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Natural Gas for Cars and Trucks: Options and Challenges

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Summary

The increase in domestic supplies of natural gas has raised new interest in expanding its use in the transportation sector. This report considers issues related to wider use of natural gas as a fuel in passenger cars and commercial vehicles.

The attractiveness of natural gas as a vehicle fuel is premised in large part on its low price (on an energy-equivalent basis) compared to gasoline and diesel fuel. When prices for gasoline and diesel are relatively low or natural gas prices are relatively high, natural-gas-based fuels lose much of their price advantage. While natural gas has other benefits—such as producing lower emissions than gasoline and diesel and protecting users of transportation fuels from the volatility of the international oil market—it is largely the cost advantage, if any, that will determine the future attractiveness of natural gas vehicles.

There are a number of technology pathways that could lead to greater use of natural gas in transportation. Some require pressurized systems to use natural gas in a gaseous state, and others convert natural gas to a liquid. Two of the most widely discussed options use compressed natural gas (CNG) and liquefied natural gas (LNG). Other technological approaches use liquefied petroleum gas (LPG), propane, and hydrogen. In addition, natural gas can be used to generate electricity to power electric vehicles.

Increasing the use of natural gas to fuel vehicles would require creation of an extensive nationwide refueling infrastructure. Although a small number of CNG vehicles have been on U.S. roads for more than 20 years, CNG use has been limited to vehicles that return to a central garage for refueling each day, such as refuse trucks, short-haul trucks, and city buses. LNG, on the other hand, requires large insulated tanks to keep the liquefied gas at a very low temperature and is therefore seen as more suitable for long-haul trucks. In both cases, the limited availability of refueling stations has limited the distances and routes these vehicles may travel.

Congress has taken a strong interest in spurring production and use of natural gas vehicles. Legislation has been introduced on a wide range of proposals that would equalize the tax treatment of LNG and diesel fuels, provide tax credits for natural gas vehicles and refueling equipment, require the production of vehicles that could run on several different fuels (such as gasoline and CNG), increase federal research and development on natural gas vehicle tank and fuel line technologies, and revise vehicle emission regulations to encourage manufacturers to produce more CNG passenger cars.

Legislation pending in the 113th Congress includes proposals that would extend expired tax credits for refueling property and fuel cell vehicles (S. 2260), authorize the use of energy savings performance contracts to support the use of natural gas and electric vehicles (S. 761), and require the U.S. Postal Service to study the feasibility of using natural gas and propane in long-haul trucks (S. 1486).

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Introduction

The discovery of new sources of domestic natural gas from shale has given rise to new interest in using natural gas more extensively in transportation. This could occur in a number of ways. Natural gas (methane) can be burned directly in conventional diesel and gasoline engines that have been modified or retrofitted. Natural gas liquids such as propane and butane can also replace gasoline. As a petrochemical feedstock, methane can be used to produce synthetic diesel fuel and gasoline substitutes such as ethanol, methanol, and butanol. A reformation process can convert methane to hydrogen for fuel cell-powered vehicles. In addition, natural gas can be burned to generate electricity for charging electric vehicles.

As natural gas supplies have increased and prices have dropped, automakers and truck manufacturers have begun taking steps to introduce new vehicle lines fueled by natural gas, principally compressed natural gas (CNG) and liquefied natural gas (LNG). Several factors have contributed to this interest:

- **Price differential.** On an energy-equivalent basis, oil has been more expensive than natural gas in recent years. Moreover, while oil prices are set in a global market, U.S. natural gas prices are largely determined domestically, and the discovery of large domestic reserves suggests that prices may remain relatively low.¹
- **Environmental preference.** Natural gas, while also a fossil fuel, generally produces lower emissions per vehicle mile than diesel and heavier oil.
- **Energy diversity and security.** Increased use of domestic natural gas for transportation may mean that less oil will be imported. The United States might be more insulated from global petroleum price volatility if more forms of transportation were based on natural gas.
- **Growth potential.** Only 2.9% of U.S. natural gas production is currently used in transportation, mainly to move gas through the pipelines, and expanded use of natural gas vehicles would likely lead to increased demand for natural gas.

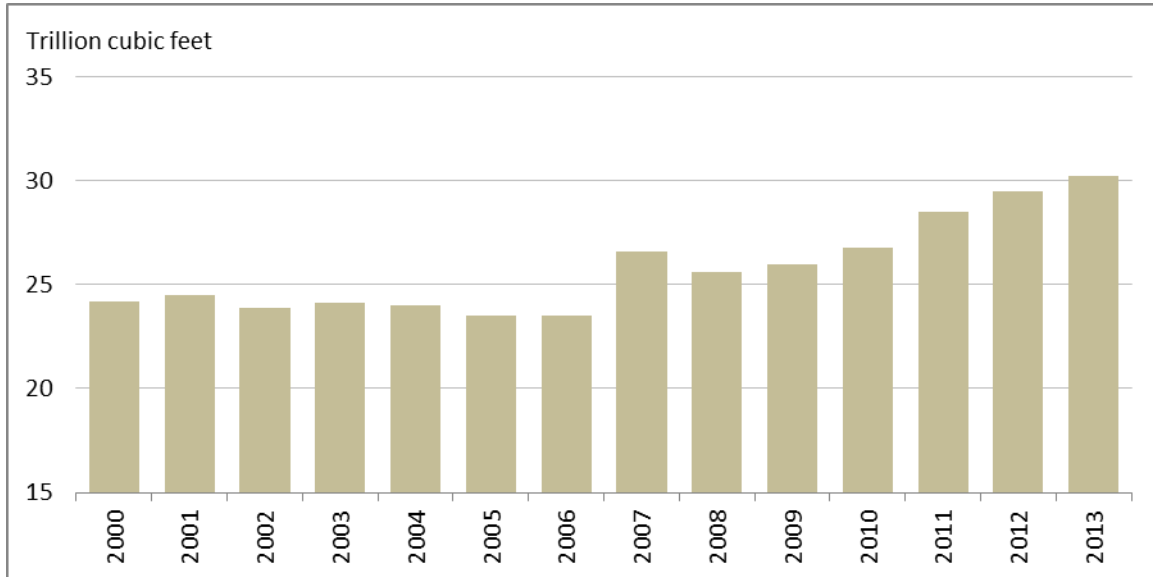
Change in U.S. Natural Gas Supply

Technology improvements such as hydraulic fracturing and directional drilling have led to massive growth in natural gas production from shale formations.² Annual natural gas production in the United States has increased by roughly one-fourth since 2006 (**Figure 1**).

¹ Although the comparative price advantage of natural gas over gasoline and diesel has shrunk recently as world oil prices have fallen and as domestic natural gas prices have held relatively steady, on an energy-equivalent basis, oil is still about three times as expensive as natural gas.

² For an analysis of the U.S. natural gas supply, see CRS Report R42814, *Natural Gas in the U.S. Economy: Opportunities for Growth*, by Robert Pirog and Michael Ratner

Figure I. U.S. Natural Gas Production
2000-2013



Source: U.S. Department of Energy, Energy Information Administration, Natural Gas Gross Withdrawals and Production, http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_m.htm.

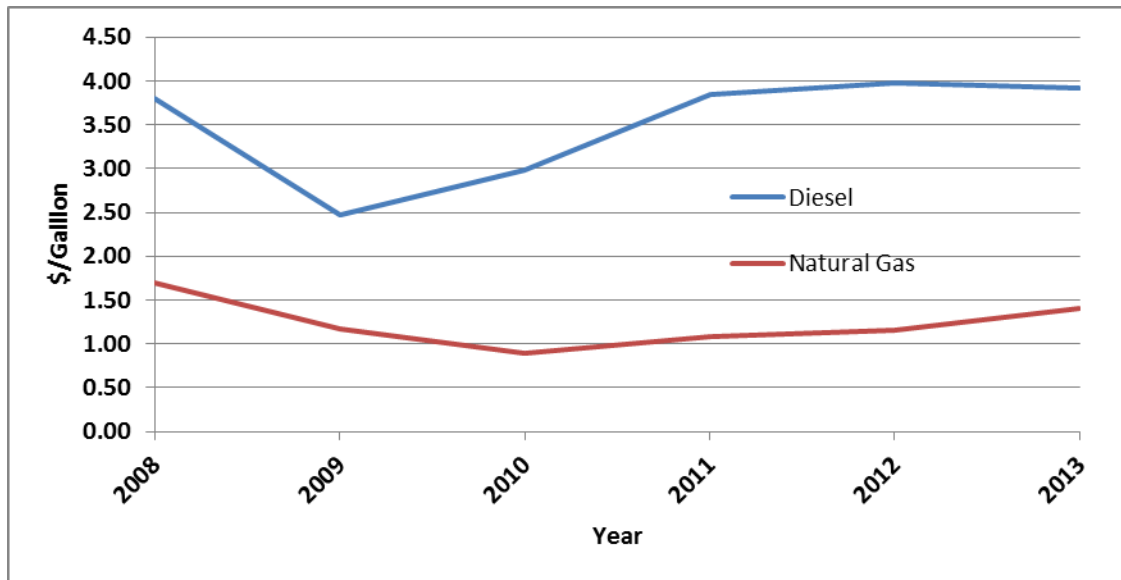
Oil-based gasoline and diesel fuel continue to remain the fuels of choice in both the domestic and commercial transportation sectors. However, U.S. demand for finished petroleum products has fallen 12% from its all-time peak in 2005, due in part to greater use of natural gas for many purposes. Although natural gas consumption by vehicles grew 26% from 2008 through 2013, natural gas still represents less than 1% of the fuels used in the transportation sector.³

Among the key factors determining the attractiveness of natural gas as a transportation fuel is its price relative to diesel fuel. The energy content of a given volume of natural gas in compressed or liquefied form differs from that of refined petroleum products. For example, one gallon of LNG has 82,644 British thermal units (Btu) of energy compared to 139,000 Btu per gallon of diesel fuel and 114,000 Btu per gallon of gasoline.⁴ Prices can be compared by converting natural gas to its gasoline gallon equivalent (GGE) or diesel gallon equivalent (DGE). Measured by Btus, a barrel of oil has historically cost several times as much as a comparable unit of natural gas (**Figure 2**). U.S. natural gas prices fell by half between 2008 and 2014 as increasing supplies from shale formations became available. The competitive price advantage that natural gas now demonstrates could be eroded if crude oil prices fall or natural gas prices rise.

