projects, including bridges, transit projects, railways, waterways, roads, and renewable energy generation projects. More information about these projects is posted online on the Federal Infrastructure Projects Permitting Dashboard. As of the date of this plan, 32 of these projects have completed the Federal review process, with 1 project denied. Estimated time savings range from several months to several years in many cases. Federal agencies have also identified a set of best practices for infrastructure permitting and review, ranging from expansion of information technology tools to strategies for improving collaboration and synchronizing processes across Federal agencies. These practices are reflected in the June 2012 "Federal Plan for Modernizing the Federal Permitting and Review Process for Better Projects, Improved Environmental and Community Outcomes, and Quicker Decisions" and individual agency plans at www.permits.performance.gov.

The Obama Administration has issued several subsequent executive directives to improve the Federal permitting and review process.

- The President also issued a memorandum on May 17, 2013, directing an interagency steering committee to develop a plan to turn permitting and review best practices identified by the Federal agencies—focused on early collaboration, increased transparency and accountability, and greater consideration of citizens' interests—into standard practice for all major infrastructure projects.[ae]

- On June 7, 2013, the President issued a separate but related memorandum, directing Federal agencies to "develop an integrated, interagency pre-application process for significant onshore electric transmission projects requiring Federal approval."[41] That 2013 memorandum also lays out principles for designation of energy right-of-way corridors on Federal lands under Section 368 of the Energy Policy Act of 2005; it also directs Federal agencies to re-evaluate existing energy rights-of-way corridor designations to determine the necessity for revisions, deletions, or additions to those energy corridors and to develop interagency mitigation plans, where appropriate, for environmental and cultural resources potentially impacted by projects sited in energy corridors.

The following highlights some of the key actions taken by the Administration to modernize the Federal Government's siting, permitting, and review processes and provides a summary of the areas that could be enhanced.

Developing Pre-Application Procedures

Pre-application permitting and review procedures can result in more efficient processing of final applications for energy infrastructure siting—particularly when such applications require multiple Federal authorizations (although, care must be taken that such procedures do not create an unnecessary additional hurdle to project approval or unnecessary additional bureaucratic delay).[42] Pre-application procedures can include meetings with appropriate agencies and project sponsors in advance of formal application submissions to help expedite the process.[af, 43]

In 2013, DOE—through the Council on Environmental Quality and the Administration's Rapid Response Team for Transmission—developed and sought public input on a proposed Integrated Interagency Pre-Application Process required under a June 2013 Presidential Memorandum.[ag, 44] DOE is now considering issuing a revised regulation under Section 216(h) of the Federal Power Act, a section through which Congress granted DOE authority to coordinate applicable Federal authorizations and related environmental

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[ae] The Administration released the "Implementation Plan for the Presidential Memorandum on Modernizing Infrastructure Permitting" on May 14, 2014. The plan can be accessed at www.permits.performance.gov/pm-implementation-plan-2014.pdf. "Major" is used in the plan to refer to projects that:
- Involve multiple Federal agencies and potentially tribal, state, or local government permit decision making or review actions associated with their development
- Provide regional (rather than localized) economic, cultural, or environmental benefits, or are directly linked to other critical infrastructure projects (e.g., rail to port)
- May have significant impacts on communities or the environment
- Involve resources and permitting actions that are not routine and necessitate focused attention and enhanced coordination
- Are otherwise classified as major by law or regulation.

[af] For example, FERC has regulations requiring a "pre-filing procedures and review process" for applications for interstate natural gas facilities under its jurisdiction (18 C.F.R. § 157.21). See: Government Accountability Office. "Interstate Natural Gas Pipelines: Process & Timing of FERC Permit Application Review." p. 6. February 15, 2013. fas.org/sgp/crs/misc/R43138.pdf. Accessed February 10, 2015. Other Federal agencies, including the Army Corps of Engineers, BLM, and the Department of Agriculture, also require applicants for certain projects to participate in multi-agency pre-application meetings.

[ag] DOE is piloting this pre-application process for the proposed Great Northern Transmission Line. See: The White House. "Fact Sheet – Building a 21st Century Infrastructure: Modernizing Infrastructure Permitting." May 14, 2014. www.whitehouse.gov/the-press-office/2014/05/14/fact-sheet-building-21st-century-infrastructure-modernizing-infrastructu. Accessed January 21, 2015.

reviews for transmission projects. In August 2013, BLM issued a proposed rule that would, consistent with the Integrated Interagency Pre-Application process, require all applicants for rights of way across public lands for 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. The BLM rule would also require proponents to pay reasonable or actual costs associated with the pre-application process.[45]

Cost Recovery for Review of Certain Project Applications

The lack of budgetary resources often constrains agencies' ability to promptly review permits. Mechanisms by which project sponsors can fund agency overhead costs associated with the review of an application are critical to their implementation capacity by ensuring that the agencies can dedicate sufficient resources to permit infrastructure projects in a timely fashion, especially if the funding happens in the earliest stages of agency involvement.[46, 47] While cost-recovery procedures must be rooted in statutory authority, departments and the

SELECT ADMINISTRATION SITING AND PERMITTING INITIATIVES

The following is a list of select Administration actions taken both across and within Federal agencies to reduce the aggregate permitting and review time for infrastructure projects, while improving environmental and community outcomes.

Coordinated Project Review

The Interagency Steering Committee established under Executive Order No. 13604 and the Interagency Infrastructure Permitting Improvement Team housed at the Department of Transportation are currently developing a Policy for Coordinated Review of infrastructure project applications among Federal agencies and with project sponsors.

Pre-Application Procedures and Cost Recovery for Project Reviews

In 2013, the Department of Energy (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) NEPAnode; (2) the Fish and Wildlife Service Information, Planning, and Conservation Tool; (3) the Environmental Protection Agency's NEPAssist; (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.

SELECT ADMINISTRATION SITING AND PERMITTING INITIATIVES (continued)

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.

Landscape and Watershed Level and 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."

agencies under them can use regulatory processes to apply that authority in intelligent and innovative ways.[ah] Some agencies do not have the statutory authority to recover such costs; others do not have authority to accept money until the application is "complete," which puts a strain on resources and also discourages early coordination. BLM has addressed the challenge of the cost of early coordination by requiring in its recent proposed rule that applicants for rights of way for transmission lines of 100 kilovolts or greater and pipelines 10 inches or more in diameter pay reasonable or actual costs associated with the pre-application process for these projects.[48]

Expanding Online Project Tracking and Developing Metrics

The development and publication of timely metrics and milestones for project permitting enables public scrutiny, provides agencies with information to identify and improve permitting and siting processes, and increases accountability and predictability.[49, ai] Moreover, consistent, government-wide data will provide actionable insight into current Federal permit and review practices, as well as inform discussions on ways to further improve the effectiveness and efficiency of these processes. Budgetary concerns have affected efforts to expand the Federal Infrastructure Projects Permitting Dashboard,[aj] to develop and collect permitting and review time-frame metrics, and to pilot environment and community outcome metrics.[50] Lack of funding also

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[ah] In its proposed rule, BLM has proposed expanding the regulatory definition of reimbursable "management overhead costs" to include costs incurred by other Federal agencies in reviewing the same project application (79 Fed. Reg. 59022; September 30, 2014). The cost reimbursement measures are intended to coincide with a Secretarial Order for delegation of Federal Land Policy Management Act cost-recovery authority to other agencies and offices of the Department of the Interior.

[ai] DOE has such an online dashboard for electricity transmission projects. This dashboard, known as e-Trans, serves as the online database containing pertinent project information about each project, including, but not limited to, the physical aspects of the line, lead agency contact information, project schedules, and required permits. The e-Trans dashboard can be accessed at trackingsystem.nisc-llc.com/etrans/utility/Search.seam.

[aj] The Federal Infrastructure Permitting Dashboard was launched in October 2011 and is used by all Steering Committee agencies and hosted by the Department of Transportation. See: Steering Committee on Federal Infrastructure Permitting and Review Process Improvement. "Implementation Plan for the Presidential Memorandum on Modernizing Infrastructure Permitting." www.permits.performance.gov/pm-implementation-plan-2014.pdf. Accessed January 20, 2015. It features a public website that displays project schedules with key milestones for more than 50 infrastructure projects and an internal site with an information technology platform that supports effective government-wide collaboration and the development of interagency project schedules. See: Federal Infrastructure Projects Permitting Dashboard. "Projects Under Active Review." www.permits.performance.gov/projects/active-projects.

limits the promise of more widely accessible geographic information system (GIS) and information technology tools that would supplement the Federal Permit Inventory[ak] and provide more transparency and clarity to project sponsors and public stakeholders.

Expanding Availability and Sharing of Data and GIS Tools

Careful project planning and selection of an appropriate project site before a permit application is filed can minimize uncertainty and significantly reduce the overall time frame for completing necessary permits and reviews.[51] 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 support Federal decision making.[52] The Administration has also emphasized the importance of providing such data, information, and decision-support tools for climate preparedness and resilience to agencies and project sponsors.[53] Key Federal and state data sharing, GIS, and other information technology tools already in use for agencies and public stakeholders include (1) NEPAnode, a geospatial and document management system made freely available to Federal staff and contractors to implement NEPA and related environmental review and permitting processes;[al] (2) the Information, Planning, and Conservation Tool developed by a partnership between the Fish and Wildlife Service and the U.S. Geological Survey;[am] (3) the Environmental Protection Agency's NEPAssist;[an] (4) the Eastern Interconnection States Planning Council's Energy Zone Mapping Tool;[ao] (5) the Army Corps' Federal Support Toolbox;[ap] (6) the DOE-funded Western Governors' Crucial Habitat Assessment Tool;[aq] (7) the Department of Commerce's National Oceanic and Atmospheric Administration's Social Vulnerability Index;[ar] and (8) Climate.Data.Gov and the Climate

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[ak] The Permit Inventory is a searchable database of required permits and approvals, as well as NEPA reviews and milestones relating to major infrastructure projects. The inventory can be accessed at www.permits.performance.gov/permit-inventory.

[al] This interactive mapping tool contains 278 data sets/layers. It can be accessed at nepanode.anl.gov.

[am] The Information, Planning, and Conservation Tool system is an interactive, Web-based tool illustrating the natural resources for which the Fish and Wildlife Service has trust or regulatory responsibility. The tool allows interested parties to access a public website to determine if there are any Fish and Wildlife Service trust resources, including endangered and threatened species, in a potential project area before beginning the project design. In addition, project sponsors can get information about a species and its needs, as well as measures they can take to help protect and conserve the species when designing and constructing their project. The tool can be accessed at ecos.fws.gov/ipac.0

[an] NEPAssist is a Web-based mapping tool to facilitate efficient and effective environmental reviews and project planning. The tool is part of an initiative developed by the Environmental Protection Agency and selected as a pilot by the Council of Environmental Quality to showcase its potential to modernize and reinvigorate Federal agency implementation of NEPA through innovation, public participation, and transparency. The tool can be accessed at www.epa.gov/compliance/nepa/nepassist-mapping.html.

