CHAPTER 7

Transportation Energy Use and Environmental Impacts

Highlights

- Despite transportation's continued dependence on petroleum, recent trends show decreasing import dependence, sharply reduced emissions of air pollutants, and small reductions in greenhouse gas emissions. U.S. dependence on imported oil has decreased from a high of 60.3 percent in 2005 to 26.5 percent in 2014, largely as a result of increased domestic oil production.

- Transportation continues to rely almost entirely on petroleum to move people and goods. However, the sector's dependence on petroleum has decreased from a peak of 97.3 percent of transportation energy use in 1978 to 91.5 percent in 2014. This is due in part to increased blending of domestically produced ethanol in gasoline and improved fuel economy.

- The highway mode continues to dominate transportation energy use. Highway vehicles used 83.2 percent of total transportation energy in 2013, with personal vehicles accounting for 71.1 percent of highway energy use and 59.2 percent of total transportation energy use.

- Transportation is the second largest producer of greenhouse gas emissions (GHG), accounting for 27 percent of total U.S. emissions in 2013. Aside from greenhouse gases, the six most widespread or common air pollutant emissions from transportation fell below their 1990 levels, and continued to decline from 2009 to 2014 due to many factors, including motor vehicle emissions controls that have contributed to considerable reductions.

- Across the 169 continuously monitored urban areas, the total number of very unhealthy air quality days that could trigger heath emergences warnings rose from 291 in 1990 to 361 in 2014.

- Significant pipeline oil spill incidents involved annual average spillage of about 69,000 barrels of oil (or 2,898,000 gallons) and other hazardous liquids each year for the 3-year period 2012 through 2014. Between

2010 and 2013, derailments of oil tank cars released on average slightly less than 600,000 gallons per year.

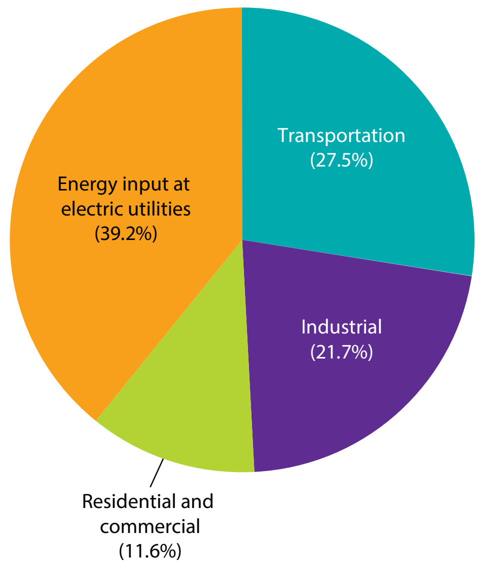
- The energy required to move one person one mile, or one ton of freight one mile has generally declined over time.

This chapter reviews the patterns and trends in transportation energy use energy and transportation's impact on the environment. These aspects of the transportation system are also important measures of performance, along with such primary measures as system reliability, efficiency, and safety.

Recent trends show reduce U.S. petroleum dependence on imported oil as a result of increased domestic production and improved fuel economy. U.S. dependence on imported oil peaked at 60.3 percent in 2005, but has since decreased from 49.2 percent in 2010 to 26.5 percent in 2014 [USDOE EIA 2015b].

In 2014 the U.S. transportation sector used 27.1 quadrillion Btu (British thermal unit) of energy, second only to electricity generation but down from the peak of 28.9 quadrillion Btu in 2007 (figures 7-1 and 7-2).[1] Transportation relied on petroleum for 91.5 percent of the energy it used in 2014, down from a peak of 97.3 percent in 1978 (figure 7-2). The United States consumes more than 19.0 million barrels of oil per day, of which 13.4 million barrels (70.5 percent) are consumed by the U.S. transportation system [USDOE EIA 2015b]. Despite transportation's continued dependence on petroleum, recent trends show decreasing import dependence, sharply reduced emissions of air pollutants, and small reductions in greenhouse gas emissions.

FIGURE 7-1 U.S. Energy Use by Sector: 2014



KEY: Btu = British thermal unit.

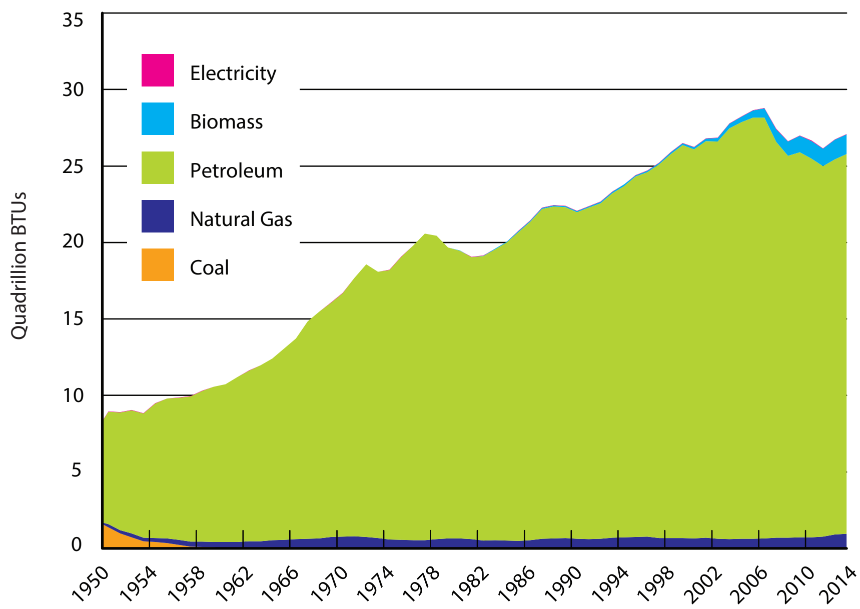
NOTES: The data for *Residential, Commercial, and Industrial* sectors include only fossil fuels consumed directly. Most renewable fuels are not included. The data for the *Transportation* sector includes only fossil and renewable fuels consumed directly. The data for *Electric utilities* includes all fuels (fossil, nuclear, geothermal, hydro, and other renewables) used by electric utilities.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, Table 2-1, Available at http://www.eia.gov/totalenergy/ as of June 2015.

Greenhouse gas (GHG) emissions (carbon dioxide, hydrofluorocarbons, methane, and nitrous oxide) closely parallel transportation energy use and, as a result, were 16.4 percent higher in 2013 than in 1990 [USEPA 2015a]. Between 2005 and 2013, however,

[1] Total transportation energy use reported in 2014 is about 1 quad higher than the detailed 2013 modal breakdown shown in table 7-1. Differences in definitions, data sources, and estimation methods also may account for the difference. For example, table 7-1 excludes some off-highway use of gasoline and diesel fuel as well as energy for international air transport and shipping.

FIGURE 7-2 Transportation Energy Use by Energy Source: 1950-2014



KEY: Btu = British thermal unit

SOURCE: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, table 2.5. Available at http://www.eia.gov as of June 2015.

transportation GHG emissions decreased as a result of less vehicle travel, improved energy efficiency, and increased use of biofuels. GHG emissions increased slightly from 2012 to 2013 [USEPA 2015a].

Energy Use Patterns and Trends

Transportation's petroleum dependence decreased from 96.3 percent in 2005 to about 91.5 percent in 2014, chiefly due to increased blending of domestically produced ethanol from biomass in gasoline [USDOE EIA 2015b]. Today almost all gasoline sold in the United States contains 10 percent ethanol (E10). Nearly all transportation-related natural gas consumption, shown in figure 7-2, is used to fuel pipeline compressors. Natural gas use by motor vehicles remains a small fraction of total transportation energy use. Recently, lower prices and abundant domestic supplies have increased interest in natural gas as a motor fuel (figure 7-2).

Transportation's petroleum use is expected to remain at about 13.5 million barrels per day through 2040 and beyond, despite decreases in personal vehicle gasoline use as a consequence of tightened fuel economy standards [USDOE EIA 2015c]. This leveling off of petroleum consumption is expected because declining personal vehicle petroleum use is projected to be offset by growth in petroleum demand by other modes, particularly medium and heavy-duty trucks. According to the Freight Analysis Framework, freight tonnage is forecast to grow 1.3 percent annually during this period (table 3-1).

Alternative fuels use (excluding gasohol) by motor vehicles is increasing. Total alternative fuel use exceeded 500 million gasoline-equivalent gallons in 2011, up 12.7 percent over 2010 levels, the latest year for which data are available [USDOE EIA 2013b]. In comparison, gasoline consumption[2] in the United States has grown from about 134 billion gallons in 2011 to nearly 137 billion gallons in 2014. [USDOE EIA 2015b]. Compressed and liquefied natural gas accounted for almost one half of the total, followed by E85, propane, electricity, and hydrogen. E85 is a blend of between 51 and 85 percent denatured ethanol and gasoline and can be used safely by approximately 10 million flex-fuel vehicles operating on U.S. roads.

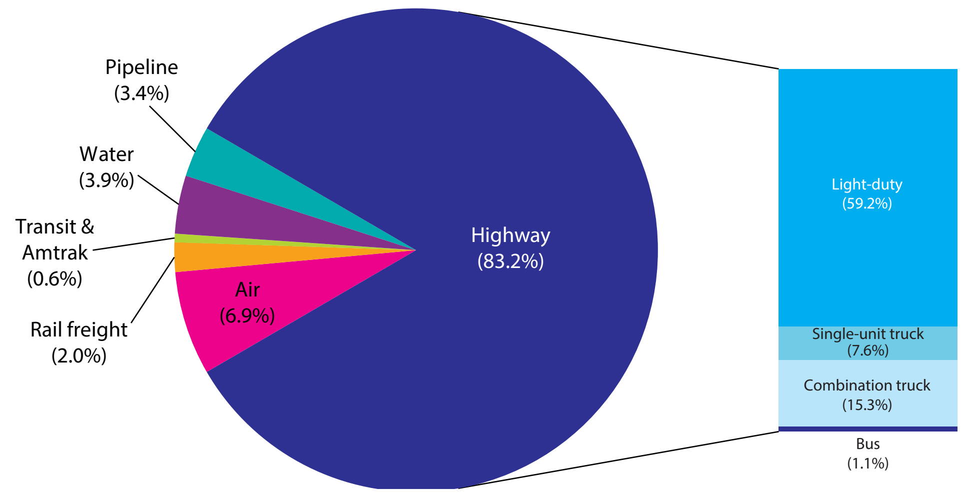
The highway mode dominates transportation energy use (figure 7-3). Highway vehicles used five times more energy than all other modes combined in 2013. Light-duty vehicles (passenger cars, sport utility vehicles, minivans, and pick-up trucks) accounted for 71.1 percent of highway energy use and 59.2 percent of total transportation energy use. The predominance of the highway mode in domestic transportation energy use in 2013 is shown in greater detail in table 7-1. Highway vehicles accounted for 83.2 percent of the total. Air transport came in a distant second with 6.9 percent of transport energy use, but this number excludes energy for international flights. Jet fuels supplied to international flights originating in the United States amounted to 931.6 trillion Btu [USEPA 2015a], which is nearly five times the amount of fuel used by domestic flights. Water transportation is third with 3.9 percent, but once again most of the energy used in international shipments is not included in this figure. An estimated 455.2 trillion Btu were supplied to international ships at U.S. ports [USEPA 2015a]. This is more than double the amount used by domestic waterborne shipping. Rail freight accounted for 2.0 percent of transportation energy use, although it carries roughly 30 percent of U.S. freight ton-miles. Pipelines used 3.4 percent of transportation energy, much of which is natural gas to fuel pipeline compressors. Transit operations accounted for 0.6 percent of transportation energy use.

