Texas A&M Transportation Institute

Alternative Fuel Vehicle Forecasts

Final report

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TRANSPORTATION
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Alternative Fuel Vehicle Forecasts

Texas A&M Transportation Institute

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Table of Contents

List of Figures

List of Tables

List of Acronyms

AFDC	Alternative Fuels Data Center
AFV	Alternative fuel vehicle
BEV	Battery electric vehicle
CAFE	Corporate Average Fuel Economy
CNG	Compressed natural gas
DOE	Department of Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ERIG	Emissions Reduction Incentive Grants
EV	Electric vehicle
EVSE	Electric Vehicle Supply Equipment
FCV	Fuel cell vehicle
FHWA	Federal Highway Administration
GGE	Gasoline gallon equivalent
HEV	Hybrid electric vehicle
H-GAC	Houston-Galveston Area Council
ICE	Internal combustion engine
IEA	International Energy Agency
LDV	Light-duty vehicle
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MHDV	Medium- and heavy-duty vehicle
MOU	Memorandum of understanding
mpg	Miles per gallon
MPGe	Miles per gallon equivalent
MSRP	Manufacturer's standard retail price
NGV	Natural gas vehicle
NHTSA	National Highway Traffic Safety Administration
OEM	Original equipment manufacturer
PHEV	Plug-in hybrid electric vehicle
TCEQ	Texas Commission on Environmental Quality
TERP	Texas Emissions Reduction Program
TRENDS	Transportation Revenue Estimator and Needs Determination System
TTI	Texas A&M Transportation Institute

Executive Summary

Federal and state fuel taxes account for the largest share of the Texas State Highway Fund at 48 percent and 29 percent, respectively, in Fiscal Year 2015. These taxes are levied on a per-gallon basis, meaning that as vehicles get more fuel efficient, they return less and less revenue for every mile driven. This is problematic from a funding standpoint because passenger and commercial vehicles are expected to continue increasing in terms of their fuel efficiency. Furthermore, vehicles that operate on alternative fuels are becoming increasingly popular. The two most popular alternative fuels, ethanol and compressed natural gas (CNG), are both taxed by the state at per-gallon rates similar to gasoline and diesel taxes. However, ethanol and CNG vehicles tend to be more fuel efficient than their petroleum fuel-based counterparts. Furthermore, vehicles that operate on fuels that are not taxed for transportation-related purposes, such as electric vehicles (EVs), are being produced and sold at an increasing pace. Battery electric vehicles (BEVs), for example, essentially operate for free on Texas roadways after their sales, registration, and inspection fees have been paid. If BEVs and other alternatively fueled vehicles (vehicles not operating on gasoline or diesel) see widespread adoption by the motoring public in Texas, then revenues going to the State Highway Fund could be reduced in the long term.

It is therefore important for Texas to be aware of trends in the alternative fuel vehicle (AFV) industry and their potential impact on fuel consumption and associated fuel tax revenue generation. Awareness will allow state policies to address any potential funding issues in the foreseeable future. This report provides a summary of recent trends in the development of alternative fuel technologies and factors impacting their adoption by the passenger vehicle and commercial vehicle fleets. Researchers relied on government, academic, and private-sector resources in compiling this report. This report also discusses the potential revenue impacts to the State of Texas with a specific focus on how alternative fuel technology adoption could affect long-term state fuel tax revenues. Finally, this report includes summary information and discussion on federal, state, and local incentives aimed at encouraging alternative vehicle technology development, deployment, and adoption.

Alternative Fuel Technologies

There are currently five major types of alternative fuels used or under development that could significantly impact state transportation revenues. These include:

- **Electricity—**Vehicles that use an electric motor, as opposed to an internal combustion engine (ICE), to propel the vehicle, with electricity being provided by a battery. Batteries may be charged through a connection to the electric power grid, such as through a wall socket, or by a gasoline/diesel-driven engine that acts as a generator. Electric vehicles that use an ICE for electricity generation may also use it to propel the vehicle and consume taxed fuels, but they are much more fuel efficient than traditional gasoline or diesel vehicles and can operate for significant distances on electricity alone. Vehicles that do not use an ICE run exclusively on electricity provided through battery charging, and the drivers pay no fuel taxes, but these vehicles have a shorter driving range. The major challenge facing the future adoption of these vehicles is a lack of retail charging infrastructure that would enable these vehicles to travel longer distances.

- **Natural gases—**Natural gas is extracted from wells during crude oil production and can be compressed or liquefied and used as a transportation fuel. Domestic energy development has stabilized and lowered the price of natural gas relative to gasoline and diesel, meaning that this alternative fuel technology could see wider adoption in the long term. Vehicles can be outfitted to run on traditional fuels, natural gases, or both. Natural gas vehicles have seen limited adoption in the passenger fleet but could be more viable for commercial and freight applications. This is particularly true for commercial vehicle fleets that are domiciled and operate out of a central location where the appropriate refueling infrastructure can be installed. Retail infrastructure is a significant challenge for natural gas in terms of adoption by the passenger vehicle fleet and long-haul trucking operations. Natural gases for use in transportation are currently taxed by the State of Texas in a retail setting, but at a lower rate relative to gasoline and diesel.

- **Ethanol—**Ethanol is produced from the sugars found in grains such as corn and is commonly blended with gasoline as per federal mandates. All vehicles on the roads consume some ethanol, and this blended gasoline is taxed just like regular gasoline. However, fuel blends can be made that are predominantly ethanol, such as E85, and this fuel can only be consumed by vehicles with the appropriate equipment. These flex-fuel vehicles are able to run on both blended fuels and E85, and they are currently the most common AFV on the road and will continue to be for the foreseeable future. Gasoline blended with ethanol is currently taxed at the rate of $0.20 per gallon, as is E85. However, the ethanol portion of blended diesel fuels is exempt from state diesel taxes. The long-term outlook for ethanol as a transportation fuel is unclear, as there is opposition to the federal mandates that largely support the industry.

- **Propane—**Propane is a by-product of natural gas production and crude oil refining and is most commonly used for cooking, heating homes and water, refrigerating food, powering farm equipment, and other non-transportation uses. However, it can be used as an alternative fuel for vehicle propulsion, and while there are propane vehicles on the market, propane is not used as much as other fuels and has seen declining utilization rates in recent years. The price of propane has been high relative to other alternative fuels, as well as to diesel and gasoline on occasion, but it is still used in some fleet operations where refueling infrastructure can be centralized. Propane used in transportation is taxed by the State of Texas through an annual permitting system. Fees vary based on the weight of the vehicle and the distance traveled over the previous year, which is self-reported by the driver.

- **Hydrogen fuel cells**—Hydrogen fuel cells use a chemical process—with hydrogen as the main fuel—that produces electricity to power an electric motor with water as a by-product. Fuel cells are among the least utilized of alternative fuel applications, as the technology is still being refined and developed, and thus is very expensive. There is little to no retail infrastructure for supplying the required hydrogen, and it is not currently taxed by the State of Texas. The long-term outlook for hydrogen fuel cells shows very low adoption rates, but these could increase if the cost of the technology can be lowered.

Factors Affecting Adoption of Alternative Fuel Vehicles

The two primary barriers facing alternative vehicle adoption are refueling infrastructure and consumer cost.

- A strong **refueling infrastructure** system is needed by all of the fuels discussed above if they are to serve as a viable alternative to traditional fuels in the passenger and commercial vehicle fleet as they increase the effective range of the vehicles. There are several federal, state, and local initiatives aimed at developing the necessary retail refueling infrastructure for EVs and natural-gas-based vehicles. These efforts are expected to significantly increase the number of retail refueling options for these technologies in the near to mid-term.

- The second barrier facing alternative vehicle adoption is the **cost to consumers**, as these types of vehicles can be more costly than their traditional fuel counterparts or can require a significant investment in order to retrofit existing technology to work with alternative fuels. However, there are also numerous federal and state incentives aimed at offsetting these costs through tax rebates or discounts to consumers. Furthermore, incentives are in place to encourage technology developers to improve existing technology and lower costs to consumers. For example, it is believed that simply lowering the cost associated with developing EV batteries could significantly lower the cost of these vehicles to consumers, increasing their attractiveness and speeding up their adoption. Vehicle cost has been identified as the number one factor impacting consumer choice in terms of purchasing alternative fuels, and existing incentives have made an impact in terms of technology adoption and are anticipated to continue doing so as long as the incentives stay in place.

Additional factors driving adoption of AFVs, particularly in the commercial sector, are federal, state, and local regulations on air quality. The transportation sector is viewed as a major contributor of airborne pollutants, and state, federal, and local entities have numerous methods for addressing this issue. The federal government imposes standards on medium- and heavy-duty vehicles (MHDVs) with regard to the fuel efficiency and emissions limits of newer models, and local governments can establish localized emissions targets. AFVs tend to have higher fuel efficiency and emit fewer pollutants, meaning that vehicles running on these fuels can help entities attain their air quality policy goals.

The State of Texas works to incentivize AFV adoption primarily through incentive and grant programs administered by the Texas Commission on Environmental Quality (TCEQ) through the Texas Emissions Reduction Program (TERP). The ostensible purpose of these grants is to help metropolitan and urban areas of Texas improve air quality, but this is accomplished in large part by providing incentives to replace older, more-polluting vehicles with more fuel-efficient, less-polluting ones. Some programs specifically identify alternative fuel applications, such as CNG or electricity, as the technology the program is oriented toward promoting.

Forecast

Alternative fuel vehicles are anticipated to account for about 18 percent of the U.S. domestic passenger fleet and 11 percent of the commercial vehicle fleet by 2040. As Table 1 shows, much of the anticipated growth in alternative passenger vehicle sales will be in the EV market, while growth in alternative commercial vehicle sales will be strongest in the natural gas market. As shown in Figure 1, alternative vehicles in general will make up an ever-increasing share of new vehicle sales in the United States through 2040.

Table 1. Composition of U.S. New Vehicle Sales.

		Traditional Fuels		*Alternative Fuels*			
	Year	**Gasoline**	**Diesel**	**Electricity**	**Natural Gas**	**Ethanol**	**Propane**
Passenger Fleet	2015	83%	2%	3%	> 1%	13%	> 1%
	2040	78%	4%	6%	> 1%	11%	> 1%
Commercial Fleet	2015	13%	86%	0%	> 1%	0%	1%
	2040	11%	78%	> 1%	10%	0%	1%

Source: U.S. Energy Information Administration, Annual Energy Outlook 2014

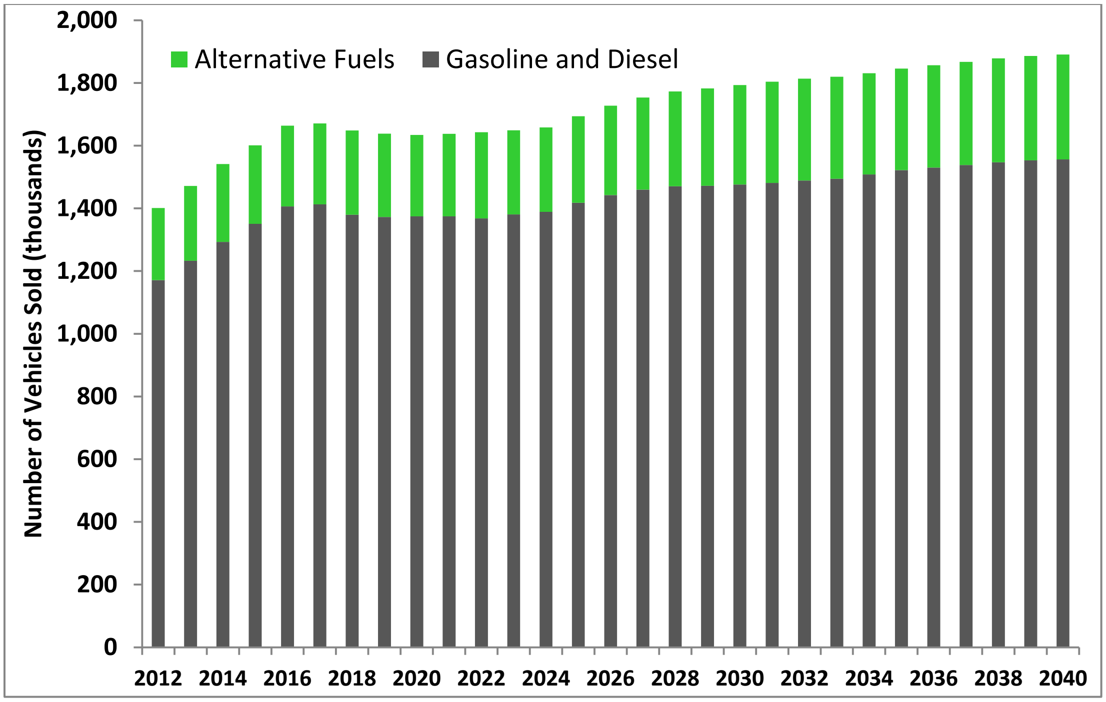


Figure 1. Projected U.S. New Vehicle Sales.

Source: U.S. Energy Information Administration, Annual Energy Outlook 2014

Natural gases are particularly attractive to the commercial fleet because prices for these fuels have been low relative to diesel and gasoline. Since 2012, the price of CNG, for example, has ranged from 38 to 44 percent less expensive than diesel. Furthermore, refueling infrastructure can be centrally located. Commercial operations that operate out of a centralized location and have fairly routine, predictable routes within range of that location (such that on-road refueling is unnecessary) are most likely to benefit from natural gas adoption. In order for interstate operators to switch to natural gases, significant retail refueling infrastructure will be required. TCEQ is responsible for administering the Alternative Fueling Facilities Program, which offsets a percentage of the cost associated with developing alternative fuel refueling stations.

The strongest growth in alternative passenger vehicle growth is likely to come from the EV segment, and specifically vehicles classified as “conventional hybrids.” These vehicles do use gasoline or diesel in order to generate electricity or propel the vehicle, but they are extremely fuel efficient, often averaging in excess of 50 miles per gallon (mpg) fuel efficiency. It is also anticipated that demand for pure-electric vehicles, those that rely on a connection with the electricity grid for power, will increase over time, but sales will still lag behind conventional hybrids.

As noted earlier, one of the reasons behind AFV adoption is that AFVs have a tendency to be more fuel efficient than their traditional fuel counterparts. It is important to keep in mind, however, that for commercial operations, fuel efficiency is highly dependent on driving behavior. Thus, some alternative fuels are optimal for some types of operations, such as fixed-route deliveries from a central location, relative to other types of operations such as interstate trucking.

The information contained in this report and the conclusions drawn from it are based on the best data currently available and are subject to certain assumptions about technology development trends. It is possible that significant unforeseen advances in certain technology applications could be realized in the near future, which might significantly alter the findings of this report. For example, cost to consumers is identified as one of the major barriers to adoption of EVs, and battery costs are among the most significant contributors to overall vehicle costs for BEVs. Reducing battery cost is the objective of several federal funding initiatives, and automobile manufacturers are continually exploring opportunities to lower battery production costs in their manufacturing operations. Projections for BEV adoption are based on current costs and market conditions, so if manufacturers are able to significantly lower battery production costs, then it is likely that the adoption projections in this report will be understated. Additionally, hydrogen-fuel-cell-based technologies are identified in this report as not being a significant presence among the domestic fleet in the long term, primarily because of the cost associated with those applications. However, like electric battery development, fuel cell technology is being studied intently with a focus on providing more cost-effective applications. If significant developments occur in this industry in the near term, fuel cell technology could see increased adoption relative to the projections contained in this report.

Implications for the State’s Fuel Tax Revenues

The generally high fuel efficiency of AFVs means they could potentially be returning less revenue to the state relative to gasoline and diesel vehicles. As such, for this effort, researchers updated the Transportation Revenue Estimator and Needs Determination System (TRENDS), a tool developed by the Texas A&M Transportation Institute (TTI) to assist in the projection of long-term transportation funding and spending.

The research team updated assumptions within the TRENDS Model related to alternative vehicle market penetration, alternative vehicle fuel efficiency, and alternative vehicle travel in order to provide a more refined estimate of long-term transportation revenues. The updated model shows that starting in 2015, the state could begin missing out on almost $24 million per year in fuel tax revenues due to the consumption of non-taxed fuels by motorists. As Figure 2 shows, lost revenue from vehicle owners not paying any fuel taxes could approach $200 million a year by 2035 as the penetration of AFVs into the passenger and commercial fleets increases.

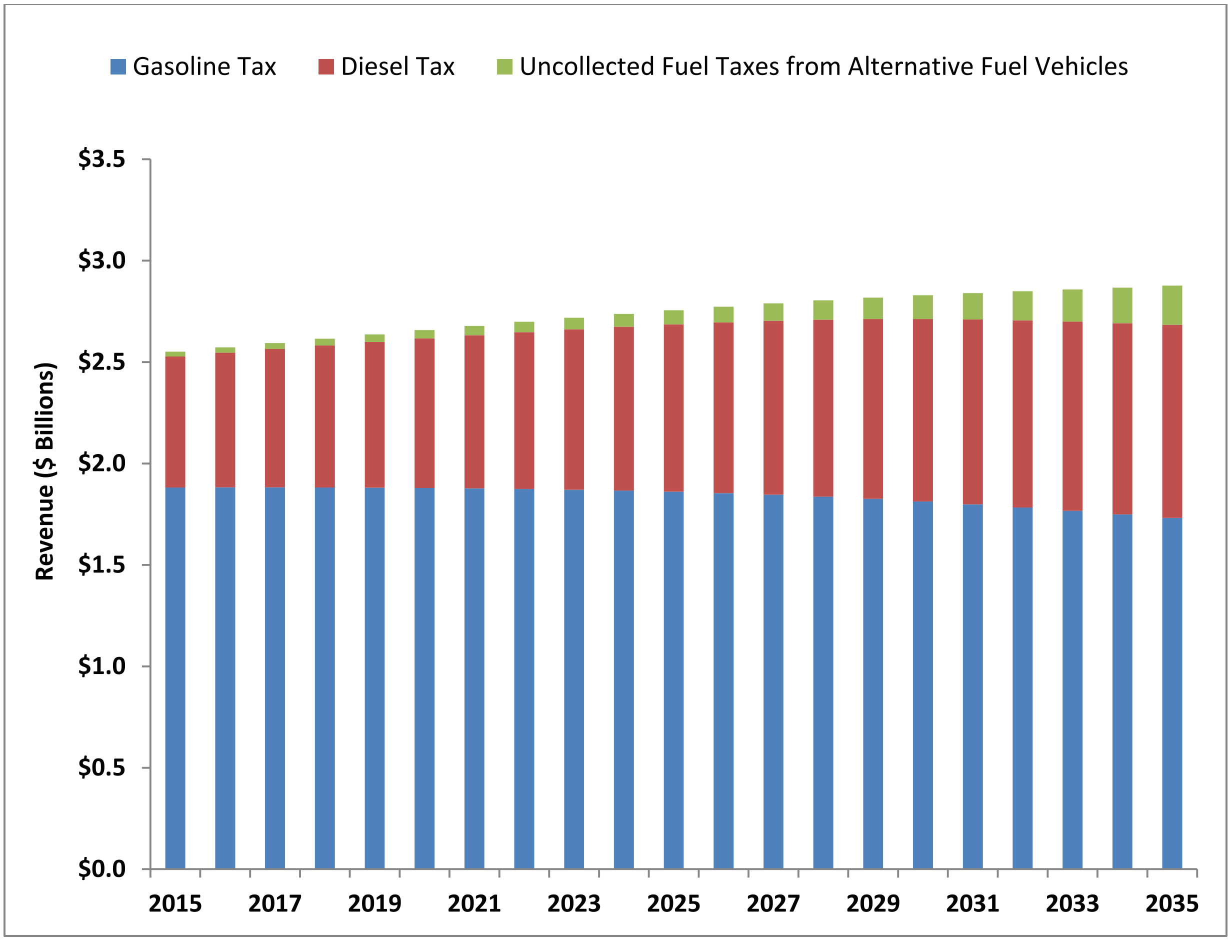


Figure 2. Projected Texas Motor Fuel Tax Revenues and Estimated Uncollected Revenue from AFVs.

Source: TTI, TRENDS

Introduction

In Texas, the largest source of state transportation funding is the state fuel tax. As Table 2 shows, state and federal fuel tax revenues account for about 77 percent of the State Highway Fund.

Table 2. Sources of State Highway Funding ($ Thousands).

Funding Source	2014	*% of Total*	2015	*% of Total*
Federal Receipts Matched (includes Federal Motor Fuels Tax)	$ 4,286,198	*48%*	$ 4,101,012	*48%*
State Motor Fuel Taxes	$ 2,772,742	*31%*	$ 2,441,016	*29%*
Motor Vehicle Registration Fees	$ 1,390,378	*16%*	$ 1,437,268	*17%*
Supplies/Equipment/Services—Federal/Other	$ 160,000	*2%*	$ 160,000	*2%*
Special Vehicle Permit Fees	$ 105,927	*1%*	$ 108,047	*1%*
Other Revenue	$ 96,707	*1%*	$ 99,763	*1%*
Motor Fuel Lubricant Sales Tax	$ 43,275	*0%*	$ 44,034	*1%*
Motor Vehicle Certificate of Title Fees	$ 29,385	*0%*	$ 30,100	*0%*
Other Federal Sources	$ 24,000	*0%*	$ 24,000	*0%*
Interest on State Deposits/Investments, General—Non-Program	$ 10,000	*0%*	$ 10,000	*0%*
Sale of Publications/Advertising	$ 6,570	*0%*	$ 6,750	*0%*
Total State Highway Fund Revenue	**$ 8,925,182**		**$ 8,461,990**	

Source: (1)

State gasoline and diesel taxes are excise taxes and are assessed at a rate of $0.20 per gallon. This means that state gasoline and diesel taxes do not return more revenue to the state if the price of fuel increases as a sales tax might. This also means that the purchasing power of the fuel taxes will decline over time if not regularly raised. Furthermore, because the fuel tax is assessed on a per-gallon basis, drivers with greater fuel efficiency pay less in fuel taxes for every mile their vehicle is driven, as illustrated in Figure 3.

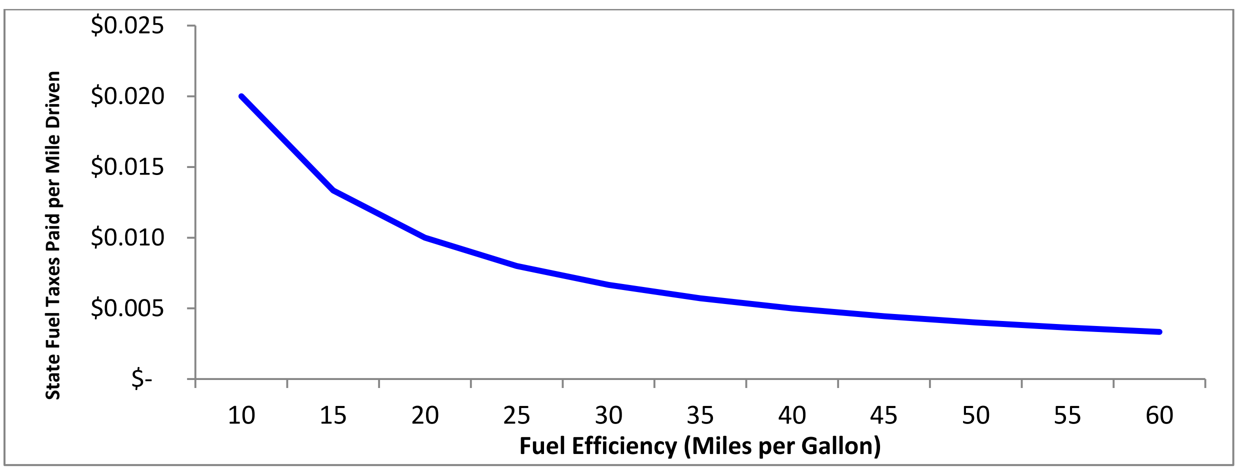


Figure 3. State Fuel Taxes Paid per Mile Driven (Based on Fuel Efficiency).