[ao] The Energy Zone Mapping Tool, funded by DOE, is a free online mapping tool that identifies potential clean energy resource areas within the Eastern Transmission Interconnection. This website provides information about the study, background on the energy resources, and details on the data layers used in the tool. The tool includes 263 GIS data layers and links to policies and regulations, printable maps, and related documents. The tool can be accessed at eispctools.anl.gov.

[ap] The Federal Support Toolbox, launched in May 2013, is a comprehensive "one-stop-shop" online water resources data portal with direct links to valuable data, state-of-the-art models, and tools for utilization in information sharing and collaboration for the water resources community in the United States and internationally. It serves as a single point of entry to comprehensive information about water resources programs, initiatives, legislation, policies, regulations, collaborations, partnerships, databases, tools, models, data, research and development, education, and leadership that is housed on a participating agency's or organization's own server.

[aq] The Western Governors' Crucial Habitat Assessment Tool is an online system of maps that displays crucial wildlife habitat based on commonly agreed upon definitions developed by the Western Governors' Wildlife Council. The tool provides information across 16 Western states and links to five state-level Crucial Habitat Assessment Tools; it will link to new state Crucial Habitat Assessment Tools as they become available. The tool can be accessed at www.westgovchat.org.

[ar] The Social Vulnerability Index measures the social vulnerability of U.S. counties to environmental hazards and the ability of those counties to prepare for, respond to, and recover from hazards. The tool was developed through a partnership with the University of South Carolina and funding via South Carolina Sea Grant and the National Oceanic and Atmospheric Administration's Office for Coastal Management. The tool can be accessed at coast.noaa.gov/digitalcoast/data/sovi.

Resilience Tool Kit.[as] The Desert Renewable Energy Conservation Plan (DRECP), a draft of which was issued in September 2014,[54] employed sophisticated integration of GIS and resource data across four agencies—two Federal agencies (BLM and the Fish and Wildlife Service) and two states—allowing them to plan development and conservation areas in 22.5 million acres in the California desert.[at]

Designating Corridors for Pipelines, Electric Transmission Lines, and Related Infrastructure

Section 368 of the Energy Policy Act of 2005 required the Departments of Interior, Agriculture, Commerce, Defense, and Energy—in consultation with FERC and tribal entities—to work together to designate energy rights-of-way corridors for oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities on Federal lands—first in 11 Western contiguous states (Section 368(a)) and later, if warranted, in the remaining states (Section 368(b)).[au, 55] The Departments of Interior and Agriculture designated more than 6,000 miles of these corridors in 2009 for 11 Western states[56, 57, av] and are currently undertaking a periodic corridor review for the Western states that may lead to revised or new corridor designations.[aw] While their use is voluntary, project developers and relevant Federal agencies have, to varying extents, used portions of the Western energy transport corridors for projects since 2009. Unless funding resources are provided to the Federal agencies to continue this work, it is likely any new corridor decisions will be delayed.

Expanding Landscape and Watershed-Level Mitigation and Conservation Planning

Federal land management agencies can implement mitigation and conservation planning at the landscape, ecosystem, or watershed level to provide environmental, cost, and time-saving benefits to energy infrastructure siting and mitigation.[58, 59] Through proper analysis and application of applicable GIS technologies, potential

[as] Climate.data.gov includes data related to climate change that can help inform America's communities, businesses, and citizens. Initially, users can find data and resources related to coastal flooding, food resilience, and water and ecosystem vulnerability. Over time, users will be able to find additional data and tools relevant to other important climate-related impacts, including risks to energy infrastructure and human health. The site can be accessed at www.data.gov/climate. The U.S. Climate Resilience Toolkit provides scientific tools, information, and expertise to help people manage their climate-related risks and opportunities and improve their resilience to extreme events. The site is designed to serve interested citizens, communities, businesses, resource managers, planners, and policy leaders at all levels of government. The site can be accessed at toolkit.climate.gov/tools.

[at] The DRECP is intended to advance state and Federal conservation goals in the Mojave and Colorado Desert regions of California—an area covering more than 22 million acres of private, local, state, and Federal land—while also facilitating the timely permitting of renewable energy projects and related electric transmission projects under applicable state and Federal laws.

[au] Designation of energy corridor on Federal lands may help expedite the siting, permitting, and review process for projects within the corridors.

[av] For the rest of the United States, which includes 37 Eastern states, Alaska, and Hawaii, a 2008 public request for interest in energy transport corridors showed a relatively indifferent and minor public response, with only one request for a designation, which was subsequently withdrawn. Therefore, the Departments of Energy, Interior, Agriculture, Defense, and Commerce collectively decided at that time not to take actions to designate energy transport corridors in those states. See: Argonne National Laboratory. "Energy Transport Corridors: The Potential Role of Federal Lands in States Identified by the Energy Policy Act of 2005, Section 368(b)." August 2011. eastcorridoreis.anl.gov/documents/docs/Section368bReport.pdf.

[aw] The corridor review is part of a court settlement to a complaint filed in 2009 and pursuant to the June 2013 Transmission Presidential Memorandum. See: Department of the Interior, Bureau of Land Management. "Electric Transmission Facilities & Energy Corridors." www.blm.gov/wo/st/en/prog/energy/transmission.html. Supporting the Western corridor review is a 2014 DOE report that assesses potential energy corridors proposed by the Western Electricity Coordinating Council. See: Department of Energy. "Analysis of Potential Energy Corridors Proposed by the Western Electricity Coordinating Council." March 4, 2014. www.ipd.anl.gov/anlpubs/2014/02/103660.pdf. Pursuant to the 2013 Transmission Presidential Memorandum, DOE issued another report in 2014 for these same states, which looked at current and potential crossings by electricity transmission lines and oil and gas pipelines of the thousands of miles of 20 federally protected national trails. The report gives new baseline information available for use by interested parties to study routing scenarios for new projects that could mitigate impacts on national trails. The report also describes the 2008 work. See: Department of Energy. "Electricity Transmission, Pipelines, and National Trails: An Analysis of Current and Potential Intersections on Federal Lands in the Eastern United States, Alaska, and Hawaii." March 25, 2014. www.ipd.anl.gov/anlpubs/2014/03/104083.pdf.

conflicts in project siting that can create substantial barriers to project completion can be avoided and minimized.[60] Determining compensatory mitigation requirements as an integrated part of project planning can expedite development and increase certainty for interested stakeholders.[61, 62, 63] The preparation of advanced mitigation strategies, which pre-identify potential mitigation measures, can facilitate important collaboration, reduce project costs, and substantially streamline the project review process through minimization of conflicts with other resource values, especially if advanced mitigation actions have taken place and provide credits that can be used to offset future project needs.[64, 65]

Federal land management agencies are implementing such initiatives. For example, in April 2014, Secretary of the Interior Jewell released the Strategy for Improving the Mitigation Practices of the Department of the Interior. Through the implementation of this strategy, the Department will work to advance landscape-scale, science-based management approaches that both encourage infrastructure development and protect natural and cultural resources.[66] DRECP (mentioned above) and the Solar "Regional Mitigation Strategy for the Dry Lake Solar Energy Zone" are two additional examples of ambitious Federal-state landscape-level planning. When completed, DRECP is expected to provide binding, long-term endangered species permit assurances for project development within specified areas, while also reserving 13.7 million acres of the California Desert for conservation.[ax] The Dry Lake Solar Energy Zone, developed pursuant to the Western Solar Programmatic Environmental Impact Statement, is designed to encourage project applicants to invest in conservation opportunities on a landscape scale, thereby maximizing the value of their mitigation dollars.[67]

Another particularly relevant initiative aimed at implementing landscape-scale and watershed-scale approaches nationwide is "Eco-Logical: An Ecosystem Approach to Infrastructure Development."[68] Eco-Logical is the outcome of a partnership among eight Federal agencies[ay] to deliver a step-wise approach to "ecosystem-based mitigation."[az] Since 2008, these agencies have continued to work together and in parallel to realize the vision laid out in Eco-Logical through regular meetings and individual agency programs. Support for landscape-scale and watershed-scale approaches also appears in the 2008 Environmental Protection Agency and Army Corps of Engineers Final Compensatory Mitigation Rule,[69] which formally established a mitigation hierarchy with a strong preference for mitigation banking and in-lieu fee programs for unavoidable impacts to wetlands, streams, and other aquatic resources.

Establishing Regional and State Partnerships and Dedicated Cross-Disciplinary Energy Infrastructure Teams

Federal partnerships with state and regional actors—such as a Transmission Siting Task Force that the Western Governors' Association and its member state siting agencies created, which includes Federal siting agencies on an ex-officio basis[70]—may prove helpful in speeding up the development of infrastructure projects because much of the review and permitting decisions for such projects occurs in regional and field offices of Federal agencies and within and across states.[71, 72] When building capacity or making other energy-infrastructure-related staffing decisions, it is advantageous to establish, wherever practical, joint, single-point-of-contact offices that consolidate agency expertise. Co-location of energy infrastructure environmental review and permitting staff from multiple Federal agencies helps to ensure coordinated, efficient, and expeditious permitting (e.g., in the Departments of Agriculture and the Interior's Service First authority[73] and BLM's Oil

[ax] DRECP is a Natural Community Conservation Plan under California State law and will include one or more Habitat Conservation Plans under the Federal Endangered Species Act.

[ay] BLM, the Federal Highway Administration, the National Oceanic and Atmospheric Administration, the National Park Service, the Army Corps of Engineers, the Environmental Protection Agency, the Fish and Wildlife Service, and the Forest Service.

[az] Eco-Logical encourages Federal, state, tribal, and local partners involved in infrastructure planning, design, review, and construction to use flexibility in regulatory processes. Specifically, Eco-Logical puts forth the conceptual groundwork for integrating plans across agency boundaries and endorses ecosystem-based mitigation, an innovative method of mitigating infrastructure impacts that cannot be avoided. Eco-Logical can be accessed at www.environment.fhwa.dot.gov/ecological/eco_index.asp.

and Gas Pilot Office Program[74]). For example, the regional response teams established by the Administration in 2013—including the Pacific Northwest Regional Infrastructure Team[75] and the Renewable Energy Action Team, a partnership between the Department of the Interior and the State of California that helped permit thousands of megawatts of renewable energy generation projects and related transmission lines[76]—have facilitated state partnerships and collaboration across agencies with different missions.

