The Rapidly Improving U.S. Energy Outlook

Positive Implications for Transportation

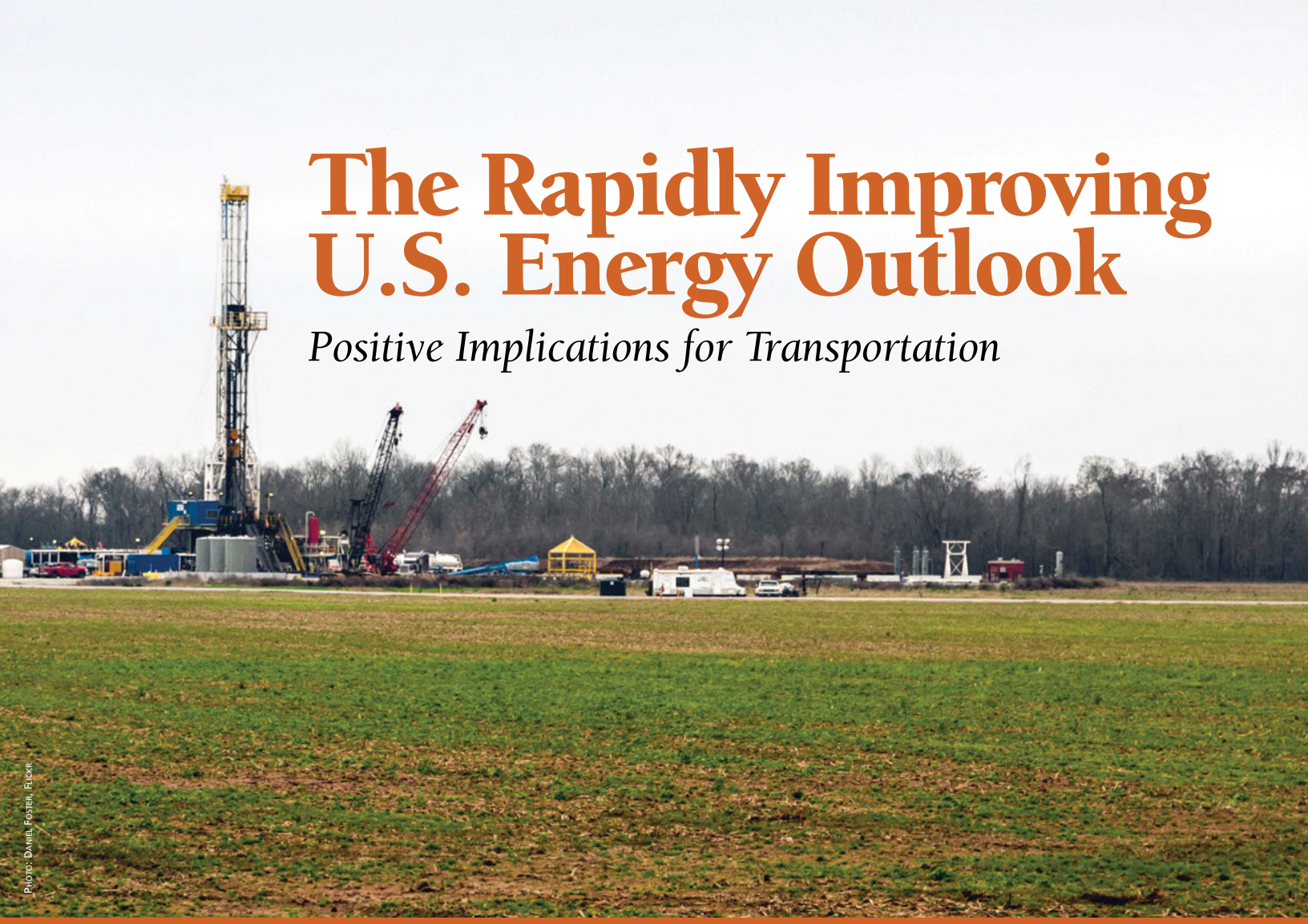

PHOTO: DANIEL FOSTER, FLICKR

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(*Photo above:*) More than one-quarter of America's energy comes from natural gas; new technologies have opened gas plays and have greatly increased supplies.