³In 2013, 0.03% of the transportation sector utilized natural gas. EIA, *Transportation Sector Energy Consumption*, 2013, http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_11.pdf.

⁴Prometheus Energy, "LNG Quick Facts," <http://www.prometheusenergy.com/benefits/documents/LNGQuickFacts.pdf>.

Figure 2. Retail Diesel and Natural Gas Price Trends
2008–2013



Source: CRS calculated natural gas pricing, converted to gallon equivalent, based on EIA data.

Note: Retail service station prices are for a gallon of diesel and a diesel gallon equivalent for natural gas.

Vehicle Technologies Using Natural Gas

Several different technologies can be used to harness natural gas as a vehicle fuel. Some of them require pressurized systems to burn the fuel in a gaseous state, and others convert natural gas to a liquid. Still others process natural gas into a variety of liquid fuels suitable for powering internal-combustion engines.

The increased use of natural gas as a transportation fuel in any form would require substantial changes in vehicles and fueling infrastructure. New vehicles would need to be developed on a large scale, in some cases requiring new technologies. New fueling stations would be required to make fuel widely available. Vehicle manufacturers, fleet owners, vehicle buyers, and service station operators would all need to make significant investments. The required investments differ with the type of technology employed.

Compressed Natural Gas

Under ambient temperatures and pressure,⁵ natural gas has a volumetric energy density of about only 1/1000 that of gasoline.⁶ In that state, it would not be able to function as a vehicle fuel. If natural gas is compressed to a pressure of 3,600 pounds per square inch (psi),⁷ however, it

⁵ Ambient temperature and pressure reflect the level of those elements in the surrounding environment.

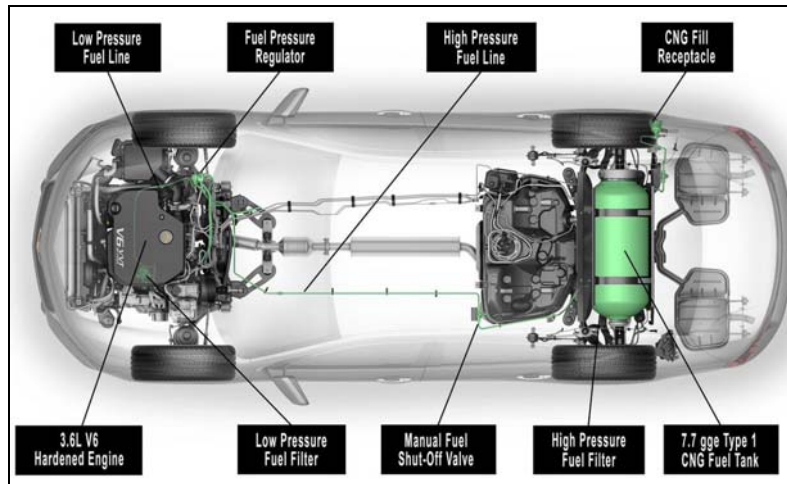
⁶ John G. Ingersoll, *Natural Gas Vehicles* (Lilburn, GA: Fairmont Press, 1996), p. 81.

⁷ Psi is a unit of measurement meaning pound-force per square inch and is the pressure resulting from a one-pound (continued...)

becomes suitable for use in a vehicle engine. As shown in **Figure 3**, a CNG vehicle’s fuel storage tank is mounted in the back of a vehicle and takes up about half of what is the trunk in a traditional vehicle. It contains about eight gasoline gallons equivalent, which give it a driving range of over 150 miles.

Figure 3. Cross-Section of a CNG Vehicle

2015 Chevrolet Impala
Components that differ from a gasoline-powered vehicle



Source: General Motors Company. Reprinted by permission.

The CNG fuel system transfers the highly pressurized natural gas from the storage tank to the engine, reducing pressure during the transfer to equate to the operating pressure of the engine’s fuel-management system.⁸ A CNG engine functions like a gasoline engine: The fuel and air mixture are compressed and then ignited by a spark plug, expanding gases to drive pistons to propel the vehicle. Certain changes are required to accommodate the pressurized, gaseous CNG, such as new valves and fuel injectors and a pressure regulator.⁹ While much of a natural gas vehicle’s composition is similar to that of gasoline-powered internal combustion engine vehicle, modifications required for CNG use currently add up to \$11,000 to the price of a passenger vehicle.¹⁰

Some current models of CNG vehicles are bifuel, with tanks for both CNG and gasoline, thereby allowing for extended driving range.¹¹ When a bifuel vehicle runs out of CNG, it automatically

(...continued)

force on a one-inch area. The higher the psi, the greater the pressure inside a container.

⁸ CNG vehicles’ fuel systems must meet Federal Motor Vehicle Safety Standards 303 and 304. See U.S. Department of Transportation, National Highway Traffic Safety Administration, “Federal Motor Vehicle Safety Standards and Regulations,” <http://www.nhtsa.gov/cars/rules/import/fmvss>.

⁹ General Motors, “Chevrolet Announces Pricing of CNG-Capable 2015 Impala”, press release May 6, 2014; Michael Austin, “2012 Honda Civic Natural Gas,” *Car and Driver*, March 2012.

¹⁰ A 2015 gasoline-fueled Chevy Impala lists for \$27,060; its CNG version lists for \$38,210. Similarly, a 2015 Honda Civic lists for \$18,490 and its CNG counterpart for \$26,640. Source: GM and Honda.

¹¹ The natural gas Honda Civic is a dedicated vehicle, with a CNG tank and no gasoline tank.

shifts into gasoline mode. Drivers can also shift from one fuel to another by selecting a dashboard button.

In addition to passenger vehicles, CNG has been adopted as a fuel for taxis; regional-haul trucks used in local freight and package delivery; construction, residential refuse pickup, and municipal fleets; and transit buses. The vehicles return each day to a central garage or maintenance yard, where refueling infrastructure may be installed. In some cases, government subsidies have been required to make CNG competitive with diesel fuel. In September 2014, for example, the brewer Anheuser-Busch announced that it would replace 66 heavy-duty delivery trucks in Houston with CNG-powered vehicles after the Texas Commission on Environmental Quality approved a \$45,000 grant for each vehicle.¹²

There are about 150,000 CNG vehicles on the road today in the United States. About 88,000 are cars, SUVs, and vans, and the rest are commercial vehicles, refuse trucks, and buses.¹³ Among passenger vehicles, and in addition to the Honda Civic natural gas sedan and the Chevrolet Impala sedan, automakers offer bifuel Chevrolet Silverado and Sierra pickup trucks and a Chrysler Dodge Ram 2500 Dual Cab pickup truck. General Motors also offers Express and Savana cargo and passenger vans with dedicated CNG engines.¹⁴ Further, several companies offer natural gas conversions of new vehicles.

Liquefied Natural Gas

LNG is produced when natural gas is cooled to -260 degrees Fahrenheit, turning it into a liquid fuel that takes up 1/600 of the volume of the fuel in a gaseous state. Long-haul trucks are a target market for use of LNG because of the fuel's price advantage and environmental benefits over diesel fuel.¹⁵ It is preferred over CNG for long-haul trucking because it requires only 30% of the space to store the same amount of energy¹⁶ and has a higher energy density per unit of volume.¹⁷ Range is also important, as long-haul truck drivers seek to reduce down-time in refueling. According to trucking company J. B. Hunt Transport Services,¹⁸ a diesel tractor with:

- a 100-gallon diesel tank has a range of 640 miles,¹⁹
- two 100-gallon LNG tanks (110 DGE) has a range of 605 miles,²⁰ and

¹² Christopher Helman, "Budweiser Puts Its Diesel Trucks Out to Pasture, Switches to Natural Gas," *Forbes*, September 9, 2014.

¹³ Natural Gas Vehicles for America presentation, September 2014.

¹⁴ Natural Gas Vehicles for America, <https://www.ngvamerica.org/vehicles/vehicle-availability/>.

¹⁵ Estimates on environmental benefits vary. A recent Department of Energy analysis predicted that after new vehicle fuel economy and greenhouse gas standards are fully implemented in 2035, CNG cars would achieve roughly 10% lower and 5% lower greenhouse emissions than gasoline and diesel cars, respectively. A natural gas industry group estimates that natural gas vehicles emit 13 to 21% fewer greenhouse gas emissions than gasoline or diesel fuels. NGVA, <https://www.ngvamerica.org/natural-gas/environmental-benefits>.

¹⁶ The tanks add weight to the truck and reduce the size of the payload that can be carried.

¹⁷ Center for Liquefied Natural Gas, "LNG Vehicles," <http://www.lngfacts.org/lng-market/lng-vehicles/>.

¹⁸ CRS interview with Jerrod Mounce, director of fuel management, J. B. Hunt Transport Services, October 2, 2014.