Facilitating Non-Federal Activity in Support of Siting and Permitting

Partnerships with state and tribal governments, regional planning authorities, and the private sector can improve infrastructure siting and permitting. For example, DOE and the Western Governors' Association partnered in 2014 to launch an online toolkit—the Regulatory and Permitting Information Desktop Toolkit—that collects publicly available information about permits and regulations affecting energy and bulk transmission project development to facilitate communication among project developers; agency personnel at all jurisdictional levels; and project stakeholders, including the public.[77] Elsewhere, the Council of State Governments developed an Interstate Transmission Line Siting Compact with model language for state legislatures to enact a compact for interstate cooperation on electric transmission siting.[78] That compact includes a mechanism through which Federal agencies and tribal governments can participate as equals with states in evaluating proposed electric transmission routes and in the decision-making processes used to determine whether an application is approved, approved with changes, or rejected for cause. More informal than a legal regional compact, regional siting protocols for siting transmission lines were signed in 2002 among the Western Governors' Association and five Federal agencies;[79] protocols were signed again in 2011 among then-member governors of the Midwest Governors Association and Manitoba, Canada.[80] Elsewhere, the New England States Committee on Electricity created in 2011 an Interstate Transmission Siting Collaborative.[81] Fostering additional efforts of this sort may benefit all project proposals and help streamline the siting and permitting process.

QER Recommendations

Siting, permitting, and review of energy-related TS&D infrastructures are critical elements for meeting energy, environmental, and competitiveness goals. Current Administration initiatives are designed to expedite siting; improve communication and engagement among tribal, state and local governments, and the public at large; and modernize tools and processes available to policymakers. To these ends, we recommend the following:

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. Competing demands for agency resources and inadequate support for affected agency staff means that energy infrastructure projects could face delays. 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: While the Federal Government's role in infrastructure siting and permitting is important, many large energy infrastructure projects depend on state and local siting decisions. The Federal Government also has a responsibility to consult with affected Indian Tribes on projects that cross tribal lands or impact traditional cultural properties and certain other historic and cultural resources. Early and meaningful public engagement with affected residential communities, nonprofit organizations,

QER Recommendations (continued)

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.

Establish regional and state partnerships and co-locate dedicated cross-disciplinary energy infrastructure teams: When possible, Federal agencies should co-locate energy infrastructure environmental review and permitting staff from multiple Federal agencies' regional and field offices. An interagency effort should be made to facilitate interagency collaboration and engage the impacted communities.

Expand landscape- and watershed-level mitigation and conservation planning: Given their size and complexity, many major infrastructure projects have impacts on the Nation's landscapes and natural and cultural resources. When adverse impacts 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. In order to produce the greatest environmental benefits, mitigation efforts should be focused on activities where environmental needs and potential environmental contributions are the greatest and in accordance with statutory requirements. 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 ensure coordination across agencies: To implement its Federal permitting and review proposals, the Obama Administration proposed establishing an Interagency Infrastructure Permitting Improvement Center in the Office of the Secretary of Transportation. Congress should authorize and fund the center, as set forth in Section 1009 of the Administration's draft legislation for the Generating Renewal, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities throughout America Act, or GROW AMERICA Act.

Adopt Administration proposals to authorize recovery of costs for review of project applications: While some agencies have legal authority to recover permitting costs from project applicants, others do not possess the authority to do so. In some circumstances, as proposed in the President's Fiscal Year 2016 Budget, additional flexibility for certain agencies to accept funds from applicants would be appropriate and could expedite the Federal permitting and review process.

RECOMMENDATIONS IN BRIEF:
Siting and Permitting of TS&D Infrastructure

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 National Environmental Policy Act 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 the Department of Transportation, as set forth in Section 1009 of the Administration's draft legislation for the Generating Renewal, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities throughout America Act, or GROW AMERICA Act.

Adopt Administration proposals to authorize recovery of costs for review of project applications. Consistent with the proposal in the President's Fiscal Year 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.

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Chapter X

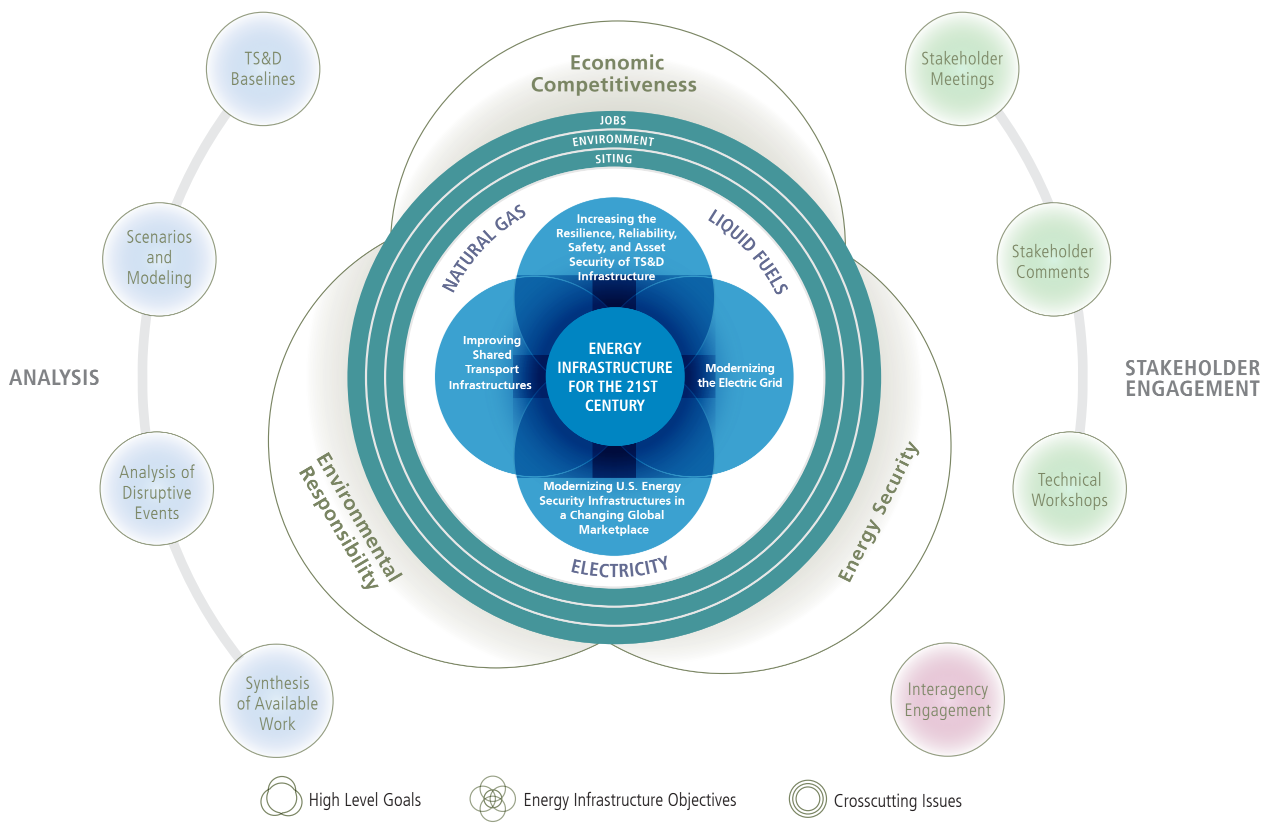
ANALYTICAL AND STAKEHOLDER PROCESS

This chapter describes the analyses and stakeholder engagement that provided the substantive basis for the Quadrennial Energy Review (QER). The first section describes the analytical work carried out for the QER, including baselines, scenarios, and specific analyses underlying some of the key chapters in this report. The second section describes how the QER process engaged a broad range of stakeholders across the Nation in its development, including through technical workshops, 13 formal public stakeholder meetings, and a special series of roundtables on methane emissions from transmission, storage, and distribution (TS&D) infrastructure. This chapter is intended to document the process of developing the QER and contains no recommendations.

QER Systems Analysis

The QER is a policy document based on robust systems/policy analysis and extensive stakeholder and interagency engagement (see Figure 10-1). These connected efforts support the findings and recommendations described in the main QER document, as well as the Natural Gas, Liquid Fuels, and Electricity appendices.

Figure 10-1. Inputs to the QER[1]



This figure shows the analytical, stakeholder, and interagency efforts underpinning the QER.

In the Presidential Memorandum establishing the QER, President Obama directed the QER Task Force to conduct policy analysis and modeling to support QER recommendations and actions. The Department of Energy's (DOE's) Office of Energy Policy and Systems Analysis (EPSA)—serving as secretariat for the QER Task Force—undertook an extensive suite of analyses, focusing on energy TS&D infrastructures. This effort included the following:

- Commissioned analyses from DOE national laboratories, including scenario modeling, synthesis, and white papers.
- Commissioned analyses from energy consulting and analytics firms, including modeling, baselines, and scenarios.
- Internal EPSA analysis—in collaboration with partners across DOE and other Federal agencies—to generate analysis, policy working papers, and public reports.
- Overlapping analysis with stakeholder engagement efforts and technical workshops with associated analytical products.

This chapter lists commissioned analyses used to support QER findings and recommendations. Many of the QER analyses are crosscutting in nature and apply to more than one energy objective or sector. Analyses (some forthcoming) are posted at energy.gov/epsa/qer-document-library.

Crosscutting Scenario Analysis

The QER used scenario analyses to assess the impact of a range of factors on the need for liquid fuels, natural gas, and electricity transmission infrastructure between 2014 and 2030. These scenario analyses do not model any specific Administration policy or projection about energy technology or markets. Rather, the goal was to explore both infrastructure changes and investments that might be required under a range of possible future conditions (in particular, considering options different from those implied under the Energy Information Administration Annual Energy Outlook 2014 Reference case). Factors analyzed included, among others, an economy-wide cap on carbon dioxide emissions driving a 40-percent reduction in 2030, reductions in renewable generation costs, increased natural gas prices, and dramatic expansions of liquefied natural gas export capacity. The individual scenarios are described in Table 10-1 (note that some scenarios—such as the electricity scenarios—were run in combination).[2]

Table 10-1. Table of QER Modeling Scenarios[3]

Scenarios	Model
Base Case: Annual Energy Outlook 2014 Reference Case	
Natural Gas • High domestic gas demand • High world gas supply • High U.S. exports	**Deloitte (MarketPoint)** • Coupled gas infrastructure and electricity market models • Outputs include major pipeline capacity expansions and new pipeline builds
Electricity • Low wind cost • Low solar cost • Low-cost storage • High/low electricity demand • High natural gas prices • 40-percent economy-wide greenhouse gas reduction by 2030 • High penetration of distributed generation (photovoltaic) • High natural gas use • No new transmission	**National Renewable Energy Laboratory (Renewable Energy Deployment System, ReEDS)** • Electricity generation capacity expansion model • Outputs include transmission capacity expansion, generation, electricity costs, etc.
Liquid Fuels • Low/high oil resource • Revisit oil export ban/keep intact • Low oil demand	**Energy Policy Research Foundation, Inc. (Ponderosa Crude Flow Model)** • Pipeline flow and refinery model allocates domestic and foreign crude oil based on refinery demand and margin optimization **Oak Ridge National Laboratory/Jacobs Model** • Detailed refinery modeling (Jacobs) informs simplified refinery, crude distribution model (Oak Ridge)

The QER explored a wide range of natural gas, electricity, and liquid fuels scenarios.