As such, trends in technologies that affect fuel efficiency, and fuel consumption, could have an impact on the state's largest source of transportation funding: fuel taxes. As vehicles grow more fuel efficient, drivers will pay a decreasing amount in fuel taxes for each mile driven. This is problematic for the state from a financial perspective because various factors have been working to increase average vehicular fuel efficiency over time. For example, federal Corporate Average Fuel Economy (CAFE) standards were implemented in the mid-1970s as a means of reducing energy consumption by increasing the fuel efficiency of the U.S. vehicle fleet. As shown in Figure 4, starting in 2012, the federal government, through the CAFE standards program administered by the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA), began implementing new rules that require the U.S. passenger vehicle automotive fleet to have an average fuel efficiency of 54.5 mpg by 2025.

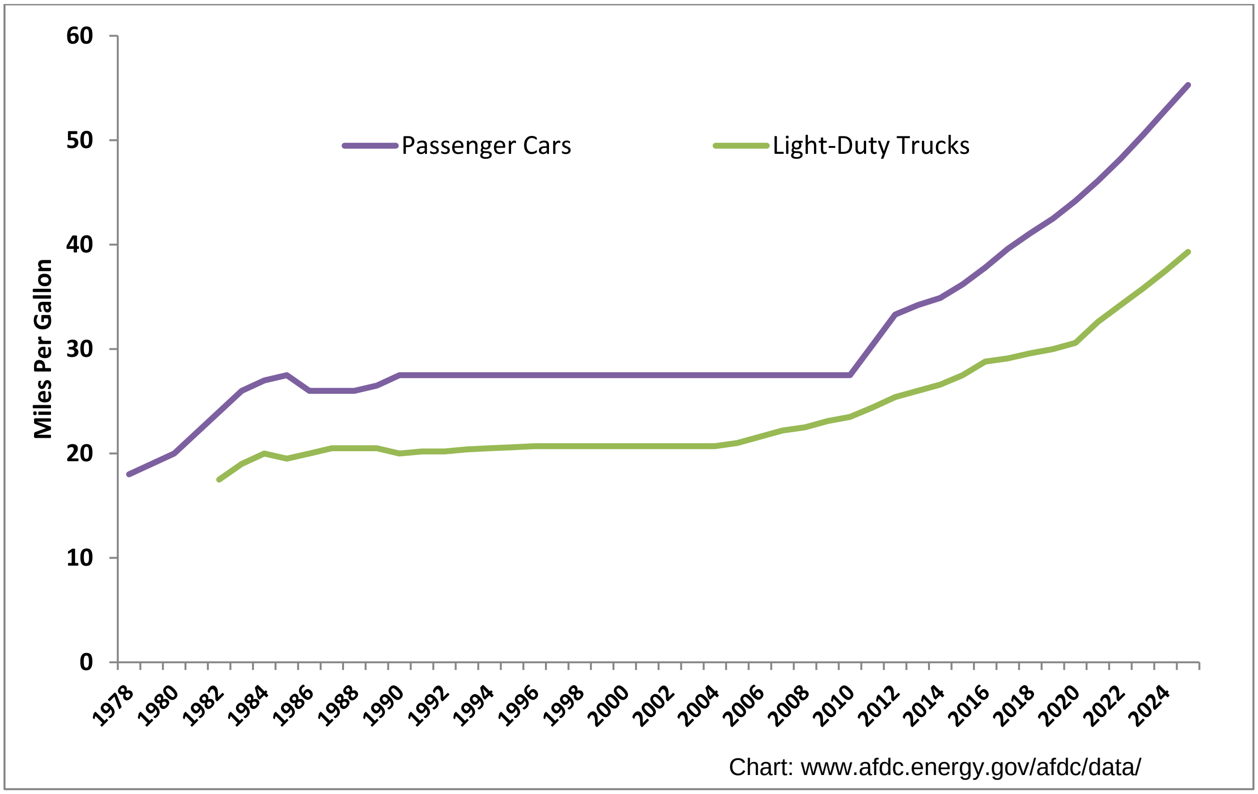


Figure 4. Vehicle Fuel Efficiency (CAFE) Requirements by Year.

Source: (2)

While there are many ways that an automotive manufacturer might go about meeting CAFE requirements for the vehicles it produces, the average vehicular fuel efficiency of the U.S. auto fleet has increased in recent years due, in part at least, to CAFE standards. As shown in Figure 5, the average fuel efficiency of the U.S. auto fleet has seen significant increases since 2004, which had the lowest average fuel efficiency since 1980. With the rule changes implemented by the federal government starting in 2012, it is likely that this increasing trend will continue in the foreseeable future.

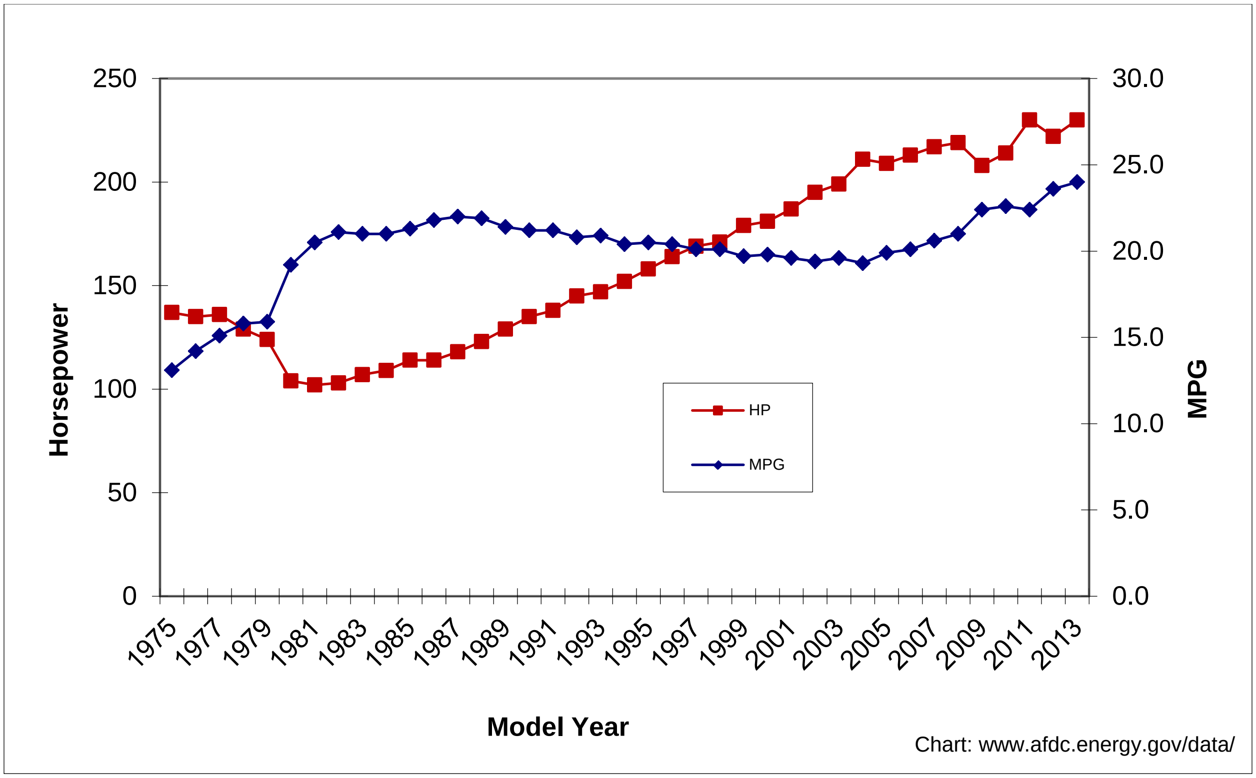


Figure 5. Power and Efficiency of the Average U.S. Light-Duty Fleet.

Source: (*3*)

More fuel-efficient vehicles mean less revenue generated per mile traveled. In fact, revenue projections for the state's two main motor fuel taxes (gasoline and diesel) show that annual revenues will peak sometime around 2030 and then gradually decline (Figure 6). These revenue projections assume that the population of the state of Texas will continue growing in line with the Texas State Demographer's "1.0 Population Scenario," which assumes migration rates into the state will be equal to those experienced between 2000 and 2010. The revenue model estimates fuel consumption based on historic data of gallons of fuel sold versus population.

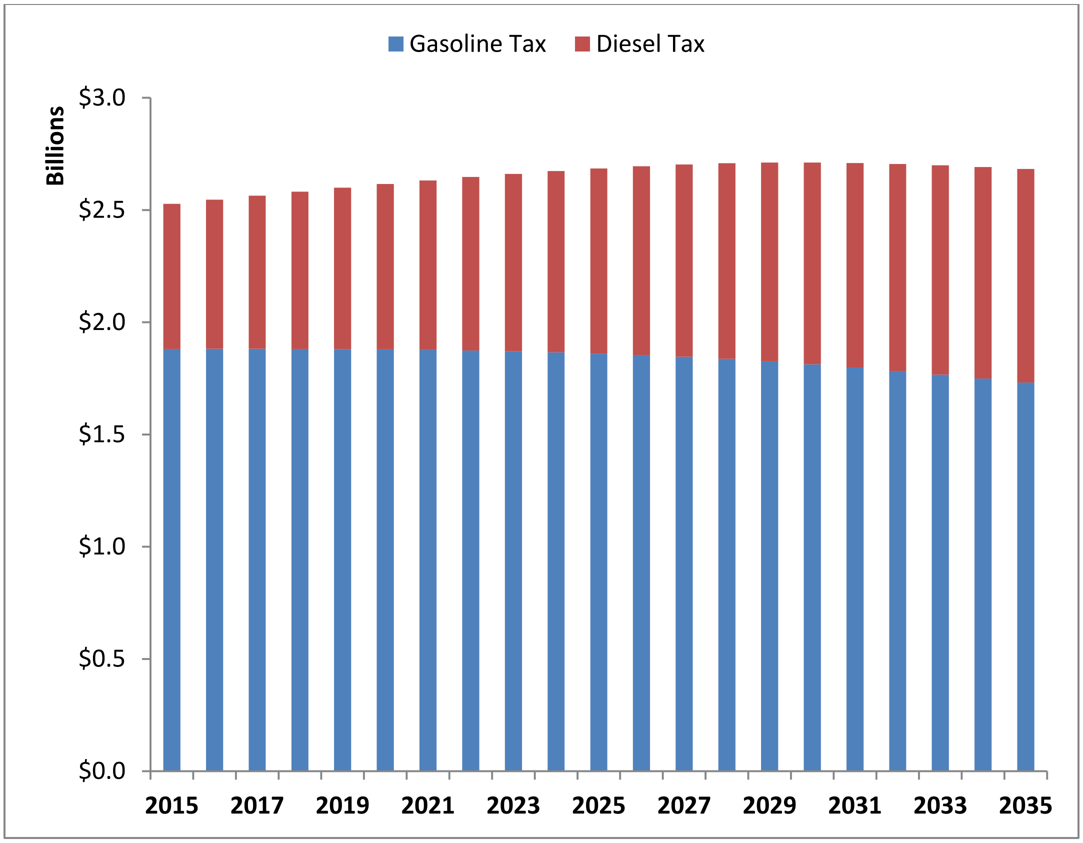


Figure 6. Projected Texas Motor Fuel Tax Revenues.

Source: TTI, TRENDS

Compounding this issue is the growing popularity of vehicles that operate on alternative fuels. Vehicles that operate on ethanol and CNG are growing in popularity, and while these two fuel sources are taxed by the state at per-gallon rates similar to gasoline and diesel taxes, ethanol and CNG vehicles tend to be more fuel efficient than their petroleum-fuel-based counterparts. Furthermore, vehicles that operate on fuels that are not taxed for transportation-related purposes, such as EVs, are being produced and sold at an increasing pace. BEVs, for example, essentially operate for free on Texas roadways after their sales, registration, and inspection fees have been paid. If BEVs and other alternatively fueled vehicles (vehicles not operating on gasoline or diesel) see widespread adoption by the motoring public in Texas, then revenues going to the State Highway Fund could be further reduced in the long term.

It is therefore important for Texas to be aware of trends in the AFV industry and their potential impact on fuel consumption and associated fuel tax revenue generation. Awareness will allow state policies to address any potential funding issues in the foreseeable future. As such, this report discusses trends in the development and adoption of AFVs, market factors driving trends including government incentives, and potential revenue impacts from developments.

Texas Funding Implications

AFVs are anticipated to make up less than 20 percent of the domestic passenger vehicle fleet by 2040 and an even smaller percentage of the commercial vehicle fleet (less than 5 percent). Furthermore, of the alternatively fueled vehicles in use over that time period, most will run on fuels that are currently taxed by the State of Texas at varying rates. The only vehicles that will not operate on taxed fuels are BEVs and, to a certain extent, plug-in electric hybrids. These two alternatively fueled vehicle types are anticipated to account for about 9 percent of all AFVs or about 2 percent of the total passenger vehicle fleet by 2040. The penetration of these technologies into the commercial vehicle fleet will be negligible.

Alternative fuel technologies operating on fuels taxed by the State of Texas tend to provide higher fuel efficiency relative to traditional fuels. In addition to consuming less fuel for travel, these vehicles also return less revenue in fuel taxes for that travel. Table 3 shows the estimated fuel taxes paid for 100 miles of travel for differing passenger vehicle types based on fuel type.

Table 3. Fuel Taxes Paid per 100 Miles by Vehicle Type and Fuel Type for New 2014 Model Vehicles.

Vehicle Type	Gasoline	Turbo Direct Injection Diesel	Plug-in 10 Gasoline Hybrid	Plug-in 40 Gasoline Hybrid	Ethanol Flex	CNG/ LNG	Propane	Gasoline-Electric Hybrid
Compact Car	$ 0.55	$ 0.44	$ 0.33	$ 0.26	$ 0.55	$ 0.38		$ 0.39
Midsize Car	$ 0.55	$ 0.44	$ 0.33	$ 0.28	$ 0.54			$ 0.38
Large Car	$ 0.63	$ 0.51			$ 0.62	$ 0.44	$ 0.45	$ 0.44
Small Pickup	$ 0.80	$ 0.65			$ 0.79			
Large Pickup	$ 0.73	$ 0.59			$ 0.73	$ 0.51	$ 0.53	$ 0.51
Small Utility	$ 0.66	$ 0.54			$ 0.65			$ 0.47
Large Utility	$ 0.78	$ 0.64			$ 0.77			$ 0.55

As shown in Table 3, traditional gasoline vehicles pay the most fuel taxes on a per-mile basis due to lower fuel efficiencies. Electricity-based vehicles, such as plug-in hybrids and gasoline-electric hybrids, pay the least amount of fuel taxes on a per-mile basis, as these vehicles are capable of driving significant distances without the use of a fossil-fuel-consuming engine. Ethanol and flex-fuel vehicles pay about the same amount, as their fuel sources are taxed at the same rate as gasoline and diesel, and these fuel types generally have a similar fuel efficiency rating. CNG, liquefied natural gas (LNG), and propane vehicles pay less in fuel taxes on a per-mile basis than traditional gasoline vehicles, but this is primarily because natural gas vehicles (NGVs) and propane vehicles are assessed at a 25 percent lower rate than gasoline or diesel. CNG and LNG vehicles tend to have only slighter better fuel economy. Pure EVs that do not run on any fuel other than electricity are not shown in this table, as they do not pay any fuel taxes. A more detailed table showing this information and fuel efficiencies for each vehicle and fuel type is provided in the appendix.

Based on the information collected for this report, TTI researchers made adjustments to TRENDS. The TRENDS Model was developed by TTI for the Texas Department of Transportation as a tool to forecast revenues and transportation expenses. Users can control many variables related to assumptions regarding statewide transportation needs, population growth rates, fuel efficiency, inflation rates, taxes, fees, and other elements. The model works by applying assumed fleet compositions and fuel efficiencies for passenger and commercial vehicles to other variables within the model in order to estimate fuel consumption and associated fuel tax revenues. Researchers updated assumptions within TRENDS's algorithms in order to better segment alternative vehicles within the passenger and commercial vehicle stock and apply updated estimated fuel efficiencies. As a result of these changes, TRENDS is able to calculate state and federal fuel tax revenues that would be uncollected relative to earlier revenue estimated as a result of alternative vehicle penetration. Figure 7 shows this uncollected state revenue.

As shown in the figure, anticipated alternative vehicle penetration within the passenger fleet, and to a lesser extent the commercial fleet, could result in over $193 million in uncollected state fuel tax by 2035. While AFVs are anticipated to continue to grow as a percentage of the commercial fleet, the revenue loss from these vehicles is expected to be low relative to alternative fuel passenger vehicles. This is because AFVs are not expected to see as wide of an adoption within the commercial vehicle fleet, and the most popular alternative fuel commercial vehicles will continue to run on taxed fuels, mainly CNG.

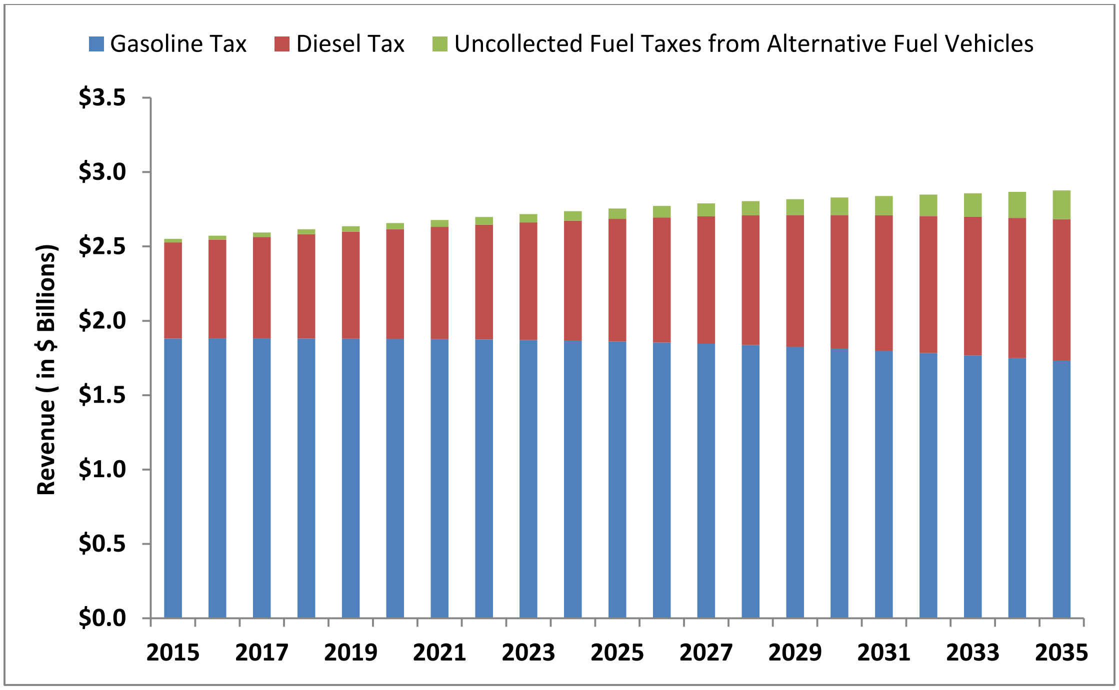


Figure 7. Anticipated Uncollected State Revenue from Alternative Vehicle Adoption.

Source: TTI, TRENDS

Alternative Fuels and Vehicle Technologies

The term "alternative fuels" refers to fuels that are significantly different from what is generally considered to be "traditional" transportation fuels such as gasoline and diesel. There are currently five major types of alternative fuels used or under development for transportation purposes in the United States. These include:

- **Electricity—**Electric vehicles use electricity to drive an electric motor for propulsion rather than fossil fuels and ICEs. Some EVs, such as BEVs, receive all their electricity from an external electric source, such as a wall socket or specialized charging station, in order to charge their batteries and propel the vehicle. Other vehicles, such as plug-in hybrid electric vehicles (PHEVs) and conventional hybrids, can generate their own electricity by burning fossil fuels and driving a generator.

- **Natural gases—**Natural gas is an odorless, colorless, and flammable gas extracted from wells during crude oil production and is often used as an energy source in residential, commercial, and industrial settings. However, it can also be used as a transportation fuel as either CNG or LNG. CNG is natural gas put under high pressure to allow storage at acceptable volumes for vehicular use, while LNG is natural gas cooled to very low temperatures to form a liquid.

- **Ethanol—**Ethanol, or ethyl alcohol, is produced from the sugars found in grains such as corn. Ethanol is commonly blended with gasoline, as all ICE-based vehicles can burn small amounts of ethanol if it is blended with gasoline in low enough volumes, and most gasoline sold in a retail setting has some ethanol in it. However, some vehicles are able to function on fuel blends that contain a high volume of ethanol and traditional gasoline. These flex-fuel vehicles are among the most common AFVs on the roadway.

- **Propane—**Propane is a by-product of natural gas production and crude oil refining and is most commonly used for cooking, heating homes and water, refrigerating food, powering farm equipment, and other miscellaneous uses. It can be used as an alternative fuel for vehicle production, and while there are propane vehicles on the market, propane is not used as much as other fuels and has seen declining utilization rates in recent years.

- **Hydrogen fuel cells—**Hydrogen fuel cells use a chemical process involving hydrogen that produces electricity to power an electric motor with water as a by-product. Fuel cells are among the least used of alternative fuel applications, as the technology is still being refined and developed.

Each of these alternative fuels and their associated vehicle technologies will be discussed later in this section. Information, when available, will be presented for all eight of the Federal Highway Administration's (FHWA's) vehicle weight classification categories. A figure showing FHWA's breakdown of vehicles by weight is provided in the appendix of this report. Passenger vehicles are generally contained within the Class 1 designation, with a few larger pickup trucks being classified as Class 2. Freight, logistics, and other commercial vehicle applications are generally contained within Classes 2 through 8, with Class 8 being the largest of vehicles on the roadway and containing those types most closely associated with over-the-road traffic. Class 8 vehicles include:

- Concrete mixers.
- Dump trucks.
- Semi sleepers.
- Heavy semi tractors.
- Refrigerated vans.

Alternative fuels each have certain advantages and drawbacks that impact their current and projected utilization within the passenger and commercial vehicle fleet. For example, there are numerous federal incentives and mandates with regard to the blending of ethanol into gasoline and the promotion of ethanol technology. As such, ethanol-based vehicles are currently the most numerous AFVs on the roadway. Propane, on the other hand, does not enjoy the benefit of these subsidies and mandates and, coupled with a lack of refueling infrastructure, is among the least used of alternative fuel technologies, and its utilization in transportation is declining.

The presence of mandates and subsidies affects the popularity of alternative fuel technologies, but fuel prices are also a major factor in the penetration of these technologies. As shown in Figure 8, the gasoline gallon equivalent (GGE) prices for electricity and CNG have for the past few years been the lowest and most stable of the alternative fuels discussed in this report. (GGE refers to the amount of alternative fuel required to equal the energy content of one liquid gallon of gasoline and allows for the comparison of fuel costs relative to gasoline.) If these trends continue in the long term, the attractiveness of alternative fuels to consumers and the freight industry is likely to increase, leading to higher adoption rates.