¹⁹ Diesel truck engines normally get about 6.4 miles per gallon (100 x 6.4 = 640).

²⁰ Two hundred gallons of LNG equate to 110 diesel gallons; LNG trucks get about 5.5 miles per gallon (110 x 5.5 = 605).

- four 25-gallon CNG tanks (100 DGE) has a range of 467 miles.²¹

When a truck engine is started, it warms the LNG, converting it into a compressed gas. While about 80% of an LNG truck engine is similar to a diesel truck engine,²² LNG-related components add about \$50,000 to the price of a truck that might otherwise sell for \$150,000.²³ According to truck manufacturer Freightliner, an LNG-fueled truck driven 50,000 miles per year could save \$85,000 in annual fuel costs, recouping the additional capital cost of the vehicle in seven months.²⁴

LNG is not ideal for passenger vehicles because of the large insulated tanks needed to keep the fuel cold.²⁵ In addition, LNG is most effective when the vehicle it fuels is used regularly, such as long-haul trucks. When LNG is not being used on a regular basis, it is slowly heated by the surrounding temperatures and eventually escapes into the air.

There are 4,000-5,000 LNG trucks operating on U.S. highways.²⁶ Fleet operators—including Waste Management, United Parcel Service, and AT&T—have shown an interest in LNG trucks. In some cases, they have installed conversion kits that enable trucks to run on either LNG or diesel, allowing owners to take advantage of changing prices. The market for truck fuel is large. Approximately 3.2 million big-rig trucks use about 25 billion gallons of diesel annually, accounting for about 9% of U.S. oil consumption.²⁷

Methanol

Methanol is a form of alcohol that can be made from plant material or anything that was once a plant. About 15 billion gallons of methanol are produced worldwide annually, most of it from natural gas.²⁸ It is used to make a wide range of chemicals that form the basis of acetic acid, formaldehyde, and other industrial products. Because it is a liquid and has a high octane rating,²⁹ it can also be utilized as motor vehicle fuel source in three ways: (1) directly in a vehicle or blended with gasoline; (2) converted into dimethyl ether (DME) as a diesel replacement, and (3)

²¹ As a CNG tank is emptied, its gas pressure declines and only about 85% of the fuel can be utilized ($85 \times 5.5 = 467$).

²² Cummins Westport, Inc., “Natural Gas Engines,” <http://www.cumminswestport.com/natural-gas-academy-videos/engines>.

²³ Bob Tita, “Slow Going for Natural-Gas Powered Trucks,” *Wall Street Journal*, August 25, 2014.

²⁴ The Freightliner calculator assumes a diesel truck travelling an average of six miles per gallon, diesel fuel at \$3.75 per gallon, and a cost of \$1.75 per diesel gallon equivalent for natural gas. Under this scenario, the annual fuel cost would be \$81,000 for natural gas and \$166,000 for diesel. See Freightline, “Calculate Your Natural Gas Savings,” <http://www.freightlinergreen.com/calculator>.

²⁵ Natural Gas Vehicles for America, “LNG/LCNG,” <https://www.ngvamerica.org/stations/Inglcng/>.

²⁶ CRS interview with Paul Kerkhoven, Natural Gas Vehicles for America, October 22, 2014.

²⁷ Rebecca Smith, “Will Truckers Ditch Diesel?,” *Wall Street Journal*, May 23, 2012.

²⁸ U.S. Congress, Senate Committee on Energy and Natural Resources, *Usage of Natural Gas*, statement of Gregory Dolan, Acting CEO, Methanol Institute, 112th Cong., 2nd sess., July 24, 2012, S.Hrg. 112-587, p. 51.

²⁹ The octane rating of liquid petroleum fuels measures the ignition quality of the fuel. For example, regular gasoline often has a posted octane rating of 87, while premium gasoline may be rated 93. The higher the octane rating, the less susceptible the fuel is to premature burning in the combustion chamber of the engine. Most four-cylinder passenger vehicle engines are built to use 87 octane. Some newer, high-compression passenger vehicle engines require a higher octane to perform efficiently.

part of biodiesel³⁰ production.³¹ Its main disadvantage is that methanol has low volumetric energy density: A gallon of methanol has about 49% of the Btus of a gallon of gasoline.³²

The incremental cost of adding methanol capability to a passenger vehicle is under \$200 per vehicle. This is normally done by installing an alcohol fuel sensor to monitor the fuel mixture and adjust fuel flow according to the ratio of methanol to gasoline, thereby creating a “flex-fuel” vehicle that can run on pure methanol, pure gasoline, or any combination of the two. No methanol flex-fuel vehicles are produced domestically at this time.³³ When they were in production, manufacturers added larger fuel injectors and stainless steel fuel tanks and fuel lines, because methanol is highly corrosive and would deteriorate aluminum or other standard metal fuel line parts.

California experimented with use of methanol as a fuel from 1988 to 2004 and spurred the production of about 15,000 methanol vehicles, most of them flex-fuel cars.³⁴ Lower gasoline prices and other industry factors led to a gradual decline in the competitiveness of methanol as a vehicle fuel.

Propane Autogas

Propane accounts for about 2% of the energy used in the United States. It is stored and transported in compressed liquid form, but it is vaporized into a gas for final use when released from a pressurized storage container.³⁵ Propane is commonly used for home and water heating, cooking, and refrigeration, especially in rural areas without natural gas. In addition, the chemical industry uses propane as a raw material.

Propane’s relatively high energy density³⁶ and clean-burning attributes have made it attractive for some types of transportation. It is known as autogas or liquefied petroleum gas (LPG) when used as a motor vehicle fuel.³⁷ Only a very small part of the propane manufactured each year is used

³⁰ Biodiesel fuel can be made from plant material, such as soybeans or sunflowers, but to convert the raw fat or oil from those plants into a fuel, they must first undergo a series of chemical reactions. Methanol is often used to facilitate this process. See National Renewable Energy Laboratory, “Biodiesel and Other Renewable Diesel Fuels,” <http://www.nrel.gov/docs/fy07osti/40419.pdf>.

³¹ Methanol Institute, “Methanol Transportation Fuel,” <http://www.methanol.org/Energy/Transportation-Fuel.aspx>.

³² U.S. Department of Energy, Alternative Fuels Data Center (hereafter AFDC), “Fuel Properties Comparison,” http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf.

³³ Methanol flex fuel vehicles were produced domestically in the 1990s.

³⁴ The California Energy Commission began testing methanol vehicles in the 1970s. In addition, the federal Alternative Motor Fuels Act of 1988 (AMFA; P.L. 100-94) encouraged the production of alcohol and natural-gas-powered vehicles. Methanol fueling stations were built in 15 states after the passage of AMFA. Gregory Dolan, “Methanol Transportation Fuels: A Look Back and a Look Forward,” Methanol Institute, <http://eri.ucr.edu/ISAFXVCD/ISAFXVAF/MTFLBLF.pdf>.

³⁵ U.S. Department of Energy, Energy Information Administration, “Propane Prices: What Consumers Should Know,” <https://www.npga.org/files/public/Propane%20Prices%20What%20Consumers%20Should%20Know.pdf>.

³⁶ Propane (91,000 Btu per gallon) has 73% of the energy of one gallon of gasoline. U.S. Department of Energy, Alternative Fuels Data Center, “Fuel Properties Comparison,” http://www.afdc.energy.gov/fuels/fuel_comparison_chart.pdf.

³⁷ To enable propane to be used as a motor fuel, other gases are mixed with it: no more than 5% propylene and 5% other gases—primarily butane and butylene.

for transportation.³⁸ Stored in a vehicle tank pressurized to about 150 pounds per square inch, it becomes a liquid with an energy density 270 times greater than the gaseous form. Because its Btu rating is lower than gasoline, it takes more fuel to drive the same distance. As with CNG, vehicles are produced as dedicated propane or bifuel, with separate fueling systems permitting use of either propane or gasoline. General Motors offers the only light-duty propane vehicles now on the market, the Chevrolet Express and GMC Savana vans.³⁹ It is estimated that about 157,000 propane vehicles are on U.S. roads, most of them school buses, police cars, and other fleet vehicles.⁴⁰

Other Natural Gas Fuels

Natural gas can be processed into a number of other fuels that are suitable for use in motor vehicles:

- DME is a colorless gas that can be derived from renewable materials and fossil fuels like natural gas and coal. When liquefied under pressure, it has properties similar to propane. It can also be used as a replacement fuel in diesel trucks.⁴¹ China accounts for about 90% of global DME consumption, using it for residential heating and cooking but also increasingly as a truck and bus fuel.⁴² A privately funded U.S. pilot program for trucks is underway.
- Using gas-to-liquids technology (GTL), natural gas can be converted into synthetic base oil with fewer impurities than petroleum, resulting in less wear of equipment and greater fuel efficiency. GTL products can be used as replacements for motor oil and diesel fuel (or blended with it).⁴³ Royal Dutch Shell operates two GTL plants outside the United States, and other companies are studying the feasibility of constructing GTL plants on the U.S. Gulf Coast.⁴⁴ There are no known plans to use GTL to fuel motor vehicles in the United States, but Shell has announced that it will use the technology to create lower-viscosity engine oils to improve fuel economy.⁴⁵ GTL-based lubricants are used in some U.S. light vehicles.⁴⁶
- Hydrogen, produced mainly from natural gas, can be used to power fuel cell vehicles. This process relies on the existing natural gas supply and pipeline

³⁸ It is used in over 17 million vehicles globally. AFDC, “Propane Fuel Basics,” http://www.afdc.energy.gov/fuels/propane_basics.html.