Chapter-Specific Analyses

The QER commissioned multiple studies across TS&D, including the following for specific chapters:

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

- An INTEK study of U.S. regional fuel resiliency based on an extensive analysis of natural gas and liquid infrastructure systems, their specific vulnerabilities to natural threats, and options to increase overall system resiliency.[4]
- A national laboratory team synthesis—including the National Renewable Energy Laboratory, Argonne National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, and Los Alamos National Laboratory—of more than 150 papers on disruptions and resilience of electricity, natural gas, and liquid fuels TS&D infrastructures, identifying vulnerabilities of each to a range of natural threats and hostile actions.[5]
- A RAND Corporation synthesis of resilience metrics, summarizing, categorizing, and analyzing the utilization of 172 metrics related to liquid fuels, natural gas, and electricity infrastructure.[6]
- A Sandia National Laboratories design and initial demonstration of a resilience analysis framework for energy systems that explicitly quantifies uncertainty in threats and disruption outcomes.[7]
- A Sandia National Laboratories modeling of a Marcellus freeze-off scenario in 2015 and 2030 using the Gas Pipeline Competition Model to assess shifts in gas production, storage withdrawals, and flow.[8]
- A BENTEK forecast of natural gas supply, demand, and infrastructure developments through 2030 using an inventory and cell model.[9]

Promoting Reliability and Climate Mitigation through the Electric Grid of the Future

- A Brattle Group report that examined the U.S. baseline electric grid system.[10]
- A Pacific Northwest National Laboratory-led workshop and analytical effort that assessed the system architecture of the electricity grid and provided future views of the architecture in addressing emerging trends, systemic issues, and structural constraints. Throughout the course of the work, two review sessions were held with industry and DOE.[11]
- Multiple white papers on electricity TS&D issues from the national laboratories on renewable integration,[12] efficiency of TS&D,[13] electricity-information technology interdependency,[14] and transmission planning with demand-side resources.[15]
- A DOE report that identified the potential infrastructure needs of the U.S. interstate natural gas pipeline transmission system across a range of future natural gas demand scenarios that drive increased electric power sector natural gas use.[16]

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

- In conjunction with the Strategic Petroleum Reserve program office and analytical support, an Oak Ridge National Laboratory study of the needs associated with the Strategic Petroleum Reserve distribution capacity and life extension.[17]
- An examination of scenarios of liquefied natural gas exports and potential impacts and needs associated with natural gas midstream build-out by two different energy analytic firms—Deloitte and Jensen.[18, 19]

Improving Shared Transport Infrastructures

- An Argonne National Laboratory analysis of coal transport by rail, including a business-as-usual case through 2030, exports, potential congestion, and other issues.[20]

Developing and Managing Energy Infrastructures in an Environmentally Responsible Manner

- A Joint Institute for Strategic Energy Analysis review of Federal and state authorities that affect investment decisions regarding natural gas system modernization (safety, economic regulation, environment, and facility permitting), with a focus on policies that relate to methane emissions, energy efficiency, and safety.[21]
- A Joint Institute for Strategic Energy Analysis synthesis of marginal abatement cost-curve analysis for methane emissions, which involves examining the relative cost effectiveness of different methane abatement strategies throughout the natural gas supply chain.[22]
- A Lawrence Berkeley National Laboratory review of opportunities for efficiency improvements in the U.S. natural gas transmission and distribution system, including recommendations of the major areas for efficiency gains based on the published literature.[23]

Enhancing Employment and Workforce Training

- A National Renewable Energy Laboratory analysis of energy-related transmission and distribution jobs, including comparison of estimates and methodology to other studies.[24]
- A Joint Institute for Strategic Energy Analysis examination of the employment implications of public and private sector investments in safety and methane abatement within natural gas TS&D segments of the supply chain.[25]

No major externally commissioned analyses were conducted for Chapter VI (Integrating North American Energy Markets) or Chapter IX (Siting and Permitting of TS&D Infrastructure).

QER Stakeholder Engagement

In the Presidential Memorandum establishing the QER,[26] President Obama directed the QER Task Force to "gather ideas and advice from state and local governments, tribes, large and small businesses, universities, national laboratories, nongovernmental and labor organizations, consumers, and other stakeholders and interested parties..." The President ordered the Task Force to "develop an integrated outreach strategy that relies on both traditional meetings and the use of information technology."

EPSA, which is serving as the secretariat for the QER Task Force, undertook an open, transparent process for informing stakeholders of the purposes and scope of the first installment of the QER. This stakeholder engagement was accomplished by multiple means throughout the QER development process, including the following activities:

- Informal meetings at DOE headquarters involving hundreds of interested stakeholders.
- Briefings on the QER process at meetings with industry associations; groups of state, local, and tribal officials; the offices of environmental groups; and with Members of Congress, their staffs, and the staffs of multiple relevant congressional committees.
- Speeches and briefings by the Secretary of Energy, the Director of the President's Office of Science and Technology Policy, other White House officials, and various members of DOE leadership to interested groups in Washington, D.C., and across the country.
- A series of informal briefings at DOE headquarters for the Washington, D.C.-based government affairs personnel and consultants of companies across all energy sectors, industry associations, organizations involved in infrastructure development or made up of users of particular infrastructures, environmental groups, organized labor, think tanks, and multi-industry/multi-client consultants—representing the widest possible spectrum of stakeholder interests.
- The creation of a public comments portal (QERcomments@hq.doe.gov) to allow interested stakeholders and the general public to provide comments on individual stakeholder meetings, as well as to allow outside experts to send the QER Task Force studies, reports, and data sets related to topics within the scope of the first installment of the QER.

- Technical workshops on topics relating to the QER where secretariat staff could explore issues in greater depth with technical experts from both inside and outside the government.
- Five methane stakeholder roundtables—convened by Secretary Moniz and with the participation of senior White House staff—to hear from stakeholders in industry, environmental nongovernmental organizations, consumer groups, public utility commissions, labor, and academia about strategies to achieve significant methane reductions from various segments of the natural gas industry.
- A series of formal public stakeholder meetings,[a] beginning in Washington, D.C., in April 2014 and extending through early October 2014 at 13 additional venues around the Nation (see Table 10-2).

Comments Portal and QER Library

From the beginning of the QER process, stakeholders and the general public were encouraged to offer suggestions, comments, insights, and criticisms on issues surrounding the planning, siting, engineering, financing, development, and utilization of infrastructure for TS&D of energy. The secretariat established a Web-based portal for stakeholders to share comments (QERcomments@hq.doe.gov), as well as studies, reports, data sets, and any additional materials stakeholder organizations wanted to get in front of QER Task Force analysts. All comments submitted to the portal are available on EPSA's website at www.energy.gov/epsa/quadrennial-energy-review-qer.

The QER Task Force received more than 300 written comments, many of which included detailed reports and studies on behalf of trade associations, utilities, and energy companies; state and local governments; nonprofit organizations; and other stakeholders (totaling thousands of pages). Each of the comments received was reviewed by secretariat staff and contractors, and insights and recommendations gleaned from these comments and materials have been included in the QER itself. Stakeholder comments fell into three broad categories of concerns and recommendations: how to operate the system safely, fairly, and efficiently; who should be responsible for reliability, security, safety, and flexibility (new investments, standards, enforcement, etc.); and how to allocate costs of resilience measures. Across sectors, stakeholders also expressed a need to better quantify, model, and predict the value of new technologies and services.

Kicking Off the QER: Informal Meetings and Briefings

Secretary of Energy Moniz, Secretartiat staff, and other high-ranking Administration officials met with energy industry representatives, other interested stakeholders, Members of Congress and their staffs, other public officials, and numerous other individuals and groups throughout the QER process to discuss the QER scope, the QER Task Force process, and how organizations and private citizens might involve themselves. The Secretary of Energy and senior DOE staff delivered numerous public presentations on the QER around the country to a variety of audiences, including industry groups, associations of state energy offices, public utility commissioners and other energy regulators, Federal advisory committee members, and various other interested stakeholder groups.

To foster discussion among stakeholders and stimulate interest in the QER in the relatively short time between the publication of the Presidential Memorandum and the beginning of the formal stakeholder events, secretariat staff held a number of informal briefings at DOE headquarters for stakeholders based in Washington, D.C. In these meetings, a representative group of stakeholders—nongovernmental organizations, industry, think tanks, state/municipality organizations, and others—received in-person briefings on the QER process and learned about the multiple ways their organizations could participate. Integral to the process, these briefings allowed secretariat staff to hear (at a very early stage) from interested parties about suggested paths

[a] There were two stakeholder meetings in Providence, Rhode Island, and Hartford, Connecticut, on infrastructure constraints in New England; because the overall topic was the same for both, these meetings are treated as a single meeting for purposes of summaries in this chapter and on the QER meeting website.

of inquiry, to take and answer questions about the scope of the first installment of the QER, to describe the manner in which information would be sought and received, and to discuss substantive concepts and topics that might be considered. These meetings were very helpful to the QER Task Force in its inquiry.

QER Technical Workshops

In developing its plan to engage stakeholders to obtain a comprehensive overview of the Nation's energy TS&D infrastructure, the QER Task Force determined that some important topics were either unique or too technically complex to be given the requisite attention during the course of its formal public meetings. Those meetings were organized around regional or sector-specific themes and intended to tackle broad themes or regional circumstances. To ensure that stakeholders were heard on these important topics, the secretariat assembled subject matter experts from relevant fields for a number of technical workshops, or to participate in previously scheduled workshops organized by DOE programs, to provide the QER expert insights through the intensive analytical approach of these 1-day and 2-day symposia.

