U.S. Department of Energy
Washington, DC 20585

Date: **May 21, 2014**

To: **Members of the Public**

From: **Quadrennial Energy Review Task Force Secretariat and Energy Policy and Systems Analysis Staff, United States Department of Energy**

Re: **Petroleum Transmission, Storage, and Distribution (TS&D) Infrastructure**

1. Introduction

On January 9, 2014, President Obama issued a Presidential Memorandum establishing a Quadrennial Energy Review. The Secretary of Energy was directed to provide support to the Quadrennial Energy Review Task Force (QER Task Force), including coordination of activities related to the preparation of the QER report, policy analysis and modeling, and stakeholder engagement.

On May 27, 2014, the U.S. Department of Energy (DOE), acting in its capacity as the Secretariat for the QER Task Force, will convene a public meeting to examine Petroleum Product Transmission, Storage and Distribution. The meeting will commence at 9:00 am at the following address:

Louisiana State University Health Sciences Center New Orleans
Lecture Room, Medical Education Building
1901 Perdido Street
New Orleans, Louisiana 70112

The New Orleans meeting will be the third in a series of regionally and topically focused meetings held in areas around the country examining issues related to petroleum transmission, storage, and distribution (TS&D) infrastructure. The May 27 meeting will consider the implications of shifting energy flows for the U.S. petroleum industry, with a particular focus on the on- and offshore regions surrounding the Gulf of Mexico. The meeting will involve three panels of experts making statements and participating in facilitated discussion. Some of the discrete topics to be covered include petroleum storage (especially the Strategic Petroleum Reserve), interdependencies between and within various infrastructure energy systems (e.g., pipelines, rail, electricity, and telecommunications), workforce issues (e.g., bimodal age distribution of the U.S. energy workforce), and rapidly evolving challenges such as resilience to increasingly severe weather patterns. There will be an opportunity for additional stakeholders to give three-minute statements via an open microphone session following the panels (please see the meeting agenda for further details). Comments may also be submitted to QERcomments@hq.doe.gov.

PLEASE NOTE: The first installment of the QER will examine mid-stream transmission, storage, and distribution infrastructure; it will not at this time consider CO_2 pipelines or enhanced oil recovery (EOR). These topics will be covered in the next installment of the QER, to be conducted in 2015, which will examine energy supply and demand infrastructure. For the current installment of the QER, DOE will also convene meetings focused on natural gas TS&D infrastructure; infrastructure constraints in the Bakken; natural gas–electricity interdependence; rail, barge, and truck transportation; infrastructure siting; and propane distribution and North American TS&D. Therefore, key questions for the May 27 meeting as outlined at the end of this memo will not cover these topics.

2. Background

In the past decade, the United States has undergone a profound shift in its energy landscape as domestic production of shale gas and tight oil has skyrocketed. Domestic crude production is at its highest level in decades, and the country is now a net exporter of petroleum products.[1]

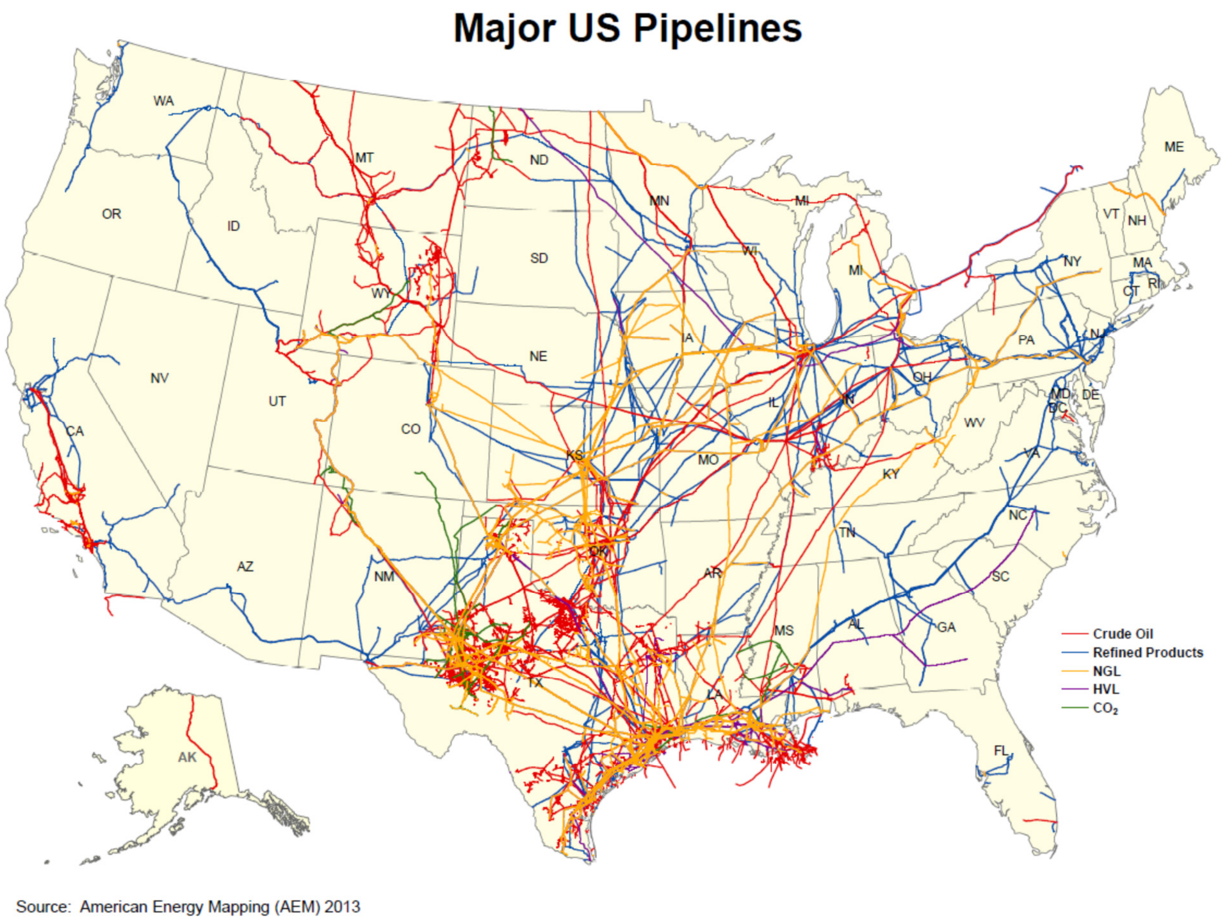

Figure 1. Major US pipelines.

