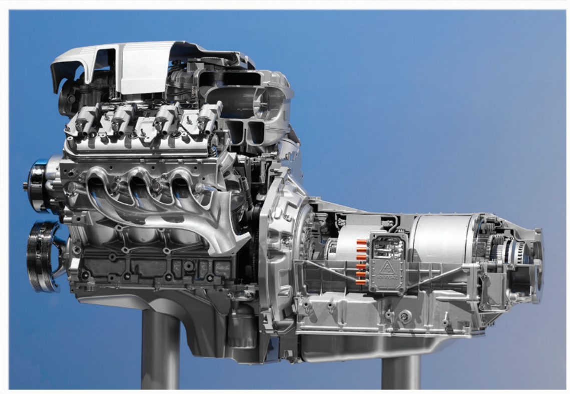
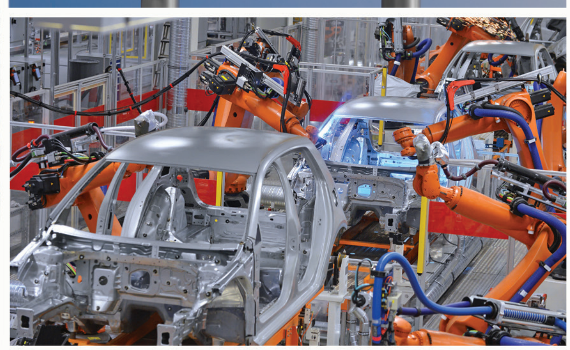
2016 Vehicle Technologies Market Report



Oak Ridge National Laboratory

Quick Facts

Energy and Economics

- Transportation accounts for about 28% of total U.S. energy consumption.
- The average price of a new light vehicle was nearly $32,000 in 2016.
- In 2015, about 17% of household expenditures were for transportation.
- Over 10 million people were employed in the transportation industry in 2015.

Light Vehicles

- Thirteen percent of vehicles worldwide were produced in the United States in 2015.
- U.S. new light truck sales volumes rose each year from 2011 to 2016 while new car sales continued to fall from 2014 to 2016.
- Sales-weighted data on new light vehicles sold show a 120% increase in horsepower and a 47% improvement in acceleration (0-60 time) from 1980 to 2016, with the fuel economy of vehicles improving 33%.
- More than 26% of new cars sold in 2016 had continuously variable transmissions.
- More than 90% of new light vehicles sold in 2016 have transmissions with 6 speeds or more.

Heavy Trucks

- Class 8 combination trucks consumed an average of 6.5 gallons per thousand ton-miles (2010 data).
- Class 3 truck sales increased by 33% from 2012 to 2016.
- Sales of class 4-7 trucks increased by 38% from 2012 to 2016.
- Class 8 truck sales decreased 23% from 2015 to 2016.
- Diesel vehicle sales of Class 4 trucks declined 70% from 2011-2015 while increasing 4% for Class 6 trucks.
- In 2015, combination trucks were driven an average of almost 62,000 miles per year, down from over 68,000 miles in 2013.
- Idling a truck-tractor's engine can use half a gallon of fuel per hour or more.
- There are 106 electrified truck stop sites across the country to reduce truck idling time.

Technologies

- Fuel injection was one of the quickest technology penetrations, with nearly 100% of market share after 16 years.
- Gasoline direct injection captured 49% market share in just nine years from first significant use.
- About 347,000 hybrid vehicles were sold in 2016, down from a high of 496,000 in 2013.
- All-Electric vehicle sales increased to over 87,000 units in 2016, while plug-in hybrid vehicle sales increased to over 70,000 units.
- At least 12 different models of all-electric vehicles and 17 models of hybrid-electric plug-in vehicles are available for model year 2017.
- There are more than 40,000 electric vehicle charging units throughout the nation in 2016.
- Single wide tires on a Class 8 truck improve fuel economy by more than 7% on flat terrain.

Policy

- Purchasers of plug-in hybrids and electric vehicles receive a Federal tax credit of up to $7,500 for select 2015-2017 vehicles along with possible state credits.
- The proposed EPA greenhouse gas standards for cars raises average fuel economy for new cars to 54.5 mpg by 2025, while the NHTSA Corporate Average Fuel Economy Standards are 49.7 mpg by 2025. These average fuel economies were estimated by the two agencies based on the new corporate standards and product plans.
- Since model year 2010, diesel engine emission standards are stricter – 0.2 grams per horsepower-hour (g/HP-hr) for nitrogen oxides and 0.01 g/HP-hr for particulate matter.

ORNL/TM-2017/238

2016 VEHICLE TECHNOLOGIES MARKET REPORT

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Prepared for the
Vehicle Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, TN 37831-6073
Managed by
UT-BATTELLE, LLC
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-00R22725

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Introduction

Welcome to the *2016 Vehicle Technologies Market Report*. This is the eighth edition of this report, which details the major trends in U.S. light-duty vehicle and medium/heavy truck markets. This report is supported by the U.S. Department of Energy's (DOE) Vehicle Technologies Office (VTO), and, in accord with its mission, pays special attention to the progress of high-efficiency and alternative-fuel technologies.

After opening with a discussion of energy and economics, this report features a section each on the light-duty vehicle and heavy/medium truck markets, and concluding with a section each on technology and policy. The first section on Energy and Economics discusses the role of transportation energy and vehicle markets on a national (and even international) scale. For example, Figures 12 through 14 discuss the connections between global oil prices and U.S. GDP, and Figures 21 and 22 show U.S. employment in the automotive sector. The following section examines Light-Duty Vehicle use, markets, manufacture, and supply chains. Figures 27 through 69 offer snapshots of major light-duty vehicle brands in the United States and Figures 73 through 85 examine the performance and efficiency characteristics of vehicles sold. The discussion of Medium and Heavy Trucks offers information on truck sales (Figures 94 through 98) and fuel use (Figures 101 through 104). The Technology section offers information on alternative fuel vehicles and infrastructure (Figures 109 through 123), and the Policy section concludes with information on recent, current, and near-future Federal policies like the Corporate Average Fuel Economy standard (Figures 135 through 142).

In total, the information contained in this report is intended to communicate a fairly complete understanding of U.S. highway transportation energy through a series of easily digestible nuggets. On behalf of the DOE and VTO, I hope that you explore and find value in this report. Suggestions for future expansion, additional information, or other improvements are most welcome.

Sincerely,

Rachael Nealer
Vehicle Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

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CHAPTER 1

ENERGY AND ECONOMICS

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Transportation Accounts for 28% of Total U.S. Energy Consumption

In 2015, the transportation sector used 27 quadrillion Btu of energy, which was 28% of total U.S. energy use. Nearly all of the energy consumed in this sector is petroleum (92%), with small amounts of renewable fuels (5%) and natural gas (3%). With the future use of plug-in hybrids and electric vehicles, transportation will begin to use electric utility resources. The electric utility sector draws on the widest range of sources and uses only a small amount of petroleum (1%).

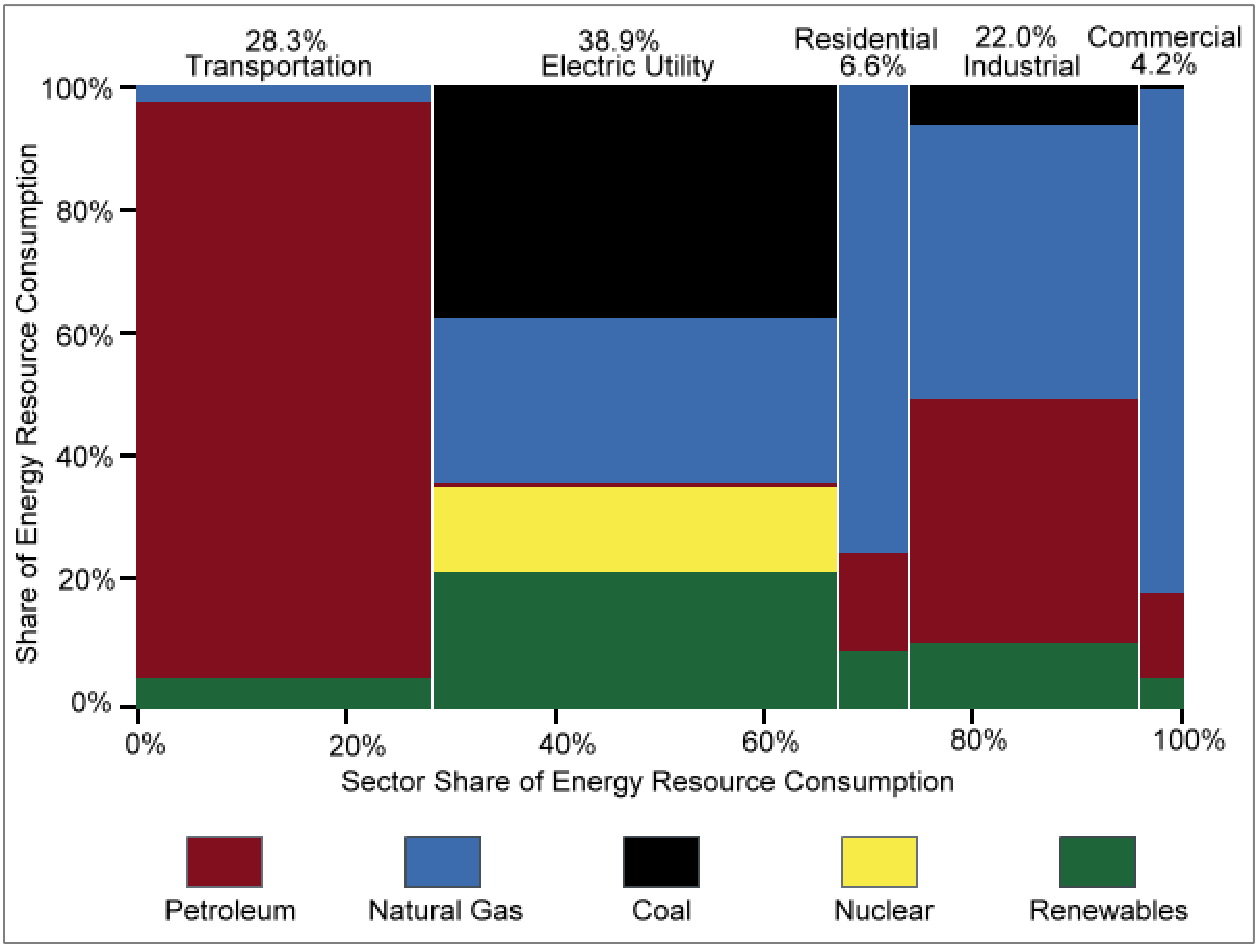


FIGURE 1. U.S. Energy Consumption by Sector and Energy Source, 2015

Source:

Energy Information Administration, *Monthly Energy Review, November 2016*, Tables 2.2, 2.3, 2.4, 2.5, and 2.6. http://www.eia.gov/totalenergy/data/monthly

The Transportation Sector Currently Uses about the Same Amount of Petroleum as Produced by the United States

Petroleum consumption in the transportation sector surpassed U.S. petroleum production for the first time in 1989, creating a gap that must be met with imports of petroleum. By 2015 the gap had disappeared and the United States produced about the same amount of petroleum as the transportation sector used. Current projections show that conventional sources will more than meet transportation demand in the coming years. Combined with non-petroleum sources, such as ethanol, biomass, and liquids from coal, the Energy Information Administration projects that production will be about 17 million barrels per day in 2050.

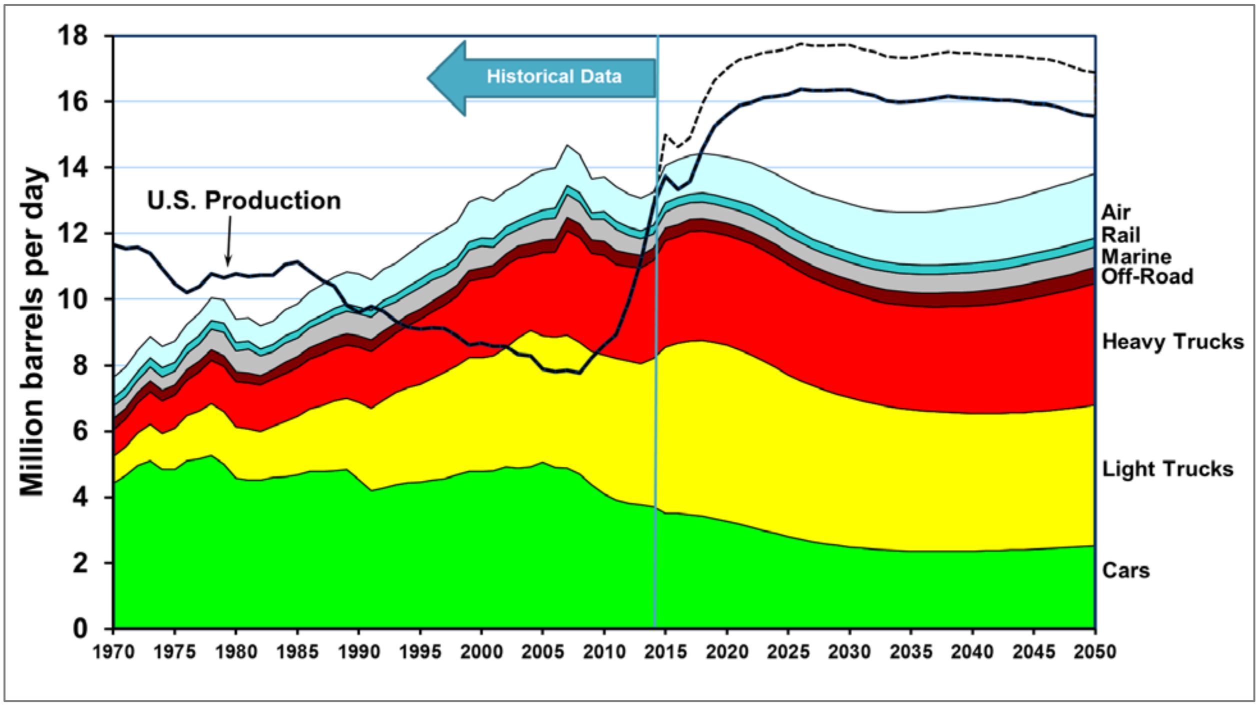


FIGURE 2. Transportation Petroleum Use by Mode and the U.S. Production of Petroleum, 1970-2050

Note: The U.S. production has two lines after 2014. The solid line is conventional sources of petroleum, including crude oil, natural gas plant liquids, and refinery gains. The dashed line adds in other non-petroleum sources, including ethanol, biomass, liquids from coal, other blending components, other hydrocarbons, and ethers. The sharp increase in values between 2014 and 2015 is caused by the data change from historical to projected values. The sharp increase in values for heavy trucks between 2006 and 2007 is the result of a methodology change in the Federal Highway Administration data.

Sources:

1970-2014: Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 35*, Oak Ridge, TN, 2016. http://cta.ornl.gov/data

2015-2050: Energy Information Administration, *Annual Energy Outlook 2016*, Washington, DC, 2016. http://www.eia.gov/forecasts/aeo/index

Class 8 Trucks Use the Majority of Fuel Consumed by Medium/Heavy Trucks

Class 8 trucks comprise only 41% of the heavy- and medium-truck fleet, but they account for 78% of the fuel consumed by medium and heavy trucks. Though more than half of all medium and heavy trucks are Class 3-6, they use less than one-quarter of total fuel. Class 3-6 trucks tend to have higher fuel economy than Class 7-8 trucks and are typically driven fewer miles.

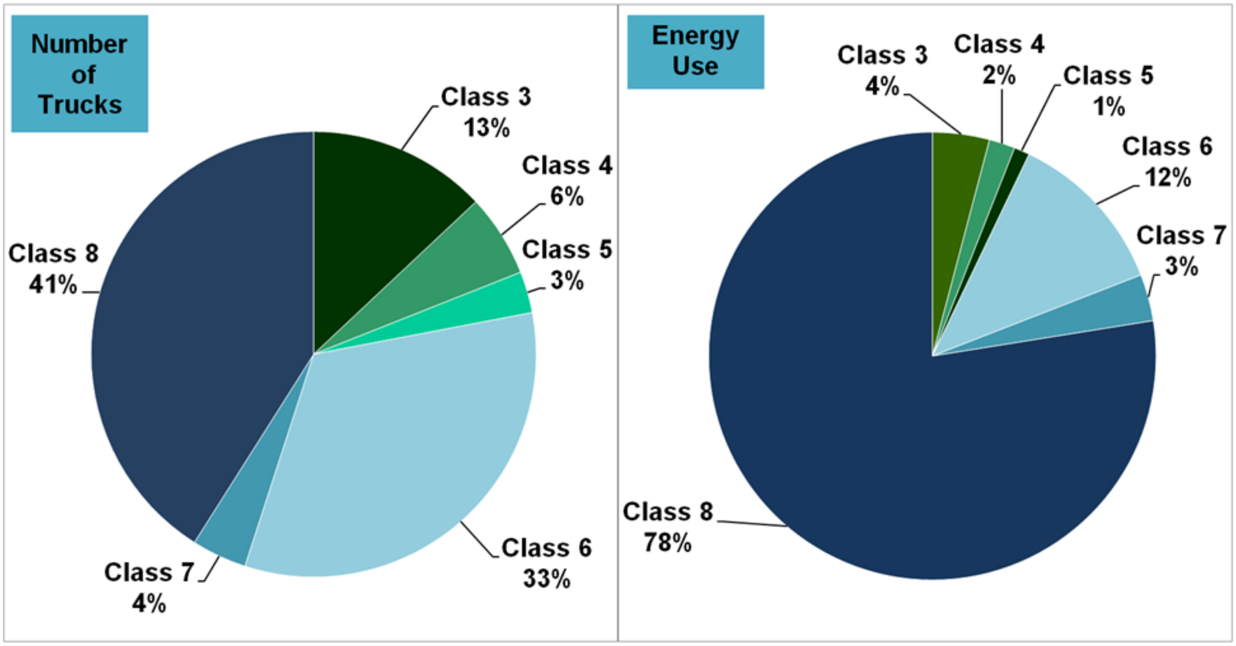


FIGURE 3. Medium and Heavy Truck Fleet Composition and Energy Usage, 2002

Note: See page 115 for truck class definitions. Data for 2002 are the latest available.

Source:
Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 35*, Oak Ridge, TN, 2016. http://cta.ornl.gov/data

Improvements in Fuel Economy for Low-MPG Vehicles Yield the Greatest Fuel Savings

The relationship between gallons used over a given distance and miles per gallon (mpg) is not linear. Thus, an increase in fuel economy by 5 mpg does not translate to a constant fuel savings amount. Trading a low-mpg car or truck for one with just slightly better mpg will save more fuel than trading a high-mpg car or truck for one that is even higher. For example, trading a truck that gets 10 mpg for a new one that gets 15 mpg will save 33 gallons of fuel for every 1,000 miles driven. In contrast, trading a 30-mpg car for a new car that gets 35 mpg will save 5 gallons of fuel for every 1,000 miles driven.

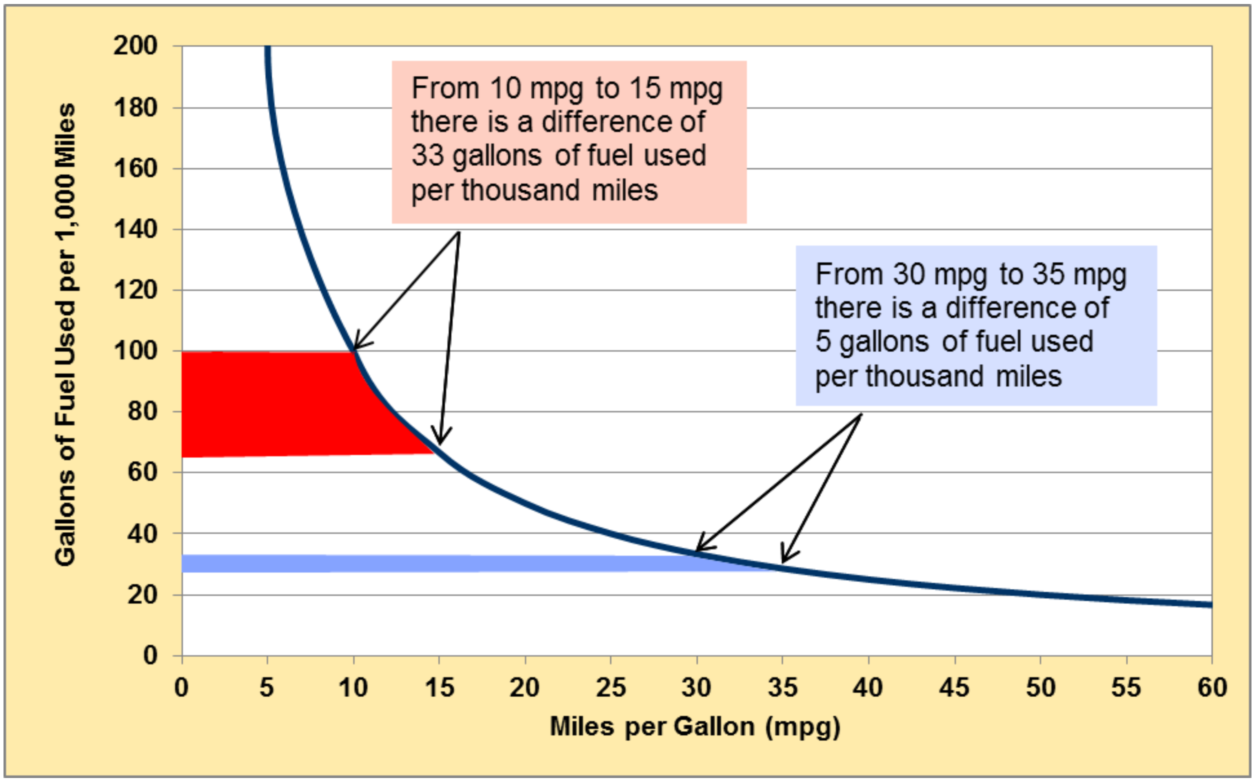


FIGURE 4. Fuel Use versus Fuel Economy

Note: Each category on the horizontal axis shows a five-mile per gallon improvement in fuel economy.

Source:
U.S. Department of Energy fuel economy data http://www.fueleconomy.gov.

Carbon Dioxide Emissions from Transportation Nearly Level Over Past Five Years

Since 2009 total carbon dioxide emissions (CO_2) from the transportation sector have remained just over 1,700 million metric tons (MMT), down from a high of 1,891 MMT in 2007. The influences of rising vehicle efficiency and increasing travel may be factors. The increased use of ethanol in gasoline may also have played a role in lowering CO_2 emissions.

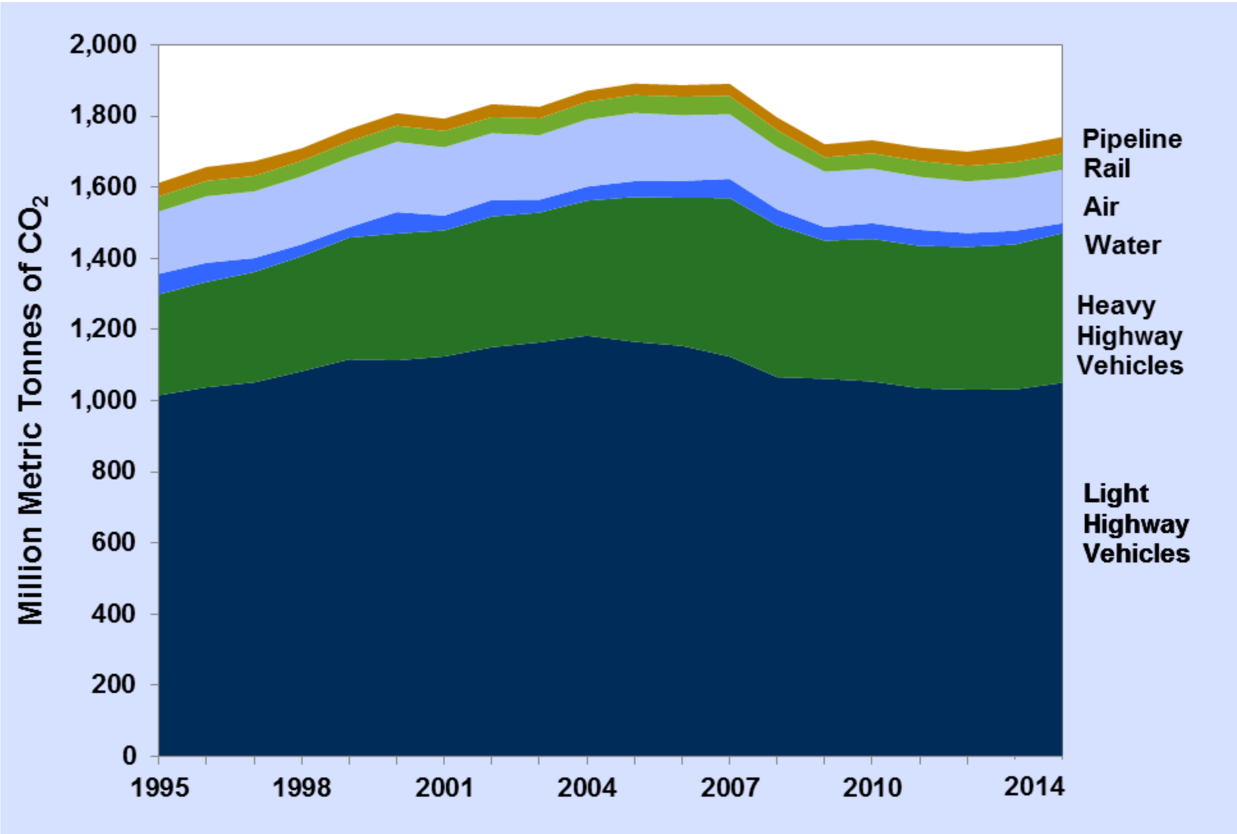


FIGURE 5. Transportation Carbon Dioxide Emissions, 1995-2014

Note: International Bunker Fuels were not included in these calculations.

Source:

U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks*: 1990-2014, Table 3-12, April 2016. www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014

Examples of Model Year 2016 Cars that Pollute Less Despite Increases in Size

As new vehicles become more efficient, the amount of carbon dioxide (CO_2) they produce decreases. Shown below are several examples of model year (MY) 2016 cars that have decreased the amount of CO_2 they produce (in grams per mile) despite the fact that they are the same size or larger (in interior volume) than they were ten years ago. Of the examples, the Hyundai Sonata and Kia Optima had the largest decline in CO_2 emissions in the ten-year period, and the Honda Civic had the greatest increase in interior volume while still reducing CO_2 emissions.

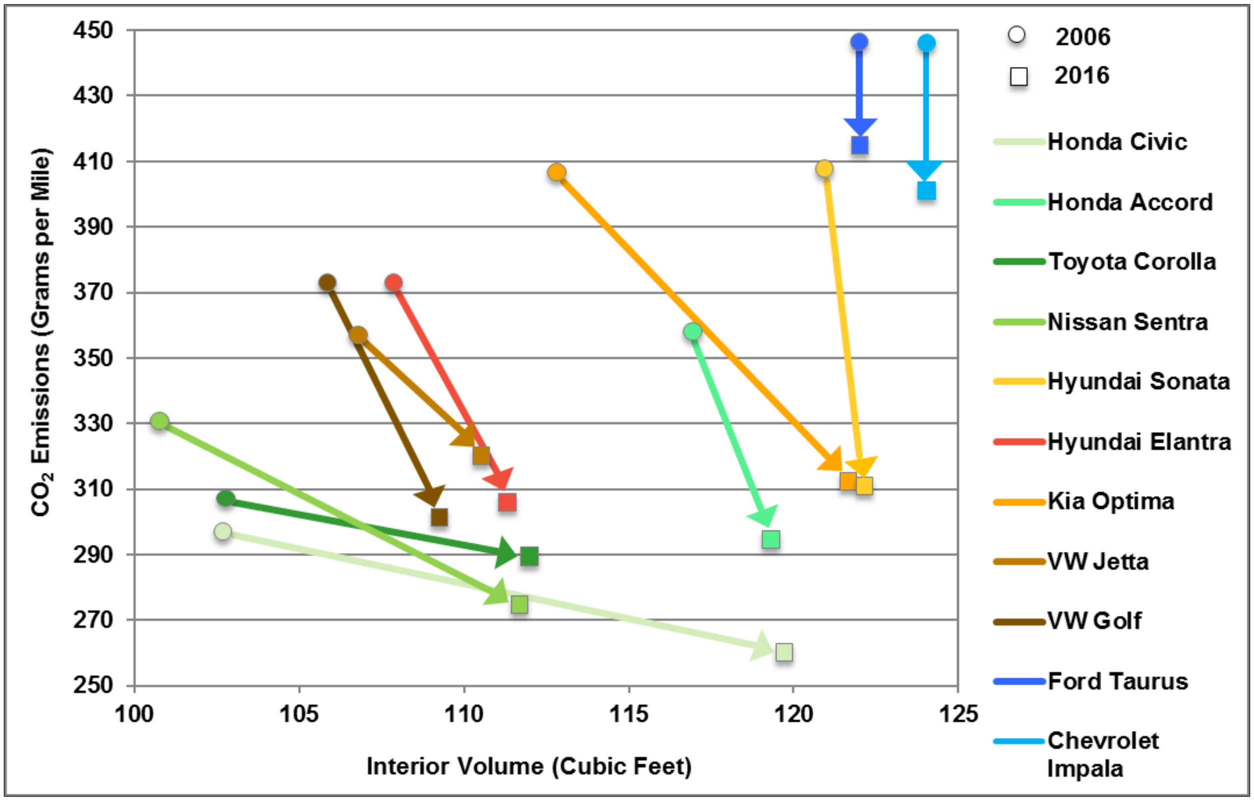


FIGURE 6. Carbon Dioxide Emissions versus Interior Volume for Selected MY 2016 Cars

Source:
U.S. Department of Energy fuel economy data, accessed December 2016. http://www.fueleconomy.gov.

Newer Cars and Light Trucks Emit Fewer Tons of CO_2 Annually

The carbon footprint measures a vehicle's impact on climate change in tons of carbon dioxide (CO_2) emitted annually. In model year (MY) 2016 the sales-weighted average of CO_2 emitted by new cars was 5.7 metric tons annually per car. For new light trucks, the average was 7.9 metric tons annually per truck.

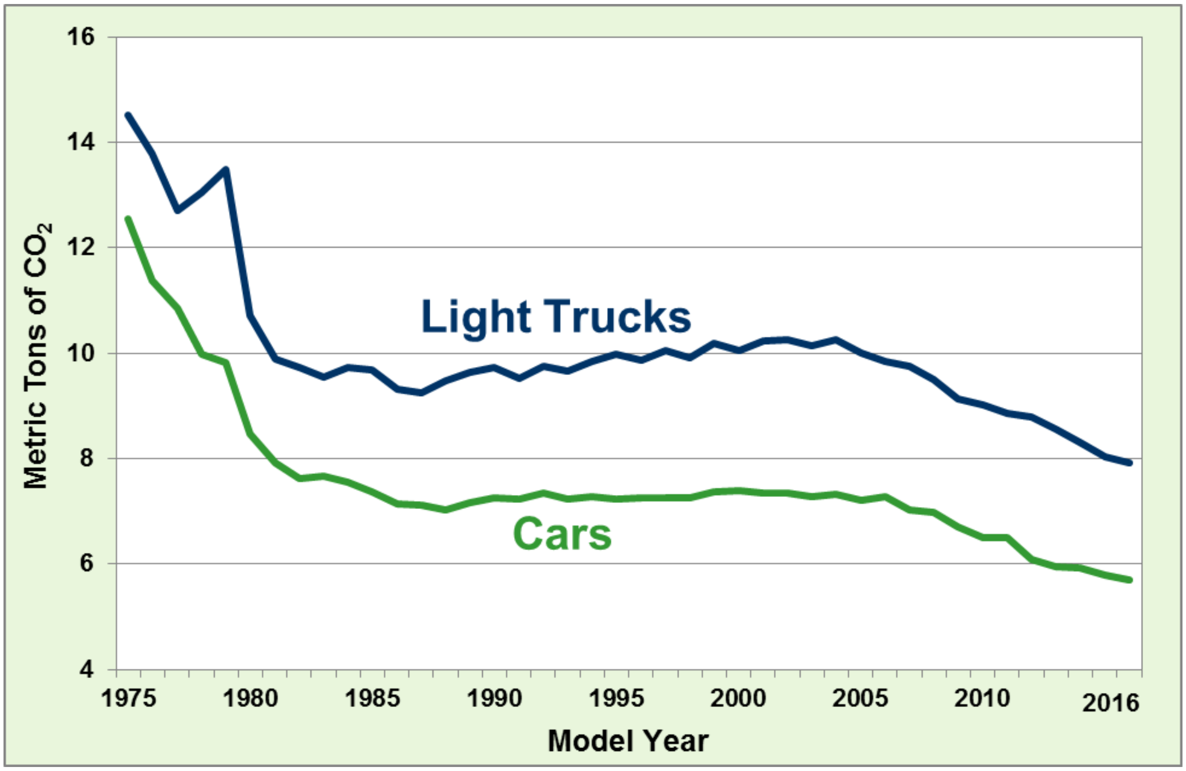


FIGURE 7. Average Carbon Footprint for Cars and Light Trucks Sold, MY 1975-2016

Note: Light trucks include pickups, vans, and 4-wheel drive sport utility vehicles.
Carbon footprint is calculated using results from Argonne National Laboratory's GREET model.

Carbon footprint = $$\left(CO_2 \times LHV \times \frac{AnnualMiles}{CombinedMPG}\right) + \left(CH_4 + N_2O\right) \times AnnualMiles$$

CO_2 = (Tailpipe CO_2 + Upstream Greenhouse Gases) in grams per million Btu
LHV = Lower (or net) Heating Value in million Btu per gallon
CH_4 = Tailpipe CO_2 equivalent methane in grams per mile
N_2O = Tailpipe CO_2 equivalent nitrous oxide in grams per mile

Source:
U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Total Transportation Pollutants Decline

Due to improvements in fuels and vehicle technologies, the total amount of pollutants emitted from the transportation sector has declined. Since 2002 transportation sector emissions declined for each of the criteria pollutants tracked by the Environmental Protection Agency despite the increased number of highway and nonhighway vehicles and their miles of travel. From 2002 to 2016, carbon monoxide (CO) emissions declined by 58%; nitrogen oxide (NOx) emissions declined by 60%; volatile organic compound (VOC) emissions declined by 53%; and particulate matter emissions less than 10 microns (PM-10) emissions declined 41%.

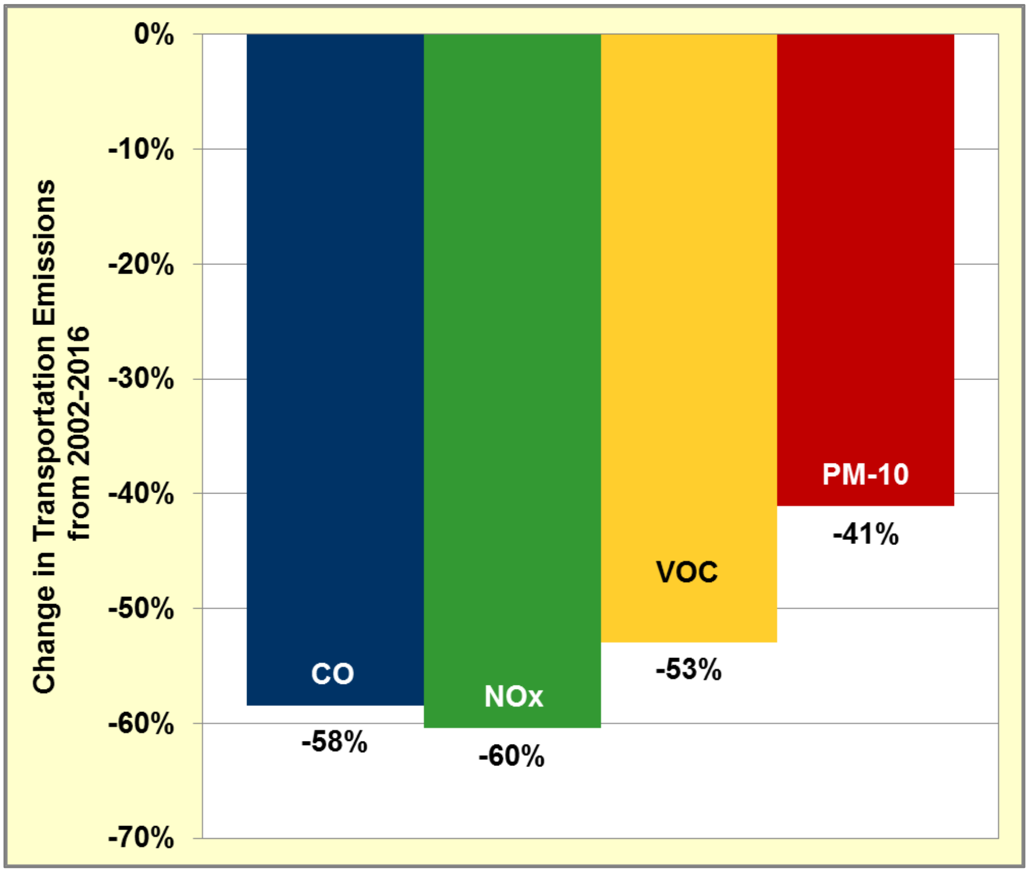


FIGURE 8. Change in Total Transportation Pollutant Emissions from 2002-2016

Note: Includes highway, air, water, rail, and other nonroad vehicles and equipment.

Source:

U.S. Environmental Protection Agency, National Emissions Inventory Air Pollutant Emissions Trends Data. http://www.epa.gov/air-emissions-inventories

Highway Vehicles Responsible for Declining Share of Pollutants

Over 50% of carbon monoxide (CO) emissions from the transportation sector in 2002 were from highway vehicles; by 2016 that fell to 30%. The share of transportation's nitrogen oxide (NOx) emissions from highway vehicles experienced a decline from 43% in 2002 to 34% in 2016. The highway share of volatile organic compound (VOC) emissions declined by 9% during this same period. Highway vehicles contributed less than 3% of all particulate matter (PM) emissions.

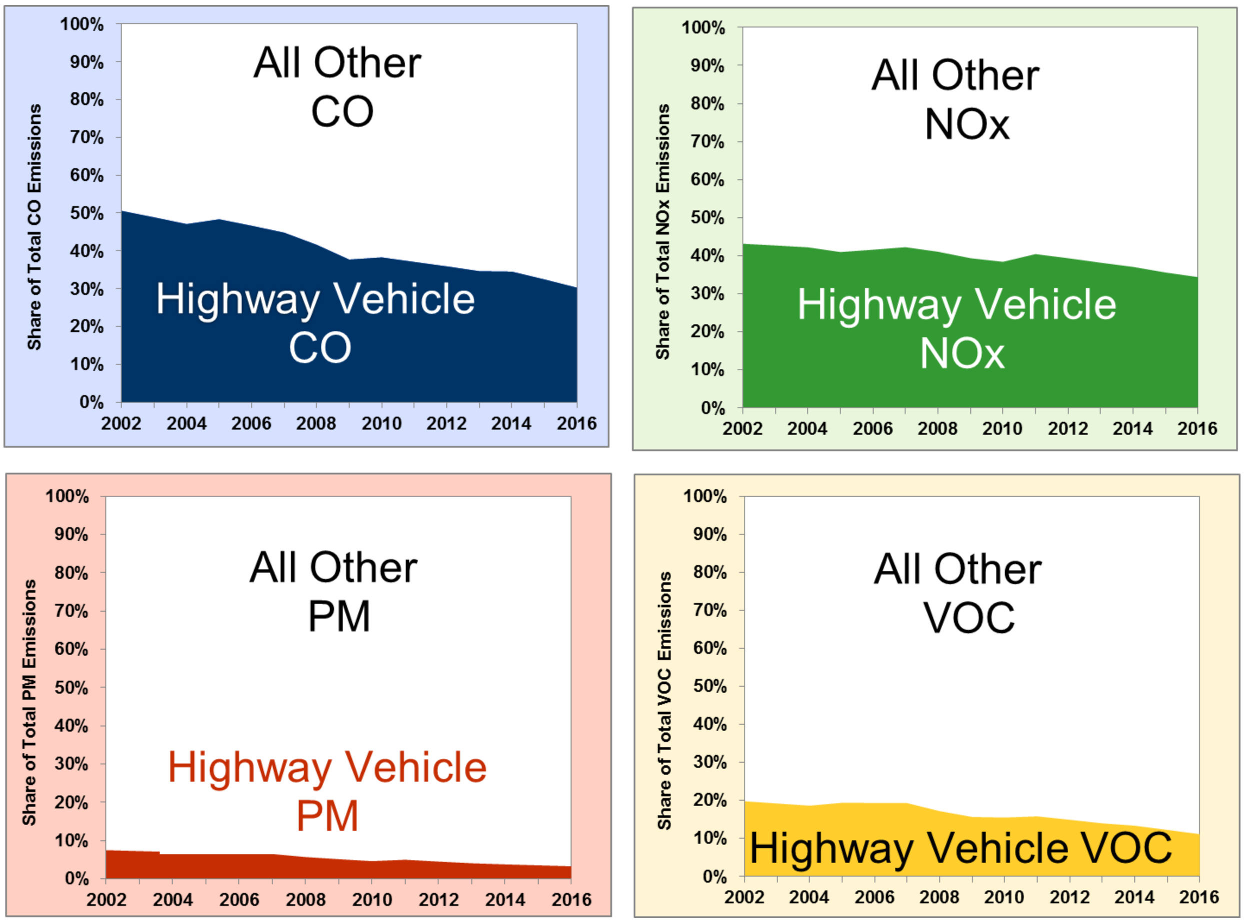


FIGURE 9. Highway and Nonhighway Share of Transportation Pollutant Emissions, 2002-2016

Source:

U.S. Environmental Protection Agency, National Emissions Inventory Air Pollutant Emissions Trends Data. http://www.epa.gov/air-emissions-inventories

Highway Transportation is More Efficient

The number of miles driven on our nation's highways has generally been growing during the past three decades, and energy use has grown with it. However, due to advances in engines, materials, and other vehicle technologies, the amount of fuel used per mile has declined from 1970. The gallons per mile declined by 48% for light trucks and 46% for cars. Fuel consumption for heavy trucks and buses has also generally decreased since 1970.

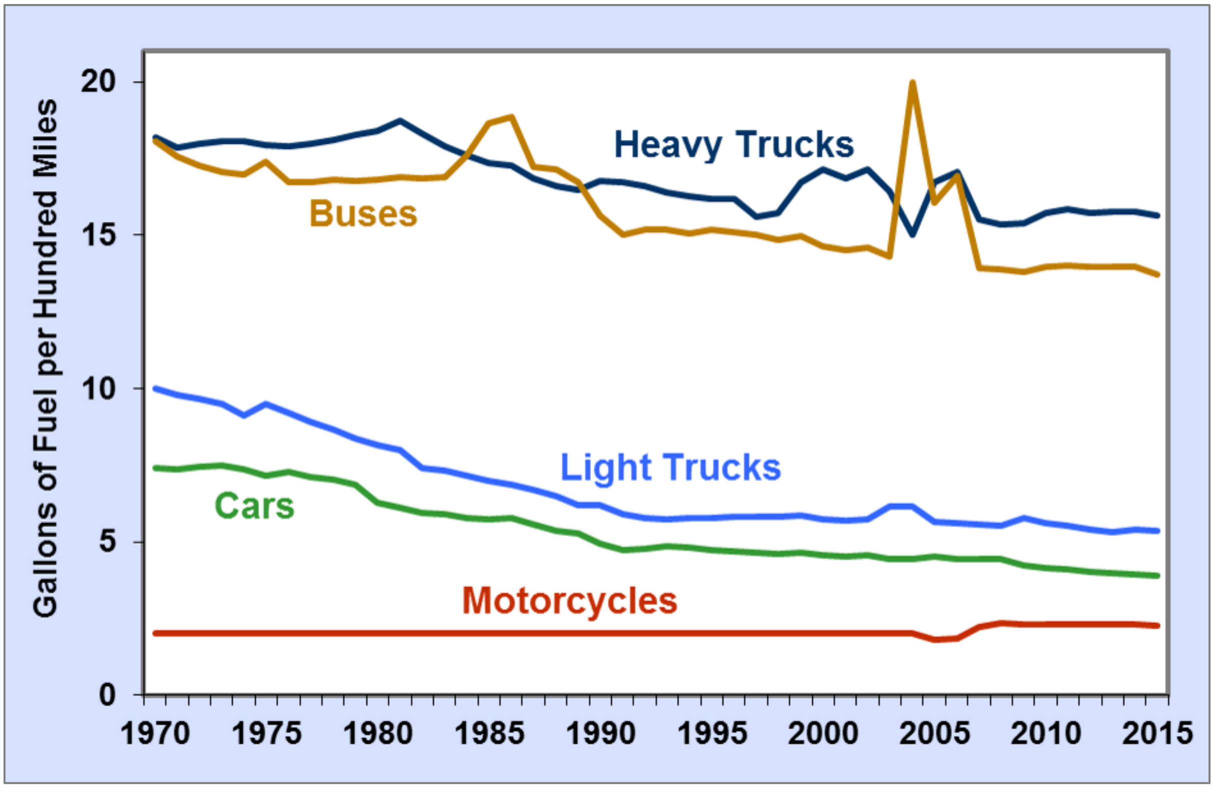


FIGURE 10. Fuel Use per Hundred Miles on the Highways, 1970-2015

Source:

Federal Highway Administration, *Highway Statistics 2015*, Table VM-1 and series 1970-2014.
http://www.fhwa.dot.gov/policyinformation/statistics.cfm

Vehicle Miles and Gross Domestic Product Both Grew in 2016

From 1960 to 1998, the growth in vehicle-miles of travel (VMT) closely followed the growth in the U.S. Gross Domestic Product (GDP). Since 1998, however, the growth in VMT has slowed and not kept up with the growth in GDP. Beginning in 2015, VMT increased more rapidly.

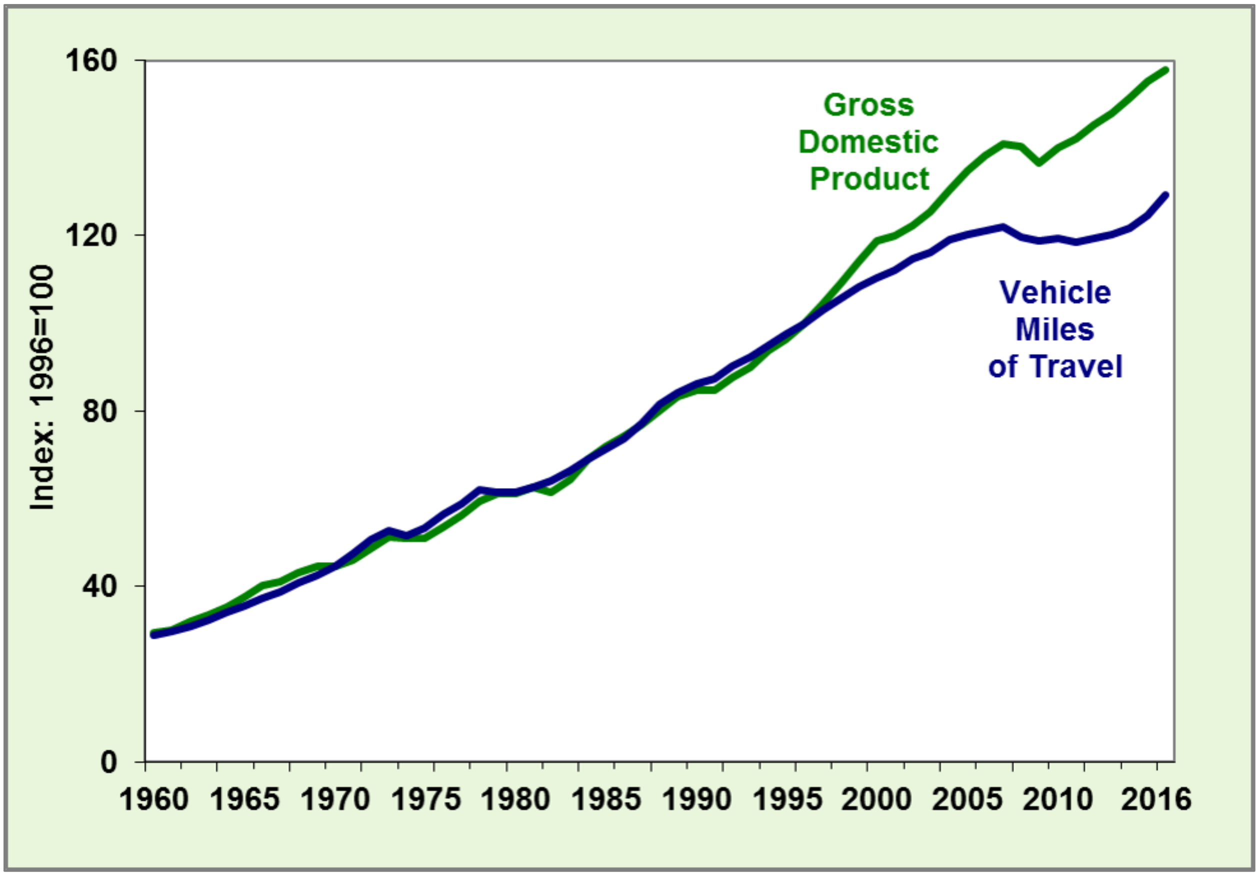


FIGURE 11. Relationship of VMT and GDP, 1960-2016

Sources:

Bureau of Economic Analysis, "Current Dollar and Real Gross Domestic Product."
http://www.bea.gov/national/xls/gdplev.xls

Federal Highway Administration, *Highway Statistics 2015*, Table VM-1 and previous annual editions.
http://www.fhwa.dot.gov/policyinformation/statistics/2015

Federal Highway Administration, *Traffic Volume Trends*, December 2016.
http://www.fhwa.dot.gov/policyinformation/travel_monitoring/16dectvt

Price of Crude Oil Is Affected by World Political and Economic Events

Crude oil prices have been extremely volatile over the past few decades. World events can disrupt the flow of oil to the market or cause uncertainty about future supply or demand for oil, leading to volatility in prices. Supply disruptions caused by political events, such as the Arab Oil Embargo of 1973-74, the Iranian revolution in the late 1970's, and the Persian Gulf War in 1990, were accompanied by major oil price shocks. Excess supply in 2014 caused a decline in crude oil prices.

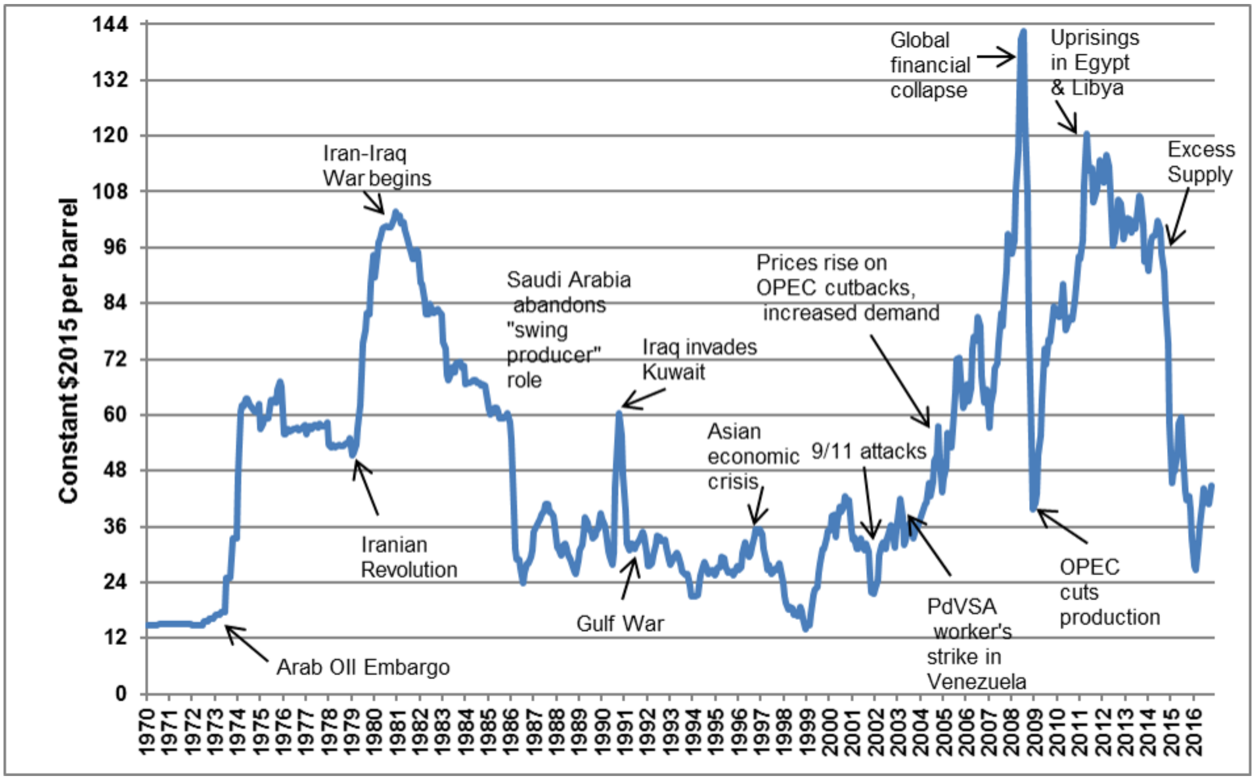


FIGURE 12. World Crude Oil Price and Associated Events, 1970-2016

Notes: Refiner acquisition cost of imported crude oil. OPEC = Organization of the Petroleum Exporting Countries; PdVSA = Petróleos de Venezuela, S.A.

Sources:

Energy Information Administration, "What Drives Crude Oil Prices?" December 31, 2016. http://www.eia.gov/finance/markets/spot_prices.cfm

Pew Center on Global Climate Change, *Reducing Greenhouse Gas Emissions from U.S. Transportation*, January 2011.

Oil Price Shocks Are Often Followed by an Economic Recession

Major oil price shocks have disrupted world energy markets six times in the past 30 years (1973-74, 1979-80, 1990-91, 1999-2000, 2008, and 2010-11). Most of the oil price shocks have been followed by an economic recession in the United States.

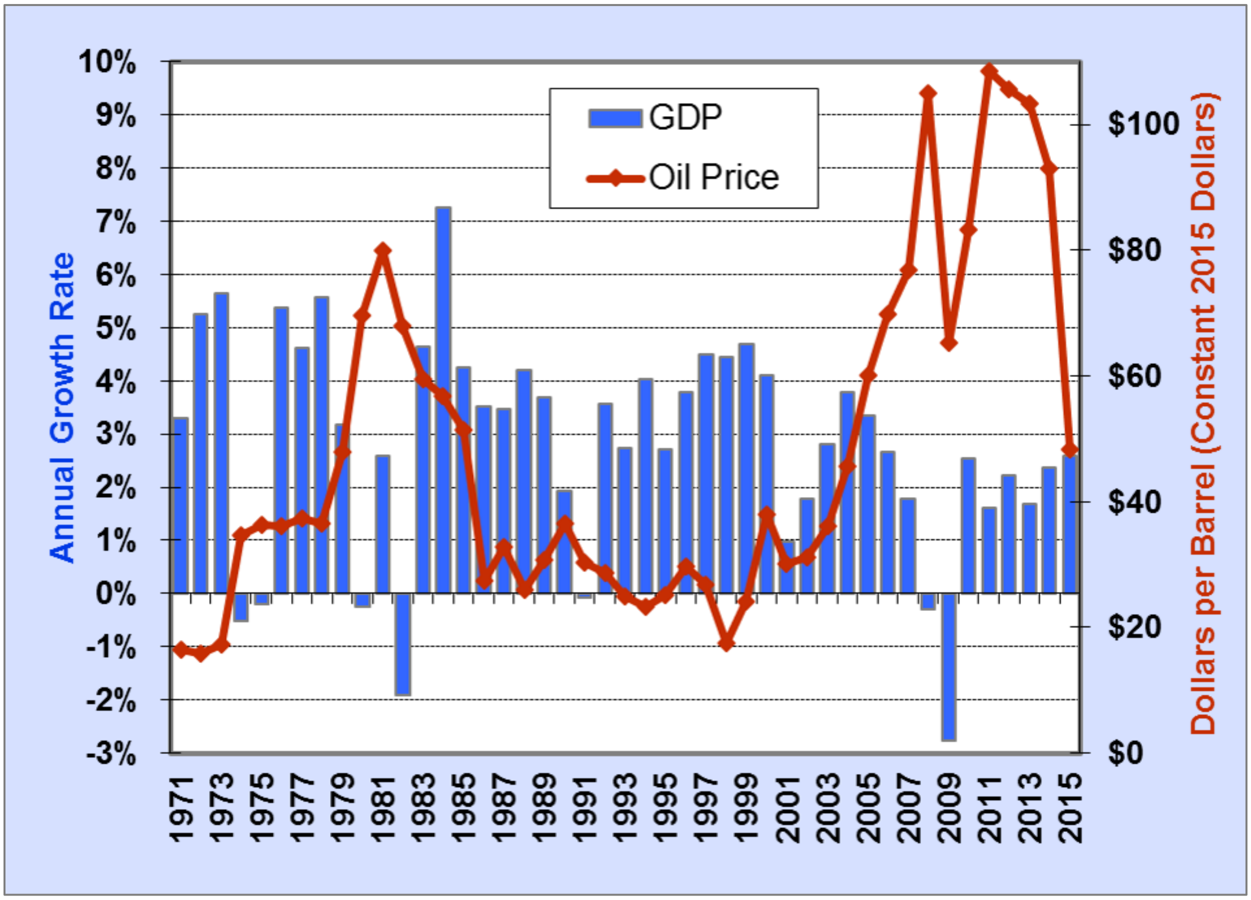


FIGURE 13. The Price of Crude Oil and Economic Growth, 1971-2015

Note: GDP = gross domestic product. Oil price is refiner acquisition cost.

Sources:

Energy Information Administration, *Monthly Energy Review, November 2016*, Table 9.1. http://www.eia.gov/totalenergy/data/monthly

U.S. Department of Commerce, Bureau of Economic Analysis, *National Income and Product Accounts*, Table 1.1.6, December 2016. http://bea.gov/iTable/index_nipa.cfm

ORNL Estimates that 2015 Direct and Indirect Oil Dependence Costs Were $104 Billion

The United States has long recognized the problem of oil dependence and the economic problems that arise from it. Greene, Lee and Hopson define oil dependence as a combination of four factors: (1) a noncompetitive world oil market strongly influenced by the Organization of the Petroleum Exporting Countries (OPEC) cartel, (2) high levels of U.S. imports, (3) the importance of oil to the U.S. economy, and (4) the lack of economical and readily available substitutes for oil. The most recent study shows that the U.S. economy suffered the greatest losses in 2008 when wealth transfer and gross domestic product (GDP) losses (combined) amounted to nearly half a trillion dollars. However, when comparing oil dependence to the size of the economy, the year 1980 is the highest. Low oil prices in 2009-2010 and 2013-2014 caused total dependence cost to drop; in 2015 the total cost was about $104 billion.

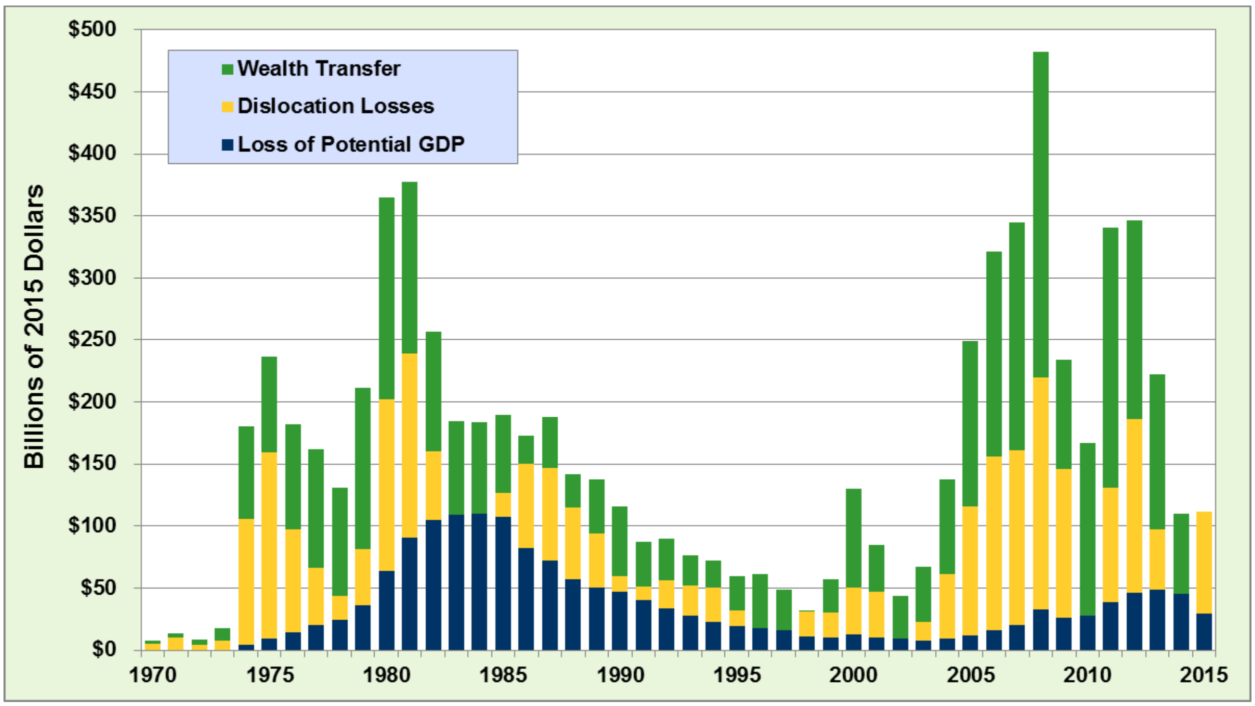


FIGURE 14. Costs of Oil Dependence to the U.S. Economy, 1970-2015

Notes: ***Wealth Transfer*** is the product of total U.S. oil imports and the difference between the actual market price of oil (influenced by market power) and what the price would have been in a competitive market. ***Dislocation Losses*** are temporary reductions in GDP as a result of oil price shocks. ***Loss of Potential GDP*** results because a basic resource used by the economy to produce output has become more expensive. As a consequence, with the same endowment of labor, capital, and other resources, our economy cannot produce quite as much as it could have at a lower oil price.

Source:

Greene, David L., Roderick Lee, and Janet L. Hopson, *OPEC and the Costs to the U.S. Economy of Oil Dependence: 1970-2010*, Oak Ridge National Laboratory Memorandum, 2011, and updates from the ORNL Transportation Energy Evolution Modeling Team.

Changes in Energy Prices and Vehicle-Miles of Travel Mirror Each Other

The prices of gasoline and diesel fuel affect the transportation sector in many ways. For example, fuel prices can impact the number of miles driven and affect the choices consumers make when purchasing vehicles. The graph below shows a three-month moving average of the percentage change of monthly data from one year to the next (i.e., February 2001 data were compared with February 2000 data). The vehicle travel often mirrors the price of gasoline – when the price of gasoline rises, the vehicle travel declines and when the price of gasoline declines, vehicle travel rises. Still, the price of gasoline is just one of the many factors influencing vehicle travel.

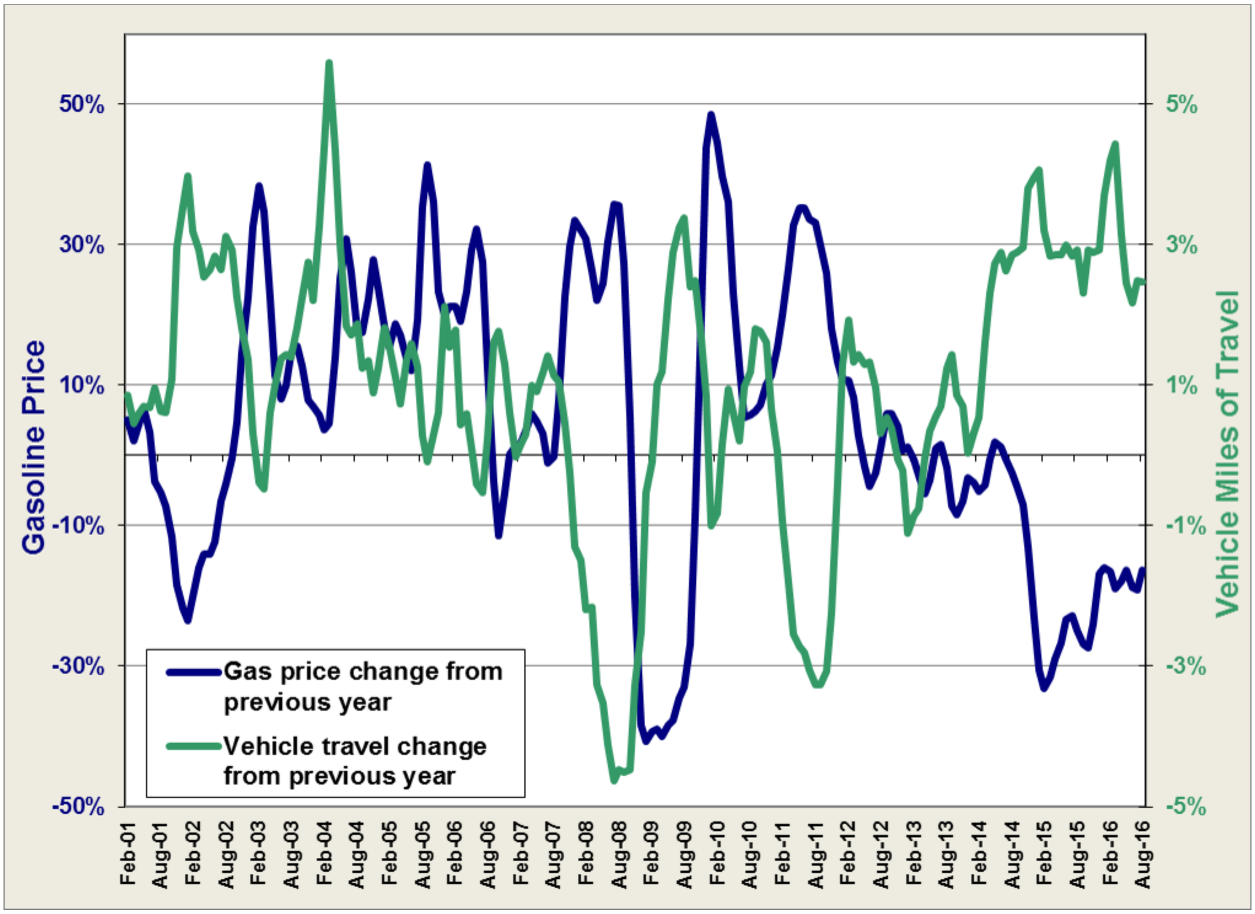


FIGURE 15. Relationship of Vehicle-Miles of Travel and the Price of Gasoline, 2001-2016

Sources:

Federal Highway Administration, *September 2016 Traffic Volume Trends,* and previous monthly editions. http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm

Energy Information Administration, *Monthly Energy Review, November 2016*, Table 9.4. http://www.eia.gov/totalenergy/data/monthly

The Average Price of a New Light Vehicle was Nearly $32,000 in 2016

The average price of a new car in 2016 was $25,774, a little lower than the 2015 average (constant 2016 dollars). That price continues to fall from a high of $29,808 in 1999, mainly driven by the high price of import cars. The price of imports peaked in 1998 at $42,270. Until 1981, domestic cars were more expensive than imports. The average price for light trucks, which include pickups, SUVs and vans, was lower than the average for cars until 1996, but has been higher since that time, at $35,829 in 2016. The average price of a new light vehicle (both cars and light trucks) was $31,790 in 2016.

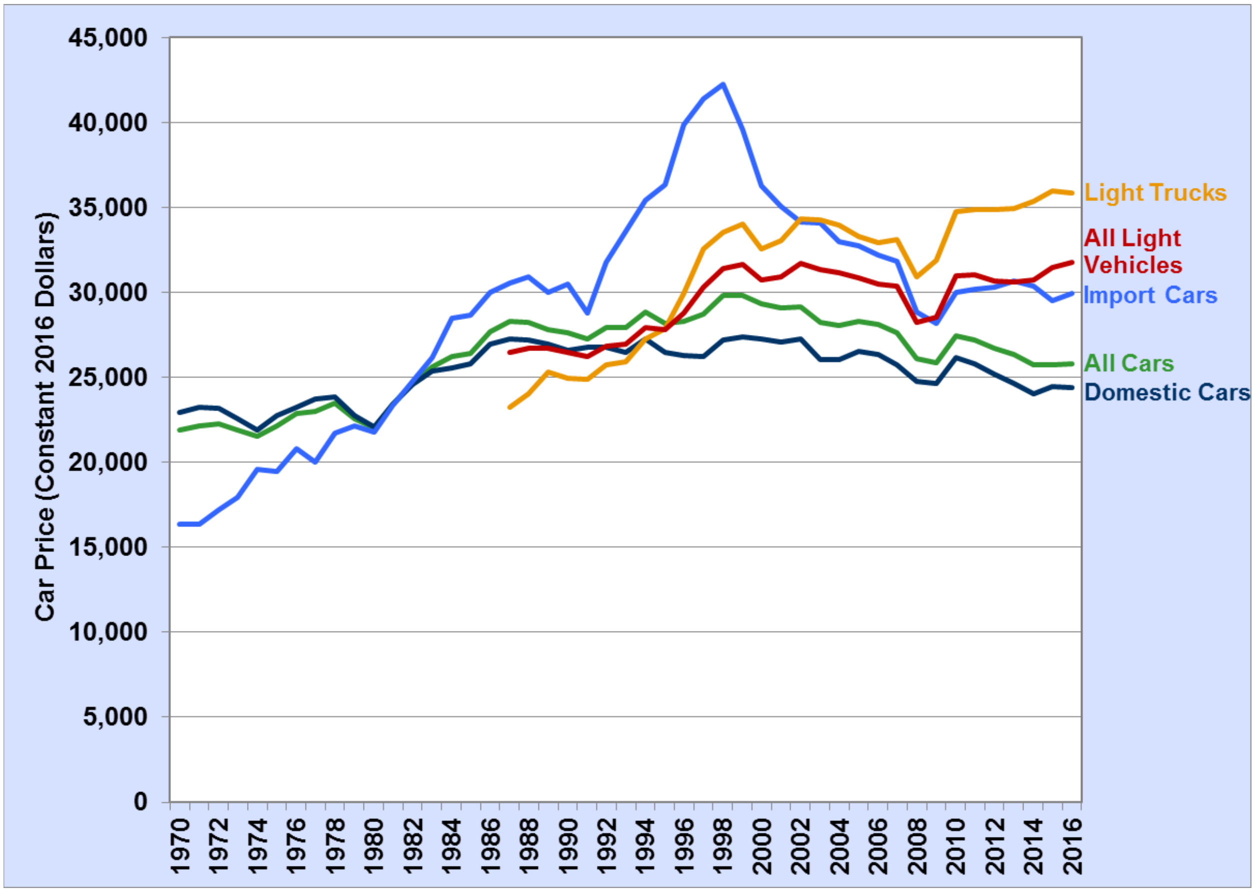


FIGURE 16. Average Price of a New Car, 1970-2016

Note: Light truck data are not available before 1987. Light trucks include classes 1-3.