³⁹ AFDC, “Propane Vehicles,” <http://www.afdc.energy.gov/vehicles/propane.html>.

⁴⁰ Estimate of the Propane Research and Education Council, October 23, 2014.

⁴¹ International DME Association, “Frequently Asked Questions,” <http://www.aboutdme.org/index.asp?bid=234#Q1.1>.

⁴² Shanghai has announced plans for a pilot program to burn DME in fleets of buses, taxis, and commercial trucks as a way to cut particulate emissions and reduce oil imports. Daniel Kauffman and Bob Riedford, “Dimethyl Ether: The Most Promising Fuel You’ve Never Heard Of,” *Gas Investing News*, January 28, 2014, <http://gasinvestingnews.com/8048-dimethyl-ether-the-most-promising-fuel-youve-never-heard-of.html>.

⁴³ Deborah Lockridge, “Gas-to-Liquids Technology Makes Fuel, Oil from Natural Gas,” *TruckingInfo.com*, September 2014.

⁴⁴ Chris Pedersen, “Sasol Clears Major Hurdle to Build America’s First GTL Plant,” *OilPrice.com*, September 4, 2014, <http://oilprice.com/Energy/Natural-Gas/Sasol-Clears-Major-Hurdle-to-Build-Americas-First-GTL-Plant.html>.

⁴⁵ Lockridge, “Gas-to-Liquids Technology.”

⁴⁶ *Ibid.*

network: 95% of the hydrogen produced in the United States is made this way in 73 plants.⁴⁷ Hydrogen fuel cell vehicles have been under development for well over a decade, with substantial research and development by automakers and the Department of Energy (DOE) to find a competitively priced vehicle technology. Methods of making hydrogen from natural gas currently result in significant greenhouse gas emissions, so further research is seen as necessary to develop better processes.⁴⁸ The absence of a refueling network is also a challenge. A few manufacturers will introduce fuel cell cars in 2015.⁴⁹

- Butanol is an alcohol that can be used as a gasoline substitute. It can be produced almost entirely from petroleum, but like ethanol, the colorless alcohol can also be brewed from sugar beets, cereal crops, and corn, though it contains more energy when mixed into gasoline. A blend of 85% butanol and 15% gasoline can be used in unmodified gasoline engines.⁵⁰ Butanol depends on natural gas indirectly as fuel source for the distillation processes, can be transported in existing gasoline pipelines, and produces more power per gallon than ethanol. It can be used in existing motor vehicles without any adjustments to the engines and can be sold through gasoline stations, much as gasoline/ethanol blends are sold now. It may debut at U.S. pumps as soon as next year: A BP-DuPont joint venture is retrofitting a Minnesota ethanol plant to begin producing butanol for vehicles in 2015.⁵¹

Natural-Gas-Based Electricity

Spurring the production and use of electric vehicles is another way to use natural gas in vehicles. In 2013, 27% of U.S. electricity was generated from natural gas, more than doubling from amounts used for that purpose in 2004.⁵² The use of natural gas in electricity generation is forecast to grow steadily in the future. In 2013, it accounted for just over half of new electric utility generating capacity.⁵³

⁴⁷ U.S. Environmental Protection Agency, *Technical Support Document for Hydrogen Production: Proposed Rule for Mandatory Reporting Greenhouse Gases*, August 5, 2008, http://www.epa.gov/ghgreporting/documents/pdf/archived/tsd/TSD%20HydrogenProduction%20EPA_2-02-09.pdf.

⁴⁸ National Research Council, *Transitions to Alternative Vehicles and Fuels* (Washington, DC: National Academies Press, 2013), p. 60, http://www.nap.edu/catalog.php?record_id=18264.

⁴⁹ John O'Dell, "8 Things You Need to Know About Hydrogen Fuel-Cell Cars," Edmunds, May 21, 2014, <http://www.edmunds.com/fuel-economy/8-things-you-need-to-know-about-hydrogen-fuel-cell-cars.html>.

⁵⁰ AFDC, "Biobutanol," http://www.afdc.energy.gov/fuels/emerging_biobutanol.html.

⁵¹ Eduard Gismatullin and Kari Lundgren, "Branson's Butanol Heading to U.S. as Ethanol Substitute," Bloomberg, January 29, 2014, <http://www.bloomberg.com/news/2014-01-29/branson-s-butanol-heading-to-u-s-as-ethanol-substitute.html>.

⁵² U.S. Department of Energy, Energy Information Administration, "Electric Power Monthly," http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_2_04_a.

⁵³ The Energy Information Administration reports that 60% of the new natural gas generating capacity was in California. Other states adding natural gas generation include Florida, Texas, Utah, North Dakota, and Iowa. U.S. Department of Energy, Energy Information Administration, "Today in Energy," April 8, 2014, <http://www.eia.gov/todayinenergy/detail.cfm?id=15751>, and "Today in Energy," September 9, 2014, <http://www.eia.gov/todayinenergy/detail.cfm?id=17891>.

Greater production and use of electric vehicles could be an indirect way to increase the natural gas/vehicle linkage. A \$7,500 federal tax credit currently exists for purchasing a plug-in electric vehicle; many states have tax incentives on top of the federal credit.⁵⁴

Prospects for Growth

Future consumer and commercial interest in natural gas vehicles hinges on the relative price of petroleum to natural gas, refueling infrastructure, environmental concerns, federal and state incentives, and the price of natural gas vehicles relative to traditional gasoline vehicles. Perhaps the most important one is the long-term relationship of gasoline and diesel prices to fuels using natural gas. The success of all alternative fuel vehicles—whether electric, ethanol, natural gas, or hydrogen—is premised on rising prices for gasoline and other vehicular petroleum products. Methanol and ethanol flex-fuel vehicles are to some extent casualties of falling petroleum prices in the 1990s and later. If vehicle buyers believe that the cost of gasoline and diesel fuel in future years will be low relative to the cost of natural gas, the hurdle for natural gas vehicles will be high.

Refueling Network

Any new vehicle fuel faces a chicken-and-egg dilemma. On one hand, the lack of a refueling infrastructure makes vehicle buyers reluctant to try the new technology. On the other hand, investors are unwilling to build the necessary infrastructure until they can see that the new fueling stations will be widely used and return a profit. This dynamic is accurately summarized by J. B. Hunt Transport Services: “finding an adequate natural gas station to support an operation is usually the biggest obstacle we encounter on this topic today.”⁵⁵

Cars and CNG

Natural gas fueling is less expensive than gasoline. For example, in mid-October 2014, a gallon of gasoline was \$3.20, and CNG on a GGE basis was \$2.69.⁵⁶ An extensive network of natural gas pipelines throughout the United States provides a ready source of gas in most communities. The most difficult step is finding an economical way to transfer that gas to facilities where it can be pressurized as CNG and distributed commercially.

Stations can offer three ways to fill up a vehicle tank: fast-fill, time-fill, and combination fill (using both fast- and time-fill). Fast-fill draws gas from the gas utility line, filters it with a dryer to remove water and humidity, compresses it, and then stores it in a tank from which it is dispensed. Most retail and some fleet operations use this process, which requires only a few minutes to fill a 20-gallon-equivalent tank. With time-fill, the CNG is provided straight from utility gas line to the compressor. Since there is no storage tank to draw from, time-fill’s speed depends on the size of the compressor; it could take a few minutes or many hours. An advantage

⁵⁴ See CRS Report R41709, *Battery Manufacturing for Hybrid and Electric Vehicles: Policy Issues*, by Bill Canis.

⁵⁵ Jerrod Mounce, “Natural Gas in Transportation,” J. B. Hunt Transport Services, February 2014, p. 2, http://www.jbhunt.com/files/0001723_NATURAL_GAS_WHITE_PAPER_022014.pdf.

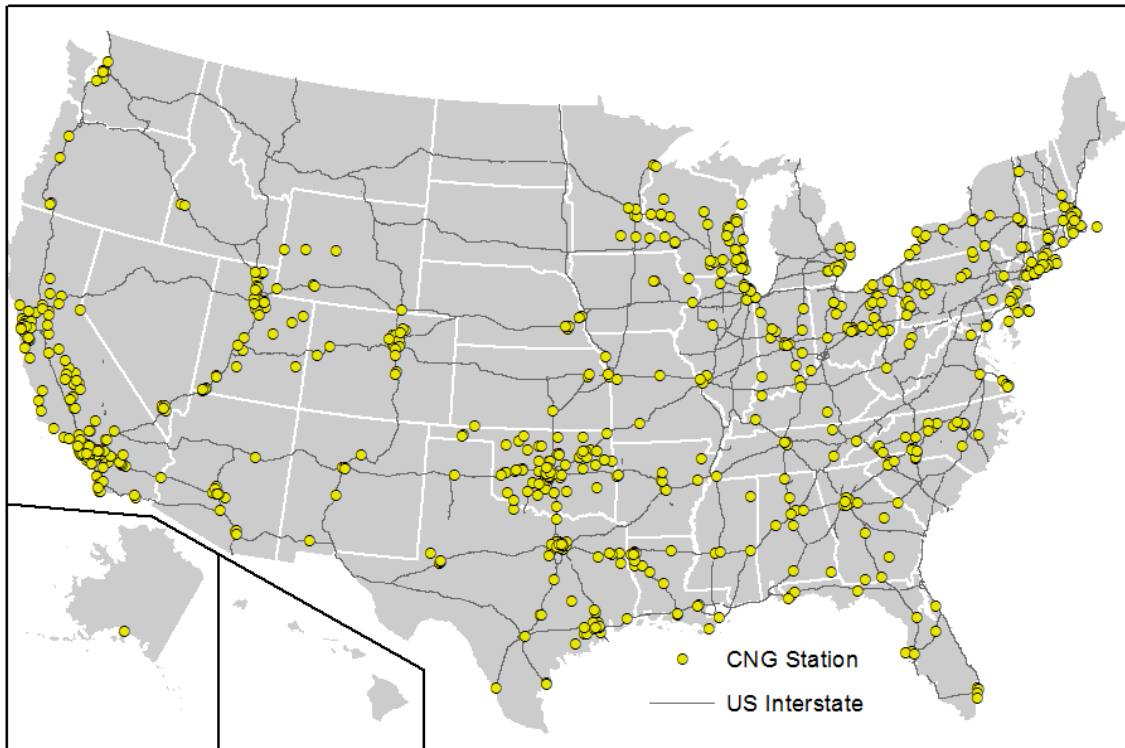
⁵⁶ Gasoline price is from U.S. Department of Energy, Energy Information Administration, “Gasoline and Diesel Fuel Update,” <http://www.eia.gov/petroleum/gasdiesel>. CNG price is from <http://www.cngprices.com>.

to a slower fill is that the tank is filled more thoroughly than with fast-fill.⁵⁷ Time-fill is usually a slower refueling option and is often used by delivery trucks and buses refueling overnight at a central garage or by car owners at home.