During the past five decades, the U.S. transportation system became increasingly dependent on foreign oil and vulnerable to disruptions of supply. Two oil crises and tightened standards for fuel economy did little to alter the dependence.

In the past five years, however, the long-term trend of declining domestic supply and increasing dependence on imports underwent a dramatic reversal. Advances in exploration and production technologies opened up vast new reservoirs that previously were not economically viable. U.S. oil production grew by more than 40 percent, and imports declined to record lows—in some cases, to the lowest levels in decades (*1*). Although the world market continues to set oil prices, U.S. supplies are now much less vulnerable to world events.

PHOTO: ENVIRONMENTAL PROTECTION AGENCY VIA NATIONAL ARCHIVES

World oil prices quadrupled between 1973 and 1974, prompting gas rationing in some states. Recent technological advances have reduced U.S. dependence on foreign oil.

New Energy Resources

Even more dramatic is the surge in U.S. natural gas production. Shale gas production in the United States has grown rapidly after a long-term effort by the natural gas industry, in partnership with the Department of Energy (DOE), to improve drilling and extraction methods in parallel with increased exploration.

Shale gas has entered the market, prices have plummeted, and market forces have encouraged the utility, manufacturing, and transportation sectors to consider switching fuels. Natural gas now accounts for more than one-quarter of America's total energy use, and more than one-half of the U.S. natural gas supply comes from shale and other unconventional sources (Figure 1, page 4) (*2*).

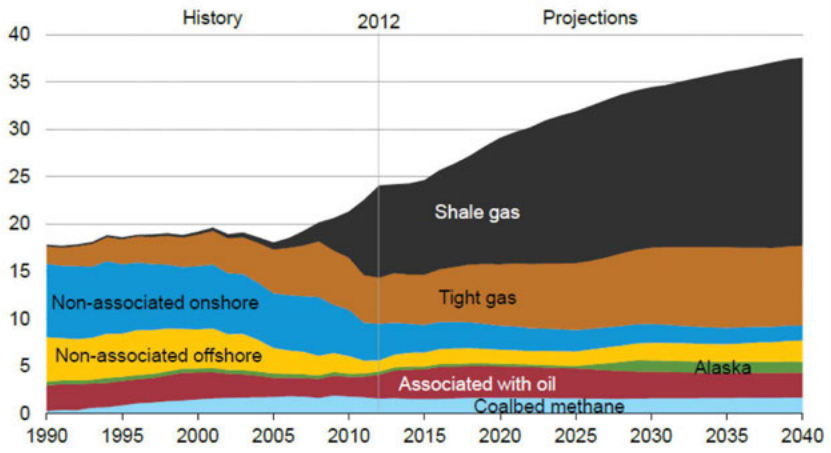


FIGURE 1 U.S. natural gas production, in trillion cubic feet, 1990–2040 (Source: EIA).

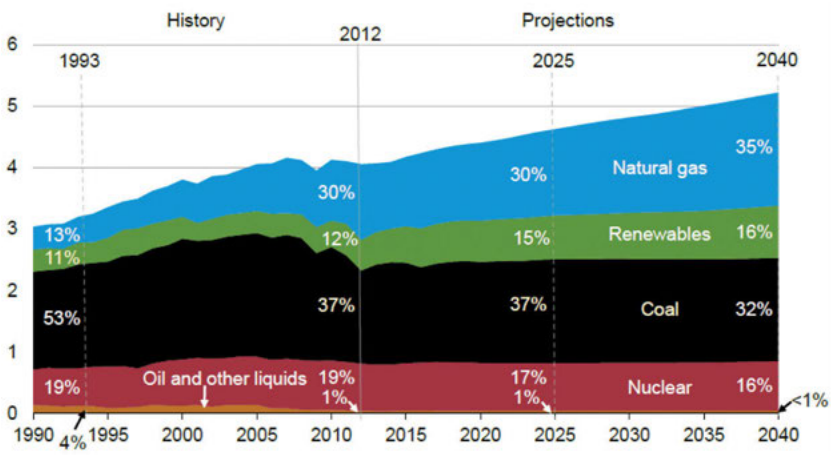


FIGURE 2 Electricity generation shifting to natural gas and renewables, in trillion kilowatt-hours per year, 1990–2040 (Source: EIA).