[2] EIA uses product supplies to approximately represent consumption of petroleum products. It measures the disappearance of these products from primary sources, such as refineries, natural gas processing plants, blending plants, pipelines, and bulk terminals.

Greenhouse Gas Emissions

The transportation sector is the second largest producer of greenhouse gas (GHG) emissions, accounting for approximately 27 percent of total U.S. emissions in 2013 [USEPA 2015a]. Transportation-related GHG emissions have been trending upward, but are below their 2005 peak (figure 7-5). Carbon dioxide (CO_2) produced by the combustion of fossil fuels in internal combustion engines is the predominant GHG emitted by the transportation sector. Passenger cars were the largest source of CO_2 from transportation, accounting for 42.7 percent, followed by freight trucks (22.8 percent), and light-duty trucks (17.0 percent). Domestic operation of commercial aircraft produced 6.6 percent of transportation CO_2 emissions, while pipelines were responsible for 2.8 percent of emissions, followed by rail (2.8 percent) and ships and boats (2.3 percent) [USEPA 2015a].

FIGURE 7-3 Energy Use by Mode of Transportation: 2013



KEY: Btu = British thermal unit

NOTES: The following conversion rates were used:
Jet fuel = 135,000 Btu/gallon.
Aviation gasoline = 120,200 Btu/gallon.
Automotive gasoline = 125,000 Btu/gallon.
Diesel motor fuel = 138,700 Btu/gallon.
Compressed natural gas = 138,700 Btu/gallon.
Distillate fuel = 138,700 Btu/gallon.
Residual fuel = 149,700 Btu/gallon.
Natural gas = 1,031 Btu/ft^3.
Electricity 1kWh = 3,412 Btu, negating electrical system losses.
To include approximate electrical system losses, multiply this conversion factor by 3.

SOURCES: Air–Bureau of Transportation Statistics, Office of Airline Information. **Rail**–Association of American Railroads. **Transit**–Federal Transit Administration. **Amtrak**–National Railroad Passenger Corporation (Amtrak), personal communication with Energy Management Department and Government Affairs Department. **Water**– U.S. Department of Energy, Energy Information Administration and U.S. Department of Transportation, Federal Highway Administration. **Pipeline**– U.S. Department of Energy, Energy Information Administration. **Highway**– Federal Highway Administration as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 4-6, available at www.bts.gov as of March 2015.

TABLE 7-1 Domestic Transportation Energy Use by Mode: 2013

Energy and physical units of measure

	Trillion Btu	Percent of total	Units	Physical units
Air				
Certificated carriers[a]				
Jet fuel	1,595	6.1%	million gallons	11,812
General aviation[b]				
Aviation gasoline	24	0.1%	million gallons	202
Jet fuel	191	0.7%	million gallons	1,413
Highway				
Gasoline, diesel and other fuels				
Light duty vehicle, short wheel base and motorcycle[c]	11,076	42.3%	million gallons	88,611
Light duty vehicle, long wheel base[c]	4,395	16.8%	million gallons	35,159
Single-unit 2-axle 6-tire or more truck	2,011	7.7%	million gallons	14,502
Combination truck	3,994	15.3%	million gallons	28,795
Bus	301	1.1%	million gallons	2,167
Transit				
Electricity	23	0.1%	million kWh	6,651
Motor fuel				
Diesel[d]	84	0.3%	million gallons	609
Gasoline and other nondiesel fuels[e]	13	0.1%	million gallons	107
Compressed natural gas	18	0.1%	million gallons	132
Rail, Class I (in freight service)				
Distillate / diesel fuel	515	2.0%	million gallons	3,713
Amtrak				
Electricity	2	0.01%	million kWh	525
Distillate / diesel fuel	9	0.04%	million gallons	66
Water				
Residual fuel oil	630	2.4%	million gallons	4,212
Distillate / diesel fuel oil	232	0.9%	million gallons	1,676
Gasoline	153	0.6%	million gallons	1,223
Pipeline				
Natural gas	888	3.4%	million cubic feet	861,583
Total	**26,155**			

KEY: Btu = British thermal unit.

[a] Domestic operations only. [b] Includes fuel used in air taxi operations but not commuter operations. [c] *Light duty vehicle, short wheel base* includes passenger cars, light trucks, vans and sport utility vehicles with a wheelbase (WB) equal to or less than 121 inches. *Light duty vehicle, long wheel base* includes large passenger cars, vans, pickup trucks, and sport/utility vehicles with wheelbases (WB) larger than 121 inches. [d] *Diesel* includes diesel and biodiesel. [e] *Gasoline and all other nondiesel fuels* include gasoline, liquefied petroleum gas, liquefied natural gas, methane, ethanol, bunker fuel, kerosene, grain additive, and other fuel.

NOTES: The following conversion rates were used:

Jet fuel = 135,000 Btu/gallon.
Aviation gasoline = 120,200 Btu/gallon.
Automotive gasoline = 125,000 Btu/gallon.
Diesel motor fuel = 138,700 Btu/gallon.
Compressed natural gas = 138,700 Btu/gallon.
Distillate fuel = 138,700 Btu/gallon.
Residual fuel = 149,700 Btu/gallon.
Natural gas = 1,031 Btu/ft3.
Electricity 1kWh = 3,412 Btu, negating electrical system losses. To include approximate electrical system losses, multiply this conversion factor by 3.

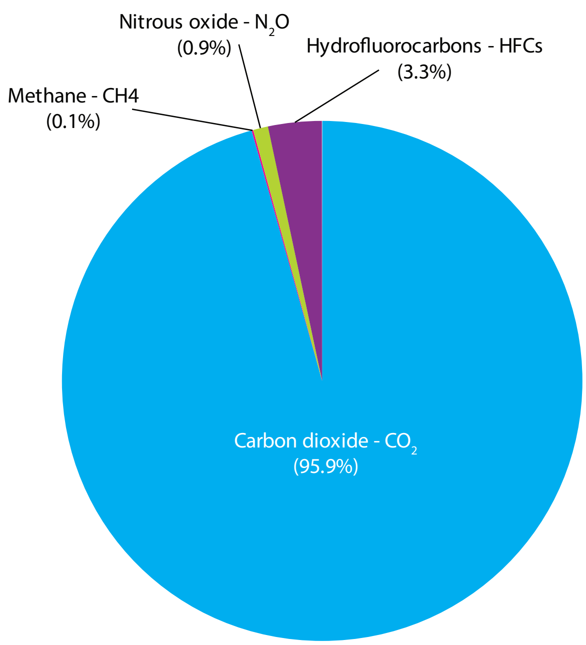
SOURCES: **Air**: U.S. Department of Transportation, Bureau of Transportation Statistics, Office of Airline Information, Fuel Cost and Consumption, available at http://www.transtats.bts.gov/fuel.asp as of June 2015. **Highway**: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*, table VM-1, available at http://www.fhwa.dot.gov/policyinformation/statistics.cfm as of June 2015. **Transit**: U.S. Department of Transportation, Federal Transit Administration, National Transit Database, table 17, available at www.ntdprogram.gov as of June 2015. **Rail**: Association of American Railroads, *Railroad Facts 2014* (Washington, DC: 2014), p. 63. **Amtrak**: National Railroad Passenger Corporation (Amtrak), personal communication with Energy Management Department and Government Affairs Department, June 2015. Water: Residual and distillate/diesel fuel: U.S. Department of Energy, Energy Information Administration, *Fuel Oil and Kerosene Sales* (Washington, DC: 2014), available at http://www.eia.gov/petroleum/fueloilkerosene/ as of June 2015. **Gasoline**: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics*, table MF-24, available at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm as of June 2015. **Pipeline**: U.S. Department of Energy, *Natural Gas Annual*, DOE/EIA-0131(04) (Washington, DC), table 15, available at http://www.eia.gov/naturalgas/annual/ as of June 2015.

Hydrofluorocarbons (HFC), methane (CH4), and nitrous oxides (N2O) are the other principle GHGs emitted by the transportation sector. Each GHG has a different global warming potential. Figure 7-4 shows the common metric of equivalent grams of CO_2 for each emission. Hydrofluorocarbons and other ozone-destroying gases once used in automotive air conditioners are second behind CO_2 in importance.[3] HFCs are the most potent GHGs known. GHG emission regulations for personal vehicles give manufacturers credits for reducing these HFC emissions, and it is likely that these emissions will decrease in the future. Nitrous oxides are chiefly produced in the catalytic converters of motor vehicles, and a very small quantity of methane emissions is produced by incomplete combustion of fossil fuels or by leakage.

Because 95.9 percent of transportation GHG emissions are CO_2 produced by fossil fuel combustion and because petroleum comprises 91.5 percent of transportation energy use, modal GHG emissions closely track modal

[3] The original coolants were chlorofluorocarbons (CFCs), which when released into the atmosphere were found to create holes in the stratospheric ozone layer that helps to protect the Earth's surface from harmful radiation.

FIGURE 7-4 Transportation-Related Greenhouse Gas Emissions: 2013



NOTES: The data for the transportation sector includes only fossil and renewable fuels consumed directly. The data for Non-Transportation includes the Residential, Commercial, and Industrial sectors, which include only fossil fuels consumed directly, and electric utilities, which includes all fuels (fossil, nuclear, geothermal, hydro, and other renewables) used by electric utilities. Most renewable fuels are not included. Totals may not add to 100% due to rounding.

SOURCE: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks (2015), table 2-12 and table ES-8, available at http://epa.gov/climatechange/emissions/usinventoryreport.html as of August 2015.