There are 772 public CNG service stations throughout the country (**Figure 4**), and another 127 are planned. Car owners also have the option of refueling vehicles at home. A home refueling unit, including installation, can cost about \$5,000.⁵⁸

Figure 4. CNG Refueling Stations

Open in 2014



Source: CRS map developed using DOE data, http://www.afdc.energy.gov/fuels/natural_gas_locations.html.

Trucks and LNG

LNG refueling infrastructure is not yet as developed as the CNG network. Stations use LNG produced off-site at liquefaction facilities. The fuel is then trucked to the refueling station for use.⁵⁹ LNG refueling is similar to diesel refueling and takes about the same amount of time: fuel is dispensed at pressures of 30-120 psi.⁶⁰ However, the cryogenic nature of LNG requires the

⁵⁷ AFDC, “Compressed Natural Gas Fueling Stations,” http://www.afdc.energy.gov/fuels/natural_gas_cng_stations.html.

⁵⁸ *Consumer Reports*, “The Natural-Gas Alternative: The Pros and Cons of Buying a CNG-Powered Car,” April 2014, <http://www.consumerreports.org/cro/2012/03/the-natural-gas-alternative/index.htm>.

⁵⁹ Natural Gas Vehicles for America, “Stations,” <https://www.ngvamerica.org/stations>.

⁶⁰ AFDC.

person filling the tank to use safety equipment, such as gloves and eye protection.⁶¹ In addition to filling stations, LNG is available from mobile tanker trucks with onboard metering and dispensing capacity.

Refueling stations are being built primarily on major interstate highways used by long-haul trucks and at wide intervals, since the trucks can usually travel about 500 miles without refueling. According to DOE, 64 public LNG stations are open (**Figure 5**), and another 82 are planned. The public network is being built by three investor groups. Clean Energy Fuels and Pilot Flying J, a truck stop operator, are building an LNG infrastructure known as “America’s Natural Gas Highway,” which will have over 200 stations in 33 states when completed.⁶² Shell Oil Company has announced plans to build 200 LNG stations across the country in conjunction with truck stop operators TravelCenters of America and Petro Stopping Centers. These truck stops will also have LNG truck repair and servicing capability.⁶³ Blu.LNG, a Utah-based company, is building an infrastructure in that state and adjoining western states as well as in a few Midwestern states.⁶⁴

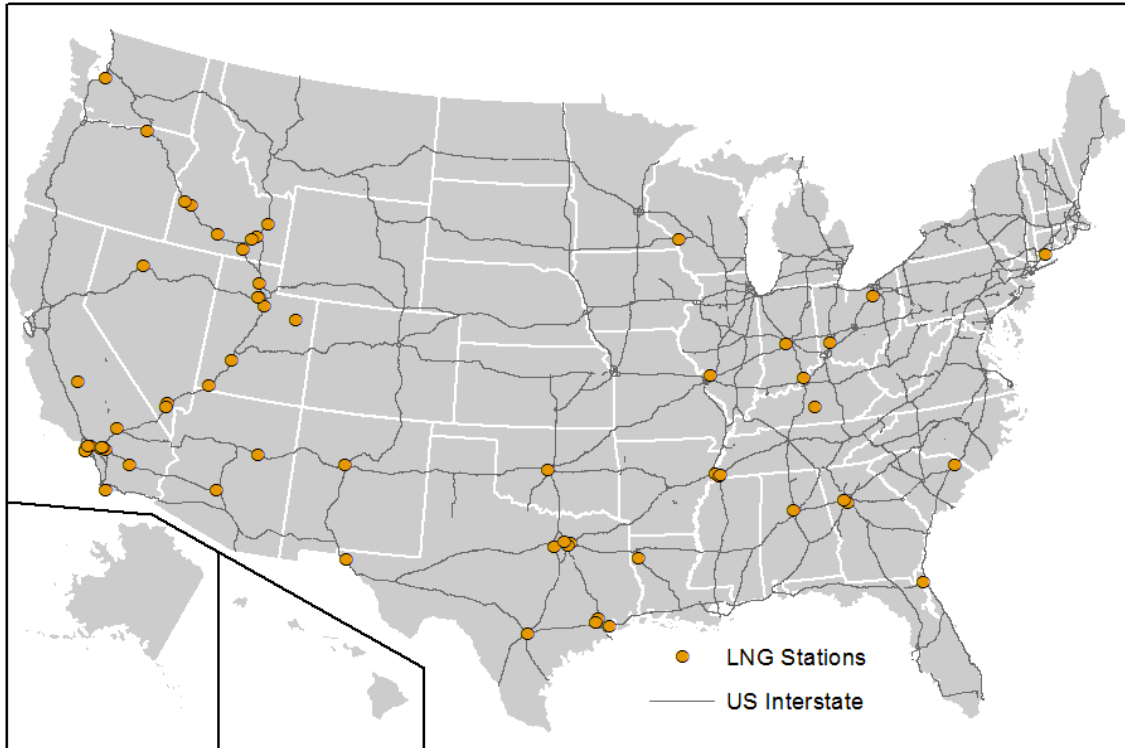
⁶¹ Body contact with very low temperature LNG gas could result in a cryogenic burn. Federal Transit Administration, “Summary Assessment of the Safety, Health, Environmental and System Risks of Alternative Fuel,” pp. 3-19, http://ntl.bts.gov/lib/000/400/422/20021101_alt_fuel.pdf.

⁶² Clean Energy Fuels has raised \$450 million in private investment for construction and operation of this network. It is a California-based company originally founded in 1997 by investor T. Boone Pickens. It constructs and operates CNG and LNG stations around the country.

⁶³ CSP Daily News, “Shell, TravelCenters of America Team Up on LNG,” May 15, 2014, <http://www.cspnet.com/fuels-news-prices-analysis/fuels-news/articles/shell-travelcenters-america-team-lng>.

⁶⁴ See the company’s website at <http://blulng.com>.

Figure 5. LNG Refueling Stations
Open in 2014



Source: CRS map developed using DOE data, http://www.afdc.energy.gov/fuels/natural_gas_locations.html.

Methanol

California, New York, and a few other states made concerted efforts to develop a methanol infrastructure for passenger vehicles, resulting in over 100 methanol dispensing locations by 1997.⁶⁵ While some stations dispensed methanol, the preferred fuel was a blend of 85% methanol and 15% premium gasoline (known as M85). Lower gasoline prices and an insufficient refueling infrastructure contributed to the gradual closing of retail methanol facilities. Today there are no retail stations dispensing methanol or M85.⁶⁶

Propane Autogas

An infrastructure of propane production, storage, and distribution facilities exists in most parts of the United States.⁶⁷ An increase in the number of propane refueling stations would require only a modest investment in dispensing equipment (storage tank, pump, dispenser, and a credit card reader). Propane autogas is delivered to stations by a transport truck, where it is stored onsite,

⁶⁵ William Tucker, "When California Had 15,000 Methanol Cars," Fuel Freedom Foundation, October 4, 2013, <http://www.fuelfreedom.org/when-california-had-15000-methanol-cars/>.

⁶⁶ Methanol Institute, "Use of Methanol as a Transportation Fuel," November 2007, <http://www.methanol.org/Energy/Transportation-Fuel/Methanol-Use-in-Transportation.aspx>.

⁶⁷ AFDC, "Propane Fueling Infrastructure Development," http://www.afdc.energy.gov/fuels/propane_infrastructure.html.

usually in an above-ground tank. Dispensers can be added to existing retail outlets for gasoline and diesel, as the equipment is similar to that used for traditional fuels. The main difference is that propane autogas is delivered to the vehicle under pressure so it remains a liquid. A full vehicle tank signals the dispenser to stop. Across the country, there are 2,687 propane refueling stations, not counting private refueling operations.⁶⁸

Hydrogen Fuel Cell Vehicles

According to DOE,⁶⁹ there are 13 publicly available hydrogen fuel cell refueling stations, mostly in the Los Angeles area, where the California Fuel Cell Partnership is promoting the commercialization of fuel cell vehicles through a partnership with automakers, government organizations, and energy providers.