The U.S. petroleum transport complex (Figure 1) represents well over a century of technology and investment, and it continues to grow and adapt to new supply regions. Today, the United States is witnessing another geographic shift: advanced technologies have enabled significantly increased recovery rates in many existing oil- and gas-producing regions, and entirely new areas of production have emerged in the far north (e.g., Canada's Athabasca oil sands and North Dakota's Bakken formation) and in America's Northeast (e.g., the Marcellus and Utica formations). Through the past century, the United States' center of gravity for incremental petroleum production has shifted westward from Pennsylvania

[1] http://www.eia.gov/todayinenergy/detail.cfm?id=5290

toward Ohio, then the Gulf Coast (Alabama, Arkansas, Louisiana, Mississippi, and Texas), California, and eventually Alaska. Significant infrastructure investments have been necessary to transport this oil from production regions that were frequently far from the industrial and population centers where oil is processed and consumed.

The rapid pace of change in U.S. oil supply has, in some cases, outstripped the response in the enabling infrastructure. This is most evident in the Bakken, where limited pipeline takeaway capacity has allowed rail to emerge as the primary mode of petroleum transportation, and in the Gulf Coast region, where crude imports by ship to U.S refineries are increasingly being replaced by domestic and Canadian crude coming south by pipe and rail, often necessitating pipeline reversals. The shift in supply regions has also required reconfiguration of refineries to deal with the different chemical properties of new crude supplies.

Annual investments in oil and gas TS&D infrastructure increased 60 percent in just the three years between 2010 and 2013, from $56.3 billion to $89.6 billion, as the industry responded to the new energy landscape of increasing North American production and declining imports.[2] By 2025, the industry is expected to invest $890 billion in new infrastructure, with more than half this expected to go to crude oil and natural gas gathering systems and direct production support facilities.[3]

These changes have significant policy implications for the U.S. economy, oil and oil product consumers, and global oil markets. Matching mid-stream infrastructure to new supplies and processing facilities, and moving these products to demand centers is essential for providing consumers with affordable, reliable and secure energy supplies. In this regard, it is important to assess these infrastructures' vulnerabilities to a range of potential and growing threats and disruptions. The QER will identify areas where federal action is needed and make policy recommendations that ensure the U.S. petroleum infrastructure continues to meet the economic, security, and environmental needs of the nation\.

3. Moving Crude and Refined Product

The United States is home to the largest network of oil and gas pipelines and most sophisticated refineries in the world. Pipelines are the overwhelmingly dominant mode for petroleum transport in the United States, shipping approximately 71 percent of America's crude oil and petroleum products, and a much higher percentage of crude alone.[4] There are more than 180,000 miles of liquid petroleum pipelines in the United States,[5] delivering over 14 billion barrels annually of crude oil, petroleum products, and natural gas liquids,[6] each through their own dedicated pipeline network.[7] Refined petroleum products include multiple grades of gasoline, diesel, jet fuel, heating oil, propane and butane. In comparison, there are

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[2] IHS Global Inc., *Oil & Natural Gas Transportation & Storage Infrastructure: Status, Trends, & Economic Benefits* (Washington, DC: American Petroleum Institute, 2013), http://www.api.org/news-and-media/news/newsitems/2014/jan-2014/~/media/Files/Policy/SOAE-2014/API-Infrastructure-Investment-Study.pdf.
[3] Ibid.
[4] "Other Means of Transport," Pipeline 101, http://www.pipeline101.org/why-do-we-need-pipelines/other-means-of-transport. Tankers and barges transport 22 percent of oil shipments. The remainder of shipments occurs via truck and rail (four percent and three percent respectively).
[5] "Where are the oil pipelines," American Petroleum Institute, http://api.org/oil-and-natural-gas-overview/transporting-oil-and-natural-gas/pipeline/where-are-the-oil-pipelines.
[6] "About Pipelines," Association of Oil Pipe Lines, http://www.aopl.org/pipeline-basics/about-pipelines/.
[7] Ibid.

approximately 300,000 miles of natural gas transmission pipelines and 2.1 million miles of distribution pipelines.[8]

Historically, the town of Cushing, Oklahoma, has hosted the North American midcontinent hub for oil distribution—mostly crude originating from West Texas production or crude oil imported to the U.S. Gulf Coast and shipped north via pipeline. Until recently, U.S. oil pipeline construction and system configuration has roughly mirrored this traditional flow pattern, facilitating crude movements to U.S. refineries located throughout the Midwest. These flow patterns are now shifting, as Canadian oil sands and U.S. tight oil production has soared over the last few years. In the midcontinent hub in Cushing, growth and growing congestion have been producing a bottleneck. To relieve the resulting pressure, energy firms and other market participants have invested in reconfigured and expanding petroleum pipeline infrastructure (as well as crude-by-rail infrastructure), enabling the southward flow of North American crude to refineries based along the U.S. Gulf Coast. For example, flow along the Seaway pipeline was reversed and now moves crude oil from Cushing down to Houston, Texas. The initial reversal cost $300 million, with an expected addition cost of $2 billion for ongoing expansion to bring capacity to 850,000 barrels per day (bpd) by mid-2014.[9] In the Gulf Region, the 350-mile Ho-Ho line used to move imported oil from Houma, Louisiana, to Houston, Texas, but now brings crude from the Eagle Ford and Bakken plays to refineries on the Gulf Coast.[10]