Sources:

Cars – U.S. Department of Commerce, Bureau of Economic Analysis, *National Income and Product Accounts*, underlying detail estimates for Motor Vehicle Output, Washington, DC, 2017.

Light trucks and all light vehicles – Calculated using total new light truck expenditures from the National Income and Product Accounts and light truck sales from Wards Automotive.

The Majority of Vehicles Sold Fall in the $25-$30,000 Price Range

Although there were variations in the number of light vehicles sold in each calendar year, the market share of light vehicles by price range was fairly consistent from 2008 to 2016 (all prices were adjusted to 2015 dollars). In each year, the highest number of sales were in the $25-$30,000 price range, with the $35-$40,000 category coming in second.

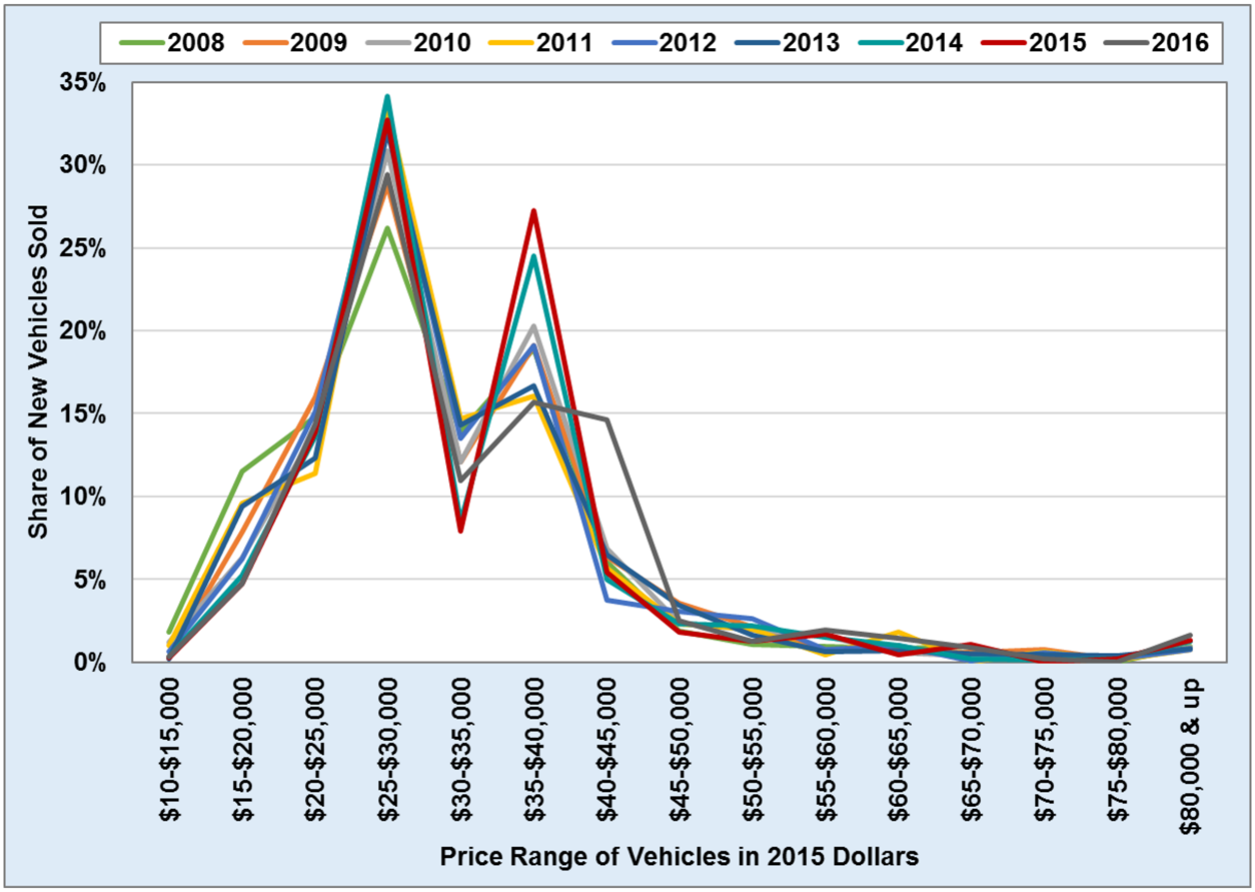


FIGURE 17. Light Vehicle Market Share by Price Range, Calendar Years 2008-2016

Note: Prices based on Manufacturers Suggested Retail Price (MSRP).

Source:
Provided by Russ Campbell, SRA International, Inc.

Fifteen Percent of Survey Respondents Consider Fuel Economy Most Important when Purchasing a Vehicle

A 2016 survey asked a sample of the U.S. population the question "Which one of the following attributes would be MOST important to you in your choice of your next vehicle?" The choices were fuel economy, dependability, low price, quality, and safety. This same question was asked in previous surveys and the results are compared in the graph below. Dependability was chosen most often in nearly every survey after 1980, but fuel economy surpassed it in 2011 and 2012. In 2016, 33% of the survey respondents indicated that dependability would be the most important vehicle attribute while 15% of the survey respondents chose fuel economy.

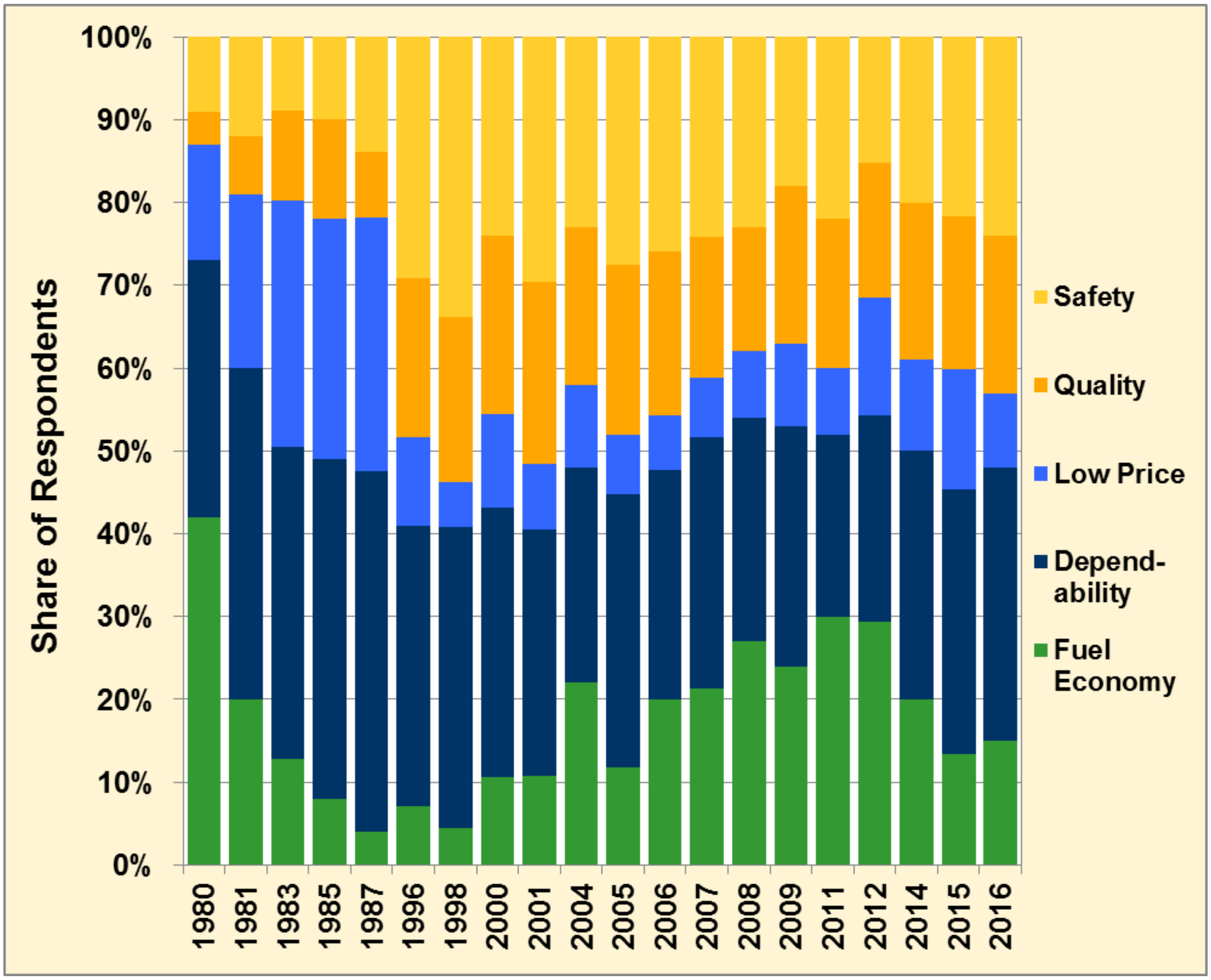


FIGURE 18. Most Important Vehicle Attribute, 1980-2016

Source:

1980-87: J. D. Power (based on new car buyers). 1998-2016: Opinion Research Corporation International for the National Renewable Energy Laboratory (Sample size ≈ 1,000 in the general population).

Hybrid-Electric Vehicles Can Save Money over Time

A selection of hybrid-electric vehicles (without plugs) were paired with comparably equipped non-hybrid vehicles from the same manufacturer. Price difference was derived from comparably equipped vehicle MSRP (manufacturer's suggested retail price) as shown on the manufacturer's online comparison tools. Annual fuel savings and years to payback were based on 15,000 annual miles and a mix of 55% city and 45% highway driving, and a 2016 national average fuel price of $2.19

TABLE 1. Selected 2016 and 2017 Model Year Hybrid-Electric Vehicles Paired with a Comparably Equipped Non-Hybrid Vehicle

Vehicles	EPA MPG	MSRP Difference	Annual Fuel Cost Savings	Years to Payback
2016 Lincoln MKZ Hybrid[1]	40	$0	$442	0.0
2016 Lincoln MKZ FWD	26			
2017 Ford Fusion Hybrid Titanium	42	$380	$532	0.7
2017 Ford Fusion FWD Titanium 4cyl	25			
2017 Ford Fusion Hybrid Platinum	42	$380	$532	0.7
2017 Ford Fusion FWD Platinum 4cyl	25			
2017 Toyota RAV4 Hybrid Limited AWD	32	$340	$342	1.0
2017 Toyota RAV4 Limited AWD/SE AWD	24			
2017 Honda Accord Hybrid Touring	48	$1,125	$630	1.8
2017 Honda Accord Touring	25			
2017 Toyota Avalon Hybrid Limited	40	$1,500	$548	2.7
2017 Toyota Avalon Limited	24			
2017 Toyota Prius Two[2]	52	$1,615	$585	2.8
2017 Toyota Camry LE	27			
2017 Toyota RAV4 Hybrid XLE	32	$800	$287	2.8
2017 Toyota RAV4 AWD XLE AWD	25			
2016 Kia Optima Hybrid	37	$855	$285	3.0
2016 Kia Optima EX	28			
2017 Toyota Avalon Hybrid XLE Premium	40	$2,250	$548	4.1
2017 Toyota Avalon XLE Premium	24			

[1]Hybrid models shown with an MSRP difference of $0 are available to consumers as a no cost option although performance may not be comparable.

[2]For hybrids with no conventional counterpart, a different model was chosen from the same manufacturer if it appeared to be reasonably similar.

Note: The hybrid models shown have a payback period of five years or less based on the assumptions above. Hybrid models available in multiple trim levels are shown only once. No two vehicles from the same manufacturer will be exactly comparable but every effort was made to match the vehicles closely in terms of amenities and utility.

Source:
U.S. Department of Energy fuel economy data, accessed January 2017, http://www.fueleconomy.gov.

Alternatives to Traditional Car Ownership

Car-sharing programs provide one alternative to car ownership. Typically, car-sharing programs have membership requirements and hourly rates. These programs may have a common vehicle fleet owned by the company or share members' vehicles. Ride-summoning programs are also used as an alternative to car ownership. Ford is experimenting with lease-sharing and lease-swapping programs.

Types of Car-Sharing	Example Companies
Fleet vehicles provided by the company can be rented by the hour.	Enterprise CarShare ZipCar, car2go
Fleet vehicles owned by members can be rented by other members.	FlightCar RelayRides
Share a leased vehicle with friends or family	Ford Credit Link
Swap your leased vehicle with another temporarily (sedan for a mini-van or truck)	Ford Car Swap

Ride-Summoning:
Uber and Lyft are the leading ride-summoning companies. Members use a mobile app to request transportation from a background-checked driver.

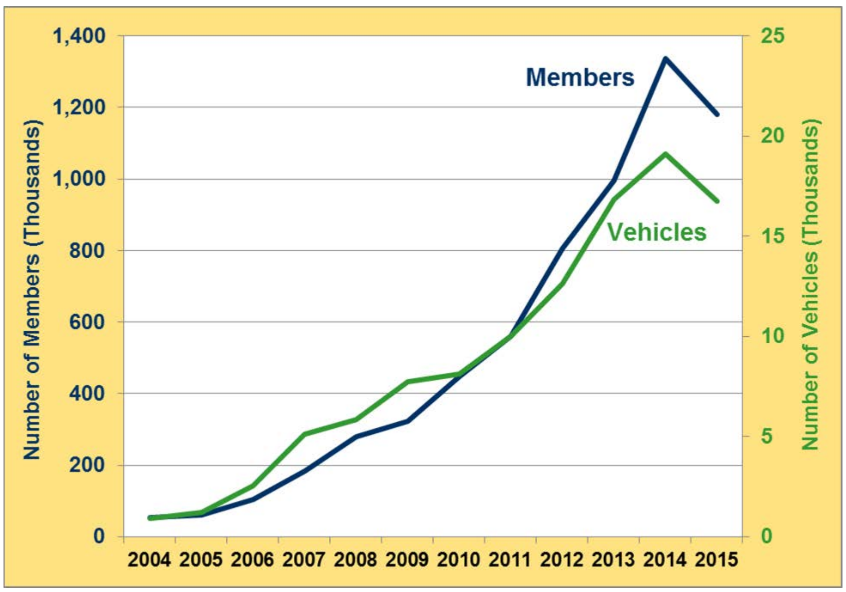


FIGURE 19. Number of Car-Sharing Members and Vehicles, 2004-2015

Data from 23 active car-sharing programs in the United States show that car-sharing membership and vehicles increased from 2004 to 2014, but declined slightly in 2015. This decline may be attributable to the closure of some car-share operations and growing competition from ride-summoning companies and bike-sharing operations.

Source:
University of California, Berkeley, Transportation Sustainability Research Center, *Innovative Mobility Carsharing Outlook, Summer 2015*. http://tsrc.berkeley.edu/node/923

Car-Sharing and Ride-Summoning Available across the Nation

TABLE 2. National Car-Sharing and Ride-Summoning Companies by State of Operation

State of Operation	Car-Sharing Company-Owned Vehicles				Car-Sharing Member-Owned Vehicles		Ride-Summoning	
	Enterprise CarShare	ZipCar	UHaul CarShare	Car2Go	Getaround	Turo	Uber	Lyft
Alabama	●	●	●			●	●	
Alaska								
Arizona	●	●	●			●	●	●
Arkansas		●				●	●	
California	●	●	●	●	●	●	●	●
Colorado	●	●	●	●		●	●	●
Connecticut		●	●			●	●	●
Delaware		●				●	●	●
Dist. of Columbia	●	●		●	●	●	●	●
Florida	●	●	●			●	●	●
Georgia	●	●				●	●	●
Hawaii	●	●				●	●	●
Idaho	●	●				●	●	●
Illinois	●	●	●		●	●	●	●
Indiana	●	●				●	●	●
Iowa	●	●	●			●	●	
Kansas	●	●				●	●	●
Kentucky	●	●				●	●	●
Louisiana	●	●				●	●	
Maine		●	●			●	●	●
Maryland		●				●	●	●
Massachusetts	●	●	●			●	●	●
Michigan	●	●	●			●	●	●
Minnesota	●	●		●		●	●	●
Mississippi		●				●	●	
Missouri	●	●				●	●	
Montana						●	●	
Nebraska	●	●	●			●	●	●
Nevada		●				●	●	●
New Hampshire		●				●	●	
New Jersey	●	●				●	●	●
New Mexico	●	●				●	●	●
New York	●	●	●	●		●	●	●
North Carolina	●	●	●			●	●	●
North Dakota						●	●	
Ohio	●	●	●	●		●	●	●
Oklahoma	●	●				●	●	●
Oregon	●	●	●	●	●	●	●	●
Pennsylvania	●	●	●			●	●	●
Rhode Island		●				●	●	●
South Carolina	●	●				●	●	
South Dakota						●		
Tennessee	●	●				●	●	●
Texas	●	●		●		●	●	●
Utah	●		●			●	●	●
Vermont		●	●			●	●	
Virginia	●	●				●	●	●
Washington		●		●		●	●	●
West Virginia	●	●				●	●	
Wisconsin	●	●	●			●	●	●
Wyoming						●		
Total locations	35	45	20	9	4	50	48	36

Source:
Company websites, research by Oak Ridge National Laboratory, December 2016.

Seventeen Percent of Household Expenditures Are for Transportation

Except for housing, transportation was the largest single expenditure for the average American household in 2015. Of the transportation expenditures, vehicle purchases and gas and oil were the two largest single expenditures. In 1984, transportation was closer to 20% of all household expenditures and the share has generally fluctuated between 16% and 20% over time. In 2009, however, the transportation share reached a low of 15.6%.

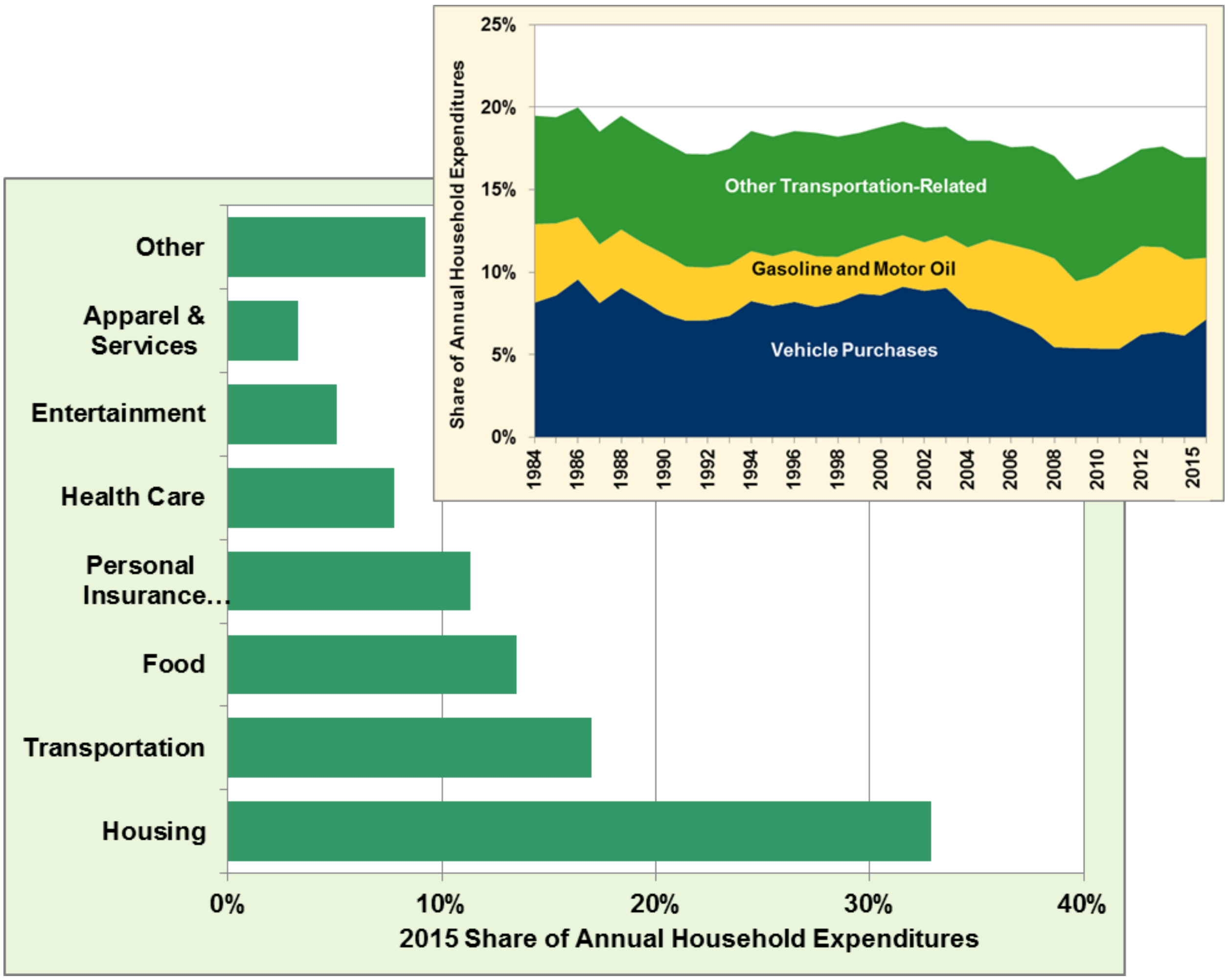


FIGURE 20. Share of Household Expenditures by Category, 2015, and Transportation Share of Household Expenditures, 1984-2015

Note: For additional details on the methodology of the Consumer Expenditure Survey, see http://www.bls.gov/cex.

Sources:

U.S. Department of Labor, *Consumer Expenditure Survey 2015*, Table 1203, Washington, DC, 2016, and multiyear survey tables. http://www.bls.gov/cex/

The Transportation Industry Employs Over 10 Million People

The transportation industry employs a wide variety of people in many different fields. From the manufacture of vehicles and parts to travel reservation services, 10.6 million people were employed in transportation-related jobs in 2015. These transportation-related jobs accounted for 7.5% of the total non-farm employment. Retail sales of motor vehicles and parts, which include dealerships, retail parts stores, and more, accounted for the most employees. Truck transportation, which includes truck drivers, was the category with the second highest number of employees.

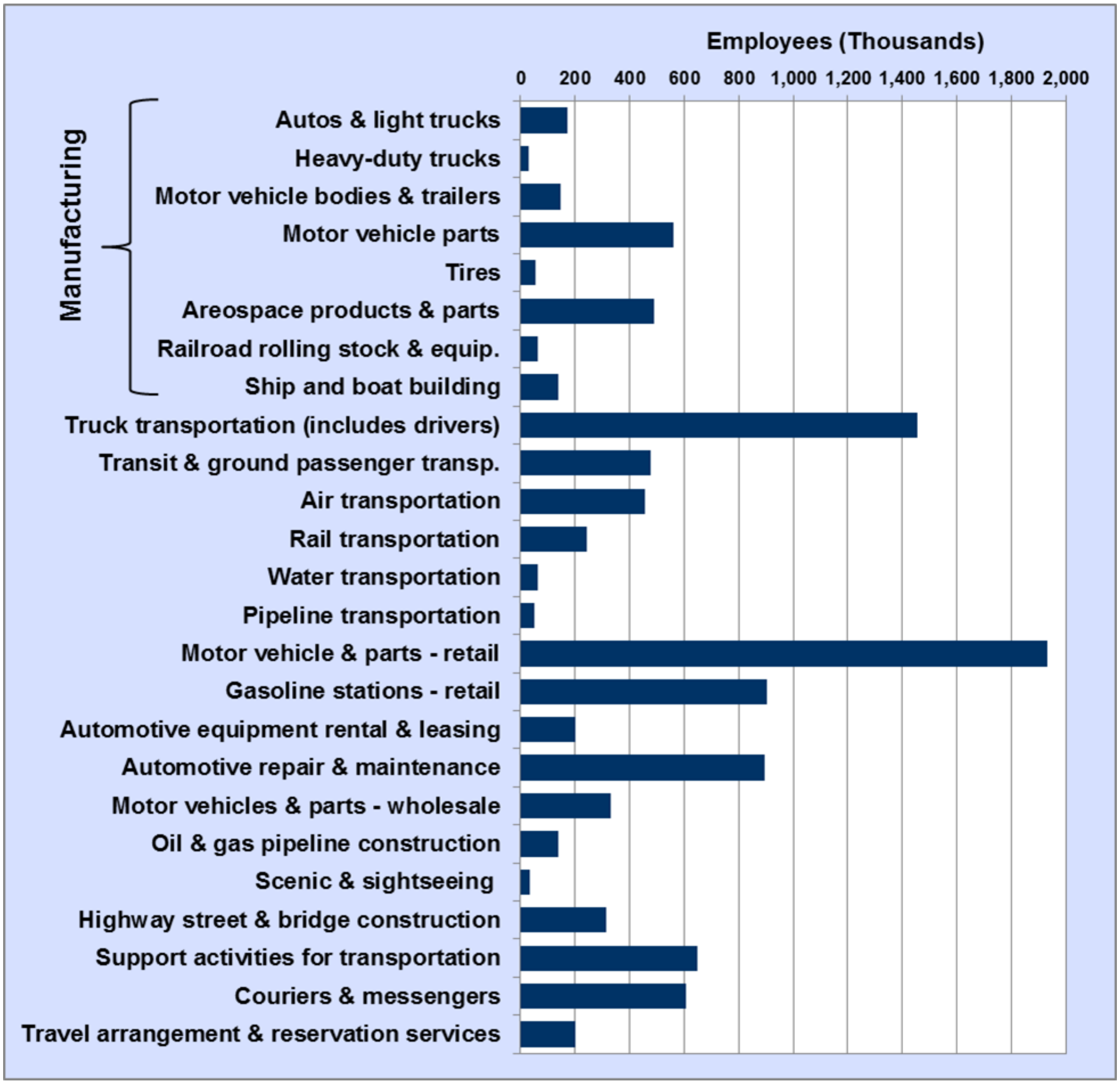
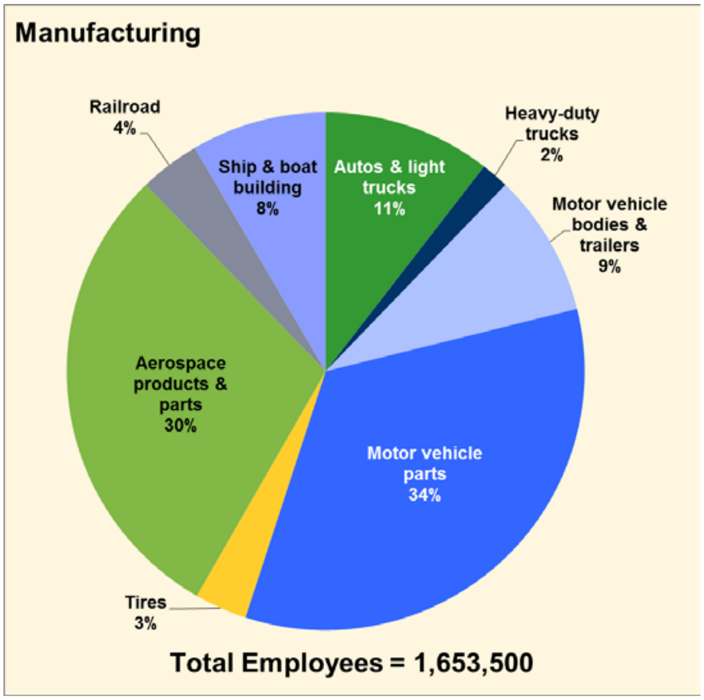


FIGURE 21. Transportation-Related Employment, 2015

Source:
Bureau of Labor Statistics, website query system. http://www.bls.gov/data/

Americans Employed in Transportation Have Diverse Jobs—From Aerospace Manufacturing to Trucking



The manufacture of vehicles and parts (left) employed over 1.6 million people in 2015. The highway mode – vehicles, parts, and tires – accounted for more than half of all transportation manufacturing employees; aerospace products (e.g., airplanes) and their parts accounted for almost one-third.

When looking at jobs related to the movement of people and goods (right), the trucking industry was responsible for more than half of the 2.7 million employees. Transit and ground transportation, which includes bus drivers and other transit and ground transportation employees, made up 17% of the total. Air transportation, which includes everything from pilots to airport workers, was 17% of the total.

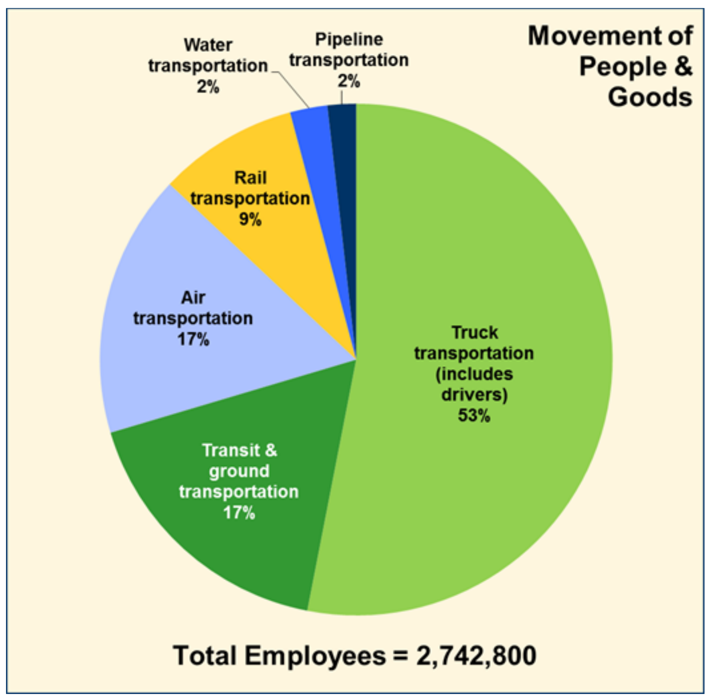


FIGURE 22. Transportation Manufacturing-Related and Mode-Related Employment, 2015

Source:
Bureau of Labor Statistics, website query system. http://www.bls.gov/ces/cesnaics.htm

The Automotive Industry Spent $105 Billion on Research and Development in 2016

The automotive industry accounted for 15% of all corporate research and development (R&D) in the United States in 2016, totaling $105 billion. Computing & electronics and healthcare were the only two industries where companies spent more on R&D than the automotive industry.

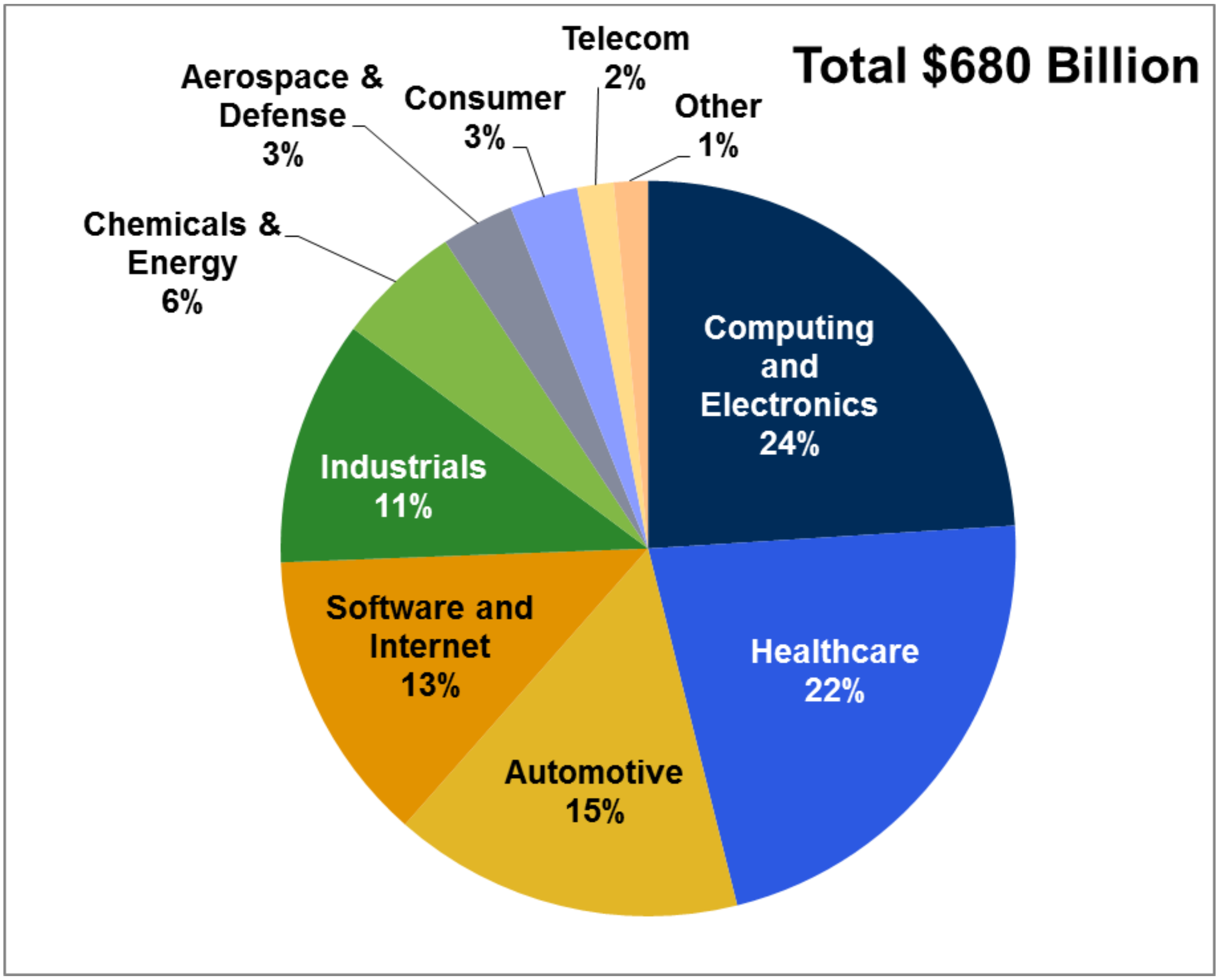


FIGURE 23. Research and Development Spending by Industry, 2016

Source:
PriceWaterhouseCoopers, *The 2016 Global Innovation 1000: Innovation's New World Order.* http://www.strategyand.pwc.com/innovation1000pwc.com/innovation1000

VW Tops the List of All Research and Development Expenditures from 2012 to 2016

Volkswagen spent more than $10 billion on research and development (R&D) each year from 2012 to 2016—more than any other publicly-traded company. The top 20 publicly-traded companies worldwide are ranked by R&D spending. Other automakers that have been in the top 20 since 2012 include Toyota, General Motors, and Daimler. Honda was in the top 20 from 2012 to 2014 and Ford from 2014 to 2016.

TABLE 3. Top 20 Research and Development Spenders, 2012-2016
(Automotive companies are highlighted)

Rank	2012	2013	2014	2015	2016
1	**Volkswagen $10.1 billion**	**Volkswagen $11.4 billion**	**Volkswagen $13.5 billion**	**Volkswagen $15.3 billion**	**Volkswagen $13.2 billion**
2	**Toyota $9.9 billion**	Samsung	Samsung	Samsung	Samsung
3	Novartis	Roche	Intel	Intel	Amazon
4	Roche	Intel	Microsoft	Microsoft	Alphabet
5	Pfizer	Microsoft	Roche	Roche	Intel Co
6	Microsoft	**Toyota $9.8 billion**	Novartis	Google	Microsoft
7	Samsung	Novartis	**Toyota $9.1 billion**	Amazon	Roche
8	Merck	Merck	Johnson & Johnson	**Toyota $9.2 billion**	Novartis
9	Intel	Pfizer	Google	Novartis	Johnson & Johnson
10	**General Motors $8.1 billion**	Johnson & Johnson	Merck	Johnson & Johnson	**Toyota $8.8 billion**
11	Nokia	**General Motors $7.4 billion**	**General Motors $7.2 billion**	Pfizer	Apple
12	Johnson & Johnson	Google	**Daimler $7.0 billion**	**Daimler $7.6 billion**	Pfizer
13	**Daimler $7.0 billion**	**Honda $6.8 billion**	Pfizer	**General Motors $7.4 billion**	**General Motors $7.5 billion**
14	Sanofi-Aventis	**Daimler $6.6 billion**	Amazon	Merck	Merck
15	Panasonic	Sanofi-Aventis	**Ford $6.4 billion**	**Ford $6.9 billion**	**Ford $6.7 billion**
16	**Honda $6.6 billion**	IBM	Sanofi-Aventis	Sanofi-Aventis	**Daimler $6.6 billion**
17	GlaxoSmithKline	GlaxoSmithKline	**Honda $6.3 billion**	Cisco	Cisco
18	IBM	Nokia	IBM	Apple	AstraZeneca
19	Cisco	Panasonic	GlaxoSmithKline	GlaxoSmithKline	Bristol-Myers Squibb
20	AstraZeneca	Sony	Cisco	AstraZeneca	Oracle

Source:
PriceWaterhouseCoopers, *The Global Innovation 1000: Top 20 R&D Spenders, 2005-2016.* http://www.strategyand.pwc.com/innovation1000#/tab-2012|VisualTabs2

Manufacturers' Stock Prices Have Their Ups and Downs

Weekly stock prices are shown on the graph below. Nearly all of the manufacturers show a decline in late 2008 as a result of the economic recession. Most manufacturers have now recovered from the decline and their current stock prices are higher than 2006 levels. Volkswagen (VW) stock experienced a "wild ride" of ups and downs in late October 2008 due to Porsche's increased holdings in VW. Tesla (TES) stock has been over $180 per share since 2014. Fiat Chrysler Automobiles (FCA) stock began trading in October 2014. General Motors (GM) is shown after the initial public stock offering in late 2010 (GM-New). Fuji Heavy Industries is the parent company of Subaru (SUB).

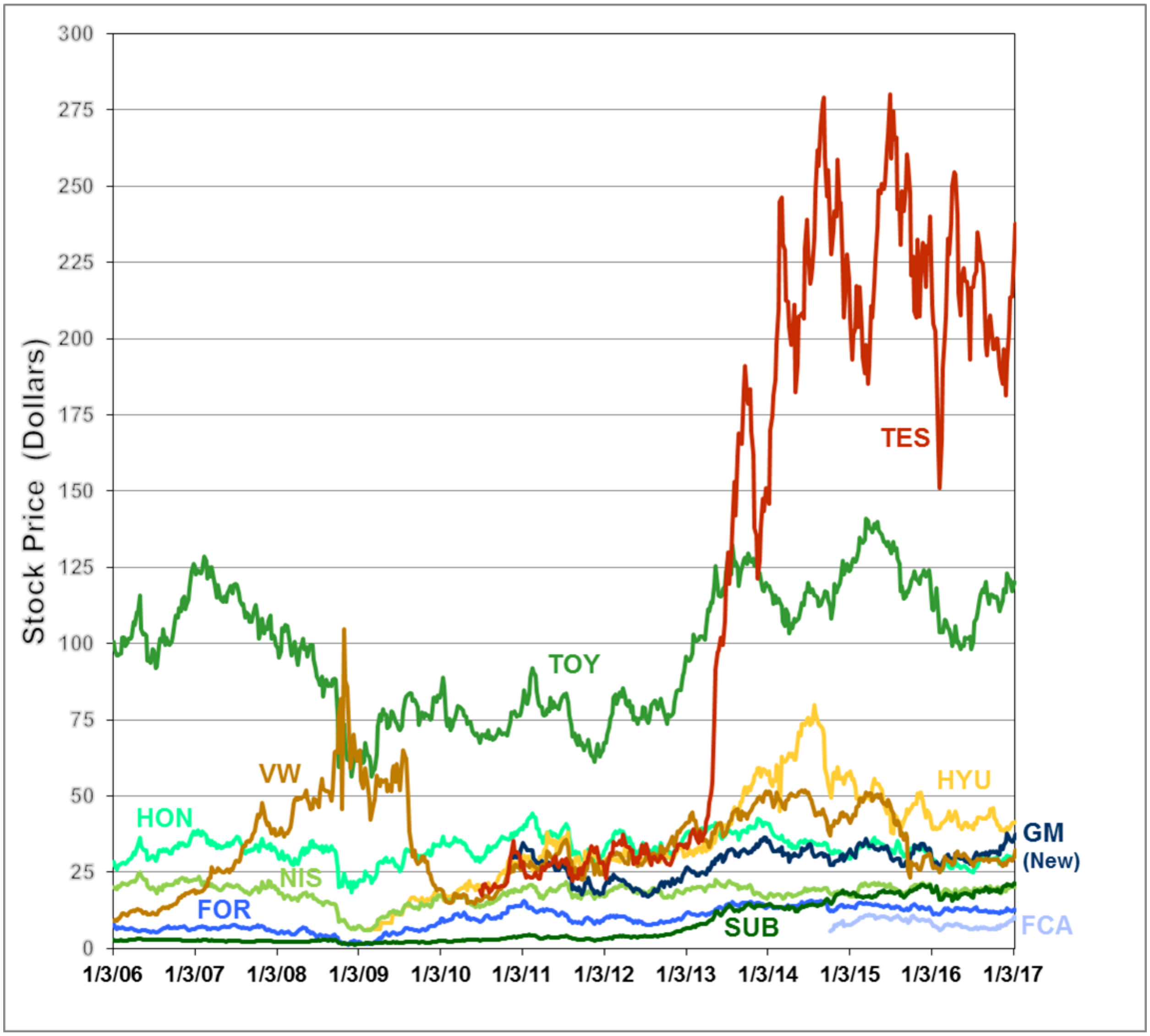


FIGURE 24. Stock Price by Manufacturer, 2006-2017

Source:
Yahoo Finance. http://www.yahoofinance.com

Toyota Has the Highest Market Cap of the Major Manufacturers

Although the stock price for Tesla is higher than the other manufacturers, Toyota's market capitalization (market cap) is more than double that of the other manufacturers listed below. Market cap is the value of the company's total number of shares of stock and is calculated as the price of a stock multiplied by the number of outstanding shares.

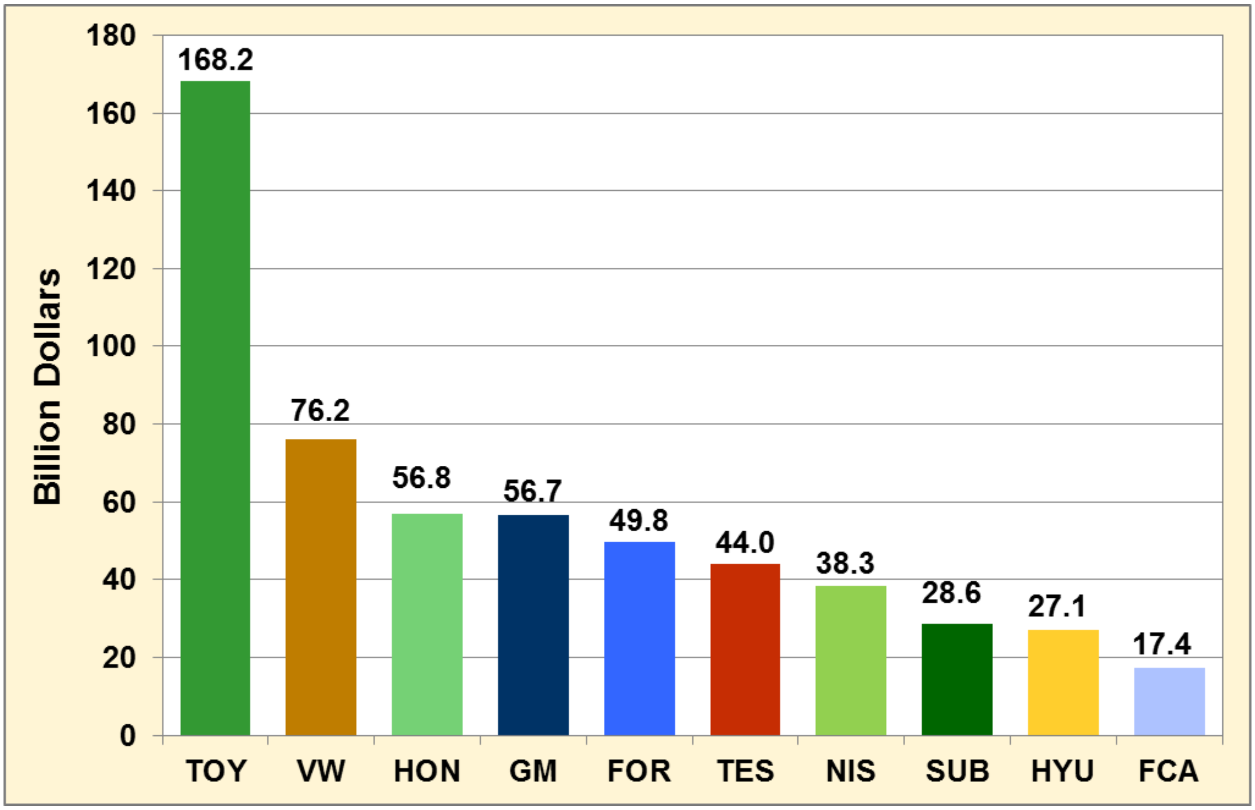


FIGURE 25. Market Capitalization by Manufacturer, February 2017

Note: Market cap as of February 22, 2017.

Source:
Yahoo Finance. http://www.yahoofinance.com

CHAPTER 2

LIGHT VEHICLE COMPANY PROFILES

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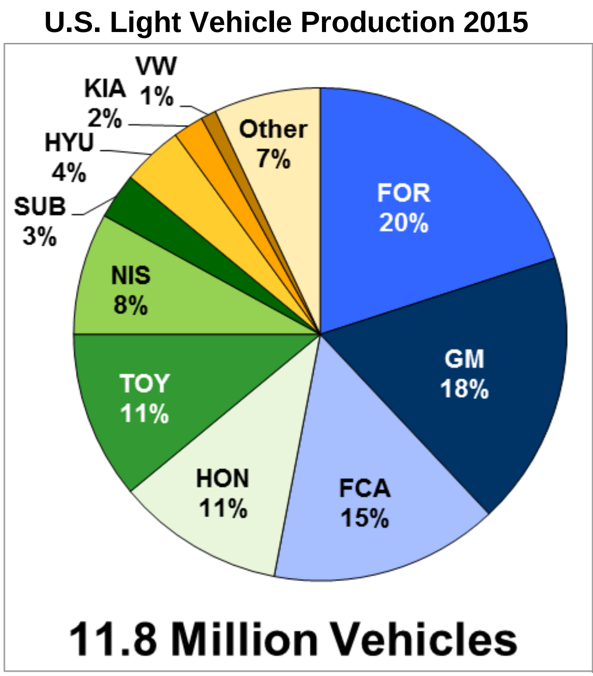
Thirteen Percent of Vehicles Worldwide Are Produced in the United States

Nearly 12 million vehicles were produced in the United States in 2015. More than half of U.S. vehicle production was from three automakers: Ford, General Motors, and Fiat Chrysler. Toyota is the largest manufacturer in the world, and produced 10% of the world's vehicles and 11% of all light vehicles in the United States. About 13% of the world's vehicles were produced in the United States.



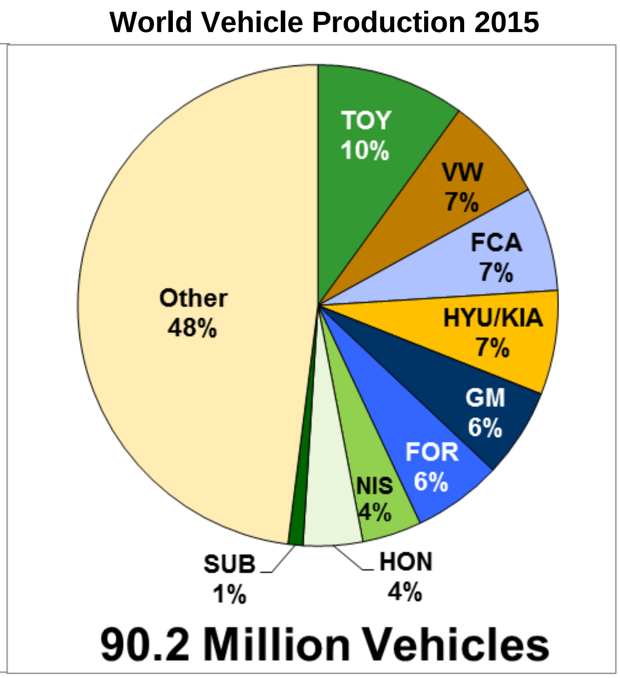


FIGURE 26. Production of United States and World Vehicles in 2015 by Manufacturer

Note: World production includes heavy vehicles, which are a small share of total production. Shanghai AIC, which is included in the "Other" category on the World chart above, is the only other automotive company to hold more than 5% of World production; it had a 6.5% share in 2015.

Source:
Ward's Automotive Group. http://wardsauto.com

Market Share Shifted among Manufacturers

The ten manufacturers that sold more than 500,000 vehicles in the United States in 2016 accounted for more than 90% of total U.S. sales. Subaru, Nissan, Kia, and Honda experienced the largest gains in car market share from 2012-2016. The market share declined for FCA, VW, GM, Ford, Toyota, and Hyundai. The three domestic manufacturers accounted for about 56% of the light truck market share in 2016.

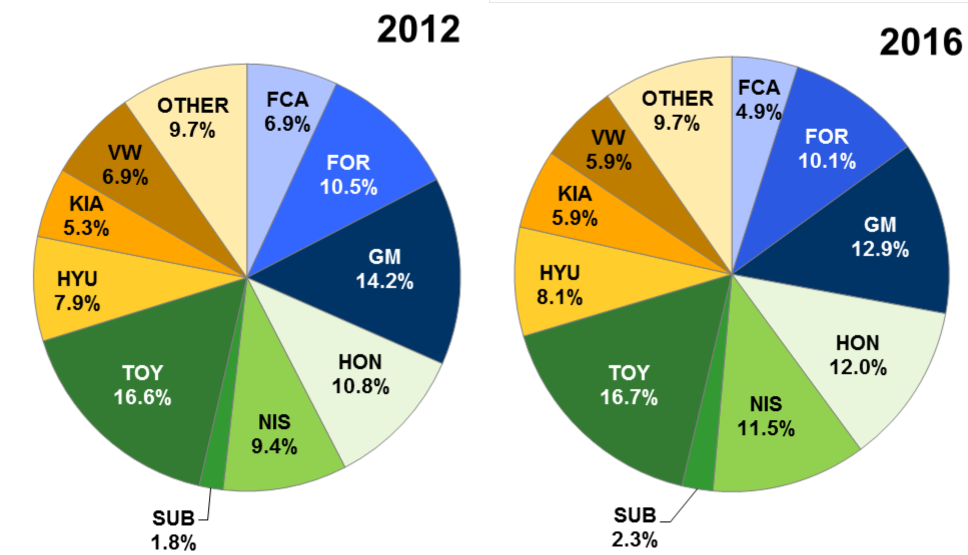


FIGURE 27. New Car Market Share by Manufacturer, 2012 and 2016

Source:
Ward's Automotive Group. http://wardsauto.com

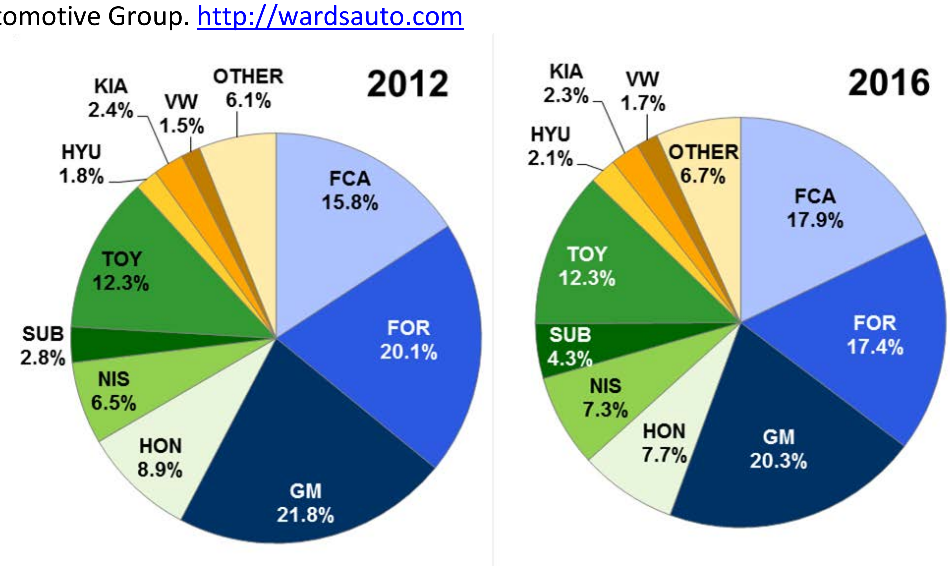


FIGURE 28. New Light Truck Market Share by Manufacturer, 2012 and 2016

Source:
Ward's Automotive Group. http://wardsauto.com

Company Profile Preface

Company profiles follow for ten different manufacturers with sales of over 500,000 vehicles in 2016.

- The first page of each profile is an overview page containing the company's Corporate Average Fuel Economy, average vehicle footprint, number of alternative fuel models, production plant locations, production, and a short summary of fuel saving technologies.
- The second page of each profile contains a figure showing an overview of the company's vehicle offerings in various market segments. A tabular listing of the vehicle models in each size class follows.
- The third page of each profile shows the market share by vehicle model within each company. This gives an idea of which vehicles are best sellers for that company.
- The fourth page of each profile includes a figure of hybrid vehicle sales by model and year. Also included is a pie chart depicting the manufacturer's share of the 2014 hybrid vehicle market. Since the number of hybrid sales by manufacturer varies, use caution when comparing one manufacturer's chart to another as the scales may be different.
- The last page of each profile shows the interworking relationships that each manufacturer has with other manufacturers around the world.

The ten manufacturers for which we have profiles are:

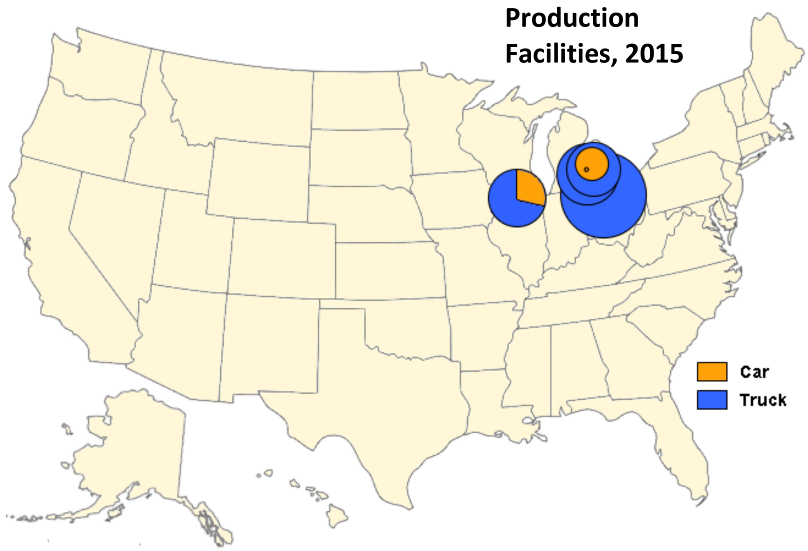
- Fiat Chrysler Automobiles (FCA),
- Ford (FOR),
- General Motors (GM),
- Honda (HON),
- Nissan (NIS),
- Subaru (SUB),
- Toyota (TOY),
- Hyundai (HYU),
- Kia (KIA), and
- Volkswagen (VW).
  In future reports some data for VW may be revised. At the current time, data in this report do not reflect any revisions due to the ongoing investigation of VW diesel models.

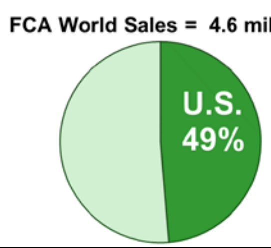
Fiat Chrysler Automobiles (FCA) Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	31.6 mpg
Import Cars	31.1 mpg
Light Trucks	26.5 mpg

Average Vehicle Footprint, MY 2016	
Cars	47.4 sq ft
Light trucks	53.8 sq ft
All	51.1 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	16
Natural Gas	0
Propane	0
Hybrid-Electric	0
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0





FCA U.S. Plants	Type	2015 Production
Toledo, OH - North & South	Truck	538,705
Detroit, MI - Jefferson North	Truck	372,989
Warren, MI	Truck	331,450
Belvidere, IL	Truck	246,359
Sterling Heights, MI	Car	190,439
Belvidere, IL	Car	96,150
Detroit, MI - Conner	Car	525

FIGURE 29. FCA Company Profile

Fuel Saving Technologies

FCA announced in early 2016 that the Dodge Dart and Chrysler 300 sedans were being phased out to focus on Jeep SUVs, Ram trucks, and vehicle electrification. Low gasoline prices and consumer trends showing a growing popularity of SUVs were cited as motivations for the realignment of FCA's product portfolio.

The 2017 Chrysler Pacifica Hybrid arrived in dealerships in early 2017 becoming the first plug-in hybrid minivan available to consumers. The Chrysler Pacifica Hybrid has an EPA-rated all-electric range of 33 miles and an MPGe rating of 84 MPGe when operating on electricity. On gasoline, the Pacifica Hybrid achieves 32 mpg making it the most efficient minivan on the market by far. The non-hybrid version of the Chrysler Pacifica is also available with stop-start to improve fuel economy in urban driving.

The Fiat 500e remains the only all-electric vehicle offered by FCA. The 500e is a Mini compact with 84 miles of range and is only available in select markets. However, FCA unveiled the all-electric Chrysler Portal minivan concept at the 2017 Consumer Electronics Show (CES) in Las Vegas. The Portal concept is a semiautonomous vehicle with a 100 kW-hr battery providing more than 250 miles of range. The Portal concept demonstrates FCA's commitment to vehicle electrification and autonomous technology.

FCA has continued their push toward 8- and 9-speed automatic transmissions. FCA estimates a 6-10% improvement in fuel economy over vehicles equipped with the 4-, 5-, and 6-speed predecessors. Other fuel saving technologies include an all-wheel drive system that automatically disconnects the front or rear axle when not needed, reducing mechanical drivetrain losses and improving fuel economy. Aerodynamic improvements are also achieved on some models through the use of active grill shutters that limit disruption of air flow by limiting the amount of air that enters the engine compartment at highway speeds along with underbody panels that help to smooth airflow.

FCA's Fleet Mix

FCA's vehicle offerings and sales leaned heavily toward trucks which tend to have lower fuel economy than cars. The Ram pickup was their largest seller with an EPA-combined fuel economy below 20 mpg. There were six models that average between 25 and 34 mpg and one (the Fiat 500e) greater than 40 mpg.

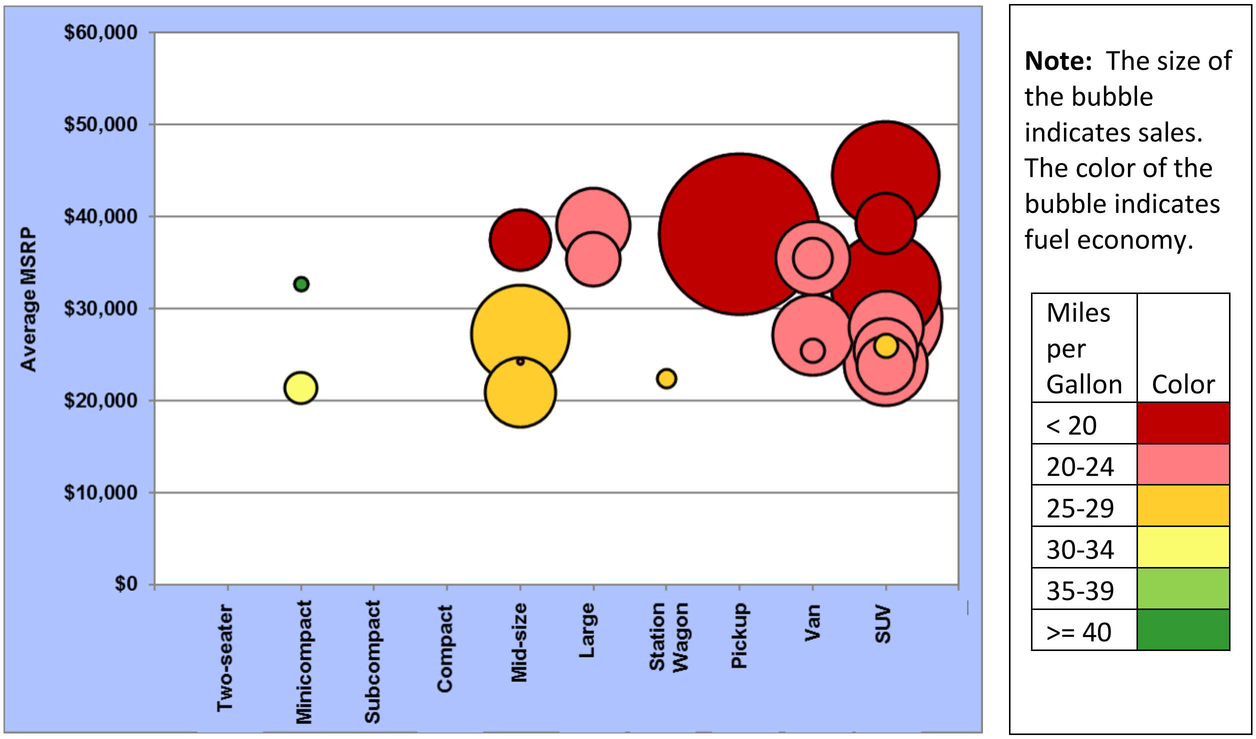


FIGURE 30. FCA Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 4. FCA Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
Ferrari *Viper* *Alpha-Romeo 4C*	500e 500			*Maserati* Challenger 200 Avenger Dart	300/300M Charger	500L	Ram	Town & Country Ram Grand Caravan Promaster City	Grand Cherokee Durango Wrangler Cherokee Journey 500X Compass Patriot Renegade

Note: Includes Chrysler, Dodge, Fiat, Ferrari, and Maserati. Models listed in *red italics* do not appear on the figure due to high MSRP.

Cars Comprised almost One-Quarter of FCA's Sales in 2015

The combined car market share of Fiat, Chrysler, and Dodge was almost 25% of the FCA market share in 2015. The Ram pickup accounted for 19% and the Jeep Grand Cherokee, Cherokee, and Wrangler together accounted for 28%. About 11% of the FCA market was vans.

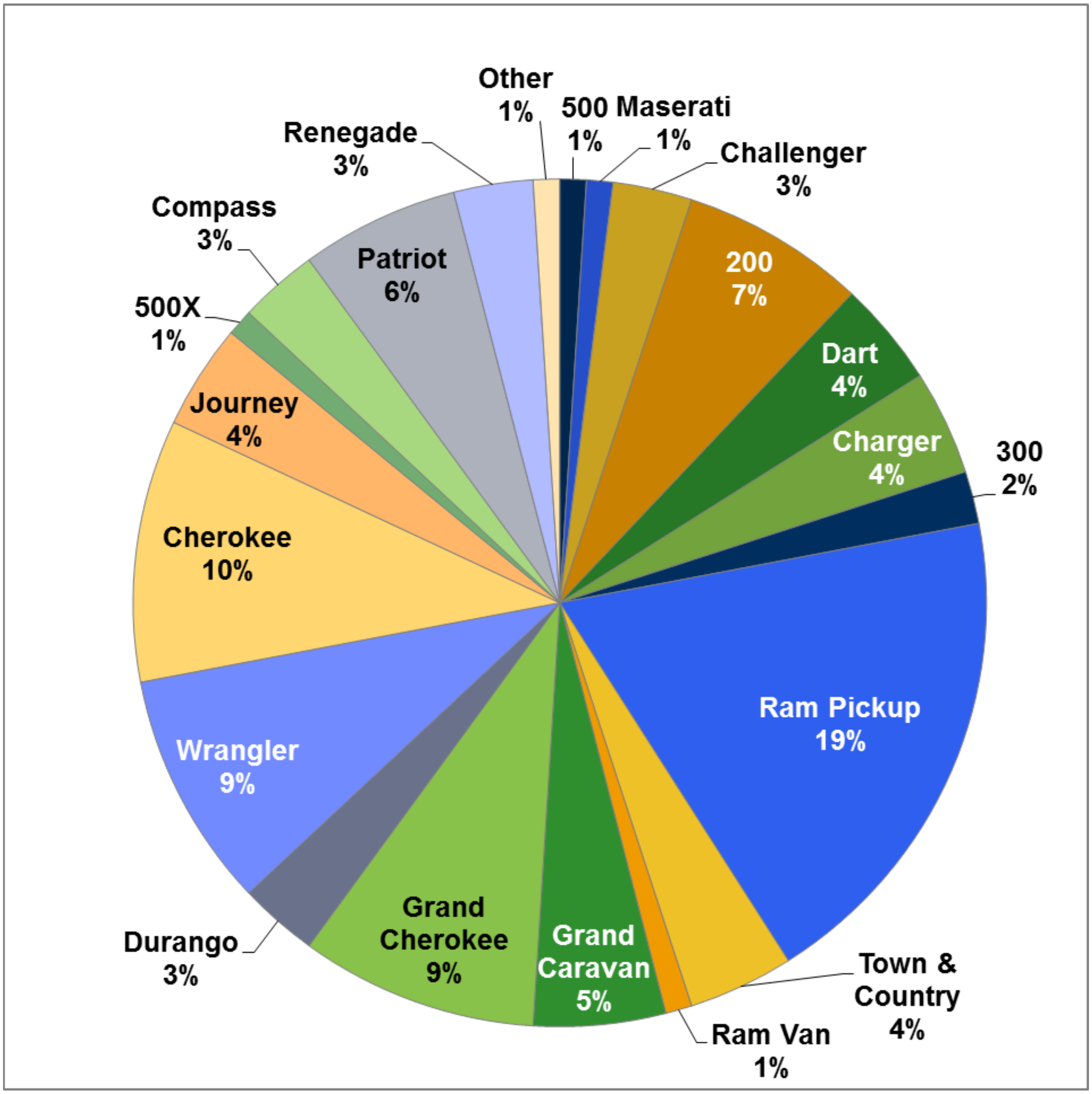


FIGURE 31. FCA Market Share by Model, 2015

Note: "Other" includes the Ferarri, Viper, 4C, 500e, Avenger, 500L, and Promaster City. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Fiat 500e Sales Are Up by 7.5% in 2016

Chrysler began with two hybrid-electric models in 2008-09, the Chrysler Aspen and the Dodge Durango. In 2013, parent company Fiat Chrysler introduced the Fiat 500e all-electric vehicle selling about 1,500 units in 2014, the first full calendar year of sales. In 2016, sales increased to over 3,700 units. The Fiat 500e was only sold in California and Oregon.

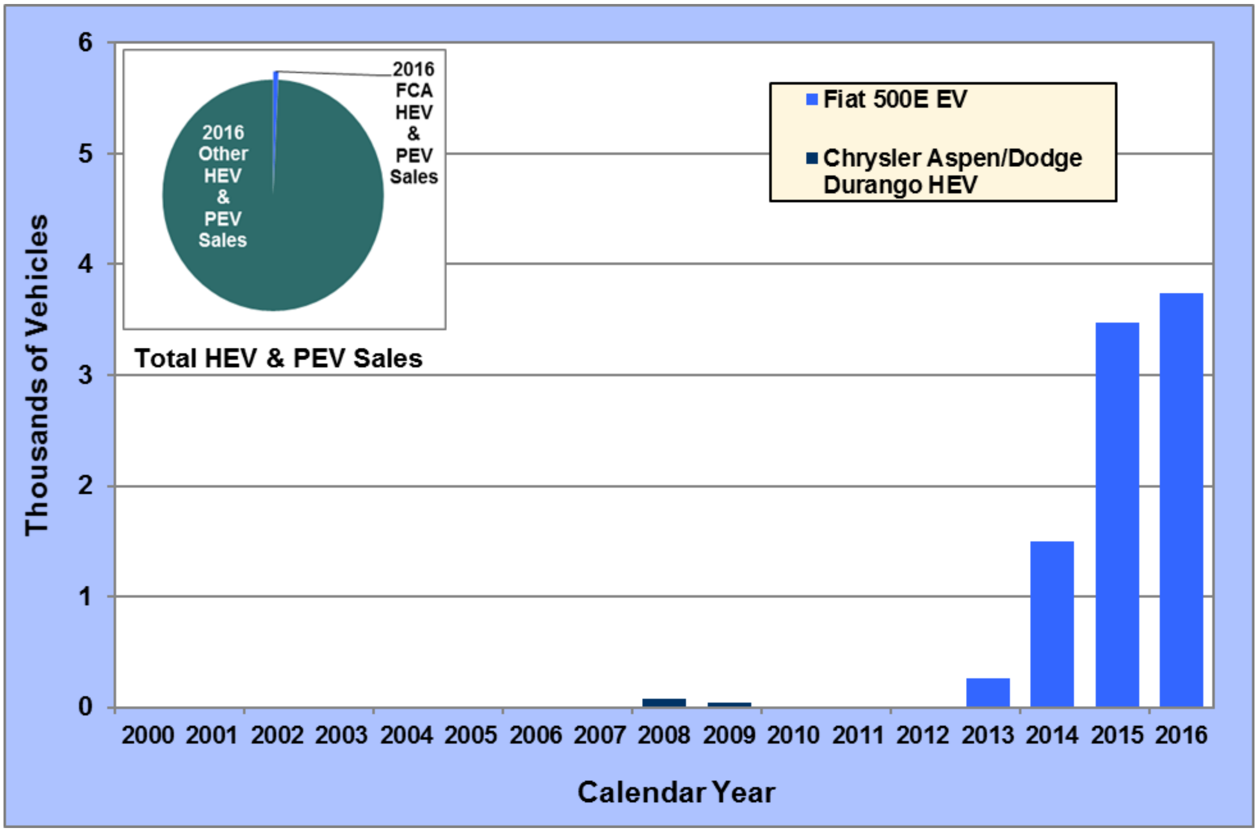


FIGURE 32. FCA Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 44, 49, 54, 59, 64, 69, 74, 79, 84) will have different vertical axis scales. EV = electric vehicle; PEV = plug-in electric vehicle; HEV=hybrid electric vehicle.