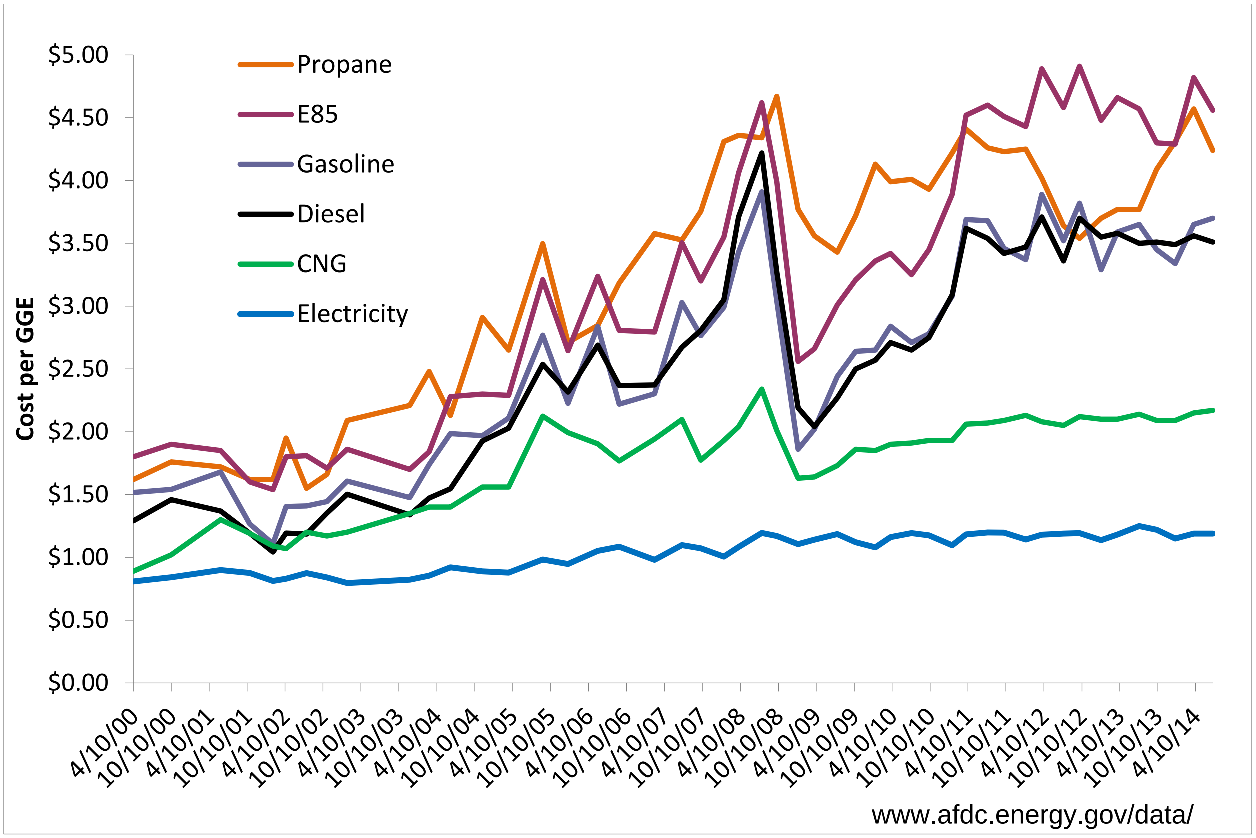


Figure 8. Average U.S. Retail Fuel Prices per GGE.

Source: (*4*)

Figure 9, which shows estimated consumption of alternative fuel by AFVs, further illustrates how changes in fuel price and government incentives may affect alternative fuel consumption. As shown in the figure, propane consumption steadily declined after its peak in 1998, a trend that continued into 2011. Over that time period, ethanol consumption steadily increased, even though it at times exceeded the price of propane. CNG usage saw the most marked increase in fuel consumption; consumption by AFVs increased by over 12 times between 1992 and 2011. Between 2007 and 2011, CNG usage by AFVs grew by over 23 percent.

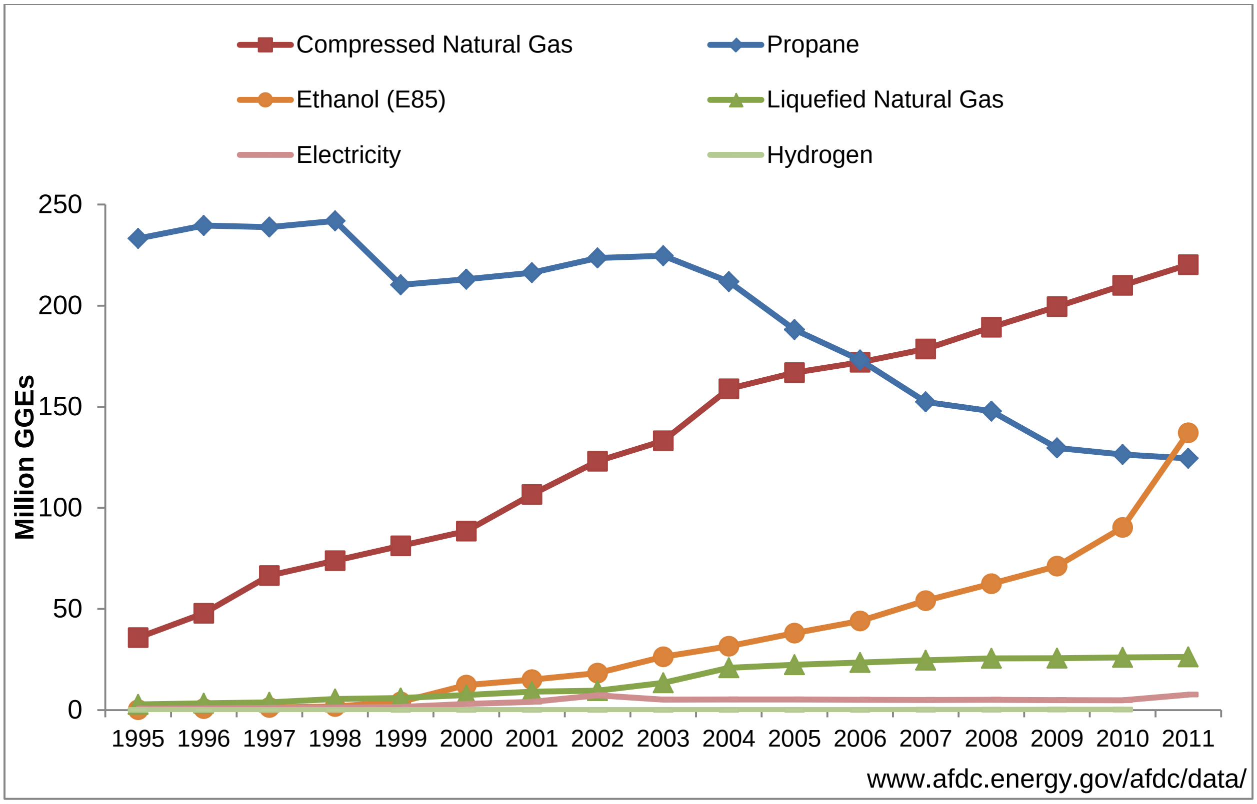


Figure 9. Estimated Consumption of Alternative Fuel by AFVs (in Thousand GGEs).

Source: (5)

Much of the growth in alternative fuel technologies for transportation can also be attributed to air quality concerns by state and local entities and federal mandates for ambient air quality standards. Alternative fuels generally emit fewer pollutants, and encouraging their usage in the transportation sector is seen as a way of lowering mobile emissions. Many states are moving toward the goal of zero, near-zero, or low emissions for transportation. For example, California recently promulgated zero emissions standards for passenger vehicles, light-duty vehicles, and heavy-duty fleets with 200 buses or more. Connecticut, Maine, Maryland, Massachusetts, New Jersey, Rhode Island, and Vermont have followed California's lead and developed the Multi-State Zero Emissions Vehicle Action Plan (*6*). These activities are expected to spur the adoption of alternative fuel technologies in certain segments of the vehicle fleet, most notably medium-duty and heavy-duty commercial vehicles.

Currently, the most popular alternative fuel passenger vehicles in terms of their use on the roadway are ethanol-powered vehicles, accounting for about 72 percent of all AFVs in 2011, the latest year with available data from the Energy Information Administration (EIA). As shown in Figure 10, ethanol vehicle usage increased dramatically in the passenger vehicle market between 1997 and 2011, accounting for most of the growth in AFV usage over that time. Propane vehicle adoption peaked in 2003 and has declined since then. Electric vehicle adoption has increased gradually, while CNG adoption has remained fairly constant.

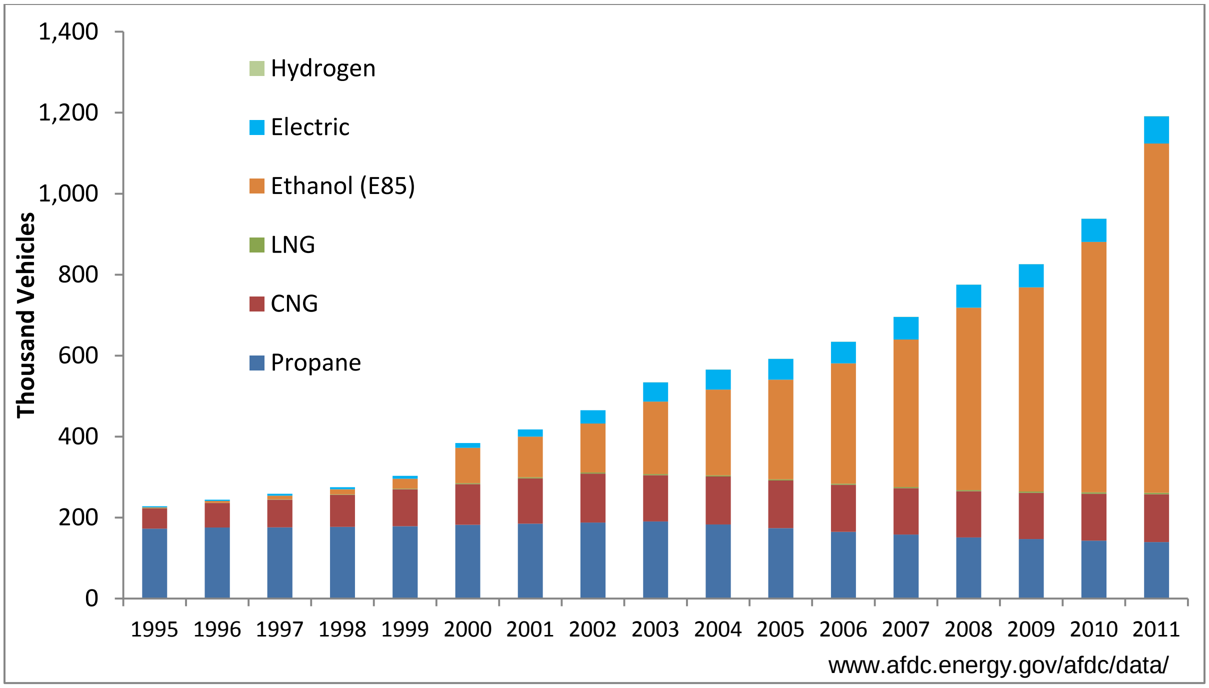


Figure 10. Alternative Fuel Passenger Vehicles in Use.

Source: (7)

It is anticipated that the majority of passenger vehicle sales through the year 2040 will be traditionally fueled ICE vehicles. As shown in Figure 11, traditional fuel vehicles will account for roughly 84 percent of new vehicle sales in 2015 compared to 16 percent of total sales for alternative fuel passenger vehicles. Sales of AFVs are expected to increase relative to traditional fuel vehicles through 2040, although the rate of increase will be small. It is estimated that by 2040, alternative vehicles will account for 18 percent of new vehicle sales compared to 82 percent of vehicle sales for traditional fuel vehicles.

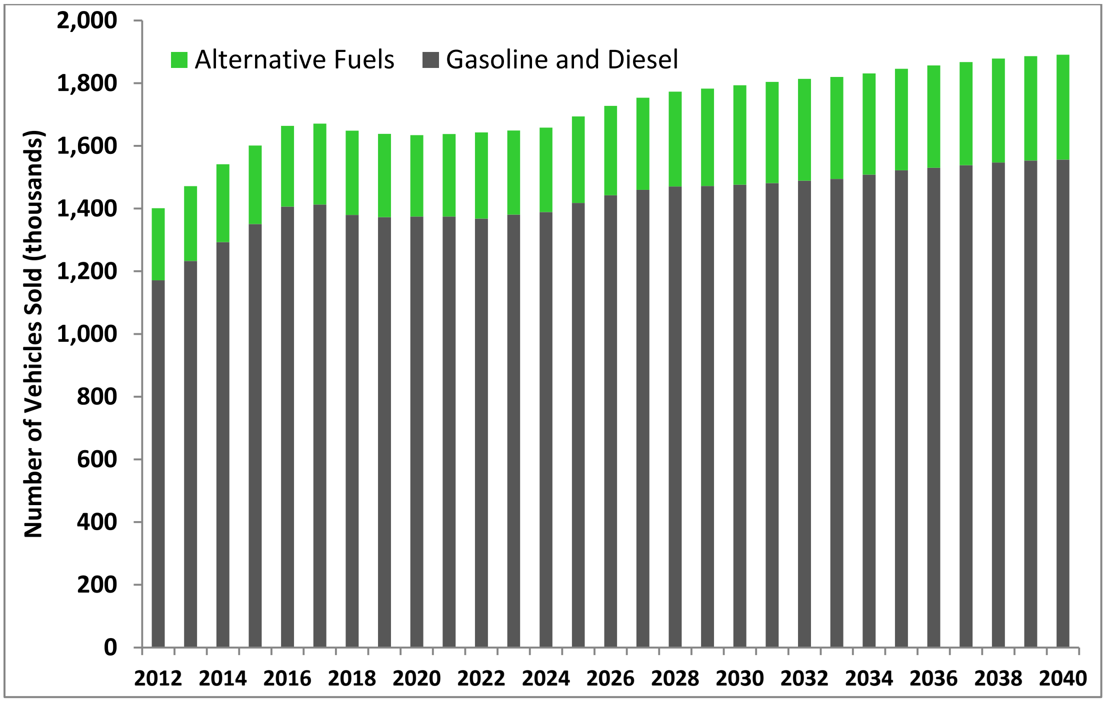


Figure 11. Estimated Passenger Vehicle and Light-Duty Truck Sales (Thousands).

Source: (*8*)

Ethanol-based technologies will continue to comprise the largest share of new alternative fuel passenger vehicle sales, accounting for an estimated 76 percent of new AFV sales in 2015 (Figure 12). However, conventional hybrid electric vehicles (HEVs) are expected to make up an increasing percentage of new sales, and by 2040, HEVs will account for an estimated 26 percent of new alternative fuel passenger vehicle sales. Sales of other EV technologies, such as plug-in BEVs and PHEVs, will also increase over time. Natural-gas-based technology sales will increase gradually but are not expected to be a significant portion of new passenger AFV sales, even by 2040.

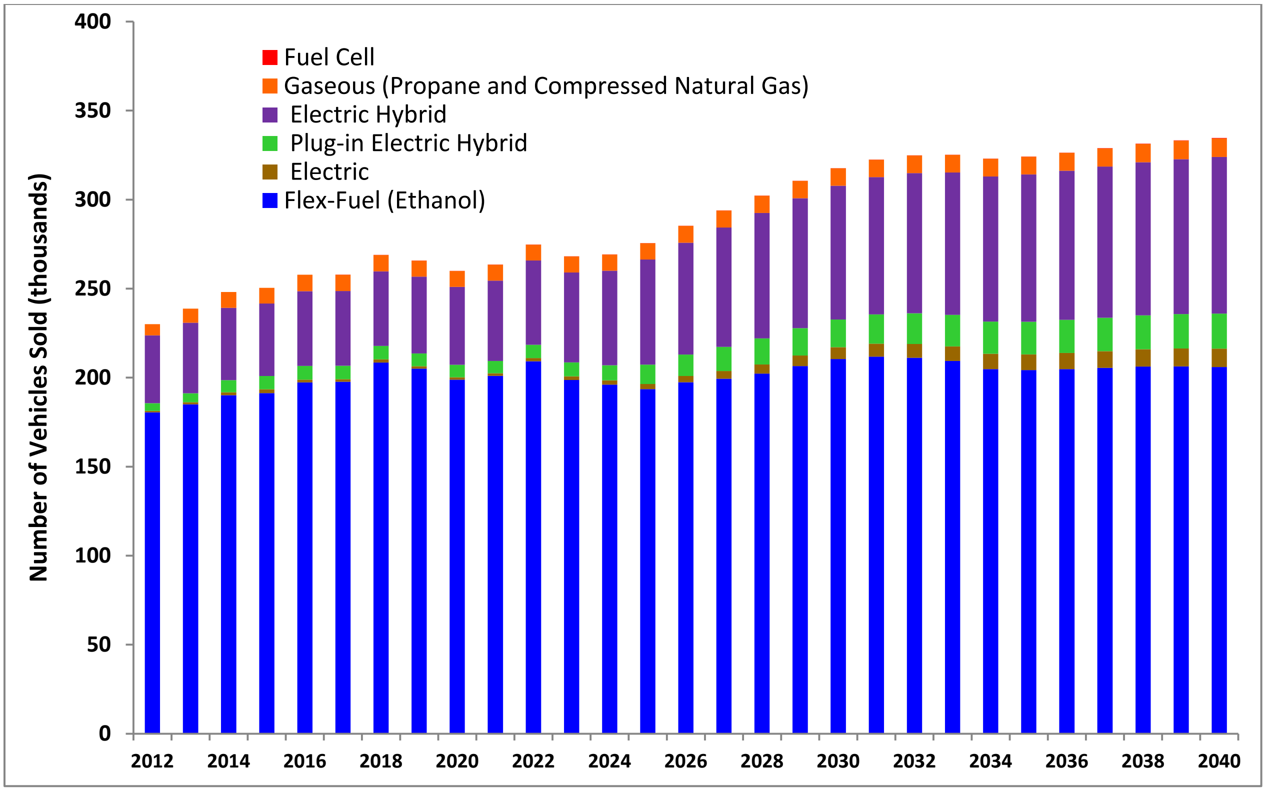


Figure 12. Estimated Annual Alternative Fuel Passenger Vehicle Sales (Thousands), West South Central Region.

Source: (8)

For commercial vehicles, traditional fuel vehicles will remain the dominant fuel in terms of both sales and overall vehicle stock through 2040. As shown in Figure 13, traditional fuel vehicles will compose over 96 percent of the MHDV fleet through 2040, which includes vehicles with an FHWA weight classification of 3 or higher, such as delivery vans, buses, semi tractor-trailer combinations, and dump trucks. However, the number of alternative fuel MHDVs on the roadway will increase relative to traditional fuel vehicles, and in 2040, MHDVs running on alternative fuels will compose 5 percent of the fleet, up from 1 percent in 2015. EVs are not expected to be a significant presence in the MHDV fleet, and most alternative fuel MHDVs will continue to rely on petroleum-based fuels.

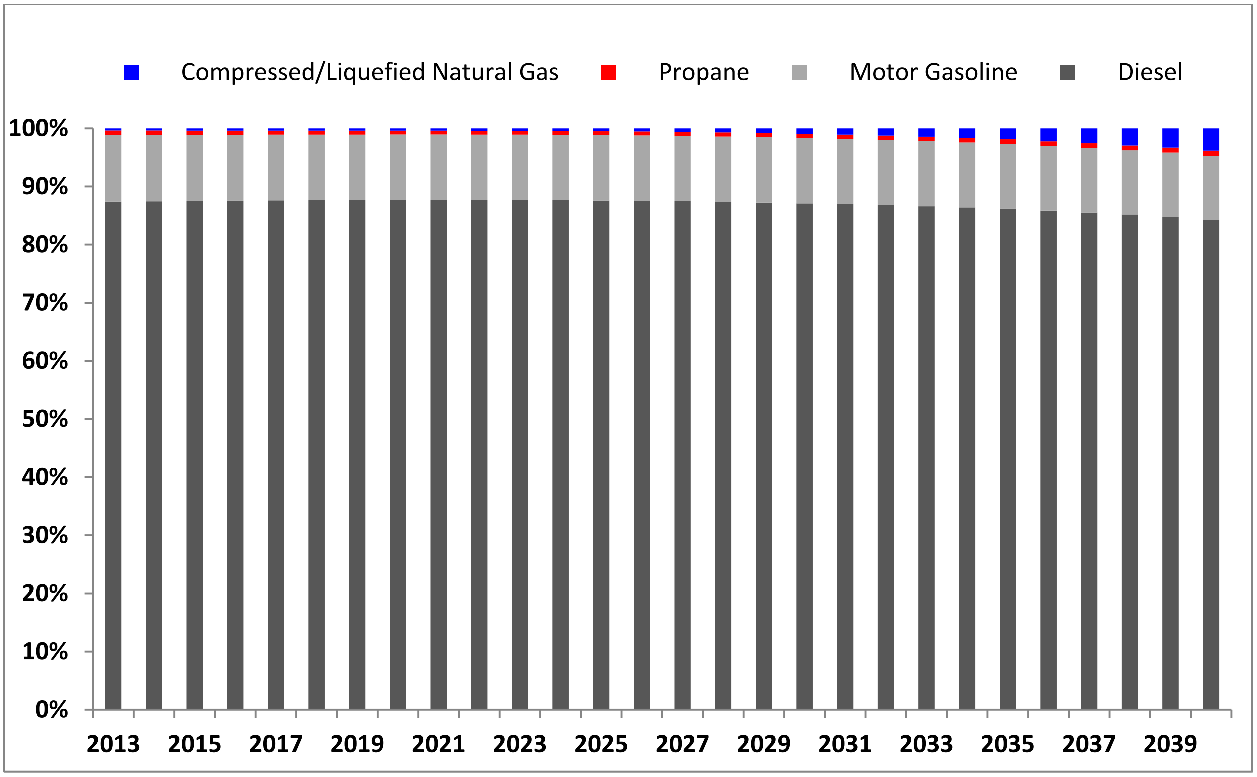


Figure 13. Medium- and Heavy-Duty Vehicle Stock Composition by Fuel Type though 2040.

Source: (8)

As noted above, sales of alternative fuel MHDVs will be dominated by alternative fossil-fuel-based applications, specifically CNG, as opposed to electricity, ethanol, propane, or hydrogen-based alternative fuel technologies. As shown in Figure 14, CNG and LNG vehicles will steadily increase in sales through 2040, accounting for most of the growth in the alternative fuel commercial vehicle market. By 2040, it is estimated the CNG and LNG vehicles will account for 10 percent of all new MHDV sales. Propane vehicle sales will increase over this time as well, but this increase will be much smaller than the increase in CNG and LNG vehicles. By 2040, propane vehicles will still only account for about 1 percent of new MHDV sales.

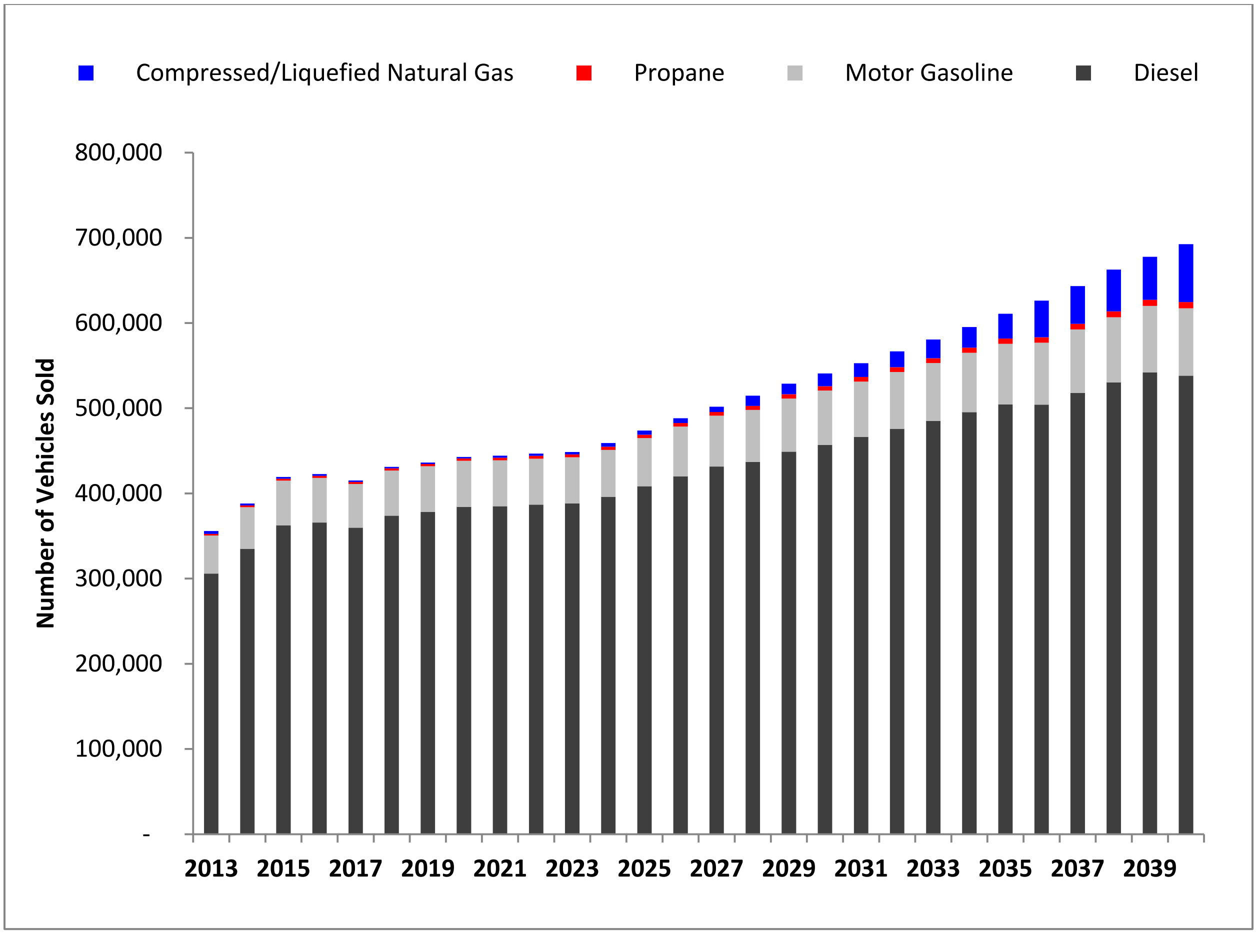


Figure 14. Medium- and Heavy-Duty Vehicle Sales through 2040.