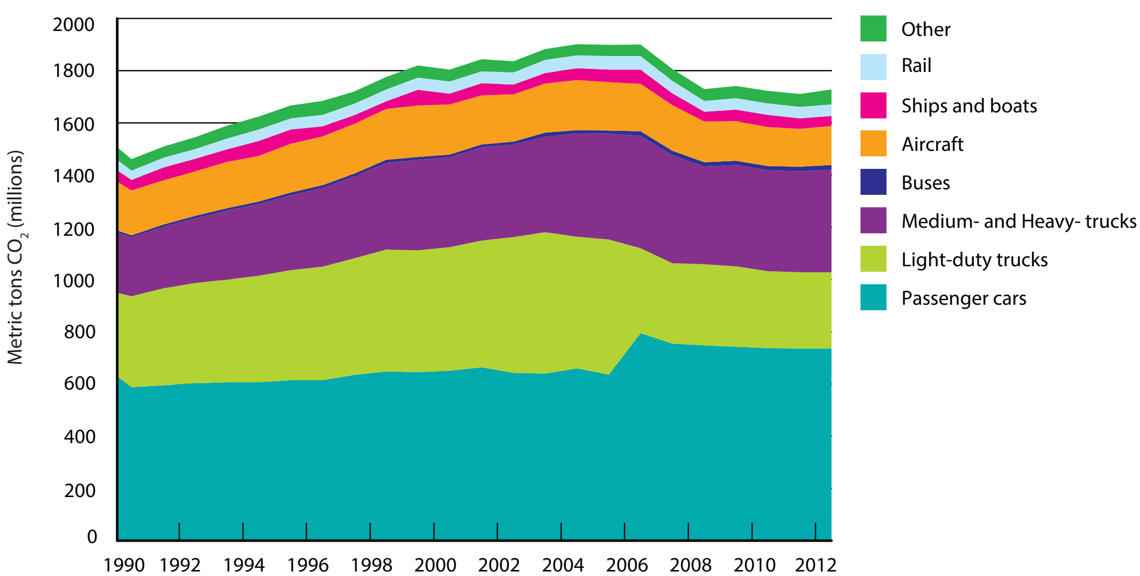
energy use. Transportation GHG emissions increased from 1990 to 2007 (figure 7-5), fell by 4.2 percent during the economic recession in 2008, and then stabilized at about 1,800 teragrams (million metric tons) from 2009 to 2013 [USEPA 2015a]. The short-term decrease in economic activity and the related decline in transportation demand contributed, in part, to the decrease in CO_2 emissions during the recession. However, the long-term trend from 1990 to 2013 shows that total transportation GHG emissions rose by 16.5 percent as a result of an increase in vehicle-miles traveled by light-duty motor vehicles, economic growth, and low fuel prices during the beginning of this period [USEPA 2015a].

Evident in figure 7-5 are the results of the U.S. Environmental Protection Agency's (EPA's) decision to change the definitions of passenger cars and light trucks in 2007. Many vehicles formerly classified as light trucks, but designed predominantly for passenger transportation, were reclassified as passenger cars, causing an apparent jump in passenger car emissions that were offset by a compensating drop in light-truck emissions.

Energy Efficiency

In the past, transportation reduced the growth of its energy use by improving the efficiency with which energy was used. The fuel

FIGURE 7-5 Carbon Dioxide (CO_2) Greenhouse Gas (GHG) Emissions by Mode: 1990-2013



NOTES: *Other* greenhouse gas emissions are from motorcycles, pipelines, and lubricants. International bunker fuel emissions (not included in the total) result from the combustion of fuels purchased in the United States but used for international aviation and maritime transportation. *U.S. Total, all modes; Aircraft; and Ships* and boats include emissions data for only domestic activity only as do all other data shown. International emissions from bunker fuels purchased in the United States are not included. Alternative-fuel vehicle emissions are allocated to the specific vehicle types in which they were classified (i.e., *Passenger cars, Light-duty trucks, All other trucks,and Buses*).

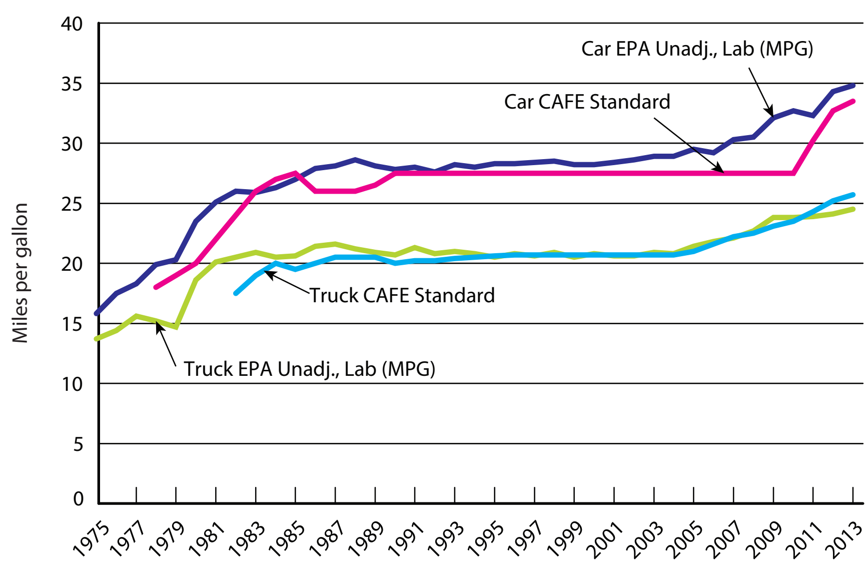
SOURCE: U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (2012), table 2-13, available at http://epa.gov/climatechange/emissions/usinventoryreport.html as of June 2015.

economies of passenger cars and light trucks have closely tracked the Corporate Average Fuel Economy (CAFE) standards since they took effect in 1978 (figure 7-6). The miles per gallon (mpg) values shown in figure 7-6 are the unadjusted test values on which compliance with the standards is based. However, the actual mpg values seen on window stickers and in public advertising are adjusted downward to better represent the fuel economy drivers will likely experience on the road.

The estimated on-road fuel economy for all personal vehicles (passenger cars and light trucks) increased through 1987 but remained nearly constant through 2000. After 2000, fuel prices increased and CAFE standards were raised, first for light trucks and then for passenger cars. The apparent decrease in on-road fuel economy estimates after 2005 more likely reflects a change in the definitions of passenger cars and light trucks and the methods used to estimate their travel and fuel use than an actual decrease in miles per gallon.

Starting in 2007, the U.S. Department of Transportation (USDOT), Federal Highway Administration (FHWA) has reported vehicle travel and fuel consumption statistics using the classifications of short- and long-wheelbase light-duty vehicles rather than the previous categories of passenger cars and two-axle,

FIGURE 7-6 Car and Truck Corporate Average Fuel Economy (CAFE) and Miles per Gallon (MPG): Model Years 1975-2013



KEY: MPG = Miles per Gallon; EPA = U.S. Environmental Protection Agency.

NOTE: Corporate Average Fuel Economy (CAFE) standards, which must be met at the manufacturer level, were established by the *U.S. Energy Policy and Conservation Act of 1975* (PL 94-163).

SOURCES: All Car and All Truck CAFE Stds: Davis, S.C., S.W. Diegel and R.G.Boundy. *Transportation Energy Data Book*, Edition 33 (July 2014), Oak Ridge National Laboratory, Oak Ridge, TN. Tables 4-21 and 4-22. Available at cta.ornl.gov/data as of June 2015. **Car and All Truck EPA MPG**: U.S. Environmental Protection Agency (EPA), *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 - 2013. Table 9.1*. Available at http://epa.gov/otaq/fetrends.htm as of June 2015.

four-tire trucks.[4] As a result, the post 2006 on-road fuel economy data are not consistent with the data from 2006 and earlier years.

Personal vehicle travel and fuel use before 1975 typically moved in parallel tracks (figure 7-7). Fuel economy improvements after 1975 broke the close connection as the amount of fuel used per vehicle mile of travel steadily decreased. The gap widened as newer, higher mpg vehicles came to dominate the on-road fleet, eventually raising average mpg from 13.3 in 1975 to 21.7 in 2013. However, drops in fuel use are tempered somewhat by increases in travel stimulated by improvements in fuel economy, a phenomenon known as the "rebound effect." In 2013 light-duty vehicles used 78.5 billion fewer gallons of motor fuel than they would have used assuming the same level of vehicle travel but 1975 average on-road fuel economy. The average price of gasoline in the United States in 2013 was $3.44 per gallon [USDOE EIA 2015d], or $2.95 before motor fuel taxes, implying a net savings due to fuel economy improvements of approximately $231.6 billion dollars in 2013 alone.

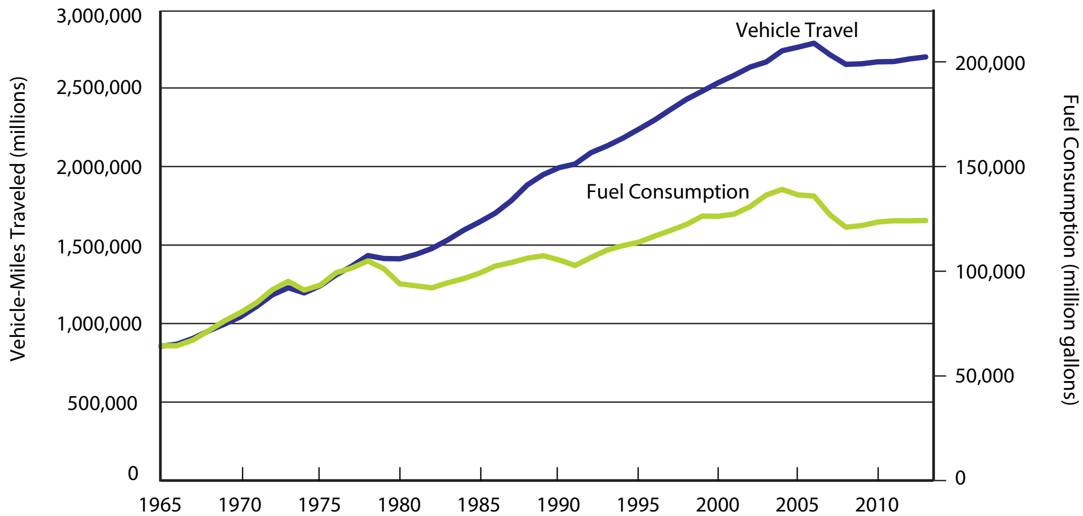
On August 28, 2012, the USDOT and the EPA set fuel economy and GHG emissions standards for passenger cars and light trucks through 2025. Nominally, the standards require a total fleet average of 54.5 mpg (163 grams of CO_2 equivalent) for new personal vehicles by 2025 [USEPA 2012]. However, this is based on laboratory test cycles rather than real world driving and does not consider the many ways manufacturers can earn fuel economy credits. Credits may be earned for more efficient air conditioners that leak less HFC, which is a potent greenhouse gas; for solar panels on hybrids; engine shut off at idle; and other features that improve real world fuel economy but which are not reflected in the test cycle. Additional credits may be earned for production of plug-in electric vehicles, hydrogen fuel cell vehicles, and vehicles powered by compressed natural gas. Furthermore, the new standards vary with the size of the vehicles a manufacturer produces. If a manufacturer produces mostly large vehicles, then its actual fuel economy requirement will be lower than if it produces mostly small vehicles.[5] Taking all these factors into account, USDOT and EPA estimated that manufacturers would achieve fuel economy levels of 46.2 to 47.4 mpg on the laboratory test cycles [Federal Register 2012]. Fuel economies achieved in actual driving would likely be 15 to 20 percent lower.