Source:

Data provided by Yan (Joann) Zhou, Argonne National Laboratory. http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

FCA Has Assembly Agreements with Nine Other Manufacturers

TABLE 5. FCA Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
China Motors						✓	Manufactures Chrysler minivans for Taiwanese market
Ford					✓	✓	Ford Ka built in Poland plant by Fiat; Ka and Fiat 500 share same platform
GM, Ford					✓		Co-research projects under the USCAR
GM				✓			Fiat supplies light commercial vehicles based on Doblo platform to Opel to sell as Combo
Guangzhou		✓		✓	✓	✓	Joint venture engaged in R&D, manufacturing, sales, and after-sales service for vehicle products, engines, and parts
Mazda					✓	✓	Will develop and manufacture a new roadster to be built in Hiroshima, Japan
Mitsubishi				✓			Supply its Thai-built Attrage sedan to Chrysler for sale in Mexico; Mitsubishi will supply rebadged L200 midsize pickups to Fiat to sell in Europe and Latin America
Peugeot		✓			✓	✓	Light commercial-truck manufacturing alliance called SevelSud in Italy that co-developed a new full-size delivery van built in Italy
Suzuki			✓				Uses Fiat diesel engines for vehicles in India
Tata		✓				✓	Jointly own Ranjangaon, India plant that builds Tata-developed vehicles and FCA-designed engines

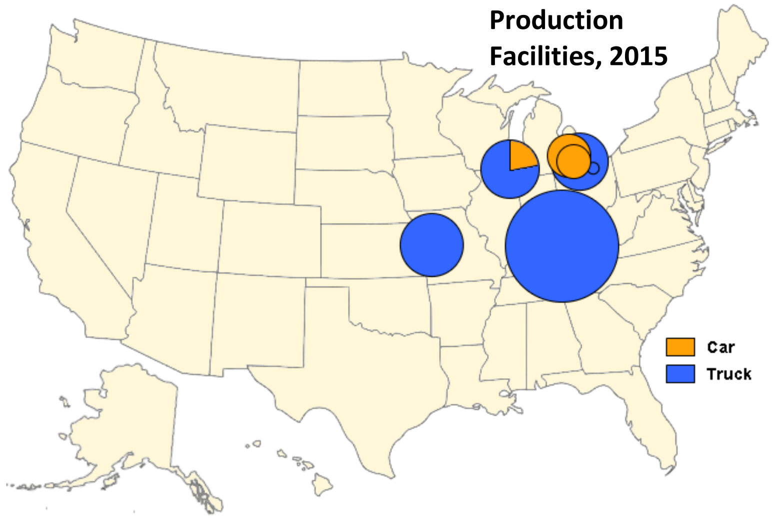
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Ford Company Profile

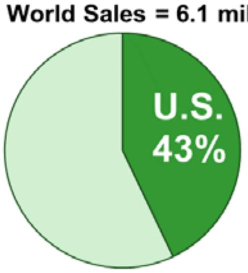
Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	36.0 mpg
Import Cars	30.8 mpg
Light Trucks	25.7 mpg

Average Vehicle Footprint, MY 2016	
Cars	46.7 sq ft
Light Trucks	59.4 sq ft
All	53.1 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	6
Natural Gas	0
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	2
Electric	1
Hydrogen	0



FOR World Sales = 6.1 million



Ford U.S. Plants	Type	2015 Production
Louisville, KY	Truck	754,763
Kansas City, MO	Truck	406,900
Dearborn, MI	Truck	365,350
Chicago, IL	Truck	286,972
Wayne, MI	Car	261,540
Flat Rock MI	Car	206,611
Chicago, IL	Car	81,857
Avon Lake, OH	Truck	52,847

FIGURE 33. Ford Company Profile

Fuel Saving Technologies

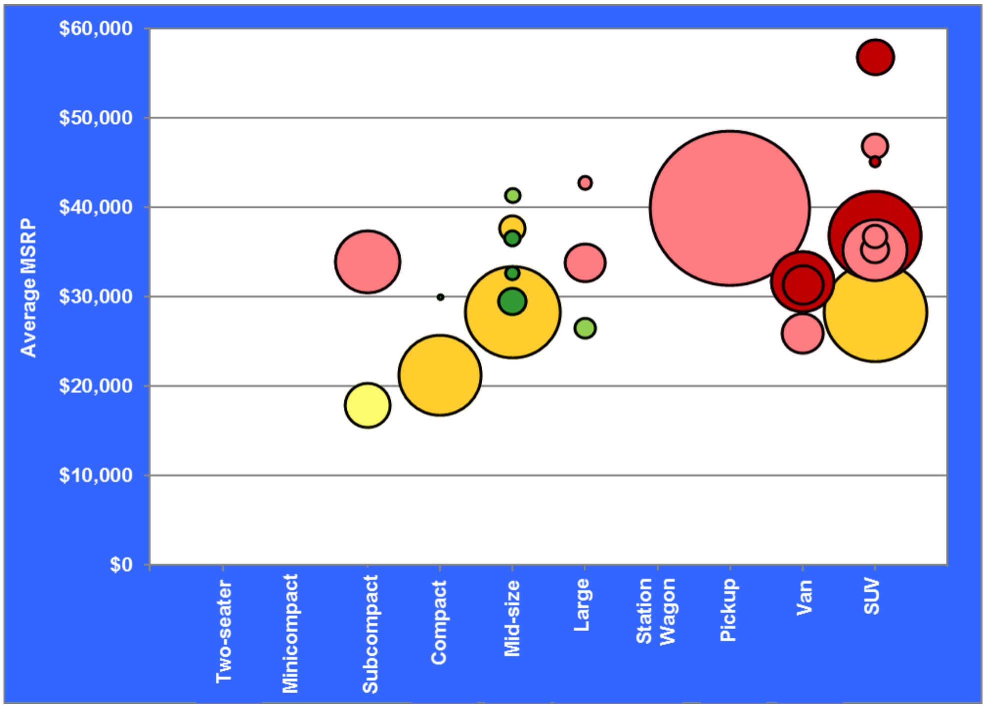
In late 2015 Ford announced an investment of $4.5 billion in vehicle electrification through 2020. Elaborating on initial plans to introduce 13 new hybrid or plug-in electric vehicles by 2020, Ford intends to introduce hybrid versions of the F150, Mustang and an all-electric small SUV with at least 300 miles of range. Ford is currently installing hybrid systems in sedans and wagons like the Ford Fusion hybrid, C-Max, and Lincoln MKZ hybrid. Ford's plug-in hybrids include the C-Max Energi and Fusion Energi, both with about 20 miles of all-electric operation. The Ford Focus Electric is currently Ford's only all-electric model and has a range of 115 miles for model year 2017, up from 76 miles for the 2016 model.

Building on the widely publicized adoption of aluminum for the body of the F150 beginning with the 2015 model year, Ford has introduced aluminum-bodied Super Duty trucks for the 2017 model year. The new aluminum body helps to reduce the overall weight by about 350 lb versus the previous model while adding more high-strength steel to increase frame strength and durability. The 2017 Ford F150 comes with a new 10-speed automatic transmission. Additionally, all F150 models with EcoBoost engines will come standard with stop-start which is expected to account for as much as 60% of F150 sales. The best-selling model in Ford's lineup after the F150 is the Escape crossover which will also come with stop-start as standard on all EcoBoost models accounting for as much as 90% of Escape sales.

Ford has continued to refine and expand the use of their EcoBoost technology that uses gasoline direct injection and variable valve timing combined with turbocharging. Efforts to innovate in a wide range of areas from electrification and mass reduction to ride sharing and autonomy, has led Ford to a record number of patent filings in 2016.

Ford's Fleet Mix

Ford Motor Company has models from the subcompact car segment to sport utility vehicles. The Ford F-150 pickup was by far their top-selling model. Of the car models that Ford sold in 2015, the majority had an average fuel economy of 25 mpg or higher with four models exceeding 40 mpg.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	
20-24	
25-29	
30-34	
35-39	
>= 40	

FIGURE 34. Ford Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 6. Ford Models by EPA Size Class, 2015

Two-Seater	**Mini-compact**	**Sub-compact**	**Compact**	**Mid-Size**	**Large**	**Station Wagon**	**Pickup**	**Van**	**SUV**
		Mustang Fiesta	Focus EV Focus	MKZ Hybrid MKZ Fusion Energi C-Max Energi Fusion-Hybrid Fusion	MKS Taurus C-Max		F-Series	Transit T150 E-Series Transit Connect	*Navigator* Expedition MKX MKT Explorer Flex MKC Edge Escape

Note: Includes Ford and Lincoln. Models listed in *red italics* do not appear on the figure due to high MSRP.

The F-Series Accounted for 28% of Ford's Sales in 2015

Twenty-eight percent of Ford's 2015 market were sales of the F-Series pickup trucks. Ford also had two cars (Focus and Fusion) and two SUVs (Explorer and Escape) that each held 8-12% of Ford's sales.

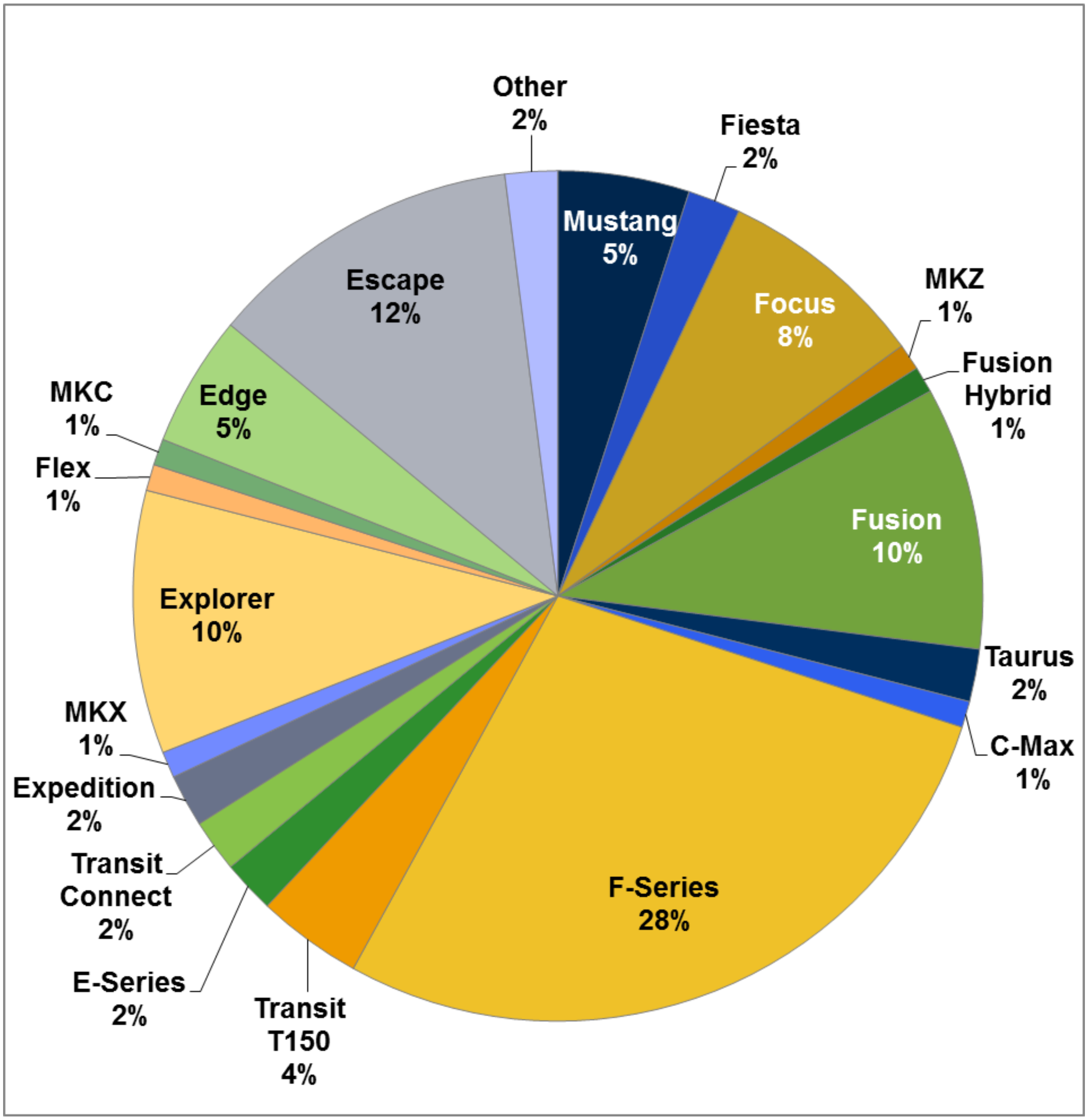


FIGURE 35. Ford Market Share by Model, 2015

Note: "Other" includes the Focus Electric, MKZ Hybrid, Fusion Energi, C-Max Energi, MKS, MKT and, Navigator. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Ford Hybrid and Plug-In Vehicle Sales Increased in 2016

After more than doubling in 2013, Ford hybrid and plug-in vehicle sales declined in 2014-2015, but then increased in 2016. The Ford Fusion hybrid and Ford Energi plug-in series (Fusion and C-Max) together accounted for the majority of Ford's hybrid and plug-in sales. Ford has the second highest share (15.3%) of the hybrid-electric (HEV) and plug-in (PEV) market.

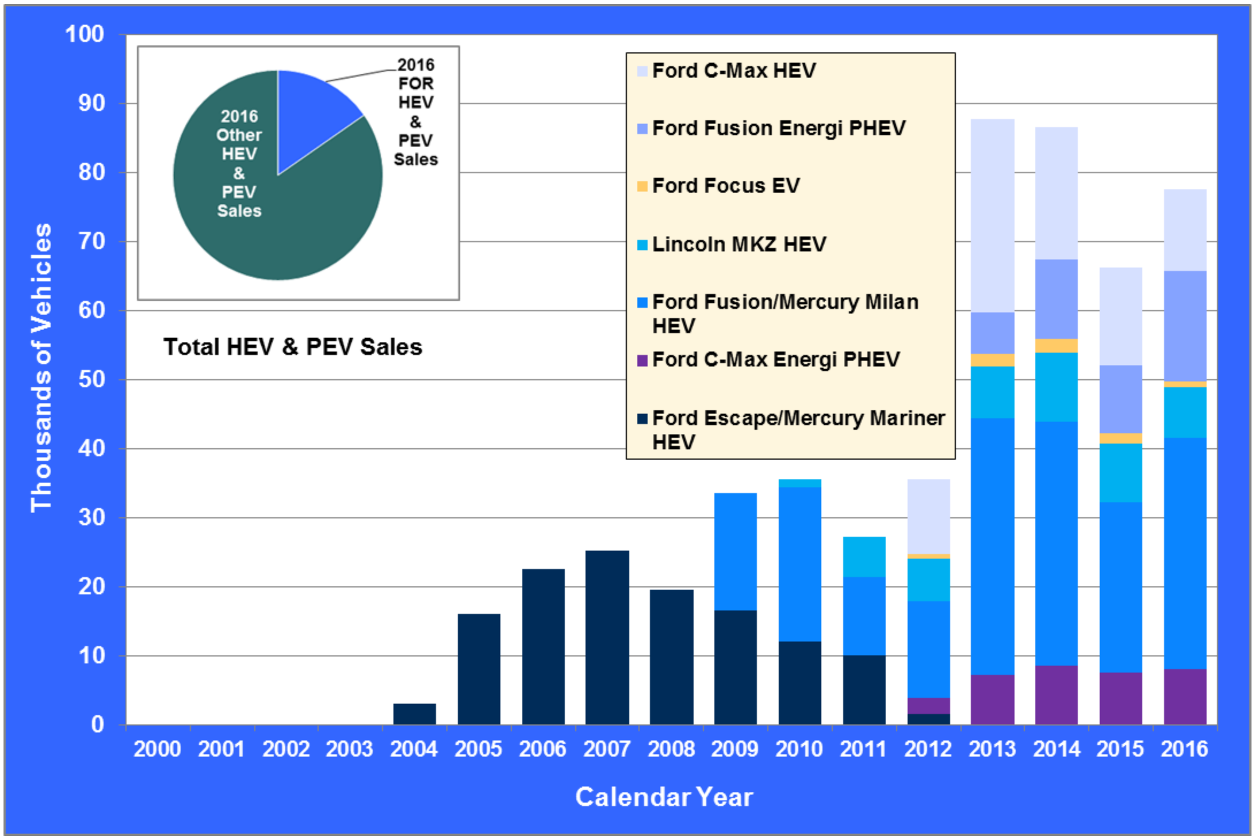


FIGURE 36. Ford Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 49, 54, 59, 64, 69, 74, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Ford Continues to Work Closely with Mazda

TABLE 7. Ford Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Mnufacturing/ Assembly Agreement	Description
Chongqing Changan		✓				✓	Joint venture that assembles Ford vehicles in Chongqing, China
BMW, Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
Daimler, Nissan					✓		Partnering in R&D called Automotive Fuel Cell Cooperation
FCA						✓	Builds Ford Ka, which shares Fiat 500 platform at its Tychy, Poland plant
GM					✓		Developing 9- and 10-speed automatic transmissions
GM, Chrysler					✓		Co-research projects under the USCAR
Mazda		✓				✓	Joint ventures in Flat Rock, MI, Thailand, and Malaysia
Mazda			✓		✓		Share platforms and parts
Mazda	✓						Ford has equity stake
Sollers		✓		✓		✓	Assembles Ford vehicles at Ford's Vsevolozhsk plant & Soller's facilities in Chelny & Elabuga. All Ford's Russian prior activities handled by Sollers through this venture

Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

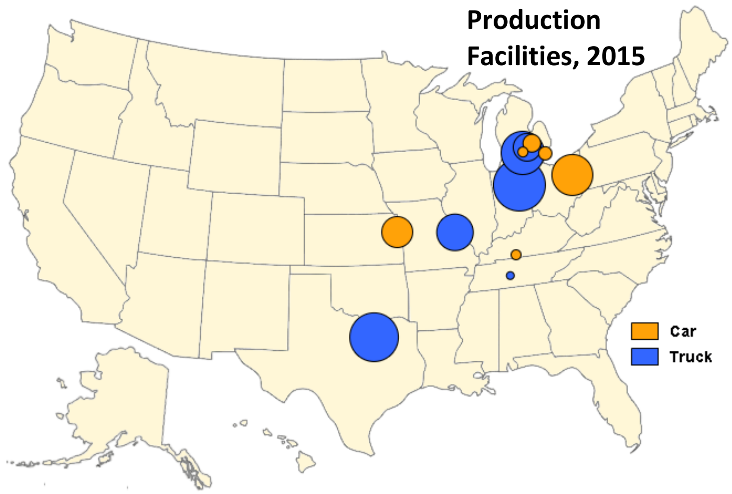
General Motors (GM) Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	34.5 mpg
Import Cars	38.7 mpg
Light Trucks	25.0 mpg

Average Vehicle Footprint, MY 2016	
Cars	46.4 sq ft
Light Trucks	59.9 sq ft
All	51.4 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	14
Natural Gas	1
Propane	0
Hybrid-Electric	5
Plug-In Hybrid-Electric	2
Electric	1
Hydrogen	0

GM World Sales = 9.5 million



GM U.S. Plants	Type	2015 Production
Fort Wayne, IN	Truck	352,125
Arlington, TX	Truck	331,160
Lansing, MI - Delta	Truck	289,257
Lordstown, OH	Car	269,437
Wentzville, MO	Truck	236,537
Fairfax, KS	Car	190,299
Flint, MI	Truck	174,444
Orion, MI	Car	102,677
Hamtramck, MI	Car	71,244
Lansing, MI - Grand River	Car	51,475
Bowling Green, KY	Car	40,403
Spring Hill, TN	Truck	33,264

FIGURE 37. GM Company Profile

Fuel Saving Technologies

In late 2016 GM began delivery of its new all-electric 2017 Chevrolet Bolt. With a price of $37,495 (before federal, state and local incentives) and an EPA estimated range of 238 miles, it is widely considered the first affordable mass market electric vehicle with a range of more than 200 miles. GM has discussed leveraging their EV expertise and the Bolt platform to introduce a wide range of all-electric vehicles. Although GM has plans to increase production of all-electric vehicles, they are not actively building charging infrastructure.

Following the redesigned second generation 2016 Chevrolet Volt plug-in hybrid, GM announced the cancellation of the Cadillac ELR plug-in hybrid. However, GM announced the all-new 2017 Cadillac CT6 plug-in hybrid which will deliver about 30 miles of all-electric range in a performance oriented sedan. The 2016 Chevrolet Malibu Hybrid uses an adaptation of the drivetrain from the Chevrolet Volt but with a 1.5 kWh battery pack and no plug. The new 2016 Malibu hybrid delivers an EPA combined rating of 46 mpg. For improved aerodynamics the new Malibu Hybrid has active grille shutters and a reduced ride height along with exhaust gas heat recirculation to warm the cabin for more consistent fuel economy in cold temperatures. GM is continuing to offer the eAssist mild hybrid systems on several Buick models.

Other approaches that GM is employing to boost fuel economy include stop-start which is expected to be available on nearly all models by 2020. An advanced form of stop-start that uses ultracapacitors to augment battery power began appearing on several Cadillac models in 2016 including the ATS and CTS models. Increased use of cylinder deactivation, mass reduction, advanced transmissions and the introduction of several diesel models including the midsized Chevrolet Colorado and GMC Canyon pickup trucks and the 2017 Chevrolet Cruze have all contributed to improved fuel economy.

GM's Fleet Mix

GM encompasses a wide range of brands and models. GM sells a high volume of pickup trucks and SUVs, many of which are large with a combined fuel economy below 20 mpg. The Chevrolet Cruze was the highest selling car in 2015 with a combined fuel economy of more than 30 mpg.

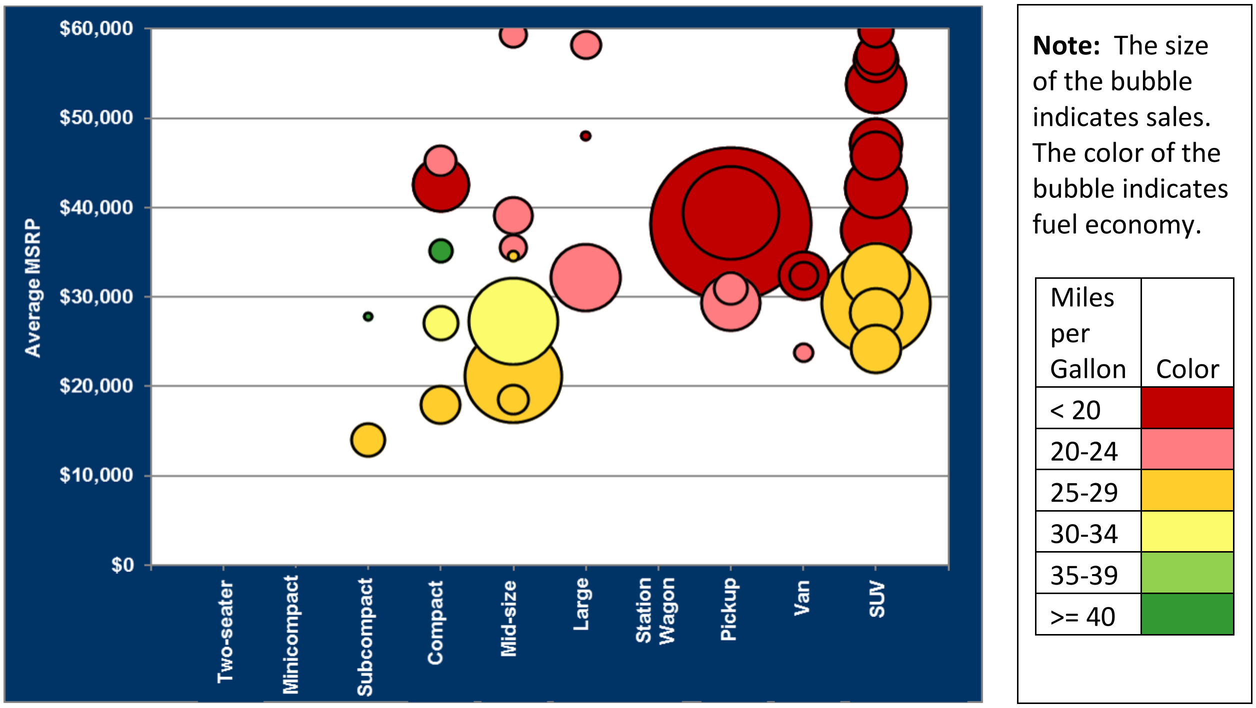


FIGURE 38. GM Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 8. GM Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
Corvette		*ELR* Spark EV Spark	ATS Camaro Volt Verano Sonic	CTS LaCrosse Regal LaCrosse eAssist Malibu Cruze Sonic 5	XTS SS Impala		Sierra Silverado Canyon Colorado	Savana Express City Express	*Escalade ESV* *Escalade* Yukon XL Yukon Suburban Tahoe SRX Enclave Acadia Traverse Terrain Equinox Encore Trax

Note: Includes Buick, Cadillac, Chevrolet, and GMC. Models listed in *red italics* do not appear on the figure due to high MSRP.

GM's SUVs Accounted for More than One-Third of GM's Total Sales in 2015

With 14 different SUV models, GM's SUVs accounted for more than 41% of GM sales in 2015. The Chevrolet Equinox was the only SUV with more than a 4% share. The Chevrolet Silverado and GMC Sierra pickup trucks were 27% of GM's sales.

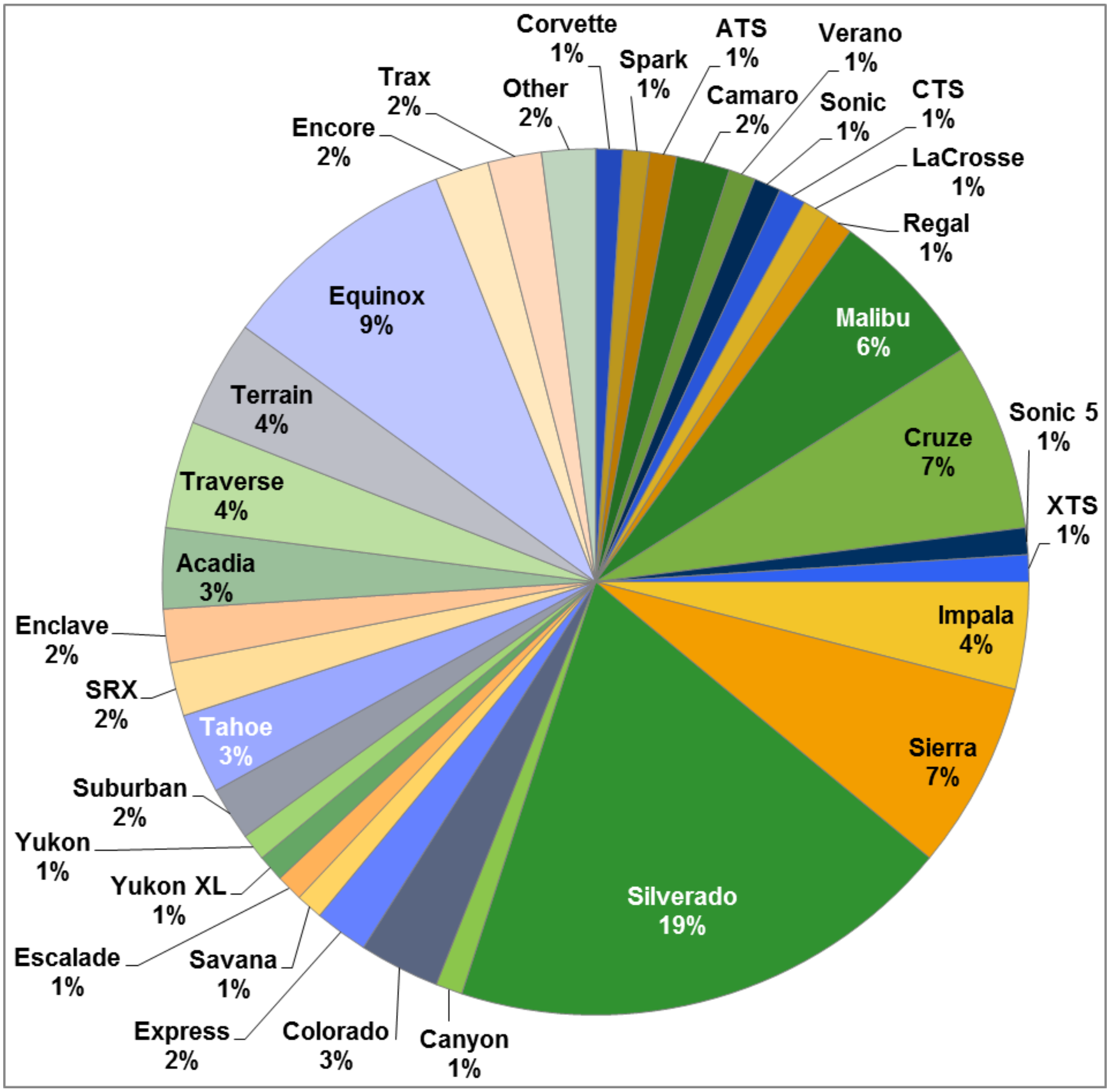


FIGURE 39. GM Market Share by Model, 2015

Note: "Other" includes the ELR, Spark EV, LaCrosse e-Assist, SS, City Express, and Escalade ESV. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Chevrolet Volt Accounted for More than Half of GM's 2016 Hybrid and Plug-In Sales

Cancellation of several eAssist models contributed to a decline in GM's 2014 and 2015 hybrid (HEV) sales. Sales of the aging first-generation Chevrolet Volt continued to decline in 2015. With declining availability of hybrid models and lower sales on hybrids and plug-ins (PEV), GM accounted for just under 7% of all hybrid and plug-in vehicle sales.

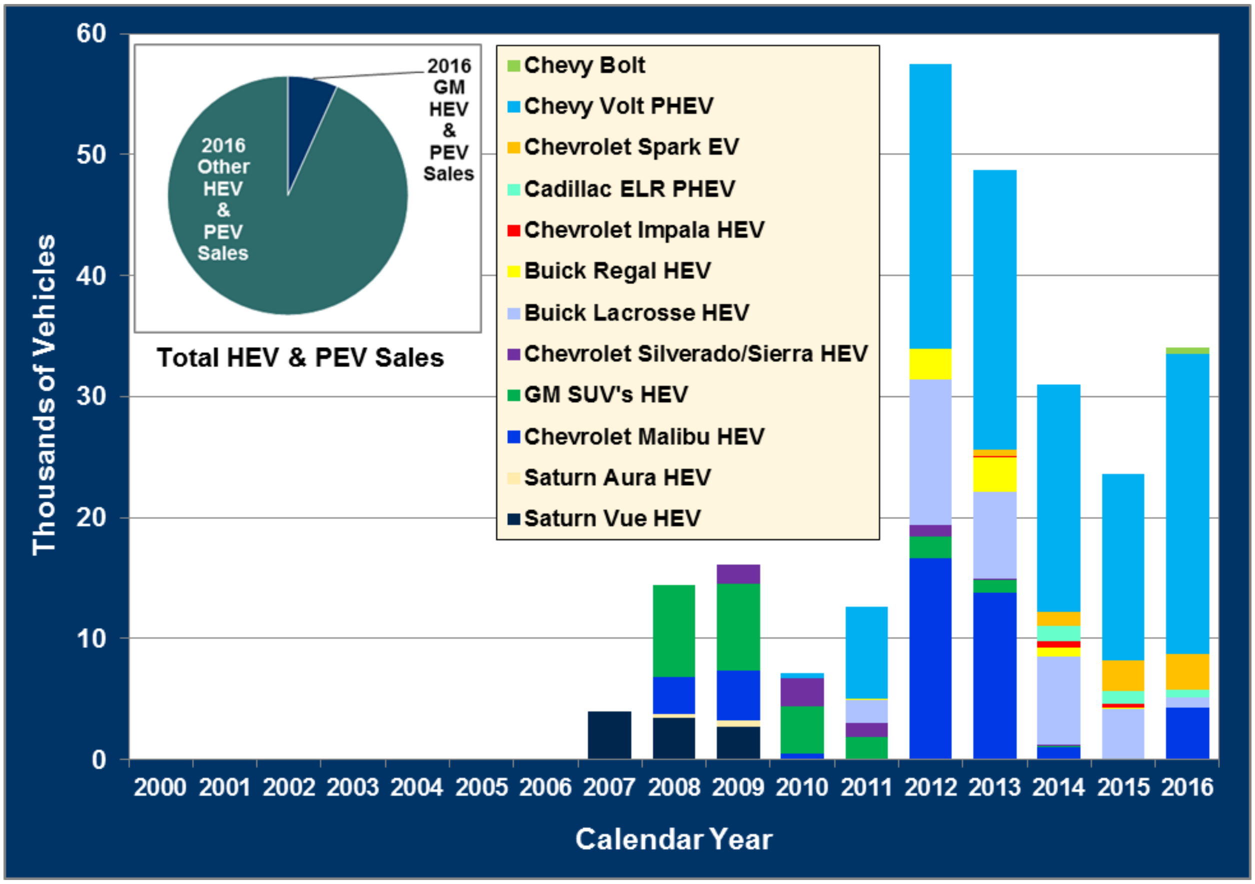


FIGURE 40. GM Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 54, 59, 64, 69, 74, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

GM Has Many Technology/Design Relationships with Other Manufacturers

TABLE 9. GM Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Avtovaz		✓				✓	Assembly joint venture in Togliatti, Russia for Chevrolet Niva
BMW					✓		Developing hydrogen refueling standards
BMW, Ford, Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
FAW		✓				✓	Production & sales of light trucks & vans in China
FCA				✓			Supplies light vehicles to Opel to sell as the Combo
Ford					✓		Developing 9- and 10-speed automatic transmissions
Ford & FCA					✓		Co-research projects under the USCAR
GAZ						✓	Assembles Chevrolet Aveo in Nizhny, Norgorod
Honda					✓		Co-developing next generation fuel cell system and hydrogen storage technologies
Isuzu					✓		Memorandum of Understanding to jointly develop a pickup truck
Isuzu			✓	✓		✓	Build and distribute trucks in South Africa, Kenya, Egypt & Tunisia
Nissan				✓			Supply NV200 vans to sell as Chevrolet City Express in Canada & U.S
Peugeot	✓			✓	✓		Jointly develop small engines & vehicles for European market
Shanghai Auto					✓		Co-develop architecture and components for electric cars sold in China
Shanghai Auto		✓		✓			Co-handles production, sales and after-sales services for GM vehicles
Shanghai Auto						✓	Partner in vehicle assembly operation in Liuzhou, China
Shanghai Auto	✓						Holds stakes in GM Korea and GM India
ZAZ						✓	Assembles Chevrolet models

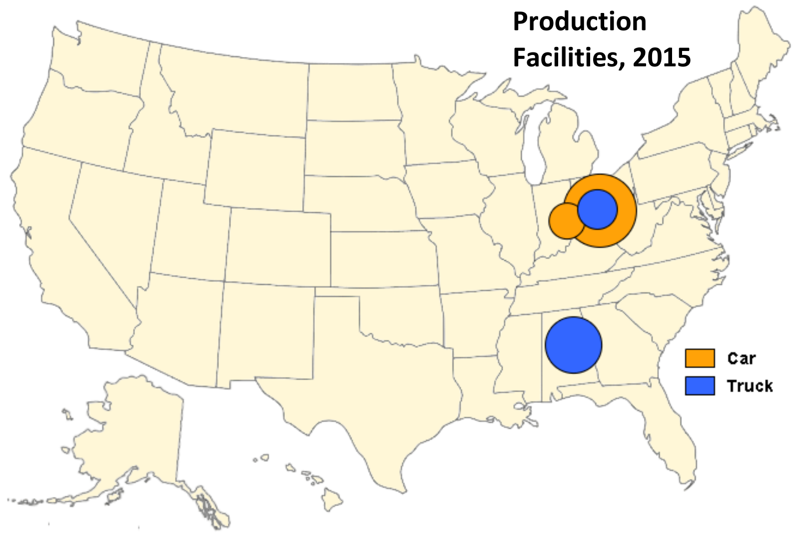
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015.
http://wardsauto.com

Honda Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	41.9 mpg
Import Cars	45.3 mpg
Light Trucks	30.9 mpg

Average Vehicle Footprint, MY 2016	
Cars	45.7 sq ft
Light Trucks	49.5 sq ft
All	47.1 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	2
Plug-In Hybrid-Electric	0
Electric	0
Hydrogen	0



HON World Sales = 4.6 million

Honda U.S. Plants	Type	2015 Production
Marysville, OH	Car	460,626
Lincoln, AL	Truck	349,703
East Liberty, OH	Truck	241,193
Greensburg, IN	Car	218,202

FIGURE 41. Honda Company Profile

Fuel Saving Technologies

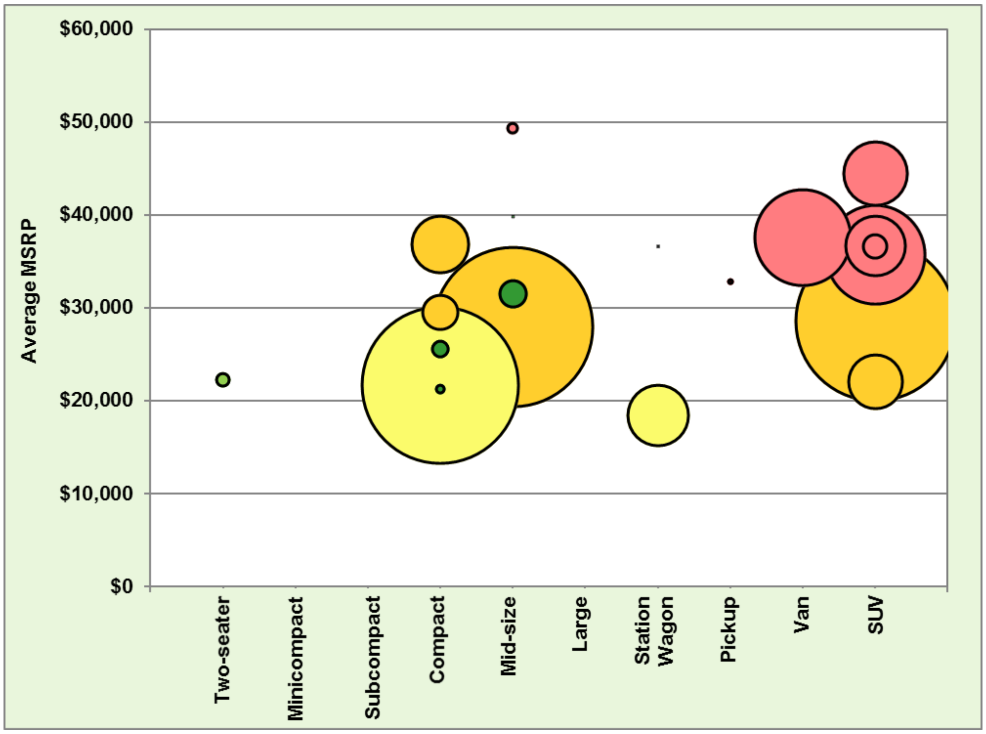
In early 2016 Honda announced a company goal for electrified vehicle sales to account for two-thirds of overall sales by 2030. In January 2017 Honda stated that half of the all-new models that Honda will launch in the United States will be electrified vehicles. Specifically, Honda will offer three versions of the Honda Clarity. Joining Honda's redesigned 2017 Clarity fuel cell vehicle, plans are to release an all-electric version and a plug-in hybrid version that is expected to deliver 40 miles of all-electric range. While the fuel cell and all-electric models will initially only be available in selected areas, the plug-in hybrid is expected to be sold in all 50 states. Production of the low volume CR-Z hybrid sports car ended in 2016 but Honda has released the newly redesigned 2017 Honda Accord Hybrid and announced the introduction of a new dedicated hybrid in 2018.

The Honda Civic Natural Gas sedan was phased out as Honda concentrates on fuel cell, hybrid, and electric vehicles. An $85-million investment between Honda and GM was announced in January 2017 to begin manufacturing fuel cell systems in Michigan for use in future product offerings by both companies. Fuel cell manufacturing is expected to begin around 2020. The companies have worked together since 2013 in a partnership to develop commercially viable fuel cell systems for vehicles. After achieving reductions in cost, size, and durability of fuel cell systems, efforts are beginning to shift toward commercial production.

For conventional gasoline vehicles, Honda has been implementing a suite of drivetrain technologies marketed under the name "Earth Dreams" that includes a new generation of direct injection engines, turbocharging, and greater use of CVT transmissions. Improvements to previously used technologies like cylinder deactivation are also part of the strategy. A 9-speed transmission is used on the 2016 Pilot, and a new Honda-developed 10-speed automatic transmission will be available on the 2018 Odyssey which also comes with active grill shutters for improved aerodynamics.

Honda's Fleet Mix

Honda Motor Company had just one model with a combined average fuel economy of less than 20 mpg and it represented a small portion of total sales. Those models that sell in the greatest number had combined fuel economies of 25 mpg or higher. The Honda Accord was the highest selling model in 2015 followed closely by the Civic with a combined average fuel economy of more than 30 mpg. All of Honda's models had an average MSRP of less than $50,000.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	
20-24	
25-29	
30-34	
35-39	
>= 40	

FIGURE 42. Honda Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 10. Honda Models by EPA Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
CR-Z			TSX ILX Civic-Hybrid Civic Insight	RLX Accord PHEV Accord Hybrid Accord		Fit EV Fit	Ridgeline	Odyssey	MDX RDX Crosstour Pilot CR-V HR-V

Note: Includes Honda and Acura.

The Accord, CR-V, and Civic Combined Were Almost Two-Thirds of Honda's Sales in 2015

The three biggest sellers for Honda are the Accord, CR-V, and Civic, each with more than 20% of Honda's market share. Altogether, the Accura-brand vehicles comprise a little more than 20% of the total.

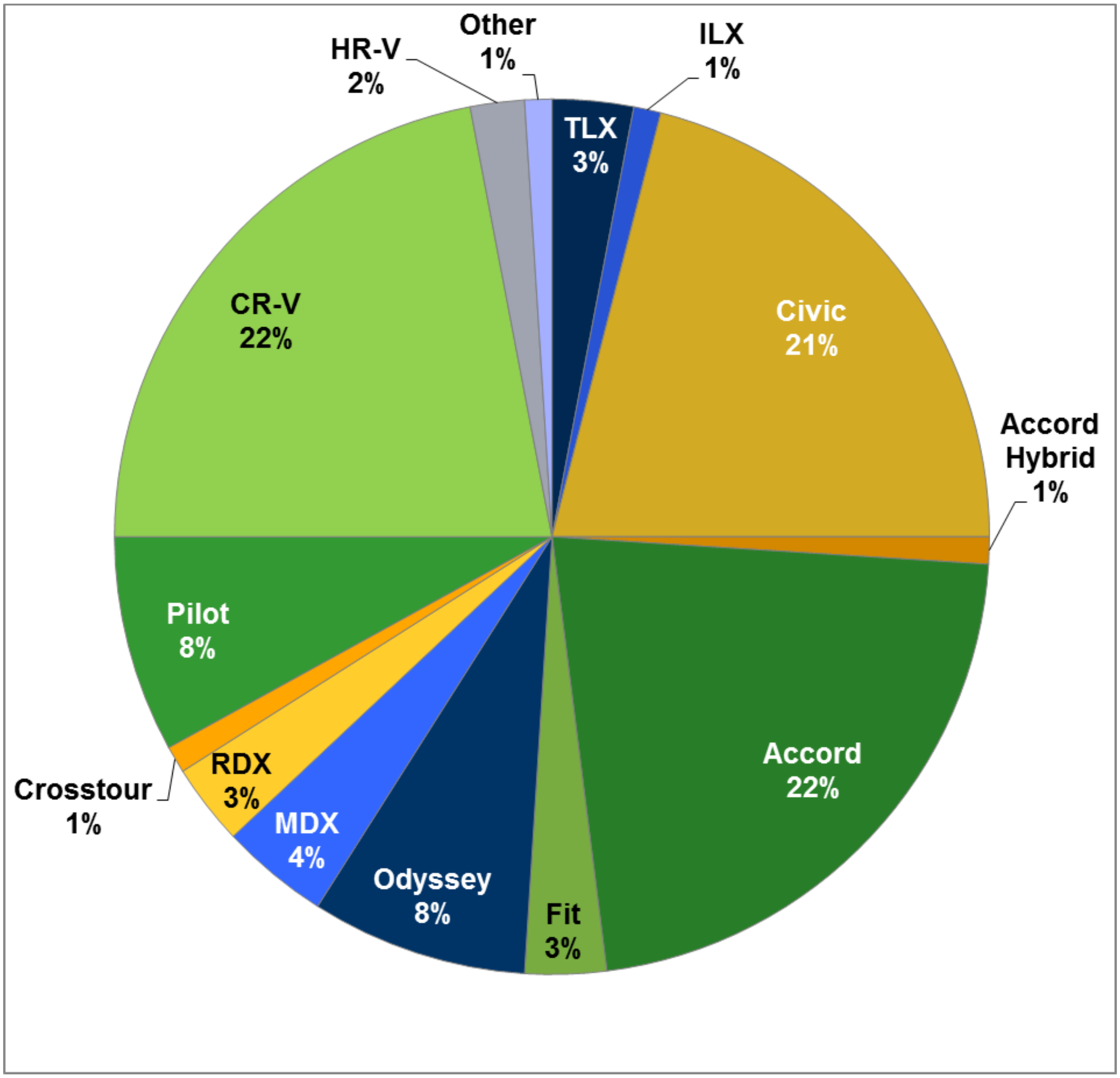


FIGURE 43. Honda Market Share by Model, 2015

Note: "Other" includes the CR-Z, Civic Hybrid, Insight, RLX, Accord PHEV, Fit EV, and Ridgeline. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Honda Hybrid Sales Declined in 2016

Honda sold no plug-in vehicles (PEV) in 2016 and sales of each hybrid model were lower than in 2015. The Honda Accord hybrid-electric vehicle (HEV) accounted for 71% of Honda's HEV sales.

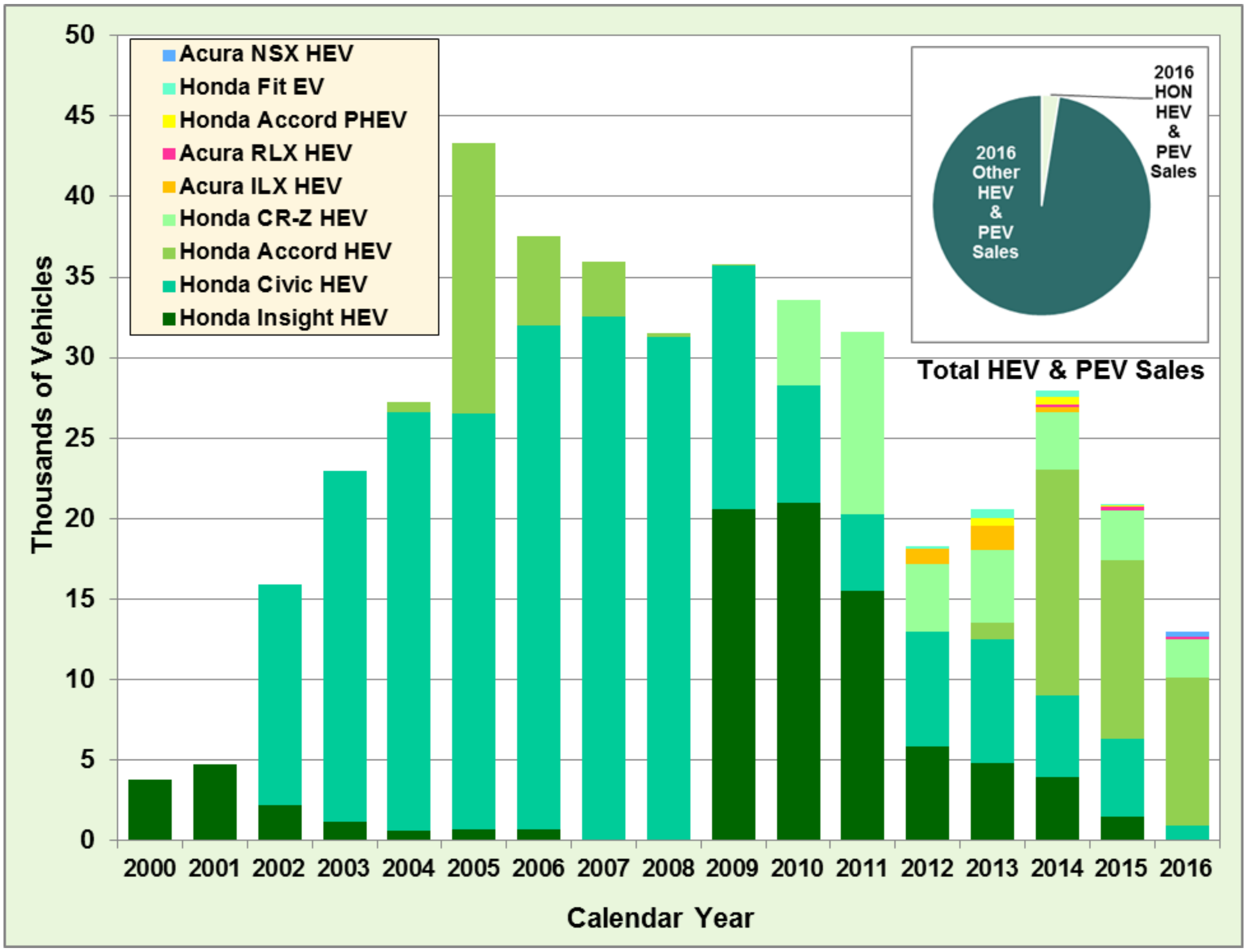


FIGURE 44. Honda Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 59, 64, 69, 74, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Honda Works with Other Manufacturers on Fuel Cells and Hydrogen

TABLE 11. Honda Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
BMW, Ford, Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
Dongfeng		✓				✓	Joint venture to build and sell cars in Wuhan, China
Guangzhou		✓				✓	Joint venture to build cars and vans in Guangzhou, China
GM					✓		Co-developing next generation fuel cell system and hydrogen storage technologies
Nissan, Toyota		✓					Joint venture project for the development of hydrogen station infrastructure in Japan
Proton				✓	✓		Planning partnership to include platform sharing and distribution arrangements

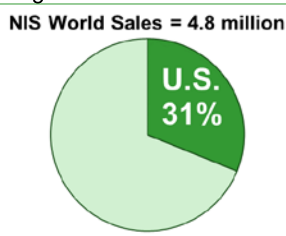
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

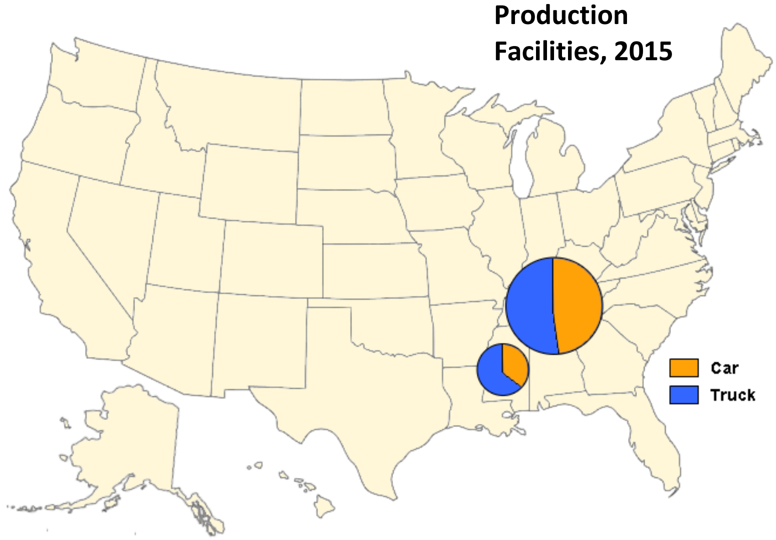
Nissan Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	42.0 mpg
Import Cars	38.0 mpg
Light Trucks	30.7 mpg

Average Vehicle Footprint, MY 2016	
Domestic Cars	46.0 sq ft
Import Cars	50.0 sq ft
Light Trucks	46.8 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	5
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0





Nissan U.S. Plants	Type	2015 Production
Smyrna, TN	Truck	328,741
Smyrna, TN	Car	304,606
Canton, MS	Truck	212,542
Canton, MS	Car	116,504

FIGURE 45. Nissan Company Profile

Fuel Savings Technologies

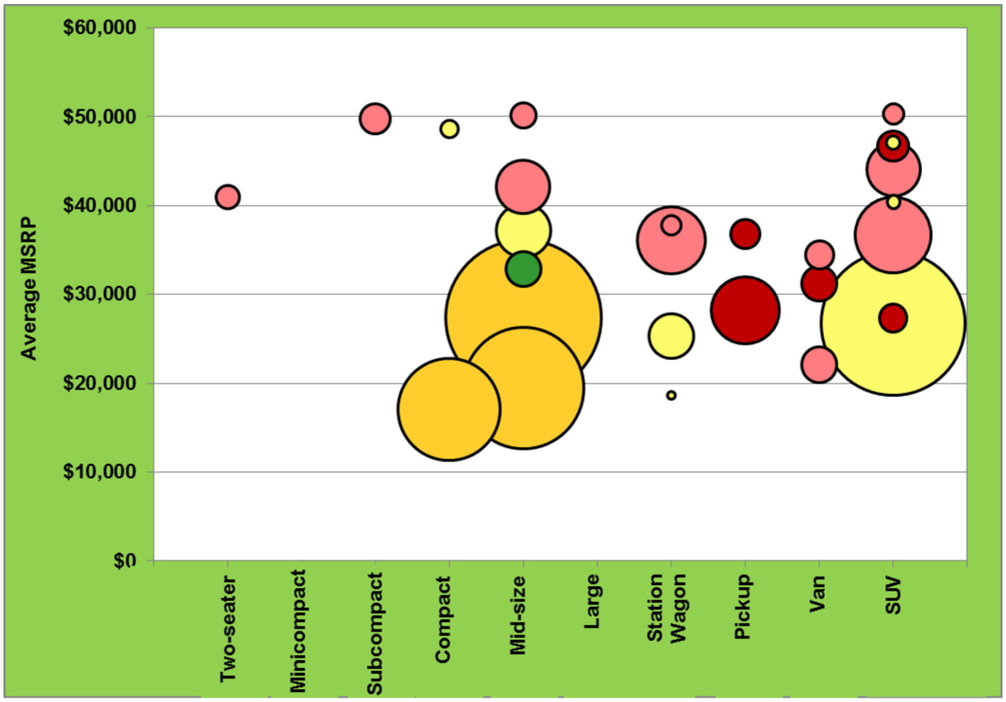
On October 20, 2016 Nissan announced the completion of a $2.29-billion deal giving Nissan controlling share of Mitsubishi Motors, Inc. The two companies will share production facilities and technologies for plug-in hybrid vehicles. Mitsubishi produces the Outlander plug-in hybrid in markets outside the U.S. and intends to bring it to the U.S. Mitsubishi also sells the all-electric iMiEV, a subcompact car with about 60 miles of range.

In 2016, Nissan phased out their 24 kWh battery pack for the LEAF, replacing it with a 30 kWh battery pack that delivers 107 miles of range. With the 30 kWh battery pack, the Quick Charge Package becomes standard, allowing for DC fast charging and an 80% charge in 30 minutes. The next generation Nissan LEAF is expected to have a 60 kWh battery and a range of about 200 miles. Some degree of autonomous driving capability is also anticipated with the redesigned next generation LEAF. Nissan introduced the Murano Hybrid for the 2016 model year and then the 2017 Nissan Rogue Hybrid. Under the Infiniti brand, the Q50 and Q70 hybrid sedans are also available for the 2016 and 2017 model years.

Nissan has long been a leader in the development and implementation of continuously variable transmissions (CVTs) and now offers them across a broad selection of vehicles. The third generation of Nissan's Xtronic CVT reduces friction by 40% and is smaller and lighter than the previous transmission increasing fuel economy and performance. The new CVT includes D-Step Shift Logic that mimics the sensation and sound of an automatic transmission while retaining the fuel economy benefits of a CVT. Nissan also employs conventional automatic transmissions, manual transmissions and an automated manual dual clutch transmission in sporty models like the Nissan GT-R. Another notable technology introduced by Nissan in 2016 is the e-Bio Fuel Cell prototype - a solid oxide fuel cell vehicle that uses ethanol and an onboard reformer to produce hydrogen rather than carrying hydrogen in pressurized tanks. This could allow refueling with existing infrastructure while providing ranges similar to gasoline powered vehicles.

Nissan's Fleet Mix

Nissan sold five models that have a combined fuel economy of less than 20 mpg in 2015, but they sell in relatively low numbers. The compact and mid-size car segments accounted for a large portion of Nissan's overall sales. Nissan had eight models with a combined rating of 30 mpg or more, with the Rogue being the most popular of them.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	(dark red)
20-24	(pink)
25-29	(orange)
30-34	(yellow)
35-39	(light green)
>= 40	(dark green)

FIGURE 46. Nissan Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 12. Nissan Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
370Z		*GT-R* Q60	Q50 Hybrid Versa	M-series Q50 Maxima LEAF Altima Sentra		QX50 Murano Juke Cube	Titan Frontier	Quest NV NV200	*QX80* QX70 QX60-Hybrid Armada QX60 Pathfinder-Hybrid Pathfinder Xterra Rogue

Note: Includes Nissan and Infiniti. Models listed in *red italics* do not appear on the figure due to high MSRP.

Nissan Altima Was Nearly One-Quarter of Nissan's Sales in 2015

The Altima was Nissan's best seller in 2015, followed by the Rogue SUV (19%). The Sentra and Versa also have a large share of Nissan sales. The pickup trucks (Frontier and Titan) held about 5% of Nissan's total sales.

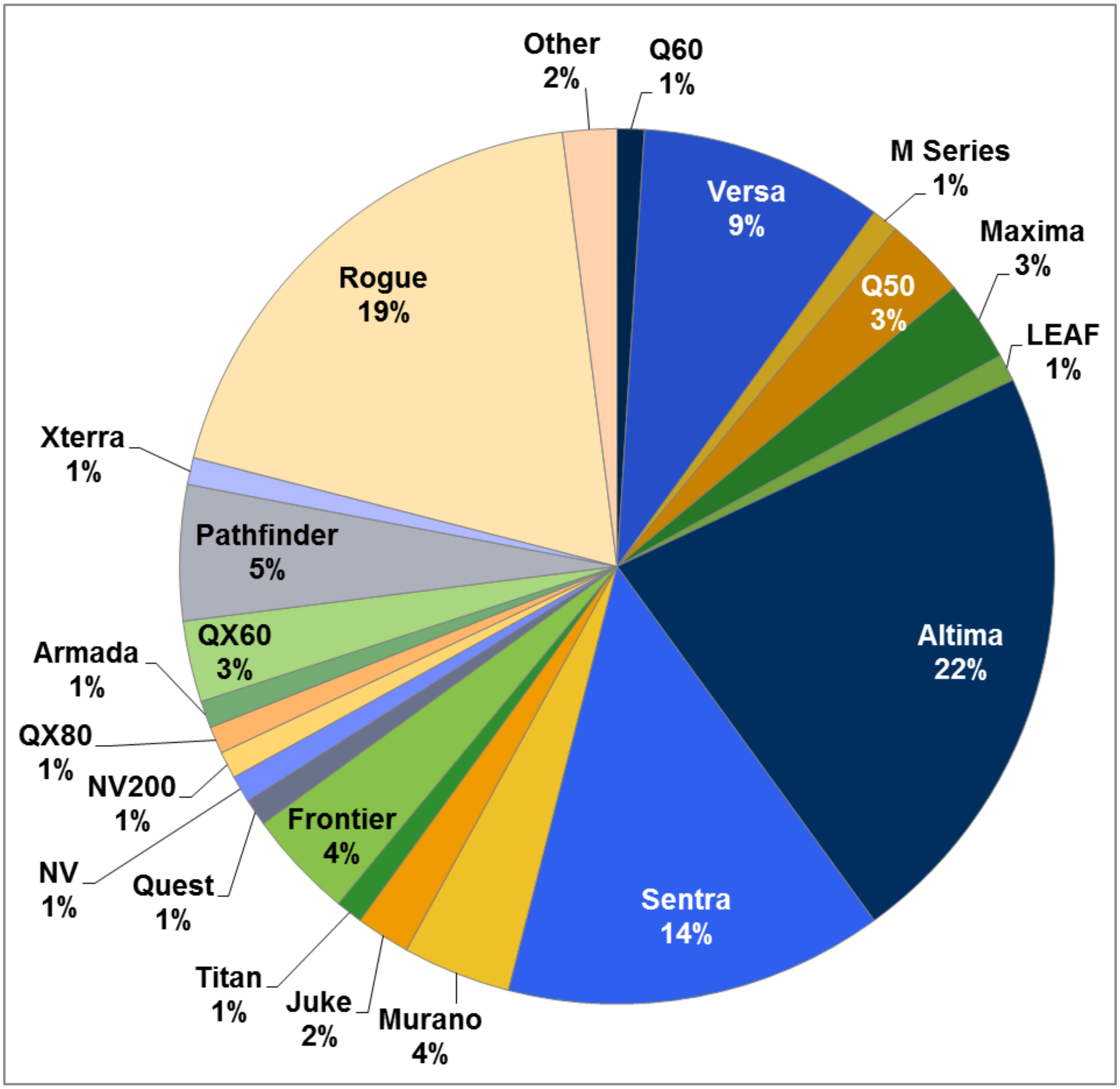


FIGURE 47. Nissan Market Share by Model, 2015

Note: "Other" includes the 370Z, GT-R, Q50 Hybrid, QX50, Cube, QX70, QX60 Hybrid, and Pathfinder Hybrid. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Nissan Leaf Was Over Three-Fourths of Nissan's Hybrid and Plug-In Vehicle Sales in 2016

Nissan Leaf electric vehicle (EV) sales represent over three-fourths of Nissan's hybrid-electric (HEV) and plug-in vehicle (PEV) sales. The sales of each Nissan HEV and PEV model declined in 2016. Nissan is responsible for just over 4% of all HEV and PEV sales.

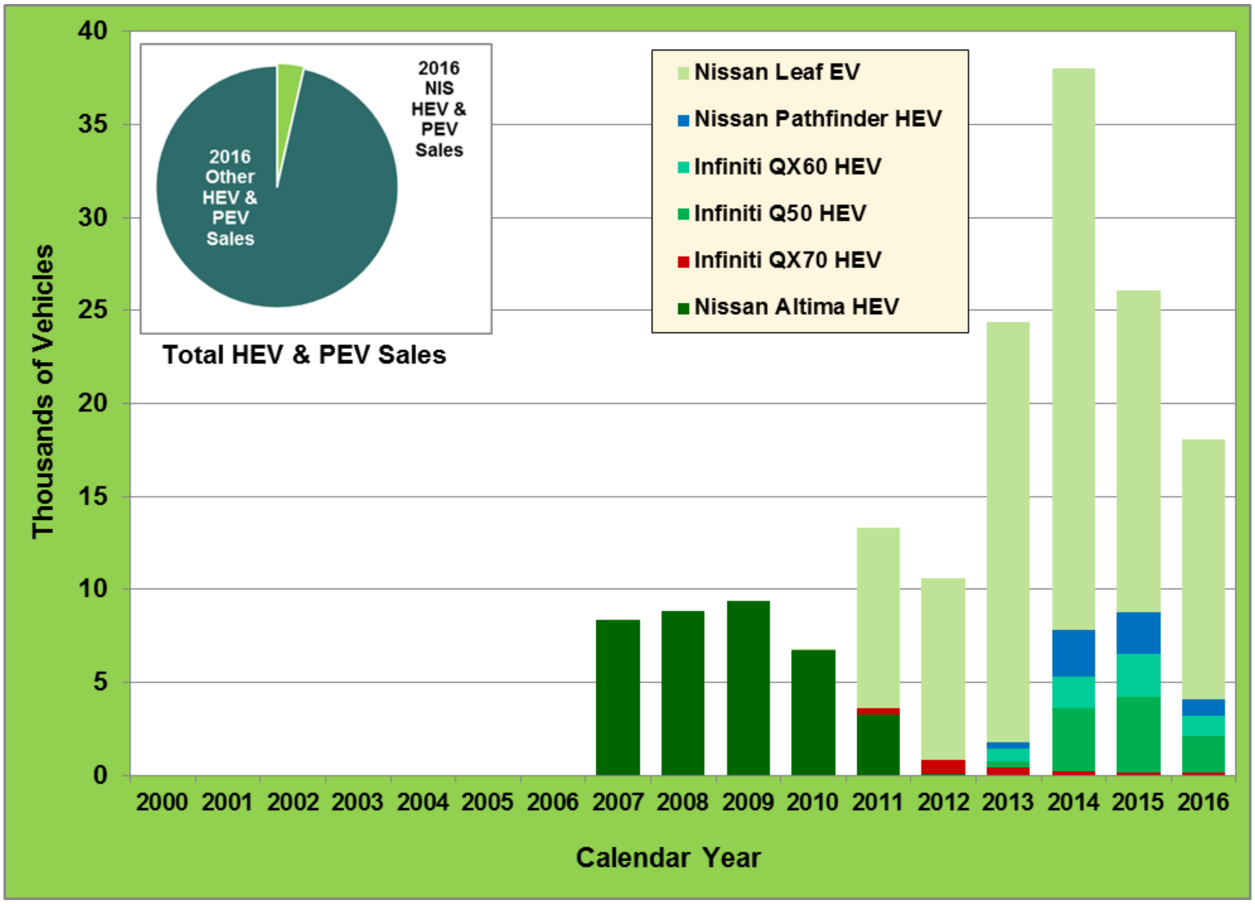


FIGURE 48. Nissan Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Notes: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 64, 69, 74, 79, 84) will have different vertical axis scales. Altima sales in 2012 are for the Model Year 2011.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Nissan Has the Most Interrelationships

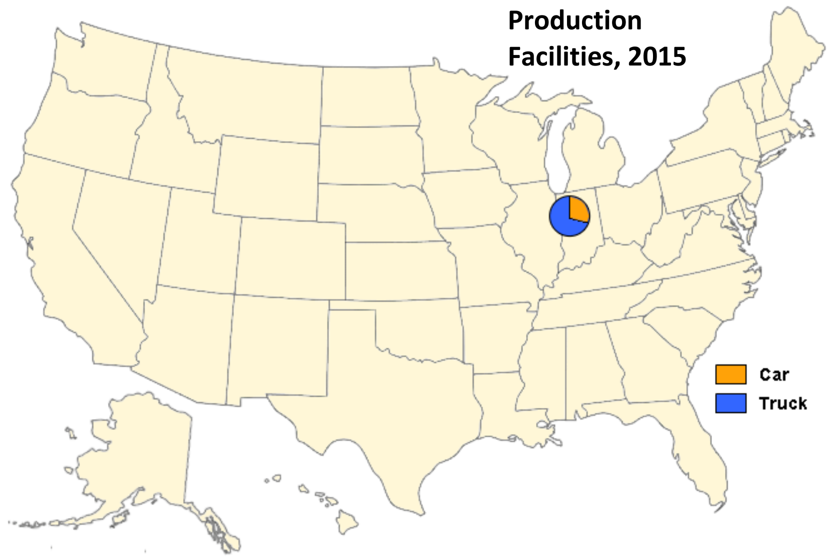
TABLE 13. Nissan Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Avtovaz	✓						Joint venture with Renault-Nissan
BMW					✓		Memorandum of understanding to jointly plan and build a national grid of vehicle charging stations in South Africa
Dacia					✓		Co-engineered Nissan Logan platform built by Dacia
Daimler, Ford					✓		Partnering in R&D Automotive Fuel Cell Cooperation
Daimler		✓			✓		Partner with Renault-Nissan to develop small cars, vans, & powertrains
Daimler			✓	✓			Supplies diesel engines for European Infiniti models
Daimler			✓				Allows Nissan to manufacture automatic transmissions for Nissan & Infiniti vehicles
Daimler						✓	Engines for Infiniti & Mercedes Benz built by Nissan in 2014
Daimler					✓	✓	Jointly develop a Mercedes-Benz midsize pickup truck to be built by Renault-Nissan in Spain and Argentina
Dongfeng		✓		✓		✓	Joint venture in Guangzhou, China to make & sell Venucia cars
Dongfeng				✓	✓		Co-developed medium truck in Avila, Spain
GM						✓	Nissan supplies NV200 vans to GM in the United States. & Canada
Mazda			✓	✓	✓		Supplies vehicles & develops components
Mitsubishi		✓			✓	✓	Joint venture in minicars called NMKV
Mitsubishi				✓		✓	Supplies light duty trucks in Japanese market
Renault			✓	✓	✓		Share platforms, components & marketing
Renault	✓					✓	Owns a stake and builds vehicles for Nissan
Renault, Avtovaz		✓					Joint venture in Tangier, Morocco
Suzuki, Mitsubishi	✓						Co-ownership with Nissan in Jatco Ltd transmission making
Suzuki				✓	✓	✓	Produces mini commercial vehicles & minicars in Japan

Source: Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Subaru Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	None
Import Cars	38.2 mpg
Light Trucks	36.4 mpg
Average Vehicle Footprint, MY 2016	
Cars	44.9 sq ft
Light Trucks	45.0 sq ft
All	44.9 sq ft
Number of Alternative Fuel Models, MY 2016	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	0
Hydrogen	0



Subaru U.S. Plants	Type	2015 Production
Lafayette, IN	Truck	162,802
Lafayette, IN	Car	66,002

SUB World Sales = 0.9 million

Note: Subaru vehicles assembled in Indiana in 2015 do not meet CAFE criteria for domestic vehicles due to the low percentage of domestic content.

