TRB TRANSPORTATION RESEARCH BOARD

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JUNE–JULY–AUGUST 2015

Moving Energy

Gulf Ports Harbor the Changes
Multimodal Freight Opportunities
Delivering Natural Gas to New England
Rural Roads and Heavy Hauling
Crude Oil by Rail: Economics and Safety

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MOVING ENERGY

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COVER: A new crude-by-rail origination terminal in Hardisty, Alberta, Canada. The changing landscape of energy use and production in the United States has implications for facilities, freight flows, technologies, and safety. (Photo: USD Partners, LP)

TR NEWS

features articles on innovative and timely research and development activities in all modes of transportation. Brief news items of interest to the transportation community are also included, along with profiles of transportation professionals, meeting announcements, summaries of new publications, and news of Transportation Research Board activities.

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ALSO IN THIS ISSUE:

COMING NEXT ISSUE

The next issue of *TR News* explores the interrelationships of public health and transportation, as metropolitan planning organizations are beginning to incorporate health-related issues into plans and programs, state departments of transportation are adopting health policies, and the research community is responding. Articles cover health impact assessments and analyses, incorporating health into transportation planning and decision making, modeling the risk of infectious disease spread through the transportation system, transportation lessons learned from the Ebola epidemic, measuring the health impacts of walking and bicycling, innovative practices and research to assess active transportation and health, health-related findings from TRB-managed research projects—and more.

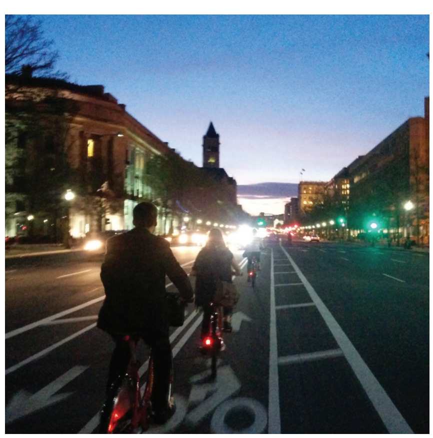

Photo: Zachary Elgart

Bicycles are becoming a popular mode of transportation in cities, offering individual and community health benefits, but also raising issues of traffic planning and operations and safety. Above, bicyclists at the end of the day travel along a dedicated lane on Constitution Avenue, NW, in Washington, D.C.

Transportation technology, modes, and routes to serve U.S. energy markets change along with shifts in energy sources and production methods.

PHOTO: IRVING OIL

INTRODUCTION

CHANGES IN ENERGY MARKETS

Effects on the U.S. Transportation System

JONATHAN RUBIN

The author is Professor, Margaret Chase Smith Policy Center, University of Maine, Orono, and Chair of the TRB Environment and Energy Section.

The U.S. transportation energy system is undergoing rapid changes, from historic increases in fuel efficiency to renewed domestic production of oil and natural gas to new routes for moving energy around the nation and the world. This issue of *TR News* addresses these changes with a clear understanding that transportation services are essential to meeting the economic and social goals of our nation. At the same time, as recognized in the most recent edition of the Transportation Research Board's *Critical Issues in Transportation*, the transportation sector exerts large-scale, unsustainable impacts on the environment and the climate (*1*).

Navigating these changes compels a shift in direction toward a more sustainable transportation future focused on significant reductions in fossil fuel use—a direction that nevertheless provides reliable and secure transportation services in a fiscally responsible way.

A New Reality

Fossil fuels supply more than 80 percent of the primary energy used in the United States (*1*, MT-6). Petroleum accounts for 36 percent of the nation's primary energy use and for 92 percent of energy use in the transportation sector (*2*, MT-55; *3*). This fossil fuel–dominated foundation supports the nation's understanding of oil and natural gas resources. Technology and world events, however, are reshaping this foundation by challenging the long-held views that fossil resources are running out and that the United States increasingly must depend on imports.

The new reality is that technological advances in oil and natural gas drilling have reshaped U.S. domestic energy supplies. Today approximately 30 percent of the petroleum consumed in the United States is imported, yet only 10 years ago approximately 60 percent was imported (2, Figure IF2.2).

U.S. domestic production, along with the continued development of Canadian oil sands, has disrupted the traditional patterns of oil and natural gas pricing and shipments. Including natural gas liquids, the United States is now the world's largest producer of oil, at 12 million barrels per day, exceeding the output of the next highest producers, Russia and Saudi Arabia. The United States, however, still produces less crude oil than both of those countries (*4*).

The public and even some in the transportation community have not fully grasped these developments, which are known to energy specialists and have national and international importance. This remarkable achievement in oil production should be celebrated for the beneficial effects on the U.S. economy in terms of jobs, balance of payments, and energy security.

Readjusting Markets

The public recognizes that gasoline and diesel prices continue to fall, with gasoline as low as $2 per gallon and diesel fuel close to $3 gallon for the first time since the financial crisis. The lower prices result from a combination of higher U.S. production, a depressed world demand that reflects a weak economic output, and an absence of supply restrictions from the Organization of the Petroleum Exporting Countries (OPEC).

The likelihood of continued high levels of U.S. domestic crude production has encouraged groups such as the American Petroleum Institute to push for easing of the 1970s-era rule that prohibits the export of domestically produced oil, except to Canada. To critics, this ban creates distortions in the domestic and international markets for oil, limits investment in the U.S. oil industry, and provides no benefits. Supporters note that the ban keeps domestically produced oil available for use in the United States. If the limits on exports cause domestic crudes to sell at lower prices, lifting the ban may raise the price of certain streams of domestically produced oil. If the higher prices for these domestic streams lead to additional U.S. production, the global price of oil could drop and with it the price of gasoline. The outcome depends on a host of factors, including the reaction of OPEC and the investments by domestic producers in future output, based on expectations for oil prices.

The United States is already a major exporter of refined products, including diesel, gasoline, and jet fuel. U.S. exports of refined products are now about 3.4 million barrels per day, up from about 1 million barrels per day in 2006 (*5*). This makes the United States one of the world's largest exporters of refined products. The export of refined products reflects, in part, the decline in U.S. demand for gasoline.

Renewable Fuels

The Energy Policy Act of 2005 established the Renewable Fuel Standard, expanded in the Energy Independence and Security Act of 2007. The legislation calls on the Environmental Protection Agency (EPA) to set requirements for the renewable content of gasoline and diesel fuel. Refiners and importers

PHOTO: WIL C. FRY, FLICKR

Low gas prices have prompted the export of some domestically produced oil.

must blend renewable fuels into gasoline and diesel fuel in proportion to the volumes sold. Renewable biofuels—including corn-based ethanol, biomass-based diesel, and advanced biofuels—must meet four interconnected requirements. Because of technical difficulties in scaling up production, as well as regulatory uncertainty and other reasons, the volumes of advanced or cellulosic biofuels are well below the legislated target.

The fuel economy of vehicles also affects the impact of the renewable fuel requirements. EPA and the National Highway Traffic Safety Administration have issued harmonized fuel economy and greenhouse gas (GHG) emissions standards under the Corporate Average Fuel Economy (CAFE) regulations. The regulations are expected to increase the fleet average fuel economy of light-duty vehicles—cars, vans, and SUVS up to 10,000 pounds in gross vehicle weight—to 48 or 49 miles per gallon by 2025; flexible compliance measures include credits for improved air conditioning systems that leak fewer GHGs. Together, these standards contribute to a declining demand for gasoline but an increase in vehicle miles traveled. Because of increasing activity in the freight sector, U.S. consumption of diesel fuel is projected to rise (*1*, MT-30).

The improvement in fuel economy will reduce the demand for gasoline and thereby reduce the number of gallons of ethanol that can be used in E10—the mixture of 10 percent ethanol and 90 percent petroleum gasoline—compatible with all gasoline-powered vehicles. EPA has approved a higher blend of ethanol in gasoline, E15 with 15 percent ethanol, for model year 2007 and newer vehicles. Additionally, blends of ethanol with gasoline up to 85 percent, or E85, can be used in cars specifically designed for this fuel. Retail availability of E15 and E85, however, is limited, reducing the market potential. As a result, EPA has reduced the total amount of ethanol renewable fuel below the levels required by law for this year and possibly beyond.

Toward a Sustainable System

The improving fuel economy also has reduced the funds available for federal and state surface transportation programs—fuel excise taxes supply most of the revenues. The Congressional Budget Office estimates that CAFE regulations will reduce the fuel tax revenues going into the Highway Trust Fund by 21 percent by 2040 (*6*). Although the Energy Information Administration's Annual Energy Outlook has projected that sales of electric and natural gas vehicles will be modest, increasing adoption of alternate-fuel vehicles will accentuate the loss of gasoline tax revenue. But additional policies to accelerate

PHOTO: ALICE WELCH, U.S. DEPARTMENT OF AGRICULTURE

Cellulosic ethanol production at Range Fuels in Broomfield, Colorado. The Renewable Fuels Standard requires renewable fuels to be blended into gasoline and diesel fuel.

reductions in GHG emissions from the transportation sector could change this dynamic.

With the current fluctuations in energy markets, the only certainty is that change will come. Oil and natural gas prices are likely to rise significantly from their current lows, but how high and when cannot be known. For the next few decades, however, fossil fuels will continue to dominate the transportation sector, which therefore will continue as a source of GHG emissions and challenges to air quality. The goal is to produce a more resilient and sustainable transportation system while improving the reliability and safety that the nation needs and expects.

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U.S. GULF PORTS HARBOR THE CHANGING ENERGY SUPPLY

MICHAEL BOMBA

The author is Research Scientist, Center for Economic Development and Research, University of North Texas, Denton, and Chair of the TRB Standing Committee on International Trade and Transportation.

The Gulf of Mexico region has served for decades as the U.S. headquarters for energy production and exploration. Although petroleum dominates the region's energy sector, other industries include natural gas and coal, as well as renewable energy sources. Recent trends in the nation's energy sector are having an effect on the ports and private terminals along the Gulf of Mexico.

Petroleum Production

As the world's population has grown and as developing nations have become wealthier, global oil production has increased to meet demand. As shown in Figure 1 (below), global oil production grew from 64.0 million barrels per day in 1980 to 89.8 billion barrels in 2013—an increase of approximately 40 percent.

Despite claims of impending energy independence, U.S. oil production grew only by 1.6 million barrels per day between 1980 and 2013, to 12.4 million barrels per day; U.S. refineries process 15 million to 16 million barrels per day. In this period, the U.S. share of global oil production peaked in 1985, when it provided almost 20 percent of the world's oil supply, and fell to its lowest level in 2005, when it contributed slightly less than 10 percent. Since 2005, the U.S. share of global oil production has increased, reaching 13.7 percent in 2013.

Many U.S. ports, including ports and private industry terminals along the Gulf of Mexico, have benefited from the petroleum industry. In addition to handling crude oil and petroleum products, these facilities support an expansive and sophisticated oil and gas exploration and production industry.

FIGURE 1 Total oil production, thousands of barrels per day, 1980–2012. (SOURCE: U.S. Energy Information Administration, 2014.)

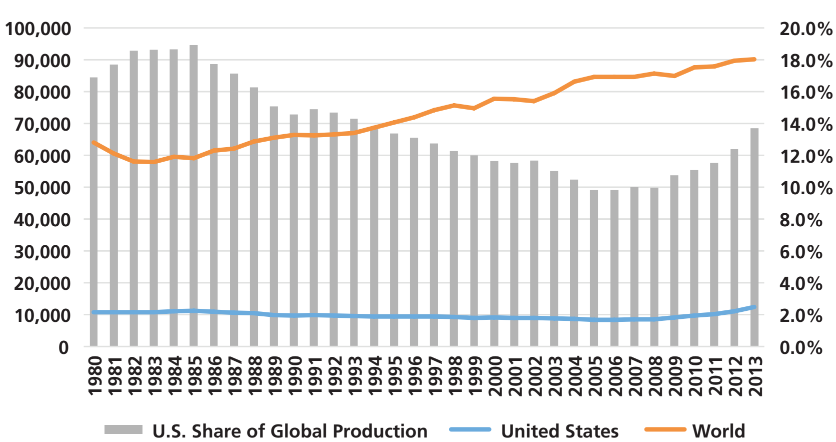


PHOTO: JENNIFER A. DLOUHY, HOUSTON CHRONICLE

The *Maersk Developer* drills an exploratory well in the Gulf of Mexico. Gulf of Mexico ports and private terminals support both the exploration and the movement of crude oil and petroleum products.

Figure 2 (page 7) shows the production of crude oil in the Gulf of Mexico region between 1980 and 2013. Crude oil production in the Gulf region declined between 1980 and 2007, as field production in Texas fell. Increased production from offshore wells in the Gulf of Mexico, however, partly offset these losses during the 1990s and into the 2000s.

Pivotal Developments

After the *Deepwater Horizon* event in 2010, crude oil production in the Gulf of Mexico stalled. The rupture and explosion of the *Deepwater Horizon* well killed 11 workers and released more than 200 million gallons of crude oil into the Gulf of Mexico, the worst oil spill in U.S. history. Federal regulators applied a higher level of scrutiny to offshore drilling and maintained a moratorium on deepwater drilling permits. These responses effectively capped Gulf oil production for several years.

Before the *Deepwater Horizon* disaster, offshore drilling in the U.S. Gulf accounted for 25 to 30 percent of total U.S. production. But while stricter oversight constrained offshore drilling, the shale plays in Texas were beginning to ramp up production—notably the Eagle Ford shale play in South Texas, the Permian Basin shale play in West Texas, and the Barnett shale play in the Dallas–Fort Worth region of North Texas.

The Eagle Ford wells, in particular, produce a large amount of crude oil and condensate, in addition to natural gas. By 2013, Texas's rapidly growing field production of crude oil reduced the Gulf of Mexico's offshore share to less than 17 percent of total U.S. oil production.

Petroleum Exploration

Gulf ports are the nexus of U.S. landside and offshore petroleum exploration and production activities, which require the movement of heavy equipment, consumables, work crews, and extracted product. For offshore drilling, all of these activities go through ports or private terminals. West of Florida, the construction, maintenance, and mooring of offshore drilling platforms, as well as offshore servicing vessels, are common sights at ports and private terminals.

Offshore platforms usually transport cargoes to shore via pipelines, although some facilities, like the Cayo Arcas terminal in Mexico, load the crude oil directly into tankers. With the lifting of the moratorium on new drilling in the Gulf of Mexico, several major deepwater projects are moving forward, providing continuing opportunities for Gulf ports.

Landside oil and gas exploration and production in the shale plays has generated significant volumes of new cargoes for Gulf ports, especially for consumables like sand and pipe. Hydraulic fracturing requires a special type of sand, which is mixed with water and chemicals and forced underground at high pressures to extract the gas and oil. The grains of sand must have the right dimensions; as a result, the sand often is transported considerable distances to the drilling sites.

All oil wells require pipe casing to line the bore hole, but hydraulic fracturing wells run deep in the ground and extend horizontally for significant distances, requiring a lot of pipe. Pipelines are the preferred mode for transporting the crude oil from the wells to the refineries, but when pipelines are not close by or may not have sufficient capacity, the crude may travel by railway tank car or by tanker truck to the pipeline network—or by barge directly to the refineries. The Eagle Ford shale play, for example, has increased barge traffic on the Gulf Intracoastal Waterway.

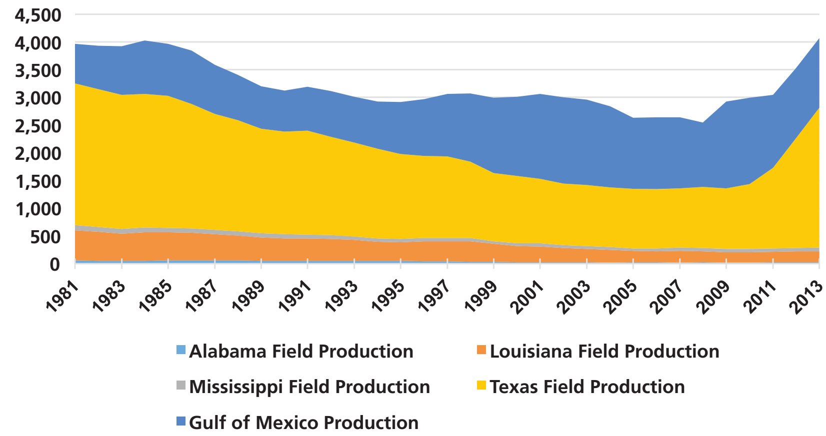


FIGURE 2 Crude oil production in the Gulf of Mexico region. (SOURCE: U.S. Energy Information Administration, 2014.)

Crude Oil

Approximately half of the nation's annual total of foreign waterborne commerce is handled at ports and private marine terminals in the Gulf of Mexico, and a large share of that cargo is crude oil. During 2012, ports and private terminals along the Gulf of Mexico handled almost 208 million tons of crude oil, with almost 93 percent at locations west of the Mississippi River (see Figure 3, page 8).

Between 2008 and 2012, the volume of crude oil handled in the Gulf declined by 21 million tons or 9.2 percent. Three factors influenced this trend. First, personal vehicles continued to gain fuel efficiency. Second, total vehicle miles traveled in the United States have declined. Third, domestic oil production from shale plays is replacing imported crude oil.

Crude oil–filled barges travel the Gulf Intracoastal Waterway, which has experienced increased traffic from hydraulic fracturing activity in Texas shale plays.

PHOTO: U.S. COAST GUARD

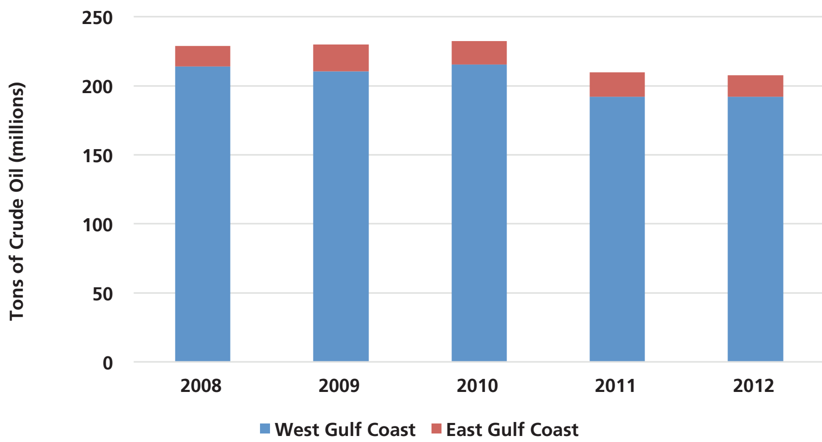


FIGURE 3 Tonnage of crude oil offloaded at U.S. Gulf ports and private terminals, 2008–2012. (SOURCE: U.S. Army Corps of Engineers, 2014.)

This last trend is evident in the share of domestic oil handled at Gulf ports (Figure 4, below). During 2008, less than 4.0 percent of crude oil handled at Gulf ports originated from a domestic port, but by 2012, that figure had risen to 10 percent and will likely increase for 2013 and 2014.

When the crude oil arrives onshore, refineries render it into gasoline, diesel, and other petroleum products or into feedstocks for the petrochemical industry. Table 1 (right) shows that the United States has the capacity to refine almost 18 million barrels of crude oil per day.

The states along the Gulf of Mexico provide almost half—49.8 percent—of that capacity. Texas provides almost 29 percent of the nation's oil refinery capacity, followed by Louisiana at 18.3 percent; the remaining U.S. Gulf states provide less than 3 percent: Mississippi, 2.0 percent; Alabama 0.7 percent; and Florida, less than one-tenth of 1 percent. The various fuels produced are transported to local distribution centers through pipelines or by tanker or barge.

Although the volume of crude oil imported by Gulf ports and private terminals between 2008 and 2012 fell by 9.2 percent—the decline nationwide was more than 25.5 percent—Gulf maritime facilities are handling larger and larger volumes of outbound petroleum products, mostly at ports and private terminals in the Western Gulf. Between 2008 and 2012, this volume grew by 41.3 million tons or 32.6 percent. The trend suggests that pipelines increasingly are feeding these refineries with domestically produced crude oil.

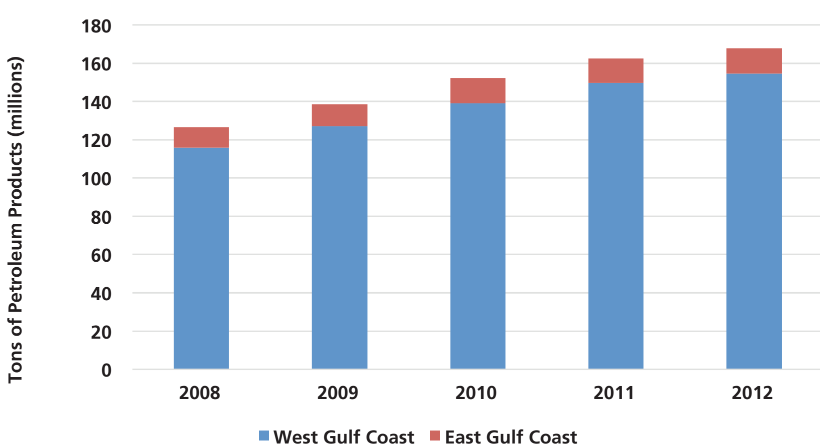


FIGURE 4 Tonnage of petroleum products originating from U.S. Gulf ports and private terminals, 2008–2012. (SOURCE: U.S. Army Corps of Engineers, 2014.)

Natural Gas

Hydraulic fracturing also has increased the production of natural gas in the United States. Between 2006 and 2013, U.S. production of natural gas increased by 27.5 percent or almost 6.5 million cubic feet (MMcf or 1,027,000,000 Btu; see Figure 5, page 9). Consumption also has grown, as natural gas replaces coal for generating electric power and as the petrochemical industry takes advantage of the cheap feedstock.

The export of natural gas has increased, although modestly. In 2013, approximately 5 percent of U.S.-produced natural gas was exported, almost entirely to Mexico and Canada. Most of the nation's supply of natural gas remains in the domestic market, keeping natural gas prices in the United States low.

Logically, producers would want to export natural gas to countries with higher prices. Table 2 (page 9) shows the price for liquefied natural gas (LNG) in Lake Charles, Louisiana, compared with the prices in locations around the world. Although the price of LNG has declined in the past year, the global price dif-

TABLE 1 U.S. Refinery Capacity for Selected States, as of January 1, 2014

Rank	Location	Barrels per Calendar Day	Production (%)
1	Texas	5,174,209	28.9
2	Louisiana	3,274,520	18.3
3	California	1,960,671	10.9
4	Illinois	958,645	5.3
5	Washington	631,700	3.5
6	Pennsylvania	596,000	3.3
7	Ohio	530,000	3.0
8	Oklahoma	523,300	2.9
9	New Jersey	468,000	2.6
10	Indiana	440,600	2.5
11	Mississippi	364,000	2.0
12	Minnesota	359,500	2.0
	Remainder of the United States	2,643,485	14.7
	Total United States	17,924,630	100.0
	Total U.S. Gulf Coast Capacity[a]	8,108,826	45.2

[a] *Only includes refineries located directly on the Gulf Coast.*
SOURCE: U.S. Energy Information Administration, 2014.