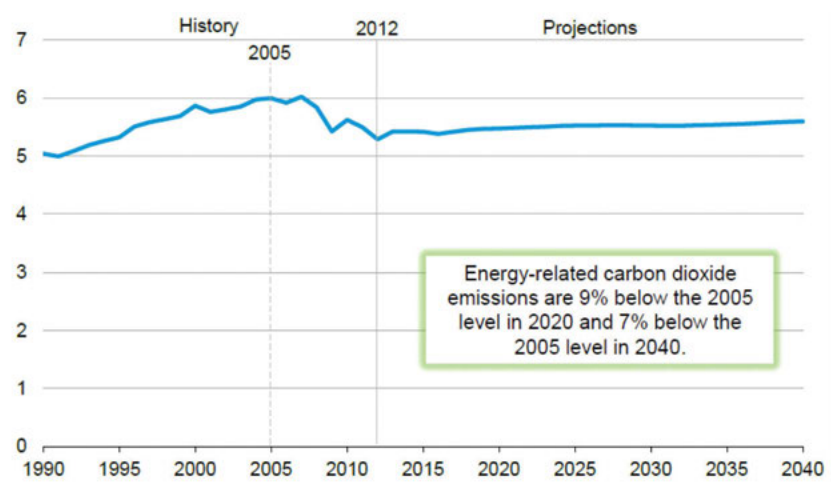


FIGURE 3 U.S. energy-related CO_2 emissions, in billion metric tons, 1990–2040 (Source: EIA).

DOE's Energy Information Administration (EIA) predicted correctly last year that the United States would be the world's top producer of petroleum and natural gas hydrocarbons in 2013, surpassing Russia and Saudi Arabia, and that imports would continue to decline. With upwardly revised estimates of Canadian and Mexican oil reserves, North America technically should have little need to import oil in the near future. The current mix of U.S. oil imports is an indicator—36 percent comes from North America, while only 16 percent originates in the Persian Gulf (*3*). This represents a major decline in U.S. vulnerability to disruptions in the oil supply from the Middle East and from other volatile areas, such as Venezuela and Nigeria.

New exploration and production technologies are not the only contributors to the changing U.S. energy outlook. Newly acquired data and updated computer models have enabled reassessments of the resources. EIA now concludes that discovered, economically recoverable resources are much larger than previously estimated. The United States, then, is not only moving closer to energy independence but may well become a net exporter of energy in the not too distant future.

Utilities Emissions

Compared with coal, natural gas is a cleaner fuel for electric power plants and could serve as a bridge for the transition to carbon-free energy sources, reducing greenhouse gas emissions to safe and acceptable levels. That process may be well under way, as the number of coal plant retirements and changeovers to cleaner sources—primarily to natural gas—reached record levels in 2012 (*4*). According to EIA projections, natural gas will generate 35 percent of all electricity by 2040, more than double the share in 2000.

Two developments are likely to increase this share: the Obama Administration's plan to issue new regulations for greenhouse gas emissions by currently operating power plants and the U.S. Supreme Court's decision upholding the authority of the Environmental Protection Agency to regulate coal plant emissions that drift across state lines. Replacing old coal-fired power generators with new natural gas–fueled units could reduce carbon dioxide (CO_2) emissions by an estimated 36 to 59 percent (*5*).