FIGURE 49. Subaru Company Profile

Fuel Saving Technologies

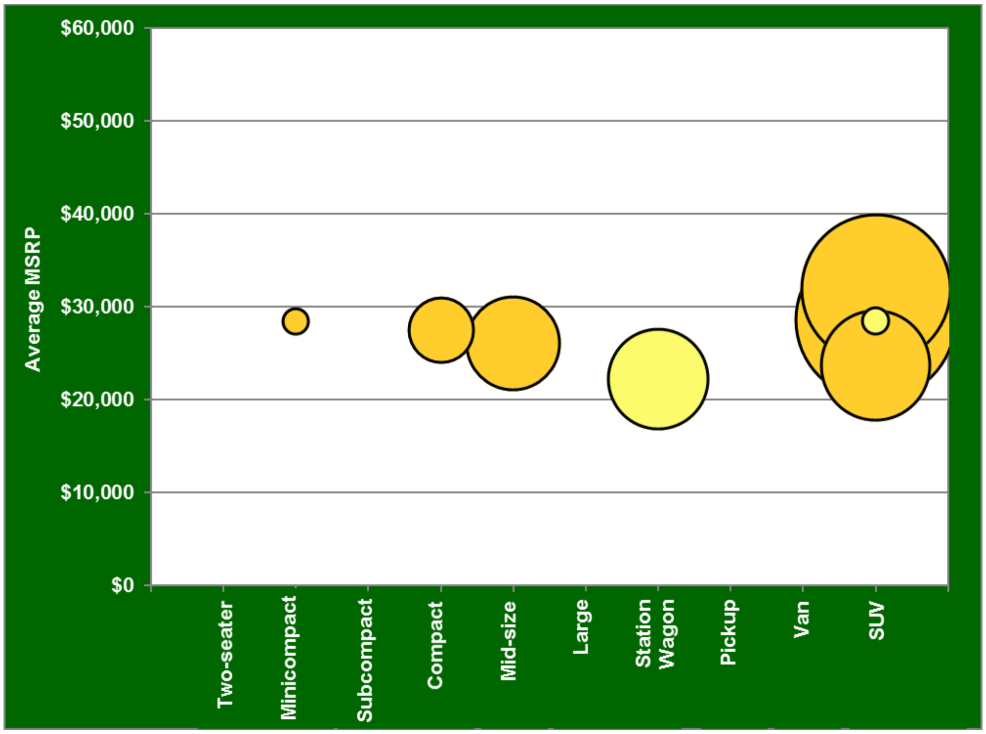
The Subaru XV Crosstrek Hybrid was the first production hybrid offered by Subaru but it was discontinued in 2016 after just three years of production. However, in March 2016, Subaru unveiled the "Subaru Global Platform" - a new car platform for all future car models through 2025. The platform is designed to accommodate a wide range of future drivetrains including conventional gasoline, hybrids, plug-in hybrids, all-electric, and other alternative-power units. This new platform reflects Subaru's view that emerging drivetrain technologies will be increasingly important in the future. The newly redesigned 2017 Impreza is the first model built on this new modular platform.

As the only major automaker to produce exclusively all-wheel drive (AWD) vehicles, maximizing the efficiency of all systems is critical for meeting fuel economy standards. Powering the symmetrical AWD system is Subaru's unique horizontally opposed Boxer engine where the pistons travel in opposite directions, positioned 180 degrees from each other on both sides of a central crankshaft. This not only balances vibrations but also reduces the size and weight of the engine versus a standard in-line set up. Subaru has also adopted direct injection and turbocharging to maximize output from small displacement engines.

For transferring power to the wheels as efficiently as possible, Subaru offers a CVT transmission called Lineartronic that uses a steel belt and pulley system to provide seamless acceleration while also offering manual stepped shifting when desired by shifting directly to a predetermined gear ratio. Other strategies like reducing structural weight are important for achieving maximum efficiency. Subaru's EyeSight was primarily designed for safety and crash avoidance but it can also impact fuel economy when features like adaptive cruise control are activated which help to smooth acceleration and deceleration in traffic when traveling on the highway. EyeSight and the new global platform are part of Subaru's goal to implement greater autonomous functions in their vehicles in the coming years.

Subaru's Fleet Mix

Half of the models produced by Subaru in 2015 are SUVs, all of them with fuel economies of 25 mpg or higher. The Forester, Outback and XV Crosstrek were the top-selling Subaru vehicles in 2015. Fuel economies of Subaru cars were between 25-34 mpg. All of Subaru's models had an average MSRP of less than $35,000.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	red
20-24	pink
25-29	orange
30-34	yellow
35-39	light green
>= 40	green

FIGURE 50. Subaru Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 14. Subaru Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
	BRZ		Impreza	Legacy		Impreza Wagon			Outback Forester XV Crosstrek Hybrid XV Crosstrek

Forester and Outback SUVs Account for Over 50% of Subaru's Market

The Forester and Outback were Subaru's largest-selling vehicles accounting for more than half of Subaru's market. In fact, SUVs were 71% of the market in 2015.

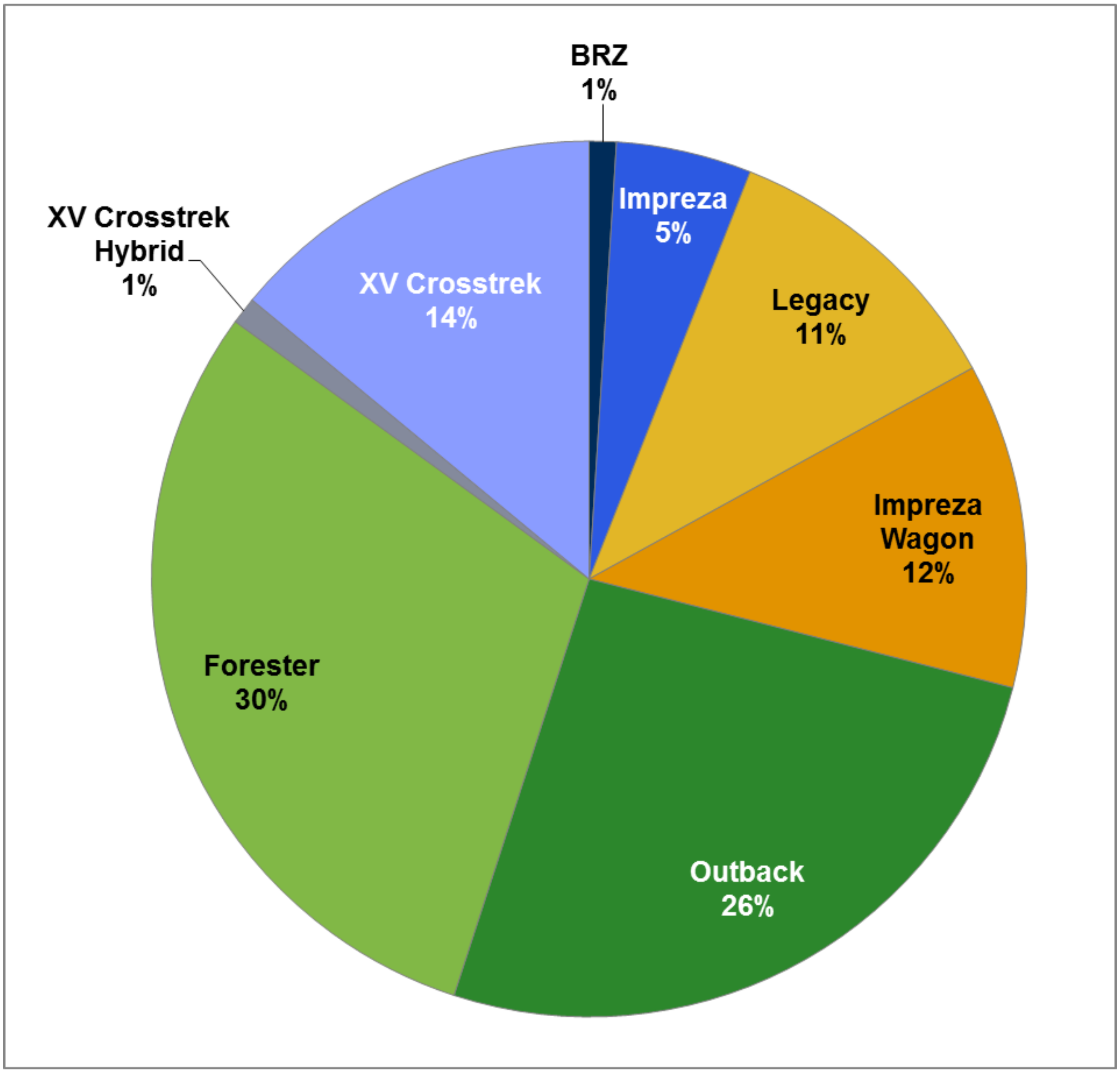


FIGURE 51. Subaru Market Share by Model, 2015

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Subaru Began Hybrid Vehicle Sales in 2014

Subaru began selling the XV Crosstrek Hybrid in 2014, but discontinued it for model year 2017. Subaru currently has no plug-in vehicles.

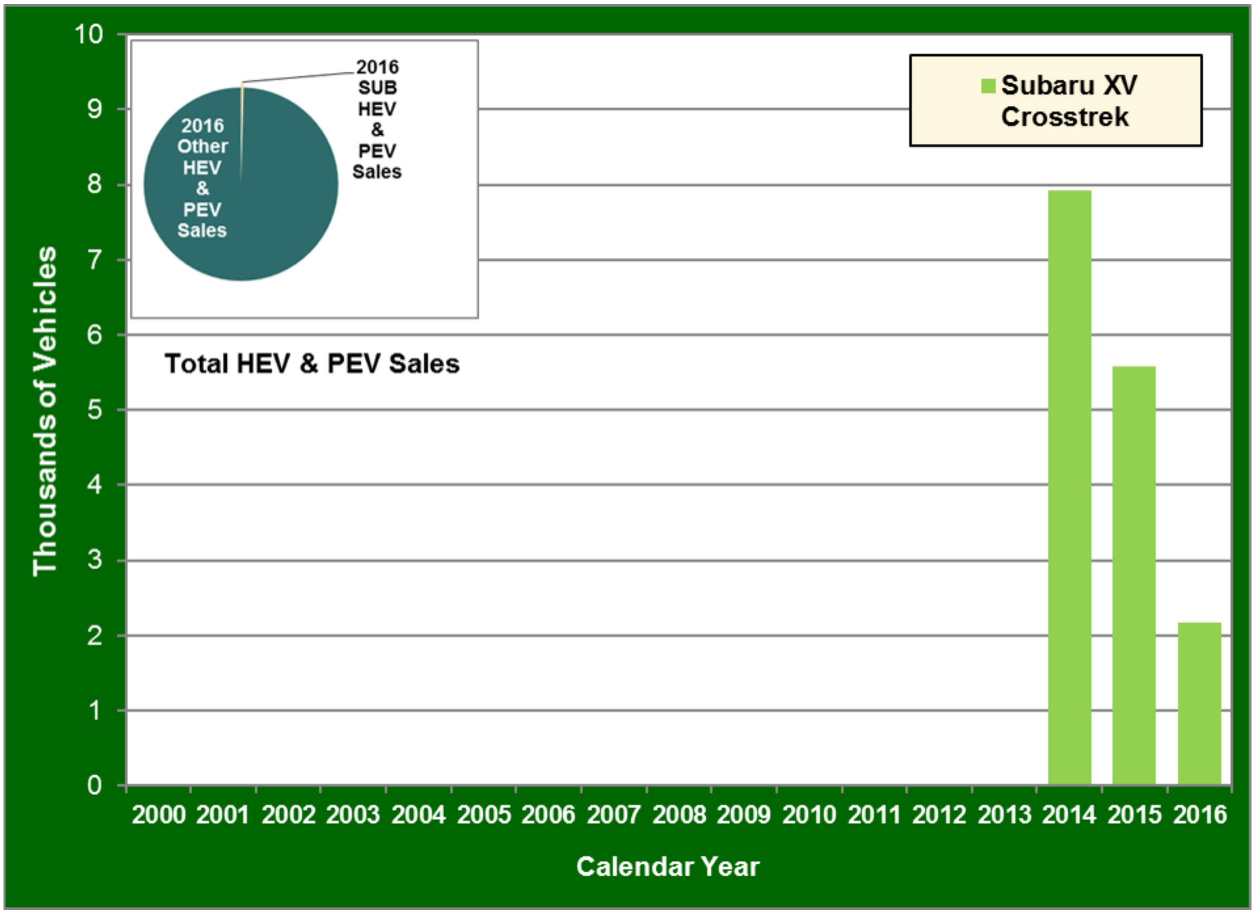


FIGURE 52. Subaru Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 59, 69, 74, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Subaru Interrelationships

TABLE 15. Subaru Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Toyota	✓						Toyota owns stake in Fuji Heavy Industries
Toyota					✓		Subaru BRZ & Scion FR-S were co-developed by Toyota and Fuji
Toyota						✓	Subaru of Indiana Automotive builds Toyota Camry

Note: In 2016 Fuji Heavy Industries changed its name to Subaru Corporation.

Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Toyota Company Profile

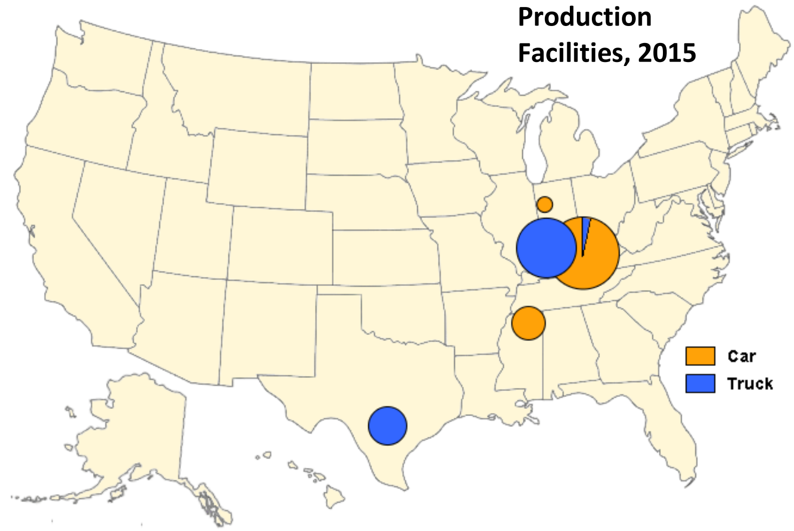
Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	37.2 mpg
Import Cars	41.2 mpg
Light Trucks	26.7 mpg

Average Vehicle Footprint, MY 2016	
Cars	45.5 sq ft
Light Trucks	53.2 sq ft
All	48.6 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	2
Natural Gas	0
Propane	0
Hybrid-Electric	8
Plug-In Hybrid-Electric	0
Electric	0
Hydrogen	1

TOY World Sales = 8.9 million

Production Facilities, 2015



Toyota U.S. Plants	Type	2015 Production
Georgetown, KY	Car	438,574
Princeton, IN	Truck	375,647
San Antonio, TX	Truck	232,910
Blue Springs, MS	Car	190,514
Lafayette, IN	Car	79,843
Georgetown, KY	Truck	19,094

FIGURE 53. Toyota Company Profile

Fuel Saving Technologies

After several years of eschewing all-electric vehicles in favor of hybrid, plug-in hybrid and fuel cell vehicles, Toyota announced in November 2016 that an electric vehicle division would be formed to develop long-range all-electric vehicles that can travel more than 300 km (186 miles). The goal is to bring EVs to market by around 2020. Toyota has produced EVs in the past including the RAV4 EV from 1997 to 2003, the 2012-2014 RAV4 EV built in partnership with Tesla, and the 2013 Scion iQ EV, but all were produced in very low volume and only available in selected markets.

The fourth generation 2016 Toyota Prius arrived with numerous powertrain and aerodynamic enhancements that resulted in an EPA combined rating of 52 mpg, up from 48 mpg for the outgoing model. The Prius Eco achieves 56 mpg making it the most efficient vehicle without a plug for the 2016 model year. The 2017 Prius Prime plug-in hybrid followed, replacing the 2015 Prius Plug-in hybrid. The new Prius Prime provides 25 miles of all-electric range which is more than double the previous model while efficiency on electricity increased from 95 to 133 MPGe and gasoline efficiency improved from 50 MPG to 54 MPG. The 2016 Toyota Mirai is Toyota's first production fuel cell vehicle. Through 2016, 1,114 units were sold although it is currently only available in select areas in California.

Conventional models have also received engine and transmission refinements. Toyota has introduced new engines with increased thermal efficiency and greater use of direct injection and has also increased the use of CVT on models with smaller displacement engines like the Corolla. In the interest of reducing vehicle weight, the redesigned 2016 Prius is built on the lightweight Toyota New Global Architecture (TNGA) platform and is offered with lithium-ion batteries that improve power density and offset weight on upper trim levels.

Toyota's Fleet Mix

Toyota produced many models and they were fairly evenly split between cars and trucks in 2015. Among the truck models, just over half achieved a combined fuel economy of more than 20 mpg. Most of the car models had a combined fuel economy of 25 mpg or higher and those models also represented a large portion of Toyota's overall sales. Seven models had a combined average fuel economy of 40 mpg or higher.

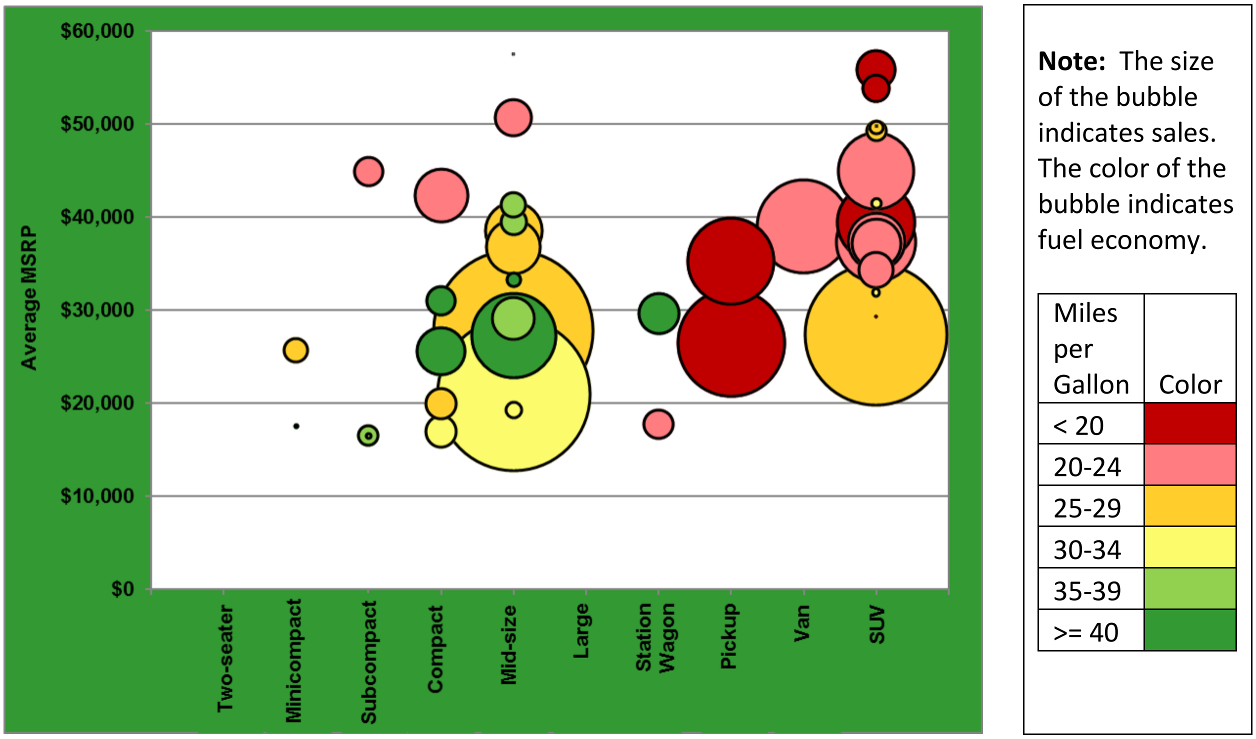


FIGURE 54. Toyota Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 16. Toyota Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
	FR-S iQ	RC xD iA	IS CT Prius C tC Yaris	*LS 600h* *LS* *GS 450h* Mirai GS ES Hybrid Avalon-Hybrid ES Avalon Prius-PHEV Camry-Hybrid Camry Prius Corolla iM		Prius v xB	Tacoma Tundra	Sienna	*LX* *Land Cruiser* GX Sequoia RAV4 EV Highlander-Hybrid RX Hybrid RX NX-Hybrid 4Runner Highlander Highlander AWD NX Venza RAV4 hybrid FJ Cruiser RAV4

Note: Includes Toyota, Lexus, and Scion. Models listed in *red italics* do not appear on the figure due to high MSRP.

Combined Sales of the Toyota Camry and Corolla Were Nearly One-Third of Toyota's Sales in 2015

In 2015, the Camry and Corolla were Toyota's biggest sellers, followed by the RAV4 SUV (12%). Together, the Tacoma and Tundra pickup trucks were 12% of Toyota's market. SUVs make up over 31% of Toyota's sales.

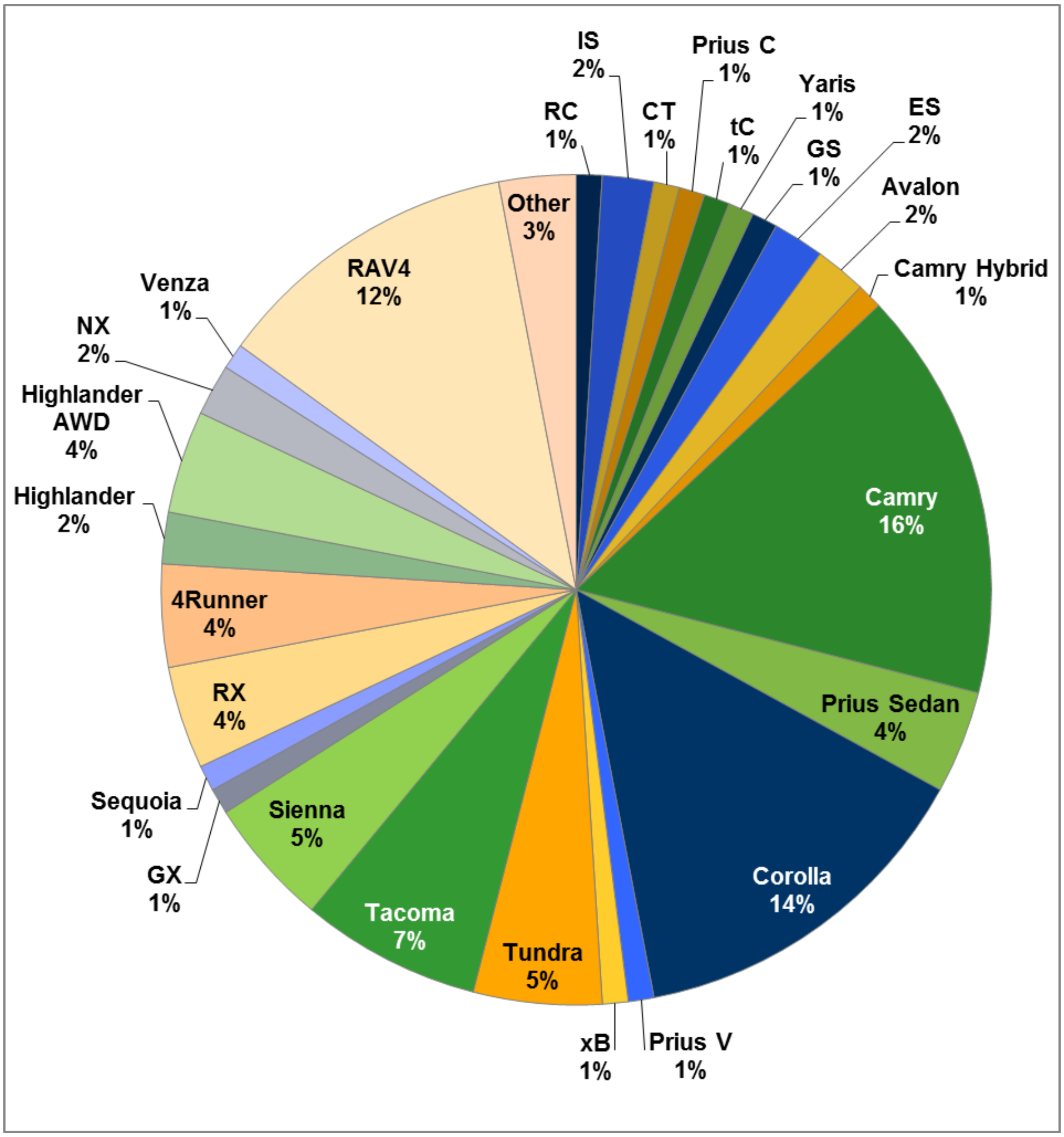


FIGURE 55. Toyota Market Share by Model, 2015

Note: "Other" includes the For Two, FR-S, iQ, iA, xD, LS, Mirai, ES Hybrid, Avalon Hybrid, Prius PHEV, iM, LX, Land Cruiser, RAV4 EV, Highlander Hybrid, RX Hybrid, NX Hybrid, RAV4 Hybrid, and FJ Cruiser. Each vehicle model accounted for less than 1% of the total.

Source: Ward's Automotive Group, March 2017. http://wardsauto.com

Toyota Accounted for Almost Half of All Hybrid and Plug-In Vehicle Sales in 2016

Although Prius sales declined by about 26% from 2015 to 2016, Toyota remained the dominant manufacturer of hybrid vehicles (HEV). In addition to the Prius, the other hybrid and plug-in vehicles (PEV) from Toyota had declining sales in 2016, with the exception of the Lexus NX Hybrid which debuted in late 2014.

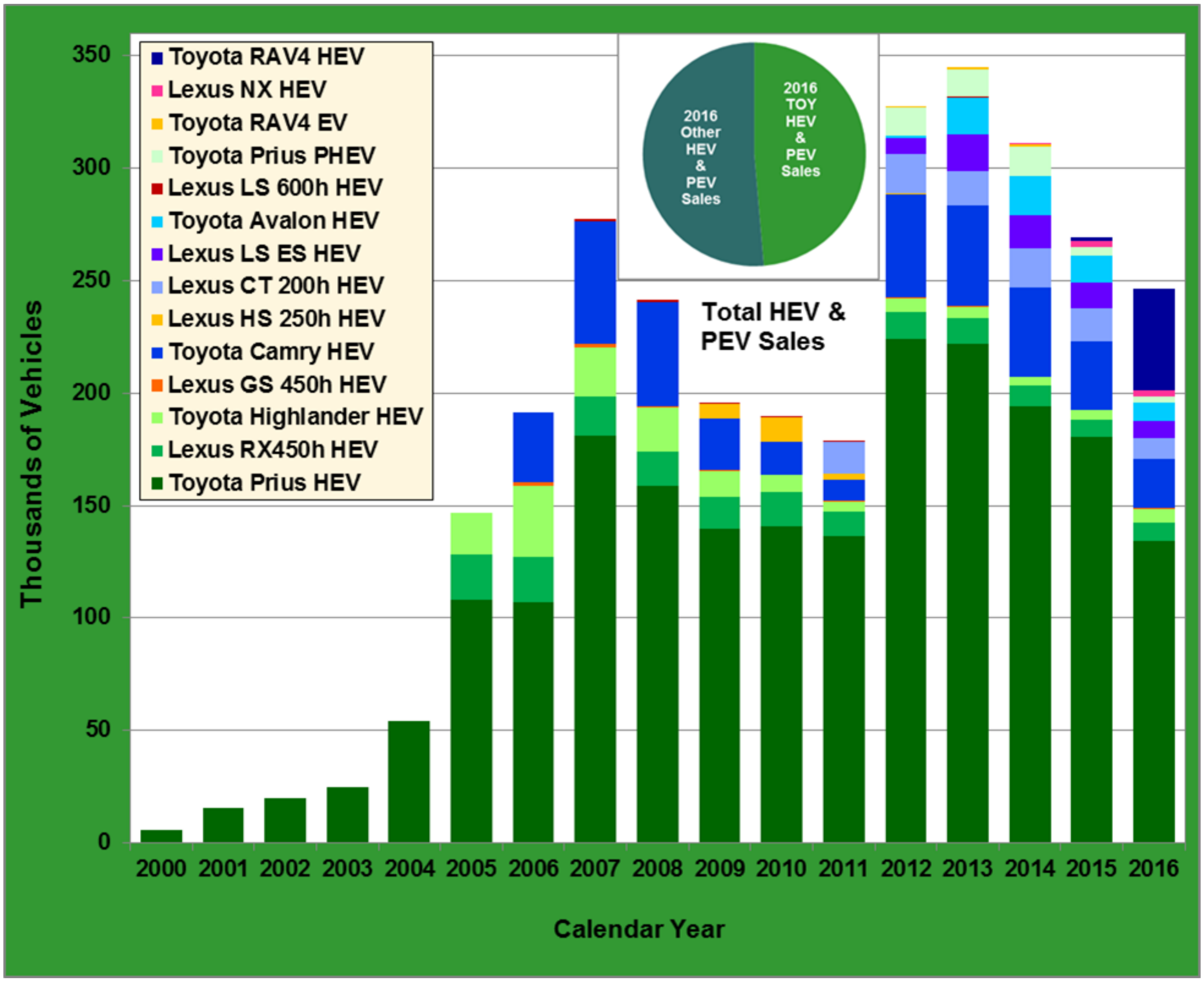


FIGURE 56. Toyota Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 59, 64, 74, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Toyota Has Six Joint Ventures

TABLE 17. Toyota Interrelationships with Other Automotive Manufacturers, 2015

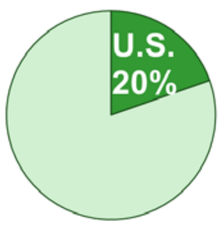
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
BMW, Ford, Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
BMW					✓		Jointly developing a sports-car platform
BMW			✓				Will supply diesel engines to Toyota Motor Europe
Brilliance China						✓	Manufactures Toyota minibuses
Daihatsu	✓	✓	✓				Owned mostly by Toyota
Daihatsu				✓	✓	✓	Develop components & vehicles, build vehicles
Daihatsu						✓	Toyota builds vehicles in Pakistan & Venezuela for Daihatsu
FAW	✓	✓					Three joint ventures in Asia
FAW				✓		✓	Engine manufacturing in China
Fuji	✓						Toyota owns stake in Fuji Heavy Industries
Fuji					✓		Subaru BRZ & Scion FR-S were co-developed by Toyota and Fuji
Fuji						✓	Subaru of Indiana Automotive builds Toyota Camry
Guangzhou		✓				✓	Joint venture that builds Toyota-based vehicles in Guangzhou, China
Isuzu	✓				✓		Toyota has a stake in Isuzu. The two companies collaborate on powertrain technology
Mazda			✓		✓		Licensing agreement gives Mazda access to Toyota's Hybrid Synergy Drive system
Peugeot		✓		✓		✓	Joint venture car production in Czech Republic. Peugeot will supply rebadged vans to Toyota to sell in Europe
Renault		✓				✓	Colombian SOFASA is owned by Renault, Toyota & Mitsui Engineering
Tesla					✓		Tesla developed the battery pack & powertrain for the Toyota RAV4 EV electric CUV
Tianjin		✓					Tianjin FAW Toyota Motor Co. is a joint venture with three manufacturing facilities in Tianjin Province
Tianjin						✓	Builds Toyota-based vehicles

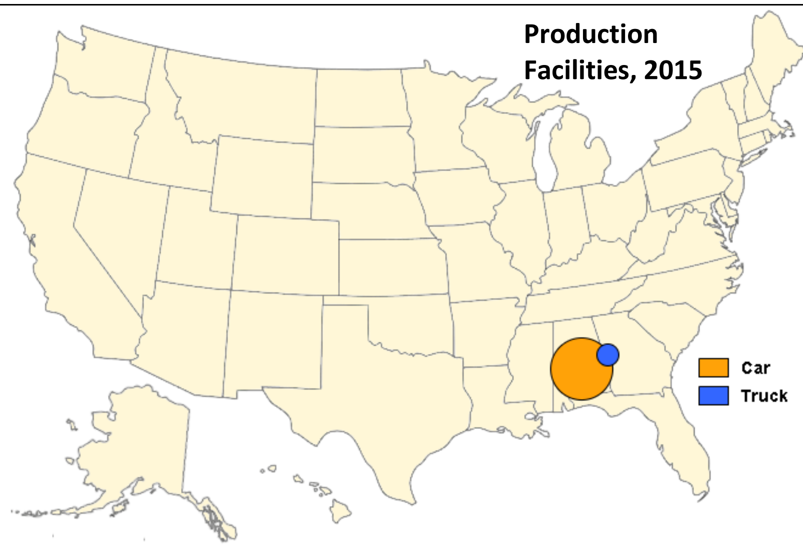
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015.
http://wardsauto.com

Hyundai Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	None
Import Cars	38.3 mpg
Light Trucks	26.3 mpg
Average Vehicle Footprint, MY 2016	
Cars	46.7 sq ft
Light Trucks	47.2 sq ft
All	46.8 sq ft
Number of Alternative Fuel Models, MY 2016	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	1
Electric	0
Hydrogen	1

HYU & KIA World Sales = 7.1 million





Hyundai U.S. Plants	Type	2015 Production
Montgomery, AL	Car	384,519
West Point, GA	Truck	114,125

Note: World sales figure includes Kia. All other data on the page are Hyundai only. Hyundai vehicles assembled in Alabama in 2015 do not meet CAFE criteria for domestic vehicles due to the low percentage of domestic content.

FIGURE 57. Hyundai Company Profile

Fuel Saving Technologies

The 2017 Hyundai Ioniq is an all-new sedan for Hyundai offered as a hybrid, plug-in hybrid, and all electric vehicle. Sales of the 2017 Ioniq hybrid and Ioniq EV began in early 2017. The Ioniq EV is rated at 124 miles of range and achieved an EPA combined rating of 136 MPGe which is the highest rating of any car ever certified by the EPA; a remarkable achievement for a vehicle classified by the EPA as a midsize car. The Ioniq Blue is a hybrid version of the Ioniq classified by the EPA as a large car due to additional trunk space compared to the Ioniq EV and it achieves an EPA combined rating of 58 MPG making it the highest rated vehicle without a plug for 2017. Hyundai also released the 2016 Sonata Plug-in hybrid which has an all-electric range of 27 miles and a combined gasoline electric range of 600 miles. An Ioniq EV with a range of more than 200 miles is planned for 2018 and a dedicated all-electric SUV is also expected within two years.

Hyundai has been a proponent of fuel cell vehicles, offering the Tucson fuel cell SUV since 2014 for selected residents in Southern California. Through the end of 2016 there were 119 units delivered to customers, so the volume is still very small. However, Hyundai is aiming at higher volumes as they develop the next generation fuel cell powertrain for 2018.

Efforts to further downsize engines and reduce vehicle weight are evident in the new Ioniq hybrid, powered by a 1.6 liter GDI engine with a claimed 40% thermal efficiency that is paired with an automated manual dual clutch transmission. To reduce weight, 54% of the body structure is constructed with high strength steel while the hood, tailgate, and some suspension components are made from aluminum. Hyundai has not embraced CVT transmissions and is instead favoring fixed gear hydraulic automatic transmissions and automated dual clutch transmissions. Hyundai's first 7-speed dual clutch automated manual transmission became available on the 2016 models of the Sonata and Tucson Eco.

Hyundai's Fleet Mix

Hyundai's model offerings, as well as sales, were dominated by cars that have a combined fuel economy of 25 mpg or higher in 2015. The mid-size Elantra was the largest seller followed by the Sonata. All Hyundai vehicles had an MSRP less than $35,000 except the Equus which, due to its high price, is not shown on the figure. Near the end of 2015, Hyundai announced Genesis as a separate premium brand. The 2015 sales shown are for the Hyundai Genesis.

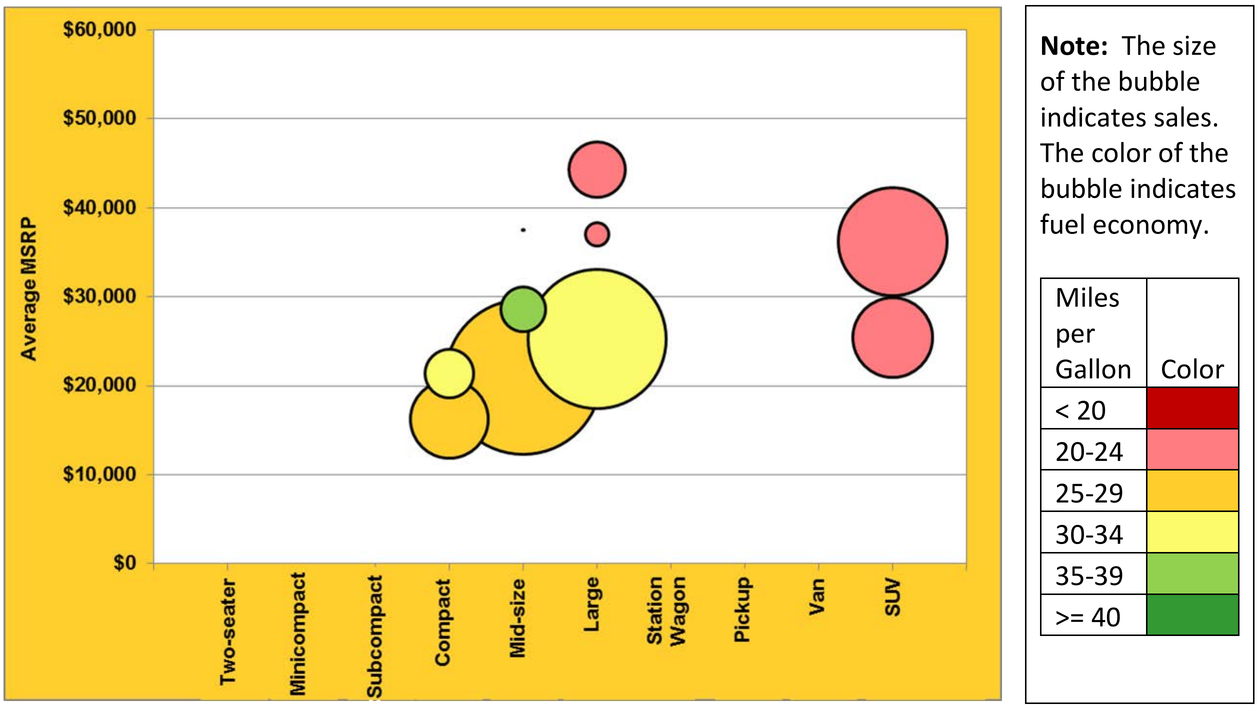


FIGURE 58. Hyundai Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 18. Hyundai Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
			Veloster Accent	Sonata Plug-in Sonata-Hybrid Elantra	*Equus* Genesis Azera Sonata				Santa Fe Tucson

Note: Models listed in *red italics* do not appear on the figure due to high MSRP.

Combined Sales of the Hyundai Elantra and Sonata Accounted for Almost 60% of Hyundai's Sales in 2015

The Hyundai Elantra was the top-selling Hyundai model (32%), with the Sonata accounting for 25% of Hyundai sales. The company concentrates on car sales—less than 25% of Hyundai's sales were for SUVs and there were no pickup trucks in the lineup.

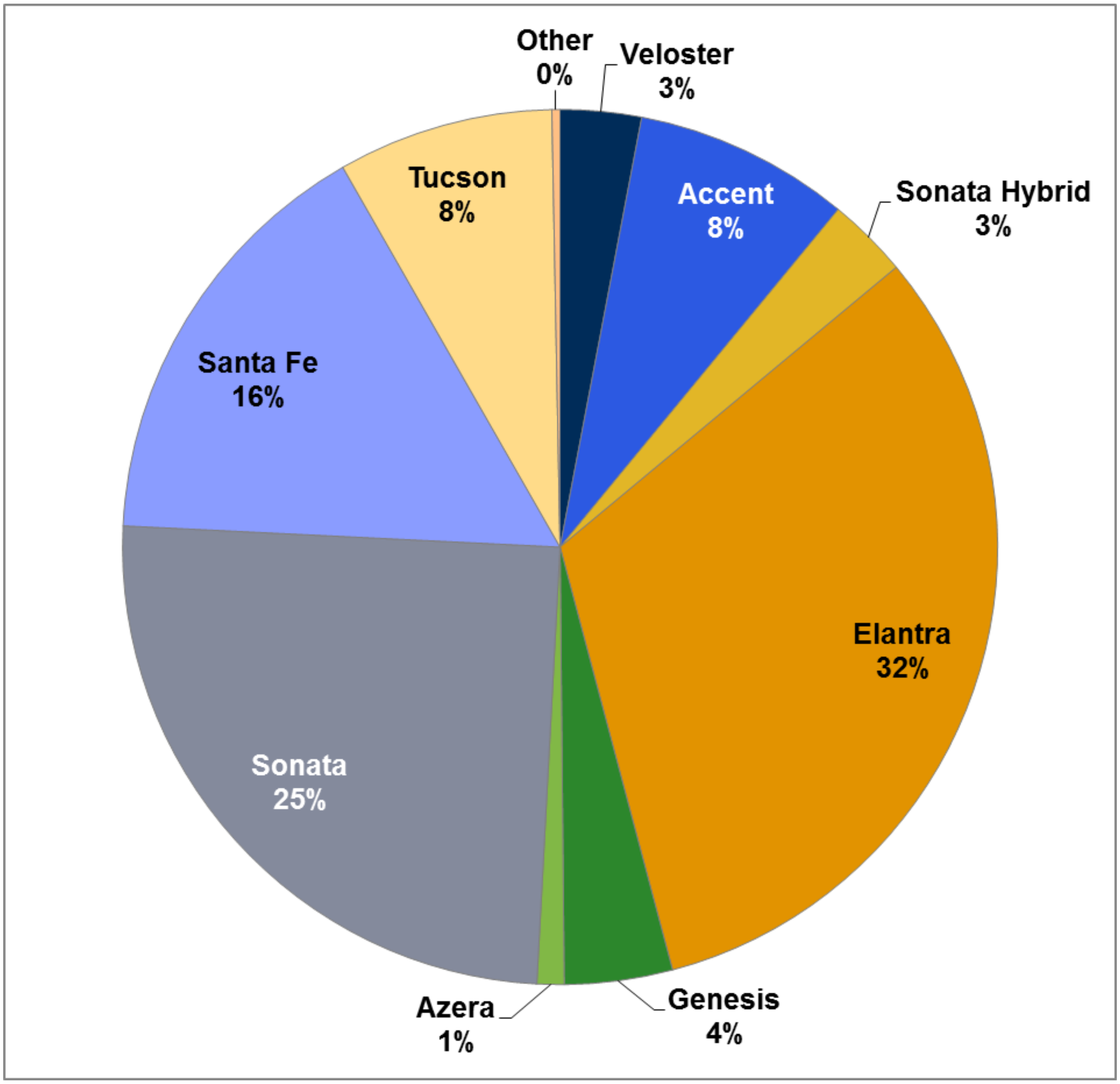


FIGURE 59. Hyundai Market Share by Model, 2015

Note: "Other" includes the Sonata Plug-In-Hybrid and the Equus. Each model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Hyundai's Sonata Available in Both Hybrid and Plug-In Hybrid Versions

The Sonata hybrid-electric vehicle (HEV) has been selling for six years, but the Sonata plug-in hybrid-electric vehicle (PHEV) became available in December of 2015. Sales for the Sonata HEV declined by 5% from 2015 to 2016 but still accounted for about 4% of all HEV and plug-in vehicle (PEV) sales. About 3,000 Sonata PHEVs were sold in 2016.

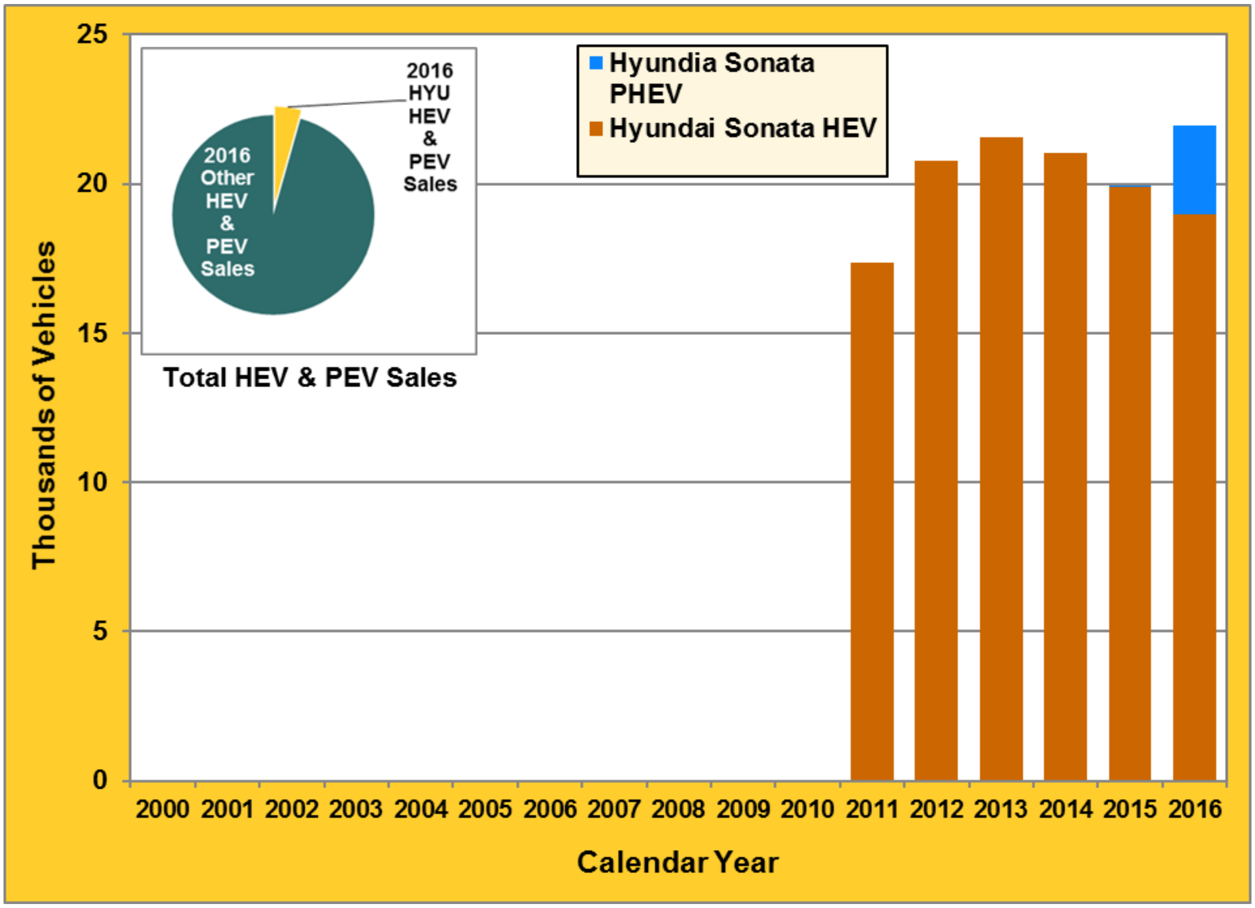


FIGURE 60. Hyundai Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 59, 64, 69, 79, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Hyundai Has a Joint Venture in China

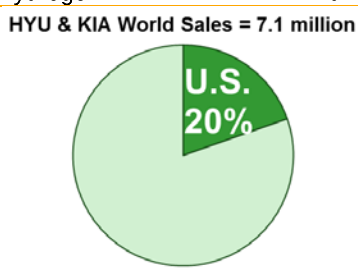
TABLE 19. Hyundai Interrelationships with Other Manufacturers, 2015

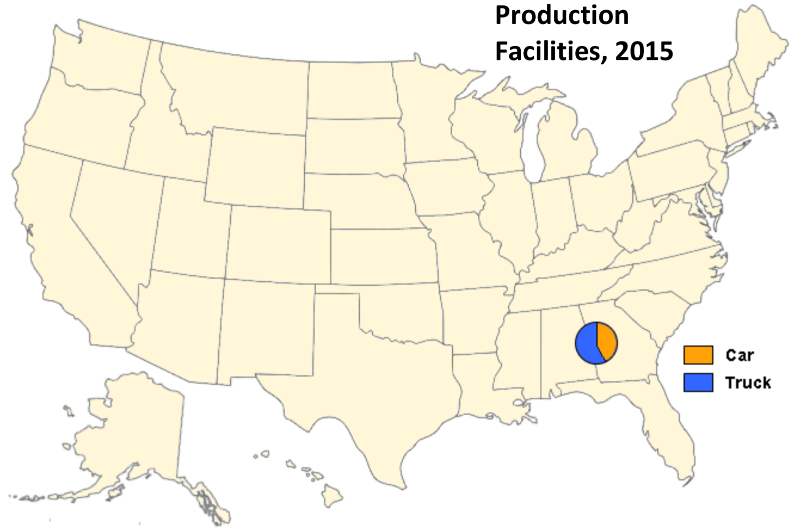
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Beijing Automotive		✓				✓	Car building joint venture
Kia			✓		✓		Share vehicle platforms, components and some R&D resources
Kia	✓						Partial ownership by Hyundai Motor & Hyundai Capital
Kia						✓	Builds the Hyundai Santa Fe

Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015.
http://wardsauto.com

Kia Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	None
Import Cars	36.2 mpg
Light Trucks	26.7 mpg
Average Vehicle Footprint MY 2016	
Cars	46.0 sq ft
Light Trucks	53.2 sq ft
All	46.9 sq ft
Number of Alternative Fuel Models, MY 2016	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0





Kia U.S. Plants	Type	2015 Production
West Point, GA	Truck	147,365
West Point, GA	Car	109,522

Note: World sales figure includes Hyundai. All other data on the page are Kia only. Kia vehicles assembled in Georgia do not meet CAFE criteria for domestic vehicles due to the low percentage of domestic content.

FIGURE 61. Kia Company Profile

Fuel Saving Technologies

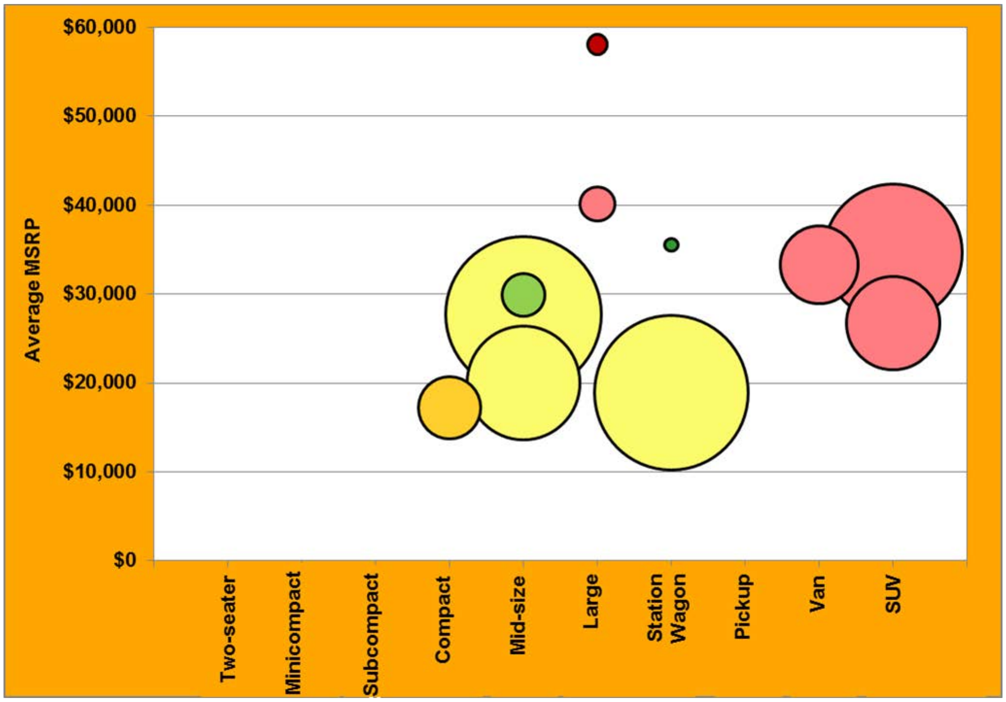
In 2016, Kia revealed the 2017 Niro which is a new nameplate and Kia’s first dedicated hybrid vehicle. The 2017 Niro is a small crossover with an EPA combined rating of 50 mpg for the FE trim which is the base trim and most efficient trim level offered. Kia also launched the 2017 Optima Plug-in Hybrid delivering 29 miles of all-electric range and 40 mpg while running on gasoline. Kia continues to offer the all-electric Kia Soul EV with 93 miles of range. The Optima is also offered as a conventional hybrid model.

In late 2015, Kia announced a $10.2 billion investment for the development of advanced powertrain vehicles over the next five years, aiming for a 25% increase in Corporate Average Fuel Economy compared to the 2014 model year. Kia’s five-year plan is guided by a belief that there is no single technology that will satisfy all segments of the vehicle industry in the short term so they plan to develop a full range of drivetrain technologies and bring 11 new advanced drivetrain models to market by 2020. This will include hybrids, plug-in hybrids, all-electric vehicles and fuel cell vehicles. Apart from the advanced drivetrain models Kia has brought to market during 2016, Kia is working on the development of a new fuel cell model. Although Kia shares fuel cell technology with parent company Hyundai, Kia has its own powertrain center that also works independently so the technology developed and used by Kia is not identical to that used by Hyundai. There are few details available on the Kia fuel cell vehicle under development but it is widely expected that it will be an SUV.

Like other manufactures, Kia has embraced gasoline direct injection (GDI) and turbocharging for maximizing engine performance and fuel economy. Other conventional strategies include weight reduction through greater use of high-strength steel and aluminum, improved aerodynamics, dual clutch automated manual transmissions, “Idle Stop & Go” or ISG, and Kia’s Active Eco System that proactively controls the engine, transmission, and air conditioning system for maximum efficiency, improving fuel economy by as much as 11%.

Kia's Fleet Mix

Kia had comparatively few models in 2015 and most had an average manufacturer's suggested retail price (MSRP) of less than $45,000. About two-thirds of Kia's sales were from models with a combined rating of 25 mpg or higher while only the K900 luxury sedan was rated below 20 mpg. About one-third of Kia's models and sales were light trucks which all fall into the fuel economy range of 20-24 mpg.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	
20-24	
25-29	
30-34	
35-39	
>= 40	

FIGURE 62. Kia Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 20. Kia Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
			Rio	Optima-Hybrid Optima Forte	K900 Cadenza	Soul EV Soul		Sedona	Sorento Sportage

Kia Optima and Soul Were almost Half of Kia's Sales in 2015

The Kia Optima had the largest market share (24%) of all Kia models in 2015 and the Soul closely followed with a 23% share. The Sorento SUV was 19% of Kia's sales.

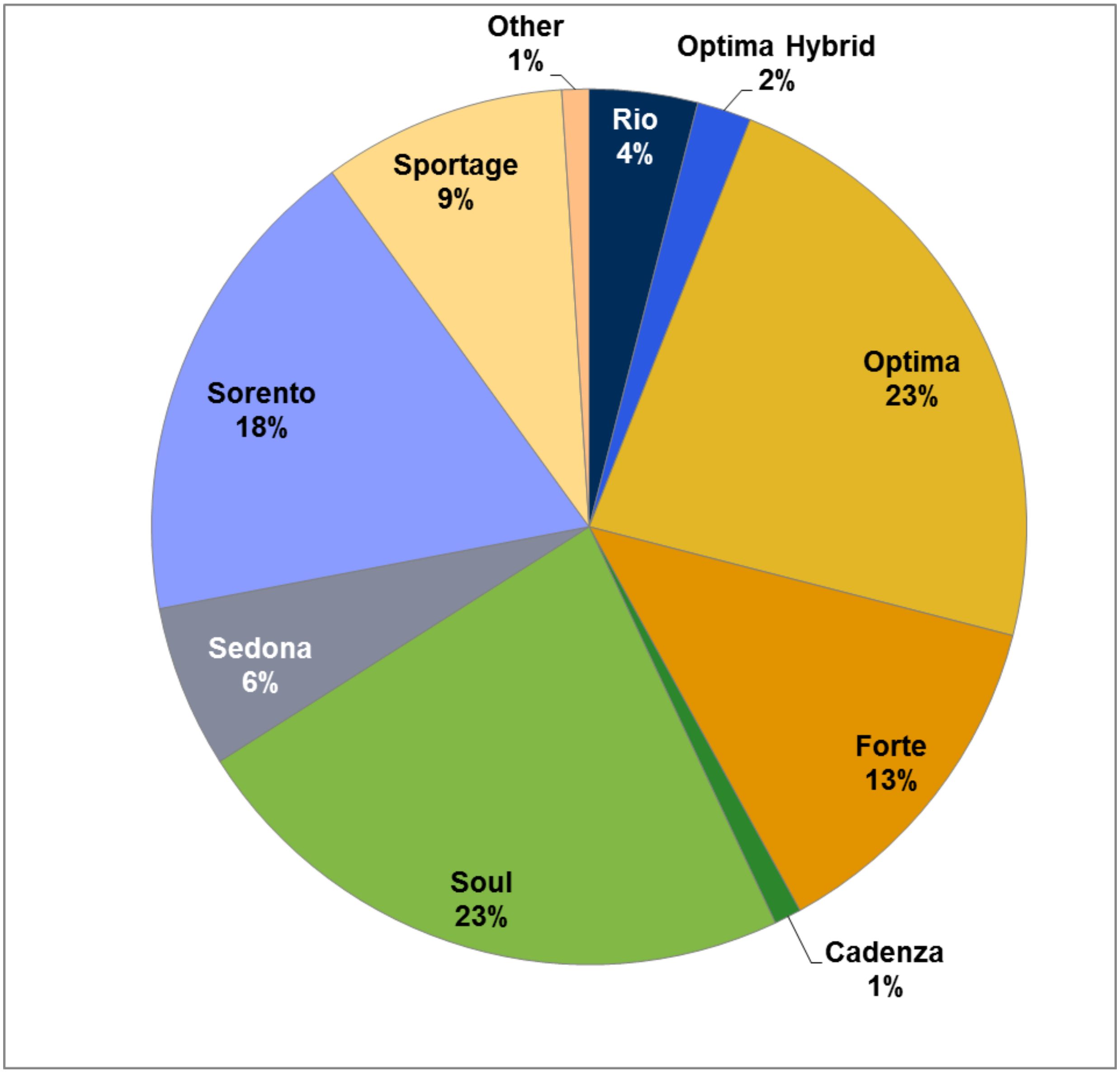


FIGURE 63. Kia Market Share by Model, 2015

Note: "Other" includes the K900 and the Soul EV. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

Kia Soul Electric Vehicle Now Sold in Ten States

The Kia Soul electric vehicle (EV) was introduced in California in 2014 but Kia has expanded the sales territory to nine other states – Oregon, Washington, Georgia, Texas, Hawaii, New York, New Jersey, Connecticut, and Maryland. Sales for the Soul EV increased by 70% from 2015 to 2016. The Kia Optima hybrid electric vehicle (HEV) sales declined by about 47% in 2016. Kia is responsible for 2% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales in 2016.

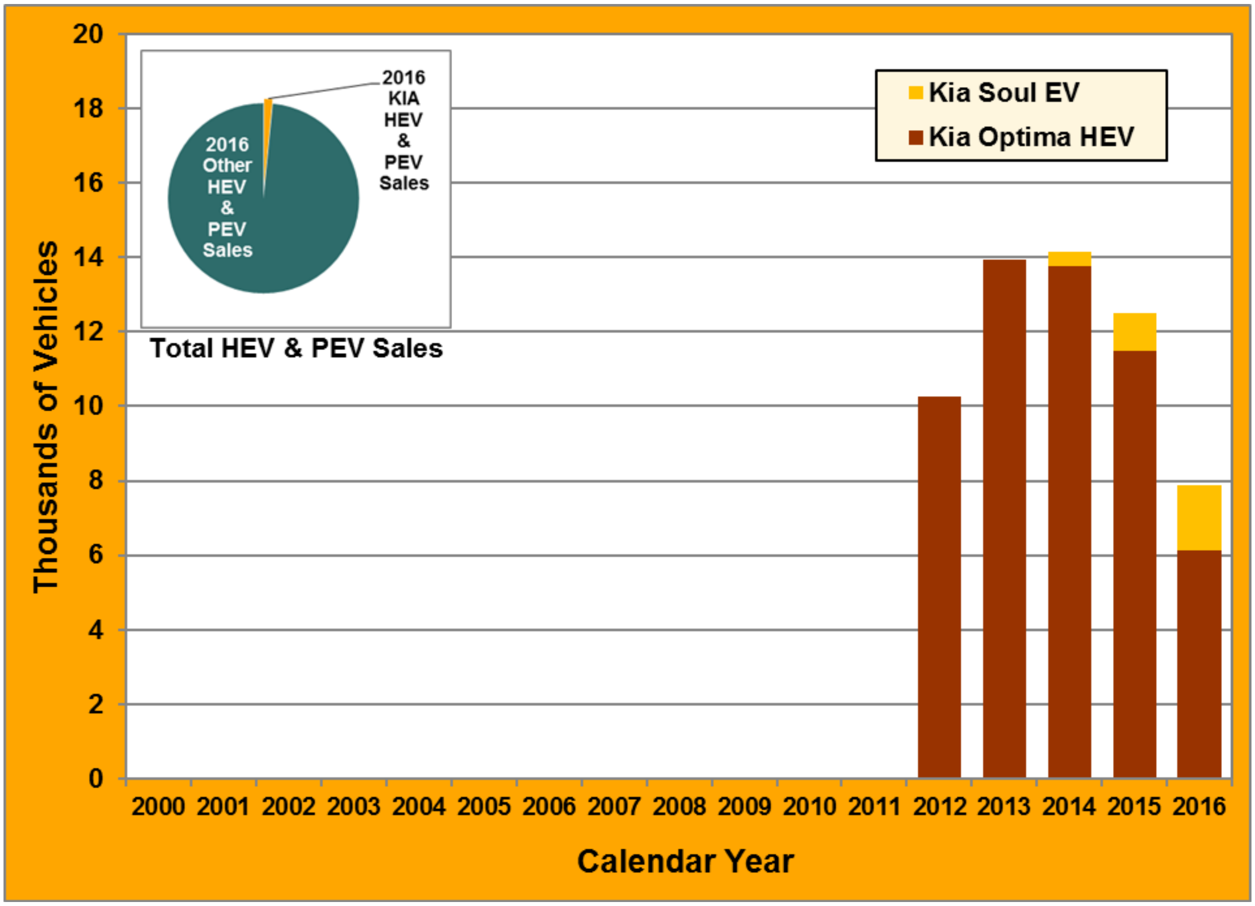


FIGURE 64. Kia Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 59, 64, 69, 74, 84) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Kia Is Owned by Hyundai

TABLE 21. Kia Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Dongfeng		✓				✓	Car-building joint venture in China
Hyundai			✓		✓		Share vehicle platforms, components and some R&D resources
Hyundai	✓						Partial ownership of Kia by Hyundai Motor & Hyundai Capital
Hyundai						✓	Kia builds the Hyundai Santa Fe

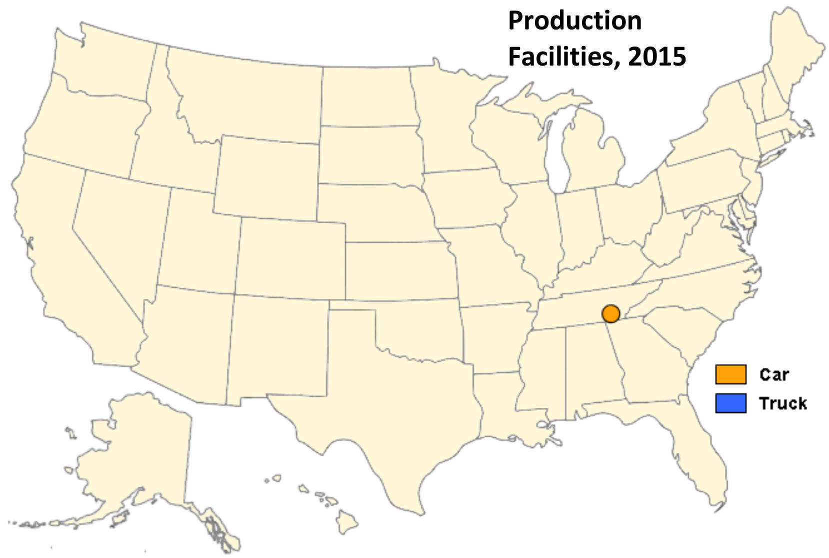
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Volkswagen (VW) Company Profile

Preliminary Corporate Average Fuel Economy, MY 2016	
Domestic Cars	38.7 mpg
Import Cars	32.1 mpg
Light Trucks	27.8 mpg

Average Vehicle Footprint, MY 2016	
Cars	45.0 sq ft
Light Trucks	48.8 sq ft
All	45.7 sq ft

Number of Alternative Fuel Models, MY 2016	
Flex Fuel	3
Natural Gas	0
Propane	0
Hybrid-Electric	2
Plug-In Hybrid-Electric	3
Electric	1
Hydrogen	0



VW World Sales = 9.5 million

Volkswagen U.S. Plants	Type	2015 Production
Chattanooga, TN	Car	87,156

FIGURE 65. VW Company Profile

Fuel Saving Technologies

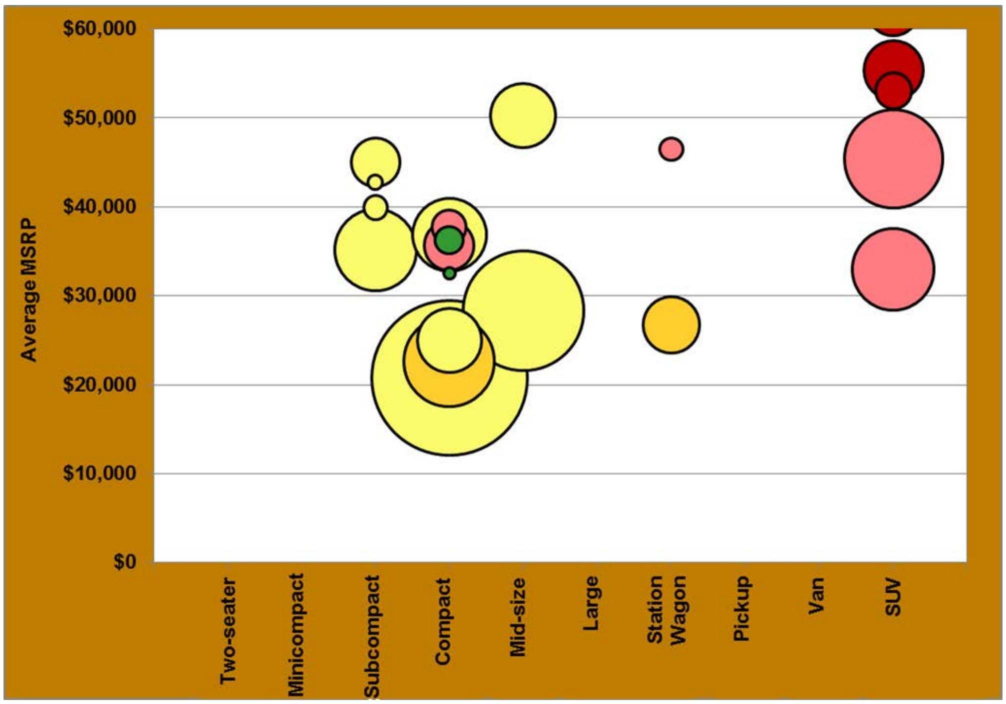
The diesel emissions scandal that broke in 2015 has had a considerable effect on Volkswagen's future product plans and has led to greater emphasis on vehicle electrification. In 2016, Volkswagen announced a goal of producing 1 million EVs per year worldwide under the Volkswagen brand alone. Other sub-brands such as Audi and Porsche also have plans to bring more EVs to market. To support those high volume EV goals, Volkswagen announced plans to build a battery factory that could supply EV batteries in-house. Currently, Volkswagen relies on external suppliers for their battery packs.

Although not abandoning diesels altogether, Volkswagen has acknowledged that they will not be pursuing a high volume of diesel sales in the US as they did in the past. Diesel may still be considered as an option for selected future offerings where appropriate but it is likely to see more limited implementation. In the settlements from the diesel violations, Volkswagen will be buying back many of the models sold and repairing some models to bring them into compliance. Some of the settlement money will be directed toward environmental remediation efforts and alternative fuel projects like expanding EV charging infrastructure.

In 2016 Volkswagen revealed the BUDD-e concept which is an all-electric microbus with a 101-kW-hr battery pack and an all-electric range of up to 373 miles. It is built on a newly developed architecture that is specifically designed for electric vehicles. The plug-in hybrid Volkswagen Tiguan SUV was unveiled in 2016 which may join current plug-in vehicle offerings under the Porsche and Audi brands. For conventional hybrid technology, Volkswagen currently offers the Jetta and Touareg as hybrids. In an industry first, Audi announced that select Q7 crossovers and A4 sedans will be fitted with equipment that will allow for communication with traffic signals. Equipped vehicles will show a countdown for traffic lights which can smooth approaches to traffic lights and could even be coordinated with future stop-start systems. Rollout of the system is expected in five US cities in 2016 and 2017.

VW's Fleet Mix

VW is the parent company of several upscale and luxury brands, so the average MSRP distribution of their models is much wider than shown on this figure, which is limited to an MSRP of $60,000. Most of the models sold by VW were cars in the subcompact, compact, and midsize segments. Although there were only four models shown with a combined fuel economy above 30 mpg, it must be noted that high-fuel-economy diesel variants of popular models like the Jetta, Golf, and Passat were not shown because separate sales data by engine type are not available.