Electric Vehicles

Electric vehicles can be charged at home or at commercial charging stations, but DOE notes that “consumers are likely to do the majority of their charging at home.”⁷⁰ Car owners who recharge at home have two main options: standard and fast.⁷¹ Similar fast charging is available at workplaces, shopping centers, and public parking lots. In addition to home outlets, there are 8,685 publicly available electric charging stations and over 21,000 charging outlets throughout the country.⁷²

Vehicle Conversions

From a technical feasibility standpoint, there are few problems with converting a passenger vehicle or pickup truck to operate on natural gas. Most existing internal combustion engines can operate on the fuel, and most conversions involve changes to the fuel system, including a new fuel tank, new fuel lines, and modifications to the vehicle’s electronic control unit.⁷³ A conversion to CNG by a certified installer would cost from \$6,500 to \$12,000,⁷⁴ depending on the type of fuel tank used.⁷⁵ The payback for a conversion would be quite long unless the vehicle has low fuel efficiency and was driven more than the average car. For example, a \$6,500 conversion with today’s gasoline and CNG prices could take almost seven years to repay the investment.⁷⁶

⁶⁸ For a map of public propane stations, see http://www.afdc.energy.gov/fuels/propane_locations.html.

⁶⁹ AFDC, “Hydrogen Fueling Station Locations,” November 5, 2014, http://www.afdc.energy.gov/fuels/hydrogen_locations.html.

⁷⁰ AFDC, “Electric Vehicle Charging Stations,” http://www.afdc.energy.gov/fuels/electricity_stations.html.

⁷¹ A standard 120-volt outlet provides up to five miles of range per hour of charging; 240-volt charging is faster, adding up to 20 miles of charge per hour. AFDC, “Developing Infrastructure to Charge Plug-In Electric Vehicles,” http://www.afdc.energy.gov/fuels/electricity_infrastructure.html#level1.

⁷² AFDC, November 5, 2014, http://www.afdc.energy.gov/fuels/electricity_locations.html.

⁷³ NGV Conversion, Inc., “Frequently Asked Questions,” <http://www.ngvus.com/faq.php>.

⁷⁴ Converting a vehicle to propane would cost \$4,000 to \$12,000. AFDC, “Propane Vehicle Conversions,” http://www.afdc.energy.gov/vehicles/propane_conversions.html.

⁷⁵ Ben Wojdyla, “Should You Convert Your Car to Natural Gas?,” *Popular Mechanics*, February 10, 2012, <http://www.popularmechanics.com/cars/how-to/maintenance/should-you-convert-your-car-to-natural-gas>.

⁷⁶ The calculation assumes one vehicle driving 12,500 miles per year and getting 15 miles per gallon, gasoline selling for \$3.25 per gallon, and CNG selling for \$2.10 per gasoline equivalent. In this case, the motorist would save \$978 per year from lower-cost CNG. If gasoline were to rise to \$4 per gallon, however, and all other factors were the same, the (continued...)

Natural gas conversions—or any other conversion—can potentially run afoul of the Clean Air Act (CAA). All new vehicles (gasoline or otherwise) must pass rigorous tests to prove that they will meet emissions standards over the life of the vehicle. The tests tend to be expensive, although when an automaker spreads them over thousands of vehicles, the cost is not prohibitive. After EPA certifies a vehicle, any changes to the exhaust, engine, or fuel system may be considered tampering under CAA.⁷⁷

Certifying vehicle conversions for small producers and individuals was formerly very expensive, since each converted vehicle needed to be independently approved. The process was further complicated by a requirement that the emissions of “engine families”⁷⁸ be tested separately, effectively precluding the use of universal conversion kits. To provide more flexibility to the conversion certification process, EPA issued new regulations in 2012⁷⁹ relaxing requirements for “intermediate age” vehicles and “outside of useful life” vehicles.⁸⁰ There may be warranty issues that consumers should investigate before contracting with a certified installer to make the changes.⁸¹

Emissions and Fuel Economy

Air Emissions

In general, natural gas vehicles are seen as better than conventional gasoline and diesel vehicles in terms of criteria pollutant⁸² and greenhouse gas⁸³ emissions. However, many factors must be considered when comparing vehicles’ emission profiles. All new vehicles, regardless of fuel, are considerably cleaner than older vehicles due to a periodic tightening of emission standards. As noted by DOE, “due to increasingly stringent emissions regulations, the gap has narrowed between tailpipe emissions benefits from natural gas vehicles (NGVs) and conventional vehicles with modern emissions controls. That’s because the U.S. Environmental Protection Agency (EPA)

(...continued)

car owner would pay off the conversion in four years and would save over \$1,600 per year in fuel costs. See CNG Now, “CNG Calculator,” <http://www.cngnow.com/vehicles/calculator/Pages/information.aspx>.

⁷⁷ Section 203(a)(3)(A) of the Clean Air Act (42 U.S.C. 7522 (a)(3)(A)).

⁷⁸ E.g., an engine family could be all Ford vehicles with 4.6L V8 engines.

⁷⁹ U.S. Environmental Protection Agency, “EPA Announces Final Rulemaking for Clean Alternative Fuel Vehicle and Engine Conversions,” August 2012, <http://www.epa.gov/oms/consumer/fuels/altfuels/documents/420f12058.pdf>.

⁸⁰ These terms refer, respectively, to vehicles: (1) from two years earlier or older than the current model year but still within their useful life, which is defined by EPA as 10 years or 120,000 miles; and (2) vehicles over 10 years old.

⁸¹ U.S. Environmental Protection Agency, “Alternative Fuel Conversion,” <http://www.epa.gov/oms/consumer/fuels/altfuels/altfuels.htm#3>.

⁸² “Criteria pollutants” are those with national air quality standards. Vehicles emit pollutants that directly affect air quality, including carbon monoxide and particulate matter, as well as compounds that lead to the formation of ground-level ozone (“smog”), including nitrogen oxides and volatile organic compounds (hydrocarbons). One particular combination of vehicle and fuel compared to another combination may have lower emissions of one pollutant but higher emissions of another, making its total effect on air quality and human health uncertain.

⁸³ Carbon dioxide (CO₂) is the primary greenhouse gas emitted by motor vehicles. However, nitrogen oxides and methane are also greenhouse gases. As natural gas is primarily methane, emissions from the extraction, transportation, and delivery of natural gas to a vehicle, as well as leakage from the vehicle, are potential sources of additional emissions as discussed below.

is requiring all fuels and vehicle types to meet the same thresholds for tailpipe emissions of air pollutants.⁸⁴

That said, most analyses conclude that CNG and LNG vehicles have somewhat lower greenhouse gas and pollutant emissions compared to gasoline and diesel vehicles. For example, a recent DOE analysis predicted that in 2035 (after new vehicle fuel economy and greenhouse gas standards are fully implemented), CNG cars will achieve roughly 10% lower and 5% lower greenhouse emissions than gasoline and diesel cars, respectively.⁸⁵ It should be noted, however, that for CNG, gasoline, and diesel, projected emissions in 2035 were roughly half that of the baseline 2012 gasoline car.

But analyzing the total emissions of any vehicle/fuel combination is complicated. Estimations of the total emissions attributable to a fuel and vehicle require detailed analysis of three key components: (1) the processes required to produce or extract fuel feedstocks, convert them into fuel, and deliver the fuel to the end-user; (2) the emissions from the vehicle itself; and (3) any indirect changes in emissions not attributable to fuel production or use, including changes in land use.⁸⁶ For petroleum fuels, potential lifecycle emissions include process emissions from exploration and extraction of crude oil, transportation of crude oil to refineries, refinery process emissions, distribution of finished products, and end-use combustion of the fuel. Assumptions about efficiency, resource use, emissions capture, and other factors must be made for each step in the process.

Similar analyses must be conducted for the natural gas fuel cycle and its emissions. For example, because natural gas is primarily composed of methane, fugitive methane emissions (both intentional from venting and unintentional from leakage) must be considered.⁸⁷ If fugitive emissions from actual operations exceed those assumed in the model, then the total lifecycle emissions associated with natural gas vehicles would be higher. Similarly, if there are fewer fugitive emissions, total lifecycle emissions would be lower. In the DOE analysis, while the median projected emissions for CNG vehicles is lower than for gasoline or diesel, there is significant overlap in the range of projected emissions from each fuel.

Fuel Economy and Greenhouse Gas Standards

Vehicle greenhouse gas emissions and fuel economy are regulated under the Clean Air Act (CAA) and the Energy Policy and Conservation Act (EPCA). EPA has authority to regulate greenhouse gas emissions while the National Highway Traffic Safety Administration (NHTSA) administers the Corporate Average Fuel Economy (CAFE) standards.⁸⁸ However, vehicle fuel consumption

⁸⁴ AFDC, “Natural Gas Vehicle Emissions,” http://www.afdc.energy.gov/vehicles/natural_gas_emissions.html.

⁸⁵ The analysis found a similar reduction for CNG SUVs relative to gasoline and diesel SUVs. Tien Nguyen, Jake Ward, and Kristen Johnson, “Well-to-Wheels Greenhouse Gas Emissions and Petroleum Use for Mid-Size Light-Duty Vehicles,” U.S. Department of Energy, May 10, 2013, http://www.hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf.

⁸⁶ For more information on lifecycle emissions analysis, see CRS Report R42537, *Canadian Oil Sands: Life-Cycle Assessments of Greenhouse Gas Emissions*, by Richard K. Lattanzio, and CRS Report R40460, *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)*, by Brent D. Yacobucci and Kelsi Bracmort.

⁸⁷ For more information on fugitive methane emissions, see CRS Report R42833, *Air Quality Issues in Natural Gas Systems*, by Richard K. Lattanzio.