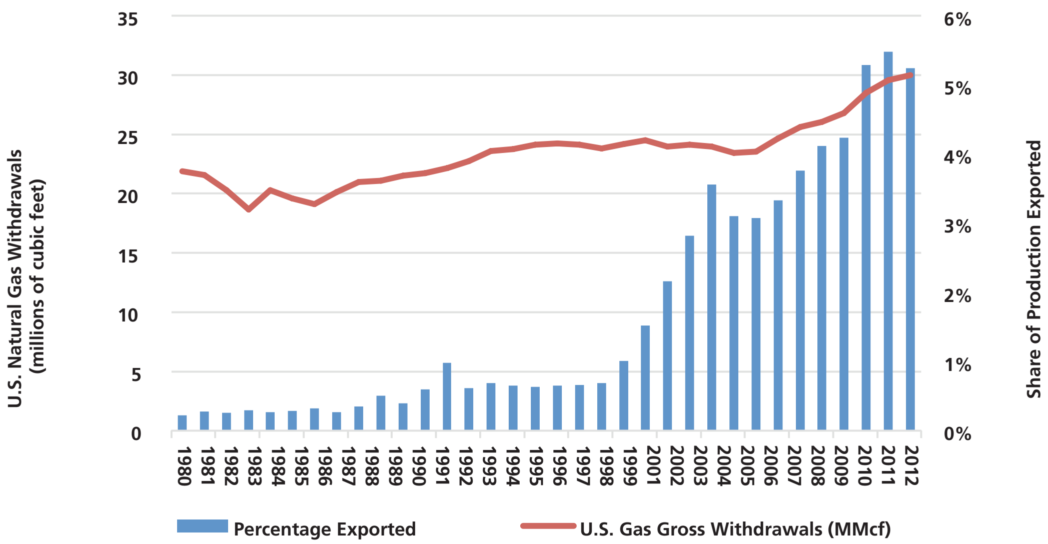


FIGURE 5 U.S. withdrawals and production of natural gas (MMcf), 1980–2013. (SOURCE: U.S. Energy Information Administration, 2014.)

ferential with the Lake Charles price ranged from $4.54 to $13.06 per million Btu as of December 2014.

The difficulty of exporting natural gas relates primarily to its transportation. Pipeline is the optimal mode, but the natural gas pipelines between the United States and Mexico or Canada are limited. Selling in more distant markets requires that the gas be liquefied by chilling to −162°C (−260°F). Liquefaction allows further compression, so that the gas can be loaded onto LNG tankers for export. This process requires a special facility; the United States currently has none.

As of December 2014, however, four LNG export terminals have received approval—three are in the Gulf of Mexico: in Sabine and Hackberry, Louisiana, and Freeport, Texas—and 10 others are planned along the Gulf Coast. Export terminals for LNG cost several billion dollars to construct, and the federal permitting process is rigorous.

Another difficulty is that the draft of most LNG tanker vessels is deep; more than 90 percent cannot fit into the locks of the Panama Canal. With the Panama Canal's expansion, however, approximately 90 percent of the world's fleet will be able to fit. Many in the shipping and petroleum industry anticipate that the liquefaction plants and the expanded Panama Canal will make LNG a significant export commodity from the Gulf of Mexico.

Coal

Coal is another source of fossil energy handled at ports and private terminals in the Gulf region. Figure

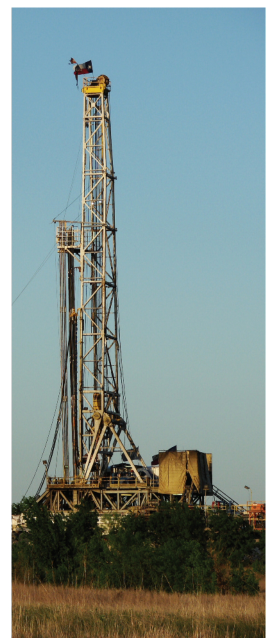


PHOTO: DAVID R. TRIBBLE

Oil drilling rig on the Barnett Shale near Alvarado, Texas. Most domestically produced crude oil stays in the United States.

TABLE 2 Estimated World LNG Landed Prices: November 2013 and December 2014 (US$/MMBtu)

Location	November 2013	December 2014	Differential with Lake Charles	2013–2014 Difference
Canaport, Canada	NA	$16.78	$13.06	NA
Altamira, Mexico	$16.40	$11.54	$7.82	-$4.86
Rio de Janeiro, Brazil	$14.65	$11.35	$7.63	-$3.30
Bahia Blanca, Argentina	$15.65	$11.78	$8.06	-$3.87
United Kingdom	$10.66	$8.56	$4.84	-$2.10
Belgium	$10.40	$8.26	$4.54	-$2.14
Spain	$10.90	$9.76	$6.04	-$1.14
Korea	$15.65	$12.00	$8.28	-$3.65
India	$13.75	$11.45	$7.73	-$2.30
Japan	$15.65	$12.00	$8.28	-$3.65
China	$15.25	$11.60	$7.88	-$3.65
Lake Charles, La.	**$3.15**	**$3.72**	**—**	**$0.57**

NOTE: NA = not available. SOURCE: Waterborne Energy, Inc., 2013 and 2014.

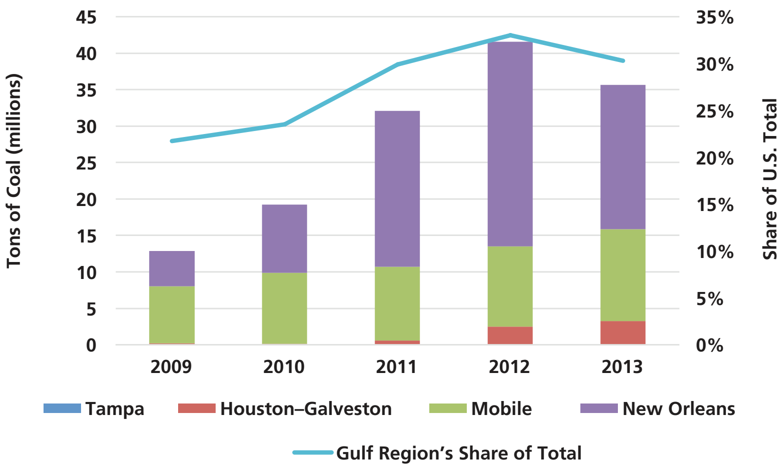


FIGURE 6 U.S. coal exports by U.S. Customs districts along the Gulf of Mexico. (SOURCE: U.S. Energy Information Administration, 2014.)

6 (above) shows the volume of U.S. coal exports handled within U.S. customs districts, large regions that include multiple ports and terminals. These figures show that coal exports from the Gulf region rose sharply between 2009 and 2012, from 12.8 million to 41.6 million tons, but dropped 14.2 percent to 35.7 million tons between 2012 and 2013.

Coal exports from the Gulf region comprised 30.1 percent of the U.S. total in 2013. The majority of the coal, however, did not go to Asia, despite China's heavy use of coal for energy production. The customers for 51.3 percent of U.S. export coal were the nations of Europe; China received only 7.0 percent; moreover, the Chinese government recently committed to cap coal use by 2020.

Major coal exporting facilities in the Gulf of Mexico are located within or near the Ports of Houston, Texas; New Orleans, Louisiana; and Mobile, Alabama. As in the Pacific Northwest, environmental groups have worked to prevent the construction of new coal export terminals. Although opponents emphasize the local effects of the terminals, climate change is usually the main concern.

Three terminals proposed in Corpus Christi, Texas, were canceled because of market uncertainties but also came under scrutiny from environmental groups. The Port of Mobile, which receives approximately two-thirds of its revenue from coal exports, is considering a $140 million expansion near a coal terminal.

Coal imports, in contrast, fell from 10.7 million tons in 2009 to 4.1 million tons in 2013 (Figure 7, below left). The Mobile customs district lost a large volume of cargo; the Tampa, Florida, customs district also experienced losses. The drop in coal imports from the Gulf region reflects a national trend.

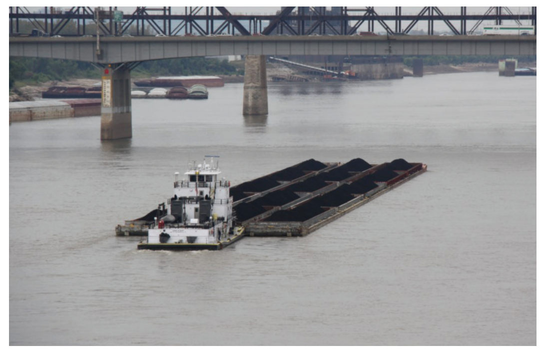


PHOTO: LANCE AND ERIN, FLICKR

Coal exports from the Gulf more than tripled between 2009 and 2012, topping 41 million tons, but by 2013 decreased to 35.7 million tons.

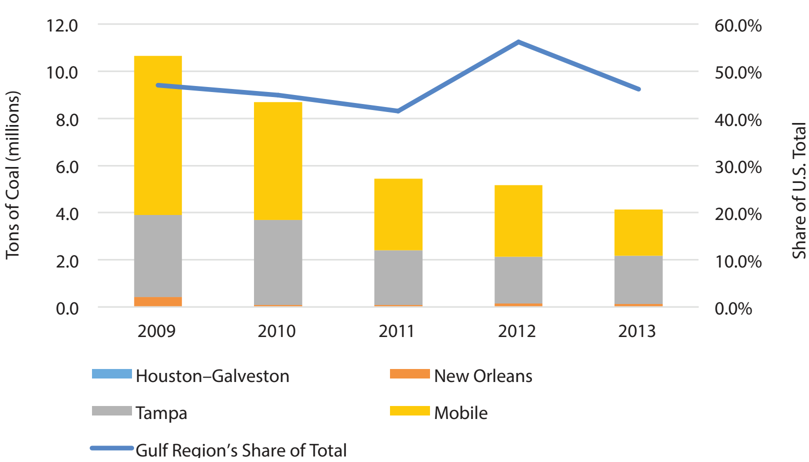
Wind

Renewable energy—namely wind—has played an important role in the cargo mix for some Gulf ports for a decade or more. The United States has only a few wind turbine manufacturing facilities—many of the nation's wind turbines are manufactured overseas. Imported wind turbines must travel a portion of their trip by water, moving in parts from the manufacturer to final assembly.

Typically, a disassembled windmill arrives as seven or more major components: three blades, three or more tower sections, and the nacelle, which contains the generator mounted at the top of the wind turbine. The blades typically range in length from 105 to 160 feet, and the assembled tower sections range from 100 to 150 feet in height. The nacelle is roughly the size of a city bus. After these components are offloaded from ships, they travel by truck and sometimes by rail as oversize movements to the places of installation.

Texas ports handle most of the wind turbine cargoes in the Gulf of Mexico. Texas and some areas of western, coastal Louisiana are the only locations in the Gulf region with wind conditions to support energy production. According to the U.S. Depart-

FIGURE 7 U.S. coal imports by U.S. Customs districts along the Gulf of Mexico. (SOURCE: U.S. Energy Information Administration, 2014.)



ment of Energy, Texas is the only U.S. Gulf state that produces wind power and ranks first among all states in wind power capacity, with 12,354 megawatts (MW) at the end of 2013; California ranks second, with 5,829 MW.

Energy production from wind power relies on a federal tax credit to make many projects financially viable. A federal tax credit of $0.023 per kilowatt-hour produced in the first 10 years of a wind project expired in 2014. The loss of this tax credit could reduce—if not eliminate—the installation of wind turbines in the United States.

In addition, offshore wind farms in the Gulf of Mexico are under proposal, with a total capacity of 4,371 MW; none of the facilities listed in Table 3, however, has been built. Except for one in Louisiana, all of the proposed offshore wind farms are in Texas.

The Port of Corpus Christi has become a renewable energy producer. The port took advantage of its location along the Gulf Coast, its abundant land holdings, and the almost constant winds in the area to install six 1.5-MW wind turbines.

Wood Pellets

Wood pellets are another sustainable energy source moving through Gulf ports. The vitamin-sized wood waste products are burned to generate electricity. Burning coal or natural gas releases carbon dioxide (CO_2) that was sequestered underground; in contrast, the CO_2 in wood pellets, like that from other biomass sources, is released by natural decomposition; therefore the net effect of the emissions is considered close to zero.

Wood pellets are in demand in Europe, where the European Union has mandated production of 20 percent of electricity from renewable energy sources. Because the pellets can be mixed with coal, utility operators do not need to retrofit power plants. Environmental advocacy groups, however, are concerned that the demand for wood pellets may encourage deforestation.

Many ports along the Gulf of Mexico already handle wood products from the timber industry of the Southeastern United States; wood pellets have become one more commodity in the mix, particularly at ports from the Florida Panhandle to Port Arthur, Texas. As many states or utilities seek to substitute biomass fuels for coal, the wood pellet industry is expected to continue growing.

Future Trends

A variety of factors, including channel deepening and navigational improvements, fluctuating oil prices, climate change, and the opening of the Mexican petroleum industry to private investment, will influence the near- and long-term future of ports and private terminals in the Gulf of Mexico and their role in the energy sector.

Channel Projects

The Water Resources Reform and Development Act of 2014 (WRRDA) has moved several significant channel projects important to the energy industry closer to construction. The projects in Texas include the $1.1 billion Sabine-Neches Waterway project, the $239 million Freeport Harbor Channel project, and the $353 million Corpus Christi Channel project, each serving a major activity center for the oil and gas industry.

WRRDA also sets aside $50 million dollars of discretionary funding for "energy transfer ports." These U.S. Customs ports must have handled at least 40 million tons of cargo during FY 2012, and energy commodities must have comprised at least 25 percent of the tonnage. Although the need for port and naviga-

PHOTO: J. BREW, FLICKR

Many wind turbine parts are manufactured overseas, delivered to Gulf ports, and shipped by truck or rail—often as oversize loads—for assembly onsite.

TABLE 3 Proposed Offshore Wind Farms in the Gulf of Mexico

State	Project Name	Generating Capacity (MW)
Louisiana	Vermillion Bay	36
Texas	Jefferson Offshore	300
Texas	Galveston Offshore Wind Farm	150
Texas	Galveston Offshore Wind Farm 2	150
Texas	Galveston Test	3
Texas	Brazoria Offshore	500
Texas	Titan Platform	7
Texas	Mustang Island Offshore Wind Farm	1,200
Texas	Rio Grande North	1,000
Texas	Rio Grande South	1,000
Texas	Texas Offshore Pilot Research Project	25
	TOTAL	**4,371**

NOTE: MW = megawatts = 1,000,000 watts.
SOURCE: OpenEI, 2014.

In 2012 the Port of Corpus Christi constructed six wind turbines along Nueces Bay in Texas—the first wind farm located on industrial port property in the country.

Photo: Jesse Samu, Port Corpus Christi Authority

tion improvements outstrips the supply of public funding, the WRRDA will address some of the nation's most urgently needed improvements for the energy sector.

Oil Prices

The refining side of the petroleum industry is relatively stable, but the exploration and production side faces intrinsic instability and risk. These instabilities lead to price fluctuations and production booms and busts. Petroleum prices often produce countervailing impacts on the economy—higher prices can encourage oil exploration and drilling but also discourage driving, reduce household incomes, and raise business costs. Lower gasoline prices, usually seen as positive for the economy, can diminish economic activity related to exploration and drilling.

Historically, Gulf ports serving the energy industry have benefited from higher prices, which encourage more offshore exploration and production. More recently, the growth in hydraulic fracturing has led to the handling of more fracking sand, pipes, heavy equipment, and crude oil. In contrast, prices that are too high can reduce the volume of crude oil imported for refinement into gasoline, distillates, and other products.

Even with higher prices, the demand for gasoline is fairly inelastic, and the number of refineries is relatively fixed—reduced production therefore has relatively small impacts on employment. The demand for exploration and drilling activities, however, is highly elastic and responds strongly to prices, generating or contracting significant ancillary employment.

Offshore drilling and hydraulic fracturing are expensive methods of extracting oil, and the viability correlates strongly with the price of oil. In December 2014, for example, oil was approximately $60 per barrel, down from more than $100 dollars a barrel at midyear and with predictions of prices in the range of $40 to $45. The high cost of extracting oil by hydraulic fracturing and from the Canadian tar sands can make some sources of oil and gas no longer financially viable.

Industry experts have estimated that the Eagle Ford shale wells can operate profitably in the range of $40 to $60 per barrel, but the Permian Basin shale play requires between $59 and $82 per barrel to break even. Canadian tar sands need prices at $90 per barrel or more to cover operating costs. As prices drop, exploration and production will diminish, and the volume of related crude oil, equipment, and consumables handled at Texas ports will drop.

Climate Change

Although the global response to climate change has been lackluster, the long-term effects and consequences are yet to come. Fossil fuels play a significant role in climate change; the world may be forced to rely less on fossil fuels and more on renewable energy sources. These changes may be decades away but

An exploratory drillship on the Gulf of Mexico. In general, demand for oil exploration rises and falls with oil prices.

Photo: KM&G-Morris, Flickr

likely will curtail or end many of the activities related to fossil fuels in the Gulf of Mexico. Current and potentially new sources of renewable energy will become more prominent in port activities, but their economic footprint is unlikely to be as large as that of the fossil fuel industries today.

Mexico's Oil Industry

In December 2013, Mexico's Congress and Executive Branch approved a constitutional amendment that would allow private-sector investment in the exploration and production of the nation's oil and gas reserves. The amendment can induce significant investment of foreign capital into Mexico's petroleum industry. Petróleos Mexicanos, or PEMEX, the national oil corporation, needs foreign investment, technical expertise, and technologically advanced drilling equipment to maximize the exploitation of current fields and to drill in new oil fields and gas plays.

Northern Mexico—notably the Burgos shale basin near the Texas border—may contain large shale gas formations comparable in scale to the Eagle Ford shale play. U.S. firms looking to expand operations or to redeploy underutilized or idle drilling equipment will likely consider sending their equipment into Mexico.

Other potential impacts to the Texas transportation system include servicing the expanded drilling in Mexico's territorial waters in the Gulf—such as the 200-mile Exclusive Economic Zone—and shipping oil and gas from Mexico to Texas for additional processing. These movements could generate substantial freight volumes, consisting of heavy oil field equipment and other materials, such as pipes, from Texas into Mexico, as well as petroleum products from Northern Mexico into Texas. U.S. Gulf ports and private terminals—particularly those west of the Mississippi River—are likely to see increased freight volumes related to activities in Mexico.

Critical Role and Challenges

The critical role of Gulf ports in the nation's energy sector is expected to continue. A return to deepwater offshore drilling in the Gulf of Mexico, the continuation of hydraulic fracturing in shale plays around the country, and the opening of the Mexican petroleum industry to foreign investment will drive demand for the services provided by Gulf ports and private terminals. In addition, navigation improvements through WRRDA and the completed expansion of the Panama Canal will make LNG a feasible U.S. export commodity.

Fluctuations in the price of oil, however, will challenge growth in the petroleum industry. The production of energy by renewable sources also will continue to have an important role at Gulf ports, although not likely to replace fossil fuels in the short to medium term. Renewable sources typically are more expensive and are not able to provide energy on the scale necessary to maintain current levels of consumption.

Over the longer term, the consequences of climate change may become too great to ignore, and the reliance on fossil fuels will have to be scaled back. The economic consequences of this shift likely will mean a contraction of the fossil fuel sector, affecting economic activity in the Gulf region.

PHOTO: BOB LAURA, U.S. COAST GUARD

The *Discoverer Enterprise* and other vessels continued to recover oil from the site for months after the *Deepwater Horizon* explosion in 2010.

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MOVING THE CHANGING U.S. ENERGY MIX BY MULTIMODAL FREIGHT

Opportunities, Prospects, and Issues

MARK J. CARR

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The structural shifts in U.S. energy production and consumption are changing the locations of energy trade lanes and the commodities and volumes transported. The transportation of plentiful and low-cost energy products on U.S. multimodal freight systems presents many uncertainties, including the effects of government regulations and incentives on emerging and traditional energy markets.

At the Transportation Research Board (TRB) Annual Meeting in January 2015, the Standing Committee on Inland Water Transportation, the Marine Group, and the Freight Systems Group sponsored a session, "Will the Changing U.S. Energy Mix Transform Multimodal Freight Systems?" exploring the policy, infrastructure, and delivery issues associated with the changing U.S. energy portfolio.

Photo: Melissa Meier, U.S. Geological Survey

Continuing with its long history as a major commercial waterway, the Mississippi River channels new freight flows from energy sources in the Midwest and Deep South.

Historic Opportunities

"The development of abundant oil and unconventional natural gas resources creates an historic opportunity to enhance economic growth throughout North America and to improve the region's competitiveness in global markets," asserted Guy F. Caruso, a senior adviser to the Energy and National Security Program of the Center for Strategic and International Studies (CSIS).

Caruso noted that "the development of these resources, along with shifting demand, necessitates an expansion of the energy infrastructure and a reevaluation of North America's place in the global energy market. This transformation of the physical infrastructure is well under way, but by its very nature, lags behind the rapid development of the resource base. The ability to smooth this transformation will play a critical role in capturing the possible benefits."

The inland barge industry, for example, is capturing new cargoes, such as the special sand required for hydraulic fracturing; the most substantial deposits are found in Wisconsin. Moving the sand to the Marcellus shale formations in Pennsylvania has generated new barge freight and patterns. Barges also are delivering steel pipe for well use via Pittsburgh, Pennsylvania, the onetime steel capital of the world.

CSIS studies conclude that the new transportation patterns reflect the wait-and-see approach in the development of infrastructure for unconventional fuels. With prices in flux because of uncertainties about regulations affecting exports and countering the causes of climate change, questions remain about the most cost-effective approach for transporting the abundant liquid resources.

For example, coal interests on the Pacific Northwest coast are applying for permits to build and operate export terminals. Reflecting the leanings of their constituencies, the governors of Washington and Oregon have denied the applications, citing objections related to the environment and safety. The coal would have traveled by rail or barge to export terminals for transloading onto ships to customers in Asia. The investments are on hold.