Three of the four technical workshops were held in Washington, D.C., to facilitate the participation of experts based at DOE headquarters. The remaining workshop—a follow up to the initial workshop in Washington, D.C.—was held at Long Island's Brookhaven National Laboratory. Each workshop featured a roster of subject matter experts from industry, academia, national laboratories, and other relevant organizations. Participants were told their attendance would be a matter of public record, in accordance with the mandate and desire for transparency in the QER process, and that while notes would be taken and a summary would be published, the public document would not attribute comments to the speaker to allow for a more open discussion.[b]

Following are details about the topics, dates, and locations of the DOE technical workshops held to inform the QER:

Resilience Metrics for Energy Transmission and Distribution Infrastructure, Session 1

April 29, 2014 – Washington, D.C.

Measuring progress toward a more resilient energy system requires metrics that assess planning, operations, and policy changes. QER Task Force analysts found that differing definitions for "resilience" exist, depending on energy system attributes, outcomes, and time scale. Additionally, to date, resilience metrics for energy systems have been unable to quantify resilience benefits. Building on this theme and ongoing work by DOE's Office of Electricity Delivery and Energy Reliability, the secretariat convened two workshops with more than 140 authorities from academia, industry, and government to provide insight on resilience metrics and offer feedback on a framework to generate resilience metrics for infrastructures that transport, transmit, and deliver electric power, natural gas, and oil.

During the initial workshop, participants explored technical research and modeling on resilience metrics, the applicability of existing metrics to energy infrastructure, and areas for further research. Subject matter experts from the American Gas Association, ConEdison, Dominion Electric, and Kinder Morgan presented sector-specific considerations and associated metrics. Workshop findings suggested that industry is currently addressing specific aspects of resilience; however, participants agreed that a comprehensive approach could help to drive policy and planning decisions (e.g., investment priorities) on a larger scale. Industry representatives asked that incorporating resilience metrics into a regulatory framework have minimal impact on reporting requirements.

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[b] The names of each participant in the technical workshops, attendees at the agency's methane roundtables, and panelists at the formal public stakeholder meetings can be accessed on EPSA's website at www.energy.gov/epsa/quadrennial-energy-review-qer.

Resilience Metrics for Energy Transmission and Distribution Infrastructure, Session 2

June 10, 2014 – Upton, New York (Brookhaven National Laboratory)

At a subsequent workshop at Brookhaven National Laboratory, Sandia National Laboratories researchers presented a prototype framework for developing resilience metrics for the electricity, oil, and gas sectors. Workshop participants expressed eagerness to put the resilience framework to use, while stressing significant research and development needs, such as improved quantification of human and societal consequences based on reduced system performance during a disruption. Feedback collected during this workshop helped to refine the resilience metrics framework, and it also informed the QER Task Force analysis and recommendations about the need for resilience metrics and tools.

Collectively, the April 29 and June 10 workshops culminated in the development of a "Conceptual Framework for Developing Resilience Metrics for the Electricity, Oil, and Gas Sectors in the United States." The framework provides a general resilience metric structure and procedures for analyzing, quantifying, and planning for resilience of energy infrastructure systems. The approach under this framework encourages a shift to energy resilience metrics that quantify expected consequences due to low-probability, high-consequence events; relies on the performance of the system rather than its attributes; and incorporates uncertainty. Suggested next steps include testing of the framework at utilities and developing a task force to address the refinement and standardization of energy resilience metrics.

Lessons Learned on Alternative Transportation Refueling Infrastructure: Implications for the QER

June 20, 2014 – Washington, D.C.

The secretariat worked with DOE's Office of Energy Efficiency and Renewable Energy on a technical workshop that examined the trends and long-term policy needs relating to the alternative transportation refueling infrastructure program to produce inputs for the QER. The workshop was held in conjunction with an Office of Energy Efficiency and Renewable Energy merit review meeting to review research, development, and demonstration trends in the transportation sector and contributions made by program grantees.

The goal of the meeting was to leverage the inherent synergies between DOE's research and policy functions and to gather expert input. Specifically, this workshop focused on the current status of deploying alternative transportation refueling infrastructure, as well as on various business models for such infrastructure. The workshop informed analysis of alternative fuel vehicles for the first installment of the QER, and it will provide baseline context and data for the next installment of the QER.

Grid Architecture

August 26 and September 23, 2014 – Washington, D.C.

The purpose of these workshops was to solicit the views of a wide variety of stakeholders to help inform the grid architecture work being performed by Pacific Northwest National Laboratory in support of the QER. This project developed a preliminary reference architecture for identifying and characterizing technical and policy issues that will affect the development of the future grid. The project was coordinated by EPSA with two other DOE offices: the Office of Energy Efficiency and Renewable Energy and the Office of Electricity Delivery and Energy Reliability.

Participants from industry, academia, national laboratories, and other interested stakeholder groups were asked to provide their organizations' views of grid architecture as a system-level model, with analysis of electrical infrastructure, communications and control, industry and regulatory structure, energy sources and related sub-structures, and value accrual frameworks. The workshop informed analysis of alternative fuel TS&D infrastructure for the first installment of the QER, and it will provide baseline context and data for future installments.

Estimating the Benefits and Costs of Distributed Energy Technologies

September 30 – October 1, 2014 – Washington, D.C.

As with the earlier alternative fuel infrastructure workshop, for this valuation workshop, EPSA worked with DOE colleagues to derive value for the QER from a previously planned technical symposium organized by DOE's Grid Tech Team. The Grid Tech Team was initiated in the first term of the Obama Administration as a crosscutting, intraagency organization to better understand the challenges and critical issues arising from the complex, pervasive, and interdependent nature of the electric power system. The Grid Tech Team has worked to foster collaborative discussions with both public and private sector grid stakeholders, as well as to develop an effective network of public-private partnerships to ease the transition to a more modern grid.

The Grid Tech Team planned this workshop to be a technical discussion about distributed energy technologies, to support the development of grid planning tools and models, and to assist states with their regulatory responsibilities as they seek to integrate more distributed electricity assets. Grid Tech Team leaders emphasized that this was part of a multi-year discussion and—specifically—a reconnoitering of the key challenges regarding valuation, including what role DOE and other parts of the Federal Government should perform in the process going forward.

Formal Public Stakeholder Meetings

The QER Task Force's most visible effort to engage stakeholders—and to highlight the various sectoral or regional differences that should be considered in a comprehensive overview of the Nation's energy systems—was the series of 13 public meetings held around the country from April 2014 to October 2014 (see energy.gov/epsa/listings/past-quadrennial-energy-review-qer-meetings). The meetings provided opportunities for energy TS&D infrastructure stakeholders, as well as the general public, to speak directly to members of the QER Task Force and to have their statements and presentations become a permanent part of the QER Library for use by Task Force analysts and later, researchers.

Each meeting began with statements by the hosting administration representatives, along with local, state, and national political leaders who participated at events in their regions. The remainder of the meetings consisted of expert stakeholder panels; panelists made individual presentations and engaged in moderated group discussions on the themes of that day's event. Each meeting concluded with an "open microphone" segment, during which members of the general public could make statements for the QER record and had the opportunity to offer prepared presentations, studies, reports, and more for review by Task Force analysts and inclusion in the QER Library.

Table 10-2. List of QER Formal Public Stakeholder Meetings (with topic, location, and date)[27]

Topic	Location	Date	Administration Chair(s)
Vulnerabilities (cyber, physical, climate, and interdependencies)	Washington, D.C.	4/11/14	Secretary of Energy Ernest Moniz Director of the Office of Science and Technology Policy John Holdren
Infrastructure Constraints—New England	Providence, RI Hartford, CT	4/21/14	Secretary of Energy Ernest Moniz
Petroleum Product Transmission, Storage, and Distribution	New Orleans, LA	5/27/14	Secretary of Energy Ernest Moniz Deputy Secretary of Interior Michael Connor
Water-Energy Nexus	San Francisco, CA	6/19/14	Director of the Office of Science and Technology Policy John Holdren Deputy Secretary of Interior Michael Connor
Electricity Transmission, Storage, and Distribution—West	Portland, OR	7/11/14	Deputy Secretary of Energy Daniel Poneman
Natural Gas Transmission and Distribution	Pittsburgh, PA	7/21/14	Secretary of Energy Ernest Moniz
Gas-Electricity Interdependence	Denver, CO	7/28/14	Deputy Assistant to the President for Energy and Climate Change Dan Utech
Rail, Barge, and Truck Transportation	Chicago, IL	8/8/14	Secretary of Energy Ernest Moniz Secretary of Transportation Anthony Foxx Director of the Office of Science and Technology Policy John Holdren Assistant Secretary of the Army (Civil Works) Jo-Ellen Darcy
Infrastructure Constraints—Bakken	Bismark, ND	8/8/14	Secretary of Energy Ernest Moniz Secretary of Transportation Anthony Foxx Director of the Office of Science and Technology Policy John Holdren Assistant Secretary of Interior for Land and Minerals Management Janice Schneider
State, Local, and Tribal Issues	Santa Fe, NM	8/11/14	Secretary of Energy Ernest Moniz Secretary of Interior Sally Jewell
Infrastructure Siting	Cheyenne, WY	8/21/14	Secretary of Energy Ernest Moniz Assistant Secretary of Interior for Land and Minerals Management Janice Schneider
Electricity Transmission, Storage, and Distribution—East	Trenton, NJ	9/8/14	Secretary of Energy Ernest Moniz
Finance and Market Incentives	New York, NY	10/6/14	Secretary of Energy Ernest Moniz

Federal Register notices announcing each formal public stakeholder meeting were published; these notices were also made available via the EPSA website at www.energy.gov/epsa/office-energy-policy-and-systems-analysis. DOE publicized the meetings by sending advisories to local media; using social media; and emailing state, local, and tribal governments, as well as representatives of energy stakeholders—both in the region of each meeting and in Washington, D.C.

To allow people to participate in the meetings without traveling, all meetings (except for the April meetings in New England) were live streamed. However, the Hartford, Connecticut, meeting was broadcast by Connecticut Public TV. In the interests of transparency and open government, court reporters produced a transcript for each meeting, and the secretariat produced a summary of each meeting's presentations and discussions. The transcripts and summaries, along with links to the live-streamed recordings and panelists' prepared remarks and presentations, are available on the EPSA website at www.energy.gov/epsa/quadrennial-energy-review-qer.

Following are details about the dates, topics, locations, and foci of the formal public stakeholder meetings organized by the secretariat to inform the QER.

Meeting #1: Enhancing Energy Infrastructure Resiliency and Addressing Vulnerabilities

April 11, 2014 – Congressional Visitors Center; Washington, D.C.

Hosted by Secretary of Energy Ernest Moniz; Director of the President's Office of Science and Technology Policy John Holdren; and Representative Henry Waxman (CA-33), Ranking Member on the House Energy and Commerce Committee.