Note: The size of the bubble indicates sales. The color of the bubble indicates fuel economy.

Miles per Gallon	Color
< 20	
20-24	
25-29	
30-34	
35-39	
>= 40	

FIGURE 66. VW Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2015

TABLE 22. VW Models by EPA Size Class, 2015

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
Carrera GT *Lamborghini R8* *Boxster/ Cayman*	*911 Series*	A5/S5 TT Eos A3	CC A4/S4 eGolf Q3 Jetta Hybrid Beetle Golf Jetta	*Bentley A7* A6/S6 Passat	*A8/S8* *Panamera S E-Hybrid* *Panamera*	allroad quattro Golf Sport-wagen		Routan	*Cayenne* *Cayenne S E-Hybrid* *Macan* Q7 Touareg Q5 Tiguan

Note: Includes VW, Audi, Lamborghini, and Bentley. Models listed in *red italics* do not appear on the figure due to high MSRP.

VW Jetta Was almost One-Quarter of VW's Sales in 2015

The VW Jetta and the VW Passat were the only models to account for more than 10% of VW's market. Over 75% of VW's sales are cars. The Audi Q5 and the VW Tiguan are the SUVs with the greatest market share.

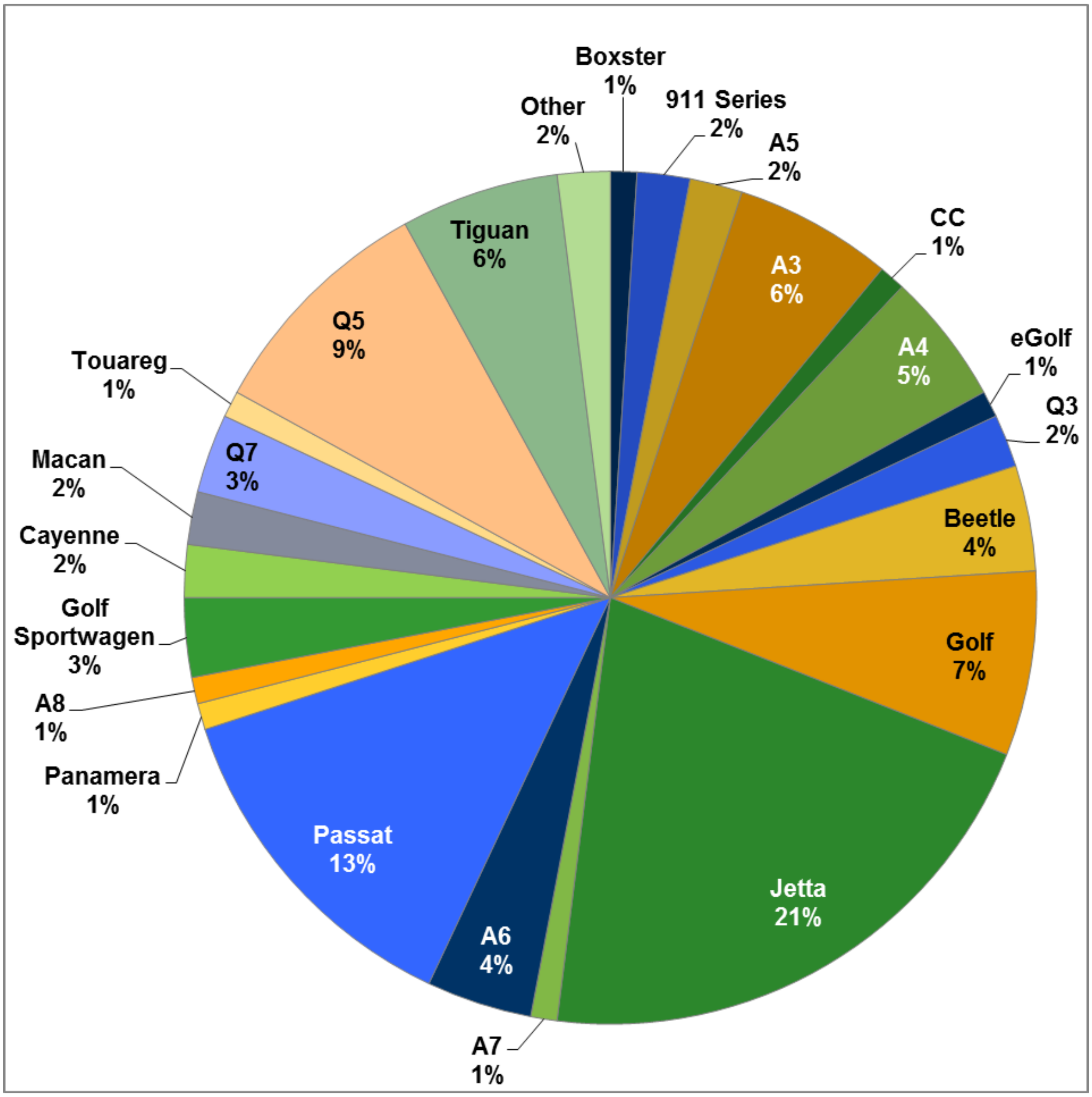


FIGURE 67. VW Market Share by Model, 2015

Note: "Other" includes Carrera GT, Lamborghini, R8, TT, Eos, Jetta Hybrid, Bentley, Panamera S E-Hybrid, allroad Quattro and Cayenne S E-Hybrid. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2017. http://wardsauto.com

VW Hybrid and Plug-In Vehicle Sales Grew by 72% Due to the New Audi A3 PHEV

Nearly every hybrid-electric vehicle (HEV) and plug-in hybrid-electric vehicle (PHEV) model offered by VW experienced a decline in sales from 2015 to 2016, but the growing sales of the new Audi A3 PHEV more than made up for those declines. Total HEV and plug-in vehicle (PEV) sales for 2016 were up by 72% in 2016. Sales for the Porsche Cayenne E-Hybrid PHEV also increased from 2015 to 2016. VW is responsible for just over 2% of all HEV and PEV sales.

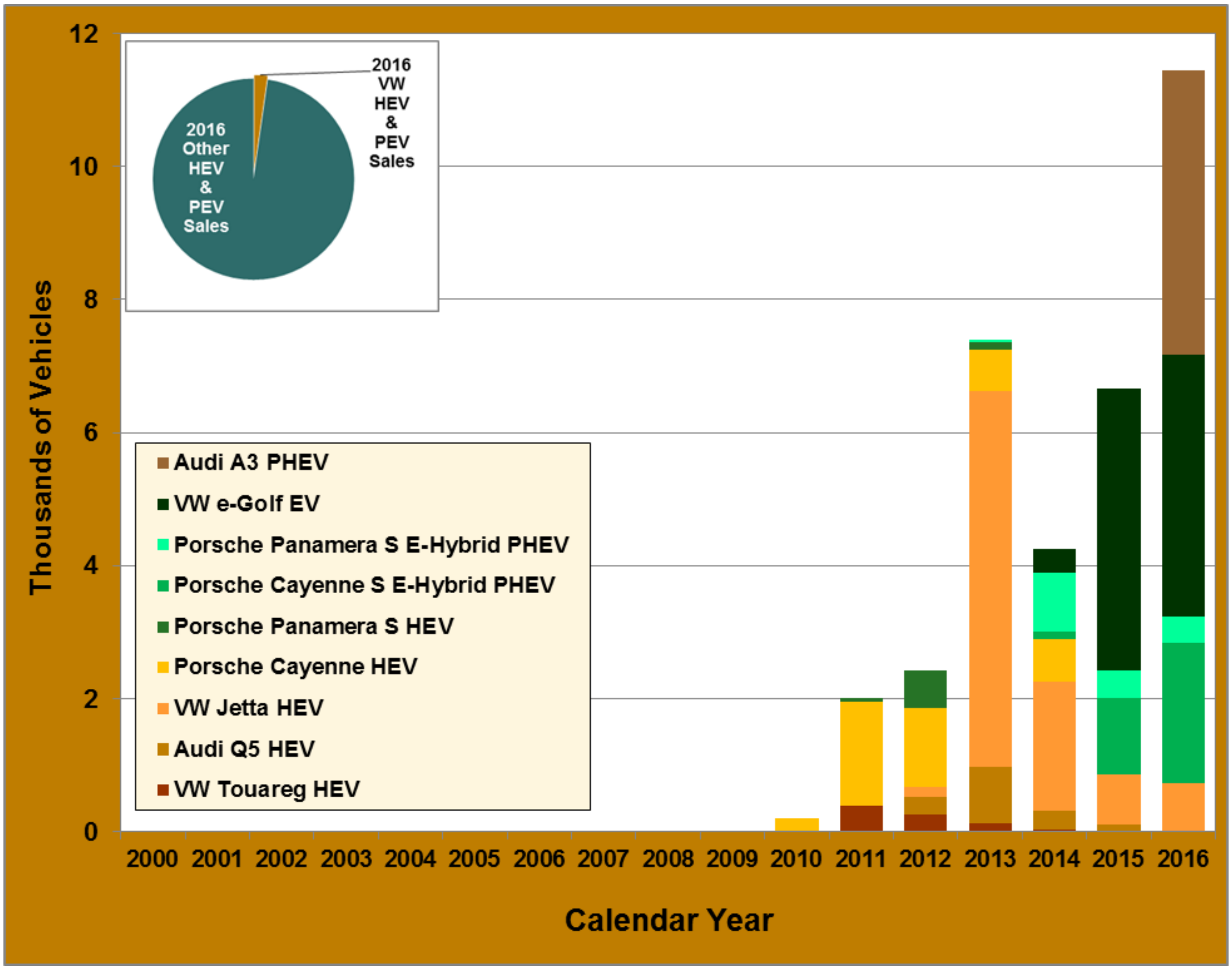


FIGURE 68. VW Hybrid and Plug-In Electric Vehicle Sales, 2000-2016

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 39, 44, 49, 54, 59, 64, 69, 74, 79) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

VW is One of the World's Largest Manufacturers but has Few Interrelationships

TABLE 23. VW Interrelationships with Other Automotive Manufacturers, 2015

Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
BMW, Ford, Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
Daimler					✓		VW & Mercedes co-designed a commercial vehicle sold as Mercedes Sprinter & VW Crafter
First Auto Works		✓				✓	Joint car-producing venture in Changchun, China
GAZ						✓	VW & Skoda models are produced in Nizhny, Novogorod (Russia)
Shanghai Automotive		✓				✓	Joint venture in Shanghai, China producing Skoda and VW vehicles & engines

Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Summary Comparison of Manufacturers' Markets

A comparison of each manufac-turer's sales chart shows that Toyota and GM have the most models. Toyota has more fuel-efficient models; Hyundai's market is mainly in cars; Subaru's market is mainly SUVs, and FCA's market is mainly light trucks.

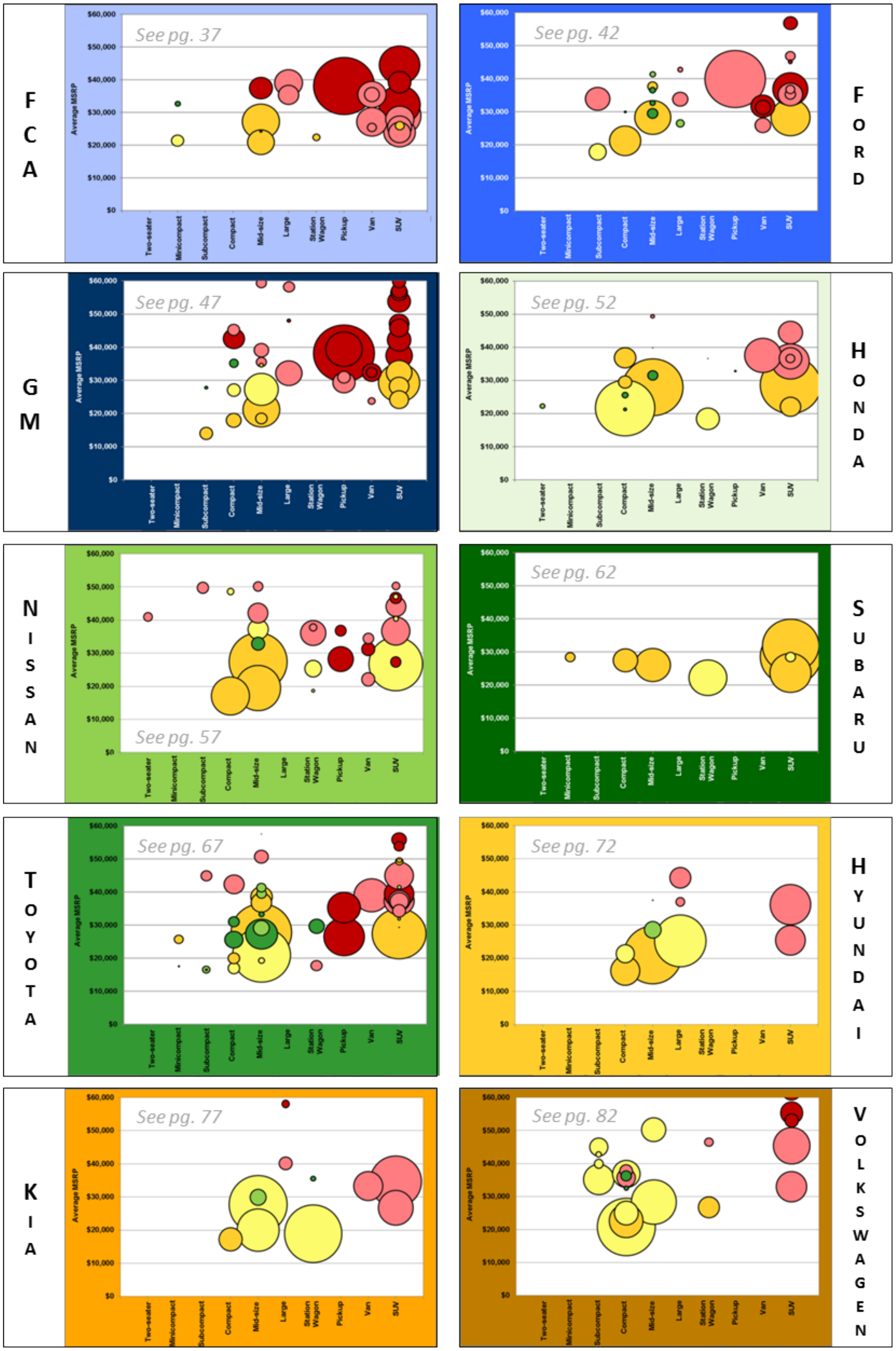


FIGURE 69. Summary Comparison of Manufacturers' Markets, 2015

CHAPTER 3

LIGHT VEHICLES

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U.S. Light Truck Sales Volumes Continued to Rise in 2016

Sales volumes rose from 2012 to 2016 for light trucks but car sales continued to fall in 2016. In 2016, sales fell below 7 million for cars but rose above 10 million for light trucks.

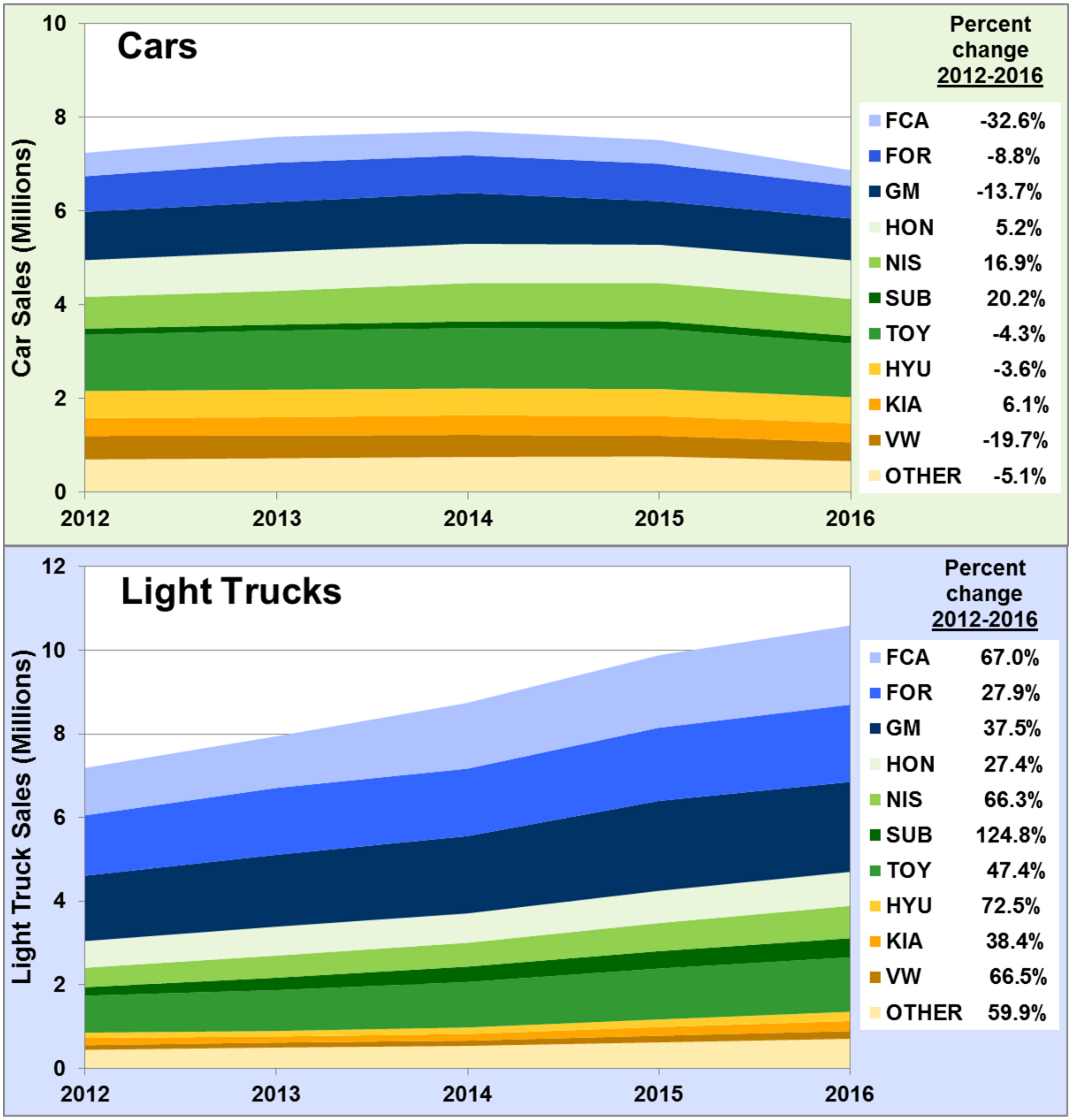

FIGURE 70. New Light Vehicle Sales by Manufacturer, 2012-2016

Note: Light trucks are classes 1 and 2.

Source:
Ward's Automotive Group. http://wardsauto.com

Approximately One-Quarter of Light Vehicle Sales Were Imports in 2016

In 1970, about 15% of all cars sold were imported (built outside of North America) and about 5% of all light trucks sold were imported. These import shares grew during the 1970's and the early 1980's. Following sharp declines in the late 1980s through the mid-1990s, import shares of both cars and light trucks rebounded, with import cars reaching a peak of just over 34% in 2009. Import light trucks reached their peak share in 1981 at almost 23% and accounted for 20% in 2016.

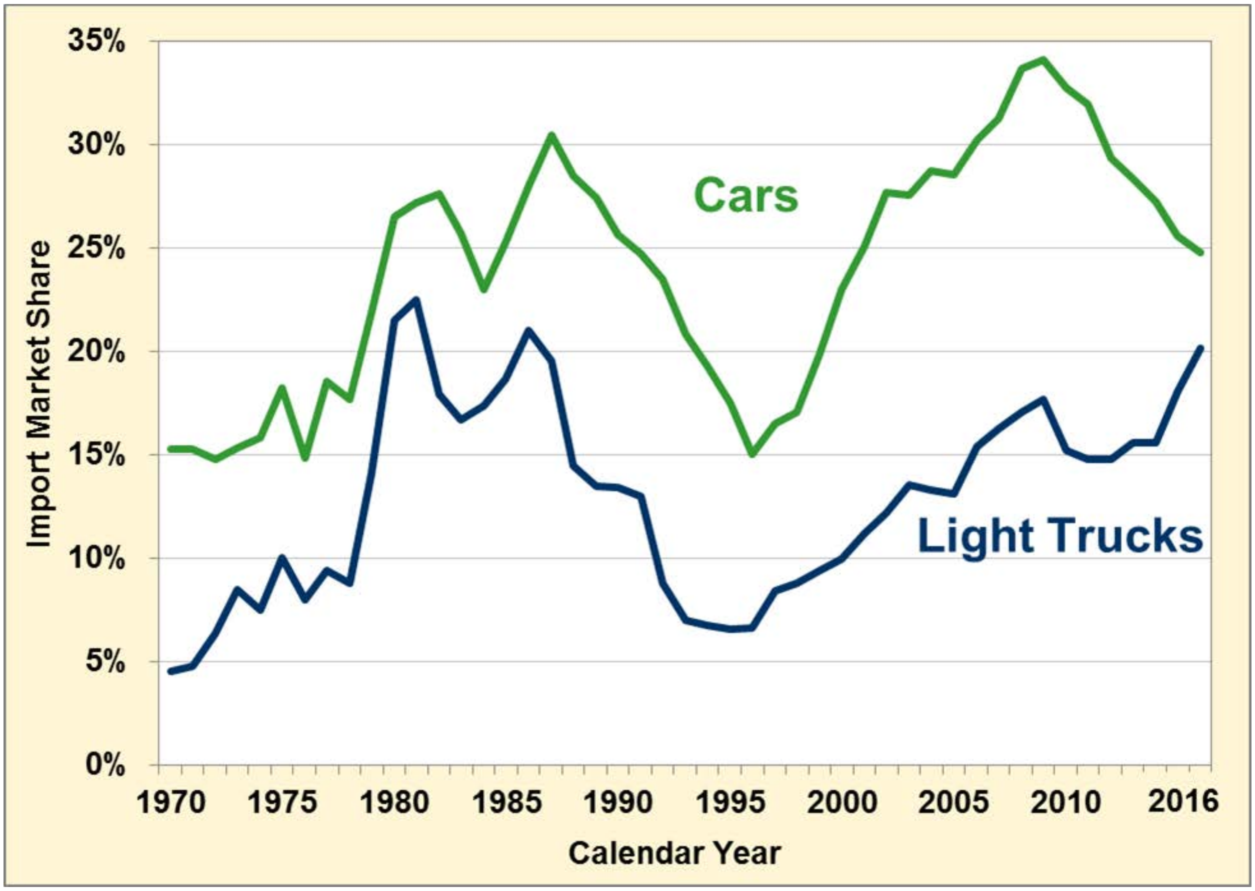

FIGURE 71. Import Market Share of Cars and Light Trucks, 1970-2016

Note: Imports are from outside North America. Light trucks are classes 1-3.

Source:
Ward's Automotive Group. http://wardsauto.com

Toyota Imports More Light Vehicles than Other Manufacturers

Most vehicle manufacturers, even if they are based in the United States, import some of the vehicles sold in this country. Of the ten largest U.S. manufacturers, Toyota sells the most imported light vehicles which accounts for about 27% of their sales. Subaru has the highest import share— imports accounted for 60% of Subaru light vehicle sales in 2016.

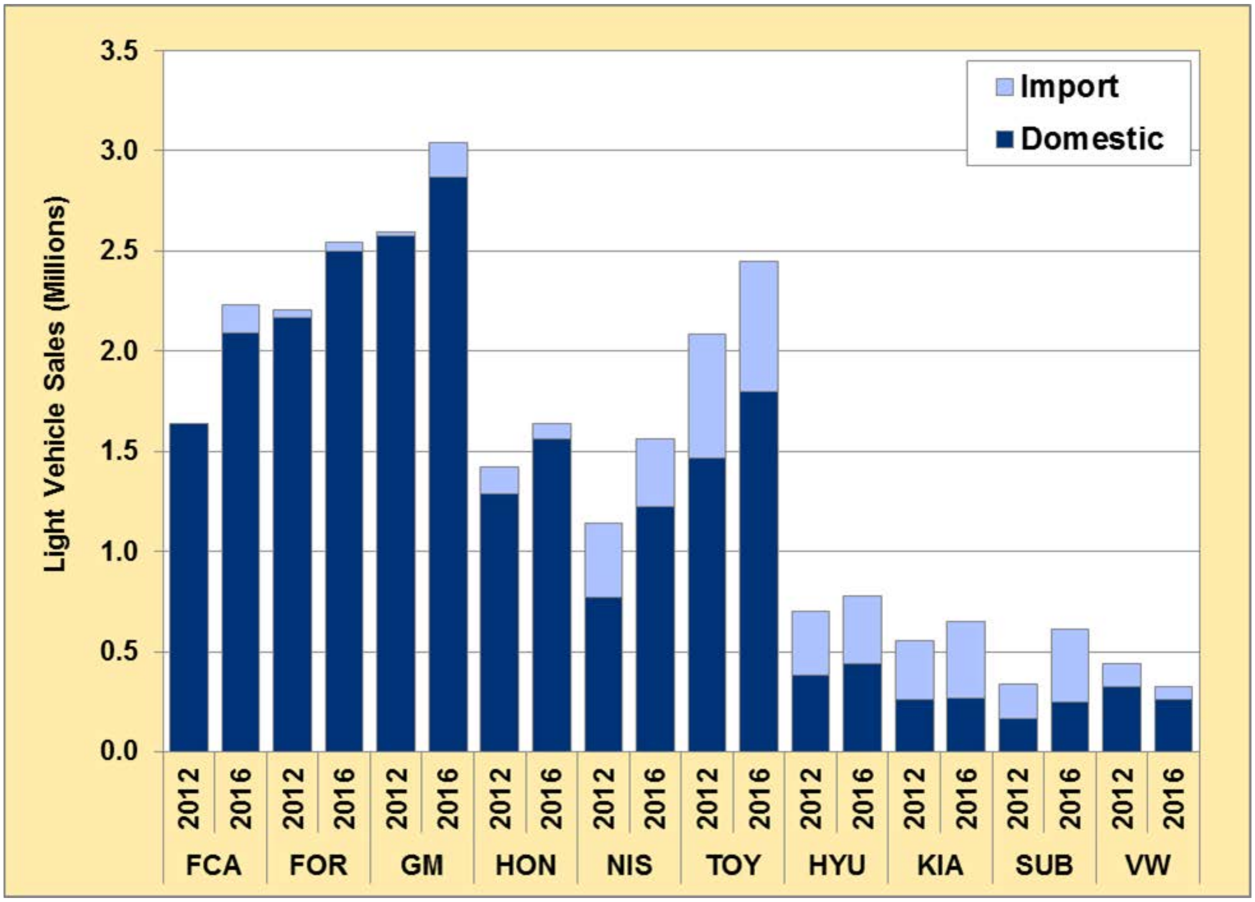

FIGURE 72. Light Vehicle Sales by Source and Manufacturer, 2012 and 2016

Source:
Ward's Automotive Group. http://wardsauto.com

Engine Displacement for Light Trucks has Declined by 10%

Average sales-weighted engine displacement for all new cars declined 5% from 2012 to 2016. In the same time period, average displacement for light trucks declined by 10%. In general, FCA and General Motors have larger engines than the other major manufacturers. Yearly fluctuations are typically a result of the introduction or elimination of a model.

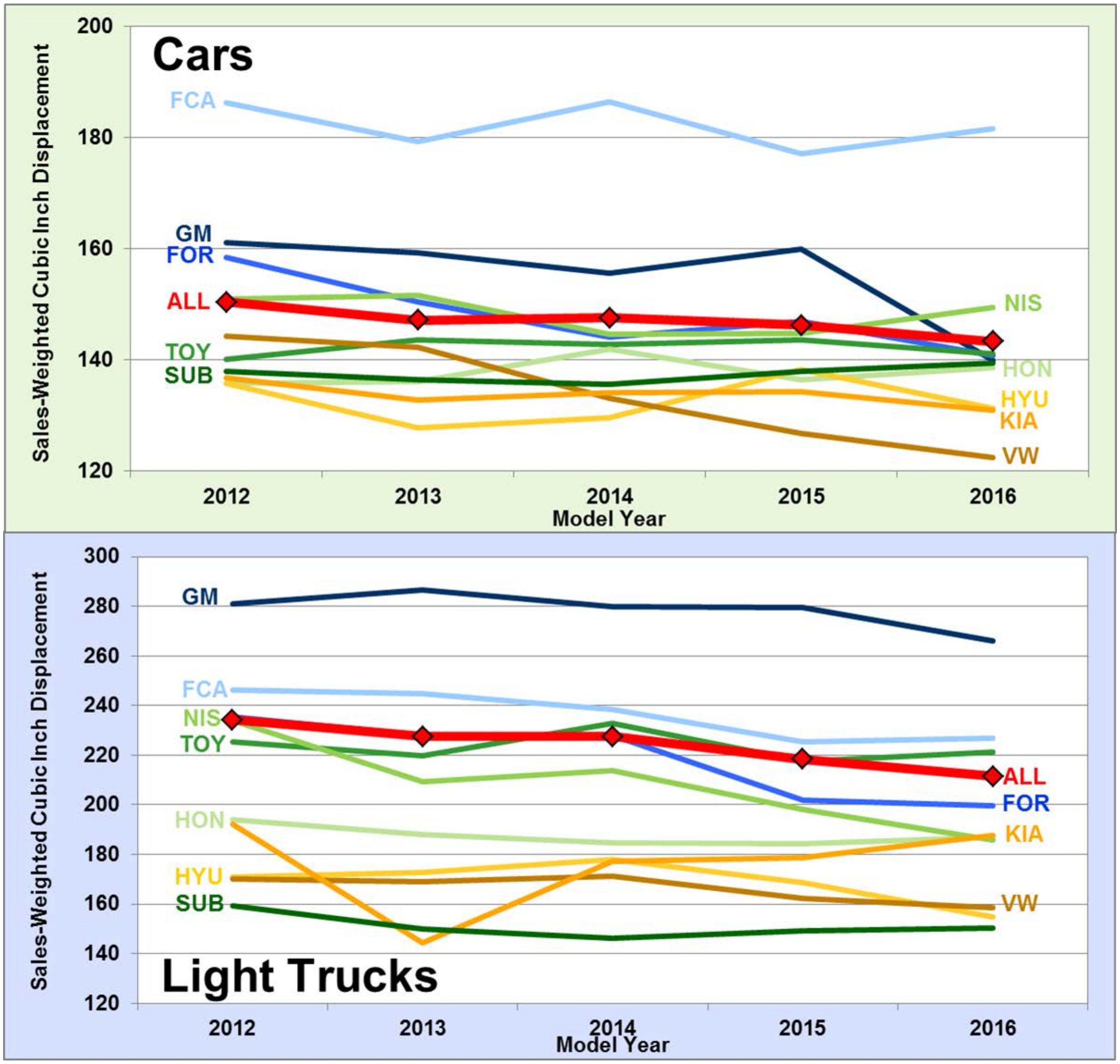

FIGURE 73. Car and Light Truck Engine Size by Manufacturer, 2012-2016

Note: The two graphs on this page have different scales.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Car Horsepower Increased by 5% from 2012 to 2016

Advancements in engine design and overall engine technology can increase horsepower without increasing the engine size. FCA, General Motors, and Ford generally have the highest horsepower engines in both cars and light trucks. The average horsepower for light trucks has stayed about the same over the five-year period.

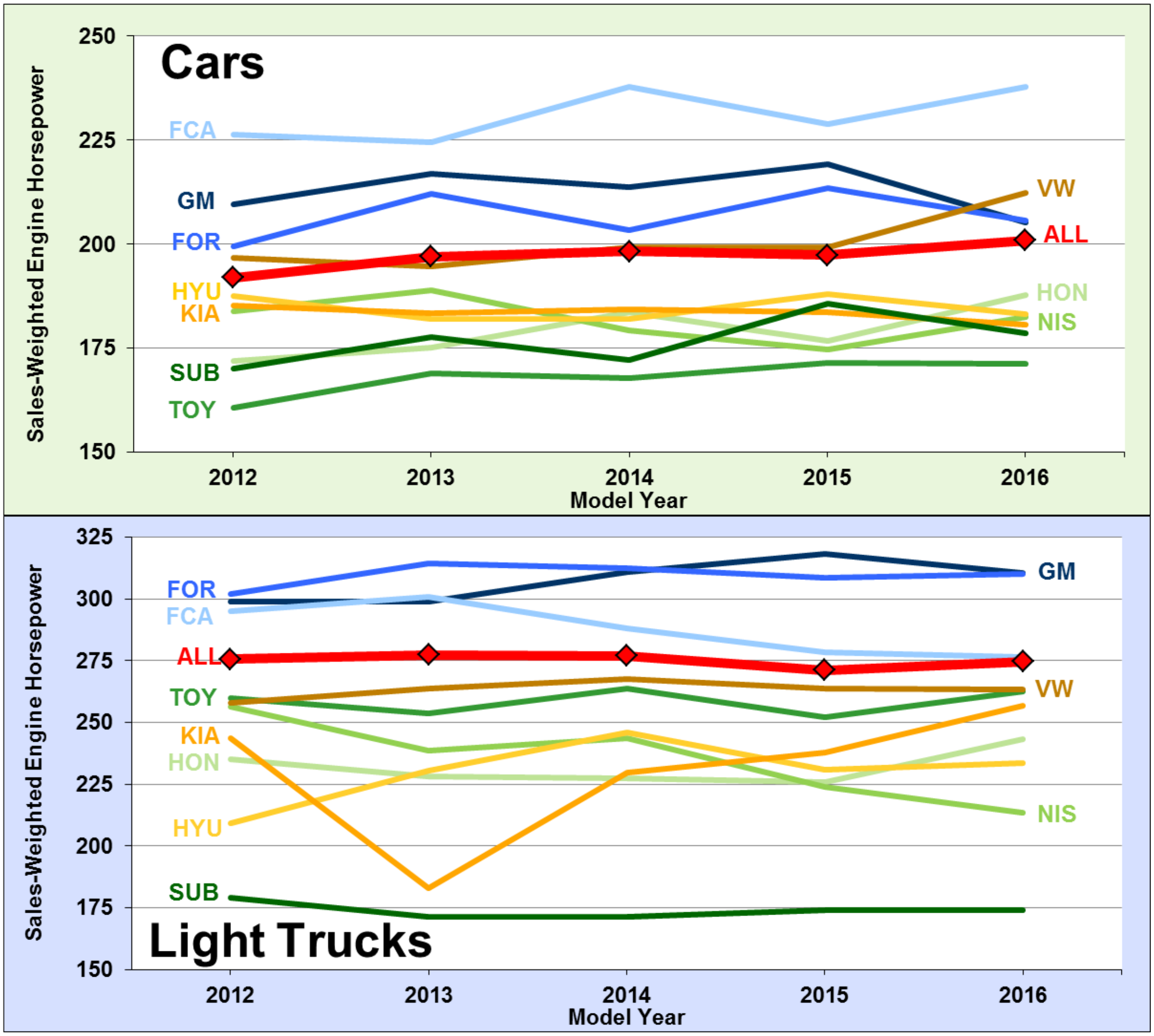

FIGURE 74. Car and Light Truck Horsepower by Manufacturer, 2012-2016

Note: The two graphs on this page have different scales.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

New Vehicle Fuel Economy has Improved 33% from 1980 to 2016

Despite a 120% increase in horsepower and 47% improvement in acceleration (measured by time to accelerate from 0 to 60 mph) from model year (MY) 1980 to 2016, the fuel economy of vehicles improved 33%. The data are based on sales-weighted averages. In the 1990s and early 2000s, fuel economy decreased while vehicle weight increased, and fuel economy has improved nearly every year since 2004.

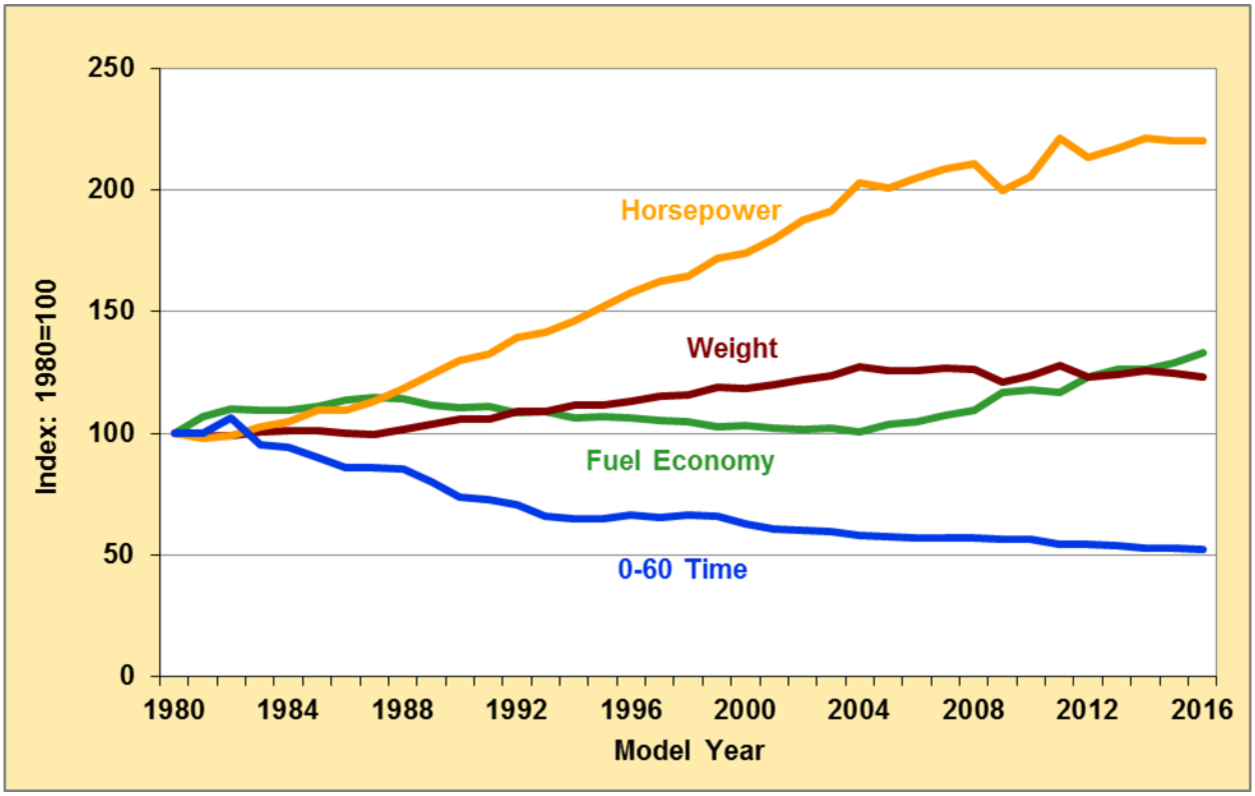

FIGURE 75. Characteristics of Light Vehicles Sold, 1980-2016

Note: Data are sales-weighted.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Horsepower above Fleet Average and Fuel Economy near Fleet Average for FCA, Ford, and GM

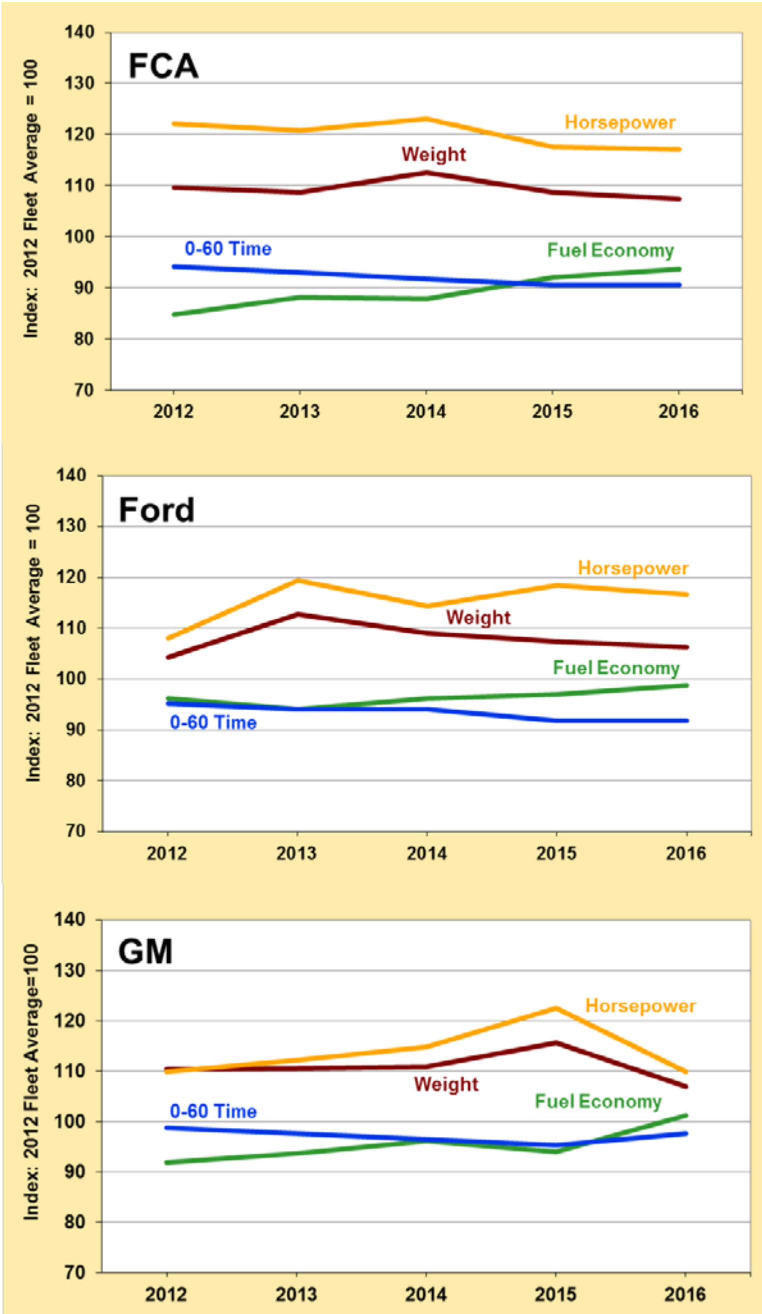

FIGURE 76. Characteristics of FCA, Ford and GM Light Vehicles Sold, 2012-2016

These sales-weighted averages show that all of these manufacturers have horsepower above the fleet average (above 100 on the graph). Vehicle weight for all three has fluctuated slightly up and down as they try to use more lightweight materials while adding additional features on the vehicles. FCA and GM made the biggest improvement in fuel economy over the five year period – a 10% improvement from 2012 to 2016. In the same time frame, Ford had a 3% improvement. Fuel economy in 2016 was below the fleet average (below 100 on the graph) for FCA and Ford.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Fuel Economy above Fleet Average and Weight below or Equal to Fleet Average for Toyota, Honda, and Nissan

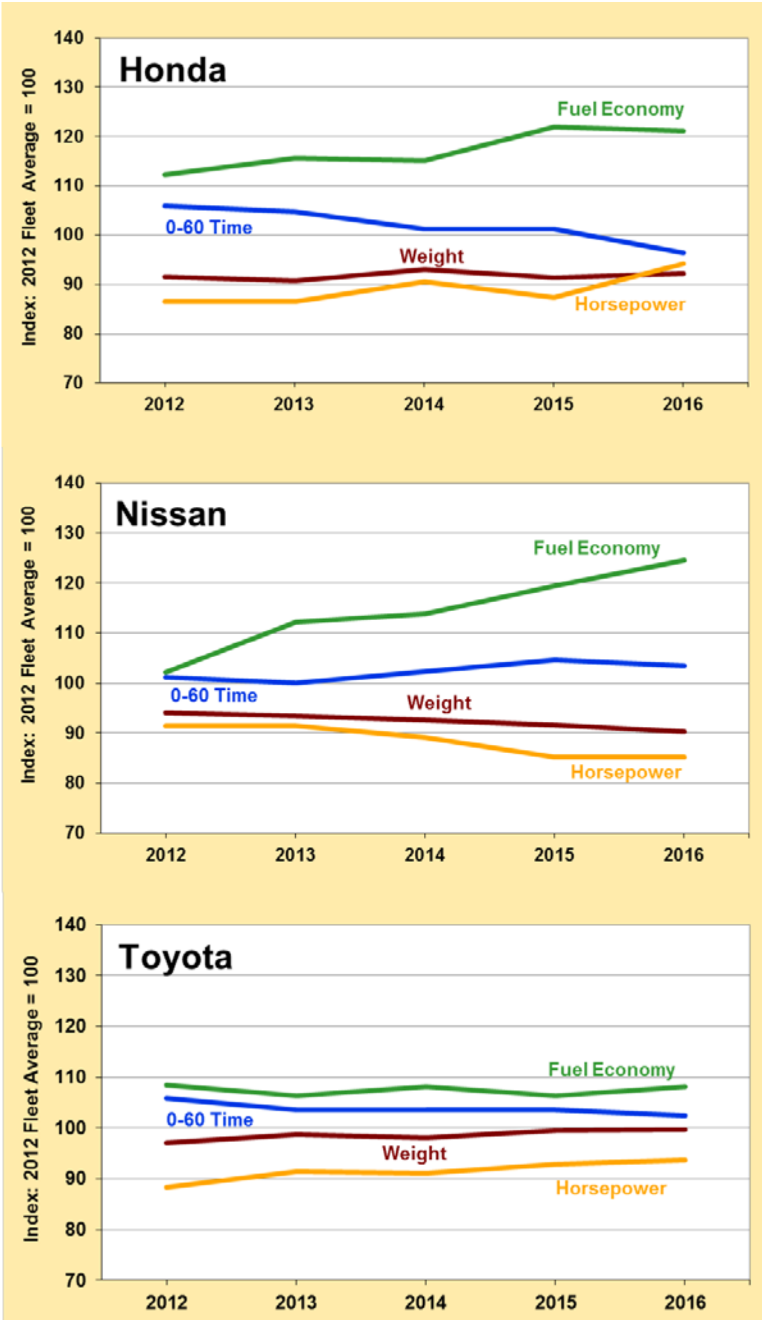

FIGURE 77. Characteristics of Japanese Light Vehicles Sold, 2012-2016

These sales-weighted averages show that the fuel economy of Toyota, Honda and Nissan has been equal to or above the fleet average (above 100 on the graph) over the last five years. Nissan had the greatest fuel economy improvement of the three Japanese manufacturers – 22% over the five-year period – followed by Honda with 8% improvement. While Nissan's fuel economy improved, horsepower declined by 7%. Weight for all three manufacturers was below fleet average.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Fuel Economy above Fleet Average and Horsepower below Fleet Average for Hyundai and Kia

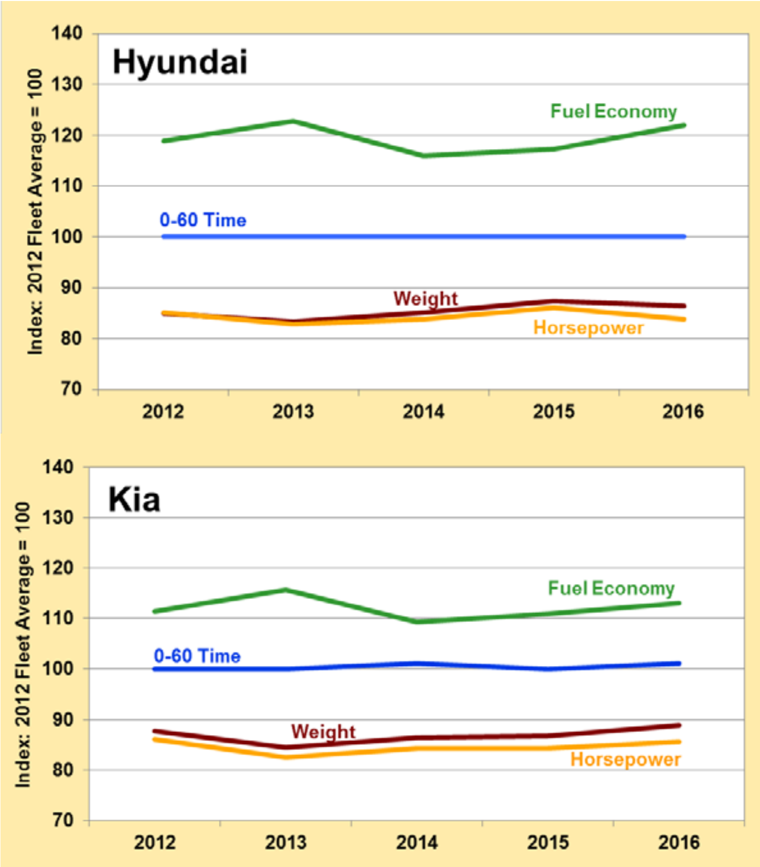

FIGURE 78. Characteristics of Hyundai and Kia Light Vehicles Sold, 2012-2016

The fuel economy for Hyundai's and Kia's light vehicles in 2012 was higher than the fleet average (higher than 100 on the graph). Horsepower and weight were below the fleet averages for both manufacturers.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Subaru Has 14% Fuel Economy Improvement While Weight and Horsepower Remain Unchanged

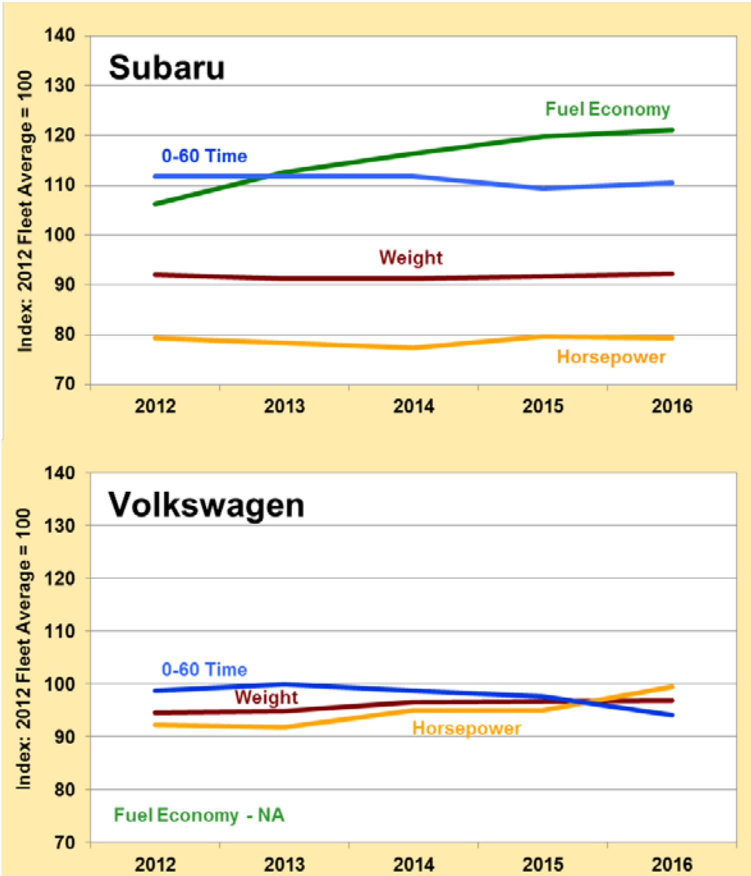

FIGURE 79. Characteristics of Subaru and Volkswagen Light Vehicles Sold, 2012-2016

The average weight and horsepower of Subaru vehicles have remained relatively unchanged from 2012 to 2016, but fuel economy improved by 14%. Average weight, horsepower, and 0-60 time for Volkswagen vehicles are at or below the industry average (100 on the graph). Volkswagen's fuel economy is not available from 2009-on due to the on-going investigation of VW diesel models.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

More than 26% of New Cars Sold Have Continuously Variable Transmissions

Continuously variable transmissions (CVT) offer an infinite number of gear ratios that allow the engine to operate at peak efficiency throughout the entire range of vehicle speeds which improves fuel efficiency. Though CVT technology has been around for many years, the sales of vehicles with CVTs began slowly and had climbed to 29.9% of car and 15.3% of light truck market share in 2015. Nissan sold 34% of the cars and 43% of the light trucks in 2016 that were equipped with CVT.

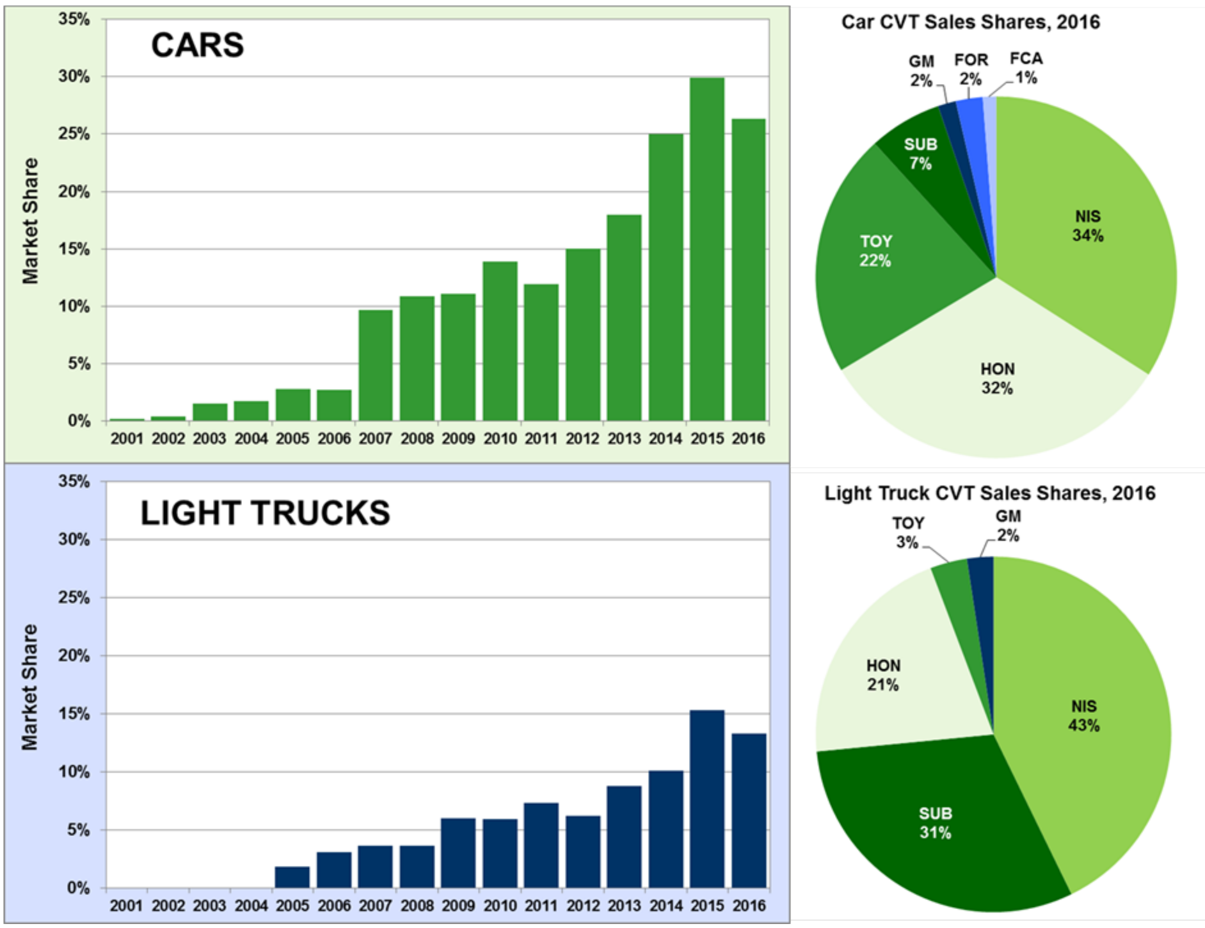

FIGURE 80. CVT Market Share, 2001-2016 and CVT Manufacturers' Share, 2016

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Almost 25% of New Cars Have Turbochargers

Turbocharging is not a new technology, but has grown in new light vehicle market share over the last six years. In 2016, almost 25% of new cars and nearly 18% of new light trucks had turbocharged engines (turbos). GM had the greatest share of turbo sales in cars and Ford in light trucks.

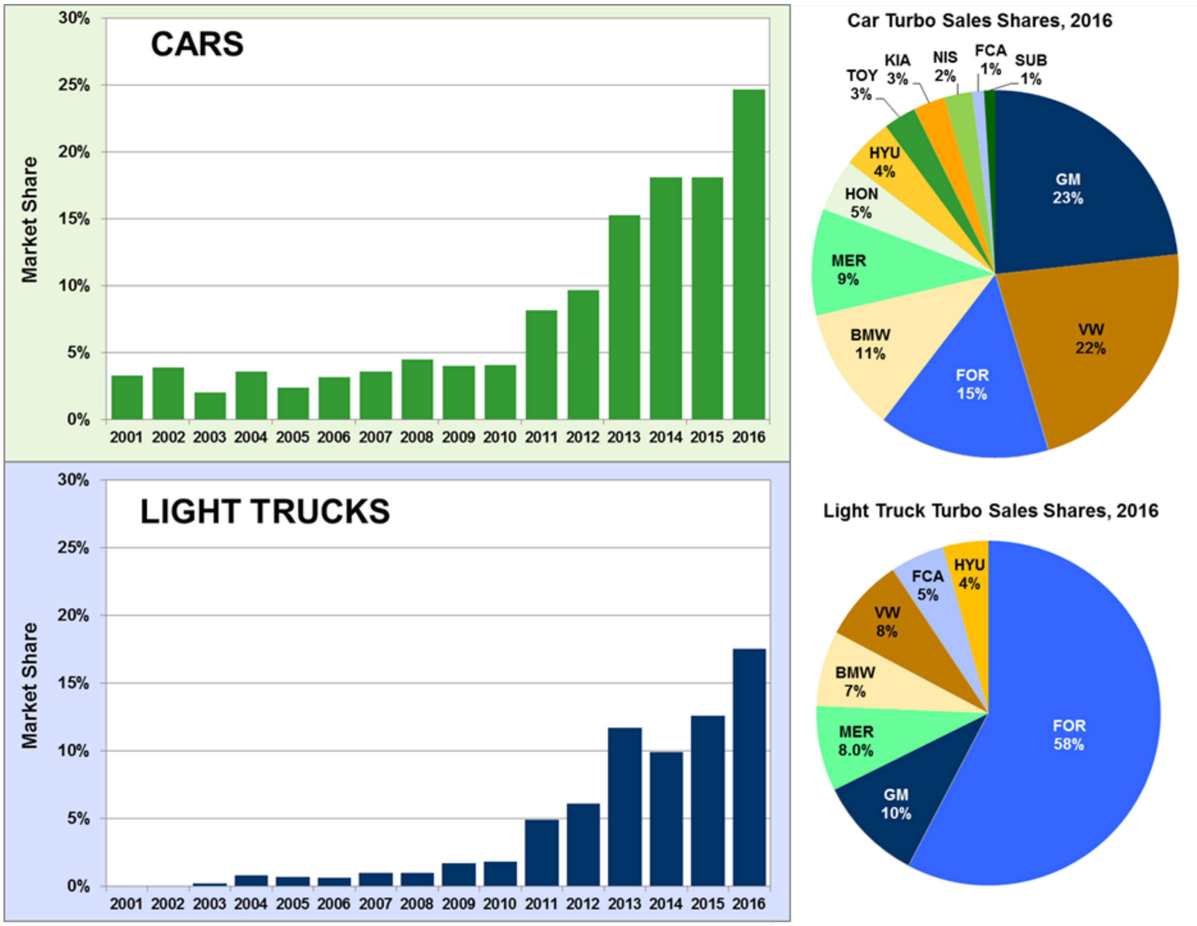

FIGURE 81. Turbo Market Share, 2001-2016 and Turbo Manufacturers' Share, 2016

Note: Light trucks include pickups, sport utility vehicles, and vans. MER = Mercedes.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Over 45% of Light Vehicles Sold Have Gasoline Direct Injection

Gasoline direct injection (GDI) began market penetration in cars in 2007 and in light trucks in 2008. By 2016, the market share for GDI was 50.7% for cars and 43.2% for light trucks. In 2016, over 40% of all light trucks with GDI were sold by GM.

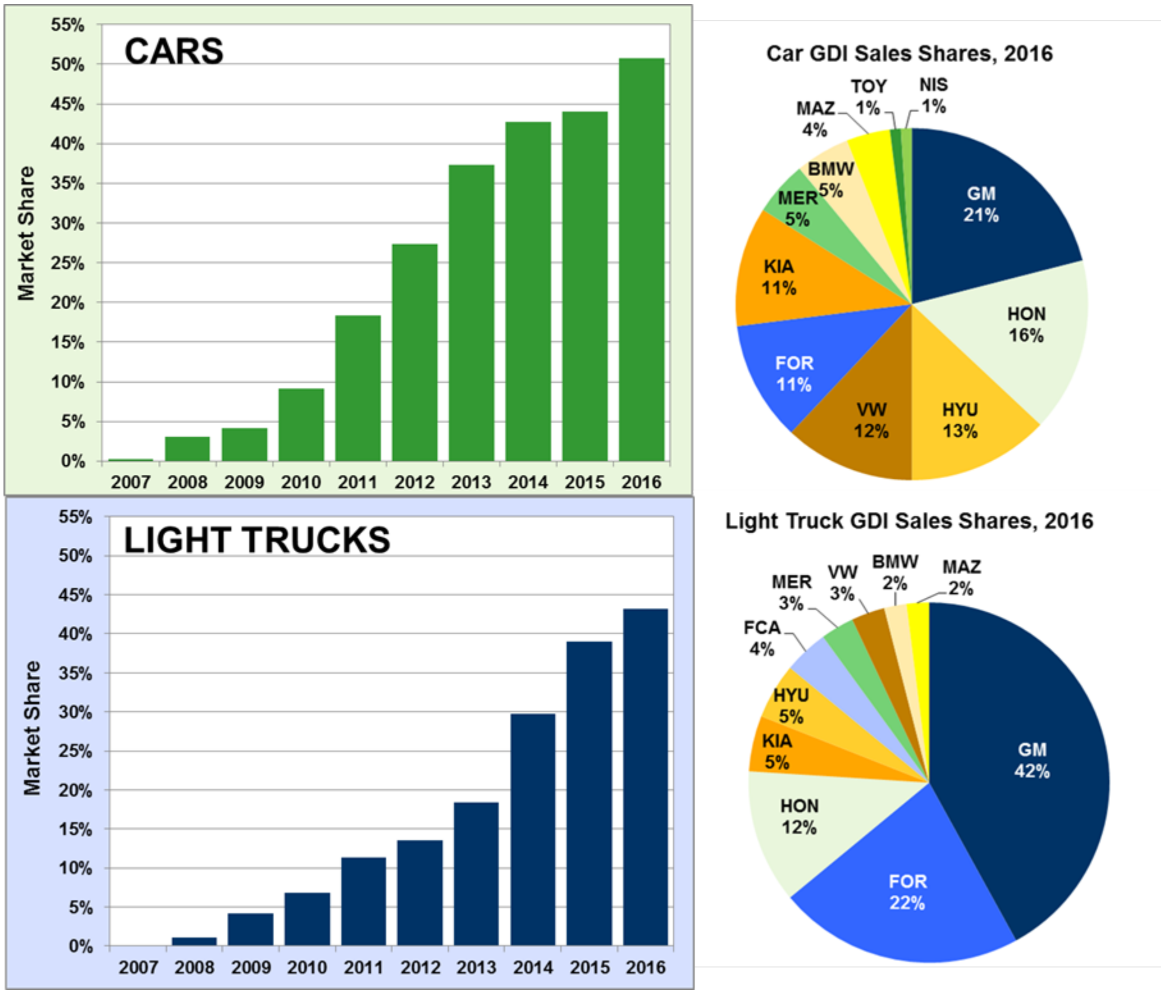

FIGURE 82. GDI Market Share, 2007-2016 and GDI Manufacturers' Share, 2016

Note: Light trucks include pickups, sport utility vehicles, and vans. MAZ = Mazda; MER = Mercedes.

Source:
U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Four Manufacturers Are Using Cylinder Deactivation to Boost Fuel Economy

GM, Honda, and FCA are using cylinder deactivation (CD) as a fuel saving technology in cars and light trucks. VW also uses CD in cars. Almost half of all cars sold with CD were from GM. GM also sold over half of all light trucks with CD.

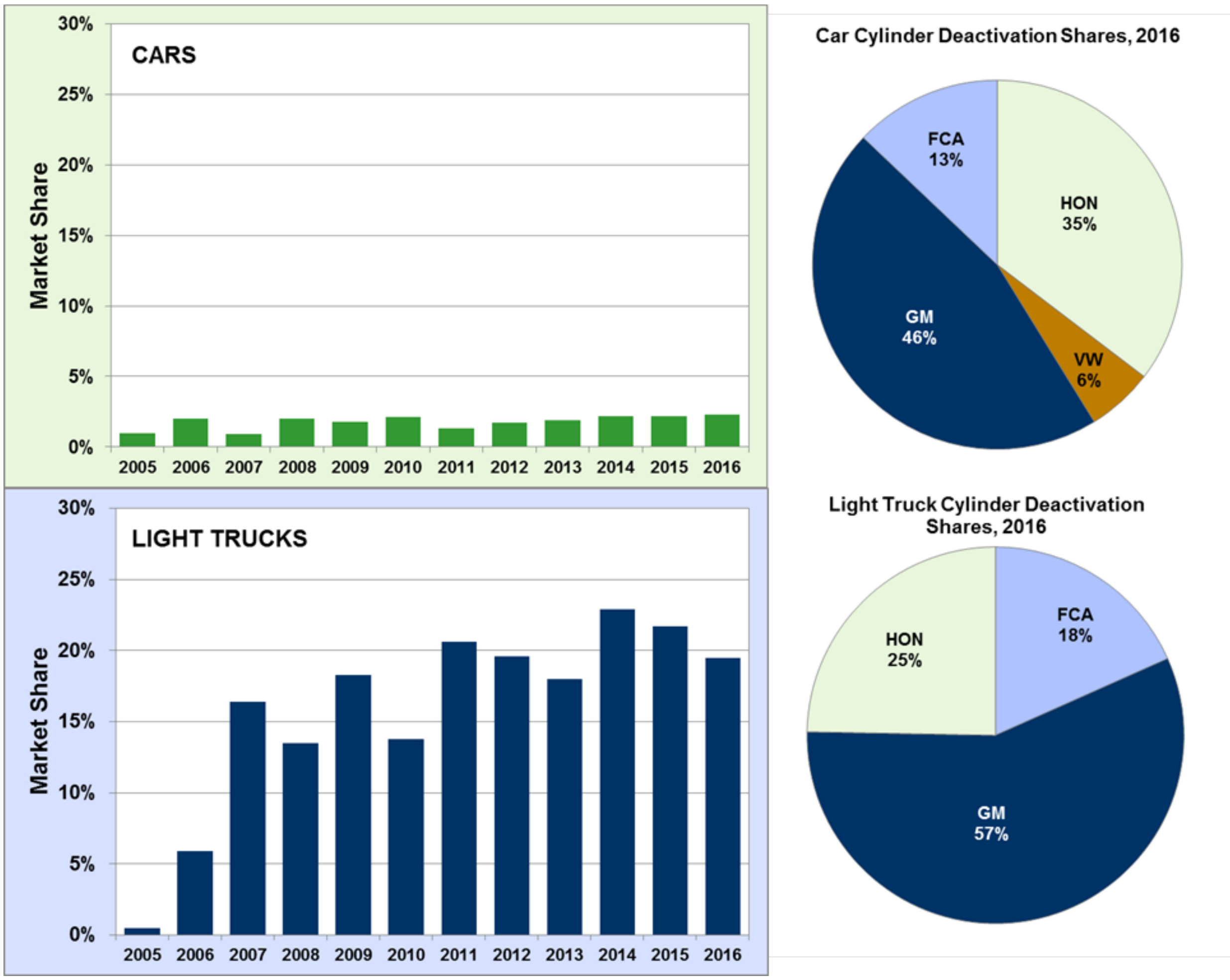

FIGURE 83. Cylinder Deactivation Market Share, 2005-2016 and Manufacturers' Share, 2016

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Eight Manufacturers Are Using Stop-Start Technology to Boost Fuel Economy

In 2016 stop-start technology was used by eight different manufacturers as a fuel saving measure. FCA and Ford dominate the stop-start light truck market (62% combined). Mercedes, BMW and GM together make up 81% of the stop-start car market. Stop-start technology penetrated 8.3% of the car market and 10.6% of the light truck market.