Conversion is not limited to flow direction. To address rapidly growing constraints in petroleum transportation, some gas pipelines are being converted into petroleum pipelines given the relatively higher price of oil. Also, natural gas produced in the United States in recent years has included an increasing proportion of associated liquids, or condensates. These liquids can be refined into end products such as gasoline and naptha that are generally derived from oil, but their transport requires pipelines rated for liquids. U.S. refineries (see later section) are generally not configured for processing the light liquids associated with natural gas, but condensates are increasingly blended with crude from Canadian oil sands, so condensates from oil and natural gas plays are being pumped northward as well as south to Gulf Coast refineries.[11] These condensates create congestion in the oil pipeline and storage system, as well as changes in availability of refined product. The Cochin pipeline between Illinois and Alberta, Canada, was reversed in late 2013 to move light condensate north to Canada and no longer delivers propane to the upper Midwest region; during the extreme cold weather in early 2014, the pipeline reversal was a factor contributing to local shortages of propane.

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[8] "Natural Gas Pipelines," Pipeline 101, http://www.pipeline101.org/why-do-we-need-pipelines/natural-gas-pipelines.

[9] Reuters, "FACTBOX-U.S. oil pipeline projects," *Chicago Tribune*, May 31, 2013, http://articles.chicagotribune.com/2013-05-31/news/sns-rt-usa-pipelineoil-factboxl2n0ec1r6-20130531_1_eagle-ford-shale-oil-pipeline-enbridge-inc-origin-destination.

[10] Matthew Monks, "Shell Said to Seek Buyers for $1 Billion Stake in Ho-Ho Pipeline," *Bloomberg*, January 27, 2014, http://www.bloomberg.com/news/2014-01-27/shell-said-to-seek-buyers-for-1-billion-stake-in-ho-ho-pipeline.html.

[11] Gary Hunt, "Why is condensate creating a big shift in Gulf Coast oil markets?" *Deloitte MarketPoint*, April 22, 2014, https://www.deloittemarketpoint.com/insights/item/12-why-is-condensate-creating-a-big-shift-in-gulf-coast-oil-markets.

Alternatives and Tradeoffs

The enormous increase in domestic petroleum production has allowed the non-pipeline alternatives to carve out a foothold in the market, which are increasingly considered to be a more permanent, less stopgap measure for oil transport. The emergence of rail as a significant mode of crude transport highlights not only a regional constraint in pipeline infrastructure but also the petroleum industry's increasing willingness to search out and invest heavily in alternatives. The numbers bear this out; between 2006 and 2013, rail transport has increased from 4,674 rail cars to 425,000, an increase of more than 9,000%.[12]

In addition to pipelines and rail, barges and trucks add to the range of options with trade-offs between between cost, speed, volume, safety, and general optionality, typically depending on location and application. These tradeoffs can change through investment and policy actions. For example, rail transport of crude is disadvantaged in its overall shipping cost of $10 to $15 per barrel, compared to approximately $5 cost per barrel for pipelines. However, rail has an established infrastructure and generally requires construction of only loading and unloading facilities, which can be accomplished quite rapidly. Rail infrastructure services every refinery in the country, and rail and related facilities can be built more quickly than pipelines and refineries, allowing them to keep pace with production growth.[13] Consequently, rail offers oil producers greater flexibility, rapid response to market changes, and fewer capital risks. However, there is increasing public safety concern about the growth of rail as a mode of oil transportation, with a number of derailments making headlines in the last two years.

Barge transport has also played a role in moving new Canadian and U.S. crude oil production to refineries and markets. Barge transport can compete with pipelines where water access is reasonably direct and often entails an intermodal exchange. Bakken production is railed to Albany, New York, and transported by barge down the Hudson River to East Coast refineries. Bakken and Canadian crude (currently about 100,000 bpd) are also transported by rail to Minneapolis and Chicago, and then by barge to the Gulf Coast.[14] Bakken crude is also transported by rail to Washington State refineries and potentially could be sent by barge to California refineries.

Intra-U.S. waterway transport of crude and products faces the same infrastructure challenges as other barge transport—namely, the age and maintenance of locks, some of which are still wooden; maintenance and dredging of shipping channels; and water depth issues. Barge traffic is susceptible to shutdowns due to both drought and flooding, as illustrated by 2013 shutdowns due to flooding of the Mississippi (June) and Illinois (April) rivers, and late 2012/early 2013 load reductions on the Mississippi due to drought conditions.

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[12] American Association of Railroads, *Moving Crude Oil by Rail.* (Washington, DC: American Association of Railroads, December 2013). https://www.aar.org/keyissues/Documents/Background-Papers/Crude-oil-by-rail.pdf

[13] Association of American Railroads, *Moving Crude Oil by Rail* (Washington, DC: Association of American Railroads, December 2013), https://www.aar.org/keyissues/Documents/Background-Papers/Crude-oil-by-rail.pdf.

[14] Curtis, T., et al., 2013. Pipelines, Trains and Trucks: Moving Rising North American Oil Production to Market, Energy Policy Research Foundation Inc. report, http://eprinc.org/wp-content/uploads/2013/10/EPRINC-PIPELINES-TRAINS-TRUCKS-OCT31.pdf

Trucks and rail are also used extensively for ethanol; transporting ethanol in the same pipelines as petroleum products is complicated by fuel quality specifications, ethanol's water-absorbing properties, and multiple pipeline owners. A multi-billion dollar ethanol pipeline project from Midwest to Northeast was considered, but the idea was abandoned in 2012 because of economic infeasibility.