Shifting from coal- to gas-fired power plants is the main reason that U.S. greenhouse gas emissions have fallen to their lowest level in 20 years, the largest drop for any country. Figures 2 and 3 (at left) show the shift to cleaner power generation and to lower CO_2 emissions, respectively (*2*). According to EIA projections, with improved energy efficiency in all sectors and a shift away from the most carbon-inten-

sive fuels, U.S. energy-related CO_2 emissions could meet the President's goal of 17 percent below the 2005 levels by 2020 and could remain below the 2005 levels through 2040.

Transportation Emissions

New Corporate Average Fuel Economy standards are expected to reduce U.S. surface transportation fuel use and CO_2 emissions by approximately 30 percent by 2030 (*6*). If natural gas replaces a significant portion of diesel fuel consumption, particularly for bus fleets and freight transportation, emission reductions could be even greater.

Engines fueled with natural gas instead of petroleum have a well-documented record of reducing criteria pollutant emissions. The benefit of switching from petroleum to natural gas engine fueling is less clear for greenhouse gas emissions, however. The principal component in natural gas, methane, is a potent greenhouse gas.

For a net reduction in greenhouse gases, engines fueled by natural gas must have total life-cycle emissions lower than the status quo. Measuring the emissions for all the steps involved in exploration, well development, and production—and averaging them over the life of the well—is no small task.

Research is under way to measure greenhouse gas emission rates for natural gas production from a large sample of shale and conventional onshore gas wells. Preliminary results suggest that greenhouse gas emissions from shale gas production may be somewhat higher than those from conventional gas wells but produce a net benefit in a full life-cycle comparison with petroleum (*7*). Nonetheless, methane can leak during gas processing, in distribution, at transfer into a vehicle, and during vehicle operation; the leakage must be kept to a minimum if natural gas is to have a substantial net positive impact.

The shift from coal to natural gas by utilities promises another transportation environmental benefit. If electricity is produced from sources with lower greenhouse gas emissions, electric vehicles can achieve greater reductions. EIA therefore projects that greenhouse gas emissions from transportation energy consumption will decline slightly or will remain stable from 2012 through 2040, despite an increase in transportation activity (*2*).

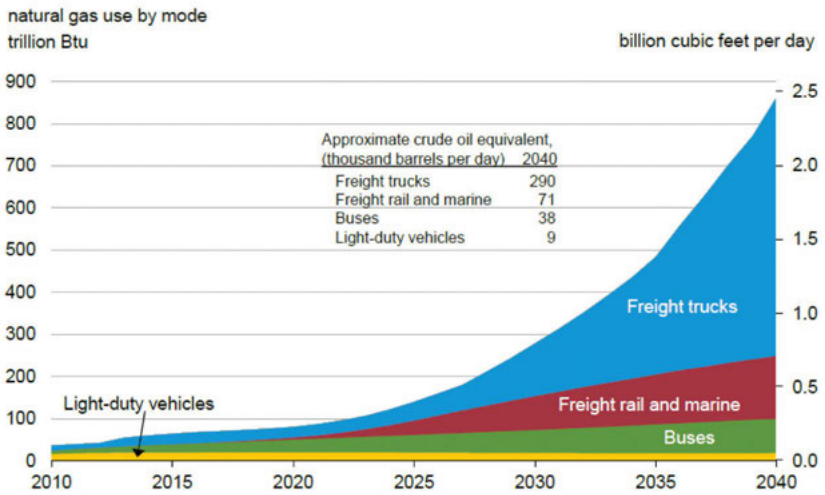


FIGURE 4 U.S. projected natural gas use by mode of transportation, in trillion Btu (*left*) and billion cubic feet per day (*right*), 2010–2040 (Source: EIA).

Photo: MARTA

Metropolitan Atlanta Rapid Transit Authority buses fuel with natural gas.

Photo: Wikimedia Commons

LA Metro converted its entire bus fleet to run on CNG fuel; the last diesel bus was retired in 2011.