The QER Task Force convened its first public stakeholder meeting to examine the challenges and opportunities resulting from the evolving U.S. energy sector. New domestic sources of energy and the expanded use of renewables have improved America's energy security and economic competitiveness and will help in achieving its environmental goals. However, not all of the changes across the energy marketplace are universally positive. As the energy sector expands and new market entrants emerge, the number and complexity of vulnerabilities threatening energy TS&D infrastructure increase. The QER Task Force asked stakeholder experts at this meeting to discuss the vulnerabilities identified by QER analysts, suggest additional topics for research and analysis, and offer policy prescriptions for consideration in preparation of this first QER installment. The vulnerabilities identified include, but are not limited to, the following:

- Challenges to TS&D infrastructure caused by new markets, changes in energy user demographics, and energy usage patterns
- Aging infrastructure and workforces
- Current and anticipated capacity constraints
- Impacts of climate change
- Threat of cyber attacks and physical attacks on the infrastructures
- Potential for any vulnerability to be exacerbated by the increasing interdependencies of energy systems with water, telecommunications, transportation, and emergency response systems.

Additionally, stakeholder experts were asked to discuss the resilience of energy infrastructure; in particular, the ability to withstand the variable nature of vulnerabilities—like climate-change-driven extreme weather—and the concept of the changing universe of energy supply options as a vulnerability in and of itself. The QER Task Force sought insights about what relevant industries are doing to plan and execute strategies that address these vulnerabilities; how the public and private sectors could work together to responsibly develop necessary new infrastructure; and what will be the appropriate roles and responsibilities of Federal, state, local, and tribal governments in these endeavors out to 2030 and beyond.

Meeting #2: New England Regional Infrastructure Constraints

April 21, 2014

Morning Session – Rhode Island Convention Center; Providence, Rhode Island

Hosted by Secretary of Energy Ernest Moniz; Governor Lincoln Chafee; and U.S. Senator Jack Reed (RI).

Afternoon Session – Connecticut Department of Energy and Environmental Protection; Hartford, Connecticut

Hosted by Secretary of Energy Ernest Moniz; Governor Dannel Malloy; Representative Elizabeth Esty (CT-5); Representative John Larson (CT-1); and Connecticut Department of Energy and Environmental Protection Commissioner Robert Klee.

The second formal public stakeholder meeting consisted of morning and afternoon sessions in separate cities to examine infrastructure constraints for energy TS&D in New England. New Englanders pay high prices for electricity, home heating oil, gasoline, and natural gas, and these prices can be volatile. For instance, the unusually severe winter of 2013-2014 saw extremely high natural gas prices (greater than $120 per million British thermal units compared to normal summer prices of around $5 per million British thermal units). These spikes can be attributed to strong demand, pipeline constraints, wellhead freeze-offs, limited regional liquefied natural gas deliveries, and a lack of storage. Similarly, the regional electricity market suffers from outdated regulatory constructs and business models that do not take full account of the importance of ensuring adequate natural gas and electric transmission.

New England governors, other political leaders, the business community, and residents in all six states are paying close attention to the region's infrastructure. The QER Task Force convened this meeting to hear these stakeholders' concerns, but also to hear about efforts underway to create regional solutions. In Providence, the Task Force heard presentations and panel discussions on two infrastructure topics: (1) needs for heat and power, and (2) how to ensure reliability and affordability of the region's energy systems. In Hartford, the Task Force heard stakeholder experts address two infrastructure topics: (1) gas-electricity interdependence, and (2) current challenges and solutions. A fifth panel made up of representatives from the Governors of Connecticut, Maine, Massachusetts, New Hampshire, and Vermont (the State of Rhode Island had participated in the morning session) discussed regional approaches to infrastructure solutions.

Meeting #3: Petroleum Product Transmission and Distribution

May 27, 2014 – Louisiana State University Health Sciences Center; New Orleans, Louisiana

Hosted by Secretary of Energy Ernest Moniz; Deputy Secretary of the Interior Mike Connor; and U.S. Senator Mary Landrieu (LA), Chair of the Senate Energy and Natural Resources Committee.

The third QER public meeting was convened to give the QER Task Force an appreciation for the regional and nationwide importance of petroleum TS&D infrastructure. Stakeholder experts were asked to discuss the implications of shifting energy flows from the standpoint of their particular organization or sector, as well as the U.S. petroleum industry, and to provide a particular focus on the onshore and offshore regions in the Gulf of Mexico. Additionally, panelists were asked to discuss the need for petroleum storage; interdependencies between various infrastructure energy systems (e.g., pipelines, rail, electricity, and telecommunications); workforce issues; and rapidly evolving challenges to petroleum infrastructure, particularly the degree to which it can be made more resilient in light of increasingly severe weather patterns.

While petroleum TS&D infrastructure was the announced topic, panelists and U.S. Senator Landrieu (LA) also emphasized that the New Orleans area (including the region's rail and marine infrastructure) was important for other industries (in particular, for the natural gas industry) and integral to the movement of other commodities (in particular, coal and agricultural products moving down the Mississippi to both foreign and domestic customers).

Meeting #4: The Water-Energy Nexus

June 19, 2014 – City Hall; San Francisco, California

Hosted by Director of the Office of Science and Technology Policy John Holdren and Deputy Secretary of the Interior Mike Connor.

The fourth QER meeting examined the intrinsic linkages between water and energy. While the first installment of the QER focused on TS&D infrastructure, the San Francisco meeting addressed a broader set of issues that relate to both current and future QER topics, as well as DOE's ongoing work on the water-energy nexus. Water is essential to energy production and electricity generation, and energy is required to extract, convey, and deliver water for these purposes, as well as to treat associated wastewater. Increasingly, the water-energy nexus is on the minds of policymakers and stakeholders: climate change has altered precipitation levels, temperature patterns, and the availability of water; population growth and migration to arid regions intensifies battles over water rights; and new technologies have been introduced and are shifting or increasing water and energy demand. Finally, governments and private sector stakeholders are trying to come to terms with the increasing interdependence in light of the fact that, though closely linked, energy and water systems historically have been developed, managed, and regulated independently at the local, state, national, and international levels.

The QER Task Force heard from two expert panels on the increasing urgency to act on the water-energy nexus, as well as how state, local, tribal, and international governments can work together to integrate water and energy infrastructure development, management, and regulation, including identifying opportunities to improve efficiency, conservation, and infrastructure resilience.

In conjunction with the San Francisco meeting, DOE released an associated report, "The Water-Energy Nexus: Challenges and Opportunities."[28]

Meeting #5: Electricity Transmission, Storage, and Distribution—West

July 11, 2014 – Lewis & Clark College; Portland, Oregon

Hosted by Deputy Secretary of Energy Daniel Poneman.

The fifth QER public stakeholder meeting addressed electricity transmission and distribution issues from a Western U.S. perspective. Panelists were asked to respond to a set of framing questions. For the first panel on transmission, panelists delivered presentations and opined on the broad question, "Can we build and operate the appropriate amount of TS&D for future needs?" Panelists discussed how to maintain reliability with a changing generation and end-use resource mix; the planning, cost-allocation, and state and Federal siting processes needed to build new transmission; and when to build new versus upgrading existing transmission. For the second panel on electricity distribution, experts were asked to react to the question, "How do we cope with new distribution challenges and opportunities?" The second panel considered a broad array of emerging technologies on the distribution grid, as well as greater customer engagement and other factors providing both technical and policy challenges to the delivery of energy services to customers.

Portland's final panel focused on whether electricity storage was finally coming of age. As part of this discussion, panelists were asked whether changing needs and improving technologies might finally make wide-scale storage a reality for the transmission and distribution grid.

Meeting #6: Natural Gas: Transmission, Storage, and Distribution

July 21, 2014 – Carnegie Mellon University; Pittsburgh, Pennsylvania

Hosted by Secretary of Energy Ernest Moniz and Representative Tim Murphy (PA-18), Chair of the Investigations and Oversight Subcommittee of the House Energy and Commerce Committee.

The sixth QER stakeholder meeting focused on natural gas infrastructure. While national in scope, the Pittsburgh meeting featured a number of expert speakers who addressed natural gas development in the Marcellus and nearby Utica shale formations. The shale gas boom has created questions about how our existing infrastructure is adapting to serve a newfound abundance in supply, as well as the need for additional infrastructure—both to maximize resource utilization and to create localized and sustainable economic development for newly producing regions.

While the American economy continues to adapt to the abundance of accessible shale and the resulting low natural gas prices, decreased carbon emissions, lower imports, and enhanced industrial competitiveness, the QER Task Force sought stakeholder insights on the effects of the shale revolution that are already being seen, what we as a Nation should focus on in terms of infrastructure and policy development to harness these resources for the regional and national economies, and how to balance the challenges and opportunities arising from the shale boom.

Meeting #7: Gas-Electricity Interdependencies

July 28, 2014 – University of Denver; Denver, Colorado

Hosted by Deputy Assistant to the President for Energy and Climate Change Dan Utech and Colorado Public Utilities Commission Commissioner Pamela Patton.

The seventh formal QER public stakeholder meeting was convened to demonstrate how the increasing demand for natural gas (in the power sector and in the economy) and the increased share of the electricity generation mix represented by natural gas have heightened the interdependence between the electricity and natural gas transmission systems. The meeting also highlighted how the importance of careful and coordinated planning and development of infrastructure for both systems is increasingly imperative. While the electricity and natural gas pipeline industries have operated together for decades, the two systems' growing interdependence has created more frequent reliability challenges in recent years. To help craft policy recommendations to avoid a future of uncertain and periodically curtailed electricity services—especially during periods of extreme temperatures—or other gas disruptions that could adversely affect human health or the economy, the QER Task Force asked stakeholder experts to address the following issues in their presentations and moderated group discussions: (1) industry and government efforts to improve coordination between the gas and electricity sectors, and (2) how the gas and electricity sectors can reconcile differing planning, financing, and construction processes to improve infrastructure development, operation, and end use, and generally reduce the risks of increased interdependence out to 2030 and beyond.

Meeting #8: Rail, Barge, and Truck Transportation

August 8, 2014 – University of Illinois at Chicago; Chicago, Illinois

Hosted by Secretary of Energy Ernest Moniz; Secretary of Transportation Anthony Foxx; Director of the Office of Science and Technology Policy John Holdren; Assistant Secretary of the Army (Civil Works) Jo-Ellen Darcy; and Mayor Rahm Emanuel.