Source: (8)

Electric Vehicles

Electricity is an increasingly popular alternative fuel for transportation and differs from the other fuel sources discussed in this report in that it is not taxed specifically for transportation uses. Electricity as a transportation fuel requires vehicles to be equipped with, at a minimum, an electric motor for propulsion and a battery to store energy. EVs may also use an ICE to either generate electricity for the battery and electrical motor or provide a secondary means of propulsion if the energy stored in the batteries is low. Others applications rely exclusively on electricity provided through a connection with an external electrical source to power the motor and propel the vehicle, or on both a gasoline/diesel engine and connection to an external power source to provide electricity.

EV penetration into the commercial and passenger vehicle fleet will largely be limited by the cost of these vehicles. High-capacity batteries remain the most expensive single EV component, and a battery that can drive a vehicle within equal range of a conventional vehicle is prohibitively expensive. Battery costs have decreased significantly in recent years, in part due to large investments in research and development in battery technology. The U.S. Department of Energy (DOE) reports that battery cost estimates have halved between 2010 and 2014 based on laboratory research (*9*). The International Energy Agency (IEA) estimates that the cost of EV batteries will decline, making EVs similar in cost to traditional ICE vehicles by 2020.

Charging infrastructure is also an element affecting EV adoption. Many models rely exclusively on an external electricity source to charge their batteries and propel the vehicle. There are currently home charging stations available for passenger vehicles, and commercial fleets have options for charging at depots and truck yards. About half of the U.S. housing stock could support EV charging equipment (*10*). However, the biggest challenge may be providing retail charging options. Abundant retail charging stations could significantly increase EV adoption, as it would effectively increase EVs' potential driving range from a home location. According to the U.S. DOE Alternative Fuels Data Center (AFDC), as of June 30, 2014, there are over 9,000 electric charging stations with over 23,000 charging units in the United States, and about 85 percent of these stations are public. According to AFDC, Texas has 1,841 electric charging stations, with 369 of those being private and 1,472 being public. Texas ranks second in terms of total number of EV charging stations behind California, which has 6,981 charging stations. Washington State has the third most stations, with 1,482 stations.

Passenger EVs

Electricity-based passenger vehicles are propelled by a system comprised of two parts: an electric traction motor (which provides power to the wheels) and a controller (which controls the application of power). In contrast, ICE vehicles require various components including the engine, carburetor, pumps, starter, and exhaust system. In an EV, the motor converts electrical energy to mechanical power. Most controllers have a system for regenerative braking that converts kinetic energy, which is usually lost as heat during braking, back into electricity to recharge the battery. This increases the range of an EV up to 5 percent and reduces brake wear and maintenance costs (*11*).

There are three general types of electricity-based passenger vehicles including:

- **Plug-in BEVs—**BEVs operate solely on an electric motor and a battery that can be recharged from an external electricity source. Unlike other EV models, BEVs contain no ICE or secondary fuel source. The battery's stored energy provides all motive and auxiliary power on the vehicle. The batteries are recharged by connecting to the electricity grid and from energy harnessed during braking. The most notable examples of BEVs currently on the road are the Nissan Leaf and Tesla S. Most BEVs can travel from 100 to 200 miles on a single charge, less than the range offered by a single tank of gas in a conventional ICE vehicle. A battery with the storage capacity needed to achieve the driving range of today's traditional ICE vehicles (at least 300 miles) is currently cost prohibitive to produce and purchase. As such, recent BEV models offer shorter driving ranges at lower battery capacities (*12*).

- **Plug-in hybrid electric vehicles—**PHEVs incorporate both an electric motor and an internal combustion engine. A PHEV's primary means of propulsion is the battery-powered electric motor, with a traditional fuel-based ICE serving as a secondary means of propulsion and/or source of electricity for battery charging. Generally, PHEVs have larger battery packs than conventional hybrids (discussed next), allowing these vehicles to drive longer distances using only electricity. The all-electric range of current PHEVs ranges from 10 to 40 miles. The engine is also generally smaller than a conventional hybrid. This can result in savings in some areas such as maintenance, but high battery costs can outweigh these savings relative to a conventional hybrid. The most notable example of a PHEV on the market today is the Chevrolet Volt.
- **Hybrid electric vehicles (or conventional hybrids)—**HEVs contain both an ICE and an electric motor that is connected to a battery. The ICE is generally used to generate electricity for the battery but may also be used to propel the vehicle. HEVs were the first commercially available EV in the modern era to use an electric motor for propulsion. The Toyota Prius is the most notable example of this technology configuration. Power supplied by the electric motor allows these vehicles to operate with a smaller engine than traditional fuel vehicles and provides supplemental power to auxiliary components such as interior sound equipment and headlights. The only external energy source for HEVs is from conventional fuel supplied to the ICE, with the battery being recharged by the engine and/or regenerative braking.

All three vehicle types tend to be extremely fuel efficient, particularly BEVs and PHEVs. Several BEV models achieve over 100 miles per gallon equivalent (MPGe), such as the Chevrolet Spark (119 MPGe), Honda Fit EV (118 MPGe), and Ford Focus Electric (105 MPGe). The Toyota Prius, a conventional HEV, is the highest-ranked model in terms of fuel efficiency when BEVs and PHEVs are excluded, with a combined 50 MPGe.

Today, BEVs and PHEVs are experiencing record-breaking sales numbers and strong support from government projects and incentives. As of early 2011, the market penetration for EVs worldwide was approaching 2 percent, with over 2.5 million vehicles sold worldwide. The United States is one of the largest markets for EVs, with over 190,000 plug-in electric vehicles sold as of March 2014 (*13*). However, despite increasing market share, EVs remain a small percentage of the U.S. vehicle market. The future success of plug-in electric vehicles (including both hybrid and battery types) will depend on cost reductions, infrastructure development, and consumer demand.

HEVs remain the highest-selling EV on the U.S. market, primarily because the technology is fairly mature, there is no need for the placement of new fueling infrastructure, and various government incentives have been in place for years to facilitate their adoption. Figure 15 shows sales of HEVs by major manufacturers since the introduction of the vehicle in 1999 (*14*). By comparison, PHEV sales have been significantly lower than HEV sales in recent history. As

Figure 16 shows, PHEV sales by the top five manufacturers of these models are significantly lower than sales of their HEV counterparts.

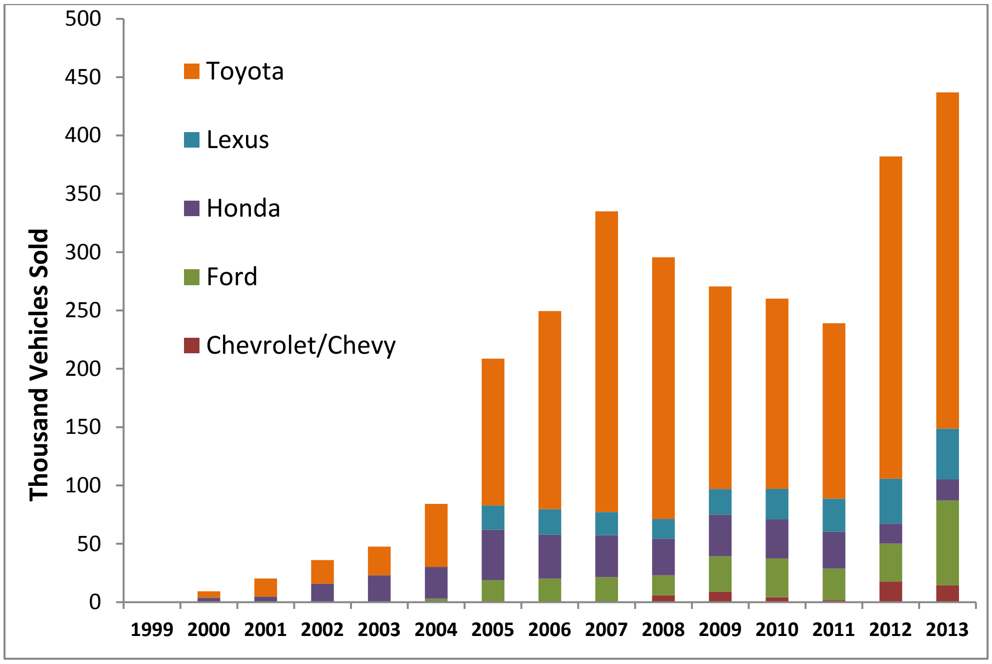


Figure 15. Hybrid Electric Vehicle Sales (1999–2013) for the Top 5 HEV Manufacturers.

Source: (14)

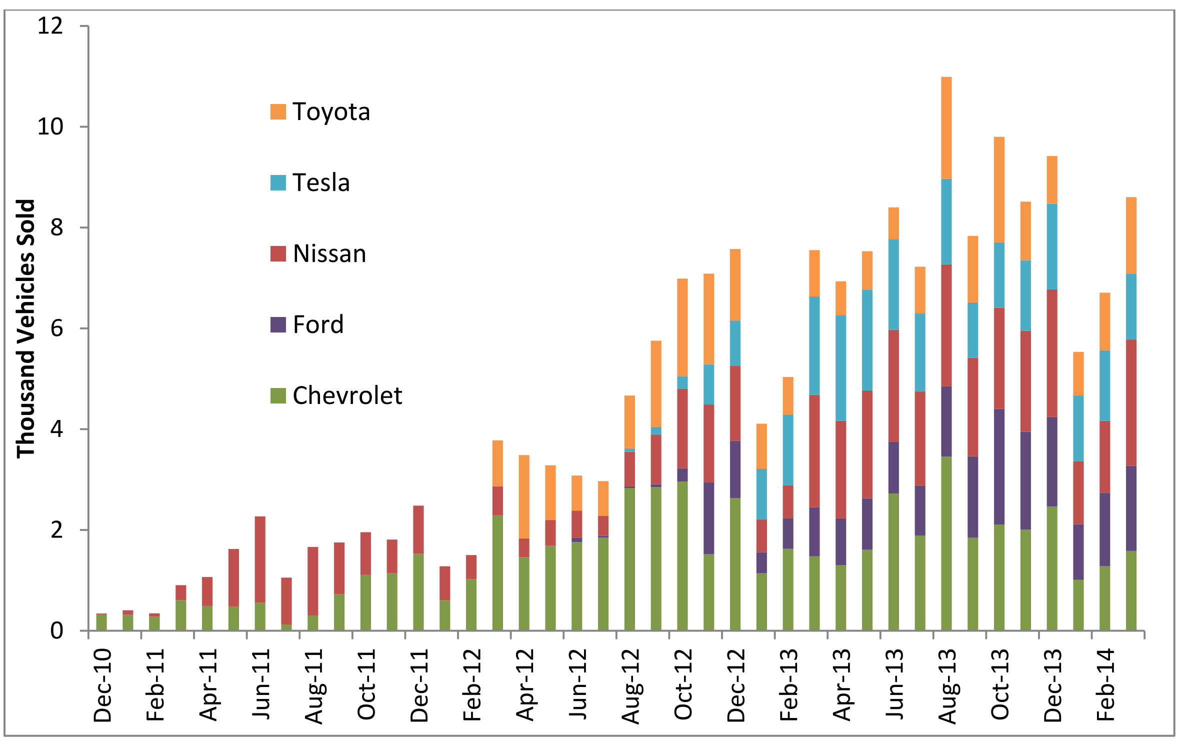


Figure 16. PHEV Monthly Sales (2010–2014) for Top 5 PHEV Manufacturers.

Source: (13)

There is currently a low volume of PHEVs, but it is anticipated that growth in demand for these models will pick up in the near future and could exceed the levels of demand seen for conventional hybrids upon their commercial release. In the first three years after being introduced to the market, sales of PHEVs and BEVs outpaced the sales of conventional HEVs over the first three years of that technology's introduction. In August 2003, 45 months after the introduction of the first HEV, over 95,000 of the vehicle had been sold. In contrast, by August 2014, 45 months after the introduction of the first mass-marketed PEV, cumulative sales of PEVs exceeded 247,000 (*15*). As such, despite the current slow penetration of these vehicles in the U.S. fleet, it is expected that they will grow considerably in the coming years.

Commercial EVs

As with passenger vehicles, commercial EV applications use an electric motor for propulsion and a battery to store energy. Commercial EV applications can similarly be classified into three broad categories: hydraulic HEVs, BEVs, and PHEVs.

- **Hydraulic HEVs—**These systems function similar to passenger HEV systems because an ICE provides electricity for the electric motor. These applications feature highly efficient regenerative braking systems that charge the electric battery during braking and have capabilities that conserve fuel by switching power to the electric components while the engine is idling. Energy captured during the braking process operates a hydraulic pump that drives a motor to provide extra torque during acceleration. HEVs in a commercial setting can generate fuel cost savings, as they are generally more fuel efficient than their ICE counterparts. HEVs also operate quieter and smoother and emit fewer tailpipe emissions. The relatively smaller engine can also reduce maintenance costs without severely degrading performance. HEV freight applications may be well suited for urban fixed-route, return-to-base delivery applications, and situations where stop-and-go traffic is common.

- **Plug-In BEVs—**These systems perform much in the same manner as passenger BEVs. BEVs are powered by electricity stored in rechargeable battery packs and generally have an average range of 80 to 100 miles per charge. Commercial BEVs may be well suited for urban fixed-route, return-to-base delivery fleets, and drayage applications. This is due to the fact that these freight applications generally require relatively short travel distances, which means that it is easier to return to charging stations when required. BEV freight transport is more efficient and cleaner than HEV applications but has a greater initial investment cost and a shorter range. Even when loaded to capacity, BEVs are able to accelerate faster than diesel vehicles due to the high torque capabilities of their electric motors. This, combined with no need to change gears during acceleration, ensures that operation in the urban environment is comparable to, and at times even better than, diesel equivalents (*16*).

- **Plug-In Hybrid Electric Vehicles**—These vehicles are also similar in function to their passenger and light-duty PHEV counterparts in that these PHEVs also use both an electric motor and an ICE. The electric motor uses energy stored in a battery, which is charged through a connection with an external electrical supply. However, unlike the typical passenger and light-duty PHEVs, commercial and freight-related PHEVs may also use the ICE for propulsion and the electric motors to power truck components such as refrigeration units, auxiliary power units, or other vehicle accessories. Because this type of vehicle might otherwise use the ICE while idling to power equipment, PHEV applications can offer significant fuel savings. The all-electric range of the PHEV medium- and heavy-duty trucks is about 10 to 50 miles depending on vehicle type, weight, and driving patterns.

Studies have shown that parallel hybrid-electric diesel vehicles can have an average fuel economy 28.9 percent greater than their diesel counterparts. Parallel hybrid-electric diesel vehicles can also have about 8 percent lower maintenance costs but are slightly less reliable. One study found that over a 12-month period, parallel hybrid-electric diesel vehicles had an uptime of 95.5 percent compared to the diesel average of 99.3 percent (*17*). BEVs can have up to four times better fuel efficiency than that of similar diesel vehicles, and BEVs are also less costly to operate, with yearly fuel costs up to 80 percent lower than diesel fuel costs (*18*).

EV adoption in the commercial vehicle sector is most viable within drayage and fixed-route applications as opposed to long-haul or variable-route operations. Specific vehicle types such as box trucks, delivery trucks, and bucket trucks appear to be the most viable vehicle segments for EV adoption in commercial vehicles. This is due in large part to the fact that the predictability of these operations facilitates easier recharging schedules. Larger, long-distance vehicles, such as those used for long-haul operations applications, are less likely to adopt EV technology because of the range requirements needed.

The majority of U.S. MHDV manufacturers have some type of HEV and/or BEV in production or near production. Although the volume produced remains low, the United States leads in the development and production of these vehicles, which range from Class 3 parcel vans through Class 8 tractors. EV commercial vehicles now in production include Navistar, Freightliner, Kenworth, Peterbilt, and Smith. There are also numerous options for converting traditional fuel commercial trucks to run on electricity. Several truck manufacturers offer hybrid systems that can be added to existing original equipment manufacturer (OEM) vehicles to produce a hybrid vehicle. These include EEtrex, Odyne Corporation, Enginer, and Boulder Hybrid Conversion (*19*).

National and international companies such a FedEx, UPS, Frito-Lay, PepsiCo, Coca-Cola, and Staples have purchased BEVs, PHEVs, and/or HEVs for use in their fleet delivery systems, as have numerous other local or regional companies. Medium-duty freight transport vehicles have potential for fuel efficiency gains as high as 40 percent because of the urban delivery, stop-and-go driving pattern that uses the HEV's regenerative braking system. The limiting factor is that incremental cost of vehicle replacement can range from $12,000 to $40,000, depending on truck class, type of hybrid system, and battery capacity. As battery cost decreases and capacity increases, the payback time frame for hybrid trucks will become more attractive, offering a more compelling business case to switch. Various state and federal rebates, grants, subsidies, and incentives make this payback time frame more achievable.

The medium-duty vehicle is the largest segment of the freight transport industry and is a growing market for EVs. Of the 900 hybrid medium-duty trucks sold in 2013, approximately 83 percent were HEVs; however, the market is expected to shift by 2020, with PHEVs taking 59 percent of the market and HEVs having 41 percent (*20*). The heavy-duty truck market, which includes long-haul tractor-trailer configurations, is still behind. In order for hybrid technology to achieve significant growth in that sector, the technology needs to see wider acceptance by long-haul trucking companies and their fleets. This may be brought about through a reduction of hybrid life-cycle costs. Upfront retail costs are expected to decline 42 percent by 2016, with most of the cost reduction in batteries (*21*).

Compressed Natural Gas and Liquefied Natural Gas

Natural gas is an odorless, colorless, and flammable gas extracted from wells during crude oil production. Natural gas is often used as an energy source in residential, commercial, and industrial settings but can be used as a transportation fuel. In vehicles, natural gas can be used as CNG or as LNG. CNG is natural gas put under high pressure to increase its energy density and to allow storage at acceptable volumes for vehicular use. LNG is natural gas cooled to very low temperatures to form a liquid that has a much higher energy density than compressed gas. Research suggests that LNG is impractical at this time for passenger cars due to its storage requirements; however, it is used in MHDVs in freight transport but at lower rates than CNG.

Natural gas resources in the United States continue to grow, and the development of low-cost and abundant unconventional natural gas resources, particularly shale gas, has had a material impact on future availability and price (*22*). Abundant resources could have potentially significant impacts on the adoption of CNG vehicles in the passenger vehicle fleet and CNG and LNG in the passenger and commercial vehicle fleets, as these new resources have lowered and stabilized the price of CNG and LNG relative to other fuels. Over time, natural gas prices have generally tracked oil prices, but shale exploration has disconnected the prices of the two commodities. Since 2008, oil prices, and the price of all other commodities, have rebounded more or less to their pre-2009 level, whereas natural gas prices have declined. The price of natural gas dropped by about 80 percent between 2008 and 2013. At 2013 oil and natural gas prices, oil is five times more expensive than natural gas on an energy equivalent basis (*23*).

Despite the low cost of natural gas fuel, a lack of refueling infrastructure presents a near-term challenge for adoption within the passenger and commercial vehicle sectors. For CNG applications, utilities deliver natural gas through the pipeline system. The gas is then compressed and stored onsite or distributed directly to vehicles. There are generally two types of CNG refueling stations: (1) fast-fill, where vehicles are refueled rapidly at a rate similar to petroleum fuel, and use larger compression equipment and high-pressure gas-storage systems; and (2) time-fill, where vehicles park overnight and are slowly refilled, taking advantage of off-peak electricity rates and smaller compression equipment (*24*). The type of fueling station needed depends on the operational requirements. Typically, retail stations and operations such as public transit use the fast-fill method, and fleets that have central refueling capabilities, such as school buses, and the operational ability to fill overnight use the time-fill method (*25*). AFDC reports that in December 2013, there were more than 500 publicly accessible CNG fueling stations nationally (*26*). According to the DOE AFDC, there are 46 CNG fueling stations in Texas. A listing of these stations and their locations can be found in the appendix of this report. Station owner-operators include private companies such as Clean Energy, CNG Texas, Trillium CNG, Peake Fuel Solutions, Independence Fuel Systems, Clean and Green—Waste Management, Apache, Love's Travel Stop, CNG 4 America, and Questar. Other owner-operators include municipal gas departments.

CNG refueling for passenger vehicles may take place at home. Approximately 52 percent of households used natural gas as their primary heating fuel in 2005, meaning that over half of U.S. households have the ability to purchase a compressor and use their home natural gas supply for a CNG-fueled car (*27*), and there are home CNG refueling appliances currently on the market. For example, the Phill connects to home gas and electricity supplies and can be mounted either in garages or on outside walls. The retail price of the unit is between $3,000–4,000, with an installation fee of $1,000–$2,000 (*28*). However, there can be issues with home refueling. Natural gas supplies often have moisture and other containments, and home refueling systems may not be able to dry the gas and remove contaminants sufficiently. If a passenger vehicle needs repair and is found to have contamination in the fuel system or damage to the fuel system as a result of using substandard natural gas, the warranty claim may be denied. As such, Honda, one of the only manufacturers of passenger CNG vehicles, does not recommend home refueling for its CNG passenger vehicle (*29*).

LNG differs greatly from CNG in terms of storage, handling, and safety. LNG is produced and stored at approximately −260°F under normal atmospheric pressure. Because of the extremely cold temperature, protective gear must be used when handling LNG components. When released from containment, the LNG will vaporize and expand to approximately 600 times the volume of its liquid state. Unlike CNG, LNG may not contain an added odorant, making leaks difficult to detect (*30*). Due to the difficulty in storing LNG and refueling LNG equipment, refueling infrastructure for this technology is even more limited.

Passenger CNG Vehicles

CNG passenger vehicles can operate either with engines designed specifically for natural gas or by modifying/converting an engine designed to run on gasoline or diesel. The natural gas is compressed and stored onboard CNG vehicles in high-pressure fuel cylinders at 3,000 to 3,600 psi. Retailers sell CNG in units of diesel gallon equivalents or GGEs based on the energy content of a gallon of gasoline or diesel fuel (*31*). Light-duty NGVs work much like gasoline-powered vehicles, with spark-ignited engines.

There are two primary types of CNG fuel systems on the market for passenger vehicles in the United States:

- **Dedicated Vehicles—**These are vehicles where gasoline-fueling hardware is removed and the engine operates exclusively on natural gas. The only non-conversion, dedicated CNG passenger vehicle currently available in the United States is the Honda Civic GX. There are dedicated vans available from General Motors and Chevrolet. A secondary manufacturer can convert vehicles with gasoline engines to run on natural gas, and dedicated vehicles are becoming increasingly prominent in the aftermarket conversion industry.

- **Bi-Fuel Vehicles—**These vehicles can switch between natural gas and gasoline as a fuel. A bi-fuel engine offers the advantage of allowing the use of gasoline when natural gas is not available for refueling. Due to the high octane rating of natural gas, an engine constructed to run exclusively on natural gas can have a higher compression ratio, which improves the engine efficiency to that of a similar gasoline engine. As such, a converted gasoline engine will have lower power and efficiency when operating on natural gas than when fueled by gasoline.

The primary economic incentive for consumer adoption of natural-gas-fueled vehicles is the potential savings in fuel cost relative to gasoline-fueled vehicles. On average, the cost of CNG at a retail filling station is about one-third less than gasoline (note: the retail price includes the commodity, distribution, electricity, and compression costs). However, the savings can vary from 24 percent to 53 percent depending on the region of the country (*27*).

The current market for light-duty passenger vehicles powered with natural gas is limited mostly to fleet vehicles for government agencies and private companies. The lack of a small passenger vehicle market is due to a lack of refueling infrastructure. CNG vehicles for fleet use are an attractive option because fleet vehicles typically return to a central station where the vehicle can be refueled after use. Fleet vehicles also typically have higher vehicle miles traveled than residential vehicles, so fleet managers can realize larger fuel cost savings by switching to natural gas (*22*).