Opportunities for Natural Gas

The boom in domestic natural gas production presents multiple opportunities for expanding the use of natural gas in transportation (Figure 4, page 5). Of the more than 250 million vehicles on U.S. roads, only about 140,000 are fueled by natural gas (*8*). In the rest of the world, more than 15 million natural-gas vehicles are in use (*9*), and nearly 35 million are projected by 2020 worldwide, including significant growth in the United States (*10*). Historically, natural-gas vehicle penetration has been highest in countries with abundant natural gas resources. With newly plentiful domestic supplies, the United States appears poised to enter that group (*11*).

Freight trucks present the largest long-term opportunity (*2*). In the 1990s, natural gas was introduced in buses, refuse trucks, delivery vehicles, and port drayage trucks to help urban areas meet air quality rules and manufacturers of heavy-duty engines to comply with exhaust emission standards. Because these vehicles return to a base location each day, fleet operators could use their own infrastructure for fueling. Many of these fleets today are making their compressed natural gas (CNG) stations available to others; fuel providers are building new publicly accessible stations to dispense CNG and liquefied natural gas (LNG), and the growing availability of low-cost fuel is encouraging additional fleets to convert to natural gas.

A similar sequence of events underlies natural gas expansion into other over-the-road truck, rail, and marine applications. Because its higher energy density reduces onboard storage needs and allows vehicles to travel farther before refueling, LNG may prevail as the fuel of choice for longer-haul trucks and locomotives (*12*).

Urban Fleets

The waste industry and bus fleets have made the largest push into natural gas. With Waste Management, Republic Services, and other large haulers in the lead, more than one-half of all refuse trucks placed into service in 2013 were fueled by natural gas. In the transit market, more than one-quarter of all new buses are fueled by natural gas.

LA Metro, for example, has the largest fleet of CNG buses in the nation—approximately 2,200. Officials estimate that the conversion to natural gas has cut the release of particulates from LA Metro by 80 percent and of greenhouse gases by approximately 300,000 pounds a day (*13*).

State and municipal fleets are another promising

Photo: UPS

A UPS driver fuels an LNG vehicle. UPS and other companies are investing in natural gas–fueled freight truck fleets.

Photo: Wikimedia Commons

GE designed the Evolution Series of locomotives to meet the U.S. Environmental Protection Agency's (EPA's) Tier 2 locomotive emissions standards. Development is under way of a dual-fuel version that will meet EPA's Tier 4 standards.

market for natural gas. Vehicles include not only trucks and buses, but increasing numbers of light-duty cars, vans, and pickups. In 2012, for instance, 22 states established a consortium "to work with car manufacturers in the United States to produce affordable, high-quality natural gas vehicles for their fleets—something that would be available not only to state governments, but to consumers in households and the private sector" (*14*). By aggregating their purchasing power, the states hope to create economies of scale so that manufacturers could lower the cost differential between natural gas vehicles and comparable gasoline or diesel vehicles.

Limited data suggest that the strategy is working, but barriers remain. For example, several state agencies in Colorado, an initiator of the consortium, have purchased competitively priced natural gas vehicles in the past year. But Denver's Regional Transit District (RTD) recently decided to purchase 52 diesel buses instead, because the cost of retrofitting the RTD bus barns to accommodate indoor CNG fueling would have added more than $28 million to the project (*15*).

Freight Trucks

Factory-produced natural gas–fueled trucks generally cost more than petroleum-fueled trucks—from $5,000 more for a light-duty model to more than $80,000 more for a heavy-duty, over-the-road tractor. Although truck manufacturers are working to reduce these costs, the fuel savings alone are compelling (*16*).

Natural gas fuel typically costs $1.50 less per gallon-equivalent of diesel; therefore the additional vehicle costs often can be recouped within two years, even without major reductions in the price of the vehicle. Trucking companies such as Dillon Transport and Ryder and private fleets such as UPS and Proctor and Gamble have announced major purchases (*17*). Proctor and Gamble plans to convert 20 percent of its truck fleet to natural gas in the next few years.

Locomotives

Natural gas is an attractive option for railroads, both for the cost savings and for the environmental benefits. Railroads consume approximately 4 billion gallons of diesel fuel per year; the prospect of saving $1.50 per diesel gallon-equivalent has prompted the railroad industry to consider LNG.