⁸⁸ For more information, see CRS Report R42721, *Automobile and Truck Fuel Economy (CAFE) and Greenhouse Gas Standards*, by Brent D. Yacobucci, Bill Canis, and Richard K. Lattanzio.

and greenhouse gas emissions are tightly linked, so the two agencies have issued joint rules since 2012. By model year (MY) 2025, passenger car light truck fuel economy will roughly double, and vehicle greenhouse gas emissions will be roughly cut in half compared to MY2007.

Within the two programs, there are incentives for automakers to produce natural gas vehicles. First, as noted above, natural gas vehicles generally emit fewer greenhouse gases than conventional vehicles, making compliance easier. Further, the CAFE standards are based on petroleum consumption: Vehicles operating on non-petroleum fuels generate credits under the program that effectively treat those vehicles as if they had significantly higher fuel economy. Depending on how expensive it is for automakers to comply with the new regulations, these incentives may help offset the incremental cost of natural gas vehicles.

Existing Federal and State Programs

Federal Programs

While federal programs supporting alternative vehicles have been centered on electric battery research and manufacturing, at least five federal programs have brought more attention to natural gas vehicles.

Energy Policy Act of 1992

Among the provisions of the Energy Policy Act of 1992 (P.L. 102-486),⁸⁹ federal agencies, state governments, and alternative fuel providers⁹⁰ are required to purchase alternative fuel vehicles. This law mandates that a certain percentage of new passenger vehicles (such as police cars) must be capable of operating on alternative fuels, including ethanol, methanol, natural gas, and propane.

Advanced Technology Vehicle Manufacturing Program

Of the \$8.4 billion in loans provided under this DOE program, \$50 million was awarded to companies seeking to produce natural gas vehicles. In March 2011, DOE made a loan to the Vehicle Production Group (VPG) to develop and produce a natural-gas-powered, wheelchair-accessible van. While some MV-1 vans were produced and sold, VPG was unable to make its loan payments and closed in 2013. Its assets were sold in the fall of 2013 to AM General, which has relaunched the MV-1 van with both a gasoline engine and an optional CNG fuel system.⁹¹

CMAQ

The Congestion Mitigation and Air Quality Improvement (CMAQ) program, established in 1991 and administered jointly by the Federal Highway Administration and the Federal Transit

⁸⁹ The act also established a tax credit for the purchase of electric vehicles and tax deductions for the purchase of alternative fuel and hybrid vehicles.

⁹⁰ Alternative fuel providers are businesses that sell or distribute alternative fuels.

⁹¹ See Mobility Ventures, "A Taxi for All: Durable, and Green ... the MV-1," <http://mv-1.us/mv-1-taxi>.

Administration, provides a funding source for state and local governments for transportation projects that will help meet CAA requirements. Eligible activities include transit improvements, travel demand management strategies, traffic flow improvements, and public fleet conversions to cleaner fuels. CMAQ was authorized at \$2.4 billion for FY2014 and at a proportionate amount through May 31, 2015, when the current program authorization expires. It has been a source for funding alternative fuel projects in many states.⁹² For example, recent CMAQ grants will enable Oregon to build CNG fueling stations.⁹³

ARPA-E

DOE's Advanced Research Projects Agency-Energy (ARPA-E) focuses on energy technologies that may be considered too early for private-sector investment. ARPA-E has several natural gas research programs, including the Methane Opportunities for Vehicular Energy (MOVE) program to advance technologies to use domestic natural gas as fuel for passenger vehicles. It seeks to develop less expensive CNG fuel tanks and compressors, which in turn would lower the price of CNG vehicles. To meet these goals, MOVE is spending \$30 million on 13 projects.⁹⁴ In addition, it has established a program to develop GTL technologies for transportation fuels. It seeks to lower the cost of GTL conversion while enabling the use of low-cost, domestically sourced natural gas for transportation. ARPA-E has announced 15 projects across nine states that will receive \$34 million under this program.⁹⁵

Clean Cities Program

This DOE program seeks to reduce petroleum use in transportation, with 100 Clean Cities coalitions around the country that focus on use of alternative fuels, fuel economy improvements, and new transportation technologies. Clean Cities provides technical and financial assistance to communities. Clean Cities grants have expanded the use of natural gas vehicles with school and transit buses, airport vehicles, taxis, and delivery fleets. To further the use of natural gas vehicles, Clean Cities has financially supported the expansion of public-access refueling infrastructure.⁹⁶

State Programs

State policies with regard to natural gas vehicles are extensive. Laws and regulations governing sale and use of natural gas vehicles differ from state to state. Natural gas motor fuel is taxed in different ways, and there is no uniform method of taxing CNG and LNG. Some states tax CNG based on a GGE or DGE basis; others tax fuels using other methods. A few states tax LNG based on its energy content.

⁹² In FY2013, \$38 million in CMAQ funds supported 30 natural gas projects for vehicles and refueling stations.

⁹³ Northwest Gas Association, "CMAQ Funding Means More CNG Stations for Oregon," August 27, 2014, <http://www.nwga.org/cmaq-funding-means-more-cng-stations-for-oregon>.

⁹⁴ Dane Boysen, "Investing in Technology Innovation to Overcome Market Entry Hurdles," Natural Gas Vehicle Conference and Expo, November 21, 2013, http://www.arpa-e.energy.gov/sites/default/files/documents/files/NGVAmerica_Boysen_Keynote.pdf.

⁹⁵ U.S. Department of Energy, *FY 2015 Congressional Budget Request*, vol. 4, March 2014, p. 354, http://energy.gov/sites/prod/files/2014/04/f14/Volume_4.pdf.

⁹⁶ U.S. Department of Energy, "Clean Cities Five-Year Strategic Plan: Reducing Petroleum Dependence in On-Road Transportation in the United States," January 2011, http://www1.eere.energy.gov/cleancities/pdfs/strategic_plan.pdf.

Some states have incentives for purchase or conversion of a vehicle,⁹⁷ including tax deductions or credits and lower license fees, vehicle sale taxes, and registration fees. Some states (such as California and Arizona) permit some types of alternative fuel vehicles to drive in high-occupancy vehicle lanes during rush hour.

The interest of states in expanding the natural gas refueling networks within their borders also differs. Local codes, standards, and permitting processes dictate how CNG stations are to be built. A few states have designated some highways as corridors for building out natural gas service station networks. The South Coast Air Quality Management District and UPS, the package shipping company, are building a natural gas corridor from Las Vegas, NV, to Ontario, CA, with stations that will sell fuel to UPS heavy-duty vehicles as well as to the public.⁹⁸ In Utah, Interstate 15 from Idaho to Arizona has been designated as a natural gas vehicle corridor, as has the Texas Clean Transportation Triangle, which connects Houston, San Antonio, and Dallas/Fort Worth.⁹⁹ Thirteen governors have initiated a multistate agreement to expand the production of natural gas vehicles, committing to “aggregate our annual state fleet vehicle procurements to provide an incentive to manufacture affordable, functional natural gas vehicles.”¹⁰⁰

Congressional Involvement

As the availability of domestic natural gas supplies has increased, so too has congressional interest in finding ways to use more natural gas in the transportation sector. The federal government’s tax, regulatory, and research and development policies are viewed as possible incentives for expanding production and use of natural gas vehicles.

Legislation to promote natural gas as a vehicle fuel has been introduced in the 113th Congress (and in previous years), including proposals that would change the taxation of alternative fuels and vehicles, modify the regulation of natural gas vehicles under federal CAFE standards, increase the weight limit for natural gas trucks on interstate highways, provide loans and grants for deployment of alternative fuel vehicles and recharging stations, and raise federal agency use of alternative fuel vehicles.

One proposal affecting natural gas vehicles has passed thus far in the 113th Congress. An amendment (H.Amdt. 93) offered by Representative Eliot Engel was added to the Military Construction and Veterans Affairs, and Related Agencies Appropriations Act of 2014 (H.R. 2216), prohibiting the Departments of Defense and Veterans Affairs from purchasing new light-duty vehicles unless they are alternate fuel vehicles such as hybrid, electric, natural gas, or biofuel. The House agreed by voice vote to this amendment, which Representative Engel noted in his floor remarks was in line with requirements in the May 24, 2011, Memorandum on Federal Fleet

⁹⁷ State fleets are covered by the Energy Policy Act of 1992.

⁹⁸ America’s Natural Gas Alliance, “Infrastructure,” <http://anga.us/issues-and-policy/transportation/infrastructure#.VFOz61c1OHe>.

⁹⁹ Texas Natural Gas Now, “Cleaner Vehicles: Texas Clean Transportation Triangle,” <http://www.texasnaturalgasnow.com/benefits/cleaner-vehicles-texas-clean-transportation-triangle>.

¹⁰⁰ NGV Global News, “State Governors in U.S. Entice Automakers with Multi-State NGV Procurement,” April 27, 2012, <http://www.ngvglobal.com/state-governors-in-us-entice-automakers-with-multi-state-ngv-procurement-0427>.

Performance issued by President Obama.¹⁰¹ The Engel amendment was included in the enacted legislation.¹⁰²

A broad energy efficiency bill (S. 761) reported out of the Senate Energy and Natural Resources Committee on June 3, 2013, includes a provision (Section 403) amending the National Energy Conservation Policy Act to authorize the use of energy savings performance contracts and utility energy service contracts for projects that support the use of natural gas and electric vehicles or the related fueling or charging infrastructure. The bill, the Energy Savings and Industrial Competitiveness Act of 2013, has not come to the Senate floor.¹⁰³

S. 2260, the Extension of Alternative Fuel Excise and Infrastructure Tax Credits Act of 2014, would extend many expiring tax provisions, including the incentive for alternative fuels, the alternative fuel refueling property credit, and the credit for new fuel cell motor vehicles. The bill was reported from the Senate Finance Committee on April 28, 2014, but has not yet received a Senate vote. A similar bill extending fuel and infrastructure credits is H.R. 5559, the Bridge to a Clean Energy Act of 2014, but it has not been acted on by the Ways and Means Committee.