Another factor contributing to slow adoption rate of small passenger CNG vehicles is return on investment. At 2010 oil–natural gas price differentials, the high incremental costs of CNG passenger vehicles lead to long payback times for the average driver, meaning that significant penetration of CNG technologies into the passenger fleet is unlikely in the short term (*22*). The incremental cost refers to the additional costs borne by the consumer by purchasing a CNG vehicle instead of purchasing a similar conventionally fueled vehicle.

Figure 17 shows the EIA inventory of CNG vehicles and fuel consumption in Texas from 2003 through 2011. In 2011, there were 8,343 light-duty CNG vehicles in Texas, a slight decline from the peak, which occurred in 2006 with 8,635 vehicles (*32*).

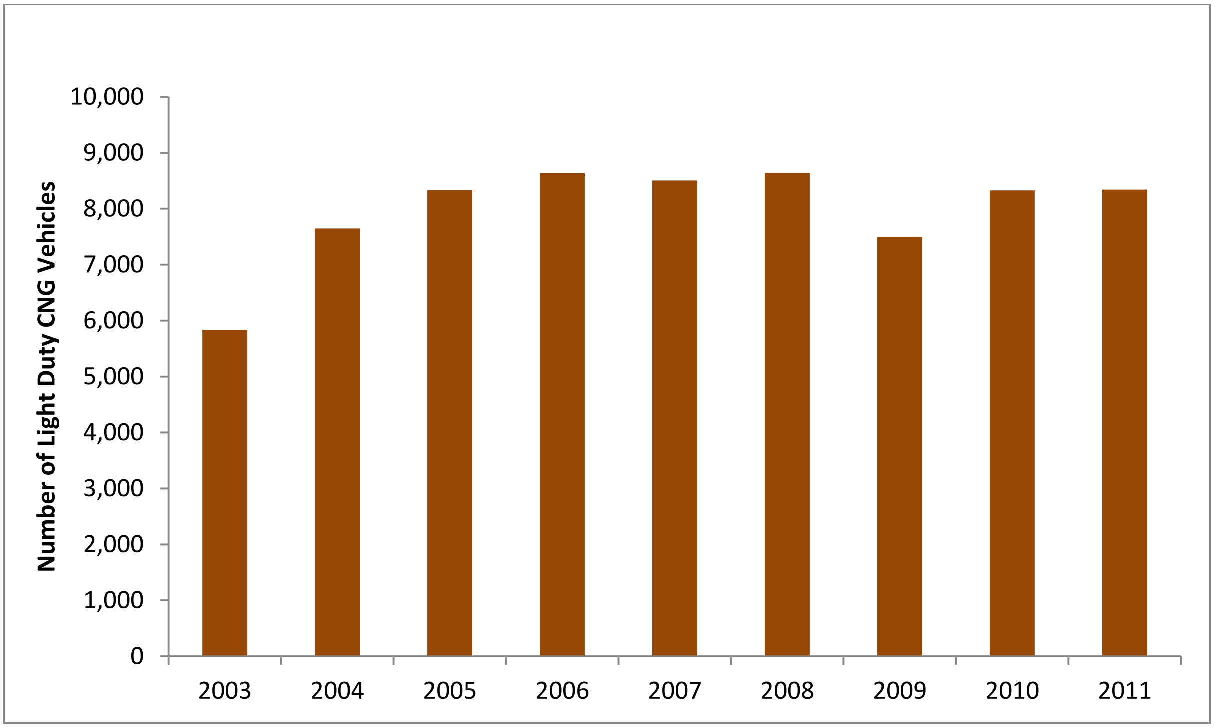


Figure 17. Total Texas CNG Light-Duty Vehicle Inventory.

Source: (32)

Figure 18 shows the number of CNG passenger vehicles in Texas by type. In 2011, the largest number of CNG vehicles in Texas was pickup trucks (4,442), followed by compact cars (1,486) and light-duty vans (1,350) (*32*).

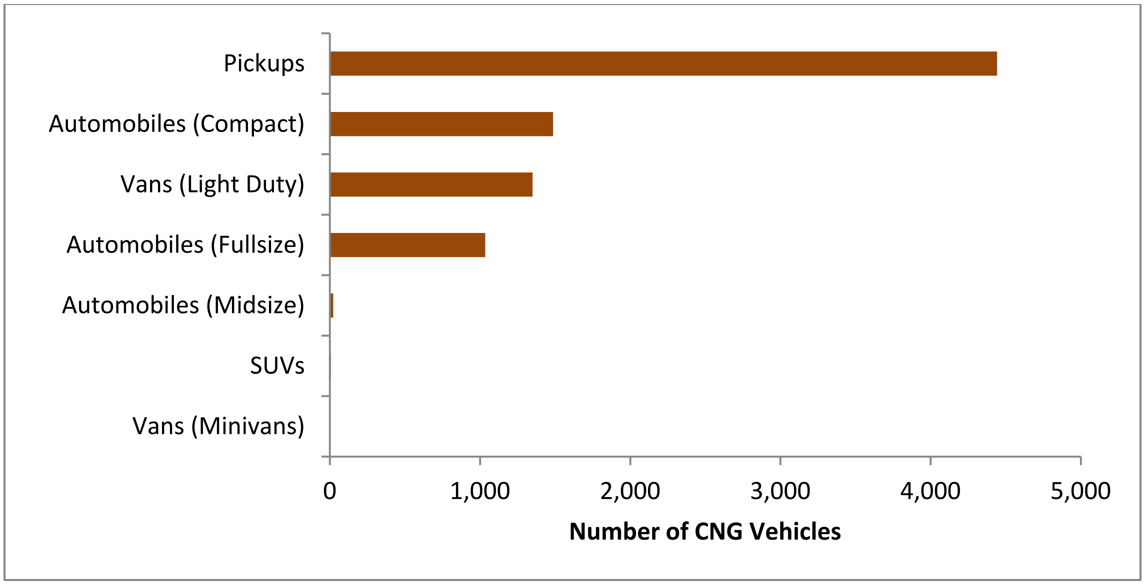


Figure 18. Texas Light-Duty CNG Vehicle Type Estimates.

Source: (32)

The *Fuel Price and Demand Scenarios for NGVs to 2025 Study* developed the Light Duty Vehicle (LDV) Potential Scenario to estimate the number of CNG vehicles on the road in 2025 in eight focus states: California, Colorado, Ohio, Oklahoma, New York, Pennsylvania, Texas, and Utah (*33*). The scenario assumptions included the following:

- There is continued growth in light-duty NGV purchases for fleet use.
- Residential market breakthroughs occur in certain states beginning in 2018.
- Beginning in 2018, market barriers are reduced, and incentives for NGVs and home refueling in eight focus states lead to stronger growth in light-duty NGV sales.
- By 2025, 3 percent of the new LDV sales in the focus states are NGVs, and in total, the focus states represent 80 percent of the incremental fuel consumption growth in the United States. The remaining 20 percent of incremental demand is made up by the remaining 42 states.

Table 4 shows that the study revealed incremental additions in passenger vehicles, increasing from 4,600 in 2013 to over 92,000 in 2025. The table also indicates an increase in MPGe over the time period, an indication of increased fuel efficiency. In total, the scenario assumes nearly 500,000 passenger NGVs on the road in the United States by 2025. Although the assumed growth is substantial, CNG vehicles still pale in comparison to the total on-road light-duty vehicles. For example, in 2010, over 230 million cars were registered in the United States (*33*).

Table 4. Incremental Additions of Natural Gas Passenger Vehicles through 2025.

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Vehicle Additions	4,600	5,000	5,500	6,000	6,000	19,300	29,200	39,400	49,700	60,000	70,600	81,300	92,300
MPGe	26.8	27.4	28.0	29.0	31.7	32.9	34.0	35.4	36.9	38.6	40.4	42.3	44.2

Source: (33)

Commercial CNG and LNG Vehicles

CNG is most commonly used in light-, medium-, and heavy-duty vehicles, as opposed to passenger vehicles, and is often used for public transportation and public works, such as city buses and garbage trucks. The MHDV commercial freight industry is also starting to adopt natural gas technologies for its fleet, as MHDV vocational applications may be well suited for these fuels. Class 8 vehicles, which generally include refuse collection, transit buses, drayage trucks, regional delivery trucks, tractors, and over-the-road trucks (often referred to as line haul), are the best case for introduction and growth in the CNG and LNG market (*34*).

While natural gas MHDVs use the same fuels as CNG passenger and light-duty vehicles, there are differences in the underlying technology applications as a result of their differing vehicle configurations. There are multiple natural gas fuel systems on the market for MHDVs in the United States including:

- **Dedicated Vehicles—**These are vehicles where gasoline-fueling hardware is removed and the engine operates exclusively on natural gas. Dedicated vehicles are a good choice for transports having a daily drive cycle with set routes and a centralized fueling station at the base location. This may include applications such as food and beverage delivery, hospitality, and parcel service.

- **Bi-Fuel Vehicles—**These are vehicles that can switch back and forth between natural gas and diesel/gasoline. A bi-fuel engine offers the advantage of allowing the use of diesel/gasoline when refueling with natural gas is not available. As with passenger vehicle systems, commercial natural gas vehicle applications tend to have a higher compression ratio and improved engine efficiency due to the higher octane rating of CNG and LNG (*27*). The additional advantage of a bi-fuel system is that the ability of these applications to run on traditional fuels can alleviate concerns associated with finding natural gas refueling infrastructure, helping alleviate the range anxiety associated with many AFVs.

- **Dual Fuel—**These vehicles run on natural gas but use diesel fuel for ignition. Technically, a dual fuel is categorized by the EPA as a "mixed fuel" because it blends natural gas with diesel by injecting it into the turbocharger. However, this type of vehicle is capable of running on 100 percent diesel if the CNG fuel supply is exhausted. For this fuel system, the existing diesel tanks remain and *additional* CNG cylinders that extend the range are installed. This type of alternative fuel application can be a good choice for existing fleets that need range and fuel flexibility for vehicles but do not want to unnecessarily replace vehicles (*35*).

- **Mixed Fuel—**This category includes any commercial vehicle that blends CNG with diesel or other fuels (outside of the dual fuel categorization discussed above). Some engines, such as the Cummins/Westport ISX, use a small amount of diesel for ignition but basically act as dedicated CNG engines. This means the CNG is the only fuel that propels the vehicle. Like dedicated systems, these vehicles are a good choice for predictable routes that need the high torque of a heavy-duty diesel engine. The main advantage of this system is that it can run 90 percent or more CNG while retaining many of the operating benefits of diesel. Mixed-fuel systems are currently available only in new trucks (*35*).

In addition to new vehicle models, there is also an increasing number of options available to freight operators to convert traditional fuel vehicles to run on natural gas. Conversion technology modifies existing diesel engines to operate on a blend of natural gas and diesel that is combined in real time inside the engine, similar to a dual fuel application. The advantage of converting to dual fuel is the ability to use existing equipment (*17*).

One of the factors slowing the progression of CNG and LNG MHDVs is the introduction of more-efficient diesel engines. The first phase of a federally mandated 6 percent improvement in fuel economy by 2017 took effect in 2014, pushing heavy-duty truck mileage closer to 7 mpg from about 6.5 mpg (*36*).

Another concern for fleet adoption of CNG is a lack of available refueling infrastructure, which is still extremely limited and underdeveloped. Some fleet operation centers have invested in their own natural gas supply stations, in particular, those with generally stable daily routes and operations in ports. However, in order to enable cross-country freight movement, natural gas refueling infrastructure with technical support for operations and maintenance would need to be constructed along the major corridors. Although there are numerous public fueling stations, not all of these are truck friendly. Many are not accessible to or equipped to handle heavy-duty vehicles and may not even be large enough to accommodate the large tractor-trailers used for interstate commerce. The equipment located at CNG fueling stations also often does not have adequate compression to completely fill these vehicles within a reasonable time (*37*).

There are approximately 709 CNG and 54 LNG fueling stations in the United States, according to the U.S. DOE Alternative Fueling Station Locator, with 13 LNG stations (4 are private) and 91 CNG stations (33 are private) located in Texas. Planned natural gas stations in Texas include 19 public CNG, 1 private CNG, 7 public LNG, and 4 private LNG stations (*38*). Bill Zobel, vice president of market development and strategy for Trillium CNG, a provider of CNG fueling services, stated that their numbers will increase about 150 to 400 stations per year up to 2020, with public access stations outpacing private stations by about 2:1. Zobel also stated that most

CNG infrastructure developers are concentrating on high-capacity stations to serve the heavy-duty, over-the-road truck market (*39*).

A final constraint on natural gas vehicle adoption in the freight and commercial vehicle sector is the high capital costs of these vehicles relative to similar diesel heavy-duty vehicles. Approximately 50 to 75 percent of the higher costs can be attributed to the onboard natural gas fuel systems. As with many relatively new technologies, higher manufacturing volumes can reduce costs, but the inherent complexity of the CNG and LNG components and onboard fuel storage systems relative to diesel fuel tanks will continue to contribute to high prices in the foreseeable future (*40*).

In spite of this, natural-gas-powered trucks experienced continued growth in unit sales through 2014, but the rate was about the same as the growth in the truck market as a whole. Sales for 2014 were expected to total 11,000 units, up 27 percent from 2013 (*41*). Refuse trucks, transit buses, certain types of drayage trucks, and other goods movement vehicles are expected to remain the dominant natural gas vehicle application in the near term. CNG technology is applicable especially in urban-area, heavy-duty, and medium-duty uses, and LNG may be more viable for heavy-duty, long-haul operations over the longer term (*34*). However, LNG technologies are not yet widely present within this sector.

Ethanol

Ethanol, or ethyl alcohol, “is a clear, colorless alcohol fuel made from the sugars found in grains, such as corn, sorghum, and barley, as well as potato skins, rice, sugar cane, sugar beets, and yard clippings” (*42*). Corn is the most common source for ethanol production in the United States, due to both its abundance and relatively low price. To manufacture ethanol, the corn’s starch is fermented into sugar, which in turn is fermented into alcohol. The Midwest accounts for the majority of the U.S. ethanol production. Ethanol production used 4.9 billion bushels of corn in 2012, representing about 40 percent of the U.S. total corn supply (*43*).

Ethanol is primarily used as an additive to gasoline for motor vehicles. Most gasoline has some ethanol in it, but the exact amount varies by region. The most widely available form of ethanol is E10. E10 is gasoline composed of 10 percent ethanol, which is now the standard motor fuel. Almost all gasoline-powered vehicles today run on E10, and vehicles do not require special modifications to use E10. Gasoline with 15 percent ethanol is known as E15, and fuel that is higher than 51 percent ethanol by volume is called E85.

Despite recent growth in ethanol as a transportation fuel, the long-term outlook for ethanol is uncertain. The Renewable Fuel Standards Act of 2005 set minimum levels for renewable fuel production and blending with gasoline, which primarily affected ethanol. The minimum thresholds were set to increase over time, with an initial target of 7.5 billion gallons to be produced in 2012 (*42*). In 2007, Congress further increased the mandate to require blending of 36 billion gallons of renewable fuels by 2022. However, the current vehicle fleet and refueling infrastructure system are not equipped to use that much ethanol, and as a result, ethanol production has exceeded consumption since 2010. The result has been an increase in domestic stockpiles and exports of ethanol. Furthermore, these federal mandates are coming under increasing criticism from the oil and gas industry. While the mandates were originally intended to improve fuel security, reduce environmental impacts, and decrease costs, they are now being blamed for increases in gasoline prices. Proponents of the mandates argue that the situation is only temporary and will compel the nation to greater usage of renewable fuels.

However, in spite of any potential unraveling of federal mandates on ethanol usage, it will continue to account for at least 10 percent of the nation's fuel usage. The EIA projects ethanol consumption will grow initially in the next few years but will fall short of the federal target of 36 billion gallons in 2022. Following 2020, EIA projects overall ethanol consumption decreasing, while the share of E15 consumption grows in comparison to its current levels (*8*).

The number of fueling stations offering E85 has grown significantly—more than tenfold since the mid-2000s—although most states still have relatively poor coverage in comparison with traditional gasoline stations (*44*). The number of stations grew from 188 in 2004 to 2,639 in 2013—an average growth rate of 27 percent per year (*45*). Despite this growth, the number of stations offering E85 only represents about 2 percent of total U.S. fueling stations. The highest concentration of stations occurs in the Midwest corn-producing states, although many new stations have opened in both California and New York in recent years. Some southern states have actually experienced negative growth in the number of available E85 fueling locations. Texas had 87 public E85 fueling stations as of 2013 and has experienced limited growth in its fueling infrastructure (*46*).

Passenger Ethanol Vehicles

Vehicles that can use E85 are called flexible-fuel vehicles (or flex-fuel, for short) (*47*). Flex-fuel vehicles are called flexible because they are equipped to run E10 or higher ratio fuels like E15 or E85. This benefit often goes unused, as both market and infrastructure hurdles limit the use of E15 or E85. Historically, E85 has not been cost competitive nationally with E10. The energy density of E15 and E85 is lower than E10, so the price of these fuels must be lower in order for them to be cost competitive with E10. Additionally, there is limited national E85 fueling infrastructure (*44*). Therefore, this combination of structural and market limitations has hindered growth in E85 as a transportation fuel.

Flex-fuel vehicles differ from traditional vehicles in that their fueling systems and powertrain calibration are specifically manufactured to run any ratio of ethanol or gasoline. This is achieved through many small modifications to various components involved in these systems, like alteration to the fuel system's electrical components to ensure they can handle the increased octane of ethanol, enlargement of the fuel pump to handle increased fuel flow, and modifications to the fuel tank to minimize the additional evaporation that occurs with ethanol. These modifications, and others like them, distinguish a flex-fuel from a traditional vehicle. Vehicles are not normally converted from traditional gasoline to flex-fuel due to the extensive modifications that must occur (*48*). Many vehicle manufacturers offer flex-fuel versions of their existing vehicle lines, with the only difference being the modifications to the fuel systems that enable ethanol use.

Flex-fuel vehicles are the most widely used AFVs, representing about 66 percent of all passenger class AFVs on the road in 2010 in the United States. As of 2011, Texas had nearly 64,000 light-duty flex-fuel vehicles on the road. EIA projects that by 2040, flex-fuel vehicles will represent 11 percent of all light-duty vehicle sales, making ethanol the single largest alternative fuel technology. It is important to emphasize that the relatively high number of flex-fuel vehicles does not imply that flex-fuel vehicles are necessarily using an equivalent amount of ethanol. Again, this is due to flex-fuel vehicles' ability to run on any blend of ethanol and gasoline. Flex-fuel vehicle owners can choose which fuel they wish to use, so large numbers of flex-fuel vehicle sales do not guarantee a large amount of E85 use. In fact, in terms of fuel consumption, ethanol actually lags behind natural gas, which accounts for nearly half of the alternative fuel consumption in all vehicles as of 2011.

There has also been reasonable growth in the use of E85 vehicles. As can be seen in Figure 19, the number of E85 vehicles in the United States nearly doubled between 2009 and 2011 alone. However, E85 vehicles are still not a significant segment of the automotive fleet, accounting for less than 1 percent of the passenger vehicle fleet in 2011.

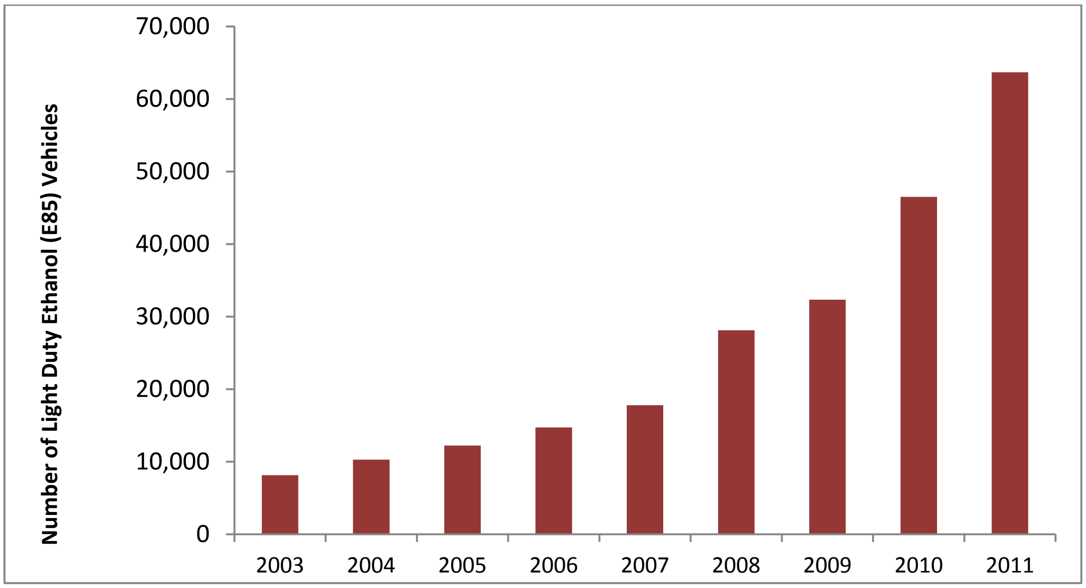


Figure 19. Number of Ethanol (E85) Passenger Vehicles in the United States.

Source: (32)

Commercial Ethanol Vehicles

Ethanol is typically blended with gasoline, which is not the primary fuel of choice in the heavy-duty vehicle sector. However, diesel ethanol, also called E-diesel, is available. E-diesel is made by blending conventional diesel, fuel-grade ethanol, and various additives with 10 to 15 percent ethanol alcohol. It is used primarily in centrally fueled vehicle fleets.

There are issues with the use of E-diesel. For example, E-diesel has a much lower flash point than regular diesel, making it more flammable and increasing the risk of explosions in traffic incidents. However, flammability can be addressed through various measures, including adding vapor recovery systems and ensuring that fuel tanks are of a safe design (*49*). Diesel ethanol also does not provide the same lubrication as regular diesel for fuel-injection components, which can result in a deterioration of those components and affect fuel metering and delivery characteristics (*50*). E-diesel can also lead to reduced engine performance due to the lower energy content of ethanol (*49*). It is also more difficult to achieve a stable blend of diesel and ethanol. As a result of these factors, E-diesel is not a widely used alternative fuel source in the commercial vehicle fleet.

Propane

Propane is a by-product of natural gas processing and crude oil refining. Propane accounts for about 2 percent of the energy used in the United States, and of that, less than 2 percent is used for transportation. Propane is mainly used for cooking, heating homes and water, refrigerating food, powering farm equipment, and other miscellaneous uses. Propane is especially useful in rural areas without access to other forms of fuel.

Propane is a relatively clean burning alternative fuel source that has been used to power a variety of vehicles for decades (*51*). Also known as liquefied petroleum gas (LPG), or "autogas" when used in vehicles, propane gas is pressurized and liquefied for storage in a fuel tank. The release of pressure converts the liquid back to a gas, which is then combusted in an engine. In a fleet setting, propane can often be less expensive than gasoline, which can provide an economic incentive for fleet adoption. In public retail sales, however, propane has historically been more expensive than gasoline or diesel.

The propane market is subject to a number of influences that commonly affect price (*52*), the first being the demand and supply of other petroleum products, especially crude oil. Propane competes with crude oil and is a by-product of oil refinement and natural gas processing. As the price for oil changes, the price for propane generally moves with it. A second factor is seasonal conditions. Propane stocks, consumption, and price are heavily influenced by weather. Propane production is not seasonal, but demand is. Strong winter weather will increase demand, diminish supplies, and drive up prices, sometimes drastically, resulting in price spikes. In contrast, gasoline is not used for seasonal purposes to the same extent, and it is not subject to as intense seasonal variation in supply, demand, and pricing (*53*).

Propane's primary use as a source of residential heating means that most demand occurs during the winter months. As a result, supply grows throughout the summer and begins to diminish as demand increases throughout the winter. If the market produces less propane than is needed in a given winter, the price for propane will increase.

Passenger Propane Vehicles

Propane, when used as a transportation fuel in passenger vehicles, is generally stored in a tank placed under the vehicle. Propane vehicles can exist either as entirely dedicated to propane or as a bi-fuel vehicle, which burns both gasoline and propane. Depending on its exact usage and a vehicle's configuration, propane can offer lower life-cycle greenhouse gas emissions than traditional petroleum-based fuels. Propane offers a naturally clean burning fuel in comparison to other fuels in emission types like particulate matter, NO_x, and VO_x (*54*).