Companies are cautious, however, because of the costs of retrofitting or replacing locomotives, adding fuel tenders and fueling infrastructure, training personnel, revamping logistics, and securing Federal Railroad Administration (FRA) approval. These outlays would compete for funds with route expansion and upgrades to accommodate the fast-growing crude oil traffic.

Both BNSF and Union Pacific are planning to test dual-fuel LNG locomotives on their networks but no specific announcements have been made. In Canada, Westport is teaming with Caterpillar and the Canadian rail industry to demonstrate the first high-pressure direct-injection natural gas locomotive in 2014.

Canadian National already operates two dual-fuel locomotives with LNG tenders between Edmonton and Fort McMurray in Alberta and has ordered additional tenders that would increase the range of the LNG trains beyond that of conventional diesels. CSX is purchasing two bifuel locomotives from General Electric (GE) and has established a testing program to evaluate GE's NextFuel natural gas retrofit kits on the Evolution series locomotives (*18*).

Indiana Harbor Belt is converting 31 switcher locomotives to CNG as part of a multiyear program funded by the Congestion Mitigation and Air Quality Improvement Program to reduce emissions in the Chicago metropolitan area (*19*). The strategy also indicates the impact of tightened Tier 4 exhaust emissions standards that go into effect for locomotives in 2015.

The final Tier 4 standards for hydrocarbons, nitrogen oxides, and particulate matter require reductions of 50 to 70 percent from current standards for line-haul locomotives and more for switcher locomotives (*20*). Meeting these standards will require technologies such as selective catalytic reduction or dual-fuel operation.

Initially, dual-fuel locomotives may substitute LNG for 60 to 70 percent of diesel; in the longer term, newer technologies could substitute for 80 to 90 percent (*21*). EIA's 2014 reference case predicts that by 2040 natural gas will supply 35 percent of freight rail energy (*2*).

Ships

As with rail, LNG offers significant cost and environmental advantages in marine applications. Environmental benefits are important for ships operating in Emission Control Areas (ECAs) subject to a 1 percent sulfur limit. Set under Annex VI of the International Maritime Organization's International Convention for the Prevention of Pollution from Ships (MARPOL), the sulfur limit will ratchet down to 0.1 percent in 2015 and 2016 within ECAs and from 3.5 percent to 0.5 percent for all other areas in 2020.

ECAs encompass the waters within 200 miles of most of the North American, European, North African, and Japanese coasts, as well as around Hawaii and Singapore, in the Mediterranean, and much of the Caribbean. Until now, MARPOL Annex VI has largely affected vessels operating within European and North American waters. Most have switched from intermediate or heavy fuel oil to marine diesel oil at considerable cost. Every seagoing vessel must comply with Annex VI if calling at a port within an ECA.

To meet MARPOL limits in the long term, vessel owners and operators are trying three strategies:

- Securing a relatively expensive Annex VI–compliant distillate fuel with less sulfur than MDO under long-term contract,
- Continuing to burn high-sulfur fuel but using scrubbers to reduce emissions, or
- Switching to a lower-cost alternative such as LNG (*22*).

Although current pricing looks favorable, LNG will likely take some time for major inroads into the marine fleet. Dozens of LNG-capable vessels are on order, but as yet only a handful have been delivered.

Fueling Infrastructure

In the United States, the infrastructure for fueling and maintaining gasoline and diesel vehicles is ubiquitous. Equipment is standardized; fire codes and safety standards are well developed and known; first responders are familiar with potential hazards; and trained mechanics and other service personnel are widely available.

Photo: Anthony Veder, PR060

A high-speed, low–fuel consumption carrier by Anthony Veder, which is building natural gas–fueled ships.