Medium- and heavy-duty highway vehicles are the second largest energy users among modes, accounting for 22.7 percent of transportation energy use in 2013 [ORNL 2015]. In 2011 the USDOT and the USEPA announced the first fuel economy and emission standards for this vehicle class for model years 2014–2018

[4] A vehicle's wheelbase is the distance from the center of its rear axle to the center of its front axle. "Short-wheelbase" light-duty vehicles include passenger cars, pick-up trucks, vans, minivans, and sport-utility vehicles with wheelbases less than or equal to 121 inches. The same types of vehicles with wheelbases longer than 121 inches are classified as "long-wheelbase" light-duty vehicles. Typically, light-duty vehicles have gross vehicles weights of less than 10,000 pounds.

[5] The size of a vehicle is defined as the rectangular "footprint" formed by its four tires. A vehicle's footprint is its track (width) multiplied by its wheelbase (length).

FIGURE 7-7 Vehicle-Miles of Travel and Fuel Use by Personal Vehicles: 1965–2013



NOTES: Includes passenger cars, light trucks and motorcycles for year 1965. The definition of light-duty vehicle was changed after 2006, affecting the vehicle types included in the personal vehicle category.

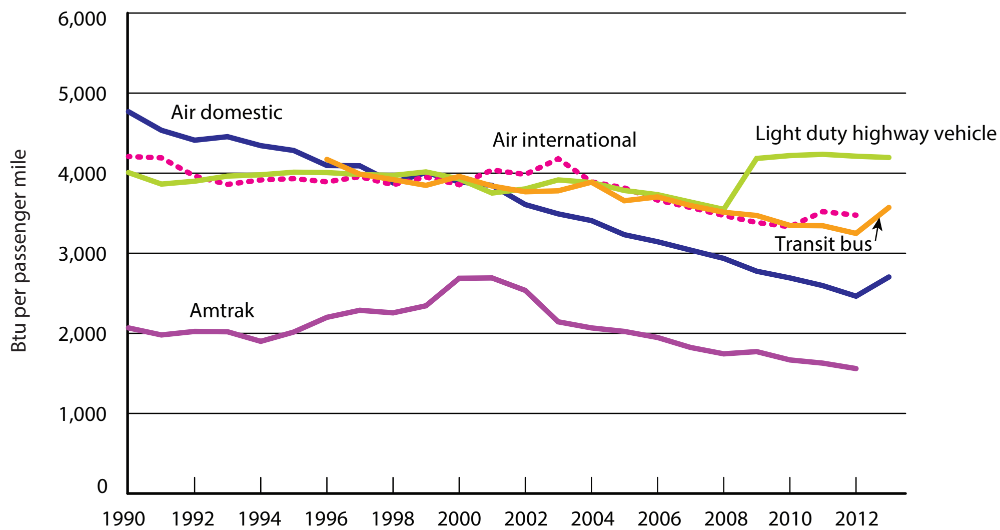
SOURCES: Vehicle-Miles of Travel: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics* (multiple years), Vehicle-miles of travel tables, available at http://www.fhwa.dot.gov/policyinformation/statistics.cfm as of June 2015. **Fuel Consumption**: U.S. Department of Transportation, Federal Highway Administration, Highway Statistics (multiple years); Motor-Fuel Use table, available at http://www.fhwa.dot.gov/policyinformation/statistics.cfm as of June 2015.

[USEPA 2011]. The standards apply to highway vehicles with gross vehicle weights above 8,500 pounds and set targets that vary depending on the type of vehicle and its functions. With the promulgation of these standards, nearly all highway vehicles became subject to fuel economy and CO_2 emissions rules. By 2018 the requirements for combination tractor trailers specify fuel economy improvements ranging from 9 to 23 percent, depending on the truck type. Goals for pickups and vans average 12 percent for gasoline engines and 17 percent for diesels. Similar improvements are required for the diverse class of vocational vehicles, such as dump trucks, cement mixers, and school buses. The EPA standards also require reductions in methane and nitrous oxides emissions and HFC leakage.

The energy intensities[6] of passenger modes have generally declined over time, with five out of six passenger modes now averaging less than 4,000 Btu per person-mile or about 30 person-miles per gallon of gasoline equivalent (figure 7-8). These declines are largely the result of more aerodynamic vehicles and efficient engines as well as improved operating efficiencies (e.g., higher air carrier load factors). From 2007 to 2013, the energy intensity of short- and long-wheel base light-duty vehicles rose while the energy intensity of other passenger modes—air, transit bus, and Amtrak—all declined.

[6] Energy intensity is the amount of energy used to produce a given level of output or activity, e.g., energy use per passenger-mile of travel.

FIGURE 7-8 Energy Intensity of Passenger Modes: 1990–2013



KEY: Btu = Britsh Thermal Unit

NOTES: Light-duty highway vehicles include passenger cars, light trucks, vans, and sport utility vehicles. Highway data for 2007-2011 were calculated using a new methodology and are not comparable to previous years. A change in vehicle occupancy rates derived from the National Household Travel Surveys results in a shift of highway passenger-miles between 2008 and 2009. Energy Intensity (Btu per Passenger mile) = Energy Use (Btu) / Passenger Miles, Energy Use calculated by using fuel and electricity usage and converting to energy by using BTS conversion rates. The following conversion rates were used: Diesel =138,700 Btu/gallon. Compressed natural gas = 22,500 Btu/gallon. Bio-Diesel = 126,200 Btu/gallon. Liquefied natural gas = 84,800 Btu/gallon. Gasoline = 125,000 Btu/gallon. Liquefied petroleum gas = 91,300 Btu/gallon. Methanol = 64,600 Btu/gallon. Ethanol = 84,600 Btu/gallon. Bunker fuel = 149,700 Btu/gallon. Kerosene = 135,000 Btu/gallon. Grain additive = 120,900 Btu/gallon. Electricity 1KWH = 3,412 Btu, negating electrical system losses. This table includes approximate electrical system losses, and thus the conversion factor is multiplied by 3.

SOURCES: Highway–Federal Highway Administration. **Air**–Bureau of Transportation Statistics, Office of Airline Information. **Amtrak**–National Railroad Passenger Corporation (Amtrak), personal communication with Energy Management Department and Government Affairs Department and Association of American Railroads. **Transit**–Federal Transit Administration as cited in U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, table 4-21, 4-22, 4-24, and 4-16, available at www.bts.gov as of March 2015.

The energy intensity of rail freight transport decreased at an average annual rate of 1.6 percent per year since 1990. Moving 1 ton of freight 1 mile in 2013 required 70.1 percent as much energy as it did in 1990. This was accomplished mostly through reducing energy use per freight car-mile by 14.1 percent and improving locomotive and operational efficiency while simultaneously increasing tons per car-miles by 132.2 percent [USDOT BTS NTS 2015].

Alternative Fuels and Vehicles

A large part of the growing use of biofuels in transportation, shown in figure 7-2, can be attributed to the requirements of the Federal Renewable Fuels Standard (RFS). Enacted as part of the *Energy Policy Act* of 2005 (Pub. L. 109-58) and extended by the *Energy Independence and Security Act* of 2007 (Pub. L. 110-140), the RFS requires the introduction of increasing amounts of renewable energy into gasoline and diesel fuels each year, ultimately reaching 36 billion gallons by 2022 [USLOC

CRS 2013 and 2015]. At least 16 billion gallons are required to be cellulosic ethanol,[7] and no more than 15 billion gallons can be ethanol produced from corn starch. In 2014 the United States consumed nearly 13.5 billion gallons of fuel ethanol and 1.4 billion gallons of biodiesel [USDOE EIA 2015b]. More than 37 billion gallons of diesel fuel were consumed by vehicles in 2013 [USDOE EIA 2015e]. Box 7-A discusses diesel-powered passenger car and light-truck sales and emissions.

There is still almost no capacity to produce cellulosic ethanol, which has led the EPA to reduce cellulosic ethanol requirements each year, and the blending of ethanol from all sources with gasoline is very close to market saturation at the current 10 percent level. This means that additional ethanol production can

[7] Cellulosic ethanol is produced from non-food based feedstock, such as wood and crop residues (corn husks, cobs and stalks), and switch grass.

BOX 7-A Diesel-powered Automobiles

Diesel-powered automobiles have been making the headlines following emission concerns raised by the U.S. Environmental Protection Agency (see the recent letter on these issues at: http://www3.epa.gov/). Diesel vehicles are a small percentage of the Nation's motor vehicle fleet, mostly medium and heavy trucks. For example, 72 percent of the trucks with a gross vehicle weight rating 10,001 and above sold in the United States in 2013 were diesel-powered, up from 69 percent in 2009 [USDOE ORNL 2015].

Sales of Diesel-Powered Passenger Cars and Light Trucks

In Model Year 2014, over 16.4 million passenger cars and light trucks were sold in the United States [USDOC BEA 2015]. Only 1.5 percent of all light duty vehicles (including passenger cars, sport utility vehicles, minivans, and all but the largest pickup trucks and vans) were diesel-powered. This percentage is up from less than 0.1 percent in the mid-90s, but below the peak of 5.9 percent in Model Year 1981. In Model Year 2014 Volkswagen had the highest percentage with 20.1 percent of diesel-powered light duty vehicles in its fleet across all automakers in the United States. Daimler had the next highest percentage with 6.9 percent, followed by BMW (6.0 percent), Chrysler-Fiat (2.8 percent), and GM (0.5 percent) [USEPA 2014a].

Emissions from Diesel-Powered Motor Vehicles

Diesel-powered motor vehicles account for about 4 percent of the fleet, but they account for about half of the on-road NOx emissions. In 2013, gasoline-powered motor vehicles contributed 2,365 kilotons; in comparison, diesel-powered motor vehicles contributed 2,125 kilotons of on-road NOx emissions [USEPA 2015]. Diesel-powered vehicles generally have better fuel economy than gasoline-powered ones, thus their CO_2 per vehicle-mile travelled is generally lower than a comparable gasoline-powered vehicle. However, diesel remains a major source of harmful pollutants (e.g., ozone forming emission, including nitrogen compounds NO_x as well as particulate matter (PM), which is a mixture of solid particles and liquid droplets found in the air) when burned. According to the U.S. Environmental Protection Agency, using ultra low sulfur diesel fuel and advanced emission control systems can reduce vehicle PM and NO_x emissions [USDOE EIA 2014].

only be absorbed by expanding the current distribution network of high ethanol blend fueling stations and increasing the numbers of vehicles capable of using these higher blends—up to and including E85 (85 percent ethanol, 15 percent gasoline). In 2013 the EPA decreased the requirement for cellulosic ethanol from 14 billion to 6 million gallons per year, less than one one-thousandth of the statutory amount, reflecting the absence of adequate production capacity for cellulosic ethanol [USEPA 2014b]. The EPA also has expanded the types of biofuels that can qualify under the RFS program to include such fuels as gasoline produced from biomass. At present, however, the capacity does not exist to produce these fuels in volumes that could make a meaningful contribution to achieving the RFS goals.