4. Pipeline Safety and Environmental Issues

Oil pipelines in the Continental United States are typically buried at a depth of three to six feet to reduce weathering and ultraviolet (UV) exposure, decrease public visibility and wildlife disturbance, and protect against collisions and deliberate sabotage. However, buried pipelines also make inspection and leak detection difficult. In recent years, a few major incidents have highlighted the need for advancement in leak detection systems for pipelines.[15]

A 2012 study commissioned by the Pipeline and Hazardous Materials Safety Administration found that pipeline control rooms, which monitor pipeline operations, identified leaks in hazardous liquid and gas transmission lines only 17 percent and 16 percent of the time, respectively. In fact, workers and members of the general public are more likely to identify oil spills and gas leaks than the pipeline companies' own detection systems. These facts suggest that leak detection technology/hardware is failing and/or operators are not adequately monitoring and utilizing the data supplied by detection systems.[16]

Cyber and Physical Threats

At different points along the routes they traverse, petroleum pipelines run above ground (typically in sensitive environments, water crossings, etc.). In addition, these pipelines extend over hundreds of miles and through remote regions. Whether segments of a pipeline system are above ground and visible or below ground and largely out of the public eye, they are difficult to protect from individuals or groups that see them as targets and are cognizant of the economic or environmental harm and safety and health impacts that can stem from deliberate efforts to damage or destroy them. Furthermore, while communications/information technology (IT) enhances TS&D operations, it also introduces a new vulnerability in cyber security.

Some maritime facilities may be more vulnerable to either intentional or accidental physical damage. The Port Fouchon and the LOOP terminal are of particular concern because of their critical place in supporting the region and nation's energy industry. Accidental damage can also affect offshore pipelines: anchors and other equipment can drag along the sea floor and catch on exposed pipelines, and underwater landslides threaten certain offshore transmission and production facilities—especially those located in high-risk geological areas.

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[15] Pipeline Safety Trust, *Pipeline Safety New Voices Project: Briefing Paper #3 – Hazardous Liquid Pipelines – Basics and Issues* (Bellingham, WA: Pipeline Safety Trust, n.d.), http://pstrust.org/docs/BriefingPaper3.pdf.
[16] Pipeline and Hazardous Materials Safety Administration, Final Report No. 12-173, Leak Detection Study – DTPH56-11-D-000001.
http://www.phmsa.dot.gov/pv_obj_cache/pv_obj_id_4A77C7A89CAA18E285898295888E3DB9C5924400/filename/Leak%20Detection%20Study.pdf

TS&D Infrastructure to Offshore Facilities

Pipeline reversals are not solely an onshore phenomenon. Alternate routing happens offshore to respond to hurricanes, and in the future, deepwater production installations may require fuel for power generation and/or electricity. Nitrogen or carbon dioxide may also be used offshore for enhanced oil recovery.

In general, most of the fuel required for offshore power generation has been produced from the location where it will be used (*in situ* gas is used to power the production facility). However, power distribution is a central concern for deepwater service companies that supply production equipment for those installations. With deepwater tiebacks, pumping is crucial to ensure efficient production flow from each well back to the production facility. The offshore LOOP terminal is also powered by onshore generation assets that are vulnerable to severe storms.

Wetlands

The Gulf Coast region serves as the portal for thirty percent of the nation's oil and natural gas.[17] The coastal wetlands preserving this geographical zone are the largest, most threatened and—because of the indigenous oil and gas resources—the most economically valuable. The wetlands serve as a natural buffer to protect the billions of dollars in energy infrastructure along the coast—the nation's largest port system and 90 percent of offshore energy produced in the United States[18]—from hurricanes and major storms.

At the same time, the United States Geological Survey reports that oil and gas activities are a primary contributor to coastal land loss (along with sea-level rise, intense hurricanes, and other human development).[19] The state has lost more than 1,900 square miles of coastal lands since the 1930s—enough to cover the state of Delaware—and 700 more square miles are expected to be lost in coming decades. A comprehensive restoration effort by state and local governments, industry groups, energy companies, foundations, and communities is under way to tackle the natural and human causes of wetlands loss and protect the region's economic and environmental capacities. In July 2013, a lawsuit filed by the Southeast Louisiana Flood Protection Authority asserted that oil, gas, and pipeline companies caused and should repair the coastal land loss.[20]

Climate Resilience

Extreme weather and shifting climactic patterns will be a challenge for onshore and offshore petroleum systems. Hurricane Sandy in the Northeast and hurricanes Katrina and Rita in the Gulf of Mexico are recent examples of how extreme weather can affect petroleum product transmission, storage, and distribution. These two disasters demonstrated different vulnerabilities of our of energy TS&D infrastructures to disruption.

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[17] "Why the Concern?" America's Wetland Foundation, http://americaswetlandresources.com/background_facts/whytheconcern.html.
[18] "Issues," America's Wetland Foundation, http://www.americaswetland.com/custompage.cfm?pageid=257.
[19] "Wetland Subsidence, Fault Reactivation, and Hydrocarbon Production in the U.S. Gulf Coast Region," U.S. Geological Survey, http://pubs.usgs.gov/fs/fs091-01/index.html.
[20] Board of Commissioners of the Southeast Louisiana Flood Protection Authority – East, et al., v. Tennessee Gas Pipeline Company, LLC, et al., No. 2013-6911 (Civil District Court for the Parish of Orleans).