Propane as an alternative fuel for passenger vehicles has not seen significant growth or market penetration. While some auto manufacturers do offer dedicated propane models, they generally have to be specially ordered from the manufacturer. It is more popular to convert an existing ICE vehicle to run on propane or function on a bi-fuel basis, but these conversions are far less common than CNG conversions. One reason for this might be that propane vehicles tend to have lower fuel efficiency on a GGE basis.

Approximately 143,000 propane vehicles were on the road in the United States as of 2010, but the number of vehicles has steadily decreased from a high of 187,000 in 2004 (*32*). Of this total, about 40,000 vehicles operated in Texas. Propane vehicle use in Texas has ebbed and flowed in recent years, but the total number of vehicles has steadily decreased since 2006 from a high of 51,293 vehicles to a low of 25,361 in 2011 (Figure 20)(*32*).

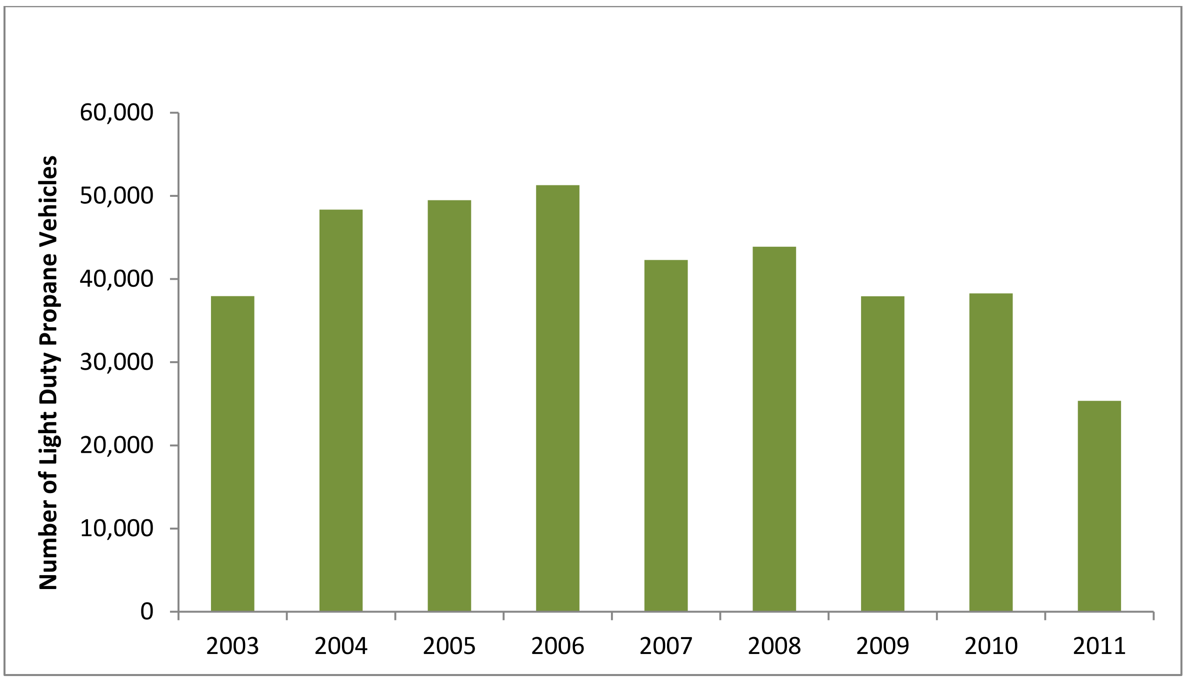


Figure 20. Total Texas Propane Light-Duty Vehicle Inventory.

Source: (32)

Propane vehicles are mostly used as fleet vehicles, due partially to the lack of publically available fueling infrastructure. Common uses are as police vehicles, school buses, and shuttles.

As can be seen in Figure 21, most propane vehicles in Texas are pickup trucks, and most of these are affiliated with fleet operations. Vans make up most of the remaining propane vehicles on Texas roadways.

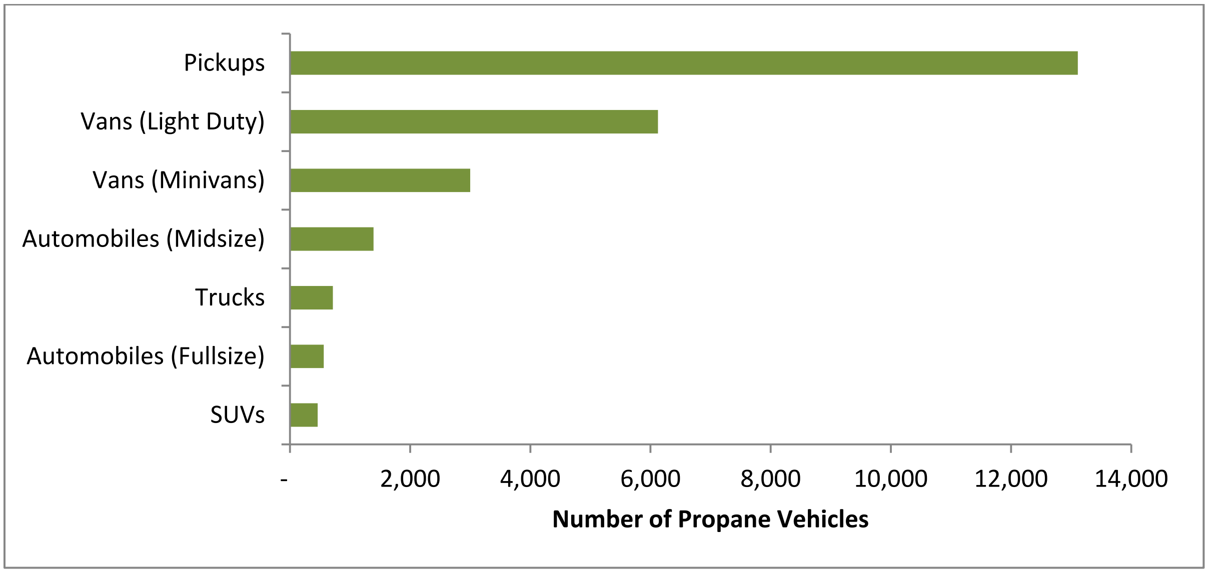


Figure 21. Texas Propane CNG Vehicle Type Estimates.

Source: (32)

Commercial Propane Vehicles

Propane is more commonly used in the MHDV sector than in the passenger vehicle fleet. However, propane is still used at significantly lower rates relative to other alternative fuels. Growth in consumption of propane for transport is expected from the on-road vehicle market, as propane is expected to maintain a favorable price position relative to diesel and gasoline, though still higher than other fuels. Additionally, in recent years there has been a surge in development of new propane vehicles and conversion systems. These factors make growth in propane on-road vehicles appear likely. Still, a doubling of on-road vehicles by 2020 would only represent approximately 300,000 vehicles—a relatively small fraction when compared to the U.S. vehicle market.

Commercial propane vehicles can exist either as entirely dedicated to propane or as a bi-fuel vehicle, which burns diesel or gasoline, and Westport Innovations is developing a 3.8-liter engine that runs on natural gas or propane autogas for off-road or stationary equipment, according to its quarterly earnings report. The engine is based on Hyundai Motor Company's automotive engine and is targeted for use in construction equipment, forklifts, oil and gas, and power generation. The engine will feature a multi-point fuel-injection system designed and manufactured by Westport and the Westport WP580 EMS. The engine is expected to meet EPA and California Air Resources Board emissions standards, according to the company.

A greater utilization of propane by the MHDV freight sector will likely require the addition of more propane aftermarket conversion systems, where a vehicle or engine is modified to operate using a different fuel or power source. Propane conversions have improved greatly over the years with the addition of computerized injection systems. However, conversions are typically done on light- and medium-duty vehicles.

Hydrogen Fuel Cell

Hydrogen fuel cell technology is distinct from other AFV technologies. For example, rather than converting chemical energy into mechanical energy (as in the case with traditional ICEs), hydrogen fuel cell passenger vehicles are powered by the conversion of chemical energy into electrical energy. Most individual fuel cells designed for use in vehicles produce less than 1.16 volts of electricity, which requires that multiple cells be assembled into a fuel cell stack in order to generate enough electricity to drive a vehicle. Each fuel cell has two electrodes—one positive and one negative—that carry electrically charged particles from one electrode to another. This electrical energy is then used to power an electric motor that propels the drive train and moves the vehicle. Thus, hydrogen fuel cell vehicles have many of the basic components of EV technologies (electric motor and drive train) without the battery storage component (*55*).

Hydrogen, the primary source of most fuel-cell-based technologies, can be produced by two general processes: electrolysis and fuel reforming. Electrolysis is a method of using direct electric current to drive an otherwise non-spontaneous chemical reaction (*56*). Most of the hydrogen produced for transportation fuels is developed through fuel reforming, where hydrogen is extracted from fossil fuels (e.g., oil, natural gas). Reforming can take place either on a large scale (such as a refinery or chemical plant) or at the point of use by small reformers that are integrated within the fuel cell.

Fuel cell vehicles (FCVs) can achieve a range of more than 300 miles on a single tank. They can be equipped with other advanced technologies to increase efficiency, such as regenerative braking systems, which capture the energy lost during braking and store it in a battery. FCV vehicular performance has not been as well studied or tested as other alternative fuel technologies, namely because fuel cell technology is still under development. However, based on available research, initial performance reviews have found that FCVs can generally offer a quiet ride with little vibration as compared to conventional ICE vehicles. As is the case with other alternative fuel technologies, FCVs are also expected to provide increased engine efficiency, lower smog-forming emissions, and reduced greenhouse gas emissions. Fuel cells operating on pure hydrogen achieve nearly zero emissions. FCVs can achieve 40 to 70 percent energy efficiency—substantially greater than the 30 percent efficiency of the most efficient internal combustion engines. FCVs are also considered more energy efficient than conventional ICE vehicles, and hydrogen contains generally three times more energy per unit of weight than conventional gasoline (*55*).

The cost of fuel cell technology is one of the most significant limiting factors for the technology’s future penetration as an alternative transportation. Fuel cell vehicles are currently more expensive than conventional ICE vehicles. Although the cost of fuel cell vehicles has decreased significantly since the fuel cell vehicle concept was first introduced as a prototype in the mid-2000s, the upfront capital costs for fuel cell vehicles are still higher per vehicle than traditional ICEs. While methods of producing hydrogen for use as a transportation fuel are currently in use, the infrastructure for producing that hydrogen and, more importantly, providing it to consumers is not well developed. The cost of producing hydrogen is also high relative to the other fuels discussed in this report. In the near to mid-term, this cost and lack of infrastructure will be a limiting factor in the penetration of these vehicles into the commercial and passenger vehicle fleets.

FCV system costs should continue to decrease as the volume of vehicles produced increases. U.S. DOE has projected that an increase in the number of fuel cell systems from 1,000 to 100,000 systems per year could reduce the cost of each unit produced from over $20,000 to just over $4,000 (*57*). The volume of hydrogen fuel cell vehicles produced and available on the market will increase, but the extent is unknown. Several automakers have forecasted the possibility of assembling 10,000 to 20,000 hydrogen fuel cell vehicles per year by 2020, but this is relatively small compared to the 1 million or more plug-in electric vehicles that are forecasted to be manufactured in 2020 (*58*). In March 2014, Honda and Toyota announced plans to build 1,000 fuel cell vehicles in 2015 with plans to slowly ramp up production to tens of thousands by the early 2020s. In 2015, Toyota and Honda expect to offer their fuel cell vehicles at a manufacturer's standard retail price (MSRP) of $97,700; however, both automakers reported that the cost would drop to an MSRP of $29,300 by the 2020s (*59*). Toyota has made one of the largest commitments to developing fuel cell technologies in vehicles, as it also announced in May 2014 that it would allow its battery-supply deal with Tesla Motors to expire and would focus instead on developing hydrogen fuel vehicles. Furthermore, the company announced plans to focus on developing hydrogen refueling stations to support fuel cell technology (*60*).

A lack of fueling infrastructure for producing, delivering, and dispensing hydrogen to consumers is perhaps one of the most significant challenges that hydrogen fuel cells face. Current infrastructure is insufficient to support the widespread adoption of FCVs. A hydrogen fueling station can cost up to $1 million per station, and tens of thousands of these stations would need to be constructed for fuel cell vehicles to likely become viable. In addition to fueling stations, an extensive hydrogen distribution network would have to be developed—an added expense and a potentially significant limiting factor. Several initiatives have been launched to improve rollout of FCV infrastructure. In 2013, U.S. DOE launched H2USA, a public-private partnership between DOE and other federal agencies, automakers, state governments, academic institutions, and additional stakeholders to coordinate research and identify cost-effective solutions for deploying hydrogen infrastructure (*61*).

There are also concerns regarding the durability and reliability of fuel cell technology. For example, passenger vehicle fuel cell systems do not have the same reliability characteristics as ICEs, especially in some temperature and humidity conditions. Some components are very sensitive to extreme temperatures and can degrade as temperatures rise. Furthermore, certain fuel cell components must be well hydrated to function and may not perform as well in environments with low humidity. In order to be competitive with conventional vehicles, FCVs must be able to travel more than 300 miles between each fill. Currently, hydrogen has physical characteristics that make it challenging to store large quantities without taking up a large amount of space. Furthermore, the durability of the fuel cell stacks that power the vehicle range from 29,000 miles to 75,000 miles. This is significantly less than the average durability and reliability of conventional ICEs, which can last on average up to 150,000 miles (*61*).

Some state and local governments are considering investing in hydrogen fueling infrastructure. California is currently the leader in terms of hydrogen fueling stations; there are 9 public stations currently in operation in California today, with 19 additional stations scheduled to open by 2015. There are approximately 200 fuel cell vehicles operating on California roads, including cars, buses, and heavy-duty trucks.

Passenger Hydrogen Fuel Cell Vehicles

Three hydrogen-electric vehicles are currently available on the market from Honda, Hyundai, and Mercedes-Benz. The Honda Clarity, the only vehicle with information on fuel economy, achieves 60 miles per kilogram in the city and 60 miles per kilogram on the highway.

While some automakers are investing heavily in EV technology, other auto manufacturers are showing increased interest in fuel cell technology. A recent trend by automakers is to lease, rather than sell, fuel cell vehicles to consumers. This helps to improve the high initial cost associated with fuel cell vehicles. For example, at a recent auto show, Hyundai Motor Company announced plans to offer consumers a fuel cell version of its Tucson crossover vehicle for the U.S. market starting in spring 2014 in the Southern California market only. Hyundai set the lease payment at $499 per month for a 36-month term with a $2,999 down payment and said the deal included unlimited free hydrogen refueling (*58*).

Commercial Hydrogen Fuel Cell Vehicles

Fuel cell MHDVs use the same technology as passenger and light-duty FCVs; hydrogen stored in tanks onboard the vehicle mixes with oxygen from the air to create electricity to drive the electric motors. However, MHDVs have different operating cycles and needs than passenger vehicles, as well as each other.

Hydrogen fuel cell vehicles in the MHDV sector are minimal relative to other alternative fuel systems. Furthermore, as with the other alternative commercial vehicles discussed in this section, fuel cell technology has seen the lowest adoption rates within the Class 8 designation, which includes long-haul tractor combination vehicles.

Range extenders are the most prevalent current use of fuel cells in the MHDV market. For example, PlugPower provides fuel cell components for refrigerated trucks—called transport refrigeration units—that keep the refrigeration unit cold even when the engine is turned off. This helps to reduce emissions and petroleum use. PlugPower is also working to integrate fuel cell technologies into BEVs in order to extend the range of delivery trucks used by companies like

FedEx, UPS, and the U.S. Postal Service. These range-extending components are expected to double the range of these types of vehicles.

Alternative Fuel Taxes and Incentives

The adoption of alternative fuels by the passenger and commercial vehicle fleets has implications for Texas transportation policy in two primary areas:

- **Taxation—**Traditional fuels such as gasoline and diesel are taxed by the State of Texas and provide significant funding for state transportation programs. As such, the extent to which alternative fuels are adopted by the public and the presence of state levies on those alternative fuels can have potentially significant impacts on state transportation funding in the long term. Currently, the State of Texas collects transportation-related taxes on all of the alternative fuels discussed in this report with the exception of electricity. Electricity may be taxed as part of municipal utility provision, and those taxes may indeed pay for some transportation-related purposes, but taxes paid for electricity usage do not go toward transportation-related uses at the state level.
- **Incentives—**Various federal, state, and local incentives are in place to encourage the development, adoption, and utilization of alternative fuels. These incentives may take many forms, from grants for technology providers to tax rebates for drivers. These incentives may also be offered to achieve any number of public policy goals, from air quality improvement to renewable energy development.

This section summarizes state-level taxes on traditional and alternative fuels as well as federal, state, and local incentives for the adoption of AFVs.

Taxes

The State of Texas levies taxes on the majority of fuels used for motor vehicle transportation including gasoline, diesel, propane, compressed and liquefied natural gas, and biodiesel:

- **Gasoline**—Taxes collected on gasoline and diesel account for the largest portion of the revenue generated by motor fuel taxes. The current state tax on gasoline is $0.20 per gallon sold or used in the state; this rate has been in effect since being set in 1991. Taxes are not collected directly from the driver but are rather collected at certain points in the fuel supply chain depending on where the fuel is produced and how it is carried into or transferred within the state of Texas. The amount paid at the pump by a driver includes taxes. Diesel used in agriculture, transit operations, and other certain activities is exempt from the state diesel tax.
- **Ethanol (E85) and gasoline blended with ethanol**—Whenever gasoline is blended with ethanol, the ethanol portion of the new blended fuel is assessed a tax at the same rate as gasoline. Assessment occurs at the point of blending, so as with gasoline and diesel taxes, drivers are not actually paying the tax itself but rather are paying a retail price that includes the already assessed (and collected) tax.

- **Compressed/Liquefied natural gas**—Effective on September 1, 2013, the Texas Legislature updated the system for taxing CNG and LNG with House Bill 2148 by requiring CNG/LNG dealers to collect a $0.15 per gallon tax when the fuel is sold or delivered into the fuel supply tank of a motor vehicle. Dealers must be licensed by the Texas Railroad Commission's Alternative Energy Division, and licenses must be renewed annually. Individuals who maintain their own storage of CNG/LNG for use in their vehicles are required to obtain a CNG/LNG dealer license as well.
- **Propane—**Propane used for transportation purposes is taxed through an annual prepaid decal system paid directly by the user. Decal rates vary based on the number of miles driven the previous year and on the vehicle's registered gross weight. The taxpayer is expected to record his or her odometer reading on the payment form and can deduct mileage accrued outside of Texas by submitting a form that enumerates all mileage incurred outside of the state.

The State of Texas does not currently have any taxation mechanisms for electricity such that funds collected by EV owners could be allocated for transportation uses. Furthermore, the state does not currently tax hydrogen used in hydrogen fuel cell vehicle applications.

Incentives

The United States, Texas, and regions throughout the state have incentives and mandates that play an important role in the shift to alternative fuels in the commercial and passenger vehicle sectors. Policy makers have looked to AFVs to meet policy objectives such as emissions reduction and energy security. Yet, because AFV costs—including upfront capital, infrastructure, adjustments, and performance tradeoffs—remain high, local, state, and federal government agencies have taken steps to reach key policy goals through regulations and incentives for AFVs (*62*). Studies have found that reducing the relative cost of owning AFVs increases the likelihood that customers will buy the vehicles (*63*). Monetary incentives may fund all or part of the capital costs of an AFV or associated costs, and may correspond to a specific fuel type.

Government incentives for purchasing alternative fuels are available at the federal, state, and regional levels. The five common types of government incentives to assist the public and fleet owners with purchasing fuel-saving upgrades include:

- Grants.
- Rebates and vouchers.
- Low-cost loans.
- Tax credits.
- Tax exemptions.

Other state-specific incentives may include preferred access to high-occupancy vehicle lanes by AFVs, reductions in registration fees, reductions in excise taxes, exemptions from emissions testing, and exemptions from state fleet procurement requirements. The five standard incentive types apply to both passenger vehicles and commercial vehicles. A table with more information on incentive types can be found in the appendix of this report.

There are two parts to the incentive itself that also affect the market penetration of different alternative fuel types. The first factor is *what* the incentive is incentivizing. Options may be:

- Research and development.
- Demonstration and deployment.
- Infrastructure.
- Capital cost of AFV.

The second factor related to the incentive is the alternative *fuel type* the incentive is encouraging. The decision to place incentives on certain fuels can be political in nature, with some administrations preferring some technologies over others. For example, at the federal level, the Bush Administration favored policies focused on promoting fuel cell and ethanol (E85) vehicles, while the Obama Administration has placed a stronger emphasis on promoting EV development (*62*).

Federal Incentives

Many different types of federal incentives support alternative fuel development and deployment in the commercial and passenger vehicle sectors. The variety of these incentives does not reflect a single, comprehensive strategy, but rather represents a range of public policy issues including reducing petroleum consumption and import dependence, improving environmental quality, expanding domestic manufacturing, and promoting agriculture and rural development (*64*).

Five federal agencies administer incentive programs for alternative fuels:

- Department of Treasury.
- Department of Energy.
- Department of Transportation.
- Environmental Protection Agency.
- Department of Agriculture.

The following is a summary of some federal incentives for alternatively fueled commercial and passenger vehicles.

Commercial

As heavy-duty vehicles emit roughly 20 percent of mobile source emissions, most federal programs for commercial vehicles incentivize idle reduction, fuel savings, and emissions reduction. Table 5 describes federal incentives for fuel-efficient commercial vehicles. Many of the incentive programs, such as the SmartWay Finance Program and Cascade Sierra Solutions Revolving Loan Fund, are backed by EPA.

Table 5. Federal Incentives for Fuel-Efficient Commercial Trucks.

Program	Details	Type
National Clean Diesel Campaign	Grant funding for idle reduction, clean fuels, vehicle replacements, and other strategies that reduce human exposure to diesel exhaust.	Grant
SmartWay Finance Program	EPA-backed program offering loans to help small trucking companies reduce fuel costs and emissions. Incentives available at federal, regional, and state levels.	Grants, Rebates, and Loans
Community Development Transportation Lending Service	Provides financing for the purchase of retrofitted trucks and idle reduction technologies. Backed by EPA-funded SmartWay Finance Program.	Loan
Cascade Sierra Solutions Revolving Loan Fund	Nationwide low-cost financing options for equipment upgrades and truck replacement. Back by EPA-funded SmartWay Finance Program.	Loan
Alternative Fuel Excise Tax Credit	Alternative fuels sold for use or used to operate a motor vehicle earn a tax credit of $0.50 per gallon.	Tax Credit
Idle Reduction Technology Excise Tax Exemption	Qualified onboard idle reduction devices and advanced insulations, and their installation, are exempt from federal excise tax.	Tax Exemption

Source: (65)

Passenger Vehicles

Financial considerations, specifically the presence of monetary incentives such as those provided by governmental entities, most influence customer consideration when purchasing alternative fuel vehicles (*63*). Thus, the presence of government incentives for the purchase of AFVs can have a significant impact on the adoption of these vehicles by the motoring public. This section summarizes the most pertinent incentives offered at the federal level.

Qualified Plug-In Electric Drive Motor Vehicle Tax Credit

Qualified PHEVs and BEVs are eligible for a federal tax credit called the Qualified Plug-In Electric Drive Motor Vehicle Tax Credit. The tax credit ranges from $2,500 to $7,500 per vehicle, dependent on battery capacity and gross vehicle weight rating. Internal Revenue Code 30D describes the credit for qualified plug-in electric drive motor vehicles acquired after

December 31, 2009, which starts at $2,500, plus $417 if the vehicle "draws propulsion energy from a battery with at least 5 kilowatt hours of capacity" and an additional $417 for every additional kilowatt hour of battery capacity above 5 kilowatts. The maximum total credit is $7,500. This federal incentive is available through 2014 or until manufacturers reach the phase-out period, which begins when the manufacturer sells over 200,000 qualifying vehicles in the United States (*66*). The phase out begins in the second calendar quarter after a manufacturer has cumulatively sold 200,000 qualified PHEVs or EVs for use in the United States (as counted from December 31, 2009).