"Today's renaissance in U.S. oil and gas production is reshaping the country's energy system as has nothing else since the oil supply shocks of the 1970s," reported session speaker Lee Lane, a Visiting Fellow at the Hudson Institute in Washington, D.C., and a veteran of the rail industry. "In 2013 alone, U.S. crude oil output soared by 13.5 percent—the largest yearly increase in U.S. history and one of the largest in world history." He added that since 2007, annual natural gas output has risen by 26 percent: "These wide-ranging changes demand multiple adjustments throughout the economy."

Effects of the Export Ban

Lane noted that U.S. crude oil exports to countries outside the North American Free Trade Agreement are banned—with limited exceptions—and that this ban has impeded measures to take full advantage of the renaissance in oil and gas production. The price controls on U.S. crude oil, instituted in the 1970s, were the initial rationale for the ban on crude oil exports, but President Ronald Reagan abolished the controls in 1981.

The new shale oil fields are producing higher volumes of light tight oil (LTO) than U.S. refiners can handle efficiently, and the refining shortfall is likely to grow. The most efficient solution is to allow the export of U.S. LTO crude, so that U.S. refineries can process heavier crudes, some of which are imported.

Abolishing the ban on crude oil export, however, would have substantial implications for U.S. freight flows, according to Lane. A recent study found that lifting the ban would lead to the export of 1.7 million to 2.5 million barrels a day (MBD) in the short term; by 2035, total exports could reach 5.2 MBD (*1*).

Allowing exports also would raise total crude oil output—according to some estimates, output could reach 2.1 MBD in the short run and as much as 4.2 MBD by 2035. Moreover, this increase in output would stimulate significant additional flows of chemicals and components to the Gulf Coast and the Rocky Mountains regions.

Regulatory Influences

Lane expressed doubt about the effectiveness of regulations in solving current problems or relieving the unintended consequences of past efforts. "Regulation is imposing high and growing costs on U.S. energy logistics, yet the prospects for reform are limited. Incremental progress on the export of crude oil and natural gas seems possible. Increased regulation of the transport of crude oil by rail will raise costs, but with uncertain effects on safety," he maintained.

Lane observed that the issues surrounding the Keystone XL pipeline are unique but indicate a larger dysfunction in the approval processes for pipelines. The policies of the Obama Administration related to climate change may portend more restrictions on domestic coal transport; moreover, state and local concerns hamper the prospects for coal exports—as occurred in the Pacific Northwest—but uncertainties in the international market may render this a moot issue.

Transporting Biofuels

A generation ago, biofuels transportation was virtually nonexistent, Lane pointed out, but in recent years, ethanol plants have become fixtures of the Corn Belt, as federal policy has required blending the high-octane additive into gasoline. Ethanol replaced the more noxious octane boosters that fell into regulatory disfavor, particularly methyl tertiary butyl ether, widely considered a source of water pollution.

Because the U.S. population and therefore motor vehicle driving are generally concentrated along the coasts, and corn is grown in the interior, a major rail trade in ethanol has developed. In 2002, 4.4 million tons of ethanol moved by rail, but by 2012, the figure climbed to 27.66 million tons. Barges moved a small amount—6.5 million tons in 2012—on the inland river system.

The increase in corn use for ethanol reduced the amounts of corn shipped by barge or rail to ports in the Central Gulf or Pacific Northwest for export to

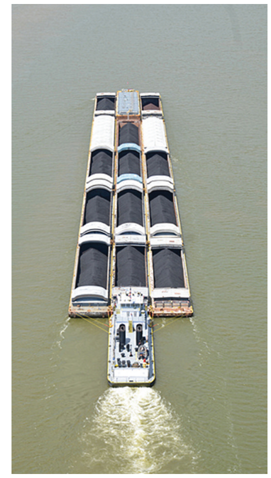

Photo: American Commercial Lines

A barge tow primarily consisting of coal in open hopper barges, each with a capacity of approximately 2,000 tons.

Photo: Consolidated Grain and Barge

Barged corn in a continuous unloader before transfer into an oceangoing ship. Barges hold approximately 2,000 tons of grain or other bulk cargoes.

Photo: American Commercial Lines

Typical liquid barge tow for products such as ethanol and petroleum. Each of the six barges in this photo carries 30,000 barrels, or 4,200 tons, of product.

world markets. Ethanol plants tend to draw corn from within a 50-mile radius, establishing local markets. Distillers dry grains, a byproduct of the ethanol distillation process, regularly move by barge to the export market or to domestic markets for animal feed.

From 2003 to 2012, corn shipments by barge declined from nearly 39 million tons to 22.6 million tons, although the size of the crops increased. The lost differential went to the ethanol markets, but distillers dry grains rose to more than 2 million tons of barge freight.

Rail and Pipelines

Supply-and-demand projections indicate continuing growth for the near term in unconventional oil and gas resources—such as shale oil and gas, Canadian tar sands, and biofuels—as long as crude oil prices remain stable, Zia Haq, Senior Analyst at the U.S. Department of Energy (DOE), informed the session. DOE expects a flat demand for petroleum in the United States, because of modest economic growth, increasing standards of vehicle fuel efficiency, increasing adoption of electric and hybrid vehicles, and the use of biofuels.

The market has adapted by increasing rail capacity, reversing pipeline flows, repurposing natural gas pipelines, and initiating major new pipeline projects. The majority of the U.S. gas and liquid pipeline system is more than 50 years old. Preventing leaks and maintaining system integrity has become a concern.

The energy industry increasingly is relying on rail for moving crude and finished oil products. This trend is expected to continue because of the relative ease of adding freight cars to the transportation system.

Caruso identified the advantage of rail transport as "flexibility." Rail cars can be manufactured and introduced into service within months, in contrast with new pipelines, which require several years. "Accompanying this increase in rail, however, has been an increase in rail accidents, bringing the discussion of transportation safety to the fore," Caruso observed.

Transportation by rail also has raised concerns about congestion and about the displacement of other types of freight, such as agricultural commodities, for moving crude oil. The transport of crude oil by rail is slowing down the movement of grain, cars, and other commodities, Caruso noted; major capital and human resource investments are needed to upgrade the rail system and to build capacity.

An eastbound Union Pacific ethanol train in Arizona. Most U.S. ethanol is transported by rail.

Photo: Clay Gilliland, Flickr

Safety Concerns

Davis Burroughs of Morning Consult addressed public perceptions of the safety of moving fuels. "Transporting crude by rail is increasing and moving closer to cities, and the number of derailments is going up," he reported. "That has motivated officials to impose more regulations on the industry in the past decade."

A poll by Morning Consult's news outlet indicated that the American public, especially voters, is not convinced that moving crude by train is dangerous. A slight plurality—49 percent—of voters believed that transporting oil by train was "very safe" or "somewhat safe," but 43 percent said it was unsafe. The opinions on this matter showed little partisan split, but a large majority of Independents—58 percent—agreed that transporting crude by rail was safe.

A 2012 study by the Texas A&M Transportation Institute found that in terms of liquid spills, shipping by barge is safer than shipping by rail. In the study period, the barge sector spilled 2.59 gallons per million ton-miles traveled compared with rail spills of 4.89 gallons per million ton-miles traveled. Freight policies that provide incentives for shippers to move petroleum by barge may therefore lead to environmental benefits.

Infrastructure Needs

Moving more crude oil by barge, however, raises questions about the adequacy of the infrastructure, Haq pointed out: "Inland waterways locks need maintenance and upgrades. Connections to ports, navigation channels, docks, and landside terminals need to work. Rail-to-barge loading facilities are being built at a fast pace to keep up with demand."

Such changes in freight flows are important to the barge industry—carriers who are focusing on coal are suffering from low demand and suppressed rates, but those who are active in the transport of oil and liquids are prospering. From 2002 to 2012, coal shipments declined from 205 million tons to 183 million tons.

Surprisingly, petroleum volume also slipped in this period, from approximately 216 million tons to 206 million tons. The drop probably reflects the economic recession, and increases in the liquids volume are expected. Liquids carriers, nevertheless, likely captured more of the barge transportation industry profits during the period.

Large changes in freight flows raise significant questions about investments in motor, pipeline, railroad, and water carriers, as well as public-sector investments in roads, navigation channels, and ports, Lane observed. Yet public- and private-sector investments alike are made amid uncertainty.

The unknowns include U.S. policy on crude oil exports and world oil prices. U.S. policies designed to limit the drilling boom's environmental effects could limit sharply the growth in production (2). Possible U.S. regulation of crude-by-rail is another source of uncertainty.

Regulatory Agendas

Haq believes that the system has adapted remarkably well to these extraordinary demands, but that high-profile incidents such as the *Deepwater Horizon* Gulf spill and the Lac-Megantic unit train derailment have highlighted the need for enhanced safety and for investments in maintenance and upgrades. The federal government has issued rules requiring thicker steel for rail tank cars that carry oil and other flammable and hazardous liquids.

Burroughs reported that other items on regulators' agendas include tighter restrictions on freight train speeds, new braking systems, improved communication with state emergency response teams, improved assessments of routing risks, and new classifications for mined gases and liquids. The rail industry may not support all of these proposals, Burroughs noted, but the industry wants good relations with regulators in the hope of avoiding more costly rules like those for Positive Train Control, which could cost rail carriers up to $22 billion, according to estimates by the Government Accountability Office (3).

Burroughs expressed doubts that federal regulations would address all of the causes of accidents. The causes of derailments, for example, include car and track failures plus human error; the train's speed may not be a significant factor—nevertheless, most of the proposed regulations are targeting speeds in the range of 40 mph. He pointed out that at least three recent accidents occurred on trains traveling at 10 mph or slower; the crash in Lynchburg, Virginia, occurred while the train was traveling at 24 mph.

Photo: Vanessa Hamer, U.S. Army Corps of Engineers

Maintenance and repair crewmembers dewater a dam and lock in the U.S. Army Corps of Engineers St. Paul District in Minnesota for major rehabilitation work.

Burroughs underscored these observations with results from an October 2014 poll, which revealed that the majority of American voters believed that the government should regulate rail transport of crude oil. In November 2014, North Dakota issued regulations calling for heavier rail cars to lessen the risk of puncture in an accident.

Caruso concluded, however, that "it is increasingly unlikely that regulatory action will stop shipment of crude by rail." The demand for rail service is too great, and the rates are too attractive to shippers and carriers alike, he noted.

Lane concluded that regulation is imposing higher costs on U.S. energy logistics; nevertheless, the prospects for reform are limited. He predicted that incremental progress was possible in exporting crude oil; that increased regulation of crude-by-rail would raise costs, with uncertain effects on safety. He reiterated that the pipeline approval processes are dysfunctional; that federal climate policies portend more restrictions on domestic coal transport; and that state and local policies also are hindering the export of coal—nevertheless, a dwindling global market may make that export opportunity moot.

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NATURAL GAS TRANSPORT IN NEW ENGLAND

Supply, Storage, Infrastructure, and Security

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The North American shale revolution has brought about rapid, far-reaching changes in how the United States produces, stores, and transports abundant and affordable natural gas supplies to demand centers and to an ever-expanding base of customers in every region. In addition, clean energy mandates and the drive to reduce the prospective impacts of climate change and to improve air quality are prompting the retirements of coal plants and accelerating the switch from coal to gas in the U.S. power sector.

Environmental regulations at every level are prompting switches to energy sources with lower carbon emissions than coal, oil, and other fossil fuels; these include a range of renewable energy and energy efficiency technologies but also clean-burning natural gas. In addition, the implementation of the country's first voluntary cap-and-trade program for emissions, New England's Regional Greenhouse Gas Initiative, coincides with the decline in coal generation and a rapid expansion in natural gas use as a baseload electric power source.

Persisting Constraints

Technology improvements and favorable economics have boosted domestic gas production, especially in U.S. shale basins, and have stimulated infrastructure investments to enhance gas system resiliency and reduce bottlenecks. In New England, however, the natural gas infrastructure is regularly constrained during periods of peak use, triggering price spikes and reduced customer service in the coldest days of winter.

Along the East Coast, from the Mid-Atlantic through New York and into New England, infrastructure limitations have constrained the flow of ample supplies of natural gas to needy customers. Although the exponential growth in the nearby Marcellus shale in the past half-decade has alleviated some of these constraints, more infrastructure investment is necessary. Even with the additional supply, natural gas prices have continued to soar during peak periods, because of the lack of storage and delivery systems.

During the cold snaps in the Northeast in 2012–2013, for example, natural gas prices across New England and in New York City rose to $34.38 per million British thermal units (MMBtu). One year later, during the southern shifts of the polar vortex in 2013–2014 (*1*), peak day prices more than doubled to $78.64 per MMBtu (2).

According to a recent Quadrennial Energy Review memo from the U.S. Department of Energy (DOE), price volatility in the winter of 2013–2014 rose even

PHOTO: WIKIMEDIA COMMONS

Salem Harbor Station in Massachusetts was until recently a working coal power plant. A smaller gas plant is planned for the site.

higher and briefly reached a threshold nearly four times the high price of the preceding year. Ways to reduce the number and intensity of price spikes must be addressed, as advocated in the memo:

> …extremely high natural gas prices (in excess of \$120/MMBtu, compared to summer prices of approximately \$5/MMBtu) resulted from a combination of strong demand, pipeline constraints, wellhead freeze-offs, limited regional liquefied natural gas (LNG) deliveries, and a lack of storage....The New England States Committee on Electricity … has declared the current state of affairs to be “unsustainable.” (3)

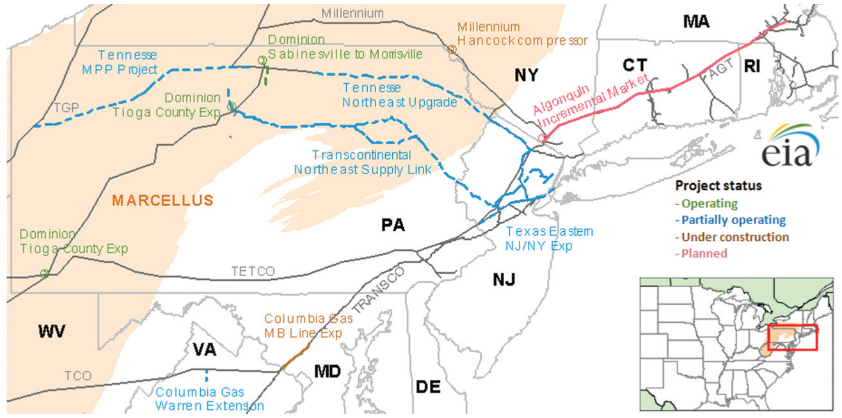


FIGURE 1 **Marcellus Shale Basin and natural gas pipelines in the surrounding region.** (SOURCE: Energy Information Administration)

Geology and Policies

New England’s geology is one of the major constraints on the infrastructure. The region lacks economically recoverable oil or natural gas deposits. In addition, the region is at the end of the line of the country’s oil and gas fuels system, geographically removed from most domestic production and infrastructure development activity—although the recent production within the Marcellus and Utica shale plays has shortened the distance that supplies must travel. New England historically has depended on natural gas imports from Canada, as well as on overseas LNG cargoes, some from the Middle East—the terminal in Everett, Massachusetts, has received supplies from Yemen in recent years.

Nevertheless, these are not the primary reasons for New England’s supply constraints. The regional limitations on natural gas supply and infrastructure stem mainly from two causes:

- ◆ Northeastern power markets traditionally have not provided incentives for power generators to secure supplies of natural gas; and
- ◆ New England states and certain constituencies have resisted industry and utility plans for pipeline development.

Producers, shippers, policy makers, and other stakeholders integral to natural gas transportation, storage, and distribution need to work collaboratively to navigate the issues and roadblocks, several of which are unique to New England. Boosting infrastructure capacity to deliver affordable gas supplies reliably to the region year-round remains an enormous challenge, but a favorable outcome is attainable for stakeholders and gas customers.

Pipeline Infrastructure

Although peak periods of demand frequently put stress on New England’s natural gas infrastructure, delivery during off-peak periods is relatively unconstrained. In 2014, regional natural gas prices mirrored prices associated with Marcellus gas production and—in some instances—fell below national benchmarks.

Nevertheless, pipeline infrastructure constraints persist, particularly in highly populated areas such as Boston, Massachusetts; Hartford, Connecticut; and other Northeastern cities. These locations present challenges to infrastructure construction, as do mandates for conservation, concerns about environmental safety and health, and stakeholder opposition to the construction of new projects. In addition, electricity markets are not offering incentives for the construction of new natural gas infrastructure.

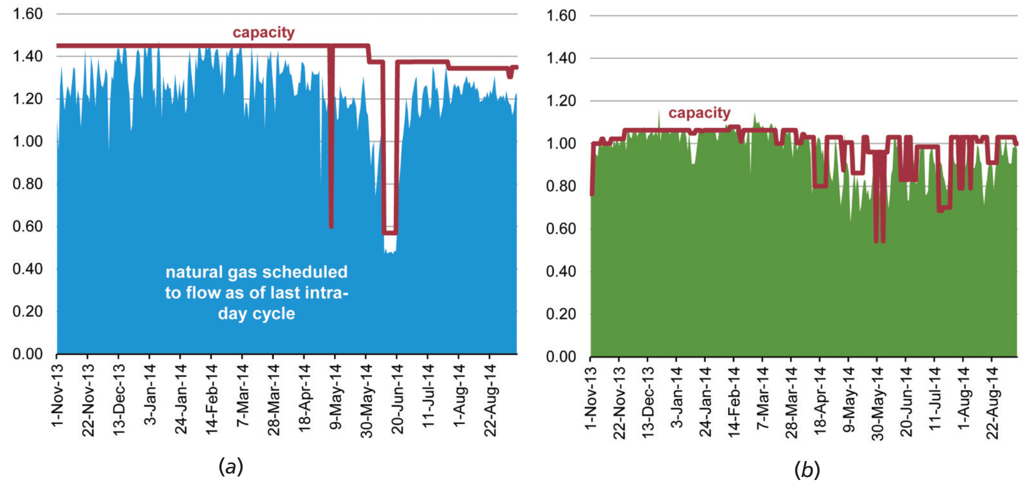
Favorable Developments

Despite these obstacles, several developments are beginning to benefit New England gas consumers—for example,

- ◆ Key natural gas pipeline systems—such as the Tennessee and Algonquin—have delivered natural gas into New England at or close to maximum capacity since the start of the recent winter fuels season (see Figure 1, above, and Figure 2, page 20) (4); and
- ◆ Several expansions of gas pipeline systems are planned and should alleviate regional transportation infrastructure constraints. Stakeholder opposition, however, may arise from environmental groups opposed to the use of natural gas produced from hydraulic fracturing processes—the operations are water-intensive and use chemicals that may require subsequent treatment, storage, and disposal.

One promising natural gas infrastructure project involves the pipeline operator Spectra Energy, based in Houston, Texas, and Northeast Utilities of Hartford and Boston. The \$3 billion investment in new pipeline capacity will deliver 1 billion cubic feet (Bcf) per day

FIGURE 2 Natural gas shipments into New England in billions of cubic feet per day from the (*a*) Algonquin and (*b*) Tennessee systems, at or near capacity since November 2013. (SOURCE: Energy Information Administration)



of natural gas to New England, which could supply nearly 3.5 million residences (*5*).

According to the *Boston Globe,* the plan will "expand the Algonquin pipeline, which runs from New Jersey to Everett, and the Maritimes & Northeast line, which carries [LNG] that is pumped from ships anchored in the waters off of Eastern Canada." If approved by the Federal Energy Regulatory Commission, which regulates interstate pipelines, the project would be completed in 2018.

The companies expect to recover the cost from customers by the first year after the project's completion (*5*). As with other gas infrastructure projects in the region, however, stakeholder opposition presents a key hurdle. Scientists and policy makers concerned about climate change maintain that continued investment in natural gas development, supplies, and infrastructure will delay widespread commercialization and deployment of renewable energy and of more energy-efficient technologies.

Natural Gas Storage

According to the Energy Information Administration (EIA), gains in natural gas production contributed to record storage levels in 2014, and production for the 2014–2015 winter season was projected to rise and remain robust, averaging approximately 71 Bcf/day—an increase of 3 Bcf/day, or approximately 4.5 percent, over the production in the preceding winter.

Working gas stocks in the final week of September 2014, however, were 373 Bcf—approximately 11 percent lower than at the same time the previous year. Nevertheless, EIA projected that natural gas storage inventories would suffice to meet the winter demand, even without the addition of significant new storage infrastructure.

Since the beginning of 2014, design capacity has increased by approximately 7 Bcf/day, but that is lower than in the preceding years. Most of the recent and projected growth in storage capacity is in salt caverns in the "producing region"—which includes Kansas, New Mexico, Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Alabama. In addition, the rapid pace and significant volume of gas storage injections during the summer are expected to meet winter demand, barring extreme weather that lingers for days or weeks.

The high levels of gas production in 2014 and into 2015 led to another boost in storage. The Reliable Home Heating Act of 2014 (PL 113-125) required the EIA Administrator to report to the nation's governors on developments affecting the winter fuels season. Specifically, EIA noted that "at the end of the 2013–2014 heating season on March 31, natural gas inventories held in storage were nearly 1 trillion cubic feet (Tcf), or 55 percent below the five-year average. Replenishment of underground natural gas storage inventories has since been rising at a faster rate than the five-year average. EIA estimated further builds of storage inventories ... [to] well within 10 percent of the five-year average by the end of October [2014]" (*6*).

Nevertheless, New England remains vulnerable to price spikes driven by peak-day demand on the constrained pipeline capacity during extended periods of cold weather.

Imports and LNG

With the North American shale revolution, LNG imports have fallen almost to zero in every region of the United States except New England. The Everett LNG import terminal is the only facility receiving cargoes and has not applied for repurposing to export LNG. Regasification—the converting of LNG to natural gas—at the Everett facility places gas into the national pipeline system; the incoming fuel either adds to flows from peaking sources or replaces volumes taken from the Algonquin and Tennessee pipeline systems.

The importing of LNG and transport of natural gas raises issues unique to New England. For example, some of the imported LNG received at Everett is distributed by truck to plants serving peak use. The timeliness of the deliveries from cargo to customer depends on the distance to be traveled from Everett to the peaking plants.

Before the growth of gas-fired power generation in the Northeast, LNG tankers filled up import storage tanks throughout the year, with distribution concentrated in the winter. This is no longer the norm, as market conditions and natural gas from North American sources have begun to reduce the volumes of imported LNG. Two offshore offloading systems store the LNG on a floating unit and regasify the LNG before pumping supplies to shore via subsea pipelines.

New England traditionally has been a seasonal market, heavily dependent on peak shaving, which allows customers to reduce their purchases of energy generated by a utility company during peak hours, when the cost of providing supplies is highest. This alleviates demands on the regional pipeline delivery capacity, which is well below peak-day sendout requirements.

Everett is the only terminal in the world originally built for servicing peaking operations. The significant volumes of LNG delivered to the peak-shaving plants via truck, however, are subject to weather and road conditions.