Hurricane Sandy was a case study in how a large Atlantic hurricane could severely disrupt petroleum product distribution in a heavily urbanized population center that is highly dependent on energy imports from elsewhere in the United States. On the other hand, Hurricanes Katrina and Rita, which hit the Gulf of Mexico in quick succession during the summer of 2005, had significant impacts on a region intensely involved in upstream and midstream oil and gas production and transmission. Both storms were accompanied by intense winds and massive storm surges that flooded large swaths of urban residential and industrial neighborhoods and severely damaged the region's energy infrastructure.

In the case of Rita and Katrina, more than 3000 oil and gas platforms and 22,000 miles of undersea pipelines were in the storms' paths. Of these, 115 platforms were completely destroyed, and 52 platforms were damaged, as were 535 segments of pipeline.[21] In both cases, the disruptions were not solely regional. Owing to the intense concentration of hydrocarbon refining and production in the region, the Gulf Coast hurricanes also led to fuel shortages elsewhere in the United States.

Each of these regional disruptions highlighted areas of growing concern regarding infrastructure interdependencies in the petroleum product transportation, storage, and distribution systems. Perhaps foremost was the interdependency of liquids transmission and electrical generation. Widespread power outages, coupled with reliance of the fuel pumping facilities and refineries on the grid for power, slowed recovery and hampered access to underground fuel stores. It soon became clear that first responders (e.g., firemen, police) were also heavily dependent on liquid fuels and electricity.

As a result of these storms, there has been significant investment and interest in "hardening" critical infrastructure. In the case of petroleum products, this hardening entails ensuring that critical control and pumping facilities are either elevated or otherwise made resilient to intrusion by both fresh and salt water. It is also necessary to ensure that these facilities have access to electricity during emergencies.[22]

Already some of the most critical pumping stations have been elevated to defend against future inundation, and some of the pumping stations now have back-up auxiliary power. However, many still receive primary power from the grid. The Port Sulphur Terminal, located in Plaquemines Parish, Louisiana, is one example of a facility upgraded and hardened after the 2005 hurricane season. In 2006–2007, this facility was expanded by the Tennessee Gas Pipeline Company to accommodate the liquid hydrocarbon and gas production produced from Independence Hub (Mississippi Canyon Block 920 A facility). At that time, processing equipment (e.g., separators, pumps, compressors, some measurement equipment) was installed on 18-foot platforms, increasing the chances that the facility can be put back online quickly in the event of another major storm surge or flood.[23]

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[21] Daniel Yergin, *The Quest: Energy, Security, and the Remaking of the Modern World* (New York: Penguin Books, 2012), 139.

[22] Federal Emergency Management Agency, *Sewerage & Water Board of New Orleans Reconstruction/Elevation and Hardening of Nine (9) Sewage Pump Stations, New Orleans, LA* (New Orleans, Louisiana: U.S. Department of Homeland Security, 2012), http://www.fema.gov/media-library-data/20130726-1858-25045-2327/hmgp_swb_sewage_pump_station_draft_ea11_2.pdf.

[23] Correspondence between the US Department of Energy Office of Energy Policy and Systems Analysis and the U.S. Department of the Interior Bureau for Safety and Environmental Enforcement, May 2014.

Another significant issue regarding oil transmission regards pipelines that are attached to dormant or decommissioned offshore oil platforms. These pipelines are often not well maintained and are a serious risk for substantial leakage. Severe weather increases the likelihood that an already damaged platform could topple or collapse, potentially leading to a major release of oil into the Gulf. The South Timbalier 301 B (ST 301 B) platform is an example of one structure that may pose such a risk. Promptly disconnecting such platforms from offshore oil pipeline systems can reduce the likelihood of substantial environmental damage.

5. Refineries

As of February 2014, the U.S. Energy Information Administration (EIA) reported U.S. refining capacity of 17.9 million bpd.[24] The bulk of U.S. refining capacity is geographically concentrated in Petroleum Administration for Defense Districts (PADDs), with almost half of the total U.S. capacity located in the Texas and Louisiana Gulf Coast region (PADD 3). The general trend within the refining sector in the United States and internationally has been toward relying on a smaller number of large refineries. Today, the largest 11 U.S. refineries make up about one quarter of the nation's refining capacity, and the smallest 71 refineries also collectively comprise approximately one quarter of U.S. capacity.[25]

New U.S. and Canadian oil production has reduced U.S. refiners' dependence on imported crudes from the Persian Gulf and Africa, declining to 2.5 million barrels per day from 4.2 million barrels per day in 2007.[26] Over 99 percent of Canada's production of synthetic "heavy" crude from the Athabasca oil sands is destined for the United States.[27] The "heavy" nature of Canadian oil,[28] combined with the new patterns of oil trade due to new domestic production and reduced imports, has led to significant changes in U.S. oil refineries and their need for transportation and distribution infrastructure.

In the 1990s, U.S refineries began to build coker and sulfur capacity enhancements to accommodate the growth of medium and heavy sour crude oils while investing to meet environmental requirements and consumer demand for transportation fuels. Medium and heavy crude make up 52 percent of U.S. crude oil inputs,[29] and the United States continues to expand its capacity to process heavy crude. The increase in U.S. production contributes to a growing mismatch between the types of crude North America produces (light sweet) and the types the U.S. refineries can most profitably refine (heavy sour).

Increasing domestic production of light crudes has also changed the economics of refinery crude slates and is affecting the return on these recent large capital investments in refineries, potentially limiting the

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[24] "Refinery Utilization and Capacity," U.S. Energy Information Administration, last modified April 29, 2014, http://www.eia.gov/dnav/pet/pet_pnp_unc_dcu_nus_m.htm.