The eighth public meeting considered the effects of the last decade's energy boom on our Nation's shared transportation infrastructure—how the Nation's rail network, highways, and the various vessels and infrastructures that make up our inland waterway, Great Lakes, and coastal maritime trade have adapted to increased commerce in crude oil and refined petroleum products, coal, ethanol, and other biobased and alternative fuels and natural gas liquids. The Chicago meeting sought to shed light on how the transformation of our domestic energy sector has created new issues for the "rail," "truck," and "barge" infrastructures; how it has exacerbated old problems; and how moving new and more energy products in a safe and efficient manner on these shared infrastructures has challenged policymakers and infrastructure planners.

The QER Task Force sought to gain a better understanding of the complexities of the interrelated systems, as well as the opportunities and challenges inherent in changes—some planned, some not—coming to these infrastructures. Industries across multiple sectors are adjusting to new or vastly increased movements of energy products by multiple modes, and the goal of the Chicago meeting was to provide QER Task Force analysts and agency leadership with an opportunity to hear how things are functioning and how they might be improved.

Meeting #9: Infrastructure Constraints—Bakken

August 8, 2014 – Bismarck State College; Bismarck, North Dakota

Hosted by Secretary of Energy Ernest Moniz; Secretary of Transportation Anthony Foxx; Director of the Office of Science and Technology Policy John Holdren; Assistant Secretary of the Interior for Land and Minerals Management Janice Schneider; Governor Jack Dalrymple; U.S. Senator John Hoeven (ND); U.S. Senator Heidi Heitkamp (ND); and Representative Kevin Cramer (ND-AL).

The ninth public meeting (and the second on August 8) examined the dramatic changes to the U.S. energy profile that resulted from the development of the fossil fuel resources of the Bakken formation, as well as the infrastructure constraints created or exacerbated by the Bakken boom. Due to Administration principals flying into North Dakota for this meeting from a morning QER meeting in Chicago, the format of the Bismarck meeting was slightly different than the rest in the series. The meeting opened with a panel on workforce development issues, which were introduced by U.S. Senator Heitkamp (ND). The QER Task Force heard from representatives of state and tribal colleges, state and local government officials, and other experts on how to address the shortage of workers and housing in the region.

After the workforce panel, state, Congressional, and Administration officials made remarks and took questions from the audience. The next two panels focused on Bakken infrastructure constraints and solutions and sought stakeholder input on changing infrastructure needs. During the meeting, panelists discussed shipping oil by rail, developing oil and gas pipelines, building electricity transmission for wind energy and conventional energy, reducing gas flaring, managing infrastructure siting and permitting issues, and extending the Highway Trust Fund.

Meeting #10: State, Local, and Tribal Issues

August 11, 2014 – New Mexico State Personnel Office; Santa Fe, New Mexico

Hosted by Secretary of Energy Ernest Moniz; Secretary of the Interior Sally Jewell; and U.S. Senator Martin Heinrich (NM).

The 10th formal QER public stakeholder meeting addressed the challenges of the changing energy marketplace for the state, local, and tribal authorities responsible for regulating energy infrastructure and maintaining the appropriate balance among pursuing economic goals; addressing system vulnerabilities; and maintaining a secure, affordable, reliable, and environmentally responsible energy system. The Santa Fe meeting sought insights from state, local, and tribal governments on a variety of topics, including the multi-jurisdictional nature of many of the regulatory and other responsibilities regarding energy TS&D infrastructure, particularly in the electricity and oil and gas sectors.

During this meeting, state policymakers, public utility commissioners, agency heads, tribal leaders, and city and county officials described new jurisdictional, regulatory, and coordination models that could enhance the Nation's energy infrastructure and allow them to adapt to changing needs. Importantly, they also explored the broader policy implications of this transition, including infrastructure's ability to withstand increasing threats; developing the workforce and training needed to build, operate, and upgrade infrastructure; designing affordable rate structures to pay for infrastructure; and addressing environmental quality concerns.

Meeting #11: Infrastructure Siting

August 21, 2014 – Little America Hotel; Cheyenne, Wyoming

Hosted by Secretary of Energy Ernest Moniz; Assistant Secretary of Interior for Land and Minerals Management Janice Schneider; and Governor Matt Mead (WY).

The 11th formal QER public stakeholder meeting focused on infrastructure siting. State government officials, infrastructure developers, representatives of utilities and the oil and gas industry, community leaders, environmentalists, and other stakeholders were given the opportunity to inform the QER Task Force on ways to improve the planning and siting processes for building new energy TS&D infrastructure. Three expert panels (on electricity transmission, oil and natural gas infrastructure, and data needs) highlighted key lessons learned in siting and planning new TS&D infrastructure that can be applied to national policy determinations, or exposed problems that might be mitigated by research and development initiatives.

As with each of the other public stakeholder meetings, the general public was provided with an opportunity to make comments at the conclusion of the expert panels. The Cheyenne meeting was the only one in the series during which no public comments were offered.

Meeting #12: Electricity Transmission and Distribution—East

September 8, 2014 – New Jersey Institute of Technology; Newark, New Jersey

Hosted by Secretary of Energy Ernest Moniz.

The 12th public stakeholder meeting sought expert insights on the same two topics covered at the July 11 Portland, Oregon, meeting (electricity transmission and electricity distribution), but from an eastern U.S. perspective. The Newark meeting also featured a panel on business models and regulation of regulated electric utilities. Stakeholder experts were asked to respond to the same questions asked in Portland: (1) Can we build and operate the appropriate amount for future needs?; and (2) How do we cope with new challenges and opportunities in distribution? The first panel emphasized reliability amid changing conditions, siting and other planning challenges, cost allocation, changing load growth, resource diversity, and cost-benefit analyses of new construction versus existing asset optimization. The second panel focused on technical and policy options created by emerging technologies.

The last panel on business models and regulation for regulated electric utilities had, as its context, the following trends: declining sales or low load growth for many utilities; increasing self-generation by some customers; and, despite this phenomenon, increasing spending to maintain and continue updating electricity transmission and distribution. Taken together, these factors had some panelists calling into question whether current business models and regulation for regulated electric utilities are still appropriate or if they need to evolve.

Meeting #13: Energy Infrastructure Finance

October 6, 2014 – New York University; New York, New York

Hosted by Secretary of Energy Ernest Moniz and Representative Carolyn Maloney (NY-12), Ranking House Member on the Joint Economic Committee and Ranking Member on the Subcommittee on Capital Markets and Government Sponsored Enterprises of the House Financial Services Committee.

The last public meeting for this installment of the QER focused broadly on the financing of energy TS&D infrastructure. The dramatic transformation of the U.S. energy sector has produced a variety of benefits, but also has resulted in a number of challenges and uncertainties. These uncertainties include how the financial industry should react when traditional signals from the energy sector—historical flow patterns, as well as assumptions of supply scarcity and demand growth—have been upended by an unprecedented period of technological advancement and adaptation. With the energy landscape seeming to change before the eyes of investors, and with the risk calculations traditionally used by the banking industry not necessarily being relevant any longer, the 13th QER public meeting examined how players in infrastructure finance were meeting the challenge of these new realities to support the development of new and expanded pipeline networks, transmission and distribution assets, storage facilities, and other infrastructure.

Financial experts in three sectors (capital acquisition, electricity, and oil and natural gas) explored the following: how to minimize the cost of capital/maximize the availability of capital in a new energy economy; the potential for stranded investments or underinvestment in assets in fast-moving market conditions; balancing regulatory costs with the need for regulation as an incentive for desired infrastructure development; how to improve cost-benefit analyses and broader dissemination of best practices; and how to evaluate the financial risk of new, unproven technologies and processes.

Methane Stakeholder Roundtables

Secretary of Energy Ernest Moniz hosted five stakeholder roundtables with government, industry, environmental, labor, and academic leaders involved in the natural gas sector to identify and highlight best practices, technology solutions, and policies for securing reductions in methane emissions from its midstream and downstream segments. The roundtable sessions allowed experts to provide input into the Administration's Strategy to Reduce Methane Emissions;[c] discussions and information shared by stakeholders also proved very informative for the QER.

The primary goal of these roundtables was to catalyze action to reduce methane emissions from distribution, transmission, storage, and processing segments of natural gas systems. Roundtable participants were invited based on their expertise in methane emissions abatement.

[c] See: The White House Blog. "A Strategy to Cut Methane Emissions." March 28, 2014. www.whitehouse.gov/blog/2014/03/28/strategy-cut-methane-emissions.

Additional goals of the methane roundtables included the following: (1) promoting a common understanding of the scale of methane emissions from natural gas systems and related abatement opportunities, (2) catalyzing greater action and engagement by policymakers at all levels of government, and (3) encouraging visible leadership and demonstrated commitments to a common vision that embraces the need to reduce methane emissions from natural gas systems. After review and consideration of stakeholder input, Secretary Moniz joined stakeholder participants at the White House in announcing several new initiatives to help advance the goals of the Administration's broader Strategy to Reduce Methane Emissions.

Following are details about the dates, topics, locations, and foci of the methane stakeholder roundtables held by DOE to inform the QER.

Kickoff Roundtable

March 19, 2014 – DOE Headquarters; Washington, D.C.

The initial meeting of the methane stakeholder roundtable series included participants from industry, state government, academia, nongovernmental organizations, and labor organizations. Participants expressed a common interest in repairing natural gas infrastructure to improve safety, create jobs, and reduce greenhouse gas emissions. There are significant remaining opportunities to reduce methane emissions from all segments of the natural gas supply chain; however, industry representatives noted that their companies have been focused on repairing leaks, replacing leak-prone pipelines, and conducting preventative maintenance for many years. The primary barrier to natural gas infrastructure modernization is getting cost recovery for the capital-intensive investments. While most states have trackers or surcharges on consumer bills to facilitate cost recovery for pipeline replacement efforts by local distribution companies, there is no equivalent mechanism for interstate pipeline networks that are regulated by the Federal Energy Regulatory Commission. Stakeholders suggested that there are still opportunities for DOE to help facilitate industry efforts (e.g., by supporting the development of new and lower-cost technologies to enable the broader use of leak detection and repair and by coordinating research efforts across government agencies and with stakeholders).

Participants shared many examples of successful infrastructure modernization programs and best practices. For example, Arkansas recently completed its statewide replacement of cast iron pipe. Arkansas policy has succeeded in part because companies can immediately recover costs with a line item on consumer bills, meaning that utilities do not have to wait for a new rate case. Georgia, Ohio, and Oklahoma are also making big strides, in part by enabling immediate cost recovery for infrastructure investments.

Labor Unions and the Manufacturing Sector

April 24, 2014 – DOE Headquarters; Washington, D.C.