Alternative Fuel Infrastructure Tax Credit

The Federal Alternative Fuel Infrastructure Tax Credit incentive expired December 31, 2013, but will remain posted until the federal tax filing deadline. Consumers who purchased qualified residential fueling equipment before December 31, 2013, may receive a tax credit of up to $1,000. The tax credit could be applied to in-home fueling infrastructure.

Income Tax Credit

There is no current income tax credit for the purchase of CNG vehicles, but previously, these credits have been an incentive to adoption. Natural Gas Vehicle America reports that the Energy Policy Act of 2005 provided an income tax credit for the purchase of a new, dedicated AFV totaling 50 percent of the incremental cost of the vehicle, plus an additional 30 percent if the vehicle met certain tighter emission standards. These credits ranged from $2,500 to $32,000 depending on the size of the vehicle. The credit was effective after December 31, 2005, and expired on December 31, 2010 (*67*).

Alternative Fuel Tax Exemption

According to IRS Publication 510, "Alternative fuels used in a manner that the Internal Revenue Service deems as nontaxable are exempt from federal fuel taxes" (*68*).

Hydrogen Fuel Infrastructure Tax Credit

According to 26 U.S. Code 30C and 38, "A tax credit is available for the cost of hydrogen fueling equipment placed into service after December 31, 2005. The credit amount is up to 30 percent of the cost, not to exceed $30,000. Fueling station owners who install qualified equipment at multiple sites are allowed to use the credit toward each location. Consumers who purchase qualified residential fueling equipment may receive a tax credit of up to $1,000.

Hydrogen Fuel Cell Excise Tax Credit

According to 26 U.S. Code 6426, "A tax credit of $0.50 per gallon is available for liquefied hydrogen that is sold for use or used as a fuel to operate a motor vehicle. For an entity to be eligible to claim the credit they must be liable for reporting and paying the federal excise tax on the sale or use of the fuel in a motor vehicle. Tax exempt entities such as state and local governments that dispense qualified fuel from an on-site fueling station for use in vehicles qualify for the incentive."

Improved Energy Technology Loans

42 U.S. Code 16513 authorizes the U.S. DOE to provide loan guarantees through the Loan Guarantee Program to eligible projects that reduce air pollution and greenhouse gases, and support early commercial use of advanced technologies, including biofuels and AFVs. The program is not intended for research and development projects. DOE may issue loan guarantees for up to 100 percent of the amount of the loan for an eligible project. For loan guarantees of over 80 percent, the loan must be issued and funded by the Treasury Department's Federal Financing Bank (*69*).

Alternative Fuel and Advanced Vehicle Technology Research and Demonstration Bonds

26 U.S. Code 54D authorizes qualified state, tribal, and local governments to issue Qualified Energy Conservation Bonds subsidized by the U.S. Department of Treasury at competitive rates to fund capital expenditures on qualified energy conservation projects. Eligible activities include research and demonstration projects related to cellulosic ethanol and other non-fossil fuels, as well as advanced battery manufacturing technologies (*70*).

Federal Mandates for Passenger Vehicles and Federal Government Fleets

There are also federal mandates related to alternative fuel passenger vehicles. These mandates set standards for fuel economy and emissions, as well as vehicle purchase requirements for government fleets.

Emissions and CAFE Standards

Requirements are currently being phased in through 2025 for automobile manufacturers to raise fuel efficiency and emissions standards. This is expected to encourage the increased production of commercial EVs, as the higher efficiency rating and lower emissions of EVs can contribute greatly to lowered fleet-wide averages and the meeting of federal requirements. In 2012, EPA issued final CO_2 emissions standards for model years 2017 through 2025 for passenger cars and light-duty trucks, including medium-duty passenger vehicles. The EPA standards are expected to require a fleet-wide average of 163 grams CO_2 per mile for light-duty vehicles in model year 2025, which is equivalent to a fleet-wide average of 54.5 mpg if reached only through fuel economy. Jointly, NHTSA issued a two-phase increase in CAFE standards for passenger cars and light-duty trucks for model years 2017 through 2025. The first phase includes final standards that NHTSA estimates will result in a fleet-wide average of 40.3 mpg for light-duty vehicles in model year 2021. The second phase, covering model years 2022 through 2025, requires additional improvements leading to a fleet-wide average of 48.7 mpg for light-duty vehicles in model year 2025 (*71*).

Federal Mandate

The National Renewable Energy Laboratory's study on No-Cost Barriers to Consumer Adoption of New Light-Duty Vehicle Technologies states that the Presidential Memorandum on federal fleet performance of May 24, 2011, directs that "by December 31, 2015, all new light-duty vehicles leased or purchased by agencies must be AFVs, such as hybrid or electric, CNG, or biofuel. Moreover, agency AFVs must, as soon as practicable, be located in proximity to fueling stations with available alternative fuels, and be operated on the alternative fuel for which the vehicle is designed" (*67*). While the federal mandate does not apply to passenger vehicles, the requirement for government fleets will likely increase the number of refueling stations built, and may affect passenger vehicle adoption.

State of Texas

The State of Texas works to encourage AFV development and adoption primarily through incentive and grant programs administered by TCEQ through TERP. These grant programs are aimed primarily at assisting metropolitan and urban areas in Texas with improving air quality, but this is accomplished by providing incentives to replace older, more-polluting vehicles with more fuel-efficient, less-polluting ones. Some programs specifically identify alternative fuel applications, such as CNG or electricity, as being eligible for funding. TCEQ is also responsible for administering programs aimed at funding the development of refueling infrastructure by covering a percentage of the costs associated with developing these facilities.

Commercial

A variety of grant programs are offered in Texas to reduce emissions by promoting alternative fuel commercial vehicles, as shown in Table 6. The programs listed in the table are all administered by TCEQ through TERP. Eligible projects typically include those that involve replacement, retrofit, repower, or lease or purchase of new heavy-duty vehicles; alternative fuel dispensing infrastructure; idle reduction and electrification infrastructure; and alternative fuel use. The TERP program provides financial incentives to eligible individuals, businesses, or local governments to reduce emissions from polluting vehicles and equipment.

Table 6. Commercial Vehicle Grant Programs as Part of TERP.

Program	Details
Clean Transportation Triangle Program	Provides grants in support of developing natural gas refueling stations. While the program was originally targeted for development of stations along major roadways connecting Dallas–Fort Worth, Houston, and San Antonio, it was expanded by the legislature in 2013 to include counties within the triangle formed by those metropolitan areas. The program awarded 18 grants from 2012 to 2013 in the amount of $3.9 million and 19 grants in 2014 in the amount of $7.76 million.
Natural Gas Vehicle Grants Program	Provides funding (up to 90% of the cost) to encourage MHDV owners to repower or replace their vehicles with natural gas. To be eligible, a vehicle must be operated in a county designated under the Clean Transportation Triangle Program. From 2009 through August 2014, the program funded 57 grants and replaced 714 vehicles for a total of $32.1 million. The program has an additional $12.4 million available for fiscal 2015 grants.
Clean Fleet Grants	Encourages diesel fleet owners to permanently remove the vehicles from the road and replace them with AFVs or HEVs. Grants are available to fleets to offset the incremental cost of such replacement projects. An entity that operates a fleet of at least 75 vehicles, including at least 20 diesel-powered vehicles, and that commits to placing 20 or more qualifying vehicles in service for use entirely in Texas during a given calendar year may be eligible. Qualifying AFV or HEV replacements must reduce emissions of nitrogen oxides or other pollutants by at least 25% as compared to baseline levels and must replace vehicles that meet operational and fuel usage requirements. Neighborhood EVs do not qualify. This program ends August 31, 2017, and is restricted to certain counties. From 2009 through August 2014, the program funded 12 grants to replace 305 vehicles at a total cost of $23.6 million. Funding in the amount of almost $7.8 million was available in 2014.
Diesel Emissions Reduction Incentive Grants Program	Provides grants to offset the cost of emissions reduction projects associated with high-emitting mobile diesel vehicles that can include the replacement of those vehicles with lower-emitting, alternative-fuel-based technologies. The program has largely targeted ozone nonattainment areas such as Dallas–Fort Worth and the Houston–Galveston–Brazoria areas, but funding has been awarded to projects in the Tyler–Longview–Marshall, San Antonio, Beaumont–Port Arthur, Austin, Corpus Christi, El Paso, and Victoria areas. From 2001 through August 2014, the program awarded more than $905 million for the upgrade or replacement of 15,623 heavy-duty vehicles, locomotives, marine vessels, and other pieces of equipment. After September 2014, there is funding available in the amount of $68 million.

Program	Details
Alternative Fueling Facilities Program	Provides grants for 50% of eligible costs, up to $600,000, to construct, reconstruct, or acquire a facility to store, compress, or dispense alternative fuels in Texas air quality nonattainment areas. Qualified alternative fuels include biodiesel, electricity, natural gas, hydrogen, and propane. The entity receiving the grant must agree to make the fueling station available to people and organizations not associated with the grantee during certain times. The program ends August 31, 2017. From 2012 through August 2013, the program funded four grants for a total of $1.8 million, and an additional 21 projects for $7.76 million were awarded in 2014.
Light-Duty Purchase or Lease Incentive Program	Provides up to $2,500 for the purchase of a light-duty vehicle operating on natural gas, liquefied petroleum gas, or plug-in electric drive. The program was established in 2013 and was allocated $7.8 million through fiscal 2015, after which its authority expires. As of August 2014, the program has awarded 317 grants for a total of $675,625, and an additional $7.07 million will be available to award in fiscal 2015.
Drayage Truck Incentive Program	Provides funding to replace drayage trucks operating at seaports and railyards in Texas nonattainment areas with newer, less-polluting drayage trucks that can include AFVs. The program was established in 2013, and the first grant application period was expected to open in September 2014 with total funding of $3.1 million.

Source: (72)

Texas has joined 15 other states in signing a memorandum of understanding (MOU) in order to stimulate demand for natural gas vehicles. Specifically, the MOU seeks to:

- Encourage OEMs to offer functional and affordable light- and medium-duty NGVs.
- Aggregate state vehicle procurement through a joint request for proposals.
- Boost private investment in natural gas fueling infrastructure.
- Encourage greater coordination between state and local agencies.

Other signatories to the MOU include Arkansas, Colorado, Kentucky, Louisiana, Maine, Mississippi, New Mexico, Ohio, Oklahoma, Pennsylvania, Tennessee, Utah, Virginia, West Virginia, and Wyoming.

Passenger Vehicles

As with federal incentives, state-level incentives toward the purchase of AFVs can significantly impact the decision of a driver to purchase such vehicles. The following is a summary of state incentives for alternative fuel passenger vehicles in Texas.

Texas Emissions Reduction Plan

Texas offers a similar rebate to the federal program discussed above with its Light-Duty Motor Vehicle Purchase or Lease Incentive Program, part of TERP administered by TCEQ. Qualified AFVs purchased on or after September 1, 2013, may be eligible for a rebate of $2,500 to assist with incremental vehicle cost. These incentives apply to electric and PHEVs weighing 8,500 lb or less and include a battery with at least a 4 kilowatt capacity. This rebate, which is limited to a maximum of 2,000 funded rebates during the state biennium beginning September 1, 2013, applies only to new vehicles and does not apply to vehicles purchased directly from a manufacturer or out-of-state dealer. Currently, 15 vehicle models are eligible under this program (*73*).

TCEQ also administers an Alternative Fueling Facilities Program as part of TERP. This program is administered in areas that are in nonattainment status for air quality and covers up to 50 percent of the eligible costs associated with the construction, reconstruction, or acquisition of facilities to store, compress, or dispense alternative fuels in Texas. Qualified alternative fuels under this program include biodiesel, electricity, natural gas, hydrogen, propane, and fuel mixtures containing at least 85 percent methanol. The cap on reimbursements under this program is $500,000. Entities receiving reimbursement under this grant program must agree to make fueling stations available to the public. This program ends August 31, 2018 (72).

Other TERP programs like the Emissions Reduction Incentive Grants (ERIG) Program and the TCEQ Texas Clean Fleet Program offer incentives or grants for various projects that improve air quality in the state. Eligible projects can include the replacement or purchase of new heavy-duty vehicles, alternative fuel use, or replacement of fleet vehicles with AFVs or HEVs. Qualifying AFV or HEV replacements must reduce emissions of nitrogen oxides or other pollutants by at least 25 percent as compared to baseline levels and must replace vehicles that meet operational and fuel usage requirements. TCEQ also administers the AirCheckTexas Drive a Clean Machine Program, which provides vehicle replacement assistance for qualified individuals owning vehicles registered in participating counties. Vouchers in the amount of $3,500 are available toward the purchase of a hybrid electric, battery electric, or natural gas vehicle that is up to three model years old.

The ERIG Program, administered by the TCEQ, provides grants for clean air projects in nonattainment areas. Eligible projects include (*74*):

- “Replacement, retrofit, repower, or lease or purchase of new heavy-duty vehicles.
- Alternative fuel dispensing infrastructure.
- Idle reduction and electrification infrastructure.
- Alternative fuel use.”

TCEQ administers the ERIG Program, which is also part of TERP, to provide grants for air-related projects that seek to improve air quality in nonattainment areas. Eligible projects include those that replace, retrofit, repower, lease, or purchase new heavy-duty vehicles; develop alternative fuel dispensing infrastructure; projects that reduce idling by heavy vehicles; and projects that promote electrification infrastructure and alternative fuel use.

Clean Fleet Grants

This TCEQ program, also administered as part of TERP, encourages diesel fleet owners to permanently remove vehicles from the road and replace them with AFVs or HEVs. Grants are provided to offset the incremental cost such projects would incur. Eligible entities must operate a fleet of at least 75 vehicles, including at least 20 diesel-powered vehicles, and must commit to placing 20 or more qualifying vehicles in service in Texas during a given calendar year. Qualifying vehicle replacements must reduce emissions of nitrogen oxides or other pollutants by at least 25 percent and must replace vehicles that meet certain operational and fuel usage requirements. Electric vehicles for use in a neighborhood setting do not qualify for this program, which is set to end August 31, 2017.

Alternative Fuel Vehicle Replacement Grants

The Railroad Commission of Texas administers the Low Emissions Alternative Fuels Equipment Initiative Program through its Alternative Energy Division. This program offers grants to those who wish to replace aging medium- or heavy-duty diesel school bus or delivery vehicles with qualified propane or NGVs. Replacement vehicles qualifying for the program must meet current U.S. EPA emissions standards, and grant amount is dependent upon estimated emissions reductions.

State Requirements for State Passenger Vehicle Fleets

The State of Texas also imposes requirements on the acquisition of AFVs for use in state fleets. State agencies with vehicle fleets of more than 15 vehicles (excluding emergency and law enforcement vehicles) are required to purchase or lease motor vehicles that use compressed or liquefied natural gas, propane, certain ethanol blends, certain methanol blends, certain biodiesel blends, or electricity (including PHEVs). Waivers to this requirement are provided if (*75*):

- "the fleet will operate primarily in areas where neither the state agency or a supplier can reasonably be expected to establish adequate fueling infrastructure for these fuels;" or
- "the agency is unable to obtain equipment or fueling facilities necessary to operate AFVs at a cost that is no greater than the net costs of using conventional fuels."

State agency fleets are required to be composed of at least 50 percent of vehicles able to operate on alternative fuels and operate using these fuels at least 80 percent of the time. State agencies can meet these requirements either through the purchase of new vehicles or the conversion of existing vehicles. Furthermore, state agencies that purchase passenger vehicles or other ground transportation vehicles for general use must ensure that at least 25 percent of the vehicles purchased during any state fiscal biennium meet or exceed certain federal emissions standards.

Regional

There are also regional incentives for alternative fuel commercial and passenger vehicles. The program types and eligibility requirements vary by region.

Commercial

In Texas, the Houston-Galveston Area Council (H-GAC) provides Congestion Mitigation and Air Quality Program grants through the Houston-Galveston Clean Cities Coalition and Clean Vehicles Program for up to 75 percent of the cost of clean vehicle or equipment replacement, AFV conversions and repowers, vehicle or equipment retrofits, and anti-idling technologies. Funding is also available for up to 75 percent of eligible equipment costs to establish alternative fueling infrastructure. In addition, the Clean Vehicles Program has state and local funds available to provide grants to local government entities and school districts. Grants are for eligible entities in the eight-county Houston–Galveston–Brazoria nonattainment area.

Researchers note that the Clean Vehicles Program in the H-GAC region is in place because this region is a severe nonattainment area with respect to the federal ground-level ozone standard. This program is part of a legally binding plan to reduce ozone pollution to safer levels by 2019.

Passenger Vehicles

In the Austin area, energy provider Austin Energy offers an Electric Vehicle Supply Equipment (EVSE) Incentive for the cost of installing charging equipment. Plug-in electric vehicle owners in the Austin Energy service area may be eligible for a rebate of 50 percent of the cost to purchase and install a qualified Level 2 EVSE. The maximum rebate amount is $1,500.

Conclusion on Market Penetration of Alternative Fuel Vehicles

Alternative fuel technologies and their adoption by the motoring public are being driven in large part by developments in the petroleum industry. Historical domestic reliance on fossil fuels makes the U.S. economy particularly vulnerable to shocks in the petroleum industry. These shocks manifest in wide fluctuations in gasoline and diesel prices, and high fuel prices over the past 10 years have increasingly pushed consumers to consider either more fuel-efficient ICE-based vehicles or AFVs. As shown in Figure 22 and Figure 23, the overall vehicle stock of ICE and AFV passenger and commercial vehicles is expected to continue increasing through 2040.

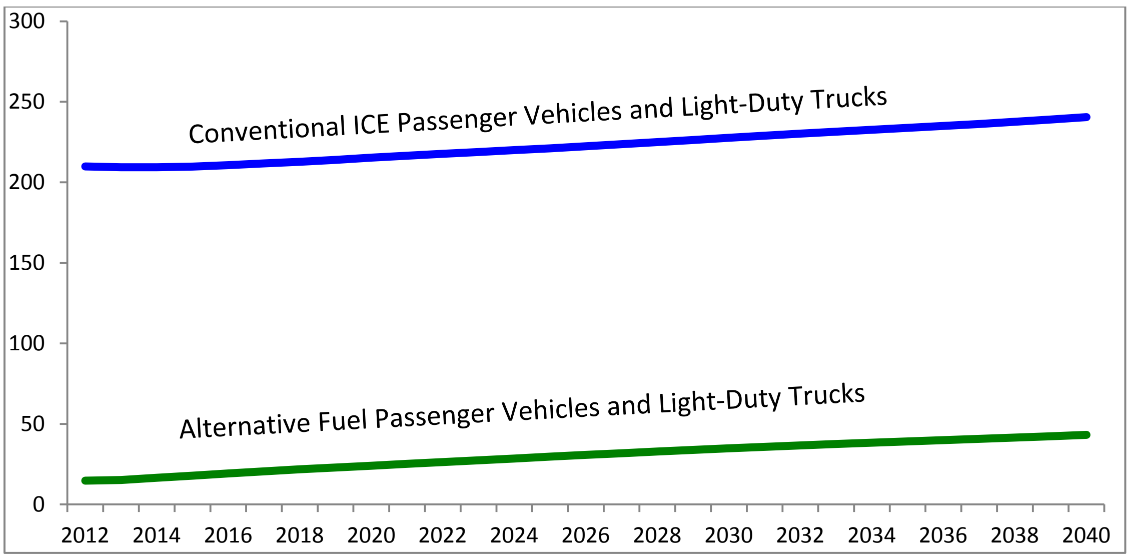


Figure 22. Projected U.S. Passenger Vehicle Stock (Millions) for 2012 through 2040.

Source: (8)

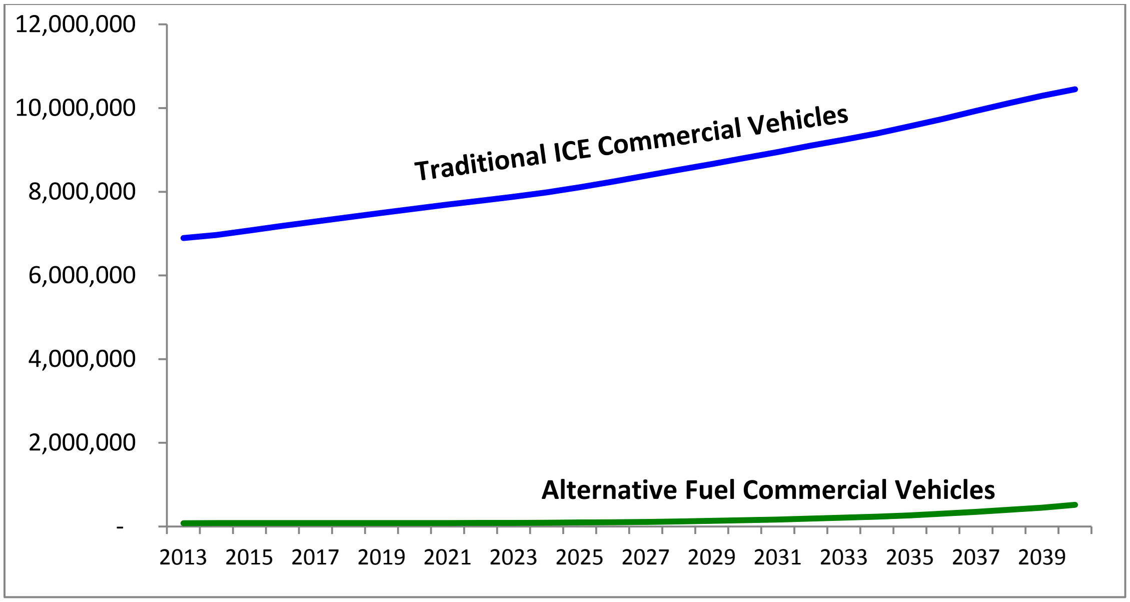


Figure 23. Projected U.S. Commercial Vehicle Stock (Millions) for 2012 through 2040.

Source: (8)

Alternative vehicle penetration will be most pronounced in the passenger vehicle stock, but traditional fuel vehicles will remain the most dominant vehicles on the roadway. In terms of the entire vehicle fleet, ethanol-based technologies such as flex-fuel applications are the most popular AFVs on the roadway followed by CNG and EVs. Ethanol utilization has increased significantly since 1998. Blended ethanol fuels and CNG are both taxed in a retail setting by the State of Texas. In the longer term, electric hybrids are anticipated to account for an increasing share of the alternative fuel passenger fleet. Conventional hybrids will account for most of the growth in AFV sales through 2040. Commercial vehicle sales through 2040 will still be dominated by traditional fuel vehicles; however, CNG applications will become more popular beginning in the 2020s as refueling infrastructure grows.

Alternative fuels face various challenges to mainstream adoption. From a lack of infrastructure to high capital and fueling infrastructure costs, these hurdles create challenges for the average consumer to replace a conventionally powered vehicle with an AFV. The following barriers are the most significant in terms of alternative fuel adoption in Texas: (a) lack of infrastructure, (b) high vehicle and operating costs, and (c) vehicle durability and reliability concerns. Table 7 describes these challenges and presents an overview of considerations for Texas policy makers. The subsections that follow summarize the barriers in greater detail.

Table 7. Summary of AFV Deployment Barriers and Considerations for Texas.

Barrier	Description	Texas Programs and Policies
Lack of Infrastructure	Most AFVs currently lack a robust fueling infrastructure network (such as that of petroleum-based fuels). Some fueling technologies (e.g., CNG, electric) have a distinct advantage over other technologies in terms of available refueling infrastructure (e.g., hydrogen).	Texas offers several programs that incentivize suppliers to construct alternative fueling infrastructure. The current alternative fueling infrastructure network in the state's urban areas (especially for plug-in electric and CNG vehicles) is robust compared to other large U.S. states.
High Vehicle and Operating Costs	AFV vehicle costs vary widely and can cost 20% to 300% more than a comparable conventional fuel vehicle. As AFV technology advances, the cost of a vehicle is projected to decrease.	The Light-Duty Vehicle Purchase or Lease Program, the Texas Natural Gas Vehicle Grant Program, and the AirCheckTexas Drive a Clean Machine Program are incentive programs for qualified buyers. Qualifying recipients may use the incentive toward the purchase of some AFVs. The continued use of these programs will likely encourage greater AFV adoption in Texas.
Vehicle Durability and Reliability Concerns	AFVs may not have the useful life that conventional fuel vehicles have. In particular, plug-in electric vehicles may need a battery replacement at least once during the vehicle's life cycle. However, as is the case with vehicle cost, reliability and durability will increase as AFV technology advances.	State programs and policies that incentivize the testing of AFVs could help to improve the long-term reliability of these vehicles.