Nearly all U.S. gasoline now contains up to 10 percent ethanol. All automobile manufacturers' warranties allow 10 percent ethanol/90 percent gasoline blends (E10). In 2014 motor vehicles used nearly 137 billion gallons of gasoline, including almost 13.5 billion gallons of ethanol [USDOE EIA 2015b]. Higher levels of ethanol of up to 15 percent (E15) may pose difficulties for motorcycles, older vehicles, and off-highway engines. The EPA has not approved or tested E15 for proper engine performance and fuel economy in motorcycles [FRANK 2013]. Generally, manufacturers have been reluctant to extend their warrantees to include higher level blends. The 10-percent limit has been termed the "blend wall," in that it appears to constrain the amount of ethanol that can be safely mixed with gasoline as a strategy for meeting the RFS. In 2011, after extensive study, the EPA issued a rule permitting E15 use in model year 2001 and newer motor vehicles (the majority of personal vehicles on the road). However, manufacturers have challenged the ruling based on concerns about the potential for misfueling of older vehicles not capable of using E15 and risking mechanical problems. Concern about the potential risk of misfueling appears to be responsible for the very limited availability of E15. As of October 2015, the number of public refueling stations offering E15 in the United States more than doubled from 2 years ago, amounting to 2,990 [USDOE AFDC 2015] out of a total of 211,000[8] gasoline stations [DOC CENSUS 2014].

Flexible-fuel vehicles (FFVs) can safely use mixtures of up to 85 percent ethanol (E85) with gasoline.[9] FFVs accounted for 91.8 percent of the nearly 2.1 million projected alternative fuel vehicles operating on U.S. roads in 2014 (table 7-2) [USDOE EIA 2015a]. However, most on-road FFVs are fueled with gasoline or gasoline/E10 blends only. Until 2016 automobile manufactures can earn extra credits toward meeting CAFE standards by making and selling FFVs. Future FFV sales are uncertain because the credits will be largely phased out by 2016 unless actual use of E85 increases substantially. Together, liquid petroleum gas/propane and compressed/liquefied natural gas-powered vehicles accounted for less than 1 percent of alternative

[8] These include businesses primarily engaged in retailing automotive fuels (114,000) and those engaged in retailing automotive fuels in combination with a convenience store (97,000).

[9] E85 may contain anywhere from 51 percent ethanol to 85 percent ethanol. Because fuel ethanol is denatured with approximately 2 percent to 3 percent gasoline, E85 is typically no more than 83 percent ethanol.

TABLE 7-2 Projected Number of Onroad Alternative Fueled Vehicles: 2014

	Light duty	Medium duty	Heavy duty	Total
Ethanol/flex fuel	1,398,800	0	W	2,085,001
Liquid petroleum gas/propane (LPG)	156	W	W	3,421
Natural gas	W	W	W	0
Compressed natural gas (CNG)	W	W	7,002	12,628
Liquefied natural gas (LNG)	0	0	W	276
Electric/battery	169,147	W	W	170,062
Hydrogen (H)	W	0	W	5
Total	**1,568,103**	**0**	**7,002**	**2,271,393**

KEY: W = withheld to avoid disclosure of individual company data.

SOURCE: U.S. Department of Energy, Alternative Fuel Vehicle Data, *Projected Number of Onroad Alternative Fueled and Hybrid Vehicles to be Made Available, by Fuel Type and Vehicle Type*, 2014 available at http://www.eia.gov/ as of November 2015.

fuel vehicles in use in 2014 [USDOE EIA 2015a]. Electrically driven motor vehicles may someday transform transportation energy use, but at present there is substantial uncertainty about their ability to compete with the internal combustion engine in the mass market.

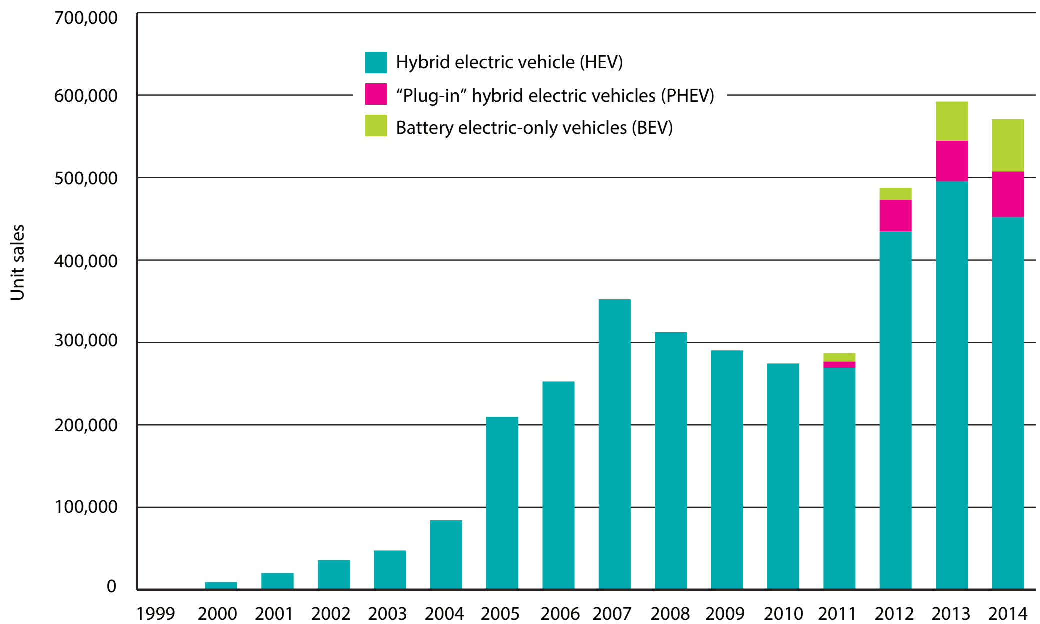
Until recently, gasoline or diesel fuel alone powered nearly all motor vehicles. The first mass-produced hybrid electric vehicle (HEV), powered by an internal combustion engine and an electric motor, was introduced in 1999. The internal combustion engine continues to provide all the energy for this kind of hybrid vehicle, but kinetic energy normally wasted during braking is instead used to generate electricity that is stored in an onboard battery for later use by the electric motor. Hybrid vehicles have become popular since the early 2000s as a replacement for traditional gasoline- or diesel-fueled vehicles. All hybrid electric vehicle[10] sales have grown from 17 vehicles sold in 1999 to a high of 592,000 vehicles in 2013, before declining in 2014 to about 571,000 (figure 7-9). In 2014, 52 makes and models of HEVs were offered for sale in the United States [USDOE and USEPA 2015]. According to the U.S. Department of Energy (USDOE), Energy Information Administration (EIA), there were approximately 4.4 million hybrid electric vehicles (passenger cars and light trucks) on the road in 2014 [USDOE EIA 2015c].

The first mass-produced "plug-in" hybrid electric vehicles (PHEV), able to draw electric power from the utility grid and store it on-board, were 2011 model year vehicles sold in 2010. In 2010 just 19 electric-only and 326 plug-in hybrid vehicles were sold. By 2014 combined sales of grid-connected vehicles totaled more than 119,000 units [HYBRIDCARS 2014]. Over the same period, the number of makes and models of battery electric-only vehicles increased from 3 to 15, while plug-in hybrid offerings increased from 1 to 10 [USDOE and USEPA 2015].

Hybrids and grid-connected vehicles comprised about 3.5 percent of the 16.4 million light-duty vehicle sales in 2014 [HYBRIDCARS 2014]. Both types of vehicles

[10] The total includes hybrid electric vehicles, "plug-in" hybrid electric vehicles, and battery electric-only vehicles.

FIGURE 7-9 Sales of Hybrid, Plug-in Hybrid and Battery Electric Vehicles: 1999–2014



SOURCE: HybridCars, December Dashboards, Annual Issues, available at www.hybridcars.com as of October 2015.

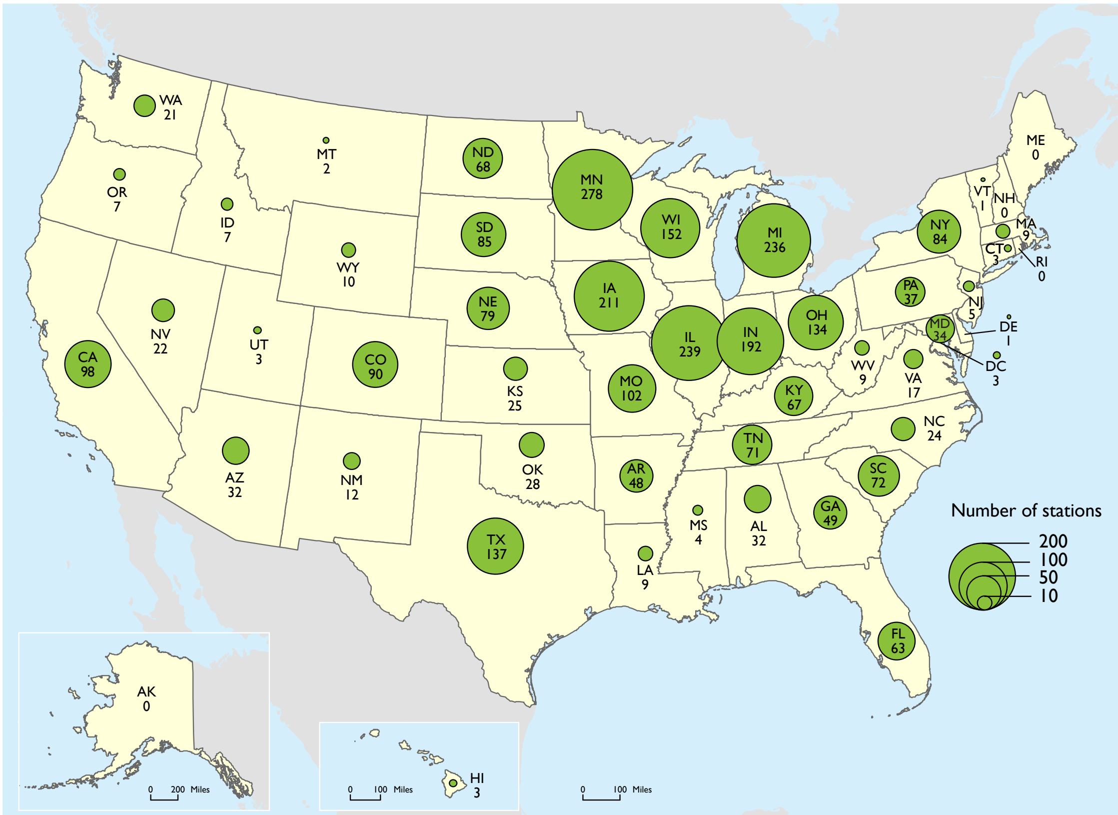
face several challenges: reducing costs, overcoming the market's unfamiliarity with the new technology, decreasing the length of time required for recharging batteries, and developing a recharging infrastructure. Considerable progress has been made in creating a nationwide recharging infrastructure. As of June 2015, there were more than 11,800 recharging stations with more than 29,800 nonresidential charging outlets across the United States, up from almost 3,400 outlets in 2011[USDOE AFDC 2015].[11]

The geographical distribution of refueling stations for alternative fuels partly reflects the numbers of vehicles in each state but also reflects the interests of residents and public policies. E85 stations are disproportionately concentrated in states that grow corn and produce ethanol (figure 7-10). The distribution of electric vehicle recharging stations tends to favor states that have opted into California's Zero Emission Vehicles (ZEV) standards (figure 7-11).[12] Manufacturers selling electric vehicles in these states earn credits towards meeting the ZEV requirements. The distribution of compressed and liquefied natural gas refueling stations, on the other hand, more closely reflects the number of CNG/LNG vehicles registered in a state (figure 7-12).