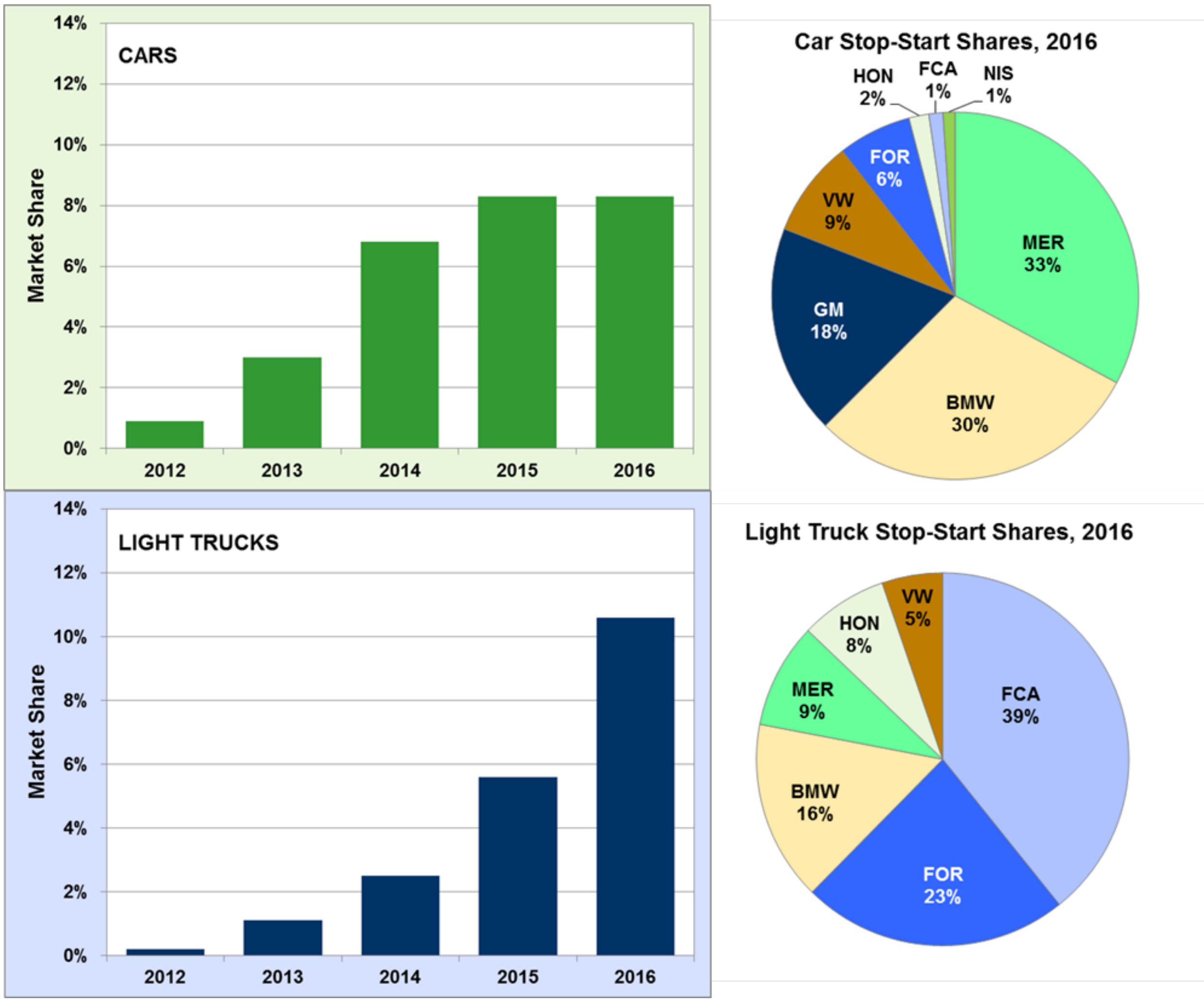

FIGURE 84. Stop-Start Technology Market Share, 2012-2016 and Manufacturers' Share, 2016

Note: MER = Mercedes.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/fueleconomy/trends-report.htm

More than 90% of New Light Vehicle Transmissions Were Six-Speed or More in 2016

The number of transmission speeds in new light vehicles has been growing over the last few decades. A greater number of gears improves fuel economy and performance by more closely matching the wheel speed to the optimum engine speed. By 2016, over half of all cars and light trucks were 6-speed. The sales share of 7-10-speed transmissions grew to 18% of cars and 22% of light trucks. Continuously variable transmissions (CVTs) were more than one-quarter of the car market and 13.3% of the light truck market.

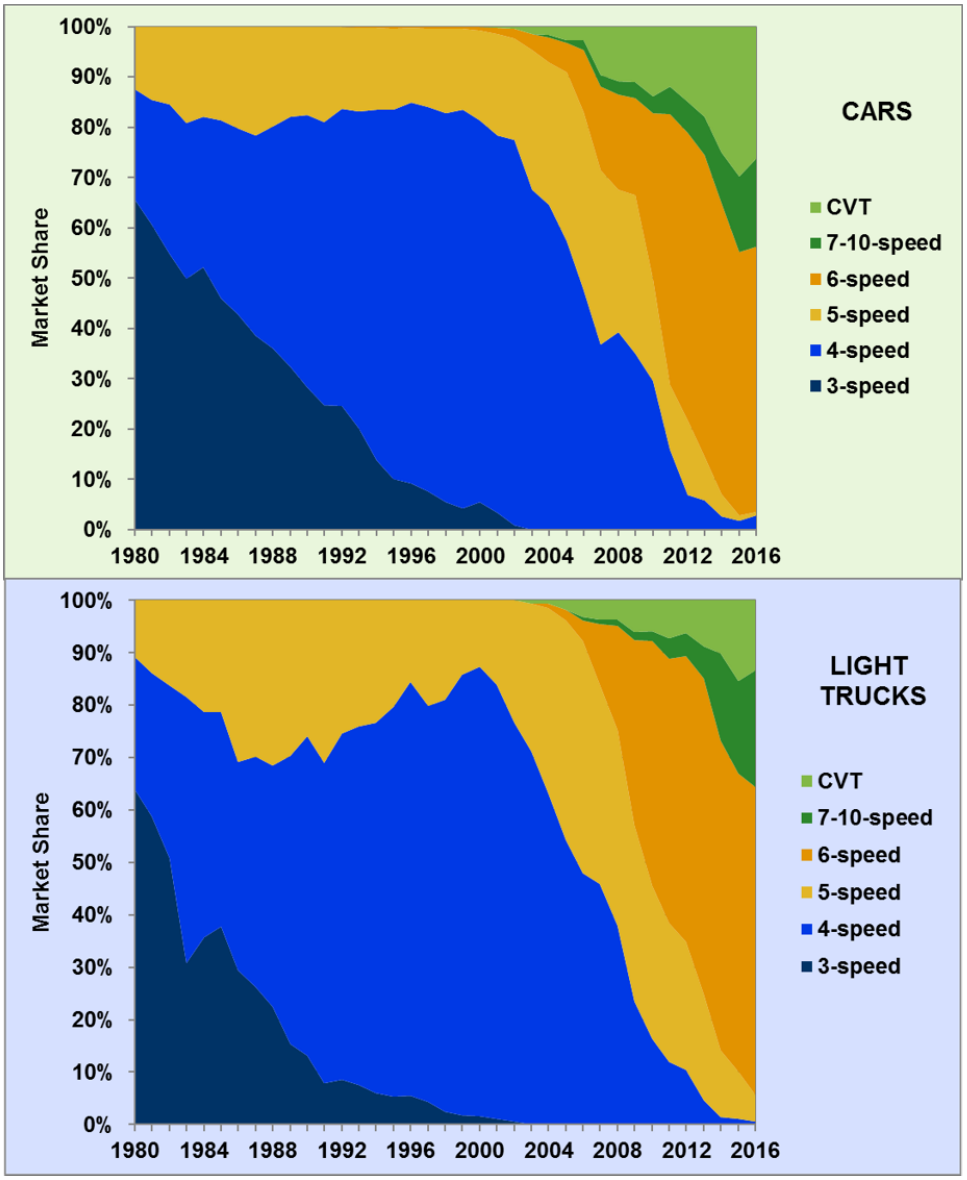

FIGURE 85. Market Share of Transmission Speeds, 1980-2016

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016,* EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Less than 20 Models of Light Vehicles Were Diesel in Model Year 2016

In the early 1980's fuel prices were high, the economy was in a downturn, and the cost of a gallon of diesel fuel was much less than that of a gallon of gasoline. Many manufacturers at that time produced diesel cars and light trucks. In model year (MY) 1984, there were 101 different models of light vehicles with diesel engines, including many common models like the Chevrolet Chevette, Ford Escort, Buick Regal, and Toyota Camry. Diesel engines in light vehicles, however, were not widely embraced by American consumers, with many finding them noisy, dirty, and hard to start in cold weather. By MY 2000, there was only one manufacturer selling diesel light vehicles. In MY 2016, six different manufacturers had 19 light vehicle models for sale with diesel engines.

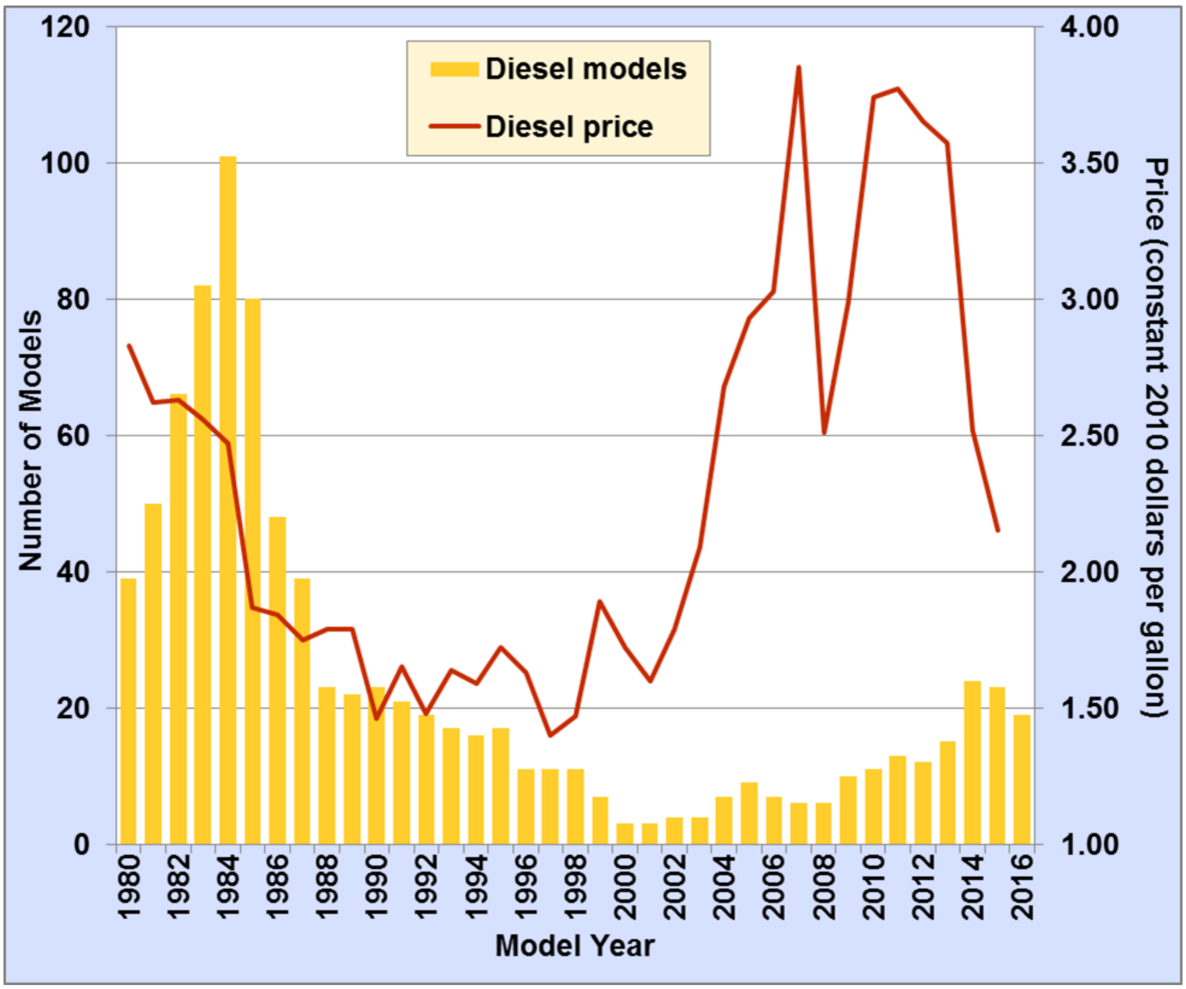

FIGURE 86. Number of Diesel Models and the Price of a Gallon of Diesel, 1980-2016

Note: Vehicles from VW that are currently under investigation are included in these data.

Sources:

U.S. Department of Energy fuel economy data, accessed February 2017. http://www.fueleconomy.gov.

Energy Information Administration, "Petroleum and Other Liquids Data Tool."
http://www.eia.gov/petroleum

Fleet Sales Were 20% or More of Ford, GM, FCA, and Hyundai/Kia Retail Sales in 2016

Ford, GM, and FCA all reduced their share of sales to fleets from 2011 to 2016 while Hyundai/Kia, Nissan, Toyota, and Honda increased their share of fleet sales. Hyundai/Kia had the greatest increase—from 10% to 21%.

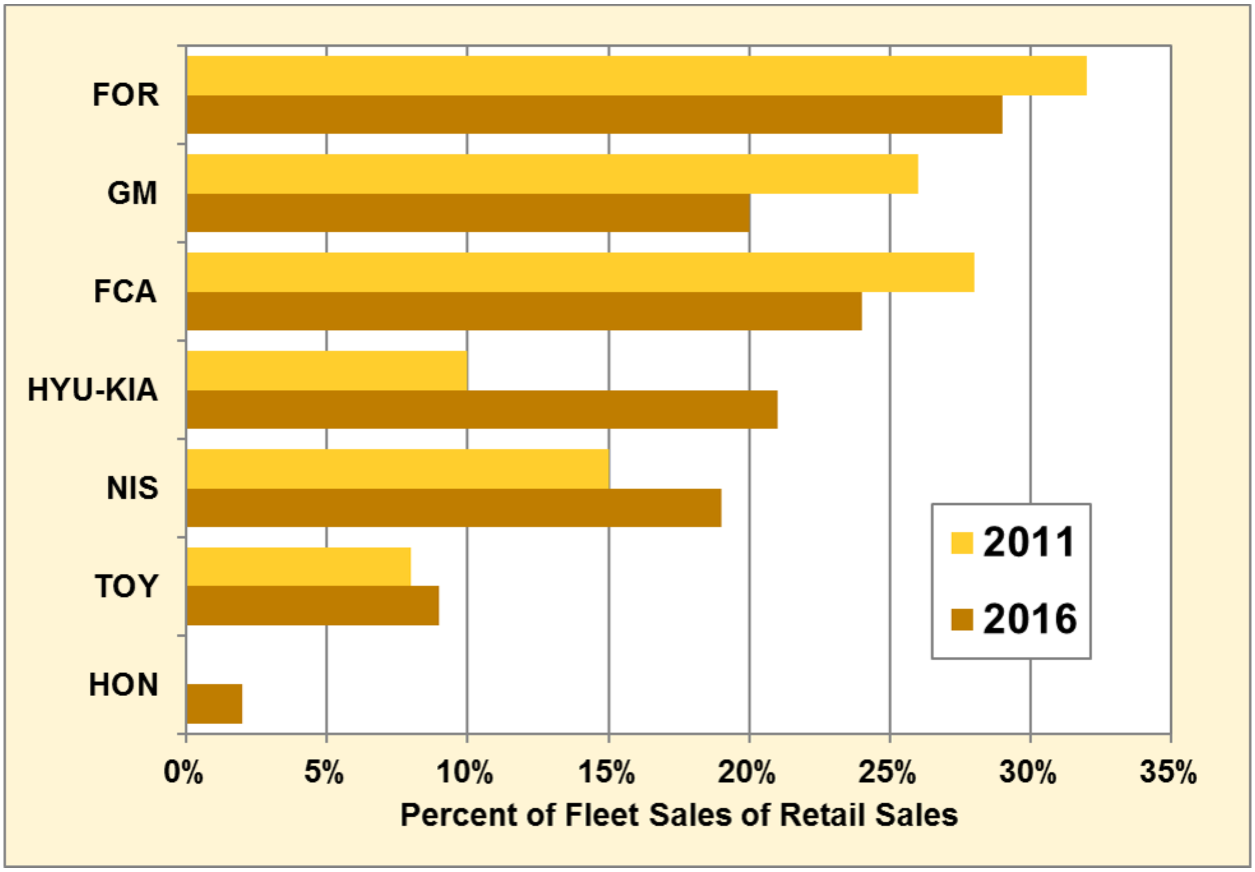

FIGURE 87. Share of Fleet Vehicle Sales by Manufacturer, 2011 and 2016

Source:

Crain Communications, Automotive News Data Center, U.S. Fleet Sales, January 2012 and January 2017. http://www.autonews.com

Fleet Management Companies Remarket Vehicles On-Line

The top ten fleet management companies owned or managed over 3.6 million vehicles in 2014. They remarketed 12% of those vehicles during the year. Remarketing is often done by auctioning the vehicles through established auction houses. However, remarketing vehicles on-line is becoming more common. Twenty-five percent of the vehicles remarketed in 2014 by the top ten fleet management companies were remarketed on-line. Emkay and Merchants Fleet Management remarketed over 80% of their vehicles on-line.

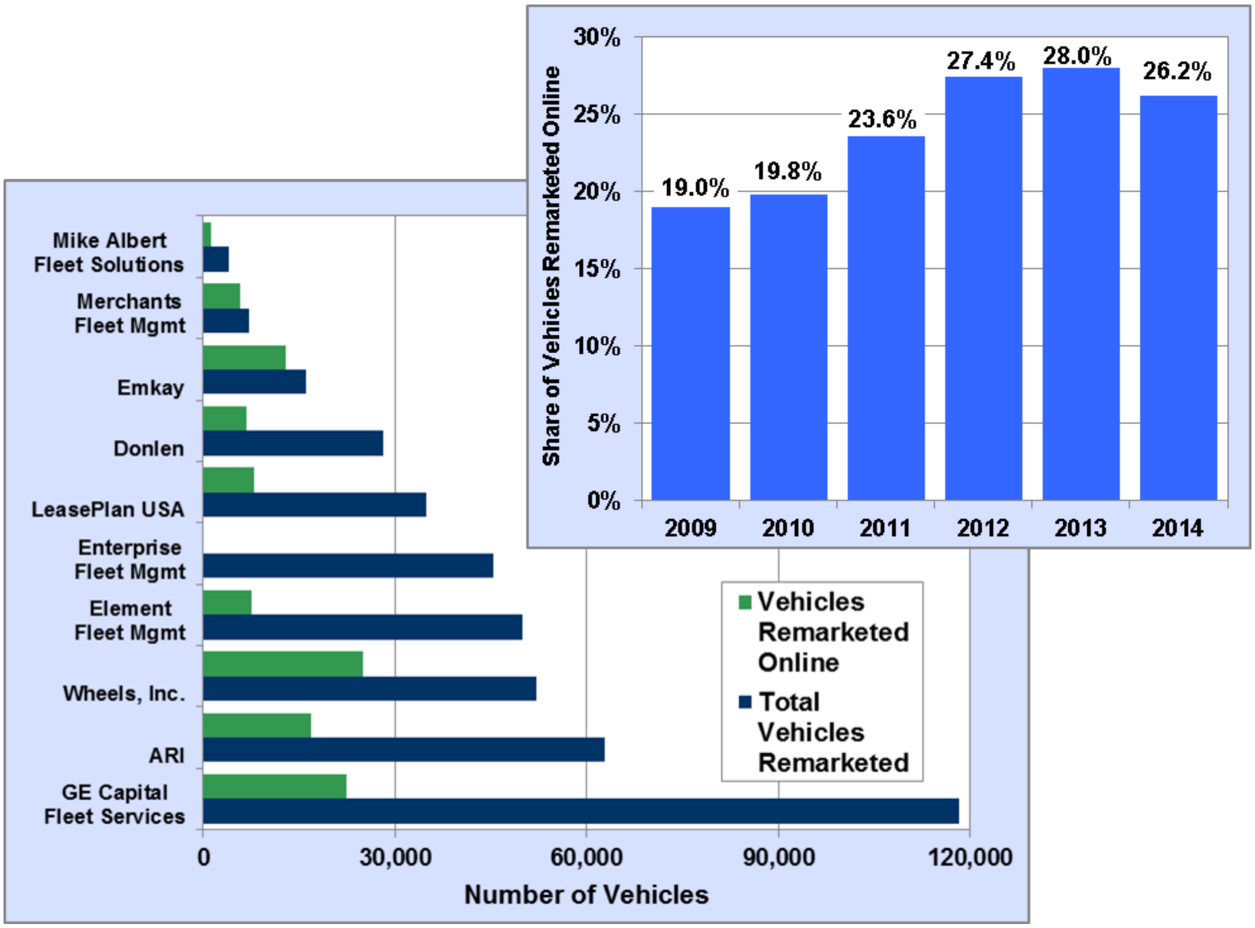

FIGURE 88. Vehicles Remarketed by the Top Ten Fleet Management Companies, 2014, and Share of Vehicles Remarketed On-Line, 2009-2014

Source:
Bobit Publishing Company, *Automotive Fleet Factbook 2015*. http://www.automotive-fleet.com/statistics

Light Vehicle Dealer Supplies Change Rapidly

Light vehicle dealer inventories change quickly throughout the year because they are affected by so many different variables: dealer or manufacturer financial incentives, economic news, supply disruptions.

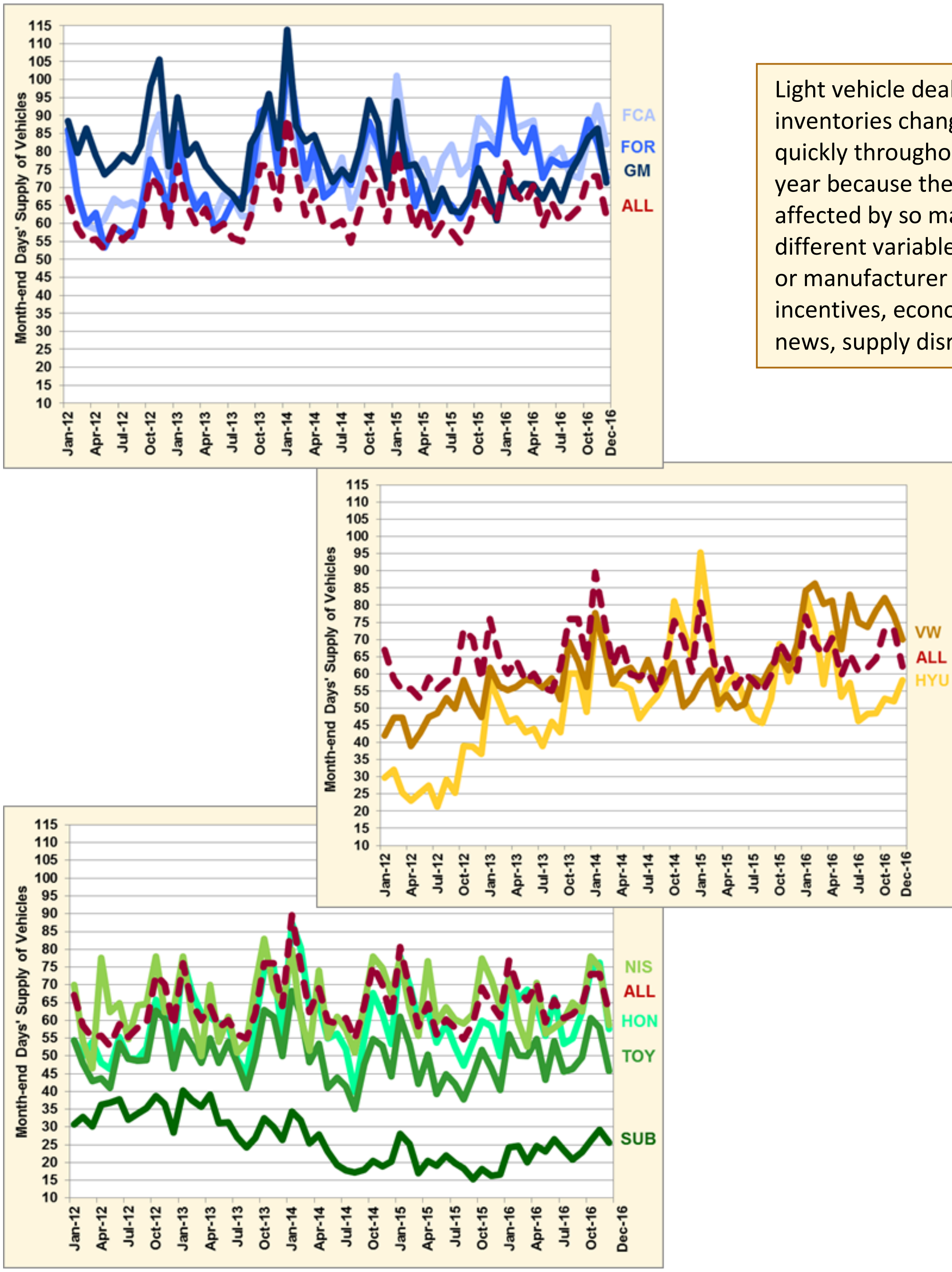

FIGURE 89. Monthly Dealer Supplies by Manufacturer, 2012-2016

Note: ALL = Average of all manufacturers. HYU includes Kia.

Source:
Ward's Automotive Group. http://wardsauto.com

“Days to Turn” Trend by Vehicle Class

"Days to turn" is an automotive industry term that refers to the number of days that vehicles stay in dealer inventories before they are sold (i.e., the time a vehicle stays on the dealer's lot). There are many factors that influence this number including fuel prices, the economy, and supply disruptions. For these reasons days to turn by vehicle class is very volatile. During the two-year period from October 2014 to October 2016, compact trucks had the lowest days to turn. Large cars and large trucks, for the most part, had the highest days to turn. Large crossover SUVs turned in 77 days in October 2014 but only took 53 days in October 2015—a 31% decline.

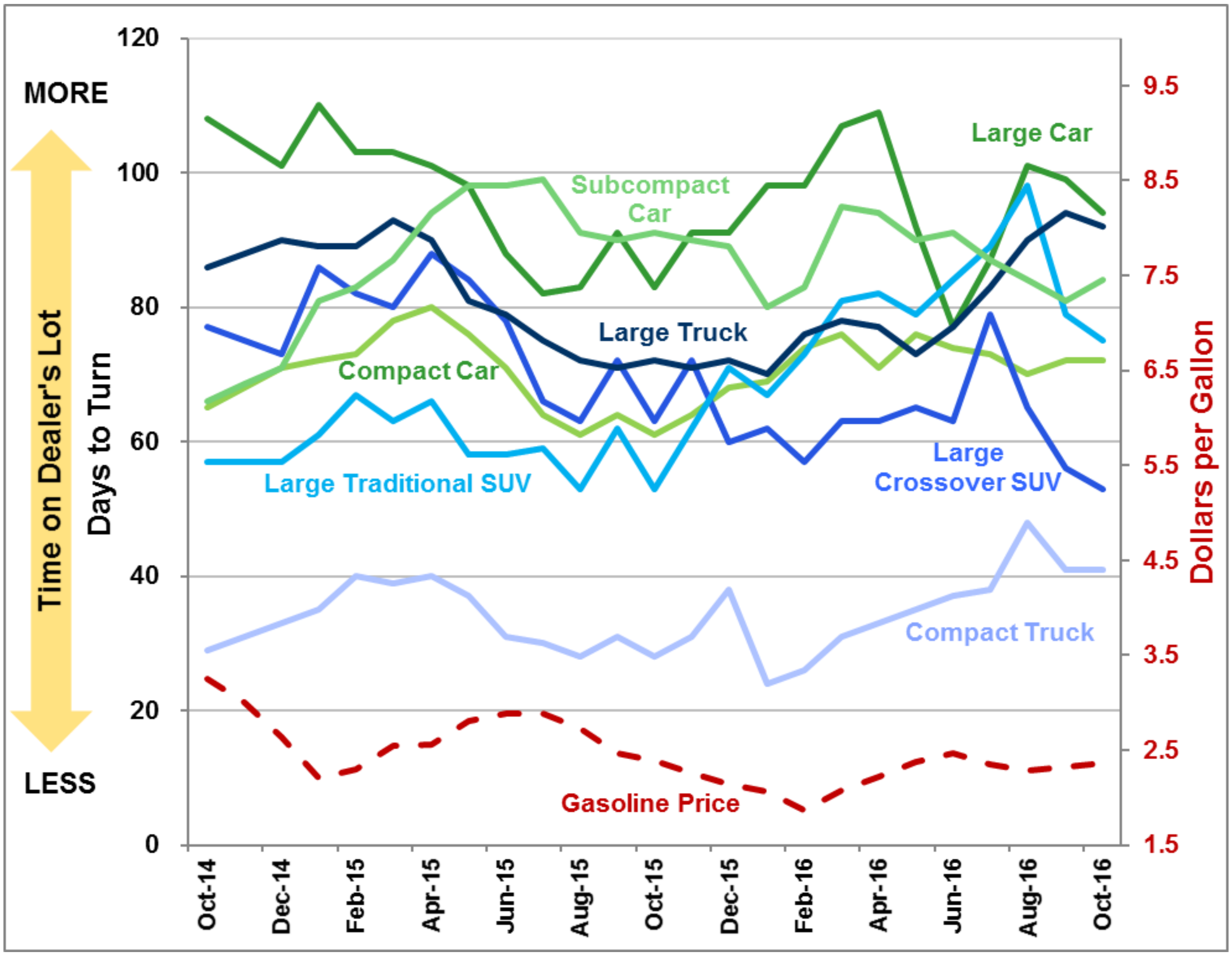

FIGURE 90. Days to Turn Trend by Vehicle Class, 2014-2016

Sources:

Edmunds website data, www.Edmunds.com.

U.S. Department of Energy, Energy Information Administration, International Statistics website, February 2017. http://www.eia.gov.

Many Tier 1 Suppliers Sell More in Europe and Asia than in North America

In the automotive industry, a Tier 1 supplier is a company that sells directly to the original equipment manufacturer (OEM). Globally, Robert Bosch GMbH is the top supplier with over $44 billion in parts sales to OEMs in 2015. Within the top ten suppliers, only two–Magna International, Inc.–(58%) and Johnson Controls, Inc. (50%) have the majority of their sales to North America. The other companies in the top ten sell to North America, but sell more in Europe and Asia combined.

TABLE 24. List of Top Ten Tier 1 Global Suppliers, 2015

			Market Share				
Rank	**Company**	**Company Headquarters**	**North America**	**Europe**	**Asia**	**Rest of World**	**Total**
1	Robert Bosch GMbH	Germany	20%	47%	31%	2%	100%
2	Denso Corp.	Japan	25%	13%	61%	1%	100%
3	Magna International, Inc.	Canada	58%	33%	8%	1%	100%
4	Continental AG	Germany	26%	49%	20%	5%	100%
5	ZF Friedrichshafen AG	Germany	28%	47%	22%	3%	100%
6	Hyundai Mobis	Korea	21%	11%	67%	1%	100%
7	Aisin Seiki	Japan	19%	9%	71%	1%	100%
8	Faurecia	France	27%	54%	15%	4%	100%
9	Johnson Controls, Inc.	United States	50%	39%	8%	3%	100%
10	Lear Corp.	United States	43%	37%	18%	2%	100%

Note: Rank based on total global OEM automotive parts sales in 2015.

Source:

Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2016. http://www.autonews.com/

Top U.S.-Based Tier 1 Suppliers Sell Globally

There are eleven U.S.-based companies in the top 50 automotive global suppliers. Only five of these companies had more than half of their sales in North America in 2015, but all of them had a least one-third in North America in that year.

TABLE 25. U.S.-Based Tier 1 Suppliers in the Top 50, 2015

Rank	Company	Percent North America Sales	Products
9	Johnson Controls, Inc	50%	Complete automotive seats & seat components,
10	Lear Corp.	43%	Seating & electrical distribution systems
12	Delphi Automotive	37%	Mobile electronics; powertrain, safety, thermal, controls & security systems; electrical/electronic architecture; in-car entertainment technologies
28	BorgWarner, Inc.	34%	Turbochargers, engine valve-timing systems, ignition systems, emissions systems, thermal systems, transmission-clutch systems, transmission-control systems, torque management systems & rotating electric machines
33	Cummins, Inc.	61%	Diesel & natural gas engines
38	Flex-N-Gate Corp.	91%	Interior & exterior plastics, metal bumpers & hitches, structural metal assemblies, forward & signal lighting, mechanical assemblies, prototyping & sequencing
39	Dana Holding Corp.	53%	Axles, driveshafts, sealing & thermal management products
40	Goodyear Tire & Rubber Co.	37%	Tires
12	TRW Automotive Holdings Corp.	41%	Steering, suspension, braking & engine components; fasteners, occupant-restraint systems, electronic safety & security systems
42	Tenneco, Inc.	51%	Emission-control systems, manifolds, catalytic converters, diesel aftertreatment systems, catalytic reduction mufflers, shock absorbers, struts, electronic suspension products & systems
47	Federal-Mogul Corp.	34%	Pistons, rings, cylinder liners, piston pins, ignition and spark plugs bearings, valve seats & guides, valvetrain products, gaskets, seals, heat shields, brake friction materials & products, systems protection products, lighting products, wipers, fuel pumps

Note: Rank based on total global OEM automotive parts sales in 2015.

Source:
Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2016.
http://www.autonews.com/

U.S.-Based Tier 1 Suppliers Have Been Diversifying Globally over the Past Five Years

There are ten U.S. automotive parts suppliers that sold more than $5 billion in parts to original equipment manufacturers in 2015. Most of these companies have been diversifying their customer base over the last five years. Nine of the companies increased their share of sales in North America. Goodyear is the only company that decreased their sales share to North America between 2011 and 2015. Dana is the only company listed that increased their sales share to Europe in the 5-year period.

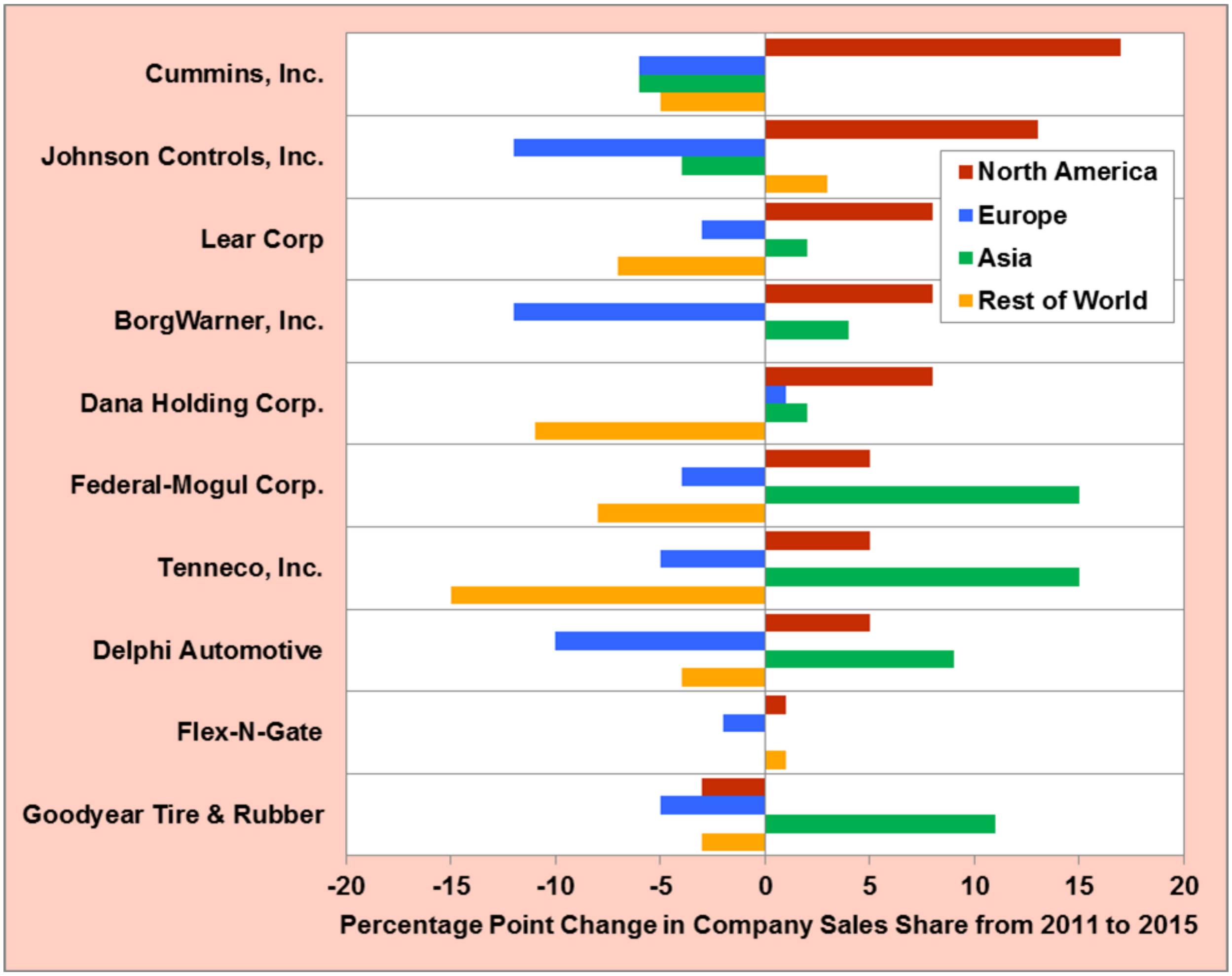

FIGURE 91. Change in Company Sales Share of Top U.S.-Based Tier 1 Suppliers, 2011-2015

Source:

Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2016 and June 2012. http://www.autonews.com/

CHAPTER 4

HEAVY TRUCKS

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What Types of Trucks Are in Each Truck Class?

There are eight truck classes, categorized by the gross vehicle weight rating that the vehicle is assigned when it is manufactured. The pictures below show examples of some of the different types of trucks that would be included in each class.

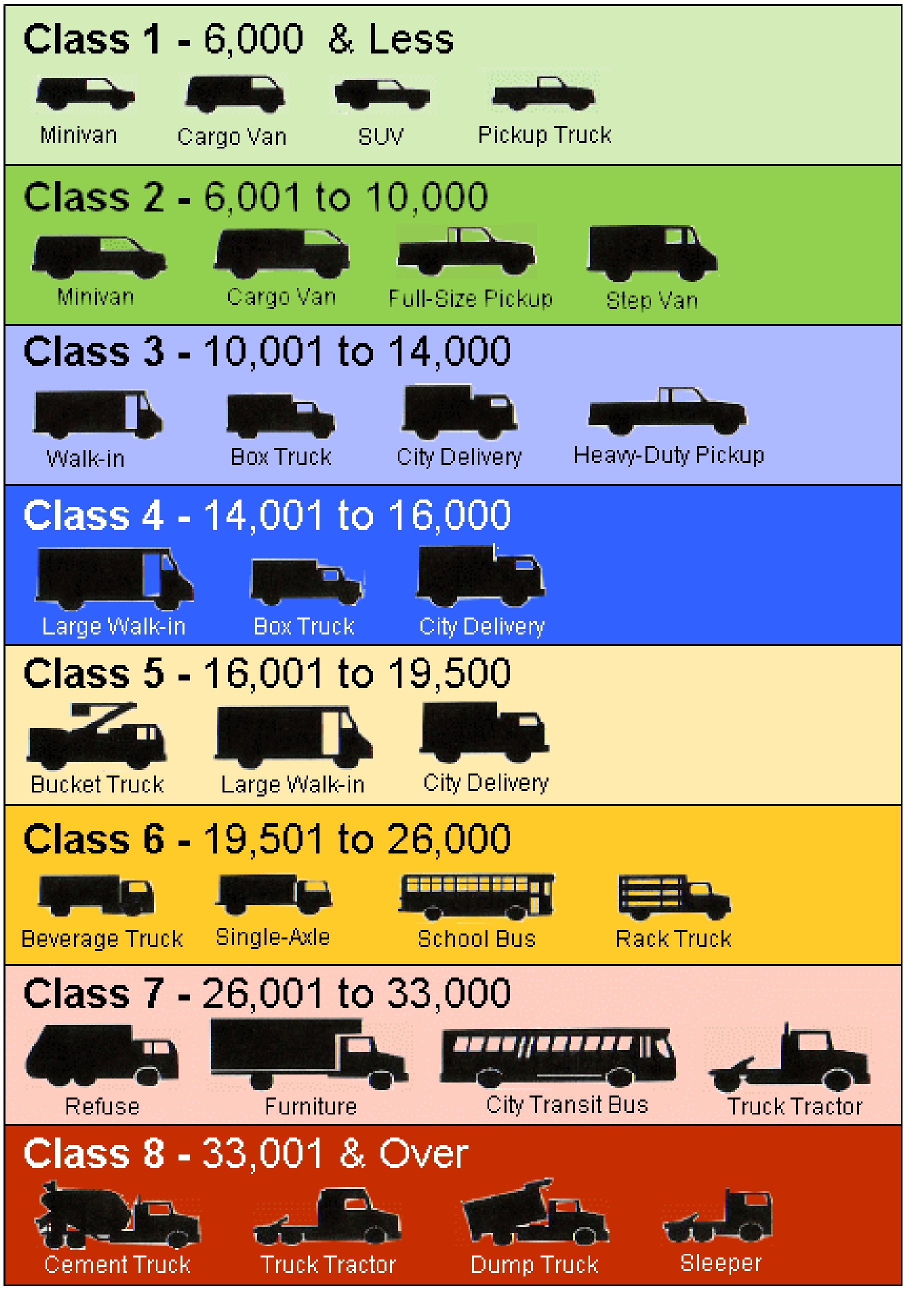

FIGURE 92. Examples of Trucks in Each Truck Class

Source:

Oak Ridge National Laboratory, Center for Transportation Analysis, Oak Ridge, TN. Weight category definitions from 49CFR565.6 (2000).

Heaviest Trucks Consume an Average of 6.5 Gallons per Thousand Ton-Miles

There are eight truck classes, categorized by the gross vehicle weight rating (GVWR) that the vehicle is assigned when it is manufactured. Cars and small pickups, vans, and sport-utility vehicles (SUVs) are shown here for comparison. Two truck classes are further subdivided into "a" and "b" designations. Class 2a and 2b are subdivided based on GVWR. Class 8a and 8b are subdivided based on the truck design (straight truck vs. combination truck).

TABLE 26. Typical Weights and Fuel Use by Truck Class

Class	Applications	Gross Weight Range (lb)	Empty Weight Range (lb)	Typical Payload Capacity Max (lb)	Typical Fuel Economy Range in 2007 (mpg)	Typical Fuel Consumed (gallons per thousand ton-miles)
1c	Cars *only*	3,200 - 6,000	2,400 - 5,000	250 - 1,000	25-33	69.0
1t	Minivans, Small SUVs, Small Pickups	4,000 - 6,000	3,200 - 4,500	250 - 1,500	20-25	58.8
2a	Large SUVs, Standard Pickups	6,001 - 8,500	4,500 - 6,000	250 - 2,500	20-21	38.5
2b	Large Pickups, Utility Van, Multi-Purpose, Mini-Bus, Step Van	8,501 - 10,000	5,000 - 6,300	3,700	10-15	38.5
3	Utility Van, Multi-Purpose, Mini-Bus, Step Van	10,001 - 14,000	7,650 - 8,750	5,250	8-13	33.3
4	City Delivery, Parcel Delivery, Large Walk-In, Bucket, Landscaping	14,001 - 16,000	7,650 - 8,750	7,250	7-12	23.8
5	City Delivery, Parcel Delivery, Large Walk-In, Bucket, Landscaping	16,001 - 19,500	9,500 - 10,800	8,700	6-12	25.6
6	City Delivery, School Bus, Large Walk-In, Bucket	19,501 - 26,000	11,500 - 14,500	11,500	5-12	20.4
7	City Bus, Furniture, Refrigerated, Refuse, Fuel Tanker, Dump, Tow, Concrete, Fire Engine, Tractor-Trailer	26,001 - 33,000	11,500 - 14,500	18,500	4-8	18.2
8a	Straight Trucks, e.g., Dump, Refuse, Concrete, Furniture, City Bus, Tow, Fire Engine	33,001 - 80,000	20,000 - 34,000	20,000 - 50,000	2.5-6	8.7
8b	Combination Trucks, e.g., Tractor-Trailer: Van, Refrigerated, Bulk Tanker, Flat Bed	33,001 - 80,000	23,500 - 34,000	40,000 - 54,000	4-7.5	6.5

Source:

The National Academies, *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*, 2010. http://www.nap.edu/catalog.php?record_id=12845

United States Accounts for 63% of Medium/Heavy Truck Production in North America

Nearly 322,000 medium/heavy trucks (Classes 4-8) were produced in the United States in 2015, which is 63% of North American production. Mexico also produced a large number of trucks (35%). The top two producers, Freightliner and Ford, made both medium and heavy trucks. FCA produced medium trucks in Mexico only. Kenworth was the only manufacturer of medium/heavy trucks in Canada.

TABLE 27. North American Production of Medium and Heavy Trucks by Manufacturer, 2015

Manufacturer	Thousands of Trucks				U.S. Share of Total
	United States	Mexico	Canada	Total	
Ford	75.3	0.0	0.0	75.3	100%
Freightliner & Western Star	77.8	93.3	0.0	171.1	45%
Kenworth	37.5	15.8	14.3	67.6	55%
Volvo	38.7	0.2	0.0	38.9	99%
Peterbilt	32.9	0.0	0.0	32.9	100%
Mack	27.0	0.0	0.0	27.0	100%
International	18.2	39.1	0.0	57.3	32%
Hino	9.5	0.5	0.0	10.0	95%
Isuzu	5.0	0.0	0.0	5.0	100%
Blue Diamond	0.0	7.7	0.0	7.7	0%
Dina Camiones	0.0	1.4	0.0	1.4	0%
FCA	0.0	18.5	0.0	18.5	0%
MAN	0.0	1.2	0.0	1.2	0%
Total	321.9	177.7	14.3	513.9	63%

Note: Includes truck Classes 4 through 8.

Source:
Ward's Automotive Group. http://wardsauto.com

Medium and Heavy Truck Assembly Plants Are Located throughout the United States

There are seven major manufacturers of Class 7 and 8 trucks in the United States–Freightliner/Western Star, Hino, International, Kenworth, Mack, Peterbilt and Volvo. Two of those, Freightliner and International, also manufacture medium trucks (Classes 4-6), along with Ford, Isuzu, and Sprinter/Daimler. Thomas and NEOPLAN manufacture buses. Most of the manufacturing plants are in the Eastern third of the United States. In 2015, Ford moved the production of medium trucks back to the United States from Mexico.

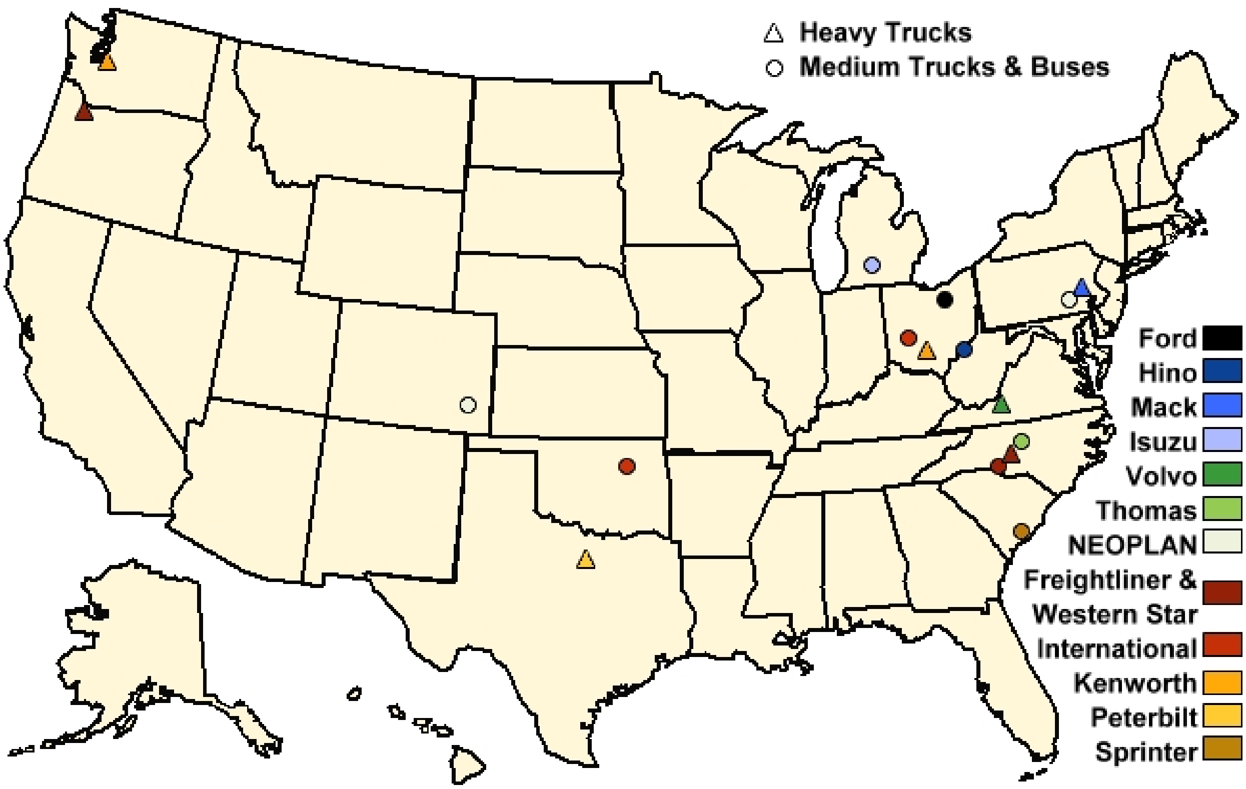

FIGURE 93. Medium and Heavy Truck Manufacturing Plants by Location, 2016

Note: Includes truck Classes 4 through 8.

Source:
Ward's Automotive Group. http://wardsauto.com

Few Medium/Heavy Trucks Are Imported from Outside North America

Sales of Class 4-8 trucks are overwhelmingly vehicles that are made in North America. Almost 40% of Class 4 trucks and 11% of Class 5 trucks were imported from outside of North America in 2016. There were no imported Class 6, 7, or 8 trucks sold. Historically the import truck market share peaked in 1987 at 7.1% and after much volatility the overall import share was 3.4% in 2016.

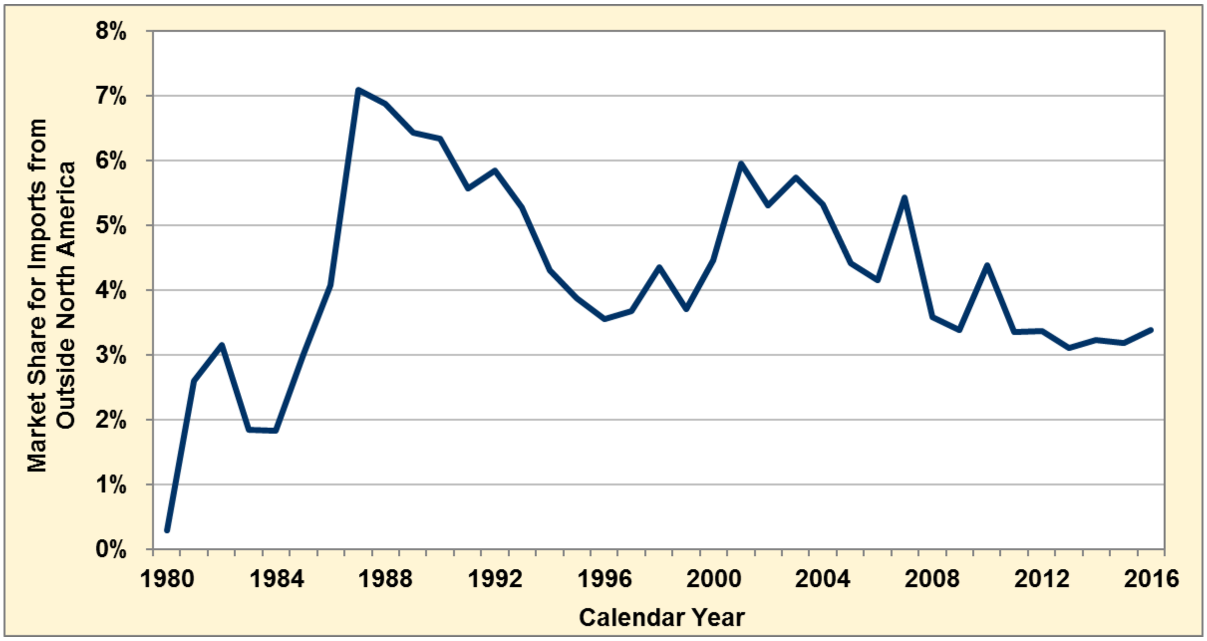

FIGURE 94. Share of Medium and Heavy Trucks Imported from Outside North America, 1980-2016

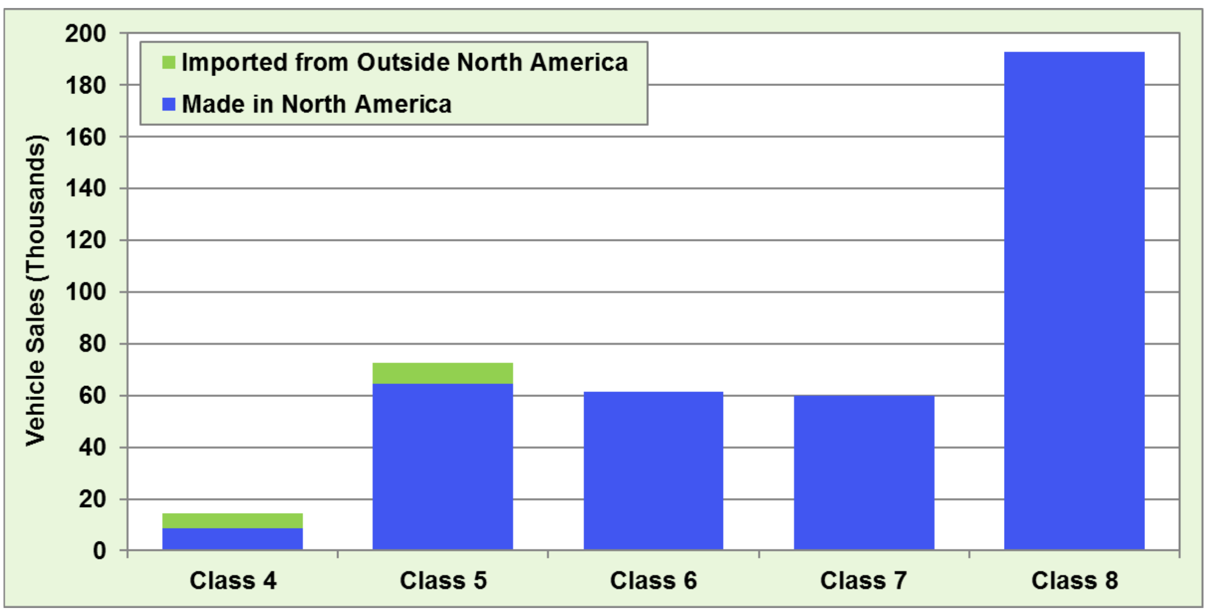

FIGURE 95. Medium and Heavy Trucks Sold by Source and Weight Class, 2016

Source:
Ward's Automotive Group. http://wardsauto.com

Class 3 Truck Sales Have Increased by 33% from 2012 to 2016

The Class 3 truck market has grown each year since 2011 and reached 296,067 units by 2016. FCA, Ford, and General Motors dominate the Class 3 market.

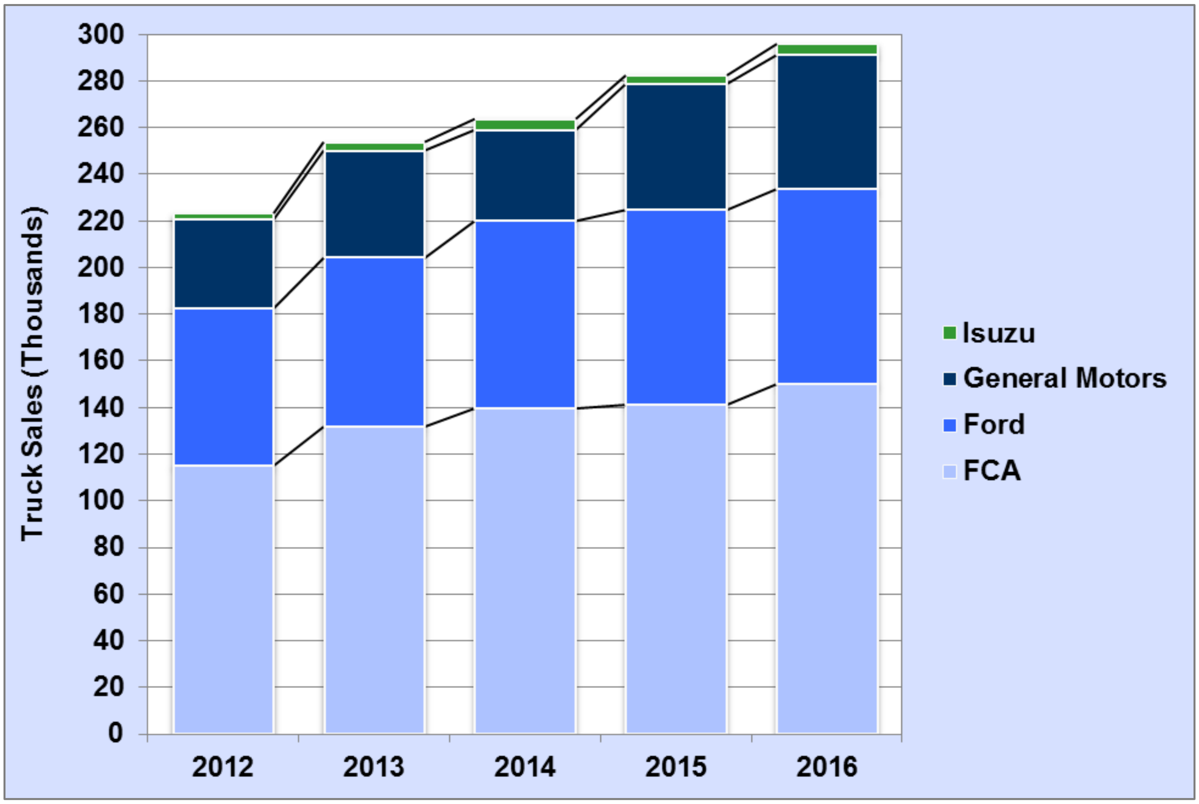

FIGURE 96. Class 3 Truck Sales by Manufacturer, 2012-2016

Note: From 2012 to 2016 Mitsubishi-Fuso annual sales of Class 3 trucks were between 100 and 400 units. This amount is too small to show on the figure.

Source:
Ward's Automotive Group. http://wardsauto.com

Class 4-7 Truck Sales Increased by 38% from 2012 to 2016

The Class 4 truck market has grown to over 208,000 units in 2016. Many of the manufacturers doubled their sales of Class 4-7 trucks from 2012 to 2016, including Hino, FCA, Ford, Isuzu and Kenworth. The only manufacturers with declining sales in this period were International and Mitsubishi-Fuso.

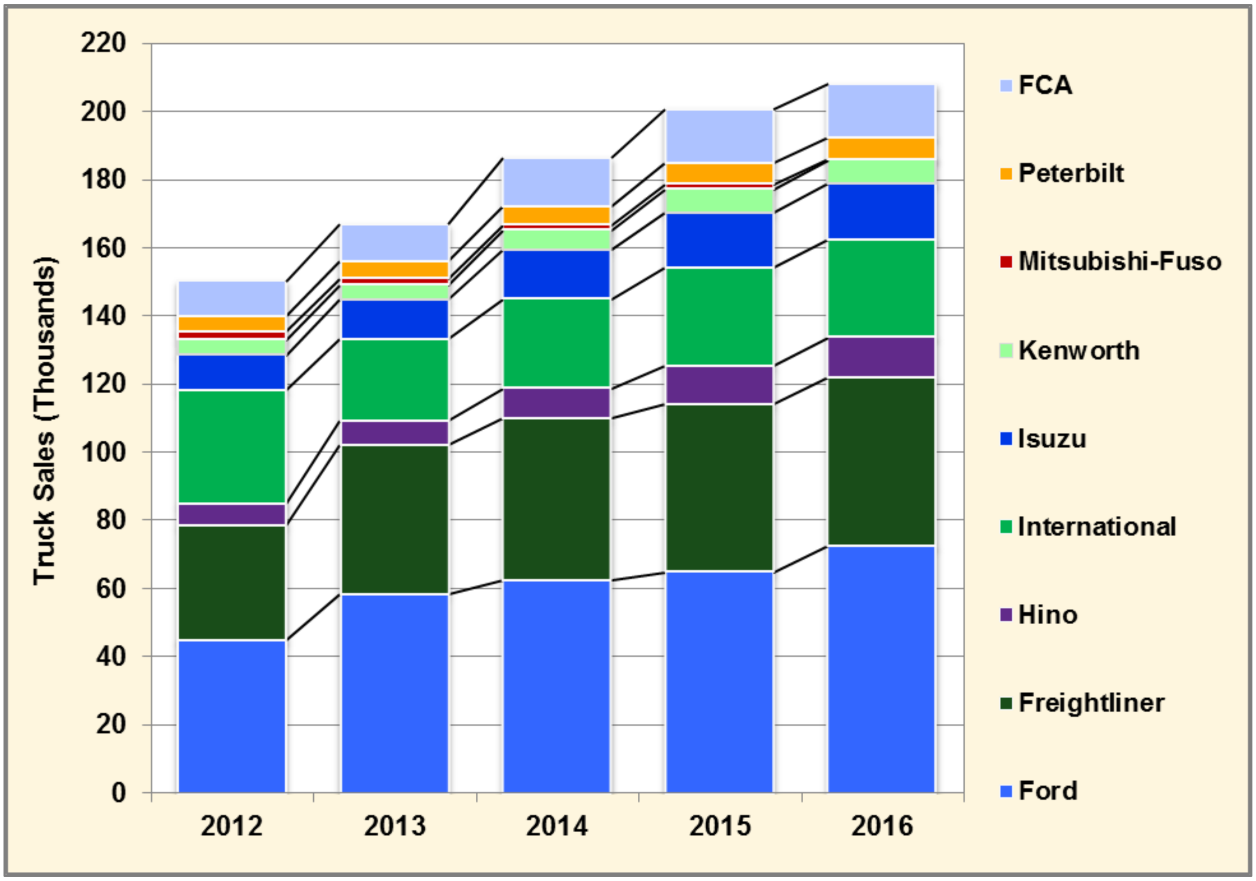

FIGURE 97. Class 4-7 Truck Sales by Manufacturer, 2012-2016

Note: From 2011 to 2013 UD and GM trucks sold 1,000 units or less annually. This amount is too small to show on the figure.

Source:
Ward's Automotive Group. http://wardsauto.com

Class 8 Truck Sales Decreased 23% from 2015 to 2016

Class 8 truck sales had grown to almost 249,000 units in 2015—the highest in the five-year period. The market shares by manufacturer were relatively steady from 2012 to 2016, with Freightliner gaining, International losing, and all the rest staying nearly the same. The decline in Class 8 sales from 2015 to 2016 was the largest decline in the five-year period at 23%.

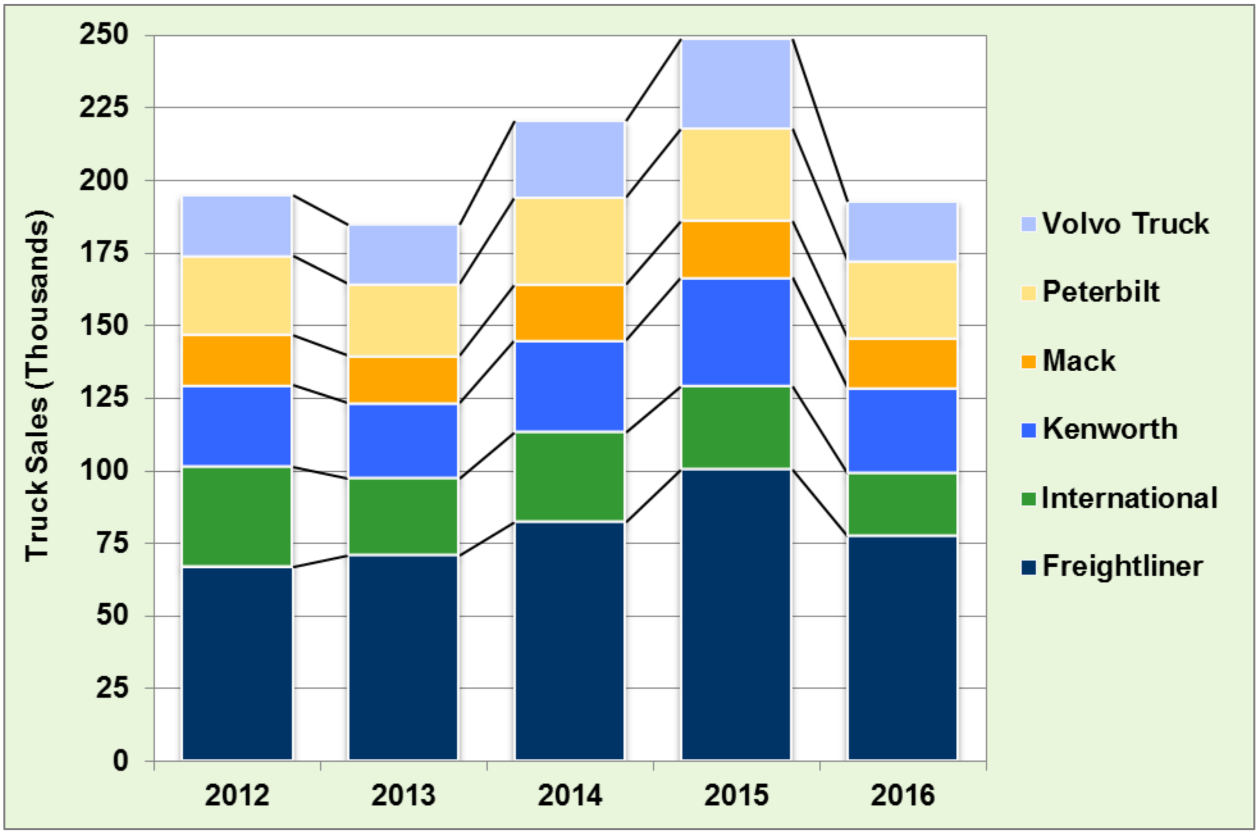

FIGURE 98. Class 8 Truck Sales by Manufacturer, 2012-2016

Note: From 2012 to 2016 sales of Class 8 trucks by "other" manufacturers were about 100 units annually. This amount is too small to show on the figure.

Source:
Ward's Automotive Group. http://wardsauto.com

Diesel Engine Use Declines 70% for Class 4 Trucks and Increases 4% for Class 6 Trucks

Although Class 8 trucks are nearly always 100% diesel trucks, Classes 3-7 often vary in gasoline to diesel sales shares from one year to another. In 2011, when truck sales of all classes were low, Classes 4, 5, and 6 each had more than 80% diesel sales share. By 2015, the diesel share of Class 6 trucks was 98%, Class 5 trucks held steady at 80%, and Class 4 fell to 24%. The only class to increase diesel sales share from 2011 to 2015 was Class 6.

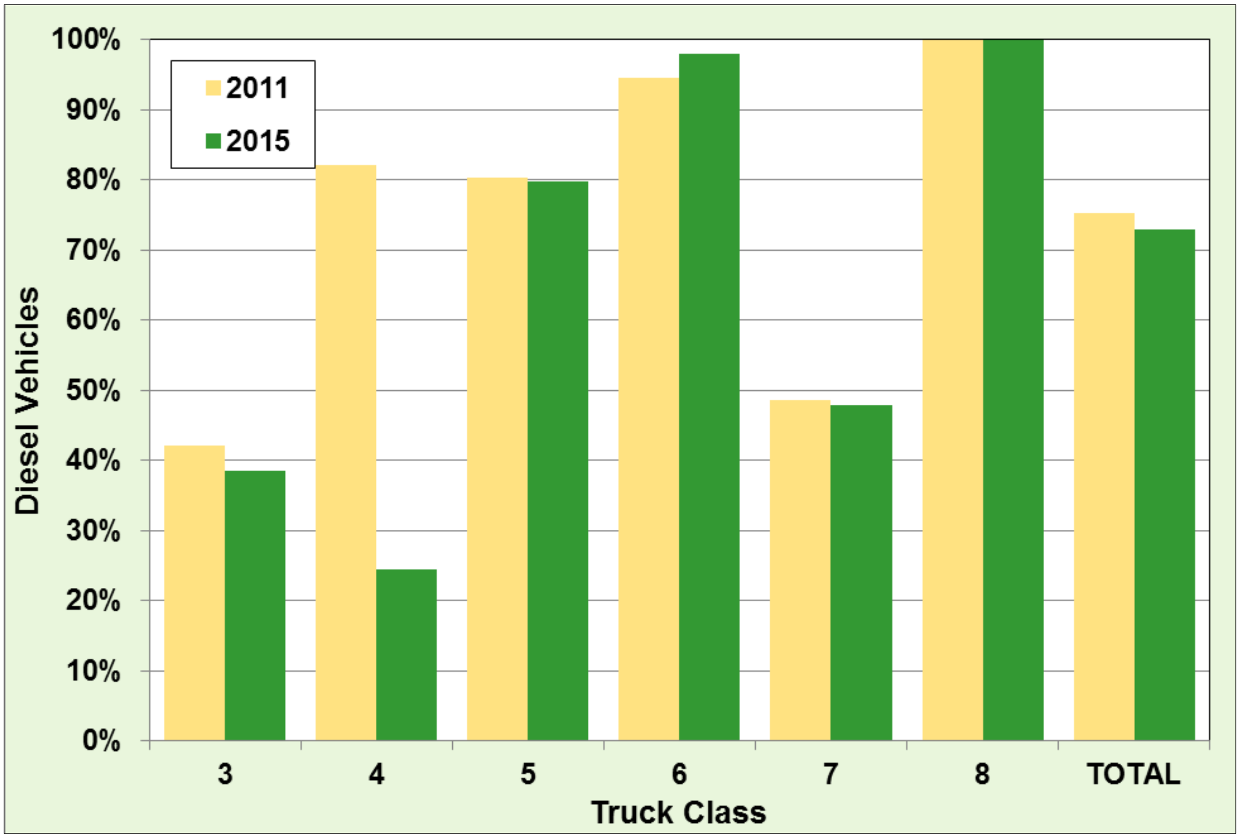

FIGURE 99. Share of Diesel Truck Sales by Class, 2011 and 2015

Note: These shares were derived using factory sales of trucks.

Source:
Ward's Automotive Group. http://wardsauto.com

Many Heavy Truck Manufacturers Supply Their Own Diesel Engines

Though many medium and heavy truck manufacturers (Classes 4-8) also manufacture their own engines, others purchase engines from engine manufacturers. Cummins supplies diesel engines for Freightliner, International, Kenworth, Mack, Peterbilt, Volvo, and Western Star. Hino builds its own diesel engines.