[25] National Petroleum Council, "Hydrocarbon Liquids," in *Advancing Technology for America's Transportation Future* (Washington, DC: National Petroleum Council, 2012), 11-1–11-41, http://www.npc.org/reports/FTF-report-080112/Chapter_11-Hydrocarbon-Liquids.pdf.

[26] "U.S. Imports by Country of Origin," U.S. Energy Information Administration, last modified April 29, 2014, http://www.eia.gov/dnav/pet/pet_move_impcus_a2_nus_epc0_im0_mbblpd_a.htm.

[27] "Canada—Background," U.S. Energy Information Administration, last modified September 17, 2012, http://www.eia.gov/countries/cab.cfm?fips=ca.

[28] IHS CERA Inc., *Extracting Economic Value from the Canadian Oil Sands: Upgrading and refining in Alberta (or not)?* (Cambridge, MA: IHS CERA Inc., 2013), http://www.ihs.com/pdfs/ihs-cera-upgrading-refining-mar-2013.pdf.

[29] U.S. Energy Information Administration, personal communication, based on Form EI-810 data.

global competitive advantages many U.S refiners currently hold because of price differences between inland and international crude. Because of low natural gas prices, limited refinery capacity in Latin American refineries, and closures of European refineries, the Gulf Coast refining hub has become a major source of competitively priced refined products for Latin America and Europe. Continued changes in the chemical composition and geographic origins of U.S.-refined crude oil and liquids supply have required, and will continue to require, substantial investment in refining capacity and related infrastructure.

6. Storage

Crude oil moves from oil fields to petroleum refineries for processing to storage areas, where the petroleum products are stored for distribution and emergency reserves.[30] Industry and government crude oil inventories are stored in locations across the United States—the only country to publish weekly stock data—and are a major indicator of supply and demand trends.[31] Energy companies and other market actors pay special attention to these figures; a more-than-expected increase in inventories means a greater supply or weaker demand (bearish for crude oil prices), while an increase that is less than expected implies just the opposite (bullish for crude oil prices).[32]

Working storage capacity is contained at refineries, at bulk storage terminals, in product pipelines, and at crude tank farms.[33] There are approximately 8 billion barrels of oil in worldwide industry and government inventory at any given time, and only around 10 percent of this stock is typically available for the industry to use as needed.[34] The United States sustains about 1 billion barrels—the largest commercial stock worldwide.[35]

The U.S. Energy Information Administration's weekly petroleum update from May 12, 2014, signaled an above-average inventory range for this time of year, at 398.5 million barrels. Total commercial petroleum inventories increased by 3.4 million barrels last week.[36] By the end of April 2014, crude oil stocks had reached a record high of nearly 400 million barrels.[37]

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[30] Library of Congress, Business Reference Services, "Transportation and Storage," *Business & Economics Research Advisor,* no. 5/6 (2005/2006), http://loc.gov/rr/business/BERA/issue5/transportation.html.
[31] Ingrid Pan, "How oil inventory figures can show supply and demand trends," *Market Realist*, May 20, 2014, http://marketrealist.com/2014/05/crude-oil-prices-got-bump-inventory-figures/?utm_source=yahoo&utm_medium=feed&utm_content=graph-1&utm_campaign=crude-oil-prices-got-bump-inventory-figures#61257.
[32] Id.
[33] U.S. Energy Information Administration, "Table 1. Working Storage Capacity by PAD District as of September 30, 2013," U.S. Department of Energy, http://www.eia.gov/petroleum/storagecapacity/table1.pdf.
[34] U.S. Energy Information Administration, "Energy Explained: Your Guide to Understanding Energy," U.S. Department of Energy, http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/oil_market_basics/Stocks_Text.htm.
[35] Library of Congress, Business Reference Services, "Transportation and Storage," *Business & Economics Research Advisor,* no. 5/6 (2005/2006), http://loc.gov/rr/business/BERA/issue5/transportation.html.
[36] U.S. Energy Information Administration, *Weekly Petroleum Status Report—Data for Week Ended May 9, 2014* (Washington, DC: U.S. Department of Energy, 2014), http://www.eia.gov/petroleum/supply/weekly/pdf/wpsrall.pdf.
[37] U.S. Energy Information Administration, "Short-Term Energy Outlook," U.S. Department of Energy, release date May 6, 2014, http://www.eia.gov/forecasts/steo/report/.

Inventories in Cushing, Oklahoma, a major inland U.S. oil hub, are one indicator of how effectively U.S. oil production is moving from major inland production areas—such as the Bakken in North Dakota and the Permian in West Texas—to end-refining markets. A buildup in Cushing inventories suggests that oil supplies are increasing faster than the refining markets, mainly in the Gulf Coast, can manage.[38]

Including oil held in the Strategic Petroleum Reserve (SPR), domestic crude stocks totaled approximately 1.07 billion barrels at the end of February 2014.[39] This is up slightly from the previous month and slightly lower than February 2013.[40] The vast majority of this total—more than 884 million barrels (including 696 million barrels in SPR)—is in Petroleum Administration for Defense District (PADD) 3 (Gulf Coast), with PADD 2 (Midwest) a distant second, at about 102 million barrels.[41] For petroleum products excluding crude, total stocks equaled 673.7 million barrels (February 2014), down slightly from the previous month and about 36 million barrels below the same time last year.[42] PADD 3 also has the largest quantity of the non-crude product—approximately 282.4 million barrels—but the difference between other regions is less pronounced: PADD 1 – 125.2 million barrels, PADD 2 – approximately 156.6 million barrels, PADD 4 – 18.65 million barrels, and PADD 5 – 90.87 million barrels.[43]

Maintaining significant storage of crude oil and refined products is one way to blunt the potential impact of shortfalls in liquid fuels supply. As a member of the International Energy Association (IEA), the United States is required to hold 90 days' consumption worth of crude oil reserves. The model that the United States has chosen for maintaining these reserves is referred to as "government-owned stocks in government storage." Based on this model, the U.S. government owns and operates the Strategic Petroleum Reserve (SPR), authorized to hold up to 727 million barrels of oil. Increases in domestic oil production and correlating reductions in crude oil imports have resulted in aforementioned changes to crude oil distribution in the United States, with potentially significant implications for the operation and maintenance of the SPR.