The lack of fueling outlets for natural gas is a barrier for penetration into the transportation sector. Nevertheless, because of the clear economic advantage of natural gas in many transport applications, an industry is developing to supply the compressors, the small-scale liquefaction units, the storage tanks, and the dispensing facilities; to train the personnel; and to distribute the LNG and CNG to fueling locations on roads, railways, and in ports, as well as to provide the natural gas engines for drilling and for pressure-pumping the shale oil and gas wells.

According to *Reuter's* columnist John Kemp, "The fuel market appears to be nearing a tipping point. If the present gap between natural gas and crude oil prices remains for another 2 to 3 years, it should be enough for natural gas to establish a major beachhead in the transport market" (*23*).

Transporting Energy

The demand for the transportation of energy is on the rise. Major pipeline projects are under way that will have dramatic effects on North America's infrastructure for oil and liquids transport during the coming years.

By Pipeline

North America leads the world in pipeline construction, with 41,810 miles of new or planned lines for oil and natural gas, according to a January 2013 report (*24*). For example, the newly completed southern leg of the Keystone Pipeline route—also called the Gulf Coast Pipeline—has begun carrying more than 700,000 barrels of oil per day from Cushing, Oklahoma, to Nederland, Texas, relieving a major bottleneck in moving domestically produced oil from Oklahoma to Gulf Coast refineries.

The northern leg of the Keystone Pipeline primarily will deliver crude from Canadian tar sand oil fields to the Gulf Coast for refining before export. This pipeline segment awaits the environmental clearances for crossing an international boundary.

Although pipelines transport the bulk of the nation's crude, capacity is limited, and competition is increasing from trucks, barges, and railroads in Canada and in the United States. According to EIA's June 2013 Refinery Capacity Report, U.S. refineries received more than 1 million barrels per day by rail, truck, and barge in 2012, a 57 percent increase from 2011 (*25*).

By Rail

Rail shipments have had the largest increase. In 2008, U.S. Class I railroads originated 9,500 carloads of crude oil; by 2012, the total had expanded to nearly 234,000 carloads; and approximately 400,000 carloads are likely to originate in 2013 (see Figure 5, page 10) (*26*). Other oil-related products such as frac sand—used in hydraulic fracturing for wells—also are increasingly transported by rail, with an estimated 200,000 carloads in 2012.

Photo © TransCanada Corporation

Welder working on construction of the TransCanada Keystone Pipeline. The southern leg of the pipeline transports more than 700,000 barrels of oil per day.

Recent major rail accidents involving the shipment of oil from North Dakota have raised concerns about the safety of energy transport and have intensified the debate about the relative merits of pipelines versus rail for the transport of petroleum. FRA issued Emergency Order 28 on August 2, 2013, increasing the requirements for securing hazardous freight rail movements.[1] U.S. DOT Secretary Anthony Foxx has stated that additional regulatory actions to strengthen rail tank car standards are under consideration.

For Export

In addition, many U.S. energy companies are looking to export LNG to Europe and Asia, where prices are higher. This has implications for energy transportation both domestically and internationally, as well as geopolitical implications.

Six LNG import terminals have received permits

[1] FRA Emergency Order 28, Establishing Additional Requirements for Attendance and Securement of Certain Freight Trains and Vehicles on Mainline Track or Mainline Siding Outside of a Yard or Terminal; see *Federal Register*, Vol. 78, No. 152, August 7, 2013.

The number of barrels of oil transported to U.S. oil refineries by rail, truck, and barge increased nearly 60 percent between 2011 and 2013.

to export up to 9.3 billion cubic feet of LNG per day—Sabine Pass, Freeport, Lake Charles, and Cameron on the Gulf Coast; Jordan Cove in Oregon; Kenai in Alaska; and Cove Point on Chesapeake Bay—and more than 20 additional applications are pending (27). The first LNG exports are expected by 2016. Only a few years ago the United States was building facilities for the import of LNG.

U.S. permitting agencies are proceeding cautiously, however, because of concerns that LNG exports could raise domestic natural gas prices closer to world levels and that gas supplies from outside the United States could cut demand for U.S. shale gas. EIA's reference case forecasts modest growth in LNG exports starting in 2016, reaching more than 2 trillion cubic ft (Tcf) by 2020, and 3.5 Tcf by 2029 (2).