Offshore Systems

New England also has the only two remaining "energy bridges" in the United States—buoy systems that allow ships to moor and offload LNG. The LNG can be

PHOTO: ARI HERZOG, FLICKR

The Everett Marine Terminal regasification site, on the Mystic River near Boston Harbor, is the only liqufied natural gas (LNG) import terminal in the country.

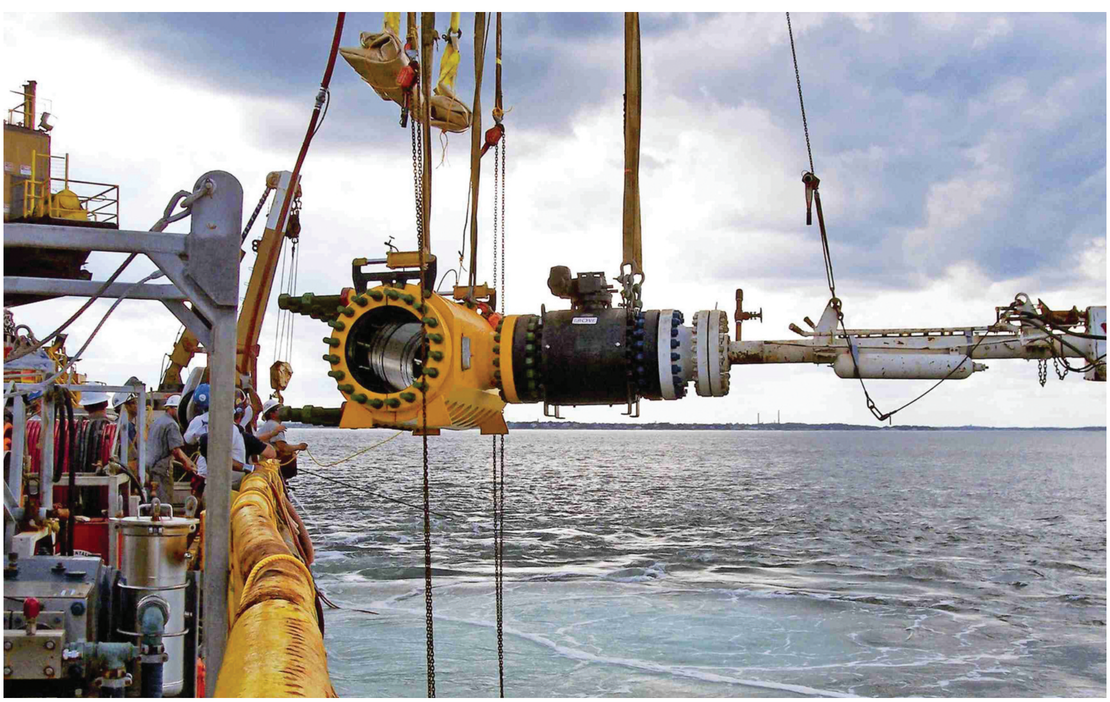
regasified at Excelerate's Northeast Gateway facility, 13 miles off Gloucester, Massachusetts, and pumped via subsea pipeline to shore (*6*). The Excelerate facility uses a floating storage and regasification unit (FSRU) and delivers the gas through a submerged buoy connected to a subsea pipeline. After delivery, the FSRU disconnects from the buoy and sails away. The only fixed infrastructure is the subsea buoy and pipeline that transports the gas to shore.

When not delivering cargoes to the area, Excelerate uses the FSRU for other projects worldwide. Although Excelerate has not delivered LNG to the Northeast Gateway facility since 2011, the facility remains operational. The Excelerate FSRUs vary in storage capacity from 138,000 to 174,300 cubic meters of LNG, or approximately 4.9 to 6.1 million cubic feet.

Other LNG Delivery Issues

LNG import cargo vessels require a high level of security when approaching and operating within U.S. ports. For example, when shipments originate from

PHOTO: SPECTRA ENERGY



The offshore Northeast Gateway LNG facility, approximately 18 miles east of Boston in Massachusetts Bay, moves natural gas into a subsea pipeline connecting to the pipeline system on land.

The U.S. Coast Guard and local law enforcement officials escort an inbound LNG container into the Boston Harbor. Many LNG shipments originate from turbulent regions and require increased security.

PHOTO: KELLY TURNER, U.S. COAST GUARD

Yemen and other nations associated with terrorist activities, the U.S. Coast Guard provides escorts and conducts inspections, including dive teams that look for explosive devices. This raises potential for delays.

The LNG export terminal under construction in Cove Point, Maryland, could serve as an emergency alternative for deliveries to the Everett import terminal. In 2012, for example, LNG cargoes from Yemen were disrupted when terrorists destroyed portions of the pipeline servicing the Yemen LNG export terminal. The loss caused a spike in prices for New England gas customers.

Potential options of shipping LNG from Cove Point to Everett, however, would require an amendment to the Jones Act, the federal statute governing aspects of oil and gas maritime trade. According to James Jensen, a noted expert on natural gas and the global LNG market, any shipment "between U.S. ports triggers the Jones Act, which requires U.S. flag vessels, built in U.S shipyards. This severely complicates the economics of any shipment of domestic LNG to domestic regasification facilities." Jensen suggests that a possible option may be a "dedicated barge" from Cove Point to Everett.

Reducing Vulnerabilities

Domestic gas production is expanding across the United States. Primarily as a result of the productivity of the Marcellus shale play, the Northeast region is poised to experience the economic benefits of domestically produced and affordably priced natural gas supplies. New storage and transportation infrastructure coming online will satisfy the growth in demand year-round and will greatly reduce the vulnerability of peak-day supplies.

PUBLISHER'S NOTE: The views expressed in this article are the author's and do not represent official policy of the U.S. Department of Energy.

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PENNSYLVANIA ROADS AND MARCELLUS FRACKING OPERATIONS

A Peaceful Coexistence in Lycoming County

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Williamsport, Pennsylvania, known as the home of the Little League Baseball International World Series, also serves as the county seat of Lycoming County, located at the epicenter of the Marcellus shale play. The state of Pennsylvania, partnering with Lycoming County, has taken bold steps with the gas industry to ensure that roads and bridges stay safe and sound today and for future generations while receiving the significant economic benefits of natural gas development.

Discovering Marcellus

In early 2008, people wearing cowboy hats and boots started arriving in large numbers in North Central Pennsylvania to record gas drilling leases at the County Register and Recorders Office. County employees had no idea why the crowds were lining up at the photocopiers. The sleepy town of Williamsport, which resembles television's Mayberry RFD, was awakening to new economic prospects like those of the California Gold Rush of 1849.

After talking to the so-called "landmen," the Lycoming County commissioners began to realize the potential of the Marcellus shale discovery and its eventual impact on every aspect of life throughout the county and its communities. Lycoming County previously had experienced the great lumber boom of the late 19th century, which had created more millionaires per capita in Williamsport than in any city in the world at the time.

The Marcellus shale and the underlying Utica shale formations are expected to remain a source of natural gas for many years; the duration and intensity of industry activity, however, are unpredictable. The volatility of the natural gas industry and its growth in Lycoming County result from changes in

- Natural gas prices,
- Federal and state legislation and regulations, and
- Residential, commercial, and industrial energy consumption.

PHOTO: ANDREW LEE, U.S. AIR FORCE

Home to the Little League World Series, Williamsport, Pennsylvania, was the site of a 19th-century lumber boom and is the center of the Marcellus shale play.

The Community Natural Gas Task Force researched and proposed public policy changes to handle the changes resulting from the natural gas exploration boom in Lycoming County.


PHOTO COURTESY MARK MURAWSKI

Currently, natural gas drilling in Lycoming County has slowed, with an ample supply of gas, lower gas prices, and pipelines operating at capacity; nevertheless, many new pipelines are under construction.

The Marcellus gas play may be the largest natural gas find in the nation and the second largest in the world. The U.S. Geological Survey estimates that the formation's total area—which spans Pennsylvania, New York, West Virginia, Ohio, and Maryland—covering approximately 95,000 square miles, to range in depth from 4,000 to 8,000 feet, and to contain more than 410 trillion cubic feet of natural gas—capable of supplying the nation's energy needs for decades. The Marcellus play includes approximately 40 Pennsylvania counties.

Taking Action

Acting with foresight, the Lycoming County commissioners and the Williamsport–Lycoming Chamber of Commerce quickly established Pennsylvania's first Community Natural Gas Task Force in 2008. The 18-member task force was charged to "identify key issues, research facts and information, and review and propose public policy regarding the positive, economic impacts of gas exploration of the Marcellus shale in Lycoming County."

The task force members immediately traveled to Tarrant County, Texas, for a better understanding of the impacts of gas exploration from the Barnett shale play. The task force is not a regulatory body overseeing the gas industry but a forum to address Marcellus-related issues collectively and in consultation with the gas industry, to realize positive economic impacts and to minimize negative impacts through cooperation and collaboration.

Drilling and Piping

Lycoming County is the largest in Pennsylvania in terms of land area—larger than the state of Rhode Island. More than 60 percent of the county's land area is under lease for oil and gas exploration.

Gas companies have drilled 838 wells countywide since 2008—approximately 11 percent of the well drilling throughout the state (Table 1, below). Drilling reached a peak in 2011 and leveled off in recent years as natural gas prices fell and a surplus of gas was available on the market (Figure 1, page 25).

In addition to well drilling, extensive work has expanded the natural gas transmission pipeline system to deliver the product efficiently to market. The pipeline infrastructure required significant investment in building hundreds of miles of new pipelines; before Marcellus, the pipeline network was limited.

More than 100 gas mining or gas mining support companies have located in Lycoming County during the seven-year boom. Major gas drillers include Anardarko, Exco, and Range, and many others have a presence.

Although Lycoming County wells make up approximately 11 percent of the state's total active wells, the county wells produced 15 percent of all the gas from the state's unconventional wells in the first half of 2014. Lycoming ranked third in production statewide.

Impacts on Roads

Lycoming County has worked closely with the Pennsylvania Department of Transportation (DOT) to develop a working plan to ensure the safety and preservation of roads and bridges that receive the transportation impacts of Marcellus activity.

In Lycoming County, each natural gas well pad typically occupies 3 to 5 acres of land and includes 6 to 8 wells. The pad development occurs over a four- to six-week period. Construction requires

TABLE 1 Pennsylvania's Active Unconventional Gas Wells, by County

Rank	County	Active Unconventional Gas Wells
1	Washington	1,149
2	Bradford	1,107
3	Susquehanna	1,076
4	Greene	873
5	**Lycoming**	**838**
6	Tioga	662
7	Butler	324
8	Fayette	256
9	Westmoreland	249
10	Wyoming	226
	All Others Combined	1,063
	Total	7,823

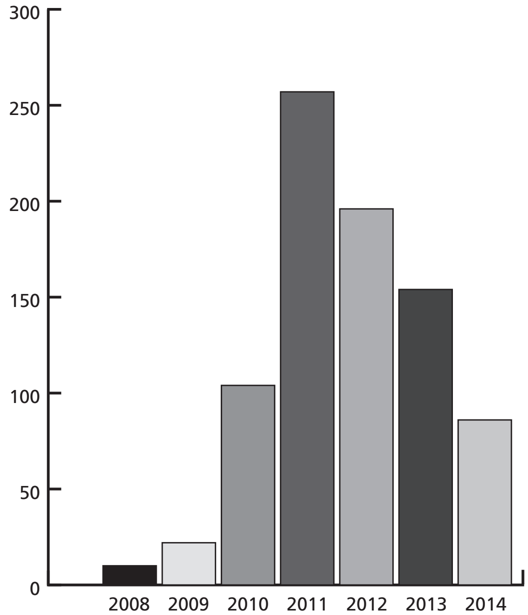

FIGURE 1 Unconventional wells drilled in Lycoming County, 2008–2014.

approximately 5,000 tons of aggregate, which generates 300 to 400 truck trips.

After construction, well drilling operations involve the transportation of more equipment, water, and cement via 150 to 200 truck trips over four to five weeks. When the well is drilled and the fracking resumes, 800 to 1,000 truck trips are needed to transport 3 million to 6 million gallons of water and frac sand over one to two weeks.

In all, the two- to three-month well pad development, well drilling, and gas fracking process requires a total of 1,250 to 1,600 truck trips per pad site. This level of truck and employee traffic on largely rural roads creates substantial impacts, considering the weight and size of the vehicles and the frequency of travel on roads and bridges not originally designed or built to accommodate intense heavy hauling.

Posting and Bonding

To address the impacts of heavy hauling, Pennsylvania issued Motor Vehicle Code Title 75 and 67, along with Pennsylvania DOT Publication 23, to establish laws, regulations, and policy for the posting of vehicle weight-and-size restrictions for roads and bridges and authorizing bonds to ensure that heavy haulers corrected the damages from their activity. The state posting and bonding program manages vehicles that weigh more than 10 tons and less than 40 tons on roads and bridges unable to support heavy truck traffic. In Pennsylvania, a road or bridge that cannot structurally support 40-ton loads must be posted with the appropriate weight limit determined by an engineering analysis.

Section 189.4 of the Pennsylvania Motor Vehicle Code states that no vehicle "shall be driven on a posted highway with a gross weight in excess of the posted weight limit unless the posting authority has issued a permit…." Procedures require the posting authority to conduct an engineering study to determine the appropriate weight limit for the road or bridge, to provide public notice, to notify law enforcement, and to install the appropriate signage.

Pennsylvania DOT approves posting and bonding on state-owned highways, and local municipalities approve posting and bonding on locally owned roads. To be able to enforce weight limits and to issue permits for heavy hauling, however, municipalities must follow the Pennsylvania Motor Vehicle Code when posting and bonding locally owned roads and bridges.

Permits and Agreements

The types of permits issued to heavy haulers include the following:

◆ Type 1, permitting one truck on one travel route;

◆ Type 2, permitting multiple trucks on one

Photo courtesy Mark Murawski

Workers at a well rig in Lycoming County; well pad development generates as many as 1,600 heavy-haul truck trips.

One of the nearly 840 wells in Lycoming County. Eleven percent of the state's oil drilling takes place within county borders.

PHOTO COURTESY MARK MURAWSKI

travel route—most of the Marcellus activity is under this variety of permit;

◆ Type 3, permitting one truck on multiple travel routes; and

◆ Letter of local determination, or LoLD, permitting multiple trucks on multiple routes.

The road posting authority and the heavy hauler execute an agreement establishing an initial road inspection, the excess maintenance responsibilities, the payments to make necessary repairs, an approved road maintenance plan, and roadway condition surveys for heavy users. The hauler provides financial security in accordance with the permit type, ranging from $6,000 per mile for unpaved roads to $12,500 per mile for paved roads under Type 1 and Type 2 permits. Type 3 permits, which apply throughout a county or municipality, cost $10,000. Certain types of local traffic may be exempt from posting and bonding requirements.

PHOTO: UNIVERSAL WELL SERVICES, COURTESY MARK MURAWSKI

The many heavy vehicles required for construction and drilling activity have had a significant effect on the low-volume roads in Lycoming County.

Data and Training Needs

According to the most recent data from Pennsylvania DOT's Bureau of Maintenance and Operations, Lycoming County includes 385.4 miles of posted, state-owned roadways; this represents about 50 percent of the total state-owned road mileage in Lycoming County. Bonded state-owned roads total 198.2 miles, or 25 percent of the county's roads.

No up-to-date, comprehensive, or reliable database is available for locally owned roadways that are posted and bonded in Lycoming County. Each municipality in the state establishes its own database system.

Lycoming County's information on local road posting and bonding is limited and outdated. Municipal outreach to collect these data in the past was unsuccessful, because many municipalities did not respond. Lycoming County is partnering with Pennsylvania DOT through the Local Technical Assistance Program to offer technical courses and training for municipal officials on establishing a posting and bonding program for local roads and bridges, allowing the legal enforcement of weight limits.

Maintenance and Upgrades

The Marcellus industry has spent millions to maintain and upgrade state and locally owned roads that have been posted and bonded, ensuring that these roads remain safe and passable, meet industry transportation needs, and offer generally improved pavement conditions. The major state-owned roads that are not posted and bonded, however, are subject to accelerated life-cycle pavement deterioration from the substantial increases in truck traffic; these roads may require more frequent and more costly treatments.

The Pennsylvania General Assembly recently passed PA Act 89, which will provide more revenue by lifting the cap on the oil company franchise tax and by increasing certain fees and fines. PA Act 13 assesses oil and gas drillers with an impact fee to mitigate a range of impacts from natural gas exploration, including the impacts from transportation. The state collects the fee and distributes a portion to counties and local municipalities according to the number of locally drilled wells.

These two legislative measures have enabled Pennsylvania to address transportation needs beyond what would be possible with a traditional program


Photo: Gerry Dincher, Flickr

This road in the Marcellus formation has been improved by gas companies to ease access to drilling sites.

for road and bridge posting and bonding. Lycoming County and its municipalities have received millions of dollars through these programs for public infrastructure and for community services affected by the extensive drilling activity.

Bridge Improvements

Three state-owned bridges and 27 locally owned bridges are posted for weight limits in Lycoming County, the only county in the state that conducts routine inspections of locally owned bridges with spans 8 to 20 feet long. Federal regulations require the routine inspection of bridges of 20 feet and longer at least every two years.

Approximately 100 state and locally owned bridges in Lycoming County are structurally deficient and pose challenges for the heavy-hauling operations of Marcellus gas drilling. Long detours are often encountered, and gas companies occasionally have constructed "jumper bridges"—temporary bridge superstructure decks—for transporting heavier loads over a deficient bridge, to avoid a costly detour.

Lycoming County and Pennsylvania DOT are undertaking a bridge improvement program to reduce significantly the number of structurally deficient bridges and to prevent structural deficiencies in other bridges through proactive repair and maintenance.

Lessons from Lycoming

Lycoming Country's experience yields the following advice for states and counties experiencing transportation and community impacts from oil and gas exploration:

◆ Be proactive—learn early on about what the operations entail. Learn from other jurisdictions how to develop an asset management program in response to the drilling activity. Employ the program that will work for local needs and conditions.

◆ Be mindful about developing and implementing advanced road maintenance plans during periods of inclement weather, when heavy-hauling activity can take a toll on roads and bridges. In North Central Pennsylvania, for example, winter weather freeze–thaw cycles soften roads, which become more susceptible to breaking up under heavy loads with inadequate pavement structures.

◆ Partner with the oil and gas industry in a spirit of cooperation. Citizens want and expect good roads and bridges, as does the gas industry, which relies on the network for business.

Lycoming County serves as a shining example that Pennsylvania Roads and Marcellus fracking activity can and do coexist.

The Lance Corporal Abram Howard Bridge replaced the former Arch Street Bridge over the West Branch Susquehanna River. Lycoming County and the Pennsylvania Department of Transportation have started a proactive maintenance and repair program for area bridges.


Photo: Gerry Dincher, Flickr

Photo: USD Partners, LP

TRANSPORTING CRUDE OIL BY RAIL IN NORTH AMERICA

Economics, Logistics, Safety, Lessons Learned, and Outlook

MALCOLM CAIRNS

The author is Proprietor, Malcolm Cairns Research and Consulting, Manotick, Ontario, Canada.

(*Photo above:*) The crude-by-rail origination terminal in Hardisty, Alberta, Canada, can accommodate up to two 120-railcar unit trains per day and also includes loop tracks that can hold five unit trains simultaneously.

The increased movement of crude oil by railroads in North America has gained continuing interest from the media. As recently as 2009, crude oil moved almost exclusively by pipelines, but since then, railroads have begun to transport crude oil in volumes that are increasing significantly each year.

In 2013, railroads moved approximately 500,000 carloads of crude oil originating throughout North America: 430,000 carloads were delivered to terminals in the United States, and 70,000 carloads to terminals in Canada.

The sources of these shipping increases are twofold: first, the rising production of nonconventional shale oil—also known as tight oil—in the United States; and second, the rising production of nonconventional oil sands in Canada.

Nonconventional Production

Shale Oil

Huge quantities of crude oil are trapped in nonpermeable shale rock, and in the past few years, technological advances—especially in hydraulic fracturing, also called "fracking," and in horizontal drilling—along with higher prices for crude oil, have made recovery of much of this oil economically feasible. Table 1 (page 29) lists the principal shale oil deposits in the United States with their recent production volumes in barrels per day.

Shale oil production in North Dakota, in particular, is taking place at locations not readily served by the pipeline network; producers therefore have resorted to moving the oil from the well head by short-haul truck to rail loading terminals for transport across the continent by rail.

Accompanying the shale oil revolution is a reduction in North American imports of crude oil from countries such as Venezuela. The coastal oil refineries on the eastern and western seaboards and the Gulf Coast are configured to receive oil by ship and are not designed to receive significant volumes from inland by pipeline—this too has encouraged the delivery of crude oil by rail.

TABLE 1 U.S. Nonconventional Crude Oil Production: Shale Oil

Shale Oil Play	Location	Estimated Barrels per Day October 2014
Permian	Western Texas	1,757,000
Eagle Ford	Southern Texas	1,582,000
Bakken	North Dakota and Montana	1,179,000
Niobrara	Wyoming, Colorado, South Dakota, and Nebraska	362,000
Haynesville	Arkansas, Louisiana, and Texas	56,000
Marcellus	Northern Appalachian Basin	52,000

Source: U.S. Energy Information Administration.

Oil Sands

Although shale oil deposits are under development in Canada, the Canadian oil sands are of particular interest. The sources are situated primarily in Alberta in three distinct locations—the Athabasca, Cold Lake, and Peace River oil sands. Two methods of oil extraction are used: mining and in situ.

Mining extraction was adopted first. The method is associated with images of disturbed mining areas and is limited to the Athabasca oil sands. The land disturbance, however, affects a relatively small area. The product is bitumen-in-sand. Bitumen is a viscous oil and is upgraded locally into synthetic crude oil; the process involves quantities of water that are discarded into tailing ponds.

In situ extraction requires drilling to greater depths, heating water, and pumping the steam into underground pipes; this heats the bitumen, generating flows to the surface. The method causes only slightly more land disturbance than conventional oil extraction.

In situ bitumen is mixed with a diluent, becoming what is called "dilbit," which can flow through a pipeline. Eventually 10 percent of oil sands recovery will use the mining method, and 90 percent will use in situ. Recent production volumes of synthetic crude oil and in situ bitumen are presented in Table 2 (below).

TABLE 2 Canadian Nonconventional Crude Oil Production: Oil Sands

Method	Product	Average Barrels per Day, 2013
In situ	Bitumen	977,798
Mined	Synthetic crude oil	900,856

Source: CAPP Statistical Handbook, July 2014.

Photo: Suncor Energy Inc.