Sources: U.S. DOE, TCEQ, and TTI

Lack of Infrastructure

One of the most important aspects of implementing AFV technology is locating or constructing the required fueling infrastructure. Most AFVs require unique infrastructure for refueling, which can present a barrier to adoption. This presents a problem where consumers are reticent to purchase an AFV if they cannot easily refuel a vehicle, as they are accustomed to with traditional fuels; refueling stations will not invest in the alternative fueling infrastructure without sufficient consumer adoption levels; and vehicle manufacturers will not produce AFVs unless there is sufficient consumer demand. As a result, each entity will not move first to adopt AFVs, and the status quo is likely to continue when all else is held equal. Outside factors such as changes in fuel supply, fuel prices, advances in technologies, investments by third parties, and government intervention can influence this cycle.

EVs in the passenger vehicle market may have an infrastructure advantage in comparison to other alternative fuels, which may influence adoption rates. Passenger EVs can be refueled in many consumers' homes through relatively minimal investments. Nearly 50 percent of households have an electric plug within 15 feet of their garage. According to data from U.S. DOE AFDC, as of June 2014, there are 463 public EV charging stations, 133 stations that are open to the public but require the customer to call ahead first, 96 private stations, and one planned station, for a total of 693 EV charging stations in Texas. Consumers can plug many EVs directly into a standard outlet, although these have relatively slow recharge times compared to a conventionally fueled vehicle. An additional investment will provide an upgraded system that greatly improves EV recharge times. Recharging infrastructure costs are occasionally subsidized through federal or state tax credits and rebates, but they may not cover the full price and/or may not be available to all consumers. Table 8 shows Texas passenger vehicle fuel stations by type compared to states with similar population sizes. In terms of plug-in electric vehicle stations, Texas currently has more total public, public call-ahead, private, and planned EV stations than Florida and New York, but fewer than California.

Table 8. Public, Public Call-Ahead, Private, and Planned Fueling Infrastructure in Texas and States with Similar Population.

Alternative Passenger Vehicle Fuel Station Type	Texas	Florida	California	New York
Plug-in Electric	693	559	2,188	455
Compressed Natural Gas	102	37	303	120
Ethanol/E85	104	58	95	85
Liquefied Petroleum Gas	482	70	48	68
Hydrogen Fuel Cell	1	0	67	8

Source: (45) Note: Total state fueling station counts include public, public call-ahead, private, and planned fueling stations.

As Figure 24 shows, EV charging stations have increased significantly in recent years. However, much of this growth can be attributed to how these stations were counted starting in 2011. For more information on this chart and to view a table of the associated data, please consult the appendix.

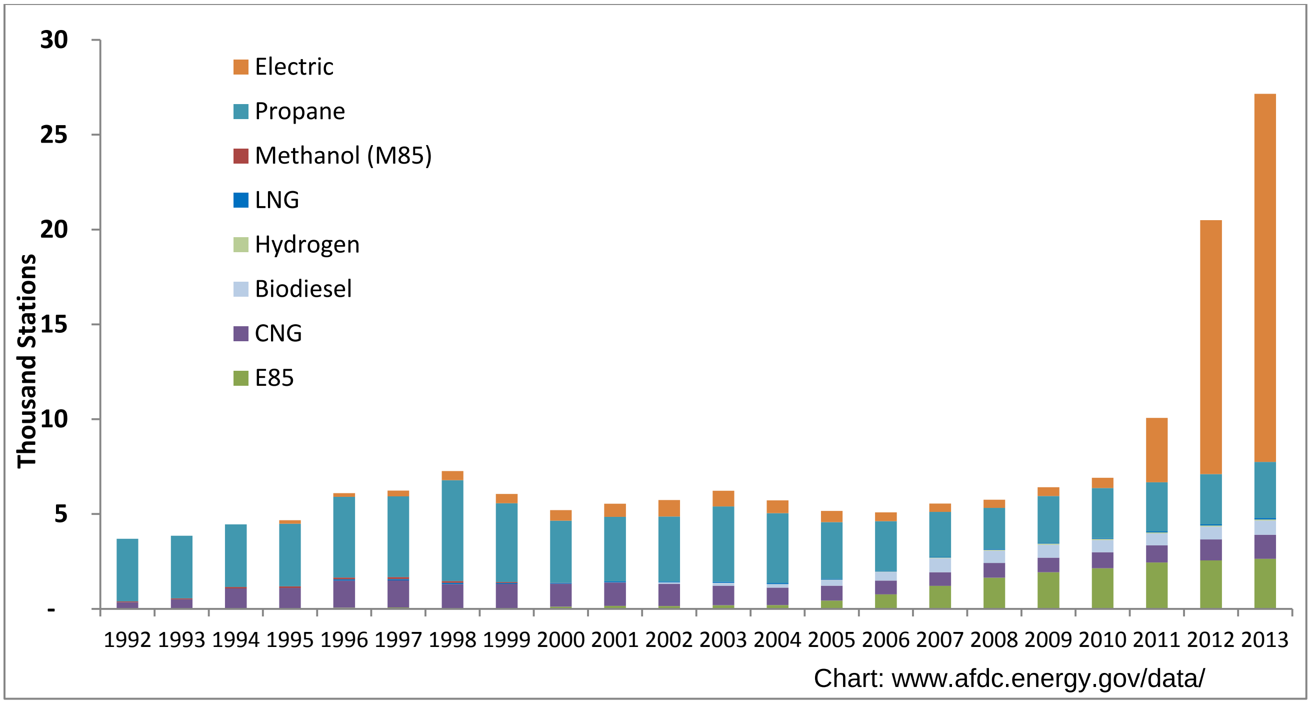


Figure 24. U.S. Alternative Fueling Station Count.

Source: (45)

Figure 25 illustrates that while Texas has a relatively robust AFV fueling infrastructure compared to other states of similar population, EV stations, CNG fueling stations, and E85 stations are primarily clustered in the state's metropolitan areas. A lack of fueling stations connecting major metropolitan areas will result in range anxiety and discourage additional consumer adoption.

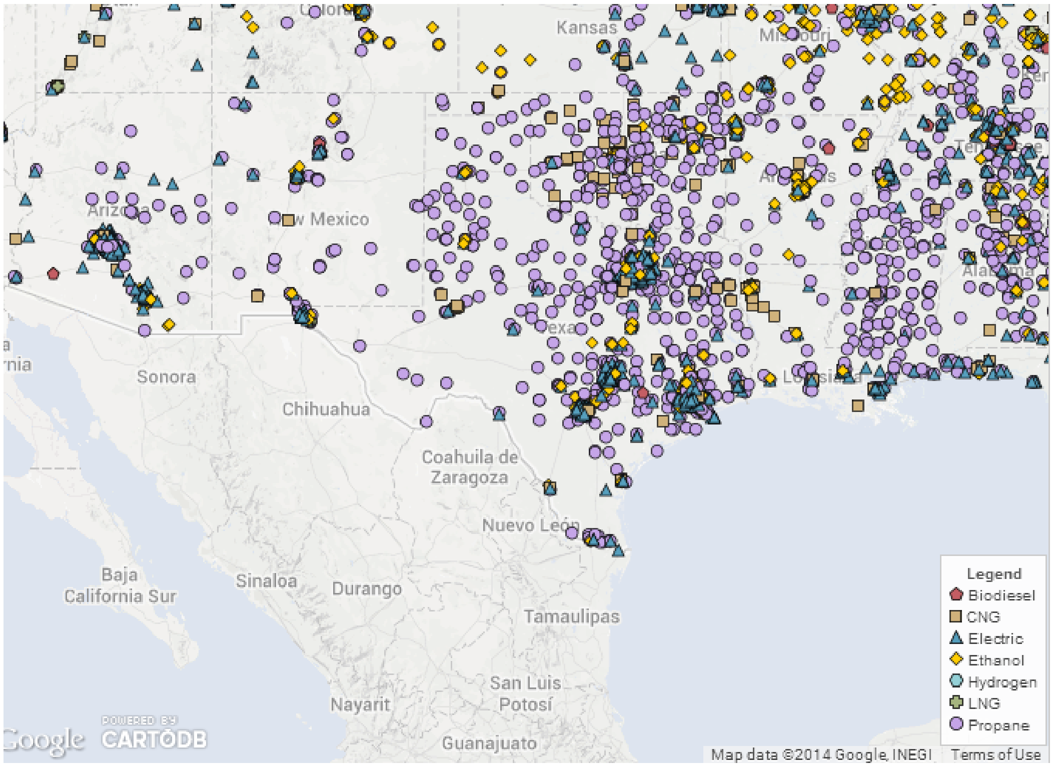


Figure 25. Alternative Fueling Stations in Texas.
Source: (76)

High Vehicle Purchase and Operating Costs

Another issue slowing AFV adoption rates is the comparatively high costs incurred in purchasing and maintaining an AFV. Generally, the upfront cost for an AFV is more than a similar standard vehicle. For example, the price differential between the 2014 Honda Civic base model gasoline-powered car and the Honda CNG model car is $8,250. The price differential between the gasoline-powered Nissan Versa Note and the fully electric Nissan Leaf (similar body style) is $7,490. Alternative fuel vehicle price premiums represent a nearly 50 percent increase over the gasoline-powered base model vehicle pricing, possibly creating a substantial barrier to adoption for many Texans.

While some AFVs have federal and state incentives subsidizing the vehicle purchase price, these tax credits are often insufficient, funding quickly runs out, or the programs simply expire and not extended.

The costs associated with fueling some AFV applications can be greater than the costs associated with gasoline or diesel, while other applications can have a lower refueling cost. Such costs, coupled with the price of oil and especially the cost of its derivatives, are notably volatile. Therefore, making definitive statements about comparative fuel cost savings can be difficult. If the alternative fuel has a sufficiently lower price differential over the long term than the traditionally powered vehicle, the consumer drives a sufficient number of miles, and the purchase price differential is sufficiently low, the individual can eventually save money over the purchase price—all other things held equal. The ability for the customer to receive a return on investment relies on a variety of factors, including vehicle capital costs, annual mileage, infrastructure costs, and ongoing maintenance costs, among other factors.

Maintenance costs are another variable that can affect the financial feasibility of an AFV. Newer technologies often have higher maintenance costs, as there is often a scarcity of skilled labor and parts for the AFV. This scarcity can result in higher costs, making these vehicles less attractive from the customer's perspective. Some AFVs could actually have lower maintenance costs than conventionally fueled vehicles. The powertrain simplicity of an EV, for example, could reduce the amount of maintenance required, potentially decreasing costs. Unfortunately, this factor is highly variable and data are limited, making maintenance costs difficult to precisely estimate.

Other maintenance costs can also drive up costs for AFVs. For example, replacing an EV's battery after its useful life has lapsed could be costly for the average consumer. Using the midpoint of $650/kW from the IEA cost range for current battery replacement, researchers estimate that replacing the Ford Fusion Energi's 7.6 kW battery would be about $5,000. Depending on the usable life of the battery, this could be a significant cost for the average consumer and potentially affect the vehicle's resale value.

However, alternative vehicle capital costs are likely to decline as production quantities increase (economies of scale)—an economic cycle that is exhibited with most new technologies. Still, current projections indicate that AFV technology is not likely to make up a significant portion of the U.S. passenger vehicle market. Most of the predicted growth will occur in ethanol and hybrid vehicles, vehicles that will still require gasoline or diesel as a primary fuel. The U.S. EIA 2014 Annual Energy Outlook provides forecasts up to 2040 for the U.S. light-duty vehicle market. EIA forecasts the most growth in micro-hybrid vehicles and flexible fuels in the light-duty vehicle market and includes the following observations (*8*):

- Overall, this report projects that new vehicle sales of light-duty diesel, alternative fuel, hybrid electric, and all-electric systems will increase from 18 percent in 2012 to 55 percent by 2040.
- Micro-hybrid vehicles, defined as conventional gasoline vehicles, represent 33 percent of new vehicle sales by 2040.
- Flexible-fuel vehicles, which can use blends up to 85 percent ethanol, represent about 11 percent of total new light-duty vehicle sales in 2040.

Texas has several incentive programs that could increase the rate at which AFVs could penetrate the Texas passenger vehicle market. According to data provided by U.S. DOE AFDC and TCEQ, several state programs offer limited incentives to qualified individuals that help reduce the overall cost consumers pay for certain AFVs.

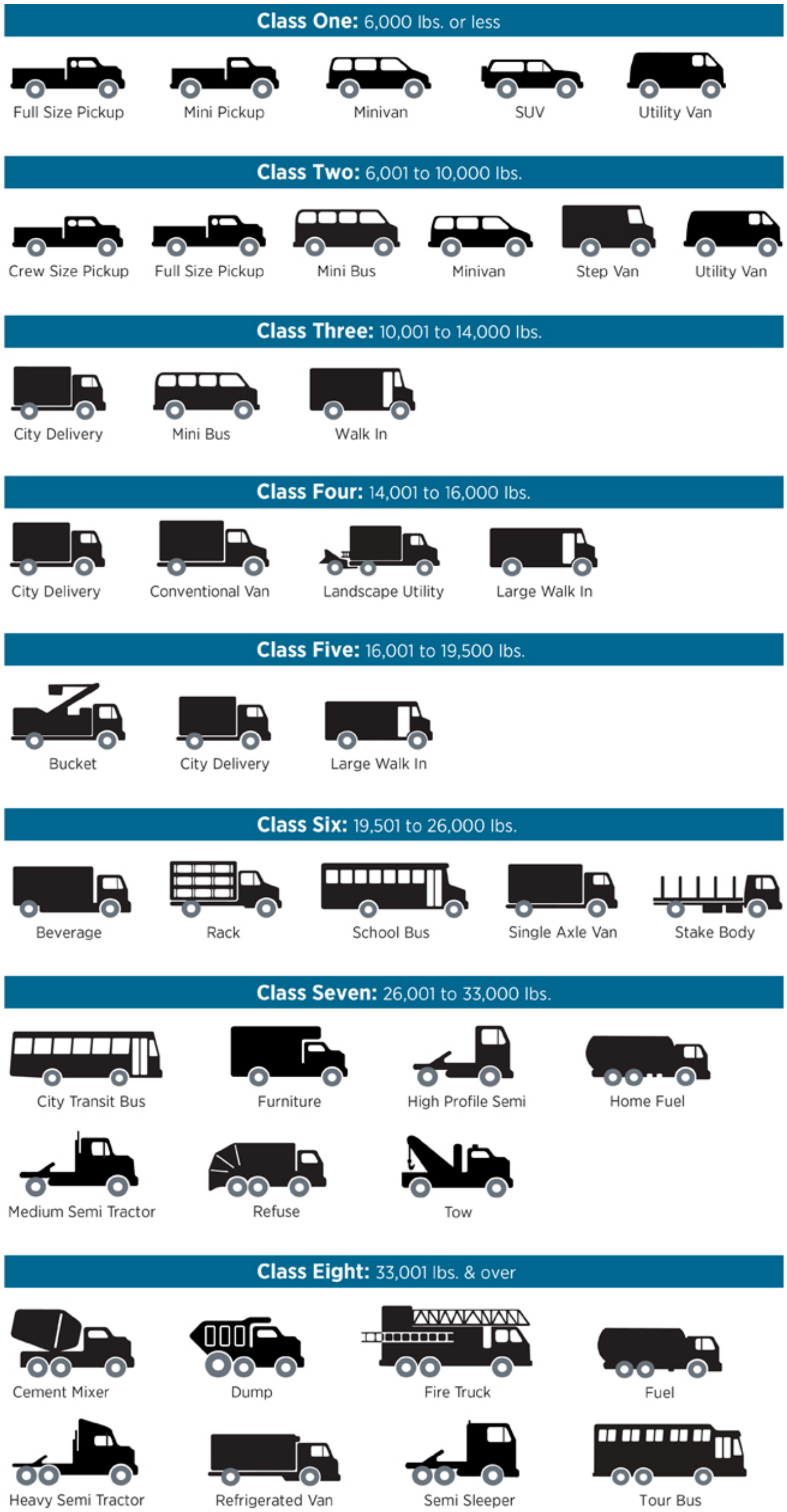
Vehicle Durability, Reliability, and Public Perception

Consumers can be hesitant to consider purchasing an AFV because AFVs can be perceived as unreliable, costly, and lacking in fueling infrastructure, possibly leaving them stranded on the side of the road. For an AFV customer to receive a return on his or her investment, the vehicle must have lower operating costs over time. If a vehicle regularly breaks down, has high maintenance costs, or is otherwise unreliable, it can quickly lose its ability to repay the initial investment. For example, the fuel cells in FCVs must be replaced every 20,000 to 30,000 miles. This service costs $10,000 to $15,000 each time, making the vehicle exceedingly unattractive from the customer's perspective. Any AFV that hopes to achieve widespread acceptance must be cost competitive with conventionally fueled vehicles.

Range anxiety is an especially bothersome concern that frequently arises in the discussion around AFVs. Consumers worry that if there is insufficient fueling infrastructure or their vehicle has comparatively poor range—like with EVs—they will be left stranded without a way to refill or recharge their vehicle. With EVs, this problem has somewhat abated recently, as the number of charging stations has grown drastically in the last few years. Still, electric and other AFV owners will have to contend with this concern until Texas has a sufficiently robust refueling infrastructure and the vehicle technologies have improved range.

Appendix

Types of Vehicles by Weight Class



Source: (77)

Types of Incentives for AFVs

Incentive Type	Details
Grants	Require the most paperwork and planning. Provide significant funding—sometimes up to 100% of project costs. Most require progress reports and recordkeeping after funds are awarded. If the project and records are in compliance, the funds do not need to be repaid.
Rebates and Vouchers	Available for a specific vehicle or piece of equipment, and must use it for a specific purpose by a specific date. May need to provide receipts, purchase orders, and original equipment manufacturer certificates.
Low-Cost Loans	Help smaller companies with less-than-perfect credit ratings obtain financing for heavy-duty vehicle fuel efficiency projects by offering low interest rates and down payments. Must pay back the funds received, plus interest and fees, within a specified timeframe.
Tax Credits	Directly reduce tax liability. Many states offer AFV tax credits when entity purchases or converts a vehicle to operate on an alternative fuel. Credits are typically available one time per vehicle and range from a few hundred to a few thousand dollars. Credits are then claimed on the tax return. Do not need to supply receipts and purchase orders to the IRS; good practice to retain receipts and purchase orders for records.
Tax Exemptions	Available at the point of purchase on qualified items, such as fuel and idle reduction equipment. Not required to file paperwork to receive a tax exemption; good practice to retain receipts and purchase orders for records.

Source: (65)

Public CNG Fueling Stations in Texas

Station Name	City	State	ZIP
North Texas			
Clean Energy—Dallas/Fort Worth Airport Rental Car Center	Irving	TX	75261
Clean Energy—South Dallas	Dallas	TX	75215
CNG Texas	Dallas	TX	75218
Clean Energy—Deep Ellum Central Service Center	Dallas	TX	75226
Clean Energy—Cockrell Hill	Dallas	TX	75211
Clean Energy—Dillon Transport	Dallas	TX	75247
Clean Energy—Love Field Airport	Dallas	TX	75235
Clean Energy—City of Dallas—NW Service Center	Dallas	TX	75220
Clean Energy—Downtown Dallas	Dallas	TX	75207
Clean Energy—Downtown Dallas	Dallas	TX	75207
Clean Energy—Fort Worth South	Fort Worth	TX	76140
Clean Energy—Fort Worth	Fort Worth	TX	76161
Clean Energy—Mesquite	Mesquite	TX	75149
Clean Energy—Garland	Garland	TX	75042
Classic Clean Fuels	Grapevine	TX	76051
Clean Energy—Valero Cowboys Stadium	Arlington	TX	76011
Clean Energy—Dallas/Fort Worth Airport North	Irving	TX	75063
Clean Energy—Dallas/Fort Worth Airport South	Irving	TX	75261
Clean Energy—City of Irving	Irving	TX	75061
Peake Fuel Solutions	Cleburne	TX	76033
South Texas			
Apache El Campo—UnitedAg	El Campo	TX	77437
City of Corpus Christi Gas Department	Corpus Christi	TX	78415
City of Laredo—Public Access	Laredo	TX	78041
City of Corpus Christi Gas Department	Corpus Christi	TX	78415
East Texas			
Clean Energy—Parking Spot Houston	Houston	TX	77032
Questar Fueling—Houston	Houston	TX	77028
Apache Houston	Houston	TX	77056
Clean Energy—Texas Department of Transportation	Houston	TX	77007
Freedom CNG	Houston	TX	77066
Clean Energy—O'Rourke	Houston	TX	77029
Freedom CNG	Houston	TX	77034
Trillium CNG—City of Beaumont	Beaumont	TX	77701

Station Name	City	State	ZIP
CNG 4 America—Bryan	Bryan	TX	77807
Clean N' Green—Waste Management	Conroe	TX	77301
Peake Fuel Solutions	Marshall	TX	75672
First Alt Fuel Inc	Tyler	TX	75702
Independence Fuel Systems	Longview	TX	75602
Independence Fuel Systems	Carthage	TX	75633
Love's Travel Stop #468	Willis	TX	77378
Central Texas			
Trillium CNG—City of Austin—Public Access	Austin	TX	78744
Clean Energy—Austin Bergstrom International Airport	Austin	TX	78719
Clean Energy—San Antonio Flying J #737	San Antonio	TX	78244
West Texas			
Trillium CNG—Pinnacle—Midland	Midland	TX	79703
Apache Midland—Stripes #207	Midland	TX	79705
Apache Midland—Stripes #2285	Midland	TX	79702
Apache Andrews	Andrews	TX	79714

Source: AFDC

Estimated Fuel Taxes Paid per 100 Miles of Travel by Vehicle Type

Fuel Type	Vehicle Type	2014 Fuel Efficiency (Miles per Gallon)	Gallons Consumed per 100 Miles	Fuel Taxes Paid per 100 Miles
Gasoline	Compact Cars	36.2	2.76	$ 0.55
	Midsize Cars	36.7	2.73	$ 0.55
	Large Cars	31.8	3.15	$ 0.63
	Small Pickup	25.0	4.00	$ 0.80
	Large Pickup	27.3	3.67	$ 0.73
	Small Utility	30.4	3.29	$ 0.66
	Large Utility	25.7	3.89	$ 0.78
Turbo Direct Injection Diesel	Compact Cars	45.1	2.22	$ 0.44
	Midsize Cars	45.6	2.19	$ 0.44
	Large Cars	39.2	2.55	$ 0.51
	Small Pickup	30.8	3.25	$ 0.65
	Large Pickup	33.8	2.96	$ 0.59
	Small Utility	37.3	2.68	$ 0.54
	Large Utility	31.4	3.19	$ 0.64
Plug-in 10 Gasoline Gasoline Hybrid	Compact Cars	60.5	1.65	$ 0.33
	Midsize Cars	60.1	1.66	$ 0.33
Plug-in 40 Gasoline Gasoline Hybrid	Compact Cars	75.9	1.32	$ 0.26
	Midsize Cars	71.4	1.40	$ 0.28
Ethanol Flex	Compact Cars	36.6	2.73	$ 0.55
	Midsize Cars	37.0	2.70	$ 0.54
	Large Cars	32.1	3.12	$ 0.62
	Small Pickup	25.2	3.96	$ 0.79
	Large Pickup	27.5	3.63	$ 0.73
	Small Utility	30.7	3.26	$ 0.65
	Large Utility	25.9	3.85	$ 0.77
Compressed/ Liquefied Natural Gas	Compact Cars	39.0	2.56	$ 0.38
	Large Cars	34.2	2.92	$ 0.44
	Large Pickup	29.4	3.40	$ 0.51
Propane	Large Cars	33.0	3.03	$ 0.45
	Large Pickup	28.3	3.53	$ 0.53
Electric Vehicles	Compact Cars	137.8	0.73	$ 0.15
	Midsize Cars	125.4	0.80	$ 0.16
	Large Cars	125.3	0.80	$ 0.16
	Small Utility	104.7	0.96	$ 0.19
Gasoline-Electric Hybrid	Compact Cars	51.8	1.93	$ 0.39
	Midsize Cars	52.5	1.91	$ 0.38
	Large Cars	45.3	2.21	$ 0.44
	Large Pickup	38.9	2.57	$ 0.51
	Small Utility	42.9	2.33	$ 0.47
	Large Utility	36.3	2.76	$ 0.55

Source: (8)

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