TABLE 28. Diesel Engine Suppliers by Manufacturer, 2015

Make	Engine Manufacturer	Share
Freightliner	Cummins	58.7%
	Detroit Diesel	40.9%
	Mercedes Benz	0.4%
	Total	**100.0%**
Hino	Hino	100.0%
International	Cummins	65.6%
	Navistar	34.4%
	Total	**100.0%**
Kenworth	Cummins	59.7%
	PACCAR	40.3%
	Total	**100.0%**
Mack	Cummins	6.2%
	Mack	93.8%
	Total	**100.0%**
Peterbilt	Cummins	57.6%
	PACCAR	42.4%
	Total	**100.0%**
Volvo	Cummins	7.9%
	Volvo	92.1%
	Total	**100.0%**
Western Star	Cummins	22.2%
	Detroit Diesel	77.6%
	Mercedes Benz	0.2%
	Total	**100.0%**
Other	Cummins	100.0%

Note: International's parent company is Navistar. Kenworth's and Peterbilt's parent company is PACCAR.

Source:
Ward's Automotive Group. http://wardsauto.com

Cummins Leads Heavy Truck Diesel Engine Market

Cummins held just over 40% of the heavy truck diesel engine market over the last five years. Navistar held a 20% market share in 2011, but declined to under 3% of the market in 2015.

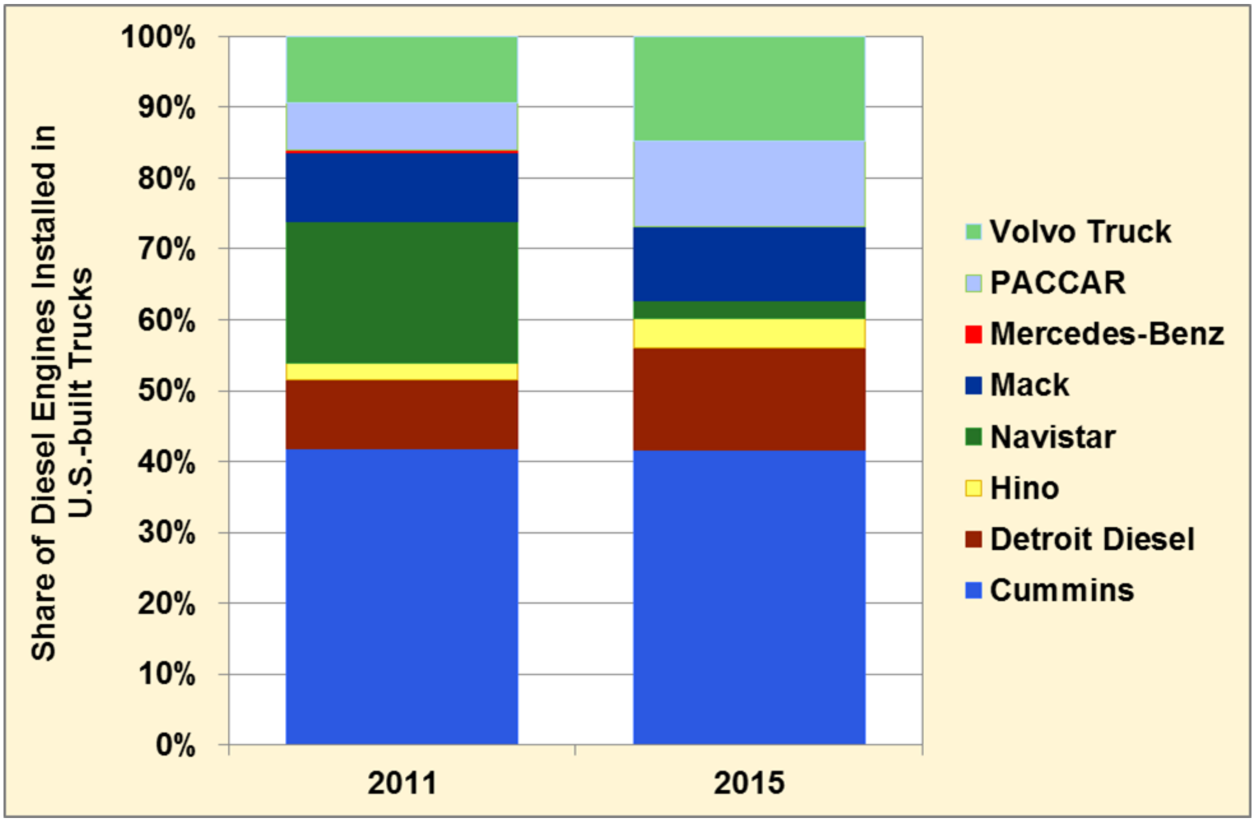

FIGURE 100. Diesel Engine Manufacturers Market Share, 2011 and 2015

Source:
Ward's Automotive Group. http://wardsauto.com

Combination Trucks Average Almost 62,000 Miles per Year

According to the latest Federal Highway Administration estimates, the average miles traveled per truck was almost 62,000 miles for a combination truck in 2015, down from over 68,000 miles in 2013. Because heavy truck duty-cycles vary, these averages have large standard deviations. Heavy single-unit trucks (above 10,000 lb and having at least six tires) were driven significantly fewer miles, because they are typically driven locally. The average fuel economy of single-unit trucks was 7.4 miles per gallon (mpg) in 2015 while the combination truck fuel economy was 5.9 mpg. The combination trucks typically have larger engines to carry heavier loads than the single-unit trucks.

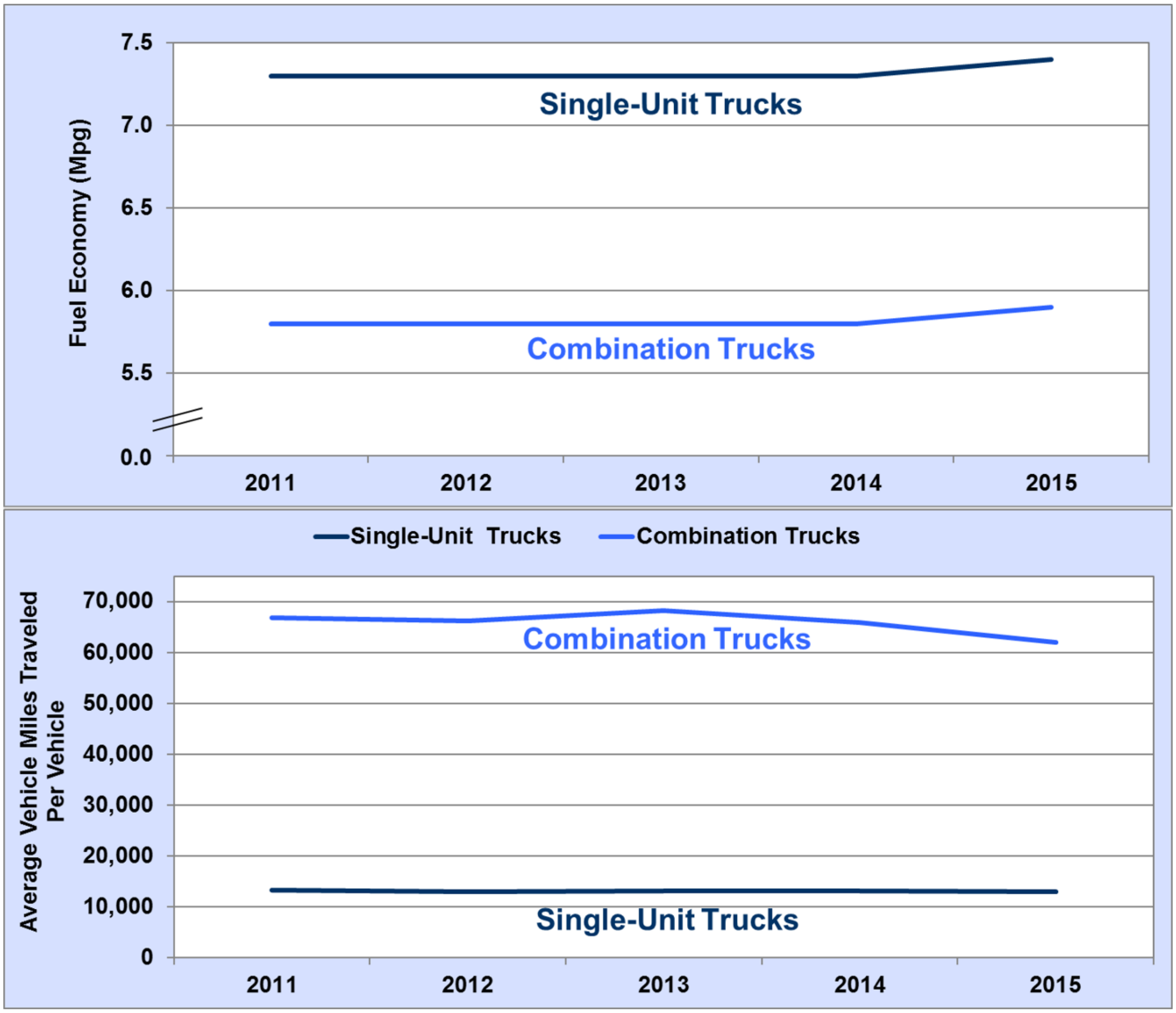

FIGURE 101. Vehicle-Miles of Travel and Fuel Economy for Heavy Truck Population, 2011-2015

Note: A combination truck is a truck-tractor that is used in combination with one or more trailers. A single-unit truck is a truck on a single frame, such as a dump truck or utility truck.

Source:

U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2015*, Table VM-1, 2017. http://www.fhwa.dot.gov/policyinformation/statistics/2015

Study Conducted of Class 8 Trucks at Steady Speed on Flat Terrain

A study conducted by Oak Ridge National Laboratory outfitted Class 8 trucks with monitoring equipment which tracked the weight, speed, and fuel efficiency of the truck along with the global position of the truck. Using only data where the roadway grade was 1% to -1% grade (flat terrain) the study showed the difference in fuel efficiency for different truck weights at the speed of 65 miles per hour (mph).

TABLE 29. Fuel Efficiency of Class 8 Trucks by Vehicle Weight Range on Flat Terrain at 65 mph

Loaded Weight Range of Tested Trucks (Pounds)	Average Weight (Pounds)	Distance Traveled (Miles)	Diesel Fuel Consumed (Gallons)	Fuel Efficiency (Miles per Gallon)	Fuel Efficiency (Ton-miles per Gallon)	Average Speed (mph)
20,000-30,000	21,222	51.4	5.4	9.5	101	65.0
30,000-40,000	34,285	505.9	53.0	9.5	164	65.0
40,000-50,000	44,911	537.8	58.7	9.2	206	65.0
50,000-60,000	55,468	541.2	63.3	8.6	237	64.9
60,000-70,000	66,558	1,356.9	171.9	7.9	263	65.0
70,000-80,000	73,248	1,363.1	172.3	7.9	290	65.0

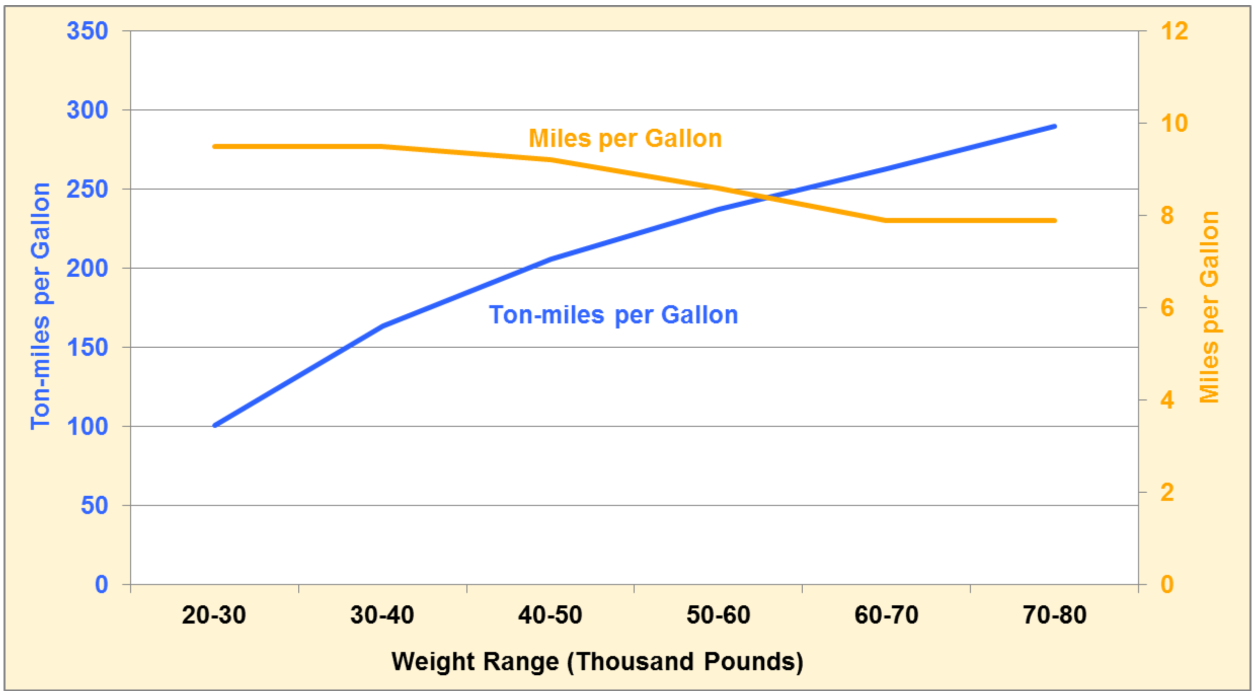

FIGURE 102. Fuel Efficiency of Class 8 Trucks by Vehicle Weight Range on Flat Terrain at 65 mph

Note: Ton-miles per gallon calculated as average weight multiplied by miles per gallon.

Source:

Franzese, Oscar, *Effect of Weight and Roadway Grade on the Fuel Economy of Class-8 Freight Trucks*, Oak Ridge National Laboratory, ORNL/TM-2011/471, October 2011. http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2011_471.pdf

Roadway Grade Affects Fuel Economy of Class 8 Trucks

A study conducted by Oak Ridge National Laboratory outfitted Class 8 trucks with monitoring equipment which tracked the weight, speed, and fuel efficiency of the truck along with the global position of the truck. The average for all trucks in the study at all speeds on flat terrain was 7.3 miles per gallon (mpg). However, the fuel economy of those same vehicles on different roadway grades was significantly different. On average, trucks on a severe downslope gained 221% of their fuel economy, while trucks on a severe upslope lost 60% of their fuel economy.

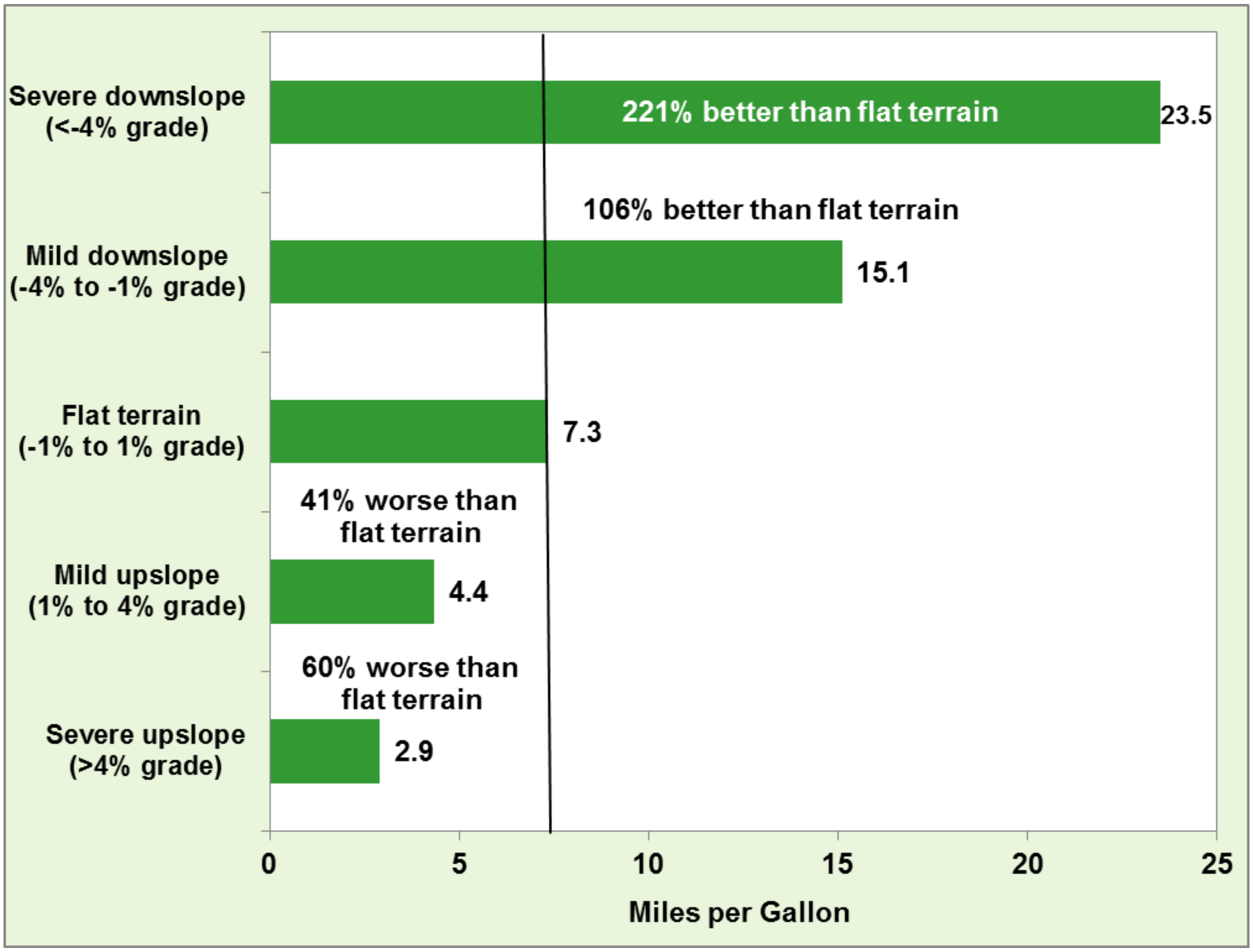

FIGURE 103. Fuel Efficiency of Class 8 Trucks by Roadway Grade

Source:

Franzese, Oscar, *Effect of Weight and Roadway Grade on the Fuel Economy of Class-8 Freight Trucks*, Oak Ridge National Laboratory, ORNL/TM-2011/471, October 2011. http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2011_471.pdf

Idle Fuel Consumption Varies by Type of Truck

Based on a worksheet developed by Argonne National Laboratory, the idle fuel consumption rate for selected gasoline and diesel vehicles with no load (no use of accessories such as air conditioners, fans, etc.) varies widely. These data were collected from a variety of studies, thus some of the data may not be directly comparable. In general, the transit bus consumed the most fuel while idling – nearly 1 gallon per hour (gal/hr). The gasoline medium heavy truck category with a gross vehicle weight (GVW) of 19,700-26,000 lb consumed more fuel at idle than the diesel medium heavy truck category at 23,000-33,000 lb GVW. By comparison, a compact sedan using diesel or gasoline uses less than 0.2 gal/hr when idling.

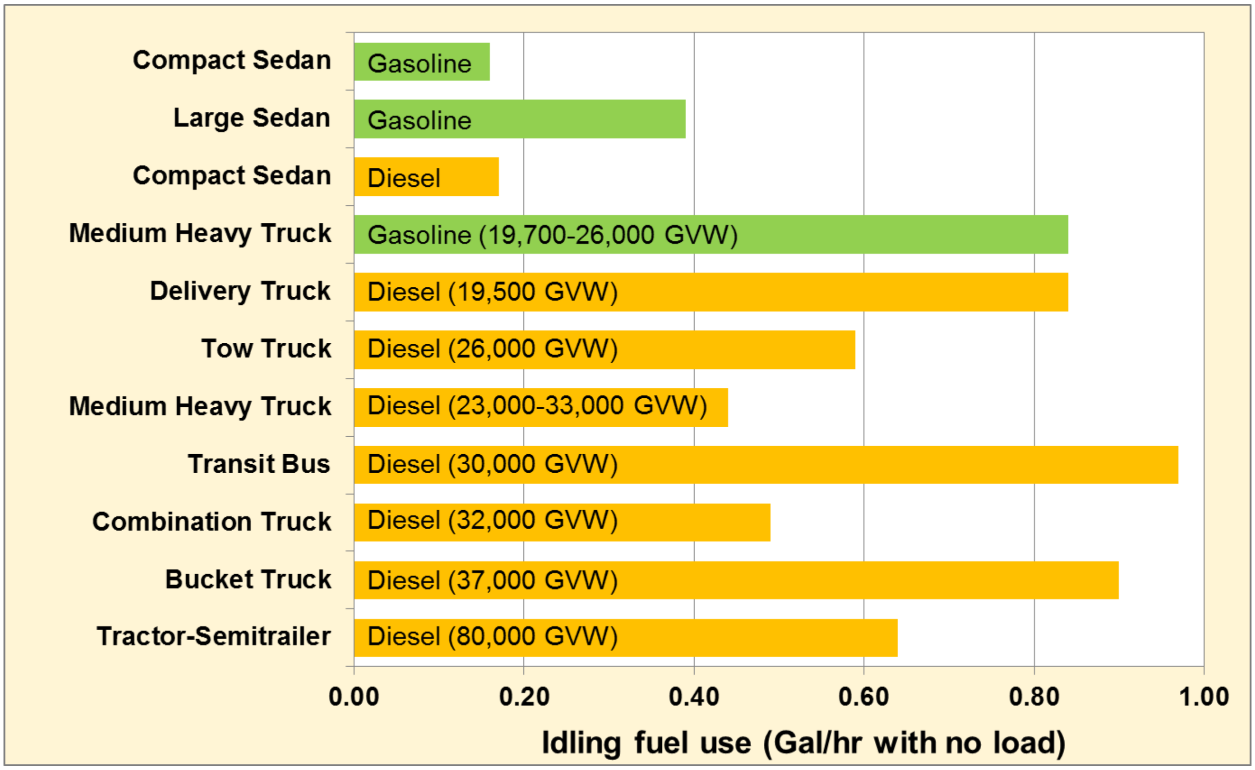

FIGURE 104. Fuel Consumption at Idle for Selected Gasoline and Diesel Vehicles

Note: Data may not be directly comparable among vehicle types. Argonne National Laboratory compiled the data from several different studies. See the Idling Reduction Savings Calculator for information on the individual studies.

Source:

Argonne National Laboratory, Idling Reduction Savings Calculator, accessed March 2017.
http://www.anl.gov/sites/anl.gov/files/idling_worksheet.pdf,

Truck Stop Electrification Reduces Idle Fuel Consumption

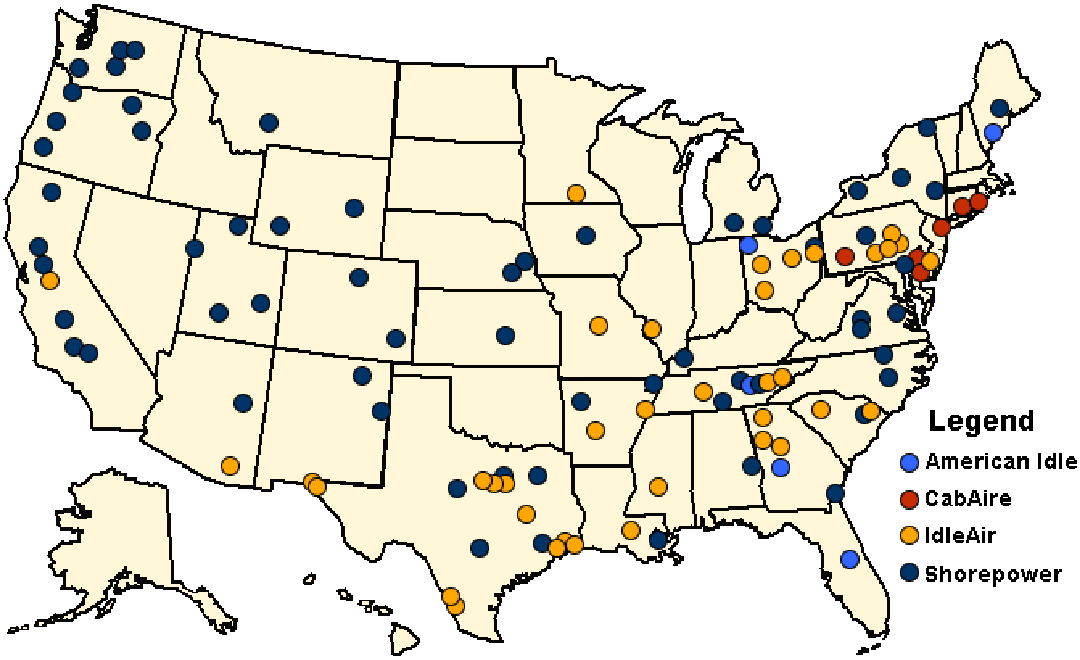

FIGURE 105. Map of Truck Stop Electrification Sites, 2017

TABLE 30. Number of Truck Stop Electrification Sites by State, 2017

State	Number of Sites	State	Number of Sites
Alabama	1	Missouri	2
Arizona	2	Montana	1
Arkansas	3	Nebraska	2
California	7	New Jersey	2
Colorado	2	New Mexico	2
Delaware	2	New York	4
Florida	2	North Carolina	2
Georgia	5	Ohio	6
Illinois	1	Oregon	5
Iowa	1	Pennsylvania	6
Kansas	1	South Carolina	3
Kentucky	1	Tennessee	7
Louisiana	2	Texas	16
Maine	1	Utah	4
Maryland	1	Virginia	3
Michigan	2	Washington	4
Minnesota	1	Wyoming	2
Mississippi	1		
Total	**106**		

The U.S. Department of Transportation mandates that truckers rest for 10 hours after driving for 11 hours, during which time they often park at truck stops idling the engines to provide heating, cooling and use of electrical appliances. Electrification at truck stops allows truckers to "plug-in" vehicles to operate the necessary systems without idling the engine. There are currently 106 publicly accessible electrification sites across the nation. Some of these sites require special equipment to be installed on the truck and others do not. Presently, four companies equip electrification sites: Shorepower, CabAire, American Idle, and IdleAir.

Source:

Alternative Fuels and Advanced Vehicles Data Center. (Data through 2/28/17).
http://www.afdc.energy.gov/afdc/tse_locator

SuperTruck Project Exceeds 12 Miles per Gallon

The U.S. Department of Energy partnered with industry to explore fuel economy improvements for class 8 trucks. In September 2015, the Volvo Trucks, USA, team announced that their fully-loaded class 8 truck achieved a fuel economy of more than 12 miles per gallon, which was a 70% increase in fuel economy and an 88% gain in freight efficiency in testing against a 2009 baseline truck.

Photo by Jim Park.

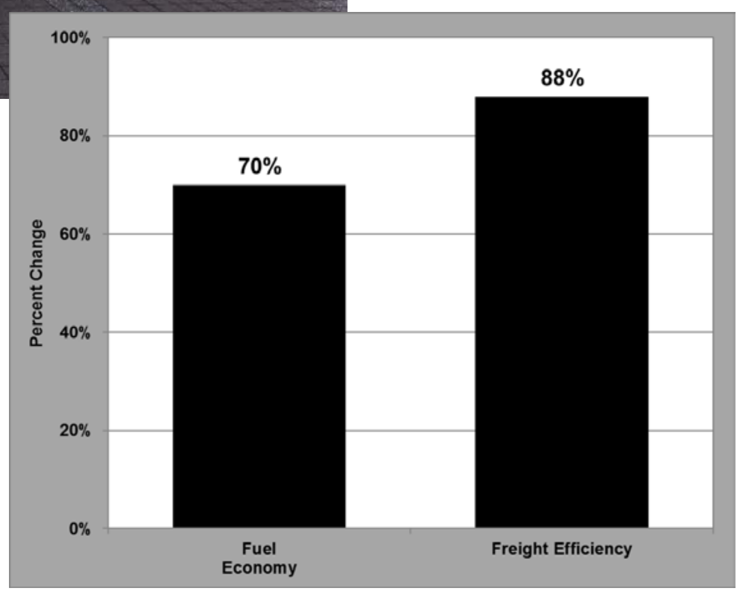

FIGURE 106. Changes in Fuel Economy and Freight Efficiency for the SuperTruck Project, September 2016

Source:
Heavy Duty Trucking, Truckinginfo.com, "Volvo's Supertruck Demonstrates the Art of the Possible," November 2016.

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CHAPTER 5

TECHNOLOGIES

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Market Penetration for New Automotive Technologies Takes Time

When a new technology is developed, it takes years to get that technology into the new cars and light trucks that are produced. Fuel injection was one of the quickest technology penetrations, with nearly 100% of market share after 16 years. Lockup transmission use peaked at 27 years with 92% of the market, but has declined due to the use of other new technologies, such as continuously variable transmissions. Similarly, multi-valve use increased to 93% before declining slightly as turbo-charging and super-charging increased. Variable valve timing use recently grew to about 98% of the light vehicle market. Front-wheel drive is primarily used in cars, thus its penetration has been limited by the number of light trucks produced.

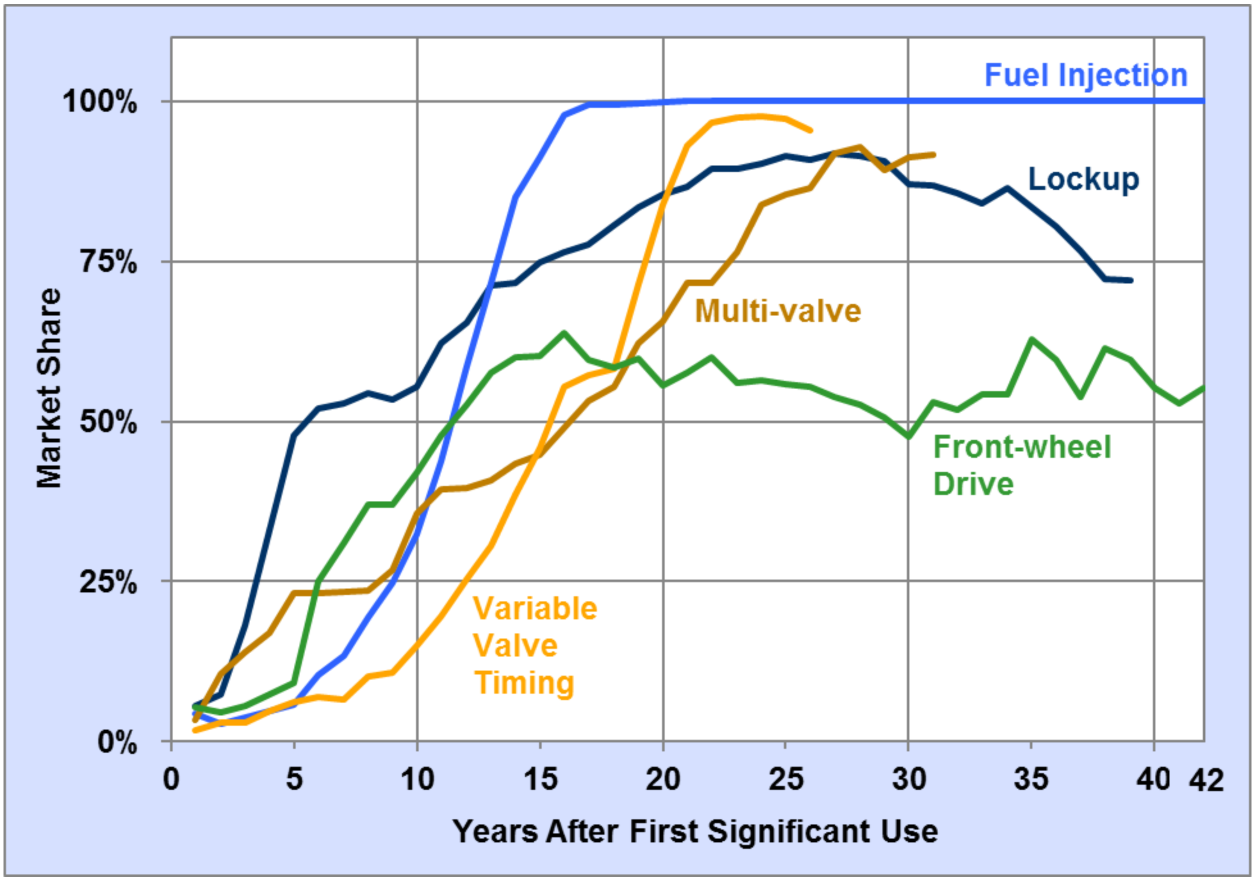


FIGURE 107. Light Vehicle Technology Penetration after First Significant Use

Note: First significant use generally represents a production threshold of about 1%, though in some cases, where full data is not available, first significant use represents a slightly higher production share.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Gasoline Direct Injection Captures 49% Market Share in Just Nine Years from First Significant Use

Gasoline direct injection (GDI) has seen rapid adoption since its first significant use. As automakers strive for improved fuel economy, many have turned to the combined benefits of GDI and turbocharging for increasing power output from downsized engines. This is evident in the rapid rise of turbo-charged engines in the last five years shown. Cylinder deactivation, which is seen mostly in 6- and 8- cylinder applications, has about 10% market share over the past five years. Stop-start technology in non-hybrid vehicles is relatively new in the U.S. market and has only been around for five years since its first significant use. However, in just five years, stop-start has reached over 9% market share while gasoline hybrids have only grown to 4% market share in the past 12 years.

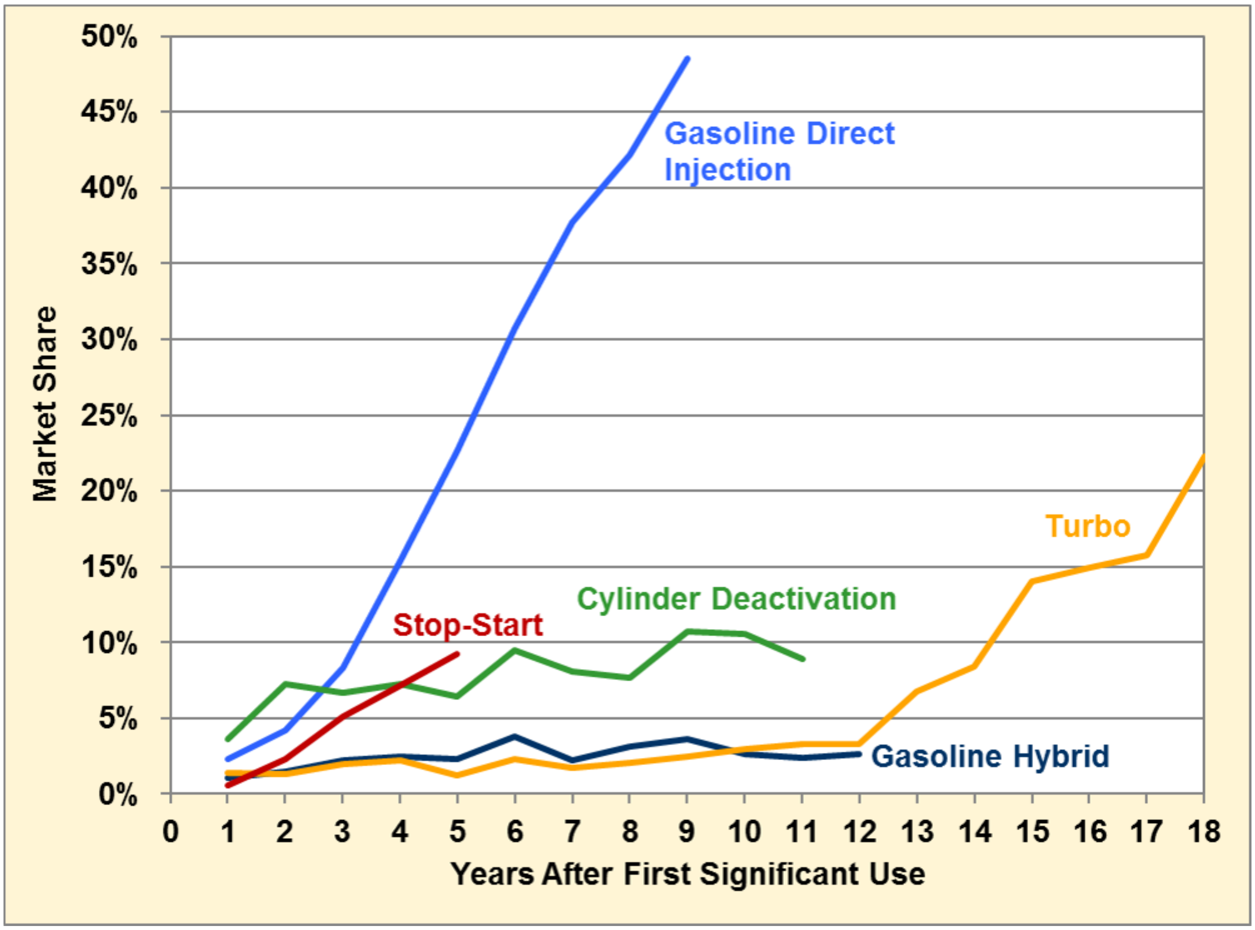


FIGURE 108. New Technology Penetration in Light Vehicles

Note: Stop-start technology data are for non-hybrid vehicles. First significant use generally represents a production threshold of about 1%, though in some cases, where full data is not available, first significant use represents a slightly higher production share.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Hybrid Sales Decline by 30% from 2013 to 2016

In 1999, the Honda Insight debuted as the first hybrid-electric vehicle (HEV) in the U.S. market, followed closely by the Toyota Prius in 2000. Since that time, many other manufacturers have entered the hybrid market. From 2008 to 2011, sales of hybrid vehicles declined but increased substantially in 2012 and 2013. Sales dropped again from 2014 through 2016 with 2016 sales at about 347,000 vehicles.

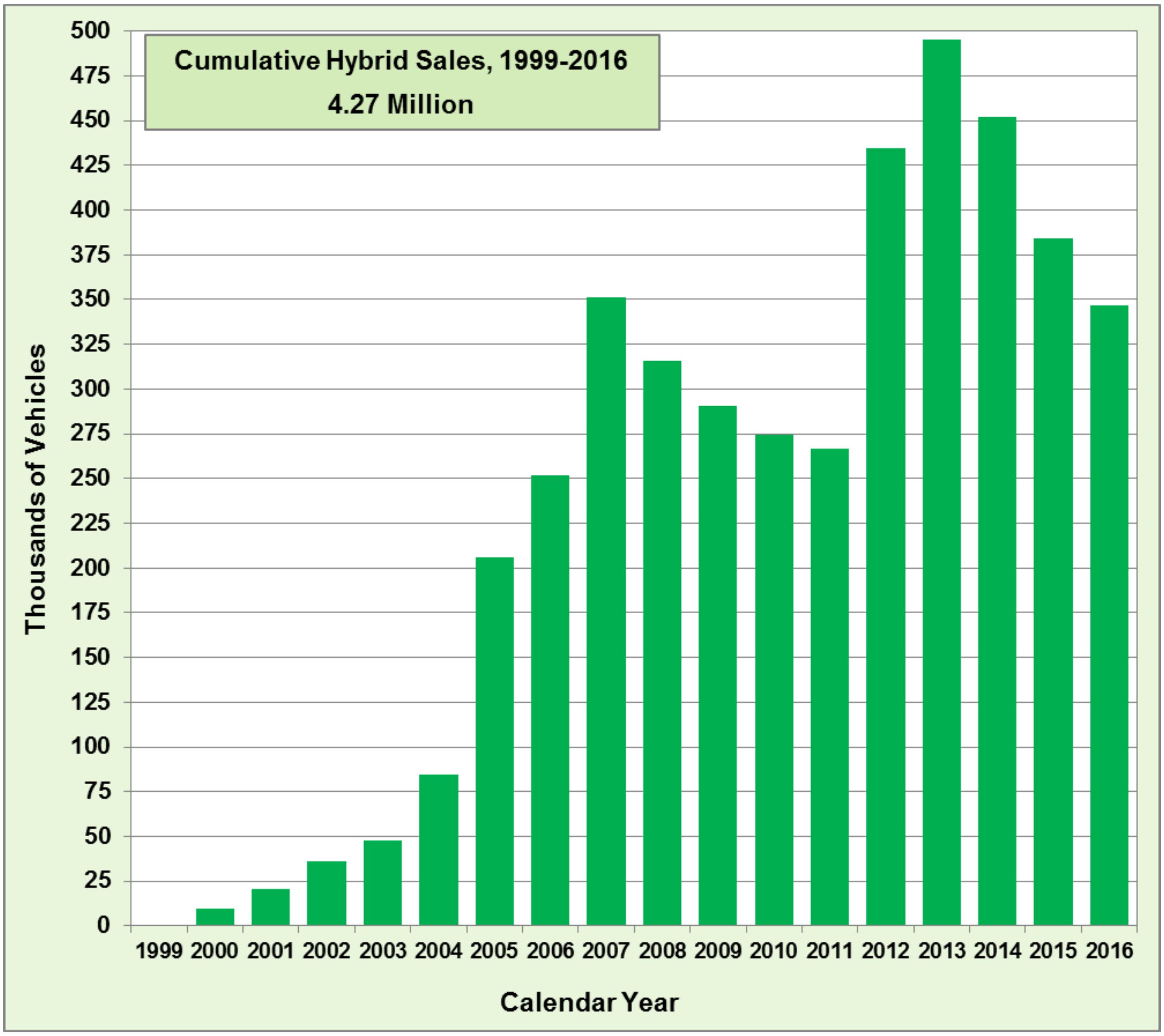


FIGURE 109. Hybrid-Electric Vehicle Sales, 1999-2016

Source:
Provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Toyota Reigns as Leader of U.S. Hybrid-Electric Vehicle Market Share

Though Honda was the first manufacturer to introduce a hybrid-electric vehicle (HEV) in the United States, Toyota has held more than 50% of the market share since 2000. Ford entered the HEV market in 2004 with an Escape HEV; Lexus began selling the RX400h a year later. Mercury, Nissan, and Saturn joined the other manufacturers selling HEVs in 2007. Thereafter, many more manufacturers began selling HEVs, though some are sold in small volumes.

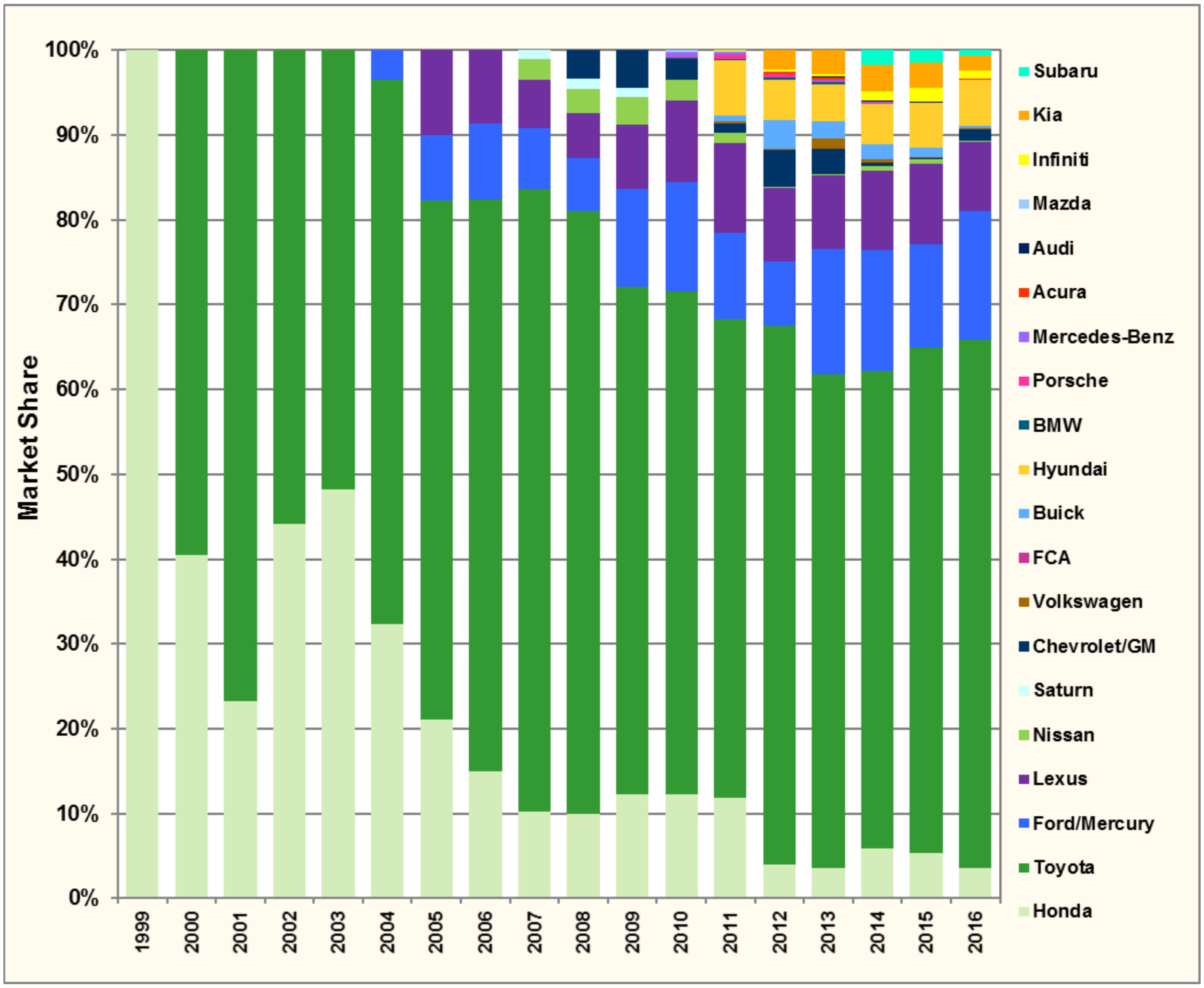


FIGURE 110. Hybrid-Electric Vehicle Market Share, 1999-2016

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center.
http://www.afdc.energy.gov/data/

Sales from Introduction: Some Plug-In Vehicles Beat Hybrid-Electric Sales in the First Four Years

The Toyota Prius hybrid-electric vehicle (HEV) was first released in the U.S. market in January 2000 and 324 were sold in the first month. The Chevrolet Volt, a hybrid-electric plug-in, and the Nissan Leaf, an all-electric plug-in vehicle, were first released in December 2010. The Prius plug-in hybrid-electric vehicle (PHEV) began sales in April 2012. The chart below shows a comparison of the sales of the Prius HEV from when it was first introduced, to the sales of the Volt, the Leaf, the Prius PHEV, and the Tesla Model S when they were first introduced.

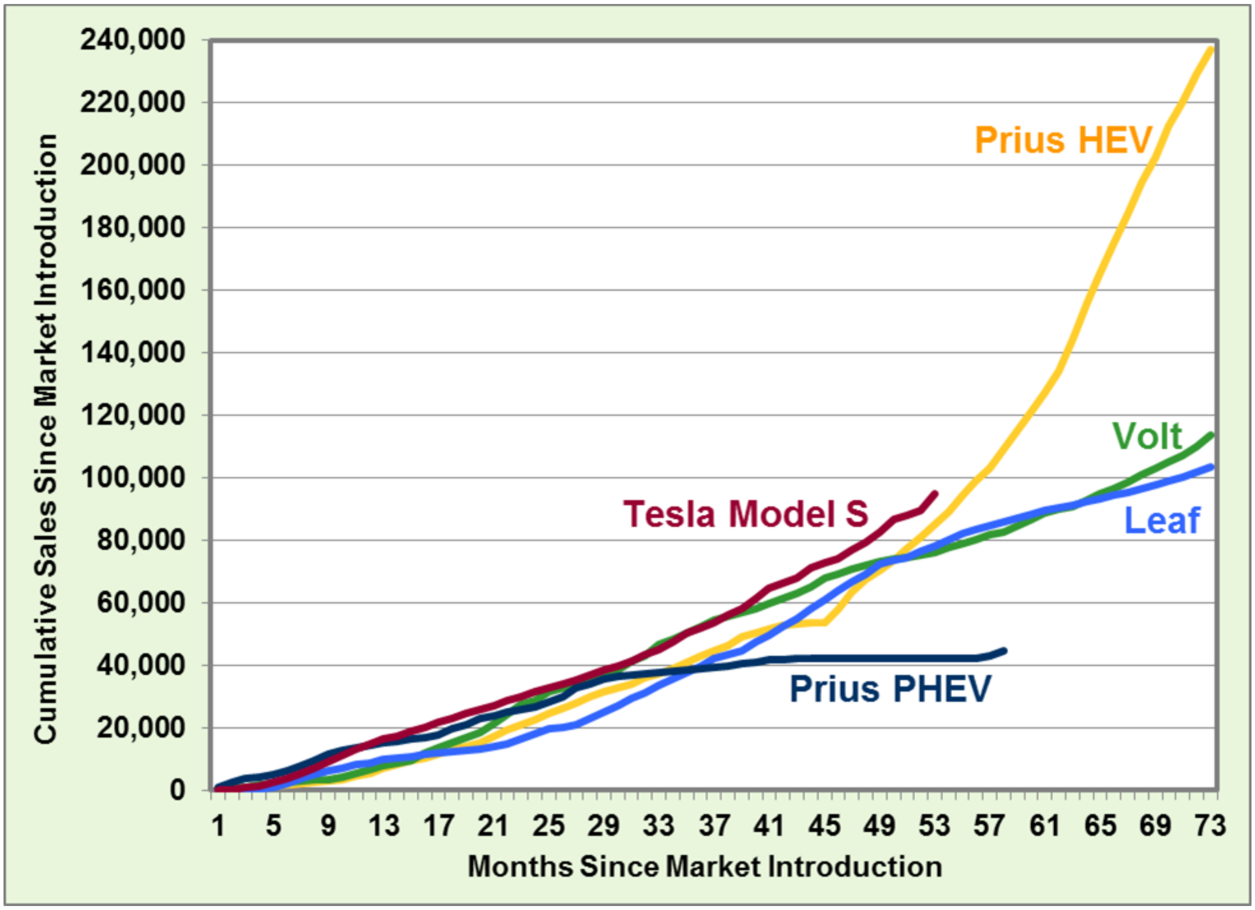


FIGURE 111. Monthly Sales since Market Introduction for Hybrid Vehicles and Plug-In Vehicles

Notes: The Prius HEV was first released in the U.S. market in January 2000.
The Prius PHEV was first released in the U.S. market in April 2012.
The Volt and Leaf were first released in the U.S. market in December 2010.
The Tesla Model S was first released in the U.S. market in June 2012. Tesla sales are estimated.

Source:
Provided by Yan (Joann) Zhou, Argonne National Laboratory. http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

Plug-In Hybrid Vehicle Sales Total over 70,000 Units in 2016

The number of plug-in hybrid vehicles (PHEV) sold in the United States in 2016 rose to nearly 73,000, a large increase. There were 17 different plug-in models available in 2016, many selling less than 5,000 units. The Chevrolet Volt has been the best-selling PHEV each year.

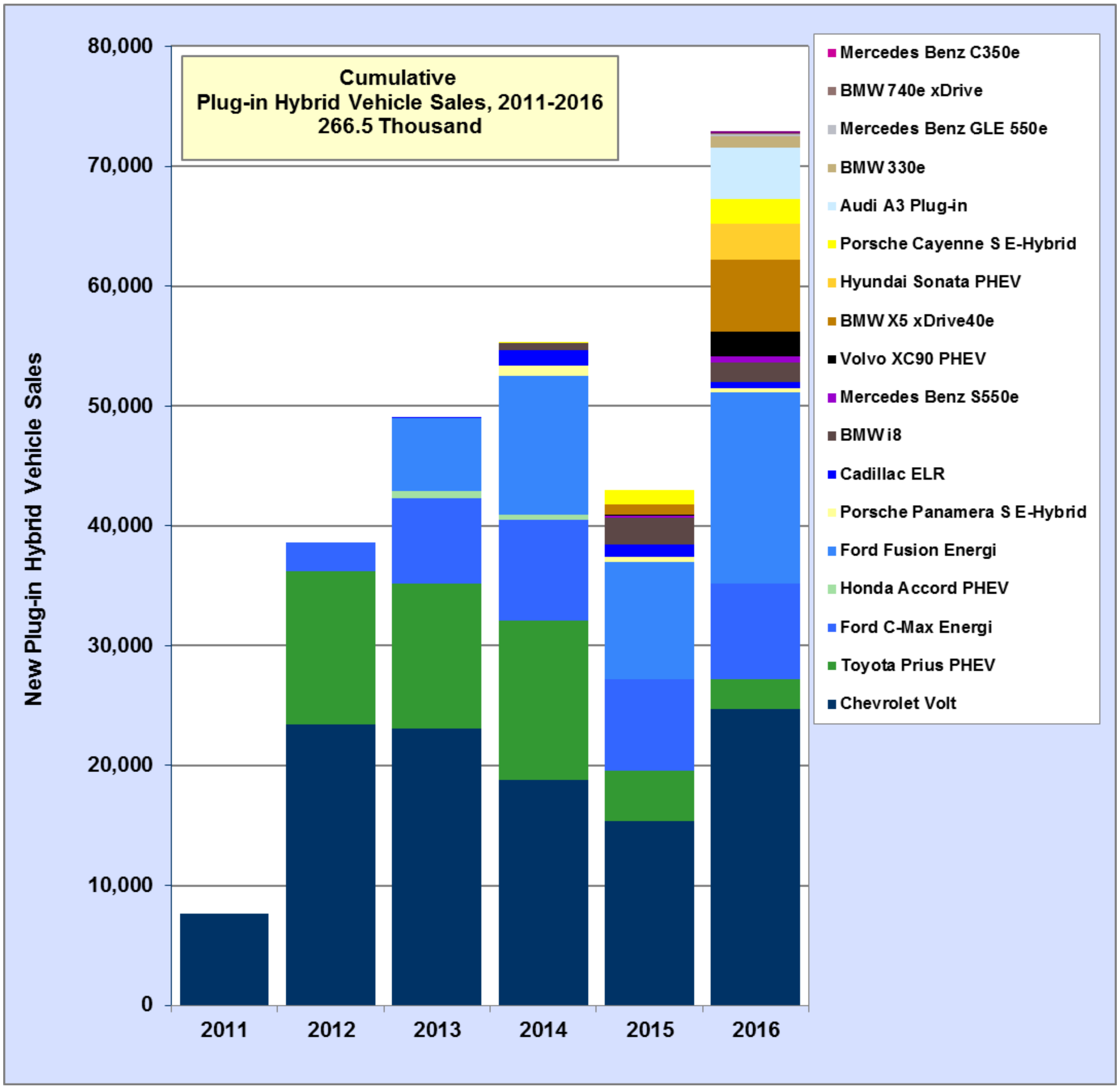


FIGURE 112. Plug-In Hybrid Vehicle Sales, 2011-2016

Source:

Data provided by Yan (Joann) Zhou, Argonne National Laboratory. http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

All-Electric Vehicle Sales Total over 87,000 Units in 2016

The number of all-electric vehicles sold in the United States in 2016 rose to nearly 87,000 from 71,000 the previous year. From 2011-2014, the Nissan LEAF was the largest-selling electric vehicle, but the Tesla Model S took that title for 2015-2016. Besides Nissan and Tesla, BMW is the only other manufacturer to sell more than 5,000 all-electric vehicles in a calendar year.

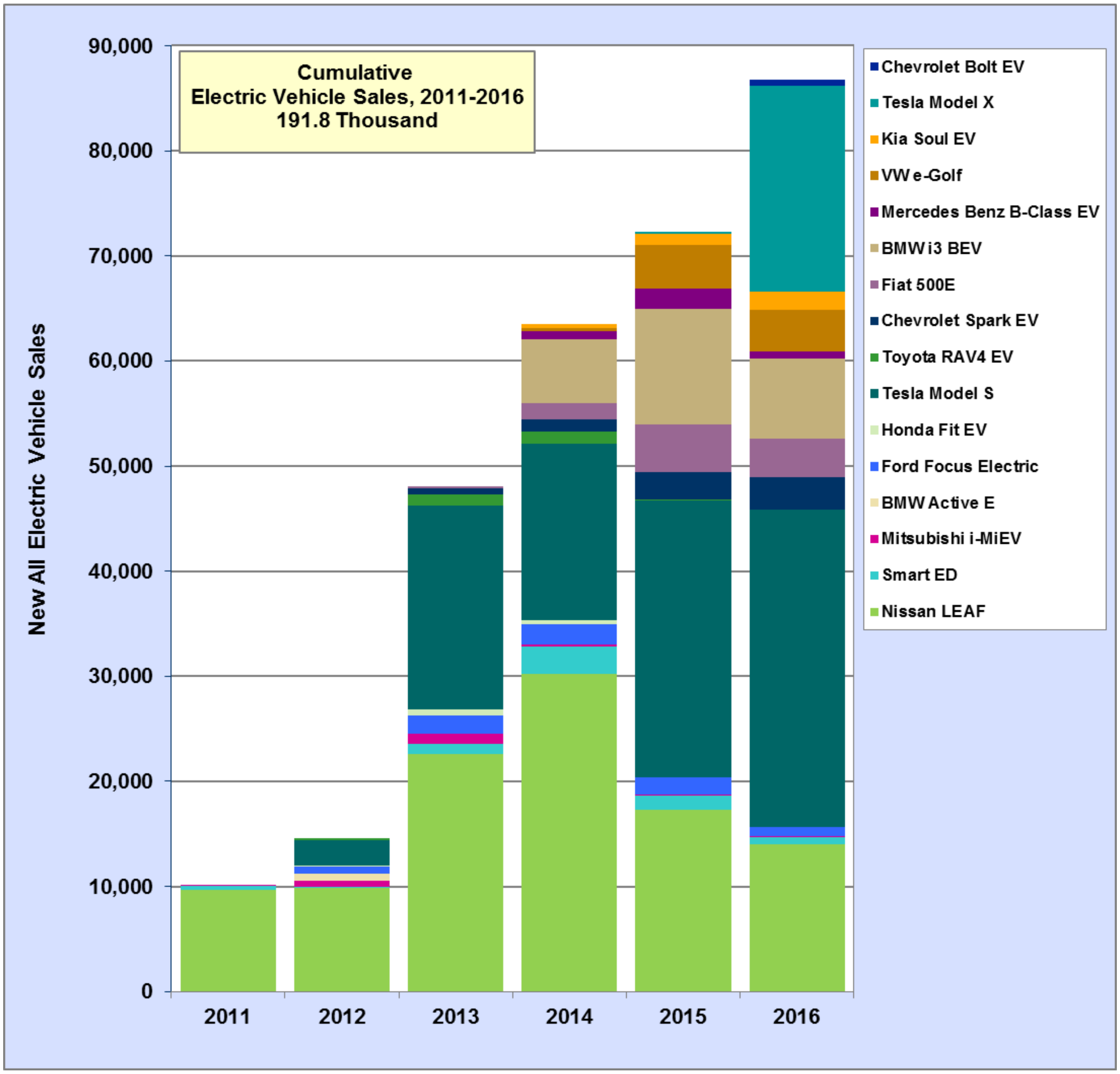


FIGURE 113. All-Electric Vehicle Sales, 2011-2016

Source:

Data provided by Yan (Joann) Zhou, Argonne National Laboratory. http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

New Plug-In and Fuel Cell Vehicles Have Been Announced

There are fourteen plug-in vehicles and one fuel cell vehicle that have been announced as currently under development. The expected ranges of the all-electric vehicles are from 80 miles with the Honda Clarity EV to 300 miles with the Audi e-tron and the Ford small SUV. The hybrid-electric plug-in vehicles, which also use gasoline, have expected electric ranges of 22 to 40 miles, but the total range using both gasoline and electricity have not been announced. The Mercedes-Benz fuel cell vehicle is expected to have a range of over 300 miles.

TABLE 31. Selected Plug-In and Fuel Cell Vehicles Under Development

Model Year	Make and Model	All-Electric Range (miles)	Total Range (miles)	Specifications
All-Electric Plug-In Vehicles				
2018	Audi e-tron	~300	~300	Crossover/wagon style vehicle. No specific details. Range based on European test cycles.
2020	Ford small SUV (unnamed)	~300	~300	Further details not known at this time.
2018	Honda Clarity EV	~80	~80	Midsized sedan priced below $40,000.
2017	Hyundai Ioniq Electric	124	124	88 kW motor, 28 kWh Li-ion battery pack.
2018	Kia Niro EV	~110	~110	Expected to share the same platform as the Hyundai Ioniq EV including a 28 kWh battery.
2018	Nissan Leaf (Second generation)	~200	~200	Range is expected to exceed 200 miles but specific details have not been announced.
2018	Porsche Mission E - Concept	~300	~300	Production expected around 2018. Range estimate based on European tests.
2017	Tesla Model 3	~215	~215	Expected to arrive with optional battery pack sizes providing a minimum of 215 miles.
2020	Volkswagen I.D. Concept	250+	250+	Volkswagen announced that a model based on the I.D. hatchback concept will arrive in 2020.
Hybrid-Electric Plug-In Vehicles				
2017	Cadillac CT6 Plug-In Hybrid	30	Not Available	2-motor EVT system, 2.0 L turbocharged 4 cyl engine, 18.4 kWh Li-ion battery.
2017	Honda Clarity Plug-in Hybrid	~40	Not Available	3.6 L V6 engine; 16 kWh Li-ion battery pack.
2017	Hyundai Ioniq Plug-in Hybrid	~22-26	Not Available	1.6 L 4 cyl engine, 43 hp electric motor, Li-ion polymer battery.
2017	Kia Niro Plug-In Hybrid	~22-26	Not Available	Expected to share some components with the Hyundai Ioniq. Specification unknown.
2017	Mitsubishi Outlander Plug-In Hybrid	32.5	Not Available	2.0L 4 cyl engine, 12 kWh Li-ion battery. EV range estimate based on European tests.
Fuel Cell Vehicles				
2017	Mercedes-Benz GLC F-Cell	~30	300+	Plug-in fuel cell SUV with a 9 kWh Lithium-ion battery pack and two hydrogen tanks.

Note: Since these vehicles are not currently for sale, the all-electric ranges are company estimates and not the result of the Environmental Protection Agency tests.

Sources:

U.S. Department of Energy fuel economy data, and other industry sources, data accessed March 2017. http://www.fueleconomy.gov

Plug-in Hybrid-Electric Vehicles Are Available from Eleven Manufacturers

There are 11 different makes and 17 different models that plug into electrical outlets to get part of their fuel. The BMW i3 REx has the longest all-electric range (97 miles), but the shortest total range (180 miles). The Toyota Prius Prime has the longest total range (640 miles)

TABLE 32. Available Hybrid-Electric Plug-In Vehicles, Model Year 2017

Make and Model	All-Electric Range (Miles)	Total Range (Miles)	Time to Charge Battery (Hours at 240V)	Specifications (Electric / Gasoline Engine)
Audi A3 e-tron	16	380	2.5	80 kW electric motor / 1.4 L, 4 cyl
BMW i3 REX	97	180	5.0	125 kW electric motor / 0.6 L 2 cyl
BMW i8	14	330	2.0	96 kW electric motor / 1.5 L, 3 cyl
BMW 740e xDrive	14	340	3.0	83 kW electric motor / 2.0 L, 4 cyl
BMW 330e	14	350	2.0	83 KW electric motor / 2.0 L, 4 cyl
BMW X5 XDrive40e	14	540	3.0	83 kW electric motor / 2.0 L, 4 cyl
Chevrolet Volt	53	420	4.5	48 and 87 kW electric motor / 1.5L, 4 cyl
Chrysler Pacifica Plug-In Hybrid	33	570	2.0	65 and 102 kW electric motor / 3.6L, 6 cyl
Ford C-Max Energi Plug-in Hybrid	20	570	2.5	68 kW electric motor / 2.0 L, 4 cyl
Ford Fusion Energi Plug-in Hybrid	21	610	2.5	68 kW electric motor / 2.0 L, 4 cyl
Hyundai Sonata Plug-In Hybrid	27	600	2.7	50 kW electric motor / 2.0 L, 4 cyl
Kia Optima Plug-In Hybrid	27	590	2.7	50 kW electric motor / 2.0 L, 4 cyl
Mercedes-Benz GLE550e 4matic	10	460	1.9	85 kW electric motor / 3.0 L, 6 cyl
Mercedes-Benz S550e	12	450	1.9	85 kW electric motor / 3.0 L, 6 cyl
Porsche Cayenne S e-Hybrid	14	480	3.0	70 kW electric motor / 3.0 L, 6 cyl
Toyota Prius Prime	25	640	2.0	16 and 37 kW electric motor / 1.8L, 4 cyl
Volvo XC90 AWD PHEV	13	350	3.0	34 and 65 kW electric motor / 2.0L, 4 cyl

Notes: kW = Kilowatt; L = Liter; cyl = Cylinder.

Source:
U.S. Department of Energy fuel economy data, accessed March 2017. http://www.fueleconomy.gov.

There Are Thirteen Manufacturers that Produce All-Electric and Fuel Cell Vehicles

In model year 2017 there are 12 different models that plug into electrical outlets to get all of their fuel and three fuel cell vehicles that use hydrogen. The Tesla Model S has the longest range at 315 miles with the 100 kW-hr battery pack. The Mitsubishi i-Miev has the shortest range with only 59 miles. The three fuel cell vehicles have ranges from about 265-366 miles.

TABLE 33. Available All-Electric Plug-In and Fuel Cell Vehicles, Model Year 2017

Make and Model	Total Range (Miles)	Time to Charge Battery (Hours at 240V)	Specifications
All-Electric Plug-In Vehicles			
BMW-i3 BEV	81 114	4.0 (60 Amp battery) 5.0 (94 Amp battery)	125 kW AC Induction
Chevrolet Bolt EV	238	9.3	150 KW ACPM
Fiat 500e	84	4.0	82 kW AC Induction
Ford Focus Electric	115	5.5	107 kW AC PMSM
Hyundai Ioniq Electric	124	4.0	88 kW AC PMSM
Kia Soul Electric	93	4.0	81 kW AC PMSM
Mercedes-Benz B250e	87	3.5	132 kW AC Induction
Mitsubishi i-Miev	59	7.0	49 kW DCPM
Nissan LEAF	107	6.0 (6.6 kW charger)	80 kW DCPM
Tesla Model S	210	10.0 (std. charger) 3.75 (80 amp dual charger)	285 kW AC Induction
Tesla Model S	249	12.0 (std. charger) 4.75 (80 amp dual charger)	285 kW AC Induction
Tesla Model S AWD 60D	218	12.0 (std. charger) 3.75 (80 amp dual charger)	386 kW AC Induction
Tesla Model S, AWD 75D AWD 90D AWD P90D AWD P100D	259 294 270 315	12.0 (std. charger) 4.75 (80 amp dual charger)	386 kW AC Induction 586 kW AC Induction 586 kW AC Induction 586 kW AC Induction
Tesla Model X, AWD 60D AWD 75D AWD 90D AWD P90D AWD P100D	200 238 257 250 289	12.0 (std. charger) 4.75 (80 amp dual charger)	386 kW AC Induction 386 kW AC Induction 386 kW AC Induction 586 kW AC Induction 586 kW AC Induction
Volkswagen e-Golf	125	5.3 (7.2 kW charger)	100 kW AC PMSM
Fuel Cell Vehicles			
Honda Clarity	366	~5 minutes to refuel	130 kW AC PMSM
Hyundai Tucson Fuel Cell	265	~5 minutes to refuel	100 kW AC Induction
Toyota Mirai	312	~5 minutes to refuel	56 kW AC Induction

Notes: AC = Alternative current; ACPM = Alternating current permanent magnet motor; DCPM = Direct current permanent magnet motor; kW = Kilowatt; PMSM = Permanent magnet synchronous motor.

Source:
U.S. Department of Energy fuel economy data, accessed March 2017. http://www.fueleconomy.gov.

Primearth EV Energy Supplied the Most Batteries by Number but Tesla/Panasonic Supplied the Most Battery Capacity for Model Year 2016

Primearth EV Energy supplied a majority of the batteries for hybrid vehicles in 2016. While hybrid vehicle sales far outnumber plug-in vehicle sales, the capacity of hybrid batteries average only about 1.2 kW-hrs per battery. Tesla/Panasonic, while supplying fewer batteries, produced them for plug-in vehicles that have much larger batteries so they supplied the greatest amount of battery capacity. The highest battery capacity for a 2016 plug-in vehicle was 100 kW-hrs – a battery offering by Tesla/Panasonic. AESC, LG Chem and Samsung also produced a substantial amount of battery capacity for plug-in vehicles in 2016.

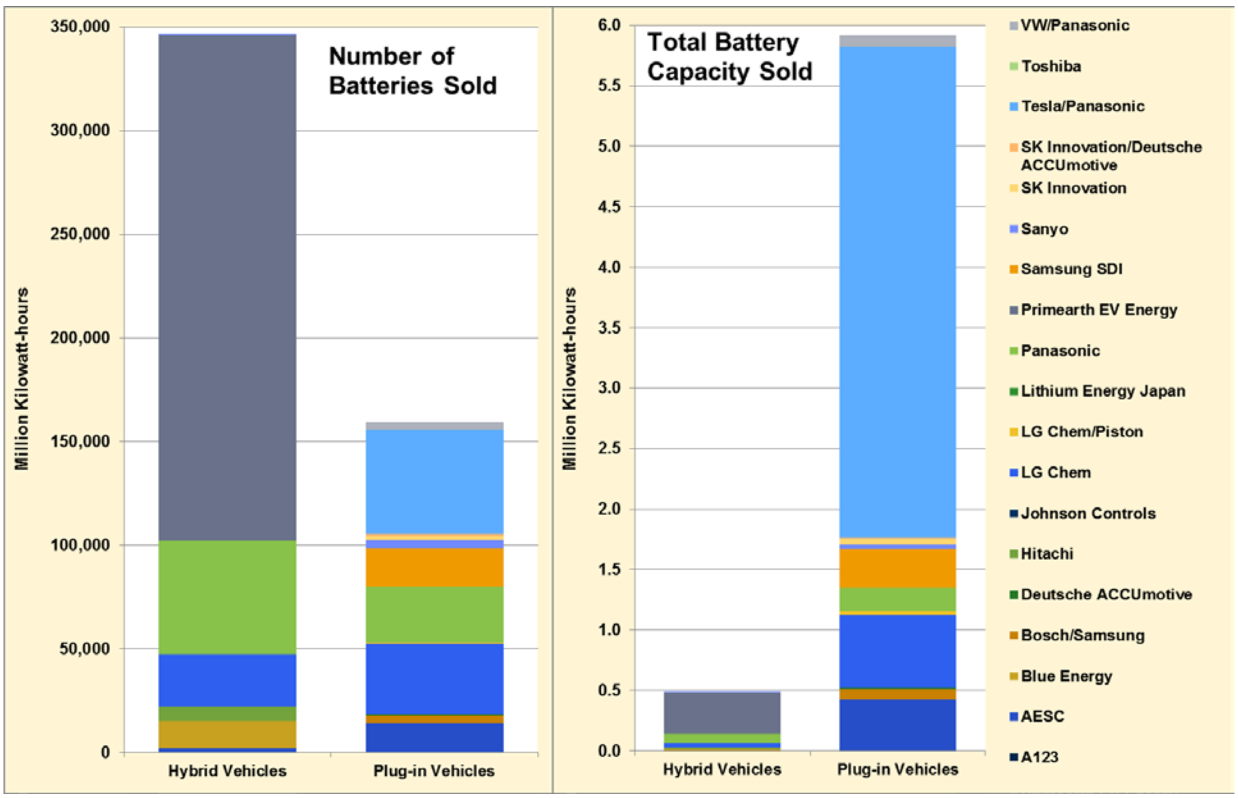


FIGURE 114. Battery Sales Estimates for Hybrid and Plug-In Vehicles, 2016

Sources:
Estimated using hybrid and plug-in sales data along with information on battery suppliers.
Vehicle Sales Data – Provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates
Battery Suppliers – Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2017.