Trucks serving the Suncor mine near Fort McMurray, Alberta, Canada, deliver approximately 500,000 tonnes of oil sands per day to ore preparation plants.

Configured to receive oil by ship from overseas, refineries on the West Coast—such as this near Los Angeles, California—are affected by increased domestic oil production.

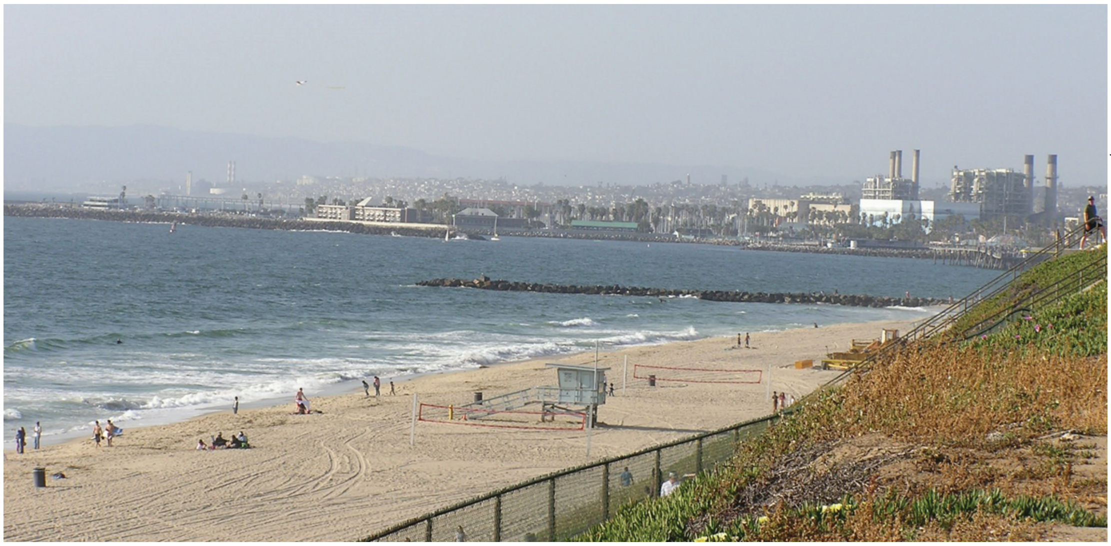

Photo: Stephen Marchetti, Flickr

Role of Pipelines

The outbound product of the Canadian oil sands—synthetic crude oil and dilbit—initially moves by pipeline. The Canadian Energy Pipeline Association describes the process as follows:

> Producing oil fields commonly have a number of small diameter gathering lines that gather crude oil from the wells and move it to central gathering facilities called oil batteries. From here, larger diameter feeder pipelines transport the crude oil to nearby refineries and to long-haul pipelines. The largest pipelines, called transmission lines, transport crude oil and other liquids across the country. (*1*)

No direct rail service reaches the oil sands region, and the outbound product is transported initially via the gathering and feeder pipelines to storage facilities in the Edmonton and Hardisty areas. Transmission pipelines and the two Class 1 Canadian freight railroads—CP and CN—serve these areas.[1]

The transmission pipelines from Western Canada, however, are at or near capacity with conventional and nonconventional oil. The anticipated increased production of nonconventional oil therefore has generated proposals to increase pipeline capacity. The proposals include the TransCanada Keystone XL into the United States, the Enbridge Northern Gateway and Kinder Morgan Trans Mountain expansion to the West Coast, and the TransCanada Energy East proposal in eastern Canada.

Objections from environmental groups and from Canadian First Nations have delayed the development of these proposals. As a result, producers have turned to moving crude oil by rail, at least as a temporary measure.

Protesters rally against a planned Kinder Morgan oil pipeline on Burnaby Mountain, British Columbia, Canada, in late 2014.

Photo: Mark Klotz, Flickr

Crude Oil by Rail

Moving crude oil by rail requires terminals adjacent to rail lines for loading and unloading. North Dakota and Texas, in particular, have dozens of newly built rail loading terminals, with many other terminals opening on the East, West, and Gulf Coasts. In addition, Canada has 20 loading terminals in operation or under construction on the prairies; these will have the capacity to handle more than 1 million barrels per day.

Crude oil moves on rail by tank car, and the increase in traffic has increased the demand for tank cars. The estimated manufacturing backlog consists of approximately 20,000 tank cars on order (see also the article in this issue by Barkan, Liu, and Saat, page 41).

[1] CN has a secondary rail line into the Fort McMurray area in the Athabasca oil sands, but the line is to the south, does not cross the North Saskatchewan River, and has limited storage facilities.

Figures 1 and 2 (right) present the number of carloads of crude oil in 2012, by origin and destination. North Dakota and Texas predominate as points of origin; Texas, Alabama, and Oklahoma predominate as destinations. Combining the data, the principal traffic flows are from North Dakota to the Gulf region. The transport of nonconventional crude oil by rail from Western Canada is only beginning. The two Western U.S. railroads, BNSF and UP, dominate in moving crude oil by rail (see Figure 3, below right).

Pipelines, however, remain the primary mode of transportation for crude oil in North America. Crude oil comprises less than 2 percent of total railroad traffic.

Advantages of Rail

In addition to providing transportation capacity in many areas with insufficient pipeline capacity, railroads offer other advantages for transporting crude oil, according to the American Association of Railroads (AAR) (2) and the Canadian Association of Petroleum Producers (3):

◆ *Geographical flexibility*. Railroads serve almost every refinery in the United States and Canada and offer flexibility in shifting product quickly to different places in response to market needs and price opportunities.

◆ *Responsiveness and low capital requirements*. Rail facilities can be built or expanded much more quickly than pipelines and refineries. A train loading terminal can be constructed in approximately 12 months, and loop tracks can accommodate 120 cars. Rail is the only transportation mode that can invest

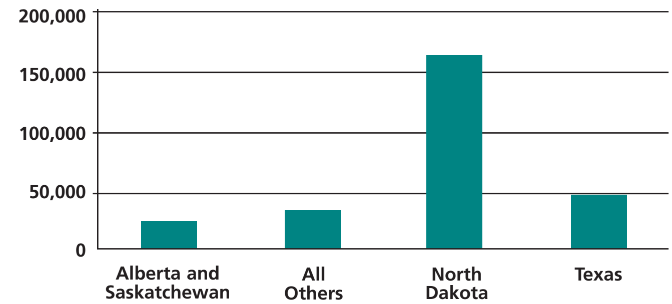

FIGURE 1 Origin of crude oil by rail, by number of carloads, 2012. (SOURCE: IHS)

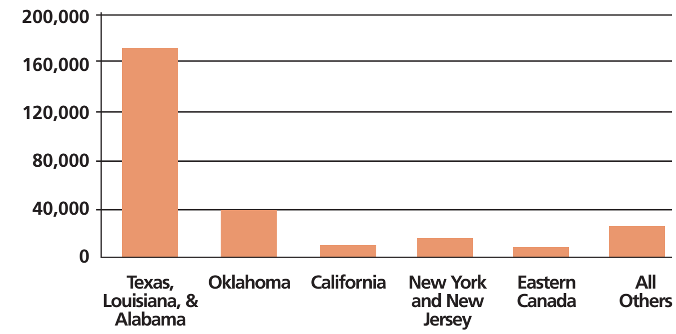

FIGURE 2 Destination of crude oil by rail, by number of carloads, 2012. (SOURCE: IHS)

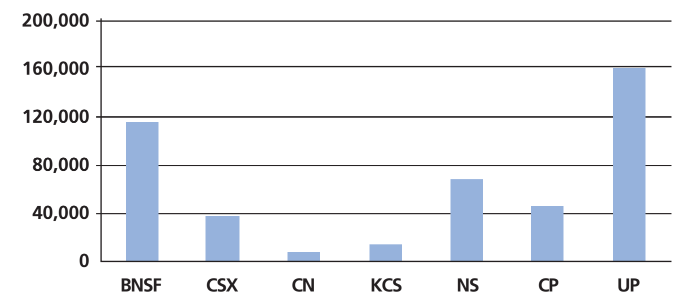

FIGURE 3 Terminated carloads by railroad, 2013. (SOURCE: IHS)

PHOTO: WADE HARRIS

Tank cars on siding at an oil refinery near Tulsa, Oklahoma. Railroads serve almost every refinery in the United States.

Unit trains for oil can comprise more than 100 cars.

PHOTO: JOSHUA PUTNAM

in facilities quickly enough to keep up with production growth in the emerging oil fields. The typical cost of building unit train terminals ranges from $30 million to $50 million, with a capital payout in 5 years or sooner.

◆ *Efficiency*. Railroads help crude oil customers find ways to load and unload tank cars more quickly and reduce delays en route. Unit trains often are a key to this process—these are long trains of 50 to more than 100 cars carrying a single commodity. Unit trains use dedicated equipment and generally follow direct shipping routes to and from facilities designed to load and unload the cars efficiently—for example, from a gathering location near oil production areas to an unloading terminal at or near a refinery. A unit train may carry 85,000 barrels of oil; be loaded or unloaded in 24 hours; and moving at an average of 20 miles per hour will reach its destination quicker than pipeline, so that the producers are paid sooner, and the refiners receive feedstock sooner.

◆ *Product integrity*. Crude oil shipped in separate rail tank cars has no loss of quality at the destination; the oil is not mixed with other grades for transport.

Modal Economics

One disadvantage, however, is that rail can be less reliable than pipeline because of weather or other unforeseen circumstances. Moreover, moving crude oil is generally less expensive by pipelines than by rail, and pipelines therefore continue to capture the dominant market share.

Table 3 (lower left) illustrates the relative economics of pipeline and rail, particularly for transporting Canadian oil sands, under different scenarios, as estimated by IHS Energy (*4*)—all costs are in U.S. dollars per barrel:

◆ The pipeline cost for moving dilbit from Western Canada to the U.S. Gulf Coast is approximately $10.50—but dilbit is 28 percent diluent, and acquiring and transporting the diluent increases the total cost to $16.50.

◆ The rail cost for moving dilbit from Western Canada to the U.S. Gulf Coast comprises the gathering and loading costs, the leasing costs for the tank cars, the unloading costs, and the direct costs for rail transport, for a subtotal of $18.25. Adding the costs of acquiring and transporting the diluent by rail brings the total cost to $26.25.

◆ The total rail cost for moving shale oil from the Bakken region to the East Coast is $14.50—shale oil is light crude and requires no diluent.

The differential between pipeline and rail for moving dilbit, estimated in Table 3, is $10 per barrel—and the cost of moving shale oil is close to similar pipeline costs. These differentials, however, must be considered in the context of price discounts for crude oil from the region, which have been in excess of $20 per barrel at various times because of pipeline constraints.

TABLE 3 Comparative Costs, Pipeline Versus Rail

		US$ per barrel		
Mode	Product and Destination	Crude Oil	Diluent	Total
Pipeline	Western Canada dilbit to U.S. Gulf Coast	10.50	6.00	16.50
Rail	Western Canada dilbit to U.S. Gulf Coast (average)	18.25	8.00	26.25
	Bakken shale oil to East Coast (average)	14.50		14.50

SOURCE: IHS.

Diluent Factors

Transportation by rail does not require diluent, and rail can move near-raw bitumen; this can favor the economics of moving oil sands by rail. Most of the diluent in typical dilbit is added during production to aid in separating oil and water. At that stage, the bitumen blend contains about 20 percent to 25 percent diluent.

Pipeline specifications require increasing the diluent to approximately 28 percent per barrel. With rail transport, the oil sands can be shipped directly from production, with the lower levels of diluent. This product is known as “railbit.”

Removing diluent to below production levels requires a specialized diluent recovery unit (DRU). A DRU can yield a near-bitumen-only product, called “neatbit,” which consists of less than 2 percent diluent. The cost of operating a DRU is an estimated $1 per barrel.

Moving near-raw bitumen by rail requires specialized nonpressure tank cars equipped with insulation and interior or exterior heater coils that prevent solidifying in cold weather. Before unloading, steam, hot water, or hot oil lines are attached to the coil inlets and outlets. As the heating medium circulates, the coils heat the bitumen and facilitate unloading.

Taking all these factors into account, IHS estimates that moving railbit can cost $2 per barrel less than moving dilbit, and that moving neatbit costs $6 per barrel less than moving dilbit.

Safety Matters

Media interest in the movement of crude oil by rail traces primarily to the July 2013 tragedy in Lac-Mégantic, Quebec, Canada—a unit train carrying Bakken crude oil to Saint John, New Brunswick, became a runaway, derailed, and exploded, killing 47 people. This was the worst rail accident in North America in 100 years.

How safe, then, is the movement of crude oil by rail, and how does the level of safety compare with that of pipelines? Only recently has crude oil moved by rail; historical comparisons therefore require care. An AAR analysis compared rail and pipeline safety over a 20-year period for products that are hazardous liquid commodities—crude oil, gasoline, diesel fuel, petroleum liquids, propane, kerosene, and others. Table 4 (below) summarizes the results; the following points may be highlighted:

◆ Rail experienced a 40 percent increase in total commodities moved between 1990 and 1999 and between 2000 and 2009; in contrast, pipeline totals have remained essentially flat. Overall, however, pipelines move approximately 30 times more product than rail and are the dominant mode.

◆ Pipeline releases involve significantly more product, but pipelines also move significantly more product; the release rates in barrels per billion barrel miles are similar for rail and pipelines during the period of 1990 to 1999.

◆ Release rates for the period of 2000 to 2009 reveal significant reductions for both rail and pipelines, but rail has made better progress—16.5 barrels per barrel miles compared with 23.9 barrels per barrel mile for pipelines.

◆ If each mode moves the product an average 3,000 miles, then in the 20-year period, rail would have moved nearly 1 billion barrels, and pipelines would have moved nearly 30 billion barrels. The quantities released in that period would have been less than 1 one-hundredth of 1 percent of the total moved by both modes.[2] Given the risks inherent in any large-scale industrial activity, both modes are safe in terms of the quantities of product released accidentally.

◆ Similarly, fatalities and injuries for the 20-year period are low, and both modes are relatively safe compared with other modes of transport, particularly highways. Three rail fatalities in the United States over 20 years puts the extraordinary single event at Lac-Mégantic into perspective.

More recently, according to AAR statistics, the hazmat accident rate has continued to decline; in 2012, the rate on U.S. railroads was 0.013 train accidents with a release per 1,000 hazmat carloads—a 38 percent drop from 2000 (*5*). Applying the 2012 rate to the 500,000 crude oil carloads moved in 2013 would suggest six or

[2] Because the average hauls for both modes are likely to be less than 3,000 miles, the release rate percentages would be lower than indicated here.

TABLE 4 Hazardous Liquid Pipelines Incidents in the United States, 1990–2009

	Rail					Pipeline				
Years	Total Transported (billions of barrel miles)	Gross Quantity Released (barrels)	Barrels Released per billion barrel miles	No. of Fatalities	No. of Injuries	Total Transported (billions of barrel miles)	Gross Quantity Released (barrels)	Barrels Released per billion barrel miles	No. of Fatalities	No. of Injuries
1990–1999	1,135,096	41,825	36.8	1	13	42,851,300	1,525,930	35.6	23	126
2000–2009	1,583,074	26,147	16.5	2	27	41,900,158	1,002,679	23.9	19	55
Total, 1990–2009	**2,718,170**	**67,972**	**25.0**	**3**	**40**	**84,751,458**	**2,528,609**	**29.8**	**42**	**181**

seven train accidents involving a release of crude oil. A list compiled by the Congressional Research Service confirms that projection: six accidents and two incidents from rail derailments involving North American crude oil in 2013 and into 2014 (6).

Lessons from Lac-Mégantic

Despite the improving performance and relative safety of moving hazardous materials, including crude oil, by rail, public concern after the Lac-Mégantic tragedy is justifiable. In the immediate aftermath, government agencies in Canada and the United States issued emergency orders to tighten operating rules to prevent runaways by trains carrying dangerous goods.

The circumstances of the event raised four additional issues:

- ◆ The safety of unit train operations, particularly in the vicinity of built-up areas;
- ◆ The propensity of the tank cars involved—DOT-111s—to rupture, releasing product;
- ◆ The correct labeling of the product—the shale oil at Lac-Mégantic was mislabeled; and
- ◆ The information and resources available to communities and first responders.

The Canadian and U.S. governments and their agencies are addressing these issues.

Train Operations

High-hazard flammable trains (HHFTs) comprising 20 or more carloads of a Class 3 flammable liquid—crude oil or ethanol—will be subject to increased oversight. Requirements may include assessments of routing safety and security, detection of wheel defects, rail inspections, speed restrictions, and enhanced braking.

Tank Cars

Canada's Transportation Safety Board and the U.S. National Transportation Safety Board had issued recommendations earlier on DOT-111 tank cars, addressing the vulnerability to rupture in an accident. Government agencies are establishing enhanced standards for new tank cars on HHFTs; retrofitting cars in HHFTs; and retiring or repurposing cars not retrofitted, or operating those cars under speed restrictions for up to five years. The United States and Canada will harmonize the regulations to avoid constraints on transborder rail traffic.

Hazardous Product Labeling

Shippers will be required to improve the classification and characterization of mined gases and liquids, such as crude oil, with an enhanced sampling and testing program. Shippers must certify that the program is in place, document the testing and sampling, and make information available on request.

Photo: Robert Ashworth

A BNSF railyard in Pasco, Washington. BNSF and Union Pacific dominate the market share of oil transport by rail in the United States.

Information to Communities

Railroads will be required to notify State Emergency Response Commissions (SERCs) or other appropriate state entities about the operation of HHFTs through their jurisdictions. Railroads will work to inform state and local emergency response officials about the commodities moving through their area and to ensure that personnel are trained to respond in an emergency. Railroads are providing $5 million to develop specialized crude-by-rail training and a tuition assistance program for local first responders.

Altogether, these enhancements are expected to reduce the frequency of derailments, environmental damage, and the total costs of injuries and fatalities over 20 years for any of the scenarios examined (*7*).

Outlook

Production

AAR reports that U.S. rail traffic of petroleum and petroleum products had increased by 12.5 percent as of September 27, 2014, over totals for the same period in 2013. CP and CN in Canada also reported similar increases. The growth of crude oil by rail shows no let-up.

The Energy Information Administration (EIA) has projected increases for U.S. and Canadian oil production through 2040 (Figure 4, above right). Between 2011 and 2040, the average annual growth rate is projected to be 1.1 percent for the United States and 2.4 percent for Canada, with a U.S. peak around 2020, but Canada's output increasing throughout the period.

Although EIA projects a peak in U.S. oil production, technological developments associated with shale oil may push the peak higher and later. In 2013, the Alberta Energy Resources Conservation Board estimated the recoverable Alberta bitumen and oil deposits would yield 2,268 billion barrels of original-oil-in-place; in comparison, Saudi Arabia and Venezuela would yield a combined total of 2,016 billion barrels (*8*).

Innovations

According to a recent article in *The Economist*, innovation promises to reduce energy use and emissions in the oil sands production processes: adding oil-based solvents to steam increases in situ recovery while reducing water use by 15 percent (*9*). A pilot project under way has replaced steam by injecting solvents under pressure at much lower temperatures; and a second pilot is melting bitumen with microwaves, which could decrease energy costs by 80 percent.

Another possibility is to generate the electricity required for the process with nuclear reactors designed to be small enough to be trucked from Edmonton to the oil sands operations around Fort McMurray. These innovations may help ensure the efficacy and sustainability of oil sands production.

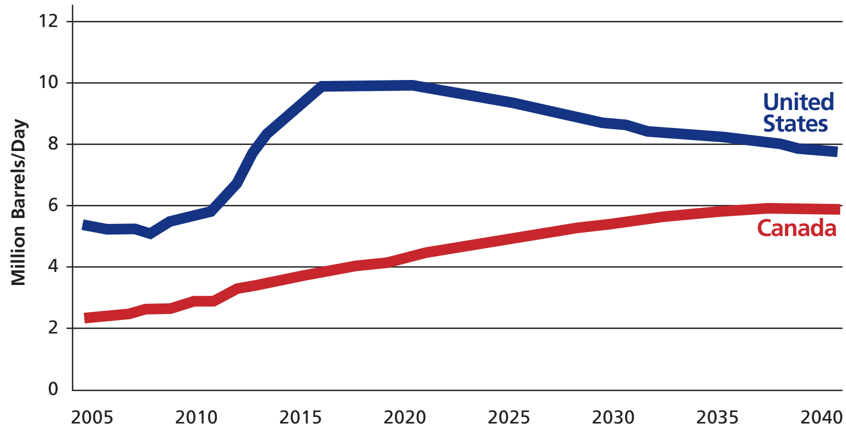

FIGURE 4 U.S. and Canadian oil production, millions of barrels per day, 2005–2040.
(SOURCE: IHS)

Market Influences

With the potential growth in crude oil production in North America, the outlook for moving crude oil by rail is favorable—at least for the short to medium term. In the longer term, the outlook for rail depends in part on pipeline development, although longer-term niche markets for rail are likely to continue.

Recently, the price of oil in global markets declined significantly. This has led to the postponement of many new nonconventional oil developments in North America and to reductions in production. The rapid increase in the movement of crude oil by rail has stalled for the moment, and the outlook for the medium term is uncertain.

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TRB 2015 ANNUAL MEETING WORKSHOP

CRUDE OIL BY RAIL

Logistics and Community Impacts

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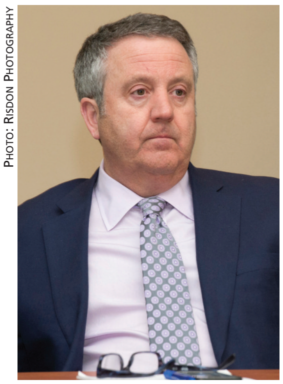
A half-day workshop at the 94th Annual Meeting of the Transportation Research Board explored the topic of Crude Oil by Rail: Logistics and Community Impacts. Private industry stakeholders and public-sector experts offered perspectives on current trends in the shipment of crude oil by rail.

"Replumbing of Hydrocarbons"

Graham Brisben of PLG Consulting reviewed the status of domestic energy production. He noted that the logistical landscape for crude oil looks much different from that of five years ago. Bakken crude oil delivered from North Dakota and Montana in dedicated unit trains has largely replaced the crude oil delivered from Alaska and foreign producers by waterborne transportation to the refineries on the Gulf of Mexico and on the Atlantic and the Pacific coasts. The change in crude oil sources has caused what Brisben termed a "replumbing of hydrocarbons" in North America. New pipelines are under construction, old pipelines are being repurposed, and—in some cases—the traditional direction of flow is being reversed.