S. 1486, the Postal Reform Act of 2014, among other provisions, would require the postmaster general to submit a report to Congress on the feasibility of a pilot program to use natural gas and propane in U.S. Postal Service long-haul trucks. The bill was reported from the Senate Homeland Security and Governmental Affairs on July 31, 2014.

Several bills have been introduced¹⁰⁴ to change the Motor Fuels Excise Tax so that LNG would be taxed on an energy-equivalent basis instead of a volume basis. As 1.7 gallons of LNG equates to one gallon of diesel on an energy-equivalent basis, transportation users of LNG pay more tax than users of an equal amount of energy from diesel. The federal excise tax on CNG is already assessed on an energy content basis. The Senate Finance Committee included this tax change in the Preserving America's Transit and Highways Act (PATH Act), but the Senate adopted the House Highway and Transportation and Funding Act (H.R. 5021), which did not include the LNG tax provision.¹⁰⁵

Tax Policy

In the recent past, federal tax policy has supported the production and sale of alternative fuels and vehicles, including those powered by natural gas (**Table 1**). However, many of those provisions have expired.¹⁰⁶

¹⁰¹ The White House, Office of the Press Secretary, "Presidential Memorandum—Federal Fleet Performance," May 24, 2011, <http://www.whitehouse.gov/the-press-office/2011/05/24/presidential-memorandum-federal-fleet-performance>.

¹⁰² Sec. 8119 of P.L. 113-76. Engels's amendment was described and voted on June 4, 2014. Rep. Eliot Engel, "Military Construction and Veterans Affairs, and Related Agencies Appropriations Act, 2014," House debate, *Congressional Record*, daily edition, vol. 159 (June 4, 2013), pp. H3078-3079, <https://www.congress.gov/crec/2013/06/04/CREC-2013-06-04-pt1-PgH3044-3.pdf>.

¹⁰³ U.S. Congress, Senate Committee on Energy and Natural Resources, *Energy Savings and Industrial Competitiveness*, committee print, 113th Cong., 1st sess., June 3, 2013, S.Rept. 113-37 (Washington, DC: GPO, 2013).

¹⁰⁴ H.R. 2202 and S. 1103, LNG Excise Tax Equalization Act of 2013.

¹⁰⁵ For more information on this legislation, see CRS Report RL30304, *The Federal Excise Tax on Motor Fuels and the Highway Trust Fund: Current Law and Legislative History*, by Sean Lowry.

¹⁰⁶ For a full list of energy-related tax provisions, see CRS Report R42566, *Alternative Fuel and Advanced Vehicle* (continued...)

Table I. Tax Provisions Affecting Natural Gas Vehicles
Existing and Recently Expired Provisions

Existing Provisions			
Program	Description	Expiration Date	Eligible Fuels
Motor Fuels Excise Tax	Gasoline: 18.4 cents per gallon Diesel: 24.4 cents per gallon LPG: 18.3 cents per gallon CNG: 18.3 cents per gallon equivalent LNG: 24.3 cents per gallon	4.3 cents per gallon of the gasoline/diesel fuel tax is permanent; the rest expires on September 30, 2016.	Gasoline, diesel, LPG, LNG, CNG, fuels with methanol from natural gas.
Plug-In Electric Drive Vehicle Credit	Credit of up to \$7,500 for purchasers of these vehicles, depending on battery capacity.	Credit is phased out when automaker sells 200,000 qualified vehicles.	Plug-in electric vehicles.
Some Recently Expired Natural Gas-Related Provisions			
Incentives for alternative fuels	Excise tax credit of 50 cents per gasoline gallon equivalent for CNG and liquid gallon of LNG.	2013	LPG, CNG, LNG, and other alternative fuels.
Alternative Motor Vehicle Credit	Separate credits for vehicles purchased with certain technologies, including those with alternative fuels.	2010	CNG, LNG, LPG and any mixture that is at least 85% methanol or a mixture of other fuels with a petroleum fuel. Credit for fuel cell vehicles expires at the end of 2014.
Conversion Kits	Credit up to \$4,000 for purchasers of a kit to convert a vehicle to plug-in electric vehicle.	2011	Qualified plug-in electric kits.
Alternative Fuel Refueling Property Credit	This tax provision was originally enacted in 2005 and has been modified and extended twice. In its last iteration, consumers purchasing qualified non-hydrogen fueling equipment received a 30% tax credit up to \$1,000; businesses received a credit up to \$30,000. (Respective hydrogen fueling credits are up to \$1,000 and \$200,000.)	2013 for all fuels but hydrogen, which expires in 2014	Natural gas, LPG, hydrogen, electricity, E85, and some diesel fuel blends.

Sources: Internal Revenue Service and CRS Report R42566, *Alternative Fuel and Advanced Vehicle Technology Incentives: A Summary of Federal Programs*, by Lynn J. Cunningham et al.

Other Federal Legislation

Other pending legislation affecting natural gas vehicles includes:

(...continued)

Technology Incentives: A Summary of Federal Programs, by Lynn J. Cunningham et al.

- S. 2065, *Alternative Fuel Vehicle Act* (originally introduced as S. 1355), seeks to provide parity for dual-fuel natural gas vehicles with electric vehicles and dedicated natural gas vehicles under the federal CAFE standards and greenhouse gas regulations. Current law provides limited incentives for dual-fuel natural gas vehicles. The sponsors would like to spur the use of dual-fuel natural gas vehicles by expanding the definition of dedicated natural gas vehicles to include models with a reserve gasoline tank for incidental or emergency use. S. 2065 would also amend CAFE standards to alter the treatment of natural gas vehicles and provide natural gas vehicles with access to high-occupancy vehicle lanes.
- H.R. 1027 and S. 488, *Advanced Vehicle Technology Act of 2013*, would authorize a DOE program of research, development, demonstration, and commercial application of passenger and commercial vehicle technologies to reduce or eliminate petroleum use.
- H.R. 1364, *New Alternative Transportation to Give Americans Solutions Act of 2013*, would allow an excise tax credit through 2018 for alternative fuels and fuel mixtures involving CNG or LNG, establish an income tax credit for CNG and LNG vehicles, and extend through 2018 the tax credit for alternative fuel vehicle refueling property. It would also require DOE to provide grants to improve the performance and efficiency of natural gas vehicles and urge EPA to provide incentives to encourage and reward manufacturers who produce natural gas vehicles.
- H.R. 2242, *State and Local Fleet Efficiency Act*, would recognize the authority of state and local governments to require their fleets to acquire only new vehicles that use natural gas as a fuel or are flexible fuel vehicles that operate on gasoline, E85, and M85.
- H.R. 2493, *Open Fuel Standard Act of 2013*, would promote the production of alternative fuel light vehicles. (Qualified vehicles include natural gas, hydrogen, biodiesel, E85, M85, and plug-in electric drive.) It would require U.S. automakers to produce at least 30% qualified vehicles in MY2016 and 50% qualified vehicles in MY2017 and each subsequent years.
- H.R. 3937 would direct the U.S. Department of Transportation (DOT) to prepare an economic and environmental assessment of using natural gas as a fuel source in long-haul trucks.
- H.R. 3938 would require DOT to designate natural gas fueling corridors for long-haul trucking.
- H.R. 3940 and S. 2721, *Natural Gas Long Haul Truck Competitiveness Act of 2014*, would require DOT to issue regulations to allow natural gas vehicles to exceed federal weight limitations to operate on U.S. interstate highways by an amount equal to the weight of the vehicle's natural gas tank and fueling system, less the weight of comparable diesel tanks and fueling systems.
- H.R. 4753, *IMPACT Act of 2014* would extend tax credits for qualified plug-in electric drive motor vehicles, heavy natural gas vehicles, and alternative fuel vehicle refueling property and provide for tax-exempt financing for refueling property for such vehicles.

- H.R. 4956, *American Energy Opportunity Act of 2014* would extend through 2019 the tax credit for fuel cell motor vehicles, advanced lean burn technology (diesel) motor vehicles, hybrid motor vehicles, alternative fuel motor vehicles, plug-in electric drive motor vehicles, and plug-in conversions. It would create a new tax credit for the purchase of a motor vehicle identified by EPA as the most efficient vehicle in its class and establish an excise tax credit through 2019 for alternative fuels and fuel mixtures involving CNG, LNG, or LPG. In addition, it would establish benchmarks for the increasing electrification of the federal fleet and establish a DOE grant program to assist local governments in the installation of electric vehicle recharging facilities.
- H.R. 5107, *Fuel Choice for American Prosperity and Security Act of 2014*, would revise the calculation for average fuel economy for alternative fuel vehicles, including those powered by natural gas, hydrogen, propane, biodiesel, fuel cells, and plug-in electricity.
- S. 1230, *Alternative Fueled Vehicles Competitiveness and Energy Security Act of 2013*, would expand categories of vehicle technologies that are eligible for DOE loans and direct DOE to provide technical assistance and grants to for the deployment of alternative fuel vehicles and infrastructure. In addition, it would require DOE to identify barriers and remedies in pipeline transmission and distribution systems to the distribution of alternative fuels and the deployment of alternative fuel recharging and refueling capability. Among other provisions, it calls for an interagency council for the development and procurement of alternative fuel vehicles by federal agencies.

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