Participants at the second methane stakeholder roundtable reiterated the shared interest in infrastructure modernization to increase the reliability of the natural gas system, create jobs for skilled workers, and reduce greenhouse gas emissions. Often, local distribution companies are willing to make upgrades if funding is available. Securing funding for infrastructure modernization can be challenging, but some state policies—such as the Strategic Infrastructure Development and Enhancement Program in Maryland—have made it easier for local distribution companies to acquire funding for infrastructure projects. However, even if funding is made available, a project-by-project approach to regulatory approval can still be a barrier to achieving widespread improvements and coordination in infrastructure repair and modernization.

A comprehensive strategy for infrastructure modernization can create jobs for skilled workers. Skilled union workers, in particular, could help companies repair pipelines to high-quality standards, avoiding repeated short-term repairs that result from poor construction. The current workforce with the skills to replace pipelines is nearing retirement, and unions can help provide worker training programs to prepare younger workers for these jobs. Job creation and training should be considered part of the investment in the asset base of natural gas infrastructure.

Academia, Nongovernmental Organizations, and Environmental Groups

May 20, 2014 – DOE Headquarters; Washington, D.C.

During the third methane roundtable session, participants discussed the research needed to improve methane sensing, reform state and Federal policies, and remove barriers to investments in infrastructure that is safer and lower emitting. One of the resounding themes of the discussion was the need for a more comprehensive system for calculating emissions and transparently providing the necessary data in an improved inventory. Although data for specific systems and locations has been calculated, there is not a complete picture of emissions from TS&D of the supply chain. There is a shared belief that sensor technology should be improved to accurately collect emissions data and that it would potentially require more funding for such improvements.

In addition, participants deliberated over which incentives need to be implemented to reduce methane emissions. Environmental groups expressed strong support for the Environmental Protection Agency taking steps to propose and finalize methane emissions performance standards for new and existing facilities across the natural gas supply chain. It was suggested that the costs of investments in infrastructure modernization should be borne more by shareholders instead of having the consumer pay out-of-pocket for all of the necessary repairs. Another theme was to amend state and Federal economic regulatory frameworks to reduce the economic disincentives to become safer and possibly encourage more investment in infrastructure. Finally, participants explored various ways for Federal and state economic regulators to treat lost- and unaccounted-for gas, which is a catch-all accounting mechanism used to reflect meter errors, theft, leakage, and other factors. Others pointed out that lost- and unaccounted-for gas is a poor metric for leakage. Participants suggested research and development to lower the cost of more accurate meters and limit the amount of lost- and unaccounted-for gas that companies are allowed to recover through rates (as some states have adopted).

Natural Gas Companies

June 11, 2014 – DOE Headquarters; Washington, D.C.

During the fourth methane roundtable session, participants discussed progress that the natural gas industry has made to reduce methane emissions and remaining barriers to emissions reductions. Companies have taken innovative approaches to reduce methane emissions and further their pipeline safety efforts, including the development of partnerships with government agencies, academic institutions, and industry to reduce emissions through programs such as the Environmental Protection Agency's Natural Gas STAR program and private sector efforts like the Downstream Initiative and the OneFuture Coalition. Some companies have undertaken in-house initiatives to reduce emissions using self-assessment of performance metrics. However, participants emphasized several barriers to accelerating investment in infrastructure. More cooperation within the natural gas industry and stronger relationships between state regulators and operators could help speed infrastructure modernization. Greater coordination between government agencies could allow for natural gas infrastructure improvements in conjunction with other public works projects (i.e., in conjunction with water and telecommunications infrastructure upgrades). Participants suggested implementing public education programs and sharing best practices between companies and regulators.

Participants also voiced concern over the lack of funding for researching and developing technologies that could facilitate infrastructure modernization. These technologies include less expensive and more accurate leak-detection equipment, innovative methods or materials that could reduce the cost of pipeline replacement, and data collection systems to monitor the entire natural gas supply chain.

Capstone Roundtable

July 29, 2014 – The White House; Washington, D.C.

The capstone roundtable included industry, labor, state regulators, and environmental and consumer groups that have been actively engaged in a range of efforts to modernize natural gas infrastructure and reduce leakage from transmission and distribution segments of natural gas systems. The focus of the roundtables was on reducing emissions from natural gas transmission and distribution systems. This meeting was the culmination of in-depth discussions with industry, unions, consumer and environmental groups, state regulators, and academics at the four previous roundtables. This series provided the opportunity for experts to provide input into the Administration's strategy. This complements efforts underway at the Environmental Protection Agency and served as one means to inform the interagency methane strategy and QER.

At this meeting, Secretary Moniz announced a number of actions that DOE will take to address methane emissions from natural gas systems. Participating stakeholders also announced several new initiatives, including significant new investments in infrastructure. While natural gas companies have made significant progress in reducing methane emissions, many expressed strong commitments to play leadership roles and do more to modernize infrastructure to help realize the safety, economic, environmental, and health benefits that natural gas provides to customers. A group of five labor unions announced an expansion of apprenticeship and training programs, while the Interstate Natural Gas Association of America committed to developing guidelines for directed inspection and maintenance at natural gas transmission facilities. A more detailed description of actions can be found on DOE's website at www.energy.gov/articles/factsheet-initiative-help-modernize-natural-gas-transmission-and-distribution.

QER Interagency Engagement

In the QER Presidential Memorandum, the President established the QER Interagency Task Force, which is co-chaired by the Director of the Office of Science and Technology Policy and the Director of the Domestic Policy Council and more than 20 executive departments and agencies[d] that play key roles in developing and implementing policies governing energy resources and consumption, as well as associated environmental impacts. The President directed the Task Force to develop a comprehensive and integrated review of energy policy resulting from interagency dialogue and active engagement of external stakeholders, as well as offer recommendations on what additional actions it believes would be appropriate. As set forth above, the final QER was developed by the Task Force in response to the President's direction. The findings and recommendations are based on Task Force deliberations, meetings with staff-level agency representatives and experts, and information provided to the secretariat and Task Force members by external stakeholders.

Since issuance of the Presidential Memorandum, the White House (supported by DOE, serving as executive secretariat of the Task Force) convened regular meetings of the Task Force and worked closely with the agencies' leadership and staff on the QER. Member agencies have collaborated with the Task Force to develop the QER by providing information on topics within their statutory and regulatory jurisdiction, or areas of particular expertise related to energy infrastructure TS&D. Agencies have delivered studies, data, and other

[d] The members of the Task Force include: (1) the Department of State; (2) the Department of the Treasury; (3) the Department of Defense; (4) the Department of the Interior; (5) the Department of Agriculture; (6) the Department of Commerce; (7) the Department of Labor; (8) the Department of Health and Human Services; (9) the Department of Housing and Urban Development; (10) the Department of Transportation; (11) the Department of Energy; (12) the Department of Veterans Affairs; (13) the Department of Homeland Security; (14) the Office of Management and Budget; (15) the National Economic Council; (16) the National Security Staff; (17) the Council on Environmental Quality; (18) the Council of Economic Advisers; (19) the Environmental Protection Agency; (20) the Small Business Administration; (21) the Army Corps of Engineers; (22) the National Science Foundation; and (23) such agencies and offices as the President may designate.

information to the Task Force for consideration in policy analysis and modeling; reviewed analysis and findings; leveraged the work of other relevant Administration initiatives;[e] and, led by the Office of Science and Technology Policy and Domestic Policy Council, collaboratively developed policy recommendations.

Task Force members also partnered with the secretariat on a series of 13 formal public stakeholder meetings, scheduled at venues around the country from April 2014 to October 2014, with themes of a regional, sector-specific, or stakeholder-group-specific nature. At each of the meetings, Administration representatives, including Cabinet secretaries, senior White House personnel, and other senior officials, often joined by Members of Congress, governors, or mayors, opened the events and set the focus for the expert panels that followed.

[e] The Task Force leveraged the work of related initiatives, including, among others, the Interagency Climate Change Adaptation Task Force, the Task Force on Climate Preparedness and Resilience, the Build America Infrastructure Initiative Working Group, the Interagency Methane Strategy, the Federal Interagency Floodplain Management Task Force, the Hurricane Sandy Building Task Force, the Arctic Council, the Mitigation Framework Leadership Group, the Committee on the Marine Transportation System, the Interagency Steering Committee on Federal Infrastructure Permitting and Review Process Improvement, the Rapid Response Team for Transmission, and the Unified Federal Environmental and Historic Preservation Review.

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LIST OF ACRONYMS AND UNITS

APE – Area of Potential Effect

ASSETS – Actions to Support Shared Energy Transport Systems

Bcf/d – billion cubic feet per day

BLM – Bureau of Land Management

BLS – Bureau of Labor Statistics

CCRIF – Caribbean Catastrophe Risk Insurance Facility

CEM – Clean Energy Ministerial

CESI – Caribbean Energy Security Initiative

CMAQ – Congestion Management and Air Quality

CO_2 – carbon dioxide

CO_2-EOR – carbon dioxide enhanced oil recovery

DHS – Department of Homeland Security

DOE – Department of Energy

DOT – Department of Transportation

DRECP – Desert Renewable Energy Conservation Plan

EIA – Energy Information Administration

EPA – Environmental Protection Agency

EPCA – Energy Policy and Conservation Act

EPSA – Office of Energy Policy and Systems Analysis

ERCOT – Electric Reliability Council of Texas

FERC – Federal Energy Regulatory Commission

FY – Fiscal Year

GHG – greenhouse gas

GHGI – Greenhouse Gas Inventory

GIS – geographic information system

GROW AMERICA Act – Generating Renewal, Opportunity, and Work with Accelerated Mobility, Efficiency, and Rebuilding of Infrastructure and Communities throughout America Act

GWP – Global Warming Potential

IEEE – Institute of Electrical and Electronics Engineers

kV - kilovolt

LNG – liquefied natural gas

LPTs – large power transformers

Million bbl/d – million barrels per day

Mm/yr – millimeters per year

MOU – memorandum of understanding

MTS – Marine Transportation System

MW – megawatt

NEHHOR – Northeast Home Heating Oil Reserve

NEPA – National Environmental Policy Act

NGL – natural gas liquids

NOAA – National Oceanic and Atmospheric Administration

PADD – Petroleum Administration for Defense District

PEV – plug-in electric vehicle

PHMSA – Pipeline and Hazardous Materials Safety Administration

$PM_{2.5}$ – fine particulate matter

PV – photovoltaic

QER – Quadrennial Energy Review

QTR – Quadrennial Technology Review

R&D – research and development

RDD&D – research, development, demonstration, and deployment

RPPRs– regional petroleum product reserves

SPR – Strategic Petroleum Reserve

STB – Surface Transportation Board

TIGER – Transportation Investment Generating Economic Recovery

TS&D – transmission, storage, and distribution

USACE – Army Corps of Engineers

USFS – Forest Service

VOCs – volatile organic compounds