Brisben predicted that with the current market price trends, shipments of crude by rail will continue to increase in the short term but at a slower rate. Shipments of crude oil by rail that originate in the Bakken region, which produces approximately 750,000 barrels per day, will increase to 900,000 barrels per day in 2017 but level off. Shipments of oil sands crude by rail will peak this year at approximately 450,000 barrels per day and then drop by half in 2019.

Photo: Risdon Photography



Matt Rose, BNSF Railway: The surge in domestic energy production is "the greatest business development of our time."

Enormous Benefits

Matt Rose of BNSF Railway—the largest rail carrier of crude oil in North America—described the surge in domestic energy production as "the greatest business development of our time." The decreased dependence on foreign sources for petroleum, particularly from areas of political unrest, will provide enormous benefits for long-term economic health

Photo: Steve Harwood, Flickr

Tank cars pass over a highway–rail grade crossing. A workshop at the 2015 TRB Annual Meeting examined the impacts of crude oil transportation by rail on local transportation networks and on communities.

and stability in the United States.

Although the transport of crude oil by BNSF has received public attention, Rose noted that the crude oil shipments accounted for slightly less than 4 percent of BNSF's total traffic volume in 2014; in comparison, coal accounted for 22 percent of the railway's total traffic volume. Asked about BNSF's plans to purchase a fleet of tank cars, announced in 2014, Rose pointed out that the tank car fleet today is almost exclusively owned by shippers and leasing companies, not by railroads. He revealed that BNSF had received some unfavorable feedback from customers about the tank car purchase, and because of this—and the uncertainty about tank car regulations—BNSF has placed plans for a tank car purchase on hold.

Rose also predicted continued yet slower growth in shipments of crude by rail. Wells that are currently producing will continue in production despite lower crude oil prices, he maintained, and wells that are currently being developed will be brought on line to recover investments.

Tank Car Risk Analysis

Christopher Barkan of the University of Illinois at Urbana–Champaign presented the results of a risk analysis for moving crude oil by unit trains. The analysis used historical data to calculate the probability of derailments on various types and classes of tracks, then the probability of a crude oil release for various types of cars, based on performance in past accidents. After the major crude oil shipping corridors are identified, and the population densities determined, the probability of a spill event can be predicted for each area of density.

According to the analysis, a derailment with a release of crude oil or alcohol from four or more DOT-111 tanker cars—the least robust tank car model in use—can be expected every 20 years in an area of high population, defined as 3,000 to 10,000 persons per square mile. The calculations for more robust tank cars predict longer intervals between accidents that involve a product release.

Thomas D. Simpson of the Railway Supply Institute described the various changes proposed for tank car construction in the then-forthcoming regulations from the Pipeline and Hazardous Materials Safety Administration. He emphasized the need for consistency between the Canadian and U.S. regulations, to maintain the seamlessness of the North American rail network. Simpson also advocated a safety approach that encompasses all aspects of crude oil transportation, not only tank car construction.

Photo: Aaron Hockley, Flickr

Workers clean up after a tank-car derailment in a Vancouver, Canada, railyard.

Public-Sector Lessons

In the public-sector portion of the workshop, a panel of state and local government representatives responded to a series of questions about infrastructure planning and prioritization, the economic benefits of shipping crude oil by rail, the community benefits, and the lessons learned. The panelists emphasized the need for response planning for incidents involving all types of hazardous materials, not only crude oil. Some panelists noted that in many areas transportation planning has shifted emphasis from transit to freight because of local crude-by-rail traffic.

Public-sector representatives are educating legislators and their staffs about freight movements, particularly for energy-related commodities. Energy development may strain local and regional transportation networks, but the economic benefits are often substantial, not only in drilling and production areas, but also in areas with refining and petrochemical industries that rely on crude oil as a raw material.

Lessons learned in the public sector include a new appreciation of the rapidity of change as economic markets adapt to new technologies. In addition, many long-standing assumptions—for example, that all crude oil always ships via pipelines, or that crude oil has a low volatility—often prove wrong. Finally, the public sector has learned that rail carriers, states, and municipalities along crude-by-rail corridors need to work together and that scenario planning is a valuable tool in preparing for emergencies.

ENERGY TRANSPORTATION SAFETY ON THE RAILS

Historical Perspectives on Applied and Cooperative Research

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Concerns about shipping flammable liquids in unit trains increased after the derailments and fires at Lac-Mégantic, Québec, Canada; Cherry Valley, Illinois; Casselton, North Dakota; Plaster Rock, New Brunswick, Canada; and Lynchburg, Virginia. These and other headline incidents are driving improvements in the risk management strategies for transporting flammable liquids, such as crude oil and ethanol, in unit trains. The improvements are building on the many advances in hazardous materials transportation safety in the past four decades, which have yielded valuable data and methodologies for risk management decisions that continuously improve safety.

Early Cooperative Efforts

The safety of transporting hazardous materials by rail requires extensive cooperation among chemical and energy producers, shippers, tank car suppliers, railroads, and federal regulatory agencies. During the 1970s, several high-profile incidents involved the release of liquefied petroleum gas (LPG) from railroad tank cars; approximately 20 LPG releases were occurring per year. Although the mechanism for the release of LPG differs from that for crude oil and ethanol, the processes that were developed in response—along with other solutions applied to related problems—have guided the design of risk-reduction features for rail tank cars.

The Inter-Industry Rail Safety Task Force (IIRSTF), organized in the 1970s, assembled the expertise of executive-level leaders representing shippers, railroads, and tank car suppliers; the task force worked in cooperation with the Federal Railroad Administration (FRA) of the U.S. Department of Transportation (DOT). The IIRSTF commissioned research into the mechanisms of incidents and the design of appropriate protective measures.

In addition, the Railway Supply Institute (RSI) and the Association of American Railroads (AAR) chartered the RSI-AAR Tank Car Safety Research and Test Project (Safety Project). Through the Safety Project,

Photo: Transportation Safety Board of Canada

Investigators examine the scene of a Canadian National Railway unit train derailment and explosion near Plaster Rock, New Brunswick. High-profile incidents have led to examination of tank car safety improvements.

Photo: Union Tank Car

Design of the new DOT-117 tank car, one of the "Tank Cars of Tomorrow," applied findings from the Next-Generation Rail Tank Car Program.

RSI and AAR began collecting information about the performance of tank cars damaged in derailments, establishing the Tank Car Accident Database.[1]

The IIRSTF and members of the Safety Project began analyzing the data and conducting research into design features that would improve the containment of hazardous materials when tank cars are damaged in railroad operations. The Safety Project developed tools that have proved effective in designing and selecting optimal features to reduce the risk of transporting hazardous materials in tank cars on railroads.

The IIRSTF companies implemented retrofit programs to incorporate the design features, and the release of LPG and other hazardous materials from tank cars during derailments was substantially reduced. The Safety Project database now includes more than 40 years of data. Analyses of the data enable prediction of the expected performance for new and untried designs for risk-reduction components.

Extending the Model

During the early 1980s, the improved performance of LPG tank cars restored public confidence in the transportation of hazardous materials by rail. The industry began to apply the research and risk-reduction design features to other hazardous materials. U.S. DOT data demonstrate the success of these measures, revealing that on a ton-mile, weighted basis, transporting hazardous materials by rail is safer than by highway. A proposal to establish a damage database for the cargo tanks that transport hazardous materials on U.S. highways has recommended the Safety Project as a model (*1*).

Periodically, new challenges have led to additional cooperative tank car safety research programs:

◆ The Next-Generation Railroad Tank Car Program developed options for protecting chlorine tank cars.

◆ The Advanced Tank Car Collaborative Research Program is developing options for the protection and security of tank cars that transport toxic inhalation hazards.

Private industries, RSI, AAR, the American Chemistry Council, the Chlorine Institute, the Fertilizer Institute, U.S. DOT, Transport Canada, and the U.S. Department of Homeland Security are cooperatively funding and managing these programs.

Unit Train Safety

The current challenge is to address issues unique to unit trains transporting liquid energy products, such as crude oil and ethanol. The Safety Project, in cooperation with its partners, is well-positioned to address these issues; its database has proved effective as a tool for predicting the performance of risk-reduction design options. Statistical analyses of these robust data—conducted primarily by researchers at the University of Illinois at Urbana–Champaign—

[1] The RSI-AAR Tank Car Safety Research and Test Project is a cooperative effort of the RSI Committee on Tank Cars and AAR. The Safety Project funds the Tank Car Accident Database and research analyses of the data.

Federal regulations specify design features such as double-shelf couplers for tank cars.

PHOTO: JON GORDON

have assisted in understanding how each design feature, individually and in combination with others, could reduce the risk of a release in a derailment (*2*).

Key personnel in the incident commands at Lac-Mégantic, Casselton, Plaster Rock, and Lynchburg welcomed the assistance of the Safety Project, because of its history of accomplishments and established credibility. Agencies cooperating with the Safety Project included Sûreté du Québec, the Service de Sécurité Incendie Lac-Mégantic, the Transportation Safety Board of Canada (TSB), Transport Canada, the National Transportation Safety Board (NTSB), FRA, emergency response and wrecking crews, and local citizens who hosted the emergency response crews.

Access to these major accident scenes allowed the Safety Project team to gather key data on tank car and unit train performance. Application of the lessons learned from each incident will enhance transportation safety.

Canada's TSB and the U.S. NTSB consider the Safety Project a potential resource in investigations of derailments involving tank car releases of hazardous materials. These relationships enable the Safety Project team to incorporate new information directly from accidents into the database and to guide current decisions.

Hazardous Materials Cooperative Research Program Report 12, *Hazardous Materials Transportation Risk Assessment: State of the Practice*, is available from the TRB online bookstore at www.mytrb.org/Store/Product.aspx?ID=1118.

Research Results

Today's set of risk management tools and resources for the safe transportation of hazardous materials is extensive, as documented in the Transportation Research Board's Hazardous Materials Cooperative Research Program Report 12 (*3*). Process safety management guidelines (*4, 5*), management of change techniques (*5*), and the ANSI risk assessment standards also can yield or contribute to practical and effective methodologies (*6*).

Safety Project analyses are providing reasonable predictions of the performance of risk reduction options for crude and ethanol tank cars. The data and analyses assist in evaluating the effectiveness of new design features such as half-inch-thick, full-height, high-strength head shields; protective housings for top fittings; varying jacket thicknesses; ceramic fiber thermal insulation; double-shelf couplers; and bottom outlet valves that can be disengaged during transportation.

These achievements point to the value of continued cooperative research efforts to improve safety. The performance-prediction tools available today aid in selecting features that lower the risk of transporting crude and ethanol by rail and in tracking performance. The data-driven, risk-reduction features that are being implemented today will achieve a level of safety that will regain the public's trust in the transportation of crude oil and ethanol by rail.

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Enhanced Tank Car Design Improves the Safety of Transporting Crude Oil and Alcohol by Rail

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The nation's quest for energy self-sufficiency has led to a dramatic increase in the transport of flammable liquids by rail. In the first decade of the 21st century, the rail transport of alcohols not otherwise specified (NOS) increased 10-fold from approximately 30,000 tank carloads per year to more than 300,000 in 2010. As the alcohol traffic stabilized, an even more dramatic increase in the transport of petroleum crude oil began with the boom in shale oil production.

Rail transport of petroleum crude oil increased more than 50-fold from approximately 9,500 carloads in 2008 to 500,000 in 2014, with further growth expected (*1*). Railroad safety improved in the same period, declining from 4.39 accidents per million train miles in 2004 to approximately 2.25 in 2014, a 49 percent reduction (Figure 1, below) and the lowest level since the Federal Railroad Administration (FRA) began recording these statistics in 1975.

Problem

Despite the reduction in the accident rate, the substantial growth in flammable liquid traffic raised concern about the risk of accidents producing large spills. The new traffic was moving differently, often in unit trains of 80 to 120 cars from origin to destination. Damage to conventional, nonjacketed DOT-111 tank cars, combined with thermally caused failures in large, multiple tank car derailments, resulted in several dramatic—and two fatal—train accidents.

The accidents galvanized industry, public, and government attention on the topic. The rail industry faced a paradoxical situation: train safety was improving, but the risk was increasing with the dramatic growth in traffic.

Solution

Improving the safety and reducing the risk involve three key elements:

- Railroad accident prevention,
- Improved tank car safety design, and
- Enhanced emergency response capabilities.

The research on tank car safety design—the focus of this article—was a collaborative, multiyear effort by several organizations, including the Railway Supply Institute (RSI)–Association of American Railroads (AAR) Railroad Tank Car Safety Research and Test Project, the U.S. Department of Transportation (DOT) FRA, the U.S. DOT National University Rail Center, the Rail Transportation and Engineering Center (RailTEC) at the University of Illinois at Urbana–Champaign (UIUC), and several other individuals and companies (2).

Safety-Related Questions

The research started by addressing two questions:

- How effectively do different tank car safety design features prevent releases?
- What is the optimal combination of design features?

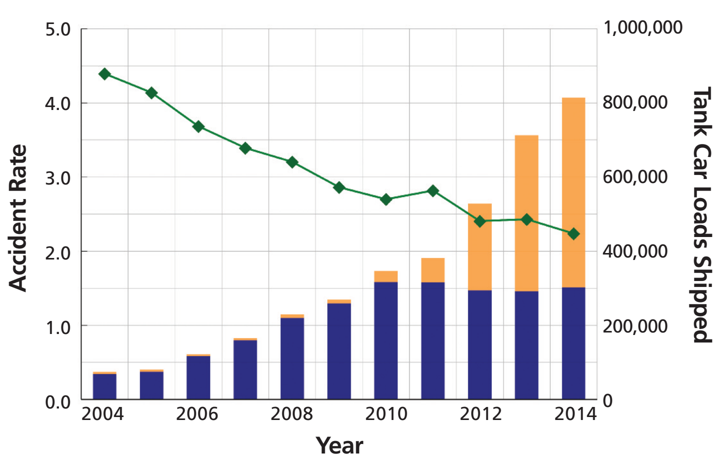


FIGURE 1 Reportable train accidents per million train miles (green) and growth in railroad tank car shipments of alcohol NOS (blue) and petroleum crude oil (orange) in the United States, 2004–2014. [Sources: For accident data: Federal Railroad Administration: http://safetydata.fra.dot.gov/officeofsafety/publicsite/summary.aspx (2014 data are preliminary); for traffic data: Association of American Railroads.]

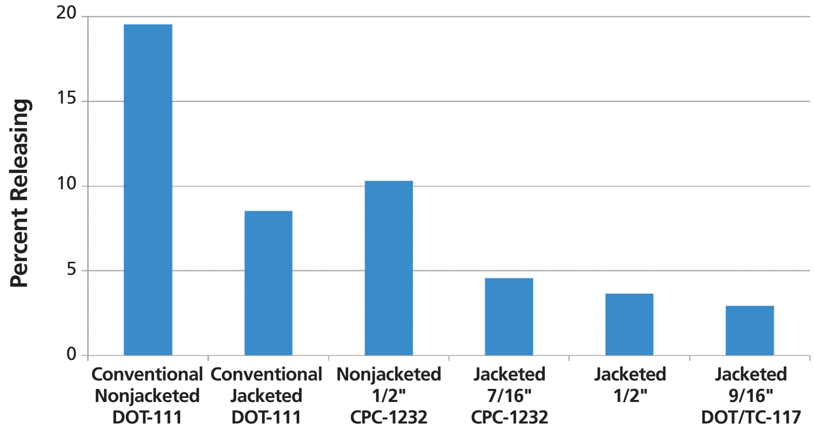


FIGURE 2 Percentage of tank cars of various designs expected to release 100 or more gallons (CPR_{100}) from physical impacts in FRA-reportable accidents (*4*).

The RSI-AAR Tank Car Safety Project analyzed data on tank car safety performance (*3*), quantifying the effect of different tank car design features on the likelihood of a release in accidents (*4*). Researchers at UIUC then used these statistics and other data to develop an optimization model for a tank car safety design (*5*). The researchers quantified the safety benefit of each design change element, along with its associated impact on tank car weight, to determine which combinations of design enhancements were most effective and efficient.

The changing nature of rail traffic, however, with increased movement by unit trains, raised new safety-related questions:

- ◆ Do unit trains derail at a rate different from that of conventional trains?
- ◆ What is the likelihood of large, multiple car releases?
- ◆ What was the effect of fire on tank car failures?

UIUC developed an integrated risk model for hazardous materials transportation to evaluate railroad infrastructure, operating practices, tank car design, and routing and to investigate the most efficient combination of measures to reduce risk (*6*). A preliminary analysis suggested that the derailment rate for unit trains was not significantly different from that of other types of freight trains. Research on this topic is continuing, but given the declining accident rate, the most plausible explanation for the increased number of incidents is the dramatic increase in unit train traffic.

Multiple Car Accidents

The RSI-AAR data enabled a statistical estimate of how each particular tank car design would perform in accidents (Figure 2, left); however, the substantial increase in unit train traffic led to concern about the occurrence of large, multiple-car release accidents. UIUC therefore used a new risk model to estimate the probability of release events of various magnitudes for different tank car designs.

The findings indicated that even relatively small differences in the probability of individual car releases yielded large differences in the probability of multiple car releases (*7*). For example, a design improvement that resulted in a 20 percent reduction in release probability for a single derailed car offered a 74 percent reduction in the probability that five or more derailed cars would release.

The risk model was used to calculate how the different tank car designs affected the relative expected time intervals between events of various magnitudes (Figure 3, below left). The most important finding was that even small differences in an individual car's probability of release diverged geometrically when the probability of larger numbers of cars releasing was calculated (compare Figure 2 with Figure 3). This result was influential in the industry's decision to support a more robust tank car design.

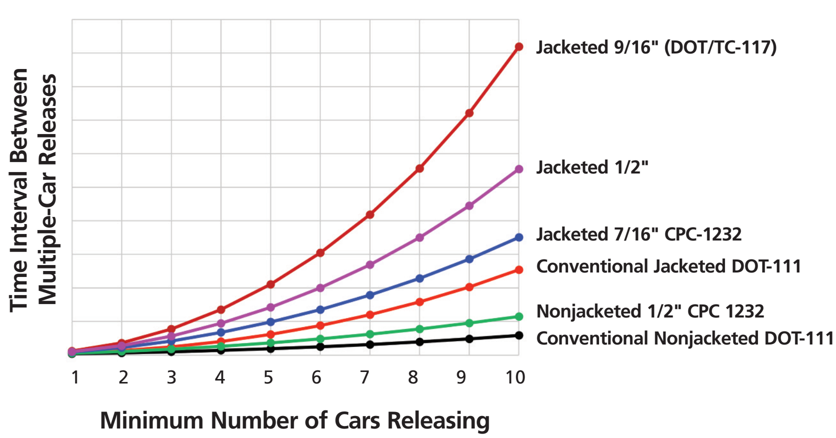
Protection from Fires

Although the improved damage resistance reduced the incidence of cars failing from the initial, physical impacts of a derailment, another aspect of unit train derailments emerged and gained importance. Even if only a few cars release their contents, a fire may ensue.

The fire can engulf other derailed tank cars that had not released in the initial derailment. The product inside the cars would heat up, increasing the pressure inside the tank, while the fire impinging on the tank would thin and weaken the steel on the upper side, reducing its strength. If the rising internal pressure exceeds the strength of the weakening tank, a separation—known as a thermal tear—could occur in the tank steel, and a large quantity of product would suddenly release, triggering the vertically directed fireballs sometimes seen in these incidents.

Industry and government had sponsored the development of a research tool known as Analysis of Fire Effects on Tank Cars (AFFTAC) to evaluate increases in thermally induced pressure and the effectiveness of

FIGURE 3 Illustration of the effect of tank car design on the geometric divergence of the expected interval between occurrences of multiple car release incidents of varying magnitude.



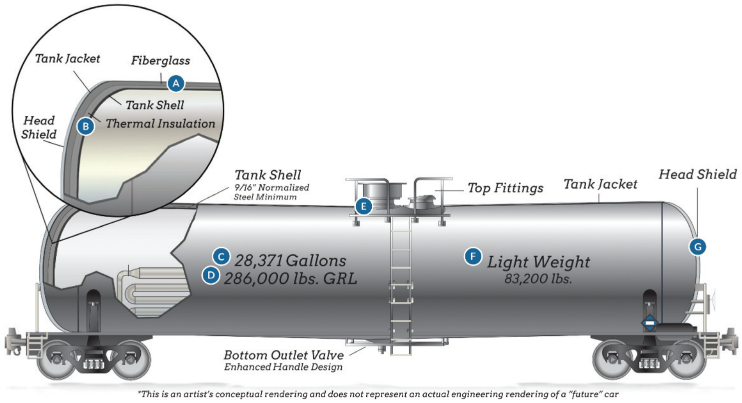


FIGURE 4 Illustration of the new safety features on tank cars for transporting petroleum crude oil and alcohol NOS. (Drawing courtesy of Railway Supply Institute)

designs for pressure relief devices (*8*). The industry used AFFTAC to develop a thermal protection system to extend the survivability of petroleum crude oil and alcohol NOS tank cars in fires as long as possible, ideally preventing the tank cars from failing altogether.

Researchers identified a twofold solution:

◆ First, place a layer of thermal insulation around the tank and encase the insulation in a steel jacket to reduce the rate of heat flux into the tank and to improve resistance to damage in derailments—in Figure 2, for example, compare the jacketed with the nonjacketed versions of the conventional DOT-111.

◆ Second, equip cars with appropriately sized pressure-relief valves to reduce internal pressure more effectively in a controlled manner.

Benefits

The research described here was used to inform the development of the enhanced tank car safety design features proposed by the rail industry for transporting petroleum and alcohol NOS:

◆ A thicker, more puncture-resistant tank constructed of stronger steel;

◆ Full-height head shields;

◆ Robust top-fittings protection; and

◆ A thermal protection system encased in a steel jacket (Figure 4, above) (*9*).

This tank car is expected to reduce the average probability of a release caused by the impacts of an accident by an estimated 85 percent compared with the probability of a release by the current nonjacketed DOT-111 car; moreover, the enhanced design is expected to reduce considerably the likelihood of secondary failures caused by fire.

U.S. DOT and Transport Canada recently promulgated regulations to incorporate these features into the new DOT-TC-117 tank car (*10, 11*). When fully implemented, these cars will improve substantially the safety of transporting petroleum crude oil and alcohol NOS by rail in the United States and Canada.

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2956; gjayaprakash@nas.edu).

Paul Bingham

Economic Development Research Group

Paul Bingham's many years of active service on TRB standing committees and task forces have centered on research that informs policy, especially as it relates to the public sector. In the 1980s, after studying economics at Cornell University under Alfred Kahn—widely considered to be the father of the economic deregulation of transportation—Bingham went to Washington, D.C., to work in private-sector economics consulting. At his first TRB Annual Meeting, Bingham attended a joint meeting of the standing committees on Ports and Channels and on Inland Waterways, receiving his first glimpse into the workings of TRB committees. Later, seeking a way to bolster his professional development in sourcing data for forecasting, he attended meetings of the Task Force on Freight Transportation Data, which became a full committee in 1993 and to which he was appointed a charter member.