[11] A single electric vehicle recharging station may include multiple recharging outlets. Residential recharging locations are not included in the station count. *Transportation Statistics Annual Report 2013* presented the number of recharging outlets rather than stations as it noted here.

[12] Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Washington, Delaware, Georgia, and North Carolina have adopted the California Air Resources Board (CARB) regulations for a vehicle class or classes in accordance with the Section 177 of the *Clean Air Act*.

FIGURE 7-10 E85 Refueling Stations by State: 2015



SOURCE: U.S. Department of Energy, Energy Efficiency and Renewable Energy, *Alternative Fuels Data Center*. Ethanol Fueling Station Locations. Available at http://www.afdc.energy.gov/ as of October 2015.

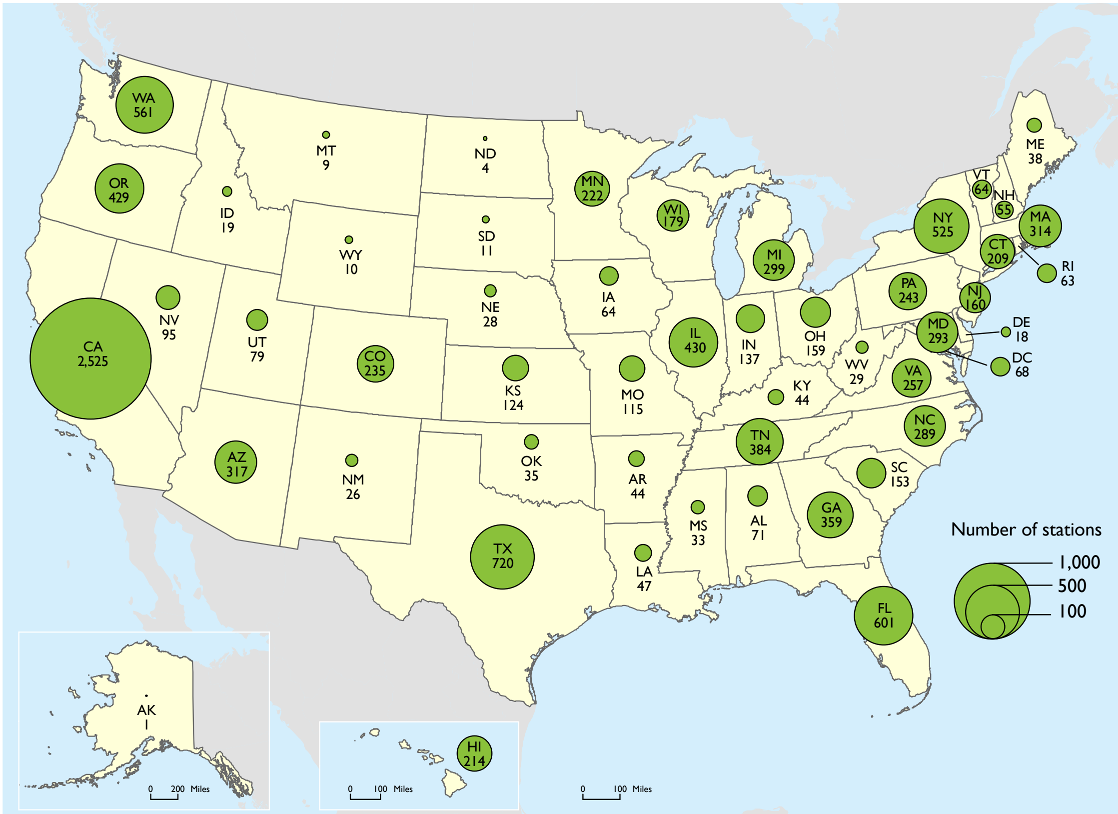
Transportation's Energy Outlook

The EIA has projected the likely effects of current trends and existing policies on transportation's future energy use and GHG emissions. The 2014 projections anticipate transportation energy use remaining at or near the current level of 27 quadrillion Btu through 2040 [USDOE EIA 2015c]. Existing fuel economy and GHG emissions standards are expected to decrease light-duty vehicle energy use by 19.7 percent by 2040, resulting in approximately 12.6 quadrillion Btu of energy use (figure 7-13). Most of this reduction is expected to be offset by growth in energy use by medium- and heavy-duty trucks, although that could change if fuel economy and emissions standards for those vehicles are further tightened.

For all other modes, activity growth is approximately balanced by improvements in energy efficiency. These projections are based on existing policies and increasing oil prices.[13] Natural gas use by motor vehicles in compressed and liquefied form is projected

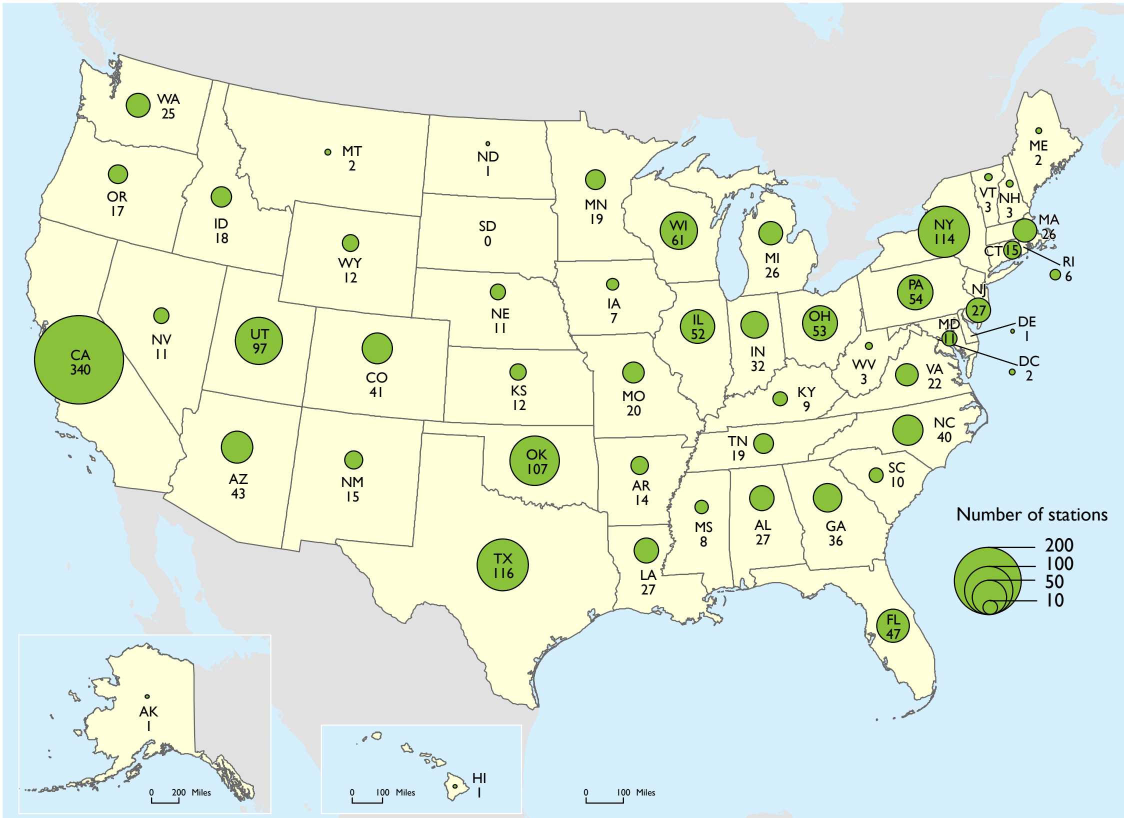
[13] EIA's *Annual Energy Outlook* does not include a scenario in which oil prices decrease over the 2013-2040 period.

FIGURE 7-11 Electric Vehicle Refueling Stations by State: 2015



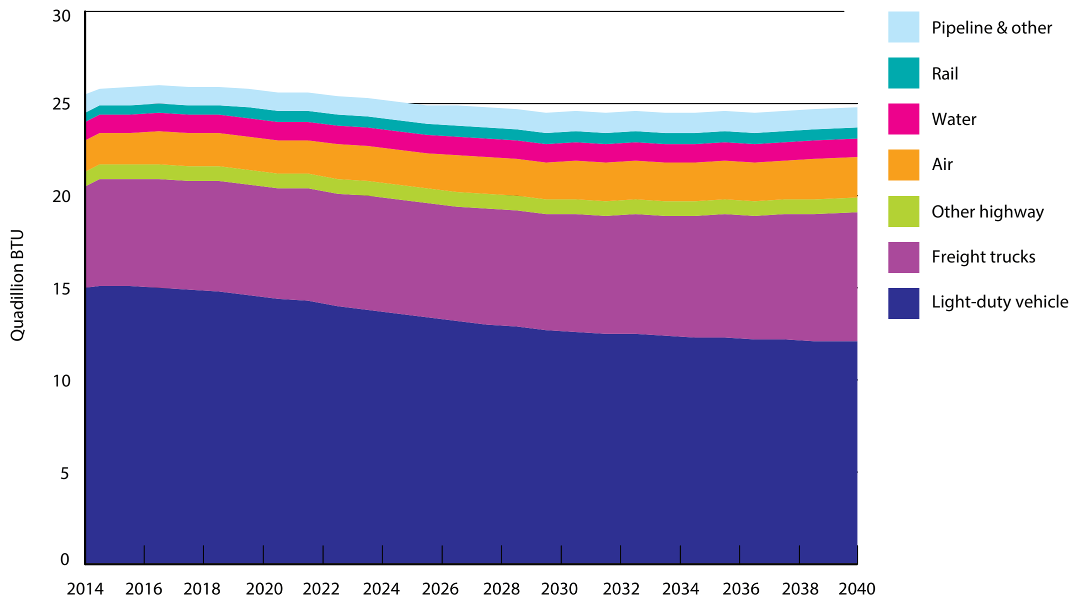
SOURCE: U.S. Department of Energy, Energy Efficiency and Renewable Energy, *Alternative Fuels Data Center*. Ethanol Fueling Station Locations. Available at http://www.afdc.energy.gov/ as of October 2015.