The SPR currently operates and maintains two sites in Texas (Bryan Mound and Big Hill) and two sites in Louisiana (West Hackberry and Bayou Choctaw). Oil is stored in large underground caverns created in salt dome formations. Salt dome storage was chosen for two reasons: it provides maximum security for the nation's stockpile of crude oil, and it is a relatively low-cost option for large-scale petroleum storage.

The SPR's oil storage facilities are grouped into three geographical distribution systems in the Gulf Coast: Seaway, Texoma, and Capline. Each system has access to one or more major refining centers,

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[38] Ingrid Pan, "How oil inventory figures can show supply and demand trends," *Market Realist*, May 20, 2014, http://marketrealist.com/2014/05/crude-oil-prices-got-bump-inventory-figures/?utm_source=yahoo&utm_medium=feed&utm_content=graph-1&utm_campaign=crude-oil-prices-got-bump-inventory-figures#61257.
[39] U.S. Energy Information Administration, "Petroleum and Other Liquids—Stocks by Type: Crude Oil," U.S. Department of Energy, release date April 29, 2014, http://www.eia.gov/dnav/pet/pet_stoc_typ_a_EPC0_SAE_mbbl_m.htm.
[40] Id.
[41] Id.
[42] U.S. Energy Information Administration, "Petroleum and Other Liquids—Stocks by Type: All Oils (Excluding Crude Oil)," U.S. Department of Energy, release date April 29, 2014, http://www.eia.gov/dnav/pet/pet_stoc_typ_a_EPP0_SAE_mbbl_m.htm.
[43] Id.

interstate crude oil pipelines, and marine terminals for crude oil distribution. Although the SPR has historically stored only crude oil, it has conducted various studies on the potential for the storage of refined petroleum products as well. The maximum nominal drawdown capability for the SPR is 4.415 million bpd.

As domestic crude oil production and imports of crude oil from Canada have increased dramatically over the past few years, so too have the volumes of crude oil shipments to Gulf Coast refining centers. These increased volumes have, in turn, led to changes to the oil distribution infrastructure surrounding the SPR facilities. Such changes include new pipeline construction, pipeline expansions, flow reversals in existing pipelines, and increased utilization of terminals and marine facilities. The SPR Texoma distribution system facilitates the delivery of SPR crude oil from the SPR storage sites at West Hackberry, Louisiana, and Big Hill, Texas, and may have been affected by significant changes to surrounding infrastructure in the past few years. These changes include flow reversals on the Shell Ho-Ho and Seaway pipelines; construction of a new Marketlink LLC pipeline from Cushing, Oklahoma, to the Port Arthur, Texas, refining center; and significant expansion and utilization of pipeline, marine, and rail infrastructure to the Sun terminal in Nederland, Texas, a key sales and distribution center for SPR Texoma system distribution capability. Cumulatively, these infrastructure changes may affect the ability of the SPR Texoma distribution system to deliver crude oil as may be required of the SPR in an emergency. DOE conducted a test sale of SPR crude oil in March 2014 to evaluate the SPR's ability to draw down and distribute SPR crude oil through multiple pipeline and terminal delivery points within the SPR Texoma distribution system. Data on the movement of crude through the system during the sale are still being reviewed.

7. Workforce Issues

According to figures compiled from state agencies and the Bureau of Labor Statistics, the oil and gas industry totaled 662,555 jobs in the Gulf Coast states of Alabama, Florida, Louisiana, Mississippi and Texas in 2011.[44] Over the last decade, more than 30 states experienced a 50% increase in oil and gas employment.[45]

However, over 60 percent of the workers in areas such as electric and gas utilities are likely to retire or leave the industry within a decade.[46] While changing workforce demographics and impacts from the retirement of the "baby boom" generation are affecting all industries, the "Great Shift Change" is of particular concern in the Gulf Coast region.

A direct outgrowth of the bust in oil prices during the 1980s, many professionals in the oil and gas industry switched to different careers and never reentered the energy workforce. This "lost generation" created an experience gap in workers with 15 to 25 years of experience in industry and the federal

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[44] Independent Petroleum Association of America, 2013. *2012-2013 The Oil & Gas Producing Industry in Your State*. http://www.ipaa.org/wp-content/uploads/downloads/2014/03/2012-2013OPI.pdf
[45] American Petroleum Institute, 2013. *The State of American Energy.* http://www.api.org/~/media/Files/Policy/SOAE-2013/SOAE-Report-2013.pdf
[46] Center for Energy Workforce Development, *Gaps in the Energy Workforce Pipeline 2011 CEWD Survey Results* (Washington, DC: Clean Energy Workforce Development, 2011), http://www.cewd.org/surveyreport/CEWD-2011surveyreport-021512.pdf.

Government.[47, 48] A young and relatively inexperienced workforce operating in an increasingly complex production environment (e.g., evolving technology, deeper water, higher pressures, and more complex geology) potentially increases the potential for safety and environmental issues.

Compounding these workforce concerns is the lack of "consistent and granular" data on the extent of potential labor shortages and workforce needs in terms of education levels and training.[49] The World Bank, in 2011, examined the issues with calculating employment created by the energy sector. The study observed that actual quantification of the industry's employment trends and potential is complicated by factors such as various job multipliers, direct (project-specific) versus indirect (supplying inputs to a project) job impacts, and employment types (e.g., construction and manufacturing, operations and maintenance).