"The question is: How do we make sense of this, for both private- and public-sector decision makers, in terms of what is happening with markets?"

Bingham brought both data-user and data-vendor perspectives to the task force. "Knowing that the data programs at the federal level could go away anytime, it became important to support existing programs," he recalls. His employer at the time, Data Resources, Inc. (now IHS Global Insight), focused less on freight flow statistics than on their application for forecasts; this still is true today, he notes. The federal government had not issued new multimodal freight flow statistics since 1977, confounding the economic modeling of freight demand. The need for research on freight flow data ensured that the task force did not lack for work. In 1997, Bingham was elected the committee's secretary, and in 1999, he became chair.

"It was a new, exploratory world of policy and analysis in freight. Legal and industrial landscapes were shifting, with technical innovations, bankruptcies, and market volatility," he comments. "The question is: How do we make sense of this, for both private- and public-sector decision makers, in terms of what is happening with markets?"

Bingham had worked in international trade statistics early in his career, and in 2000 joined the Standing Committee on International Trade and Transportation, as much of his work dealt with international commodity forecasting. Although he was not a member of the Standing Committee on Ports and Channels, he attended the meetings and often found himself conducting outreach between the two committees, as well as with the Standing Committee on Freight Transportation Data—for example, in conjunction with the annual Summer Meeting of the Freight Systems and Marine Committees and the biannual North American Travel Monitoring Exposition and Conference. "The goal was to improve communication between the committees and the larger freight and marine groups," Bingham recalls.

From 2007 to 2010, Bingham served as chair of the Freight Systems Group and as a member of the Technical Activities Council. Although he had never been a committee chair within the group, he still had maintained a deep involvement in freight; TRB senior program officers determined that his cross-cutting work among committees positioned him to lead freight-related research activities. Bingham was named an emeritus member of the Freight Systems Group in April.

He also served as secretary of the Task Force on Innovations in Freight Modeling, which advanced the understanding of freight modeling practice and its wide range of application. Out of this initiative came the Workshop on Adapting Freight Models and Traditional Freight Data Programs for Performance Measurement, which he helped to plan.

"That conference served as an example of an evolving policy development—namely, the broader application of performance measurement in transportation planning and program management," Bingham comments. He also served on the planning committees for the Commodity Flow Survey conferences, often speaking at those events as a data user.

More recent service includes the Standing Committee on Freight Transportation Economics and Regulation, the Task Force on Data for Decisions and Performance Measures, and the Standing Committee on the Logistics of Disaster Response and Business Continuity. Bingham also served on the committees for policy studies on Freight Capacity for the Next Century and on Freight Transportation Data: A Framework for Development.

Bingham currently cochairs the Task Force on the Value of Transportation Infrastructure. The initiative, related to the Moving Ahead for Progress in the 21st Century Act, focuses on data and methods for monitoring and analyzing infrastructure valuation. "These applications cut across an enormous subset of TRB's work," he notes. "They are important to policies involving any mode of transport—from airports to roads, rail and transit facilities, bridges, tunnels, harbors and pipelines."

"Ultimately, you want to make correct decisions for big-picture impacts and for the economy," Bingham muses. "This is to improve the productivity of the economy and to provide a competitive advantage to the country as a whole—for everybody who depends on transport for their mobility and delivery of goods."

David B. Clarke

University of Tennessee, Knoxville

When David Clarke was appointed the fourth permanent director of the Center for Transportation Research (CTR) at the University of Tennessee (UT), Knoxville, in 2008, he already had a long relationship with the university, where he had earned a bachelor's degree, master's degree, and Ph.D. in civil engineering. As CTR director, Clarke guides the activities of the university's hub of transportation-related research, technology transfer, and continuing education. Among his accomplishments are stabilizing the center's finances and reducing its contract backlog; implementing a strategic planning process; and developing faculty fellow, visiting scholar, and continuing education programs.

"I have always had an interest in freight transportation, particularly railways," Clarke comments. "I was fortunate to attend a university that permitted me to craft a curriculum combining both business and engineering classes relevant to my interests." As a graduate student, Clarke served as research assistant at UT Knoxville and at Oak Ridge National Laboratory.

"Even if a student has no plans to pursue a career in formal research, the ability to apply the research process is hugely advantageous."

After working as an engineer and program manager at Bechtel Power Corporation and at Science Applications International Corporation, Clarke returned to academia in 1990 as assistant director of UT's Transportation Center, supporting research collaboration with Oak Ridge and managing transportation and logistics modeling, database design and construction, software development, and data collection efforts. He also led the center's freight and intermodal transportation activities and developed an intermodal management system for the Tennessee Department of Transportation.

In 1998, Clarke was hired by Clemson University in South Carolina to rebuild the Civil Engineering Department's transportation program. He returned to Tennessee in 2004 and since then has served as director of the Tennessee Local Technical Assistance Program, providing technical assistance, training, and technology transfer to county and municipal transportation agencies throughout the state. He is a Professional Engineer in Tennessee and South Carolina.

Some of Clarke's notable projects include the initial feasibility study for the Heartland Corridor Rail project, a public–private partnership between Norfolk Southern, the Federal Highway Administration, and three states, which opened for service in 2010. Along with colleague Mark Burton, Clarke inspected the routes between Columbus, Ohio, and Radford, Virginia, assessing clearance needs for the new double-stack rail movements. He also was the chief engineer who restored the 42-mile former CSX Old Line Railroad in southeast Tennessee to short-line service. "I assessed track and bridge rehabilitation needs, helped oversee contractor work during the rehabilitation, assisted with operations planning, and just had a great time," he recalls.

Clarke values his work developing and teaching rail courses for college students, faculty, and industry professionals throughout the United States, as well as in Asia and Latin America. He serves as the lead for rail research and education activities with the National University Rail Center, or NURail, the first rail-focused University Transportation Center. He was part of the team that formed NURail.

"Exposure to research is an invaluable experience for students," Clarke muses. "Even if a student has no plans to pursue a career in formal research, the ability to apply the research process is hugely advantageous. As a young engineer, I quickly found out that very few of my assignments had textbook solutions."

Clark attended his first TRB Annual Meeting in the 1970s as a graduate student and joined the Standing Committee on Freight Rail Transportation in 1991. "I attended every freight- and rail-focused session—which, in that era, were all too few," Clarke notes. "It has been wonderful to see the event grow in the intervening years."

Clarke also is a member of the Standing Committees on Freight Transportation Economics and Regulation and on Railroad Operating Technologies, and is chair of the Subcommittee on Rail Capacity. Clarke chaired the Standing Committee on Freight Rail Transportation and recently was named an emeritus member.

"It was a real honor to chair the committee, and through it I was able to work with many tremendous people," Clark observes. "We expanded the committee's scope from local railroads to freight railroads at all levels." Under his leadership, the committee also sponsored and cosponsored Annual Meeting sessions and workshops and, in 2007, organized the first SummeRail midyear committee meeting. At SummeRail, attendees gather for two days of railroad site tours, inspection trips, and presentations from industry and government speakers.

Along with his TRB service, Clarke is a member of the American Society of Civil Engineers and of its Transportation and Development Institute Rail Transportation Committee. He also serves on the American Railway Engineering and Maintenance-of-Way Association, the American Public Works Association, and the Lexington Group in Transportation History.

Rest Stops for Safer Highways

SOPHIA BENNETT

The author is a freelance writer and communications professional in Eugene, Oregon.

In 2014, the New Mexico Department of Transportation (DOT) received $2 million to complete a one-year project renovating seven buildings at four rest stops along the state's major highways. Adding to the tight budget was the need to preserve the historical features of several of the structures: a rest area on I-25 near Ft. Union—an important landmark along the Santa Fe trail—was built to look like a replica of the fort, and the bathrooms in the Sierra Grande rest stop along US-64 resembled traditional southwestern cabins. The buildings reflected New Mexico's cultural heritage and also served as tourist attractions; renovations had to preserve their unique features.

Photos: New Mexico DOT

The new rest areas built by New Mexico DOT incorporate design elements that echo parts of the state's history—from a replica of Ft. Union (*above*) to cabins in the traditional southwestern style (*below*).

New Mexico DOT administrative operations manager Sev Sisneros focused on safety because of the factors unique to the state's roads: summer heat along bare stretches of desert—or roadway-closing winter snow—that can turn a roadside breakdown into a life-threatening situation. "Part of the safety aspect is a rest stop where people can use the facilities and be back on their way," he notes.

Several of New Mexico's rest stops offered only one bathroom for men and one for women, however. Lines could stretch up to 20 people long, which caused motorists to bypass them altogether. According to a 2012 study on the appropriate level of service for Michigan rest areas, welcome centers and rest stops prevent 273 fatigue-related crashes in the state every year—approximately three fewer crashes per rest stop per year (*1*). A 2007 study for Minnesota DOT presented a similar conclusion: that single-vehicle truck crash density increased in areas that were more than 30 miles from a rest stop (*2*).

Sisneros hired Romtec, Inc., an Oregon company specializing in site-built restroom buildings. The builder utilized a standard set of plans to engineer structures, making the design process quick and relatively inexpensive. Metal fabrication and woodworking took place in-house and allowed for customization.

The new restrooms at the Ft. Union, Sierra Grande, Thaxton, and Pajarito rest stops are ADA-compliant and are more spacious. Each bathroom can accommodate up to six people at once; each rest stop also has two family restrooms for people with young children and for elderly users. The buildings have heat and air conditioning—something they lacked before. Overhangs provide shade, and potable water is available at the rest stops.

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Winter Maintenance Clears $1 Billion

Twenty-three states spent a total of $1.1 billion on winter maintenance operations in 2014 and 2015, according to a survey by the American Association of State Highway and Transportation Officials (AASHTO). Each of the responding states—including several from hard-hit New England—spent an average of $49 million on salting, treating, plowing, and other maintenance operations from October 2014 to March 2015 (see Figure 1, right).

The Massachusetts Department of Transportation (DOT) contended with more than 30 winter storms, two of which were among the worst on record; nearly 111 inches of snow fell in the Boston area. The agency spent approximately $154 million on snow and ice removal, mostly on equipment and new personnel. Pennsylvania DOT's winter operations budget was the largest of the states surveyed, at $272 million for approximately 2.5 million man-hours, 10 million gallons of salt brine, and 1 million tons of salt.

According to AASHTO, the Maryland State Highway Administration used more than one-third of its annual maintenance budget—$108 million—on winter operations and spent $600,000 to repair the many potholes on state roads. New Hampshire DOT spent $46 million—55 percent of its annual maintenance budget—on snow and ice removal and as of March had plowed more than 2.5 million miles of roads.

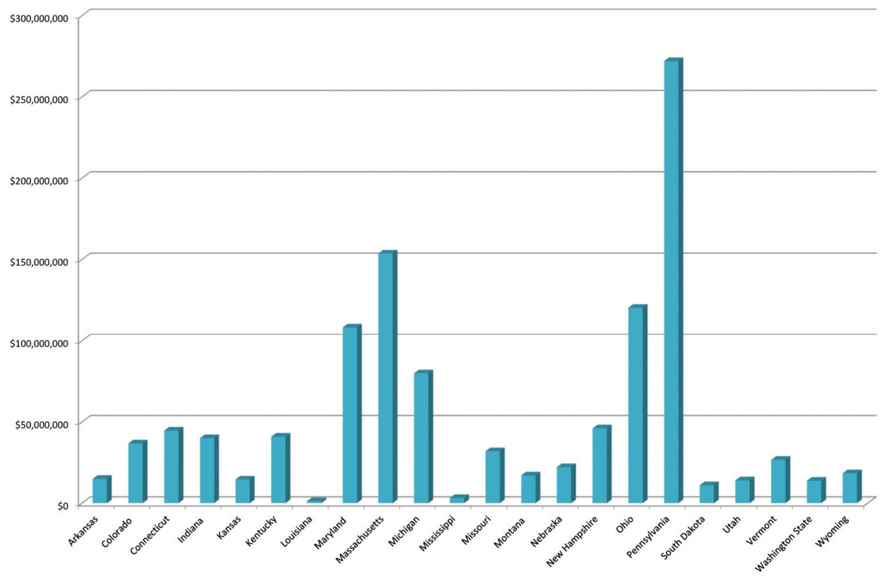


FIGURE 1 Winter maintenance costs by state.

Most of the states surveyed reported a mild or average winter season, but 11 states—Arkansas, Connecticut, Louisiana, Maryland, Massachusetts, Mississippi, New Hampshire, New York, Ohio, Pennsylvania and Vermont—described a "difficult to severe" season.

For the full data spreadsheet, visit http://downloads.transportation.org/AASHTO_2014-2015WinterSurvey.xlsx.

Photo: Washington State DOT

Washington State DOT vehicles clear the North Cascades Highway for its 2015 reopening in March.

Technology Prevents Repeat Drunk Driving

Continuous alcohol monitoring (CAM) technology can reduce repeat drunk driving offenses, according to the National Highway Traffic Safety Administration (NHTSA). A NHTSA study of alcohol monitoring programs in Wisconsin and Nebraska investigated the effectiveness of CAM bracelets on the recidivism rates of drunk driving offenders, as well as the characteristics of current CAM users.

Working with regional NHTSA offices, state highway safety offices, and CAM sellers or distributors such as SCRAM, the agency identified alcohol monitoring programs with the largest numbers of clients, to ensure proper sample size. Nebraska's Supreme Court Department of Probation Services and Wisconsin Community Services were selected to participate in the study.

After developing memoranda of understanding and Privacy Act agreements, NHTSA examined SCRAMnet program data and Department of Motor Vehicles (DMV) records of offenders who used CAM devices and who had been arrested for drunk driving between 2007 and 2009. Researchers established rates of recidivism by looking at rearrests after the first eligible arrest that occurred between 2007 and 2009—the "target offense." If a subject committeed another drunk driving offense within 2 years of the target offense, researchers counted this as an instance of recidivism.

Using the SCRAMnet database, NHTSA also obtained data on all SCRAM participants in Nebraska and Wisconsin from 2007 through 2011. These data included the dates that offenders started using the CAM device; the date they were taken off the device and the total number of days on it; and the date, time, and type of tamper or alcohol alerts. DMV and SCRAMnet data were merged to connect arrest dates to SCRAM assignments and any subsequent arrests.

According to NHTSA, CAM devices delayed the onset of recidivism by 36 percent in Wisconsin and by 43 percent in Nebraska. Recidivism rates were less than 2 percent while the devices were deployed—14 repeat offenders out of 837 subjects in Wisconsin and 1 repeat offender out of 672 subjects in Nebraska. Study results in Nebraska showed that offenders using CAM devices for at least 90 days had a significantly lower risk of recidivism.

To see this and other NTHSA reports, visit www.nhtsa.gov/Driving+Safety/Research+&+Evaluation.

INTERNATIONAL NEWS

PHOTO: MICHAEL VERHOEF

Not all transportation data used to examine traffic flows are collected with user consent.

Big Data and Privacy—Or Not

The collection and storage of large volumes of data, or "big data," have significant impacts on the transportation sector, according to a study from the International Transport Forum. Drawing on research and input from public- and private-sector experts and practitioners, the report investigates the evolution of mobility-related data generation, collection, and use; reviews existing data protection frameworks; and highlights gaps in data privacy protection.

Chief among these big data systems are location-sensing technologies that can locate and track people, vehicles, and objects with extreme precision. Vehicle-embedded sensors and the capacity for data storage and transmission can lead to safety-enhancing features in conventional and automated vehicles, the report states. Data no longer are collected only with user consent—opportunistically collected and crowd-sourced data pose privacy risks even while providing insight into transportation flows. The personal nature of location and trajectory data is difficult to render anonymous. Data protection policies lag behind new modes of data collection and uses—especially for location-related data, according to the report.

To download the report, visit www.internationaltransportforum.org/cpb/projects/mobility-data.html.

CALENDAR

TRB Meetings

August

24–25 8th New York City Bridge Conference*
New York, New York

September

1–3 Transit GIS Conference*
Washington, D.C.

7–9 3rd Conference on Smart Monitoring, Assessment, and Rehabilitation of Civil Structures*
Antalya, Turkey

14 Geotechnical Risk Assessment and Performance Management
Sturbridge, Massachusetts

15–17 International Symposium on Nondestructive Testing in Civil Engineering*
Berlin, Germany

16–18 International Conference on Transportation System Resilience to Climate Change and Extreme Weather Events
Washington, D.C.

20–23 Environmental Analysis in Transportation Summer Workshop
San Diego, California

20–24 International Conference on Ecology and Transportation
Raleigh, North Carolina

21–25 11th National Conference on Access Management*
Seattle, Washington

21–25 4th International Orthotropic Bridge Conference*
Tianjin, China

28–30 European Transport Conference*
Frankfurt, Germany

October

6–8 5th International Road Safety and Simulation Conference*
Orlando, Florida

26–28 International Symposium on Frontiers of Road and Airport Engineering*
Shanghai, China

29 Commodity Flow Survey Workshop
Washington, D.C.

November

4–5 9th University Transportation Centers Spotlight Conference: Connected and Automated Vehicles
Washington, D.C.

11–15 Disrupting Mobility: A Global Summit Investigating Sustainable Futures*
Cambridge, Massachusetts

15–17 13th APTA–TRB Joint National Light Rail and Streetcars Conference: Transforming Urban Areas
Minneapolis, Minnesota

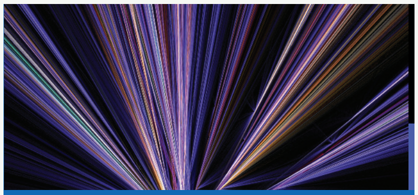
15–18 15th Pan-American Conference on Soil Mechanics and Geotechnical Engineering*
Buenos Aires, Argentina

December

7–8 National Accelerated Bridge Construction Conference*
Miami, Florida

17–20 3rd Conference of the Transportation Research Group of India*
Kolkata, India

January



10–14 TRB 95th Annual Meeting
Washington, D.C.

For information, visit www.trb.org/AnnualMeeting/Annual Meeting.aspx

Additional information on TRB meetings, including calls for abstracts, meeting registration, and hotel reservations, is available at www.TRB.org/calendar. To reach the TRB staff contacts, telephone 202-334-2934, fax 202-334-2003, or e-mail TRBMeetings@nas.edu.

*TRB is cosponsor of the meeting.

Communicating Freight Needs Effectively

Annual Competition Identifies Best Practices

TERRI H. PARKER

The author is Division Head, Marketing, Communications, and Agency Relations, Texas A&M Transportation Institute, College Station.

Barbara Ivanov, Freight Systems Director at Washington State DOT, which received the 2014 Communicating Concepts to John and Jane Q. Public Award.

Freight's vital role in goods delivery, the economy, and quality of life is not always well-understood by the public. Transportation professionals often find that communicating critical transportation concepts to a nontechnical audience can be a significant challenge. At its annual competition, Communicating Concepts to John and Jane Q. Public, the Planning and Environment Group recognized four organizations for successfully communicating freight needs and issues. The award winners were featured in poster and lectern sessions at the 94th Annual Meeting of the Transportation Research Board in January.

The Washington State Department of Transportation (DOT) received top honors for its 2014 freight plan, "We Can Meet This Challenge Together." The agency developed several easily understood communication tools to inform and engage the public about the plan's findings and recommendations: supply-chain maps of key state industry-sector clusters on freight corridors; an animated infographic explaining how the freight system helps sustain Washington's economy; and a video series, "Freight Matters," featuring business people discussing the value of freight in their lives.

The public education and awareness campaign "Pro Motion," developed by Florida DOT, was a runner-up in the competition. After setting the context for understanding freight, the Florida DOT project explains how freight and multimodal initiatives contribute to the state's economy and quality of life, with communications about freight planning, the establishment of stakeholder groups, and consistent efforts to update the message.

Another runner-up was "Freightworks: Southern California Delivers the Goods," created by the Southern California Association of Governments (SCAG). To emphasize the importance of investing in the transportation system, SCAG developed a video highlighting the movement of imported goods from one mode to another through an extensive transportation network—undergoing several handling processes—to arrive on the store shelf.

Norfolk Southern Railway Corporation's Exhibit Car received an honorable mention. A rolling museum of modern transportation technology, the Exhibit Car features interactive displays, a locomotive simulator, computer animations demonstrating rail safety, and video presentations about train operations.

To learn more about the 2014–2015 winners, as well as how to participate in the session at the 95th TRB Annual Meeting in January 2016, visit the Standing Committee on Public Involvement website, http://sites.google.com/site/trbcommitteeada60, or e-mail t-parker@tamu.edu.

PHOTO: NORFOLK SOUTHERN

The Norfolk Southern Exhibit Car received an honorable mention.

Search Tips for TRID

With more than 1.09 million records of published research covering all modes of transportation, TRID is an integrated database that combines the records from the Transportation Research Information Services and the Joint Transport Research Centre's International Transport Research Documentation. More than 156,000 records contain links to full-text documents. TRID staff have assembled the following tips:

◆ The engine searches for all terms in a query. To search for a phrase, enclose the phrase within quotes—for example: "traffic signals"—to streamline.

◆ The engine does not automatically search for the singular and plural forms of a word. To search for word variations, use an asterisk (*) after a partial word. Example: sign* retrieves sign, signs, signals, signalization.

◆ To combine words in a search, use OR, AND, or NOT in capitals between words or phrases.

◆ To search on multiple terms, perform what is called a nested search, by enclosing a search within parentheses; for example, (plow* OR salt*) AND "snow removal" can focus the search.

Photo: Rayi Christian Wicaksono/Unsplash

Enclosing text in quotes and using wildcards (*) can improve a TRID search.

The advanced search (http://trid.trb.org/search.aspx) provides more focus and obtains better results. A user can search specific fields, including title, persons, agencies or publishers, serial or conference, index term, or subject areas. When searching for a person, enter the surname and the given name or initial, if known. Entering terms in multiple fields automatically searches for all terms in the query, and searches can be limited by date, language, or source.

The keyword search box searches all indexed TRID fields: title, abstract, notes, index terms, subject areas, authors, project managers or principal investigators, series, corporate authors, publishers, and funding or performing organizations.

Users may modify a query from the search results page by using the options on the right side of the screen. Search results can be shared by using tools and social networking options from the TRID interface. Subscriptions to RSS feeds of updates of searches also are available.

To access TRID, visit http://trid.trb.org.