FIGURE 7-12 CNG and LNG Refueling Stations by State: 2015



SOURCE: U.S. Department of Energy, Energy Efficiency and Renewable Energy, *Alternative Fuels Data Center*. Ethanol Fueling Station Locations. Available at http://www.afdc.energy.gov/ as of October 2015.

FIGURE 7-13 Transportation Energy Use: 2014–Projected to 2040



SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2015*. Transportation Sector Energy Use by Mode and Type. Available at http://www.eia.gov/forecasts/aeo/ as of June 2015.

to increase from just 0.05 quads in 2013 to 0.7 quads by 2040 [USDOE EIA 2015c]. EIA attributed all of the projected increase in natural gas use by motor vehicles to medium- and heavy-duty trucks and buses.

According to the EIA, the 2011–2025 fuel economy standards, together with the market's response to higher gasoline prices, are projected to save personal vehicle owners about 40 billion gallons of motor fuel in 2025, compared to what consumption would have been at the same level of vehicle travel without any increase in fuel economy (figure 7-14).

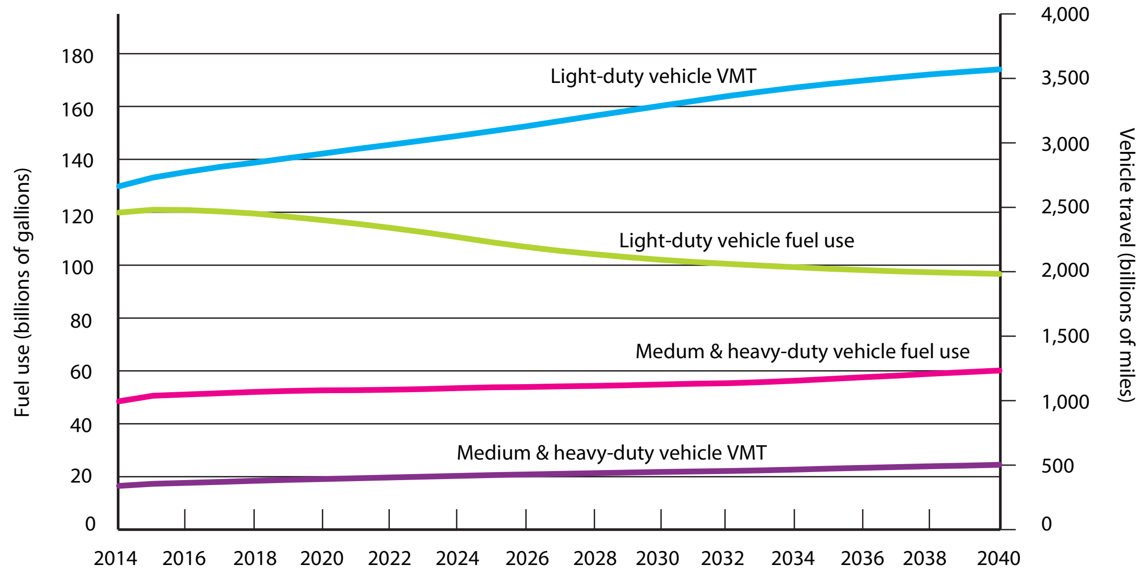
By fuel type, EIA projects gasoline use to decline from 15.9 quads in 2013 to 12.6 in 2040, in line with light-duty vehicle energy use. Diesel fuel use will increase from 5.8 to 7.9 quads, which is consistent with the growth of truck freight energy use. E85 and electricity use will increase but will still amount to only 0.28 quads and 0.06 quads of energy in 2040, respectively [USDOE EIA 2015c].

Air and Water Quality, Noise, and Habitat Impacts

With the exception of greenhouse gases, addressed earlier in the chapter, vehicle emissions controls and other policies have reduced transportation's six most common air pollution emissions to below their 1990 levels, a trend that continued through 2014[14] (figure

[14] Often called "criteria pollutants" because the U.S. Environmental Protection Agency sets permissible levels for these air pollutants using criteria based on scientific guidelines on human health or welfare under the *Clean Air Act*.

FIGURE 7-14 Highway Vehicle Fuel Use and Travel: 2014–Projected to 2040



KEY: VMT = Vehicle-miles traveled.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2015*. Reference Case table 7. Available at http://www.eia.gov/forecasts/aeo/ as of June 2015.

7-15). Smog-forming emissions of volatile organic compounds (VOC) and nitrogen oxides (NO_x) were 66.8 and 46.5 percent lower, respectively, in 2014 than they were in 1990. In recent years NO_x emissions have decreased more rapidly, partly due to more advanced diesel emission controls and the use of cleaner, ultra-low sulfur diesel fuel.

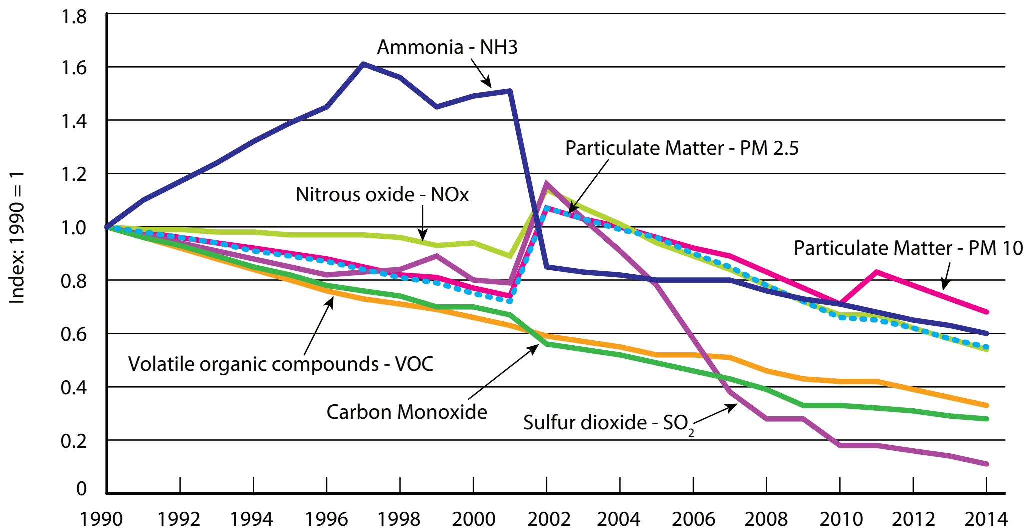
Transportation's share of total U.S. PM-2.5 emissions decreased from 8.2 percent in 1990 to 5.7 percent in 2014, while the share of PM-10 emissions decreased from 2.6 in 1990 to less than 2.4 percent of total emissions over the same period.

Emissions of sulfur dioxide (SO_2) were 87.8 percent lower in 2013 than in 1990, due in large part to reductions in the sulfur contents of gasoline and diesel fuel. The Clean Air Act of 1970 led to the reduction in lead emissions, once a major air pollutant from transportation; lead is not shown in the figure because it has been virtually eliminated from transportation with the phase-out of leaded gasoline.

Emissions of ammonia (NH_3), another air pollutant, increased between 1990 and 2001, but in 2013 they were 38.1 percent of the 1990 level. Transportation comprised 2.4 percent of total U.S. emissions of ammonia in 2013.[15]

[15] Ammonia is not a by-product of fuel combustion but is formed in a vehicle's three-way catalytic emissions control systems. The introduction of 3-way catalytic converters initially caused increased NH_3 formation, but this was later offset by improvements in newer emissions control systems and the aging and retirement of vehicles with the earliest three-way catalytic systems.

FIGURE 7-15 Indexes of Key Air Pollutant Emissions from U.S. Transportation: 1990–2014



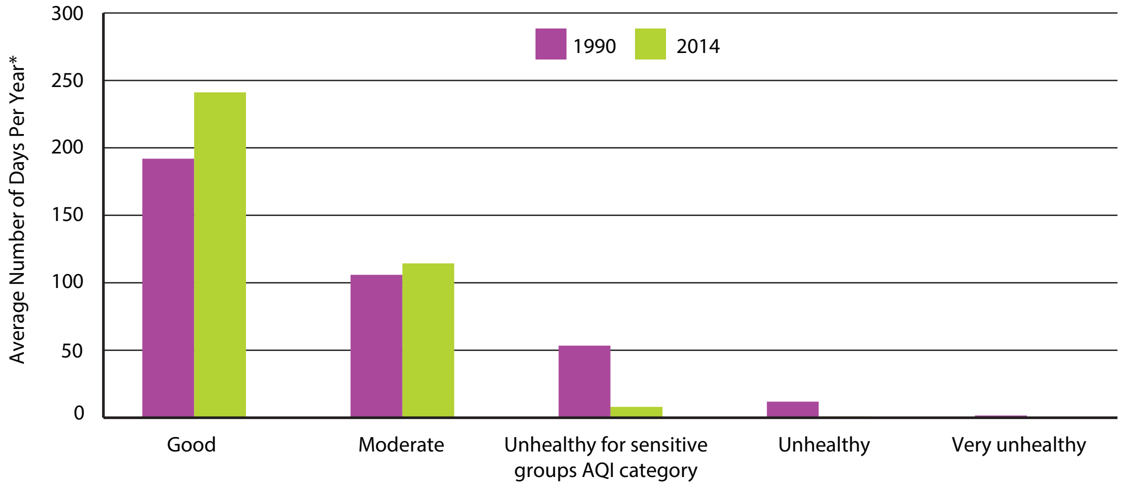
SOURCE: U.S. Environmental Protection Agency, National Emissions Inventory *Air Pollutant Emissions Trends Data, 1970-2014*, Average Annual Emissions All Criteria Pollutants, Available at http://www.epa.gov/ttn/chief/trends/index.html as of June 2015.

Reductions in transportation's air emissions have contributed to improved air quality in the Nation's urban areas. Figure 7-16 compares air quality days for 169 continuously monitored urban areas in 1990 and in 2014. The number of days from the 169 urban areas in which air quality was reported to be unhealthy for sensitive groups (e.g., people with lung disease, young children, and older adults) dropped from an accumulated total of 9,025 in 1990 to 1,363 in 2014; the number of days with unhealthy air quality for the population as a whole declined from 2,009 in 1990 to 180, and the number of very unhealthy days (which could trigger health emergency warnings for the general public) rose from 291 to 361. The great majority of days had good or moderate air quality in both 1990 and 2014, but 2014 had many more days of good or moderate air quality in these cities. In 2014 good air quality days totaled 40,758 days—about 8,300 more good air quality days than in 1990. Also for 2014, there were 19,348 moderate air quality days—compared to 17,908 moderate days in 1990 [USEPA 2015b].

Pipelines, ships, railroad cars, and tank trucks are among the sources of spills of crude oil and petroleum products into surface waters and navigable waterways.[16] The annual volume spilled varies greatly from year to year and is strongly affected by infrequent, large events (figure 7-17). For example, Hurricane Katrina caused numerous spills into navigable waterways from a variety of sources in Louisiana and Mississippi in 2005 as the volume of petroleum spilled jumped to 9.9 million in 2005, more than three times the

[16] Safety issues associated with spills of hazardous materials are covered in Chapter 6.