For Domestic Industries

Increased domestic natural gas production also has the potential to spur domestic manufacturing—including reshoring, or the return of manufacturing to the United States—by offering lower energy input costs. If this occurs, the transportation costs of supply chains could be reduced.

Industries likely to be affected by natural gas supply and pricing include steel, chemicals, glass, plastics, and fertilizer. For example, EIA is forecasting a growth of 3.4 percent per year from 2012 to 2025 in domestic industrial shipments of bulk chemicals, compared with the 2013 projected growth of 1.9 percent per year (2).

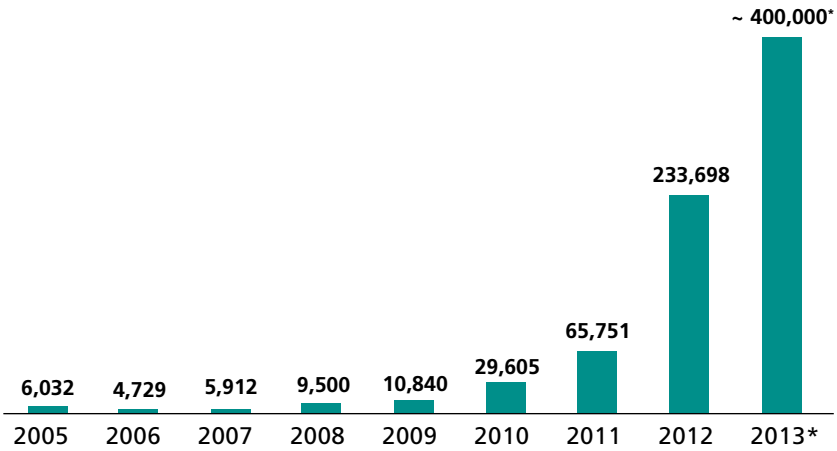
Energy Outlook Implications

Dramatic changes in energy supply and in technology development are leading to a more economical, cleaner, and more secure U.S. transportation system. EIA projects that by 2035 the United States will have reduced oil imports significantly and may even have eliminated dependence on imports. EIA predicts continued rapid growth in natural gas production, with the United States becoming a net exporter in the next decade (2).

In the short to medium term, new vehicle emissions standards, a plentiful supply of relatively cheap fuel, and growing numbers of natural gas–capable vehicles are likely to spur a significant shift to natural gas in over-the-road vehicles and in rail and marine applications. Conversion to natural gas offers economic benefits, energy security, and reductions in vehicle emissions. The increased use of natural gas for generating electricity also will reduce power source emissions for the increasing supply of electric vehicles.

Finally, the demand for transportation of energy is likely to change dramatically, with significant increases in pipeline construction and use of rail for energy transport. The safety of petroleum transport will become a more significant issue. Freight vehicles will increasingly use natural gas, supported by the necessary fueling infrastructure and responding to

FIGURE 5 Rail carloads of crude oil, 2005–2013 (* = estimate based on first three quarters, annualized. Source: American Association of Railroads).



changes in global supply chain patterns. Ports will be at the forefront of natural gas conversions for the marine industry both in landside drayage vehicles and in encouraging and facilitating the use of gas liquefaction and LNG in shipping.

Unique Win–Win

Transportation planners and operators need to stay abreast of these rapidly changing developments, which will affect local transportation system plans and energy, air quality, and climate plans at regional and state levels.

In summary, the positive developments in the U.S. and North American energy supply and technological development could represent a unique win–win for U.S. transportation, economic development, energy, air quality, and climate policy in the next few decades. Meeting these needs will be a challenge, but the rapidly improving U.S. energy outlook could lighten the task.

Photo: Ian Fuller, Flickr

A natural gas–powered truck in Sa Khwan, Thailand. U.S. exports of LNG to Asia and Europe are expected to begin in 2016.

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