High-Level Workshop Crosses the Ocean

TRB is seeking nominations of researchers to participate in the Chan Wui and Yunyin Rising Star Workshop in July 2016. Conducted on a transatlantic cruise from the United States to China, the workshop will facilitate research sharing and connections among early-career and experienced professionals in the fields of transportation and telecommunications.

Prospective fellows should have 1 to 3 years of postdoctoral experience. Candidates for senior fellows should have more than 30 years of academic experience, as well as experience as mentors. Application materials are due November 2, 2015, at 5 p.m. U.S. Eastern time.

Up to eight fellows and four senior fellows will be selected. All communication will be in English, and selected participants will be announced at the 2016 TRB Annual Meeting in January in Washington, D.C.

For more information, visit www.trb.org/Main/Blurbs/172605.aspx.

COOPERATIVE RESEARCH PROGRAMS NEWS

Guide for Optimal Replacement Cycles of Highway Operations Equipment

A state highway agency's equipment fleet assets comprise a large investment of capital and require recurring maintenance, as well as operational and replacement expenditures. Agencies have used many methods to establish replacement cycles for highway operations equipment, but no process is widely accepted.

Dye Management Group, Inc., has received a $398,059, 24-month contract [National Cooperative Highway Research Program (NCHRP) Project 13-04, FY 2014] to develop a guide for optimal replacement cycles of highway operations equipment. The guide will include processes and tools for state highway agencies to consider in making decisions about the optimal replacement cycles of on- and off-road highway operations equipment.

For more information, contact Amir N. Hanna, TRB, 202-334-1432, ahanna@nas.edu.

Guide for Utilization Measurement and Management of Fleet Equipment

Measuring, monitoring, and reporting on levels of asset utilization is a necessity in managing a highway agency's equipment fleet. Highway agencies have used many processes for utilization measurement and management, but no process has been established to determine the criteria for utilization, measures, or management approaches for fleet equipment.

Washington State University has received a $399,998, 24-month contract (NCHRP Project 13-05, FY 2015) to develop a guide for utilization measurement and management of fleet equipment. The findings will supplement the guide to be developed under NCHRP Project 13-04 (see above).

For more information, contact Amir N. Hanna, TRB, 202-334-1432, ahanna@nas.edu.

Enhanced Ultrasonic Methods to Measure Joint Penetration Steel Bridge Welds

Inspection of welds in steel bridges ensures the quality of workmanship during fabrication and construction. Two nondestructive evaluation methods help assess complete joint penetration welds in steel bridges: radiographic and ultrasonic. Recent advances in enhanced ultrasonic methods—such as phased-array ultrasonic technology—have facilitated the detection and characterization of flaws, with the option of automated data collection and imaging.

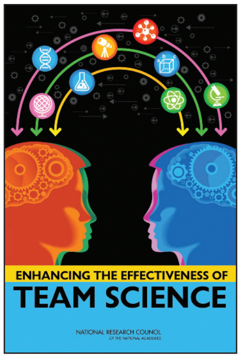
Criteria for categorizing weld discontinuities are codified in the *Bridge Welding Code* of the American Association of State Highway and Transportation Officials and the American Welding Society. The criteria, however, do not reflect the full capability of enhanced ultrasonic testing methods or the effect of weld discontinuities on bridge performance.

Purdue University has received a $540,000, 36-month contract (NCHRP Project 14-35, FY 2015) to develop guidelines to evaluate complete joint penetration welds in steel bridges in accordance with updated acceptance criteria and to suggest modifications to the *Bridge Welding Code*.

For more information, contact Waseem Dekelbab, TRB, 202-334-1409, wdekelbab@nas.edu.

Photo: Minnesota DOT

Two NCHRP projects will assist highway agencies in managing their highway equipment fleets.

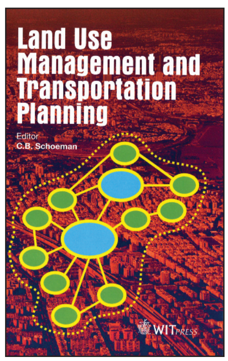


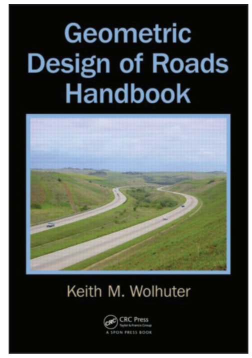
Enhancing the Effectiveness of Team Science
Board on Behavioral, Cognitive, and Sensory Sciences, Division of Behavioral and Social Sciences and Education. National Academies Press, 2015; 320 pp.; $71; 978-03-0931-679-8.

This report, available in prepublication format, provides guidance on effective leadership and collaboration in science teams. It also examines institutional and organizational structures and policies to support science teams—such as education and professional development—and identifies areas for further research.

Land Use Management and Transportation Planning
Edited by C. B. Schoeman. WIT Press, 2015; 225 pp.; $206; 978-17-8466-077-2.

Presented in this volume are best practices for integrating land use management and transportation planning. Case studies from the United States and abroad illustrate themes of smart growth and sustainability in rural and urban areas.





Geometric Design of Roads Handbook
Keith M. Wolhuter. CRC Press, 2015; 626 pp.; $260; 978-04-1552-172-7.

This handbook examines road geometric design elements: horizontal and vertical alignments, cross-sections, intersections, and interchanges. Supporting disciplines such as statistics, traffic flow theory, and systems analysis also are addressed.

The titles in this section are not TRB publications. To order, contact the publisher listed.

TRB PUBLICATIONS

The Role of Freight Transportation in Economic Competitiveness
Conference Proceedings on the Web 16

The eighth in a series sponsored by the U.S. Department of Transportation's University Transportation Centers Program, this spotlight conference in December 2014 explored trends in freight transportation and economic competitiveness as well as global business models and supply chains.

For more information, visit www.trb.org/Publications/Blurbs/172672.aspx.

Evaluation of the Federal Railroad Administration Research and Development Program
Special Report 316

The Federal Railroad Administration requested a policy study on its process for identifying research priorities and on its research and development (R&D) railroad safety products. In this report, the study committee presents conclusions on the productivity and safety focus of the R&D program and recommends ways to strengthen the program.

For more information, visit www.trb.org/Publications/Blurbs/172277.aspx.

The Essential Federal Role in Highway Research and Innovation
Special Report 317

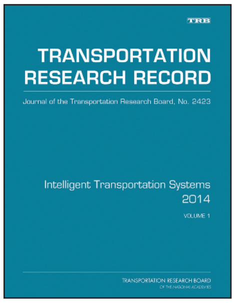
Summarized in this report are conclusions and advice from TRB's Research and Technology Coordinating Committee on the Federal Highway Administration's critical role in highway research, development, and technology.

For more information, visit www.trb.org/Publications/Blurbs/172447.aspx.

Intelligent Transportation Systems 2014, Volumes 1–2
Transportation Research Record 2423 and 2424

Presented in these volumes are the safety impacts of intervehicle warning information systems in con-

TRB PUBLICATIONS *(continued)*



The TRR Journal Online website provides electronic access to the full text of approximately 15,000 peer-reviewed papers that have been published as part of the Transportation Research Record: Journal of the Transportation Research Board *(TRR Journal) series since 1996. The site includes the latest in search technologies and is updated as new TRR Journal papers become available. To explore the TRR Online service, visit www.TRB. org/ TRROnline.*

nected-vehicle environments, an empirical evaluation of drivers' route choice, cooperative bus priority system implementation and testing, and more.

2014. Vol. 1, 78 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Vol. 2, 75 pp.; TRB affiliates, $44.25; nonaffiliates, $59. Subscriber categories: Vols. 1–2, operations and traffic management; Vol. 1, planning and forecasting, data and information technology; Vol. 2, vehicles and equipment, safety and human factors.

Traffic Law Enforcement; Occupant Protection; Alcohol 2014
Transportation Research Record 2425

Strategies for sustaining seat belt use in a high-use state, quad bike modeling for simulating rollover events, and roof damage patterns and head injuries in rollover crashes are among the topics addressed in this volume.

2014; 73 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber category: safety and human factors.

Marine Environment, Marine Safety, and Human Factors 2014
Transportation Research Record 2426

The papers in this volume examine optimal dredge fleet scheduling within environmental work windows, waterway performance monitoring, data fusion of maritime incident databases, and other topics.

2014; 53 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber categories: marine transportation, environment, safety and human factors.

Air Quality 2014, Volumes 1–2
Transportation Research Record 2427 and 2428

Among the topics explored in these volumes are speed-controlled vehicles at signalized intersections; the fuel economy of ecodriving programs in the Philippines and Japan; and an evaluation of energy and emissions performance for electric rail transit options.

2014. Vol. 1, 92 pp.; TRB affiliates, $47.25; nonaffiliates, $63. Vol. 2, 86 pp.; TRB affiliates, $47.25; nonaffiliates, $63. Subscriber categories: environment, energy.

Travel Demand Forecasting 2014, Volumes 1–2
Transportation Research Record 2429 and 2430

Presented in these volumes is research on models for New York City taxi demand by time of day; practical solutions for sampling alternatives in large-scale models; Generation Y's travel behavior and perceptions of walkability constraints; models of cyclist route choice based on GPS data; and more.

2014. Vol. 1, 187 pp.; TRB affiliates, $54.75; nonaffiliates, $73. Vol. 2, 215 pp.; TRB affiliates, $61.50; nonaffiliates, $82. Subscriber category: planning and forecasting.

Maintenance and Preservation 2014
Transportation Research Record 2431

A Bayesian model for predicting the performance of pavements treated with thin hot-mix asphalt overlays, measured anchor rod tightening of high-mast

Transportation Research E-Circulars

E-Circulars comprise committee reports, interim research findings, and problem statements on timely topics. Recent circulars include the following:

◆ Literature Searches and Literature Reviews for Transportation Research Projects (March 2015)

◆ Improving Safety Data Programs Through Data Governance and Data Business Planning (April 2015)

◆ Traffic and Transportation Simulation: Looking Back and Looking Ahead—Celebrating 50 Years of Traffic Flow Theory, A Workshop (April 2015)

◆ Improving Safety Data Programs Through Data Governance and Data Business Planning (April 2015)

◆ Moisture Damage to Hot-Mix Asphalt Mixtures (June 2015)

◆ Geotechnical Research Deployment (June 2015)

For more information on E-Circulars, visit www.trb.org/ Publications/PubsTransportationResearchCirculars.aspx.

TRB PUBLICATIONS *(continued)*

light poles in Alaska, and a defect-based condition assessment of concrete bridges are among the subjects examined in this volume.

2014; 96 pp.; TRB affiliates, $47.25; nonaffiliates, $63. Subscriber categories: maintenance and preservation, pavements, bridges and other structures.

Safety Data, Analysis, and Evaluation 2014
Transportation Research Record 2432

Authors explore the link between police and hospital road accident records, the maximum abbreviated injury scale in vehicle crashes, limiting driveway access at intersections, the use of microsimulation to estimate intersection safety, and more.

2014; 148 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber categories: safety and human factors, data and information technology.

Geology and Properties of Earth Materials 2014
Transportation Research Record 2433

Subjects in this volume include the bearing capacity of low-volume roads in Minnesota, a new procedure for selecting chemical treatments for unpaved roads, the economic impact of closing structurally deficient or functionally obsolete bridges on very low-volume roads, and assessing transferability of crash prediction models to Italian data.

2014; 135 pp.; TRB affiliates, $53.25; nonaffiliates, $71. Subscriber categories: geotechnology, pavements, materials.

Human Performance, User Information, and Simulation 2014
Transportation Research Record 2434

Explored are the effects of distractions on driving performance for touch screen–using drivers, cellphone resting locations, truncated arrow per lane guide signs, pedestrian flow at signalized crosswalks, bicycles in urban areas, and more.

2014; 146 pp.; TRB affiliates, $56.25; nonaffiliates, $75. Subscriber category: safety and human factors.

Analysis of Naturalistic Driving Study Data: Safer Glances, Driver Inattention, and Crash Risk
SHRP 2 Report S2-S08A-RW-1

Research is presented on the relationship between driver inattention and crash risk in lead-vehicle precrash scenarios corresponding to rear-end crashes.

2015; 125 pp. Subject areas: data and information technology, highways, operations and traffic management, safety and human factors, vehicles and equipment. For more information, visit www.trb.org/Publications/Blurbs/171327.aspx.

Designing the Archive for SHRP 2 Reliability and Reliability-Related Data
SHRP 2 Report S2-L13A-RW-1

This volume includes information on the development, testing, and deployment of the second Strategic Highway Research Program's Reliability Archive data repository.

2015; 107 pp. Subject areas: highways, data and information technology, operations and traffic management, safety and human factors. For more information, visit www.trb.org/Publications/Blurbs/171436.aspx.

Evaluation of the 13 Controlling Criteria for Geometric Design
NCHRP Report 783

This report explores the impact of the controlling roadway design criteria on safety and operations for urban and rural roads.

2014; 100 pp.; TRB affiliates, $43.50; nonaffiliates, $58. Subscriber category: design.

Best Practices for Crack Treatments for Asphalt Pavements
NCHRP Report 784

Best practices for crack treatments for asphalt pavements, selected after a critical review of the current states of the art and practice, are presented in this volume.

2014; 46 pp.; TRB affiliates, $33; nonaffiliates, $44. Subscriber categories: construction, maintenance and preservation, materials.

Performance-Based Analysis of Geometric Design of Highways and Streets
NCHRP Report 785

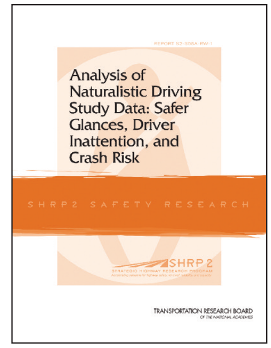
This volume offers an approach for understanding the desired outcomes of a project, selecting performance measures, evaluating the impact of alternative geometric design decisions, and arriving at solutions that achieve desired outcomes.

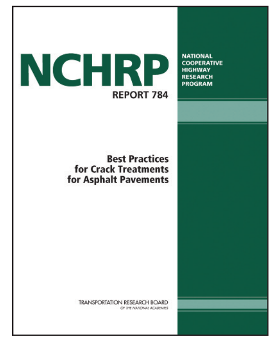
2014; 130 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber categories: design, highways.

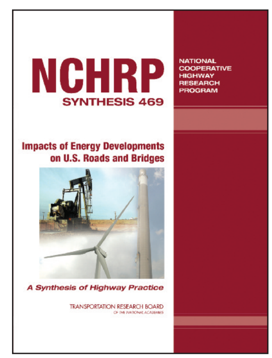
Impacts of Energy Developments on U.S. Roads and Bridges
NCHRP Synthesis 469

This synthesis documents the economic impact of heavy truck traffic related to energy development on U.S. roads and bridges.

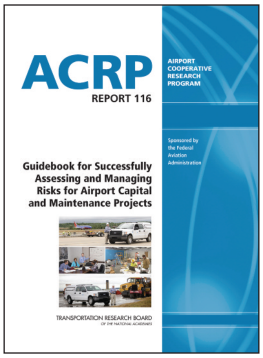
2015; 96 pp.; TRB affiliates, $41.25; nonaffiliates, $55. Subscriber categories: highways, finance, maintenance and preservation.

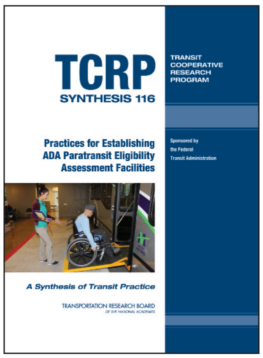


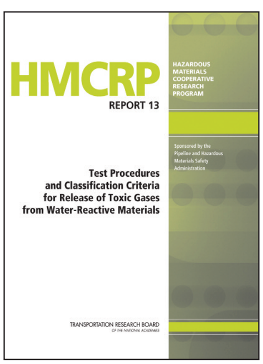




TRB PUBLICATIONS *(continued)*







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Maintenance Quality Assurance Field Inspection Practices
NCHRP Synthesis 470

Examined in this volume are practices used by state transportation agencies to support maintenance investments. The PDF version of the report includes links to online appendixes.

2015; 180 pp.; TRB affiliates, $34.50; nonaffiliates, $46. Subscriber categories: administration and management, highways, maintenance and preservation.

Guidebook for Successfully Assessing and Managing Risks for Airport Capital and Maintenance Projects
ACRP Report 116

This report establishes a step-by-step process for evaluating and managing risk for capital and maintenance projects that can be scaled depending on the complexity of the project.

2014; 127 pp.; TRB affiliates, $45.75; nonaffiliates, $61. Subscriber category: aviation.

Airport Escalators and Moving Walkways: Cost-Savings and Energy Reduction Technologies
ACRP Report 117

Presented in this volume is a systematic approach for identifying, evaluating, and selecting cost-saving and energy reduction technologies for airport escalators and moving walkways. A spreadsheet tool is included with the report.

2014; 53 pp.; TRB affiliates, $42; nonaffiliates, $56. Subscriber category: aviation.

Integrating Aviation and Passenger Rail Planning
ACRP Report 118

Planning options, funding challenges, and potential actions to improve integration of rail services with airports, particularly in congested corridors, are explored in this volume. A user guide and technical appendix accompany, as well as an air–rail diversion model on CD-ROM.

2015; 279 pp.; TRB affiliates, $70.50; nonaffiliates, $94. Subscriber categories: aviation, roads, planning and forecasting.

Guidebook on Pedestrian Crossings of Public Transit Rail Services
TCRP Report 175

This report addresses a range of engineering treatments to improve pedestrian safety for three types of public transit rail services: light rail, commuter rail, and streetcars.

2015; 173 pp.; TRB affiliates, $18.75; nonaffiliates, $25. Subject areas: pedestrians and bicyclists, public transportation, safety and human factors.

Quantifying Transit's Impact on GHG Emissions and Energy Use: The Land Use Component
TCRP Report 176

This report examines relationships between transit and land use patterns and their contribution to compact development, as well as potential greenhouse gas reduction benefits. An Excel-based calculator tool accompanies the report.

2015; 76 pp. Subject areas: public transportation, society.

Practices for Establishing ADA Paratransit Eligibility Assessment Facilities
TCRP Synthesis 116

Examined in this synthesis are practices that transit agencies use to determine if a user is eligible for paratransit under the Americans with Disabilities Act (ADA)—specifically, the processes, facilities, equipment, and tools used by transit agencies.

2015; 173 pp.; TRB affiliates, $18.75; nonaffiliates, $25. Subject areas: public transportation, energy, environment.

Integrating MTS Commerce Data with Multimodal Freight Transportation Performance Measures to Support MTS Maintenance Investment Decision Making
NCFRP Report 32

This report investigates the feasibility of evaluating potential navigation operation and maintenance projects on the Marine Transportation System (MTS) as they relate to waterborne commerce and landside freight connections.

2014; 85 pp.; TRB affiliates, $36.75; nonaffiliates, $49. Subscriber categories: marine transportation, freight transportation, maintenance and preservation.

Test Procedures and Classification Criteria for Release of Toxic Gases from Water-Reactive Materials
HMCRP Report 13

Identified in this volume is a procedure for measuring the rate of gas production when a water-reactive material involving flammable or toxic gas is combined with water.

2014; 81 pp.; TRB affiliates, $39; nonaffiliates, $52. Subscriber categories: marine transportation, railroads, safety and human factors.

INFORMATION FOR CONTRIBUTORS TO

TR NEWS

TR News welcomes the submission of manuscripts for possible publication in the categories listed below. All manuscripts submitted are subject to review by the Editorial Board and other reviewers to determine suitability for *TR News*; authors will be advised of acceptance of articles with or without revision. All manuscripts accepted for publication are subject to editing for conciseness and appropriate language and style. Authors receive a copy of the edited manuscript for review. Original artwork is returned only on request.

FEATURES are timely articles of interest to transportation professionals, including administrators, planners, researchers, and practitioners in government, academia, and industry. Articles are encouraged on innovations and state-of-the-art practices pertaining to transportation research and development in all modes (highways and bridges, public transit, aviation, rail, marine, and others, such as pipelines, bicycles, pedestrians, etc.) and in all subject areas (planning and administration, design, materials and construction, facility maintenance, traffic control, safety, security, logistics, geology, law, environmental concerns, energy, etc.). Manuscripts should be no longer than 3,000 words (12 double-spaced, typed pages). Authors also should provide charts or tables and high-quality photographic images with corresponding captions (see Submission Requirements). Prospective authors are encouraged to submit a summary or outline of a proposed article for preliminary review.

RESEARCH PAYS OFF highlights research projects, studies, demonstrations, and improved methods or processes that provide innovative, cost-effective solutions to important transportation-related problems in all modes, whether they pertain to improved transport of people and goods or provision of better facilities and equipment that permits such transport. Articles should describe cases in which the application of project findings has resulted in benefits to transportation agencies or to the public, or in which substantial benefits are expected. Articles (approximately 750 to 1,000 words) should delineate the problem, research, and benefits, and be accompanied by one or two illustrations that may improve a reader's understanding of the article.

NEWS BRIEFS are short (100- to 750-word) items of interest and usually are not attributed to an author. They may be either text or photographs or a combination of both. Line drawings, charts, or tables may be used where appropriate. Articles may be related to construction, administration, planning, design, operations, maintenance, research, legal matters, or applications of special interest. Articles involving brand names or names of manufacturers may be determined to be inappropriate; however, no endorsement by TRB is implied when such information appears. Foreign news articles should describe projects or methods that have universal instead of local application.

POINT OF VIEW is an occasional series of authored opinions on current transportation issues. Articles (1,000 to 2,000 words) may be submitted with appropriate, high-quality illustrations, and are subject to review and editing.

BOOKSHELF announces publications in the transportation field. Abstracts (100 to 200 words) should include title, author, publisher, address at which publication may be obtained, number of pages, price, and ISBN. Publishers are invited to submit copies of new publications for announcement.

LETTERS provide readers with the opportunity to comment on the information and views expressed in published articles, TRB activities, or transportation matters in general. All letters must be signed and contain constructive comments. Letters may be edited for style and space considerations.

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◆ All manuscripts should be supplied in 12-point type, double-spaced, in Microsoft Word, on a CD or as an e-mail attachment.

◆ Submit original artwork if possible. Glossy, high-quality black-and-white photographs, color photographs, and slides are acceptable. Digital continuous-tone images must be submitted as TIFF or JPEG files and must be at least 3 in. by 5 in. with a resolution of 300 dpi. A caption should be supplied for each graphic element.

◆ Use the units of measurement from the research described and provide conversions in parentheses, as appropriate. The International System of Units (SI), the updated version of the metric system, is preferred. In the text, the SI units should be followed, when appropriate, by the U.S. customary equivalent units in parentheses. In figures and tables, the base unit conversions should be provided in a footnote.

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TRN298