FIGURE 7-16 Air Quality Index for 169 U.S. Cities: 1990 and 2014

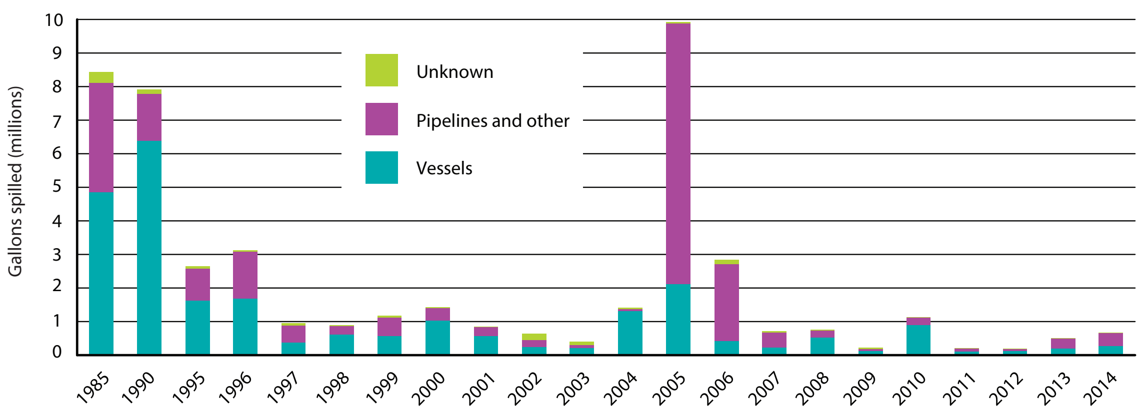


NOTES: Based on number of days in the year in which an AQI measurement was reported from any monitoring site in the county or Metropolican Statistical Area to the Air Quality Statistics database.

Days Good: number of days in the year having an AQI value 0-50
Days Moderate: number of days in the year having an AQI value 51-100
Days Unhealthy for Sensitve Groups: number of days in the year having an AQI value 101-150
Days Unhealthy: number of days in the year having an AQI value 151-200
Days Very Unhealthy: number of days in the year having an AQI value greater than 200. This includes the AQI categories very unhealthy and hazardous.

SOURCE: U.S. Environmental Protection Agency, Air Quality Index Information. Available at http://www.epa.gov/airtrends/aqi_info.html as of August 2015.

FIGURE 7-17 Petroleum Spills Impacting Navigable Waterways: 1985, 1990, and 1995–2014



NOTES: The spike in gallons spilled for 2005 can be attributed to the passage of Hurricane Katrina in Louisiana and Mississippi on Aug. 29, 2005, which caused numerous spills approximating 8 million gallons of oil in U.S. waters. The largest spill in U.S. waters involved an incident on the mobile offshore drilling unit (MODU) *Deepwater Horizon* beginning Apr. 20, 2010. The most commonly accepted spill amount from the well is approximately 206.6 million gallons, plus approximately 400,000 gallons of oil products from the MODU and are excluded from above.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 4-54, Available at http://www.bts.gov as of November 2015.

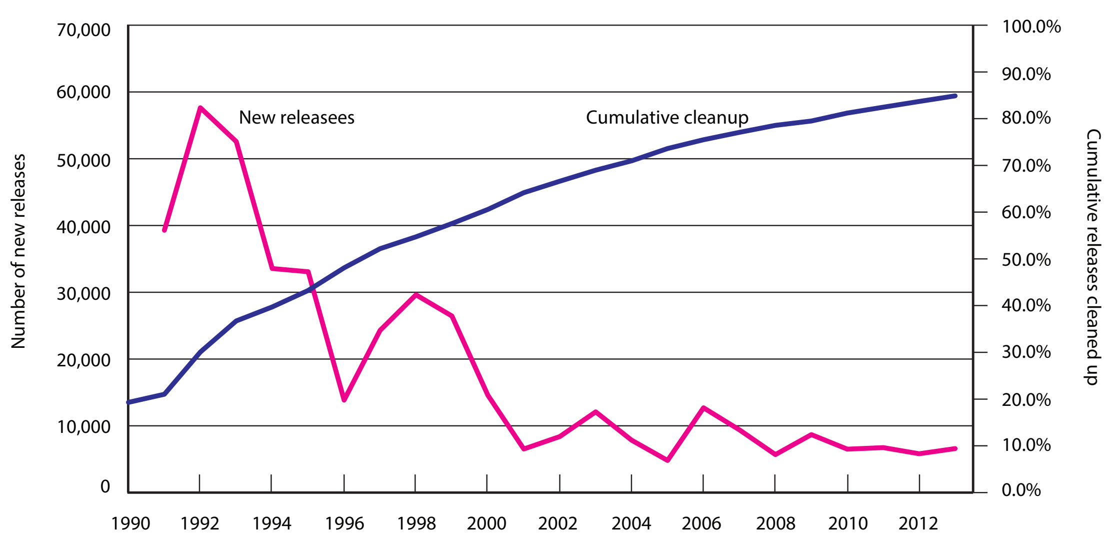
amount of petroleum spilled in any other year from 1995 through 2014.[17] While the number fluctuates from year-to-year, the 1,716 spill incidents from vessels in 2014 were slightly less than the 2005 to 2014 average of about 1,735 spills. The 963 spill incidents from pipelines into navigable waters in 2014 were slightly less than the 973 annual averages for the 2005-2014 period.

In 1985, in response to a congressional requirement, EPA began an effort to regulate underground storage tanks that can contaminate ground water, to clean up leaks, and prevent them in the future [USEPA 2015c]. Since then the number of new leaks from storage tanks has been reduced by nearly an order of magnitude, and over 85 percent of all leaks cleaned up (figure 7-18).

As rainwater or snowmelt runs off transportation infrastructure, like roads, parking lots, and bridges, it picks up de-icing salts, rubber and metal particles from tire wear, antifreeze and lubricants, and other wastes that may have been deposited on infrastructure surfaces. The runoff carries these contaminants into streams, lakes, estuaries, and oceans. An indepth study of road-salt impacts on water quality examined U.S. Geological Survey historical data collected between 1969 and 2008 from 13 northern and 4 southern metropolitan areas. During the November to April period, when road salt application is most common, the concentration of chloride (an ingredient of salt) chronically surpassed

[17] The much larger Deepwater Horizon oil platform fire and spillage in the Gulf of Mexico of 207 million gallons is not considered to be a spill into navigable waters of the United States or a spill from a transporting vessel (USLOC CRS 2013).

FIGURE 7-18 Leaking Underground Storage Tank Releases and Cleanup: 1990–2014



NOTES: All data are cumulative from the start of the U.S. Environmental Protection Agency's Underground Storage Tank program, which began in 1984. Data represent fiscal year, October 1 through September 30.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics*, Table 4-55, Available at http://www.bts.gov as of June 2015.

EPA's water-quality criteria at 55 percent of the monitoring locations in northern metropolitan areas; chloride levels acutely surpassed the criteria at 25 percent of these northern stations. From May to October, only 16 percent of the northern stations chronically exceeded the criteria, and just 1 percent showed acute exceedances. At southern sites, where road salt is less frequently applied, there were few samples in any season that exceeded the chronic water-quality criteria, and none exceeded the acute criteria [Corsi, et al 2010].

Highways and other transportation infrastructure also affect wildlife via road kills, habitat loss, and habitat fragmentation. Numerous projects have been undertaken across the United States to mitigate these impacts, from salamander and badger tunnels to mountain goat underpasses on highways to fish passages through culverts.[18] There are no systematic estimates of the numbers of wildlife killed by transportation vehicles in the United States. In certain circumstances, the population effects of road kill have been shown to be substantial, even threatening the survival of endangered species. In general, the number of bird kills greatly exceeds the number of mammals killed. Insurance industry records indicate that there are between one and two million reported collisions between animals and vehicles each year. These numbers only include reported incidents; collisions with small animals resulting in no vehicle or human damage are not generally reported [Gaskill 2013].

Transportation noise is pervasive and difficult to avoid in the United States [USDOT FHWA HEP 2013]. It is generated by engines, exhaust, drive trains, tires, and aerodynamic drag. At freeway speeds tire-pavement noise dominates for highway vehicles, while exhaust and aerodynamic noise dominate for aircraft. However, a national noise exposure inventory does not exist. The United Kingdom has developed a noise inventory for 23 large urban areas by estimating noise levels using computer models that are based on transportation activity data [UKDEFRA 2014]. Similar methods could be applied to collect and analyze noise issues in the United States.

Unwanted noise can have a variety of impacts including annoyance, sleep disruption, interference with communication, adverse impacts on health and academic performance, and consequent reductions in property values. There is almost no part of the United States in which transportation noise is not noticeable [WAITZ 2007]. When transportation noise levels are below 45 decibels (dB), the level of annoyance in the population is negligible, but when noise levels exceed 65 dB, impacts can be severe.[19] Although highways are the most widespread source of transportation noise, exposure to transportation noise is systematically measured only for aircraft. In 2014, 321,000 individuals lived in high noise (>65 dB) areas around U.S. airports. The number of people residing in high noise areas around U.S. airports was down from 7 million in 1970 and from 2.7 million in 1990. The

[18] While there are no comprehensive statistics on mitigation efforts, numerous case studies of highways mitigation efforts can be found at http://www.fhwa.dot.gov/environment/wildlife_protection/index.cfm.

[19] Noise (sound) is measured in decibels (dB) on a logarithmic scale. Each increase of 10 dB represents a doubling of the noise level.

number was reduced through a combination of changes in engine and airframe design and operational strategies [USDOT BTS NTS 2015]. Take-off and landing operations are the primary source of annoying aircraft noise, which per dB is generally more annoying to the public than highway or rail noise.

Under certain circumstances, unwanted and unnecessary light is considered "light pollution" [MRSCW 2014]. Transportation vehicles and facilities can be sources of light pollution. While light pollution is a special concern for facilities like astronomical observatories, it is also known to adversely affect biodiversity in urban areas and to have harmful effects on human metabolism [COE 2010]. No systematic data on light pollution due to transportation in the United States exists.

In addition to the primary performance measures of how efficiently, reliably, and safely people and goods move on the system, transportation's energy usage and its environmental impacts are also important measures of how well the transportation system performs its societal function. In recognition of this, there have been efforts to mitigate transportation's dependence on petroleum and environmental impacts. As detailed in this chapter, transportation has become more efficient over the past few decades in its use of energy and has reduced many of its environmental impacts even though activity levels have increased. It continues, however, to be the second leading emitter of greenhouse gases in the United States and has had other major impacts on the environment, such as oil pollution, habitat loss, and noise. Going forward, appropriate and accurate data will be needed to monitor progress and determine whether societal efforts to improve the system's performance are having the desired effect.

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