The oil and gas workforce also confronts geographic challenges. An estimated 40 percent of engineering graduates from the Louisiana region are leaving the Gulf Coast region of the United States following graduation. Saudi Aramco and other national oil companies (particularly from West African nations) are sending students to U.S. schools, and after graduation, these students generally return back to their home countries. These students represent a substantial portion of the available engineering workforce graduating from the Gulf Coast region.

Evolving workforce needs have to be met with the appropriate level of education and training. A focus on providing and expanding access to science, technology, engineering and math (STEM) curricula are increasingly important to support the transformation. A recent report by API and IHS Global purports that 1.3 million new job opportunities will be available by 2030.[50] Importantly, that growth will be geographically dispersed with 417,000 expected in the Gulf Coast.[51] There is a major industry push to ensure that minorities, women, and veterans make up a larger portion of that potential. Specifically, the API and IHS projects that "…408,000 positions of the 1.3 million opportunities will go to African American and Hispanic workers, and female employment in the oil, gas and petrochemical industry will account for 185,000 of the total job opportunities through 2030."[52]

During the 2007–2009 recession, oil and gas jobs remained stable; according to a 2013 industry report, the oil and natural gas industry currently supports 9.2 million jobs.[53] Further, the IEA projects that the

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[47] Gene Lockard, "Generational Guru, Recruiter Discuss Energy's Diverse Workforce," *Rigzone,* May 16, 2014, https://www.rigzone.com/news/oil_gas/a/133132/Generational_Guru_Recruiter_Discuss_Energys_Diverse_Workforce.

[48] Edith Allison, "Energy Industry Impacts: NAS Report Tracks Workforce Issues," *Explorer,* May 2013, http://www.aapg.org/publications/news/explorer/column/articleid/2472/nas-report-tracks-workforce-issues#sthash.5zeRsvoA.dpuf.

[49] Ibid.

[50] IHS Global Inc., *Minority and Female Employment in the Oil and Gas and Petrochemical Industries* (Washington, DC: American Petroleum Institute, 2014), http://www.api.org/news-and-media/news/newsitems/2014/apr-2014/~/media/Files/Policy/Jobs/IHS-Minority-and-Female-Employment-Report.pdf.

[51] Ibid.

[52] Ibid.

[53] American Petroleum Institute, *The State of American Energy* (Washington, DC: American Petroleum Institute, 2013), http://www.api.org/~/media/Files/Policy/SOAE-2013/SOAE-Report-2013.pdf.

United States will be the world's top oil producer by 2020.[54] Workforce will continue as a significant priority in this sector.

8. Key Questions

The QER aims to address a range of fundamental and emerging issues in regard to the petroleum TS&D infrastructure. Key questions for stakeholder input include:

1. What infrastructure modifications are needed to accommodate rapid shifts in development of North American oil supply, increasing domestic light crude production and the difference in chemical composition compared to heavy crude, and flat or decreasing domestic demand? What impacts do relatively steep decline curves of shale plays have on infrastructure investment?
2. To what extent is the shift in fossil fuel production away from federal onshore and offshore lands a product of regulatory dynamics, markets, or geology? Should TS&D policies anticipate future shifts back to, or away from, federal land?
3. What are the projections for end-of-life retirements across petroleum product TS&D infrastructure, and how much of that infrastructure is operating beyond its intended lifespan? Are private infrastructure owners incentivized and informed enough to make investments in new equipment, maintenance, repairs, and replacements to address system reliability, security, and environmental protection?
4. What infrastructure modifications are needed to make the system more resilient to major threats such as earthquakes, hurricanes, deep freezes, fires, and other extreme weather or natural events? What are the major threats to system resilience, by region?
5. How will anticipated industry build-out to 2030 affect the overall reliability and resilience of the TS&D network?
6. Are any alternate petroleum TS&D infrastructure models or new technologies inherently more resilient?
7. What steps need to be taken to improve physical and cyber security in the North American liquid fuels network? How do security lapses and disruptions in pipeline networks, refineries, petro-chemical plants, and storage facilities affect overall system performance?
8. Is the United States producing enough petroleum, mechanical, and civil engineers to support the projected midstream oil industry? What is the outlook for oil TS&D industry workforce supply and demand, generally, and what is the government role in addressing any shortfalls between supply and demand?
9. To what extent do rail's and pipelines' differing contracting and market structures affect the investment and expansion of either/both?
10. Are the risks of certain pipeline construction materials and techniques adequately understood, tracked, and addressed by leak detection and maintenance? Is there a role for technology to improve safety and prevent spills and leaks from pipelines?

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[54] IHS Global Inc., *Minority and Female Employment in the Oil & Gas and Petrochemical Industries* (Washington, DC: American Petroleum Institute, 2014), http://www.api.org/news-and-media/news/newsitems/2014/apr-2014/~/media/Files/Policy/Jobs/IHS-Minority-and-Female-Employment-Report.pdf.

11. Does the increased use of barge transport present new vulnerabilities and environmental risks? Are on- and off-loading facilities in ports, as well as locks and other waterways, sufficient for projected levels of barge transport?
12. Are SPR offloading infrastructure and policies appropriate in light of increased domestic production and pipeline reversals?
13. What can be done with petroleum product storage to ensure better system resiliency, and what is the government role in facilitating these improvements (e.g., are government-owned regional product reserves needed)? What policies would encourage greater secondary storage holding?
14. What are the impacts of maximizing domestic crude processing on the international competiveness of the U.S. refining system?
15. What innovation in refining technologies and processes would support reconfiguration or flexibility to accommodate more domestic crude?
16. What is the role of the federal government in promoting resilience to a range of vulnerabilities (cyber, physical, climate, interdependencies) within the refining industry?