Battery Capacity of All-Electric Vehicles Varies From 22 to 100 kW-hrs

The all-electric plug-in vehicles (EV) have capacities ranging from 22 kW-hrs in the BMW i3 to 100 kW-hrs in the Tesla Model S (and Model X). All EVs currently have lithium-ion (Li-ion) batteries. Vehicle manufacturers do not always reveal battery supplier information. The supplier information below was compiled from various public sources.

TABLE 34. Batteries for Selected Available All-Electric Vehicles, Model Year 2017

Model Year	Vehicle	Battery Capacity (kW-hrs)	Battery Type	Supplier
2017	BMW i3 (60 Ah battery)	22	Li-ion	Samsung SDI
2017	BMW i3 (94 Ah battery)	33	Li-ion	Samsung SDI
2017	Chevrolet Bolt	60	Li-ion	LG Chem
2017	Fiat 500e	24	Li-ion	Samsung SDI, Robert Bosch Battery Systems
2017	Ford Focus Electric	33.5	Li-ion	LG Chem (assembled by Piston Automotive Group)
2017	Hyundai Ioniq Electric	28	Li-ion	LG Chem
2017	Kia Soul EV	27	Li-ion	SK Innovation
2017	Mercedes-Benz B250e	28	Li-ion	Tesla/Panasonic
2017	Mitsubishi iMiEV	16	Li-ion	Lithium Energy Japan
2017	Nissan Leaf	30	Li-ion	ASEC
2017	Telsa Model S 60, 60D	60	Li-ion	Tesla/Panasonic
2017	Tesla Model S 75, 75D	70	Li-ion	Tesla/Panasonic
2017	Tesla Model S 85, S85D, P85D	85	Li-ion	Tesla/Panasonic
2017	Tesla Model S 90D, P90D	90	Li-ion	Tesla/Panasonic
2017	Tesla Model S 100D, P100D	100	Li-ion	Tesla/Panasonic
2017	Tesla Model X 60D	60	Li-ion	Tesla/Panasonic
2017	Tesla Model X 75D	75	Li-ion	Tesla/Panasonic
2017	Tesla Model X 90D, P90D	90	Li-ion	Tesla/Panasonic
2017	Tesla Model X 100D	100	Li-ion	Tesla/Panasonic
2017	Volkswagen e-Golf	24.2	Li-ion	VW/Panasonic

Notes: Automotive Energy Supply Corporation (AESC) is a joint venture between NEC and Nissan. Lithium Energy Japan is a joint venture between GS Yuasa and Mitsubishi.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2017.

Battery Capacity of Plug-In Hybrid-Electric Vehicles Varies From 7.1 to 33 kW-hrs

The plug-in hybrid-electric vehicles have capacities ranging from 7.1 kW-hrs in the BMW i8 to 33 kW-hrs in the BMW i3 REX. Plug-in hybrid-electric vehicles typically have smaller battery capacities than all-electric vehicles because their range is extended with a gasoline engine. All plug-in hybrid-electric vehicles currently have lithium-ion (Li-ion) batteries. Vehicle manufacturers do not always reveal battery supplier information. The supplier information below was compiled from various public sources.

TABLE 35. Batteries for Selected Available Plug-in Vehicles, Model Year 2017

Model Year	Vehicle	Battery Capacity (kW-hrs)	Battery Type	Supplier
2017	Audi A3 Sportback eTron	8.8	Li-ion	Panasonic / Sanyo
2017	BMW 330e	7.6	Li-ion	Samsung SDI
2017	BMW 740e xDrive	9.2	Li-ion	Samsung SDI
2017	BMW X5 xDrive 40e	9.2	Li-ion	Samsung SDI
2017	BMW i3 REX (94 Ah)	33	Li-ion	Samsung SDI
2017	BMW i8	7.1	Li-ion	Samsung SDI
2017	Chevrolet Volt	18.4	Li-ion	LG Chem
2017	Chrysler Pacifica Plug-in Hybrid	16	Li-ion	LG Chem
2017	Ford C-Max Energi	7.6	Li-ion	Panasonic
2017	Ford Fusion Energi	7.6	Li-ion	Panasonic
2017	Hyundai Sonata Plug-in	9.8	Li-ion	LG Chem
2017	Kia Optima Plug-in	9.8	Li-ion	LG Chem
2017	Mercedes-Benz GLE550e	8.8	Li-ion	SK Innovations / Deutsche ACCUmotive
2017	Mercedes-Benz S550e	8.7	Li-ion	SK Innovations / Deutsche ACCUmotive
2017	Porsche Cayenne S e-Hybrid	10.8	Li-ion	Panasonic/Sanyo
2017	Porsche Panamera S e-Hybrid	14.1	Li-ion	Samsung or Panasonic
2017	Toyota Prius Prime	8.8	Li-ion	Panasonic/Sanyo
2017	Volvo XC90	9.2	Li-ion	LG Chem

Notes: Sanyo is a wholly-owned subsidiary of Panasonic. Deutche ACCUmotive is a joint venture between Daimler and Evonik Industries AG.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2017.

Hybrid-Electric Vehicles Typically Use Batteries with Capacities Less than 2 Kilowatt-Hours

Battery capacities for hybrid-electric vehicles range from 0.5 to 1.9 kilowatt-hours. Some manufacturers have moved to lithium-ion (Li-ion) or lithium-polymer batteries, while others continue with the nickel-metal hydride (NiMH) batteries.

TABLE 36. Batteries for Selected Hybrid-Electric Vehicles, Model Year 2017

Model Year	Vehicle	Battery Capacity (kW-hrs)	Battery Type	Supplier
2017	Acura NSX Hybrid	1.3	Li-ion	Blue Energy
2017	Acura RLX Hybrid	1.3	Li-ion	Blue Energy
2017	Chevrolet Malibu	1.5	Li-ion	Hitachi
2017	Ford C-Max Hybrid	1.4	Li-ion	Panasonic
2017	Ford Fusion Hybrid	1.4	Li-ion	Panasonic
2017	GMC/Chevrolet Sierra/Silverado	0.45	Li-ion	Hitachi
2017	Honda Accord Hybrid	1.3	Li-ion	Blue Energy
2017	Hyundai Ioniq & Ioniq Blue	1.56	Li polymer	LG Chem
2017	Hyundai Sonata Hybrid & SE	1.6	Li polymer	LG Chem
2017	Infiniti Q50 Hybrid + AWD	1.4	Li-ion	AESC
2017	Infiniti Q70	1.4	Li-ion	AESC
2017	Infiniti QX60 + AWD	0.7	Li-ion	Hitachi
2017	Kia Niro FE, Niro, Niro Touring	1.56	Li polymer	LG Chem
2017	Kia Optima	1.62	Li polymer	LG Chem
2017	Lexus CT 200h	1.31	NiMH	Primearth EV Energy
2017	Lexus ES 300h	1.6	NiMH	Primearth EV Energy
2017	Lexus GS 450h + AWD	1.9	NiMH	Primearth EV Energy
2017	Lexus NX 300h AWD	1.6	NiMH	Primearth EV Energy
2017	Lexus RX 450h	1.9	NiMH	Primearth EV Energy
2017	Lincoln MKZ Hybrid	1.4	Li-ion	Panasonic
2017	Nissan Rogue Hybrid	0.8	Li-ion	Hitachi
2017	Toyota Avalon Hybrid	1.6	NiMH	Primearth EV Energy
2017	Toyota Camry Hybrid, LE & XLE/SE	1.6	NiMH	Primearth EV Energy
2017	Toyota Highlander Hybrid, & LE Plus	1.9	NiMH	Primearth EV Energy
2017	Toyota Prius c	0.936	NiMH	Primearth EV Energy
2017	Toyota Prius Two	1.3	NiMH	Primearth EV Energy
2017	Toyota Prius Two Eco, Three, Three Touring	0.746	Li-ion	Toyota/Panasonic
2017	Toyota Prius v	1.3	NiMH	Primearth EV Energy
2017	Toyota RAV4 Hybrid	1.6	NiMH	Primearth EV Energy

Notes: Automotive Energy Supply Corporation (AESC) is a joint venture between NEC and Nissan. Primearth EV Energy is a joint venture between Panasonic and Toyota. Blue Energy is a joint venture between GS Yuasa and Honda.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2017.

Hybrid-Electric Medium and Heavy Vehicles on the Market

The first line production of commercial diesel-electric hybrid trucks was the International DuraStar Hybrid which began production in 2007. There are currently numerous models of hybrid cargo trucks on the market. Most of the hybrid trucks available are diesel-fueled and are used for a variety of purposes, ranging from delivery vehicles to transit buses.

TABLE 37. Hybrid-Electric Cargo Trucks on the Market

Manufacturer	Model	Category
Autocar	E3-Hybrid Drive	Refuse
Daimler Buses North America	Orion VII Hybrid Low-Floor	Transit Bus
DesignLine Corp.	EcoSaver IV	Transit Bus
ElDorado National	E-Z Rider II	Transit Bus
ENC	E-Z RIDER II	Transit Bus
Foton America	FCB 30-foot; FCB 35-foot; FCB 40-foot	Transit Bus
Gillig Corp.	Standard, BRT, BRTPlus, Commuter	Transit Bus
Gillig Corp.	Trolley	Transit Bus
Glaval Bus	Universal	Shuttle Bus
Hino	195h Hybrid COE, 195h-DC Hybrid COE	Vocational/Cab Chassis
International	DuraStar Hybrid	Vocational/Cab Chassis
Motor Coach Industries	D4500 CT Hybrid Commuter Coach	Transit Bus
Navistar	HC300 Hybrid	School Bus
New Flyer	Xcelsior	Transit Bus
North American Bus Industries	31LFW / 35LFW / 40LFW	Transit Bus
North American Bus Industries	CompoBus	Transit Bus
North American Bus Industries	42BRT	Transit Bus
North American Bus Industries	60BRT	Transit Bus
Nova Bus	LFS Artic HEV	Transit Bus
Nova Bus	LFS HEV	Transit Bus
Turtle Top	Odyssey XLT	Shuttle Bus
Via Motors	VTRUX	Van
XL Hybrid - Chevrolet	Express 2500/3500 HD	Van
XL Hybrid - Ford	Transit	Van
XL Hybrid - General Motors	Savana 2500/3500 HD	Van
XL Hybrid - Isuzu	Reach	Van
XL Hybrid - Ford	E 350/450	Vocational/Cab Chassis
XL Hybrid - Ford	F-59 Super Duty	Vocational/Cab Chassis
XL Hybrid - General Motors	3500/4500 HD	Vocational/Cab Chassis

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed March 9, 2017. http://www.afdc.energy.gov/vehicles/search

Hydraulic-Hybrid Medium and Heavy Vehicles on the Market

A hydraulic-hybrid truck captures energy through regenerative braking by storing hydraulic fluid in a high-pressure tank so that it can be reapplied as power to the wheels and assist the vehicle's engine during acceleration. Vehicles that stop and start frequently, such as urban delivery vehicles or refuse haulers, would experience the greatest fuel savings from a hydraulic-hybrid system. Currently, no original equipment manufacturer is selling hydraulic-hybrid trucks, but one company, Lightning Hybrids, is converting several makes and models of medium/heavy trucks to hydraulic-hybrids. As the hydraulic hybrid is a parallel hybrid system, no modifications to the engine or transmission are necessary.

TABLE 38. Hydraulic-Hybrid Cargo Trucks on the Market

Manufacturer	Model	Category
Lightning Hybrids - Ford	E 350/450	Vocational/Cab Chassis
Lightning Hybrids - Ford	F 350XT/450XT/550XT	Vocational/Cab Chassis
Lightning Hybrids - Ford	F-59 Super Duty	Vocational/Cab Chassis
Lightning Hybrids - Ford	Transit	Vocational/Cab Chassis
Lightning Hybrids - Ford	Transit Cab Chassis	Vocational/Cab Chassis
Lightning Hybrids - Freightliner	M2 106	Vocational/Cab Chassis
Lightning Hybrids - Freightliner	MB 65	Transit BusShuttle Bus
Lightning Hybrids - Freightliner	MT 45	Step Van
Lightning Hybrids - Freightliner	MT 55	Step Van
Lightning Hybrids - General Motors	3500/4500/5500	Vocational/Cab Chassis
Lightning Hybrids - Mercedes Benz	Sprinter	Vocational/Cab Chassis
Lightning Hybrids - Thomas Built	SAF-T-LINER C2	School Bus

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed March 9, 2017. http://www.afdc.energy.gov/vehicles/search

Electric and Hydrogen Fuel Cell Medium and Heavy Vehicles on the Market

There are 34 electric medium and heavy trucks available in a variety of body types—step vans, vocational vehicles, transit buses, school buses and tractors. In addition, there are four hydrogen-fueled medium and heavy trucks on the market.

TABLE 39. Electric and Hydrogen Fuel Cell Medium and Heavy Vehicles on the Market

Manufacturer	Model	Category
Electric		
BYD (Build Your Dream)	C6 23ft Coach	Transit Bus
BYD (Build Your Dream)	C9 40ft Coach	Transit Bus
BYD (Build Your Dream)	C10 45ft Coach	Transit Bus
BYD (Build Your Dream)	K7 30ft Transit Bus	Transit Bus
BYD (Build Your Dream)	K11 60ft Transit Bus	Transit Bus
BYD (Build Your Dream)	K9 40ft Transit Bus	Transit Bus
BYD (Build Your Dream)	K9S 35ft Transit Bus	Transit Bus
BYD (Build Your Dream)	Q1M	Truck
BYD (Build Your Dream)	Step Van	Truck
BYD (Build Your Dream)	T5	Vocational/Cab Chassis
BYD (Build Your Dream)	T7	Vocational/Cab Chassis
BYD (Build Your Dream)	T9	Truck
Capacity Trucks	HETT	Tractor
DesignLine Corp.	Eco-Smart 1	Transit Bus
Ebus	40 Foot Composite Ebus	Transit Bus
Ebus	EBUS22	Transit Bus
First Priority GreenFleet	Lion Bus Type C	School Bus
First Priority GreenFleet	Medium Duty Truck	Truck
First Priority GreenFleet	Trans Tech Type A	School Bus
First Priority GreenFleet	Walk-In Van	Van
GGT Electric	Electric	Vocational/Cab Chassis
Navistar-Modec EV Alliance	eStar	Step Van
New Flyer	Xcelsior	Transit Bus
Nova Bus	LFSE	Transit Bus
Orange EV	Multiple	Tractor
Phoenix Motorcars	Flatbed	Vocational/Cab Chassis
Phoenix Motorcars	Shuttle Bus	Shuttle Bus
Phoenix Motorcars	Utility Vehicle	Vocational/Cab Chassis
Proterra	Catalyst	Transit Bus
Trans Tech	ETrans	School Bus
Workhorse Custom Chassis	E-Gen	Vocational/Cab Chassis
Zenith Motors	250/350	Van
Zenith Motors	Shuttle Van	Van
ZeroTruck	ZeroTruck	Vocational/Cab Chassis
Hydrogen Fuel Cell		
Van Hool	A300L Fuel Cel	Transit Bus
Vision Motor Corp.	Tyrano	Tractor
Capacity Trucks	ZETT	Tractor
Vision Motor Corp.	ZETT Zero Emission Terminal Tractor	Tractor

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed March 9, 2017. http://www.afdc.energy.gov/vehicles/search

Flex-Fuel Vehicle Offerings Decline by 7% for Model Year 2016

In the last five years, GM, FCA, and Ford have been the front-runners in the number of flex-fuel models offered to the public (includes cars and light trucks). Nissan, Toyota and VW have offered flex-fuel models each of the last five years, too. Other manufacturers, Mercedes-Benz and Jaguar-Land Rover also offered flex-fuel vehicles in this time frame. In 2016 there were 66 different flex-fuel vehicle models available. The manufacturers receive credits in the Corporate Average Fuel Economy program for producing flex-fuel vehicles, which run on E85 and/or gasoline.

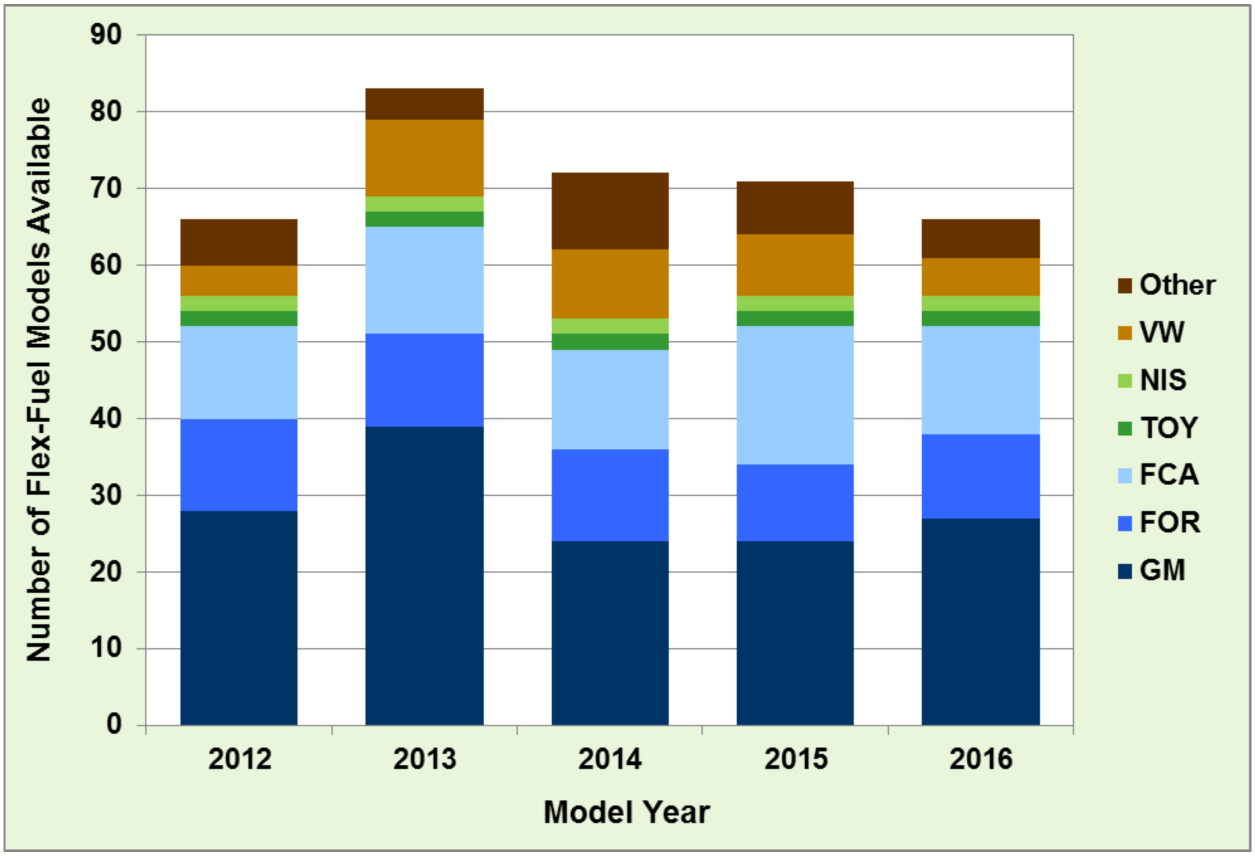


FIGURE 115. Number of Flex-Fuel Models Available, 2012-2016

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center. http://www.afdc.energy.gov/vehicles/search

Alternative Fuel Vehicles Supplied Are Mostly Flex-Fuel Vehicles

The Energy Information Administration publishes the number of alternative fuel vehicles supplied each year from original equipment manufacturers and conversions. These data will more closely align with sales than with vehicle population. Flex-fuel vehicles supplied decreased from 2013 to 2015, but it still remains the largest alternative fuel vehicle type. Unfortunately there is no estimate of how many flex-fuel vehicles are actually using E85 or how many gallons of E85 are consumed.

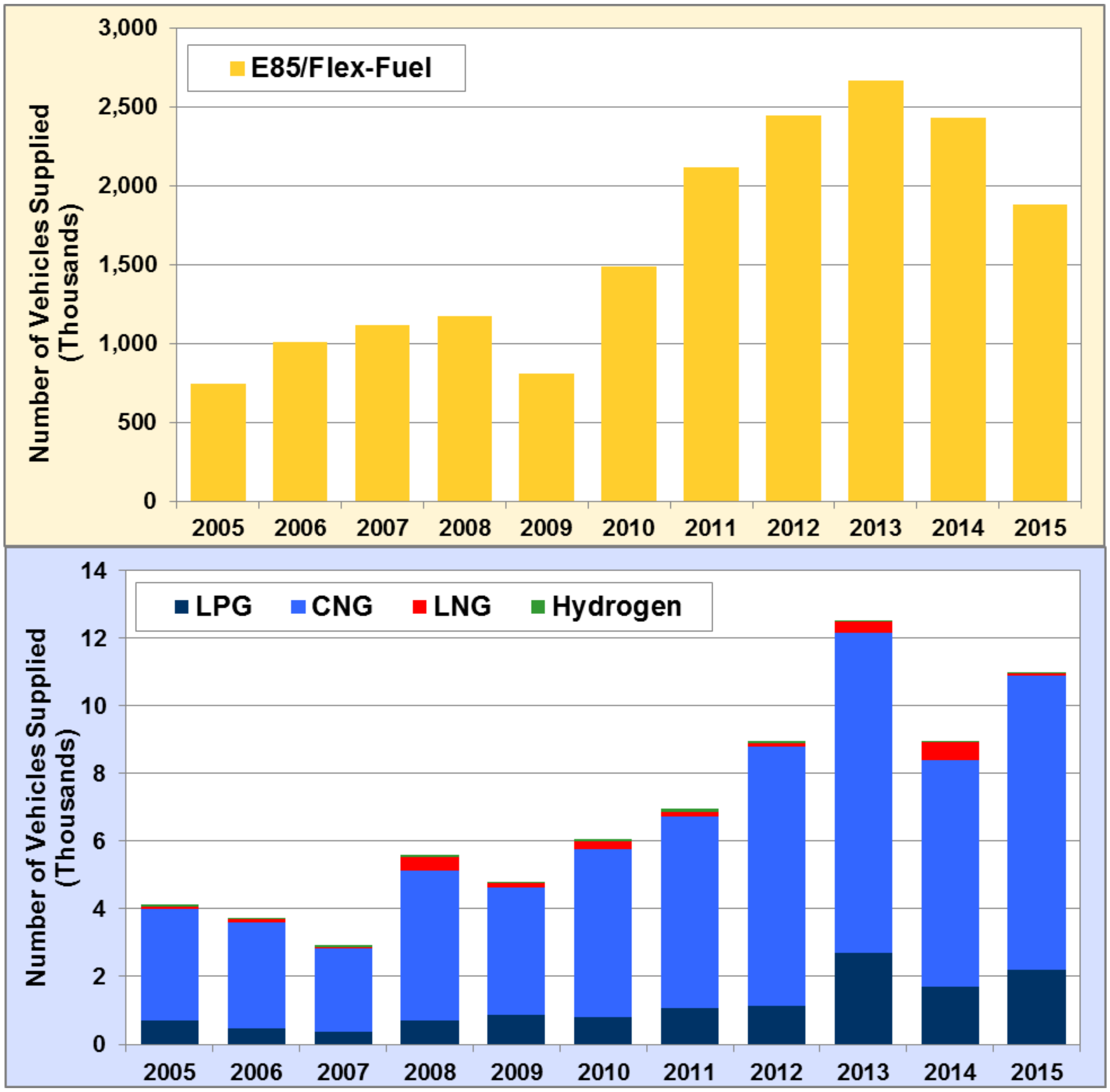


FIGURE 116. Number of Alternative Fuel Vehicles Supplied, 2005-2015

Notes: LPG = Liquefied petroleum gas; CNG = Compressed natural gas; LNG = Liquefied natural gas. For data pertaining to electric vehicles, see pages 140 and 141.

Source:
U.S. Department of Energy, Energy Information Administration.
http://www.eia.gov/renewable/afv/supply.cfm

Electric Charging Stations Are the Fastest Growing Type of Alternative Fueling Station

The number of electric charging units (plugs) grew from about 3,500 in 2011 to over 42,000 in 2016. It should be noted that beginning in 2011, electric charging units replaced the electric charging station data. Electric charging units refers to individual plugs rather than a station which may have multiple plugs. Electric vehicle charge times are much longer than refueling times for other fuel types so the number of plugs is critical, but it can inflate the station count for electricity relative to the other alternative fuel types. In 2015, there were almost 3,700 propane stations, 3,000 E85 stations, and 1,700 compressed natural gas (CNG) refueling stations. The other fuel types (biodiesel, liquefied natural gas (LNG) and hydrogen) altogether have less than 1,000 stations nationwide.

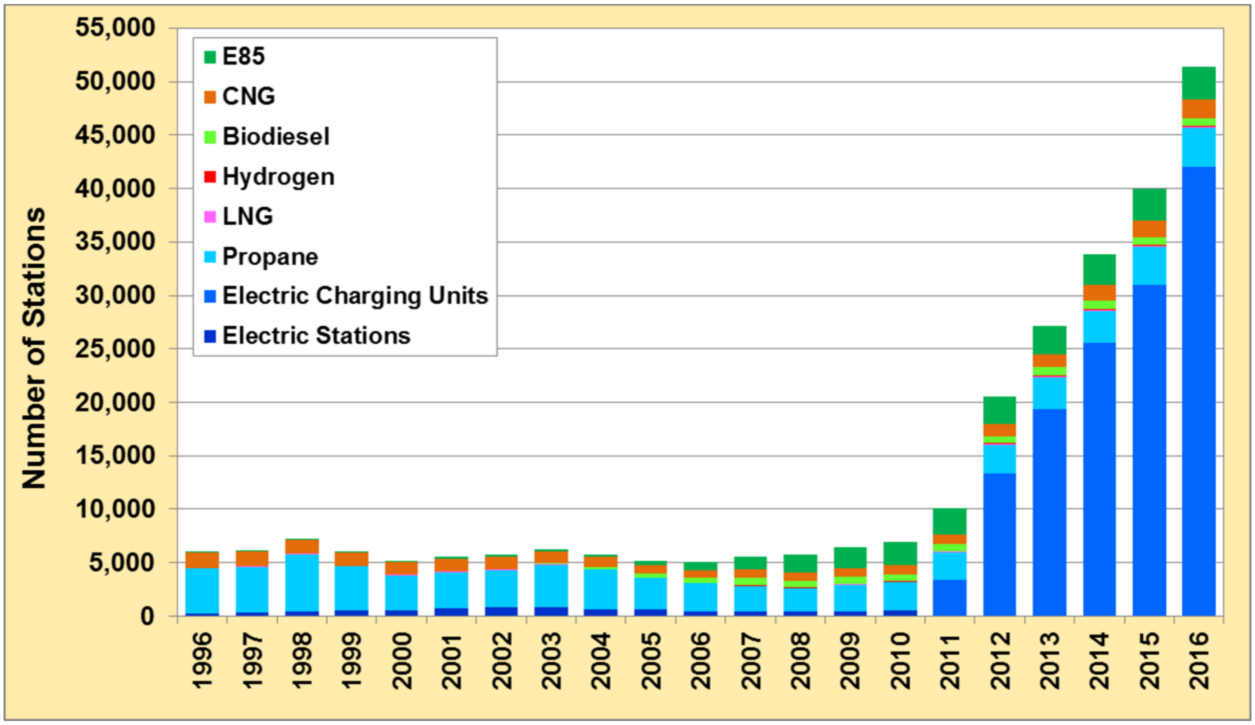


FIGURE 117. Alternative Fueling Stations by Fuel Type, 1996-2016

Notes:

- Starting in 2011, electric charge equipment was counted by the plug rather than by the geographical location. This is different than other fuels, which only count the geographical location regardless of how many dispensers or nozzles are on site.
- Stations selling low-level biodiesel blends (less than B20) are included in the station listing only for the years 2005-2007.
- Stations are counted once for each type of fuel sold.
- Includes public and private stations.

Source:

U.S. Department of Energy, Alternative Fuels Data Center, "Alternative Fueling Station Counts by State," data accessed March 2017. http://www.afdc.energy.gov/data/10332

Biofuel Stations Spread beyond the Midwest

E85, which is nominally 85% ethanol and 15% gasoline, is sold at 3,095 stations nationwide. Many stations are located in the Midwest where the majority of ethanol feedstock is grown, but E85 stations are found throughout the nation. Biodiesel is sold at 708 stations across the country, with 41% of the stations in the Southeast. Data are as of January 26, 2017.

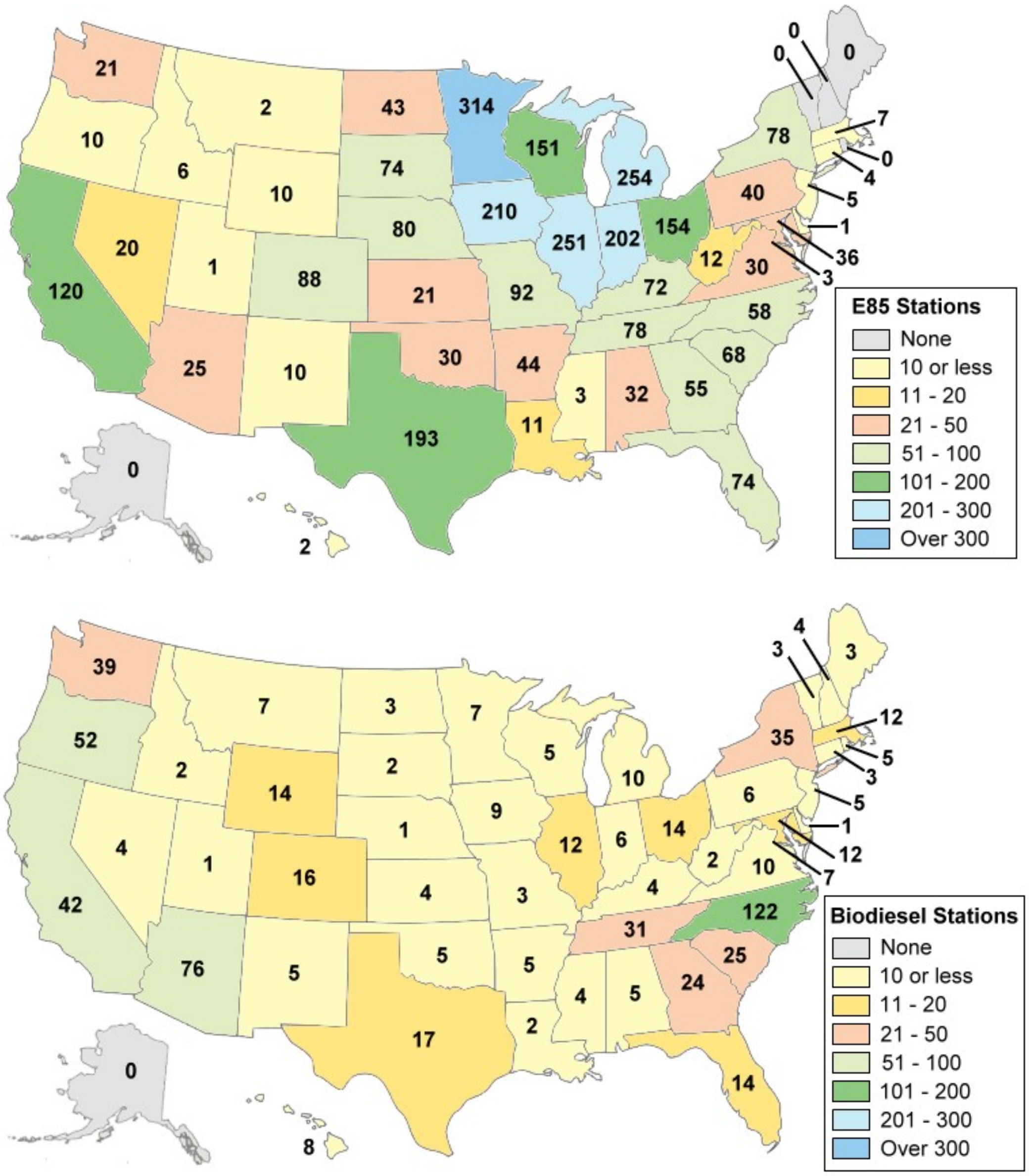


FIGURE 118. Number of E85 (top) and Biodiesel Stations by State, 2017

Note: Includes public and private stations.

Source:
U.S. Department of Energy, Alternative Fuel and Advanced Vehicles Data Center.
http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

Most States Have Stations with Propane and Natural Gas

There is a wide distribution of the 3,663 propane stations across the country. Texas and California together comprise 22% of the propane stations. Natural gas, compressed or liquefied, is not as widely available as many other alternative fuels. There are 1,831 stations nationwide. California and Texas have the most natural gas stations. Data are as of January 26, 2017.

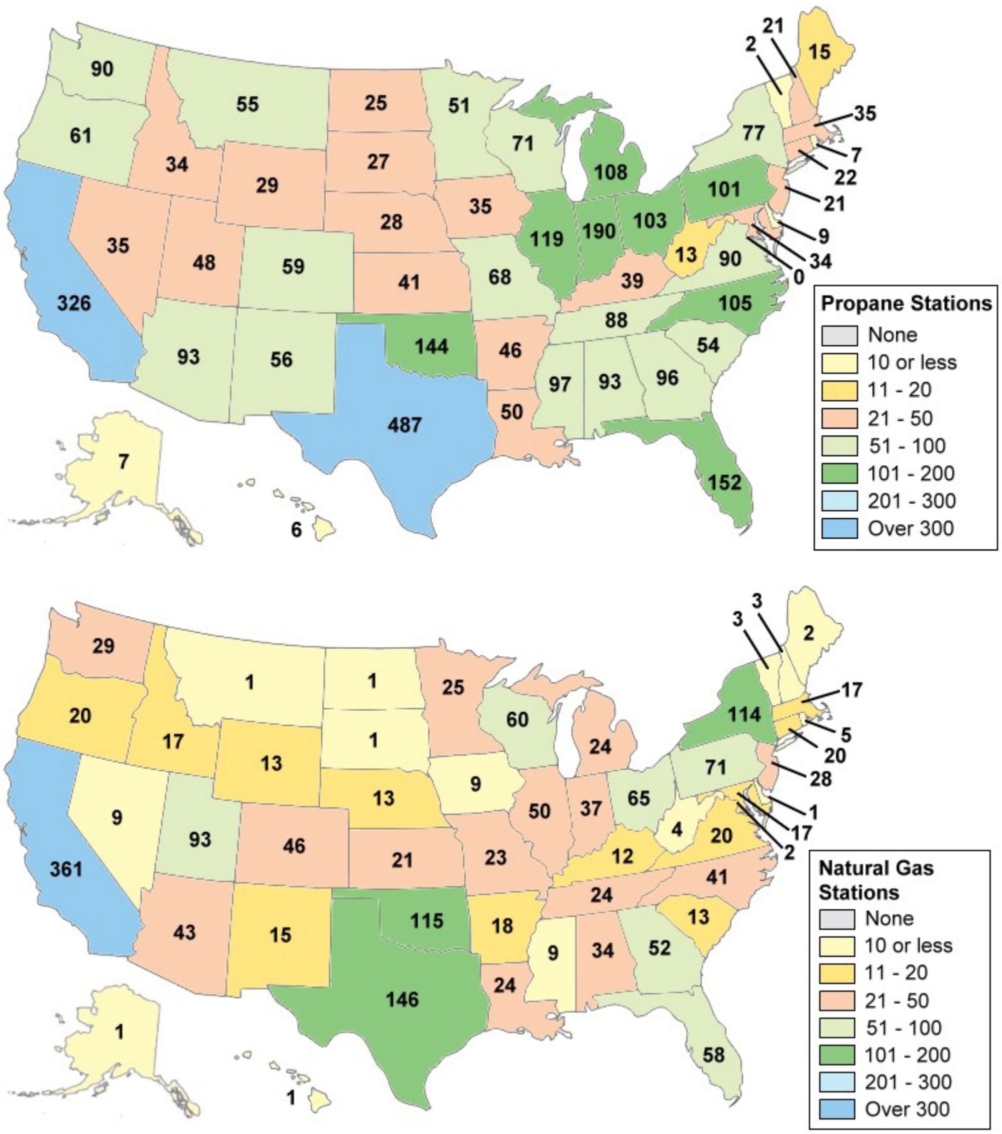


FIGURE 119. Number of Propane (top) and Natural Gas Stations by State, 2017

Note: Includes public and private stations.

Source:

U.S. Department of Energy, Alternative Fuel and Advanced Vehicles Data Center. http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

Hydrogen Stations Are Mainly in California

Hydrogen stations are mainly located in California where the first hydrogen-fueled light vehicles are available. Other states may have hydrogen refueling stations for research and development purposes. There are 14 states with at least one hydrogen refueling station. Data are as of January 26, 2017.

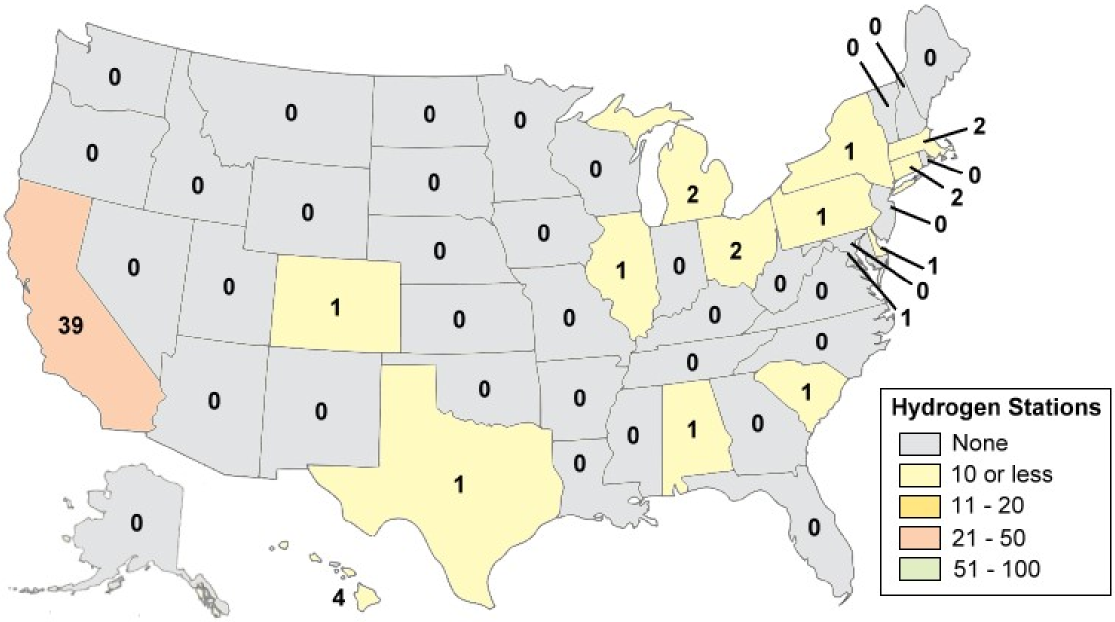


FIGURE 120. Number of Hydrogen Stations by State, 2017

Note: Includes public and private stations.

Source:
U.S. Department of Energy, Alternative Fuel and Advanced Vehicles Data Center. http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

Number of Electric Stations and Electric Charging Units Increasing

There are more electric stations than any other alternative fuel (17,982 stations). At these 17,982 stations, there are 45,986 electric charging units. While most refueling for other fuels is completed in a matter of minutes, electric vehicles may occupy a charging unit for hours so it is important to know the total number of available charging units. Data are as of January 26, 2017.

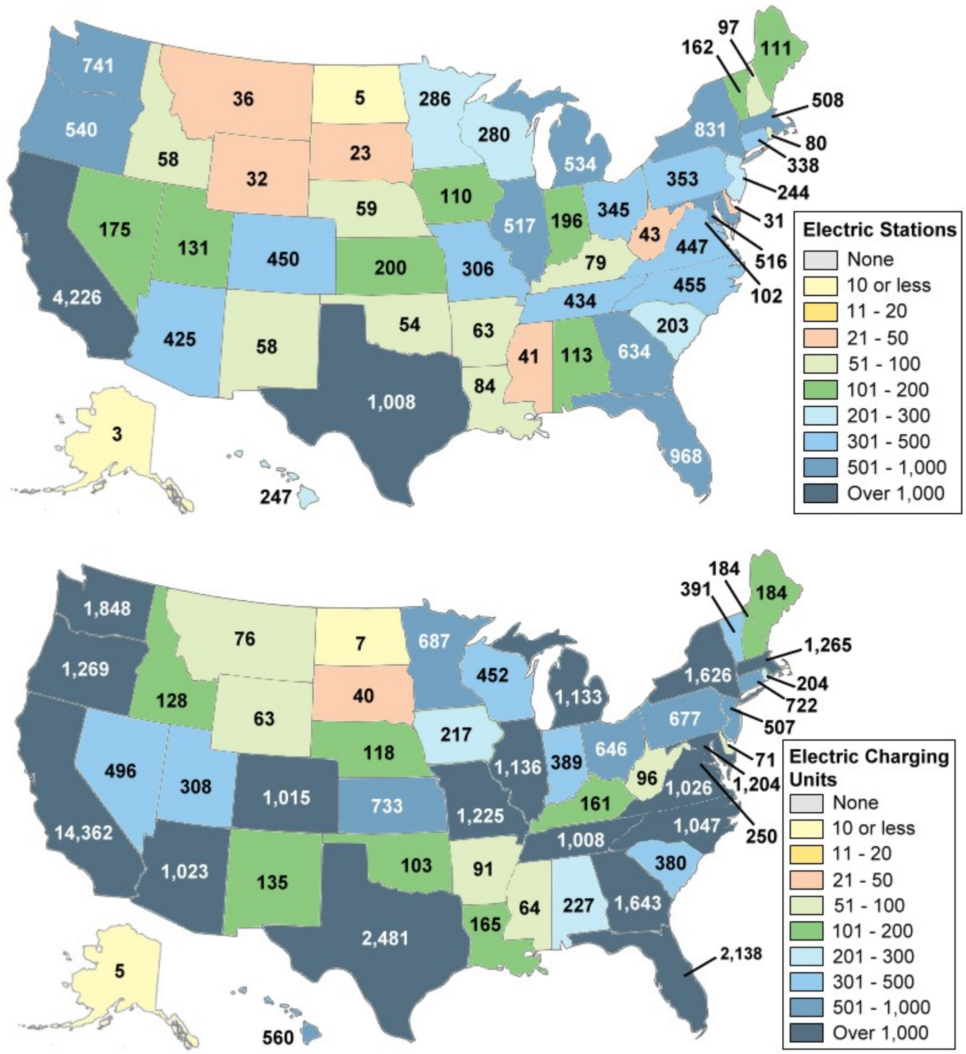


FIGURE 121. Number of Electric Stations (top) and Electric Charging Units by State, 2017

Note: Includes public and private stations and units. About 70% of stations and units are public.

Source:
U.S. Department of Energy, Alternative Fuel and Advanced Vehicles Data Center.
http://www.afdc.energy.gov/afdc/fuels/stations_counts.html

Federal Government Uses Alternative Fuel

The Federal Government is a large user of alternative fuel. Over 18 million gasoline-equivalent gallons (GGEs) of biofuels (E85 and biodiesel) were used in 2015. Federal use of other alternative fuels has been less than one million GGEs combined in 2011-2015. Note the large difference in the scales of the two graphs.

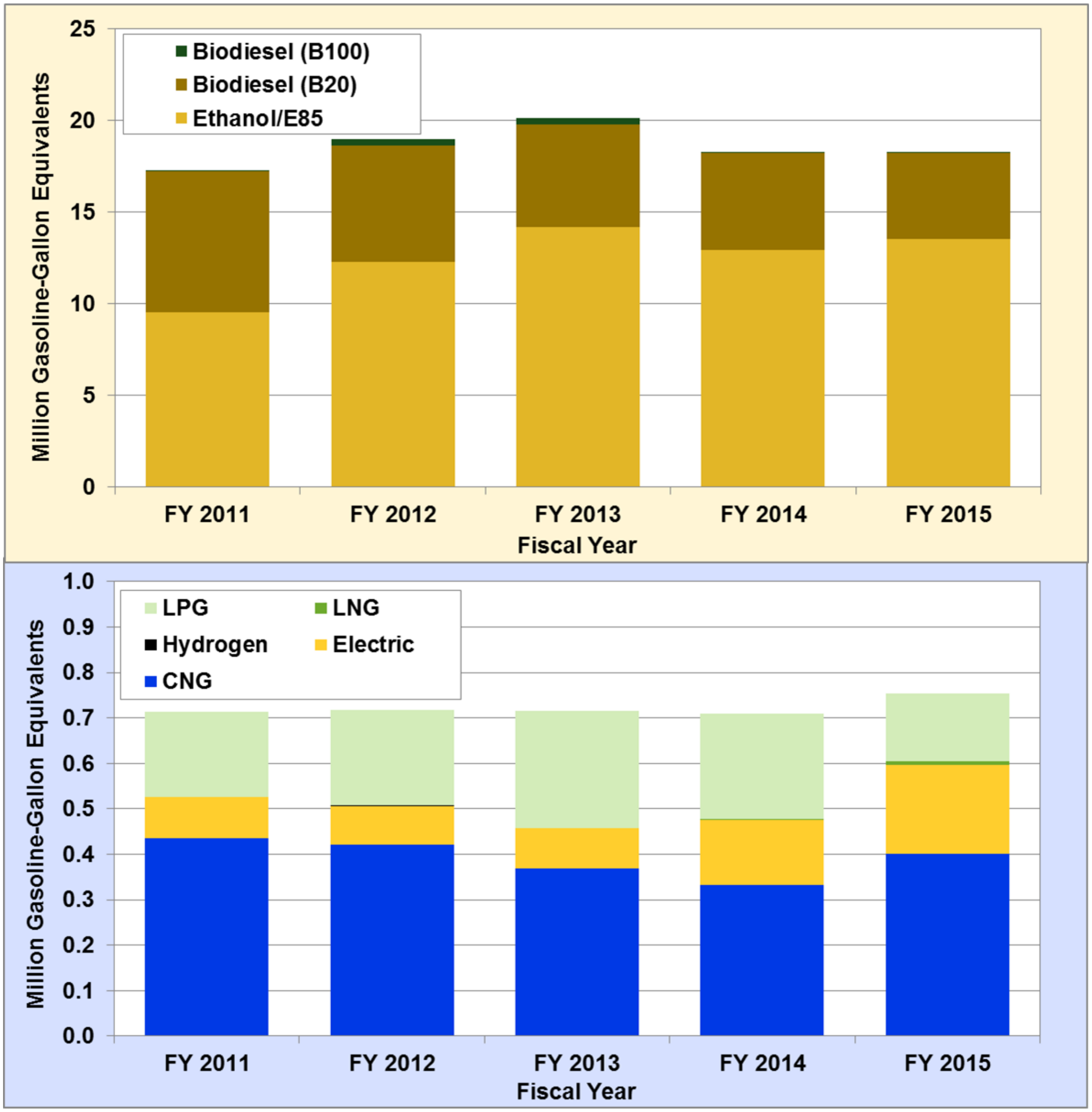


FIGURE 122. Alternative Fuel Use by the Federal Government, 2011-2015

Source:

U.S. General Services Administration, *FY 2015 Federal Fleet Report*, Washington, DC, 2016.
http://www.gsa.gov/portal/content/102943

E85 Vehicles Top Diesels in the Federal Government Fleet

Though gasoline vehicles are the most prevalent in the Federal Government fleet, there are more E85 vehicles than diesels in the inventory. The number of gasoline hybrid vehicles rose substantially between 2011 and 2015.

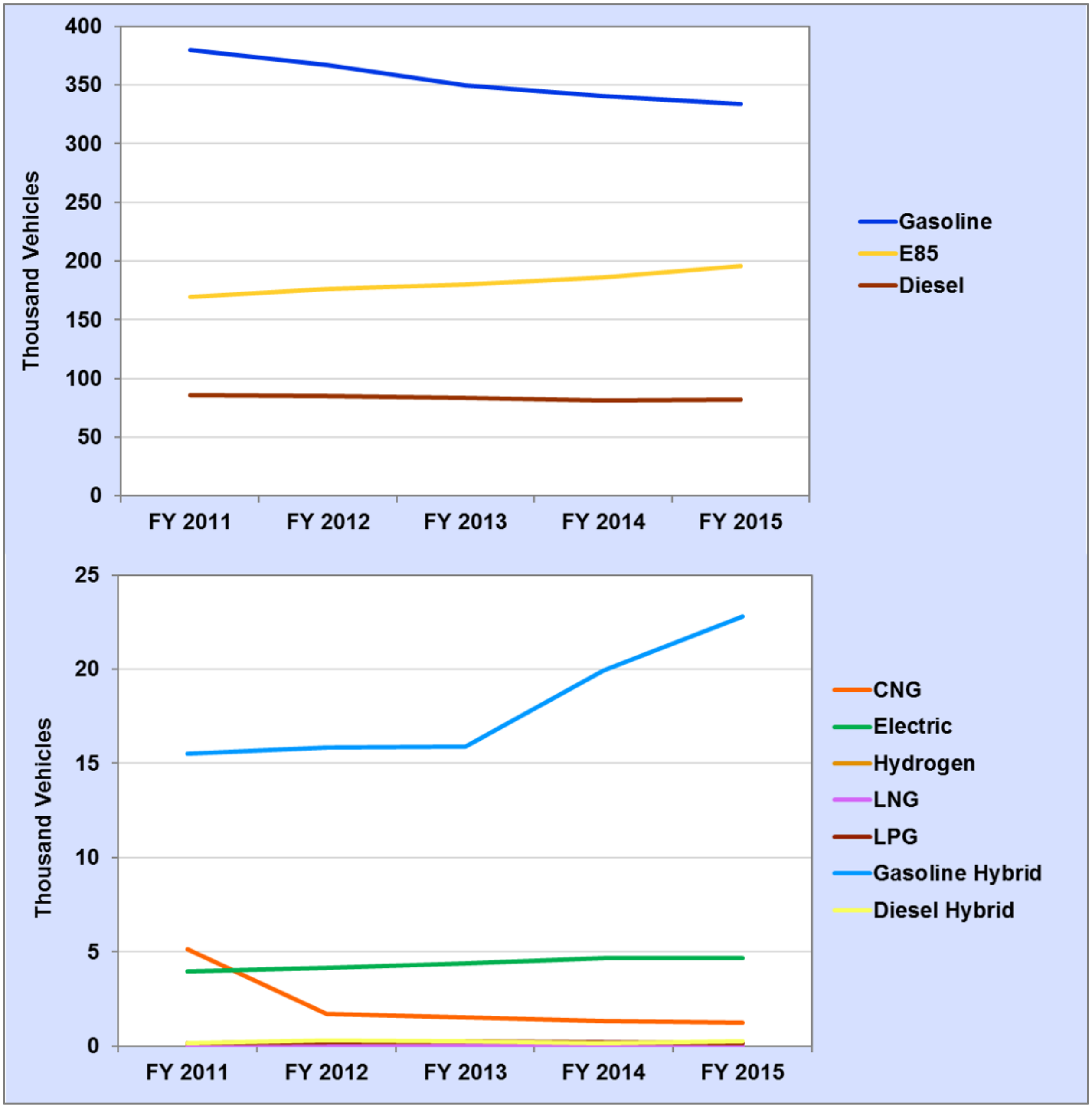


FIGURE 123. Federal Government Vehicles by Fuel Type, 2011-2015

Source:

U.S. General Services Administration, *FY 2015 Federal Fleet Report*, Washington, DC, 2016.
http://www.gsa.gov/portal/content/102943

Use of Lightweight Materials Is on the Rise

As automakers strive to improve fuel economy, they have turned increasingly to lightweight materials to reduce overall vehicle weight. For example, most light vehicle engine blocks are now made of aluminum rather than cast iron, and in many cases, aluminum wheels have replaced heavier steel wheels as standard equipment. Use of regular steel has declined by over 250 lb per vehicle from 1995 to 2014 while the use of high- and medium-strength steels has increased by 325 lb per vehicle. The increased use of high- and medium-strength steel is significant because it allows manufacturers to improve the structural integrity of vehicles while keeping the overall vehicle weight to a minimum. The use of plastics and composites has also increased by almost 40% and lightweight magnesium castings have seen greater use in dashboards and other interior applications such as seat components, replacing the heavier steel components that were previously used.

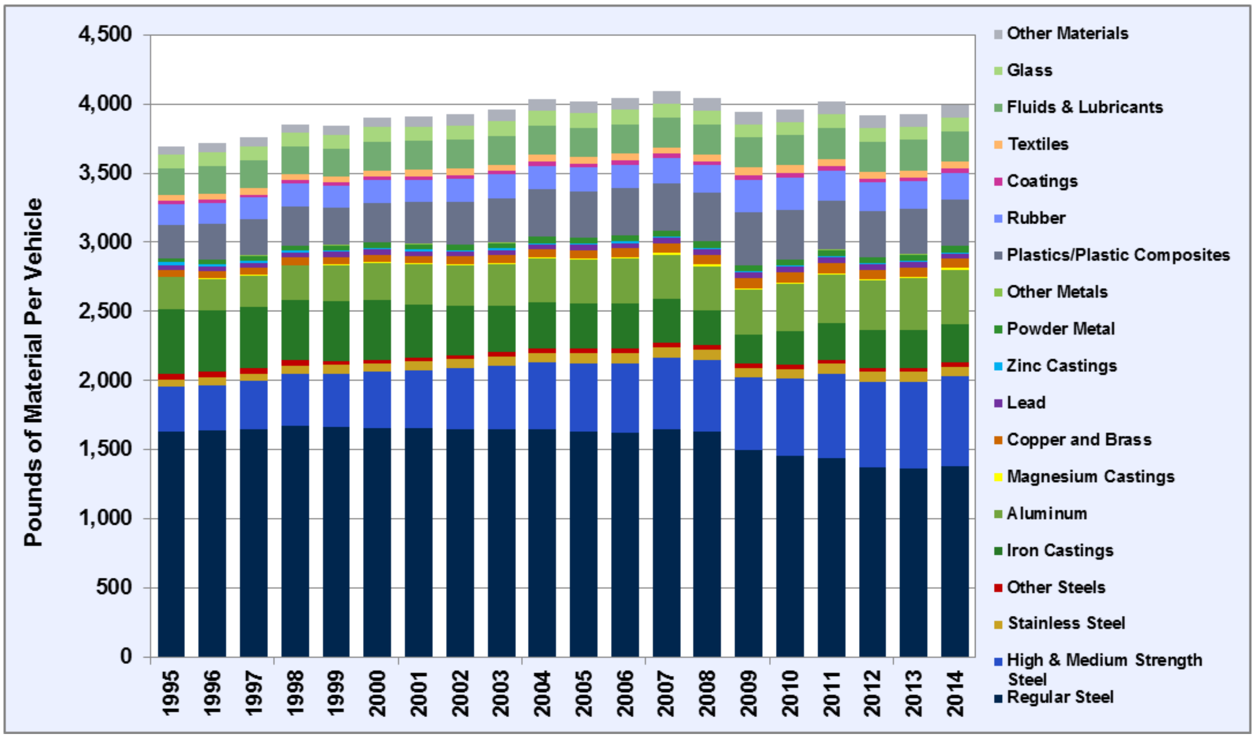


FIGURE 124. Average Materials Content of Light Vehicles, 1995-2014

Source:
Ward's Automotive Group. http://wardsauto.com

Engine Technologies Improve Fuel Economy and Reduce Emissions

The table below shows some of the notable technologies that have been adopted by manufacturers to improve performance and efficiency.

TABLE 40. Fuel-Saving Engine Technologies

Technology	Description
Engine Friction Reduction	Reduction of engine friction losses can be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, and piston surface treatments, etc.
Cylinder Deactivation	Cylinder deactivation allows the engine to shut down some of its cylinders during light load operation for greater fuel efficiency.
Intake Cam Phasing	Valvetrains with intake cam phasing modify the timing of the inlet valves by phasing the intake camshaft while the exhaust valve timing remains fixed.
Coupled Cam Phasing	Valvetrains with coupled (or coordinated) cam phasing modify the timing of both the inlet valves and the exhaust valves an equal amount by phasing the camshaft of a single overhead cam engine or an overhead valve engine.
Dual Cam Phasing	Dual (independent) cam phasing controls the intake and exhaust valve opening and closing events independently. This allows the option of controlling valve overlap, which can be used as an internal exhaust-gas recirculation strategy.
Discrete Variable Valve Lift	Discrete variable valve lift increases efficiency by optimizing air flow over a broader range of engine operation which reduces pumping losses. Accomplished by controlled switching between two or more cam profile lobe heights.
Continuously Variable Valve Lift	Continuous variable valve lift is an electromechanically controlled system in which cam period and phasing is changed as lift height is controlled. This yields a wide range of performance optimization and volumetric efficiency, including enabling the engine to be valve throttled.
Variable Valve Timing and Lift (VVT&L)	Unlike gasoline engines that use a fixed valve lift, where the valve lift does not change with the speed and load of the engine, VVT&L allows the period of valve opening to vary based on need, which reduces pumping losses and valve train frictional loss. It also increases the compression ratio and reduces idle speed.
Dual Port Injection	Rather than a single injector per port, a dual injector arrangement improves combustion and increases performance and fuel economy.
Gasoline Direct Injection	Gasoline direct-injection technology injects fuel at high pressure directly into the combustion chamber to improve cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency.
Direct Injection (with Turbocharging)	Direct fuel injection allows fuel to be injected directly into the cylinder so the timing and shape of the fuel mist can be controlled more precisely. This uses fuel more efficiently because of the higher compression ratios. The combination of direct injection and turbocharging has allowed manufacturers to downsize engines without compromising performance.
Turbocharging and Downsizing	Turbocharging and downsizing increases the available airflow and specific power level, allowing a reduced engine size while maintaining performance. This reduces pumping losses at lighter loads in comparison to a larger engine.
Turbocharging and Supercharging	Turbochargers and superchargers both use small impellers to force compressed air into the cylinders to improve combustion and boost power. Turbochargers are powered by the exhaust while superchargers are powered as an accessory through a mechanical connection to the engine.
Turbo Compounding	Used in heavy vehicle sectors, turbo compounding recovers waste heat energy from the exhaust stream and converts it into usable energy. Mechanical turbo compounding converts waste heat energy into kinetic energy and electric turbo compounding converts the waste heat energy into electrical energy.
Cooled Exhaust-Gas Recirculation	Cooled exhaust-gas recirculation increases the exhaust-gas recirculation used in the combustion process to increase thermal efficiency and reduce pumping losses.

TABLE 40. Fuel-Saving Engine Technologies (continued)

Technology	Description
Continuously Variable Transmission (CVT)	CVT transmissions control the ratio between engine speed and wheel speed, using a pair of variable-diameter pulleys connected by a belt or a chain that can produce an infinite number of engine and wheel speed ratios.
Increased Transmission Speeds	Increasing the number of speeds or gears increases engine efficiency. Manufacturers have been adding more gears to their automatic transmissions. Six-speed transmissions are now common and seven-, eight-, and nine- speed transmissions are available. Ten-speed transmissions will be introduced soon.
Dual Clutch Transmissions	A dual clutch transmission uses separate clutches (and separate gear shafts) for the even-numbered gears and odd-numbered gears. In this way, the next expected gear is pre-selected, which allows for faster and smoother shifting.
Early Torque Converter Lockup	A torque converter is a fluid coupling located between the engine and transmission in vehicles with automatic transmissions and continuously-variable transmissions. This fluid coupling allows for slip so the engine can run while the vehicle is idling in gear (as at a stop light), provides for smoothness of the powertrain, and also provides for torque multiplication during acceleration, and especially launch.
Aggressive Shift Logic	Aggressive shift logic can be employed in such a way as to maximize fuel efficiency by modifying the shift schedule to upshift earlier and inhibit downshifts under some conditions, which reduces engine pumping losses and engine friction.
High Efficiency Gearbox	A high efficiency gearbox offers continuous improvement in seals, bearings and clutches, super finishing of gearbox parts, and development in the area of lubrication, all aimed at reducing frictional and other parasitic losses.
Axle Disconnect for 4-wheel Drive System	Front or secondary axle disconnect for four-wheel drive systems provides a torque distribution disconnect between front and rear axles when torque is not required for the non-driving axle. This results in the reduction of associated parasitic energy losses.
Selective Catalytic Reduction (SCR)	Though an emission control technology used for diesel engines, SCR saves fuel over other types of emission control systems because it allows the engine combustion to occur unhindered while treating the exhaust with urea to control NOX after combustion. Other systems compromise the combustion process to limit the formation of NOX or use fuel to maintain the filters resulting in a greater loss in fuel economy. Most heavy duty engine manufacturers have adopted SCR and it has been adopted by some light passenger vehicle manufacturers as well.
Bottoming Cycle Waste Heat Recovery	Bottoming cycle waste heat recovery systems like the Organic Rankin Cycle (ORC) use a fluid that is heated by waste engine heat which then expands to generate electricity and supplement the engine. It is used in heavy trucks.
Variable Displacement Oil Pump	Rather than pump oil through the engine at a constant rate and pressure, the intensity and rate of pumping are varied to meet the needs of the engine at different load levels.
Variable Speed Water Pump	Variable speed water pumps improve efficiency by limiting the output during low load periods rather than running at a fixed rate.
Low Drag Brakes	Low-drag brakes reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake pads are pulled away from the rotors.
Low Rolling Resistance Tires	Low-rolling-resistance tires have characteristics that reduce frictional losses associated with the energy dissipated in the deformation of the tires under load, thereby reducing the energy needed to move the vehicle.
Aerodynamic Drag Improvements	Aerodynamic drag improvements are achieved by changing vehicle shape or reducing frontal area, including skirts, air dams, underbody covers, and more aerodynamic side view mirrors.
Active Grille Shutters	Active grille shutters on the front of vehicles close off a portion of the front grille which limits the amount of air entering the engine compartment. This reduced flow of air into the engine compartment improves the aerodynamics of the vehicle while still allowing enough airflow to cool the engine.

Source:

U.S. Environmental Protection Agency and U.S. Department of Transportation, *Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards,* EPA-420-R-12-901, August 2012. Additional data were compiled from published sources by Bob Boundy, Roltek, Inc., Clinton, TN, 2012. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Joint_final_TSD.pdf

Turbocharging and Downsizing Engines Result in Fuel Savings

TABLE 41. Costs and Fuel Savings for Selected Technologies, 2012

Technology	Reduction in Fuel Consumption (Percent)	Vehicle Attributes	Estimated Incremental Cost for 2017 (2010 dollars)
Engine Friction Reduction	2.0 to 2.7	I4	$59
		V6	$89
		V8	$118
Cylinder Deactivation	4.7 to 6.5	V6	$196
		V8	$220
Intake Cam Phasing	2.1 to 2.7	I4	$46
		OHC-V6/V8	$93
		OHV-V6/V8	$43
Coupled Cam Phasing	4.1 to 5.5	I4	$46
		OHC-V6/V8	$93
		OHV-V6/V8	$43
Dual Cam Phasing	4.1 to 5.5	I4	$95
		OHC-V6/V8	$205
		OHV-V6/V8	$104
Discrete Variable Valve Lift	2.8 to 3.9	OHC-I4	$163
		OHC-V6	$236
		OHC-V8	$338
Continuously Variable Valve Lift	3.6 to 4.9	OHC-I4	$244
		OHC-V6	$448
		OHC-V8	$489
		OHV-V6	$1,205
		OHV-V8	$1,317
Stoichiometric Gasoline Direct Injection	1.5	I4	$277
		V6	$417
		V8	$501
Turbocharging and Downsizing	12.1 to 14.9	18-bar DOHC V6 to I4	$248
	16.4 to 20.1	24-bar DOHC V8 to V6	$1,188
	20.6 to 24.6	27-bar DOHC V8 to V6	$2,073
Cooled Exhaust-Gas Recirculation	5	All	$305
Aggressive Shift Logic - Level 1	1.9 to 2.7	All	$33
Aggressive Shift Logic - Level 2	5.1 to 7.0	All	$34
Early Torque Converter Lockup	0.4 to 0.5	Automatic	$30
High Efficiency Gearbox	3.8 to 5.7	Automatic/Dual clutch	$251
Increased Transmission Speeds	3.1 to 3.9	6-sp AT from 4-sp AT	-$9
	4.9 to 5.34	8-sp AT from 6-sp AT	$80
	11.1 to 13.1	8-sp DCT from 4-sp DCT	$62

TABLE 41. Costs and Fuel Savings for Selected Technologies, 2012 (continued)

Technology	Reduction in Fuel Consumption (Percent)	Vehicle Attributes	Estimated Incremental Cost for 2017 (2010 dollars)
Dual Clutch Transmissions	5 to 6	6-sp DCT-dry	-$116
	4 to 5	6-sp DCT-wet	-$82
	5 to 6	8-sp DCT-dry	-$16
	4 to 5	8-sp DCT-wet	$47
Low Rolling Resistance Tires Level 1	1.9	10% lower resistance	$7
Low Rolling Resistance Tires Level 2	3.9	20% lower resistance	$73
Low Drag Brakes	0.8	All	$74
Axle Disconnect for 4-wheel Drive System	1.2 to 1.4	All 4-wheel drive	$98
Aerodynamic Drag Improvements	2 to 3	All	$213

Notes: OHC = overhead cam; OHV = overhead valve; DOHC = dual overhead cam; AT = automatic transmission; sp = speed. The Environmental Protection Agency estimated the incremental costs to be the increase in the cost of manufacturing a vehicle with the technology.

Source:

U.S. Environmental Protection Agency and U.S. Department of Transportation, *Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards*, EPA-420-R-12-901, August 2012. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Joint_final_TSD.pdf

Fuel-Saving Engine Technologies under Development

These fuel-saving technologies are currently under development to improve engine efficiency.

TABLE 42. Selected Fuel-Saving Engine Technologies under Development

Technology	Description
Compression ignition technologies for gasoline engines HCCI, GCI, RCCI and PPC	Homogenous charge compression ignition (HCCI) is a combustion strategy that applies diesel technology to gasoline engines. A very lean mixture of gasoline and air are thoroughly mixed and compressed in the cylinder until auto-ignition occurs without the need for a spark. This achieves some of the benefits of a diesel engine such as high efficiency without the emissions drawbacks associated with diesel. Other variants of this technology include gasoline compression ignition (GCI), reactivity controlled compression ignition (RCCI), and partially premixed combustion (PPC).
High EGR or dedicated EGR gasoline engines	This technology features high levels of exhaust gas recirculation (EGR) meaning the combustion is diluted compared to conventional combustion. In a particular form of this technology, one cylinder can be dedicated to providing exhaust to the other cylinders. The exhaust generating cylinder can be operated fuel rich to feed some products of incomplete combustion to the other cylinders which can improve fuel efficiency and reduce emissions.
Camless Valve Actuation	Rather than opening and closing the valves mechanically with a cam shaft, there are efforts to reduce these mechanical losses by opening and closing the valves electronically.
Variable Compression Ratio	In standard engines, the compression ratio is fixed across all operating conditions based on cylinder geometry. Variable compression ratio increases efficiency by altering the cylinder compression ratio. New engine designs can mechanically vary cylinder geometry. This allows for engines that can operate at a high-compression ratio under partial or light-load conditions and at a lower compression ratio under heavy-load conditions.
Advanced Corona Ignition System (ACIS)	As fuel mixtures become increasingly lean in gasoline engines, the importance of achieving maximum combustion efficiency is critical. In contrast to the traditional spark plug that produces a small, localized spark at the top of the combustion chamber, the ACIS provides a plasma burst throughout the combustion chamber, igniting the fuel air mixture more quickly and evenly. This not only improves fuel economy but could also reduce maintenance costs because the ACIS does not suffer from electrode erosion like a traditional sparkplug.
Dynamic Skip Fire (DSF)	A variable displacement technology that uses software to make firing decisions for individual cylinders based on vehicle speeds and load requirements. This differs from standard cylinder deactivation that has a fixed pattern of cylinders that are activated and deactivated.
Opposed piston engines	Opposed piston design features two pistons per cylinder that share a common combustion zone between the cylinder crowns. This design eliminates the cylinder head and reduces engine block size and increases efficiency, but must have a more complex crank system and features port valves.

Source:
Compiled from published sources by Bob Boundy, Roltek, Inc., Clinton, TN, 2017.

Hybridization and Other Engine Technologies Show the Most Promise for Improving Fuel Economy of Medium and Heavy Trucks

As a precursor to the Federal heavy truck fuel economy standards recently finalized, the National Academy of Sciences produced a study of the technologies and approaches to reducing fuel consumption (FC) in medium and heavy trucks. They determined that the most effective technologies in terms of fuel consumption reduction are: hybridization; replacement of gasoline engines with diesel engines; improvement in diesel engine thermal efficiency; improvement in gasoline engine thermal efficiency; aerodynamics, especially on tractor-trailers; reduced rolling resistance; and weight reduction. Hybridization and other engine technologies show the most promise for improving fuel economy of medium and heavy trucks.

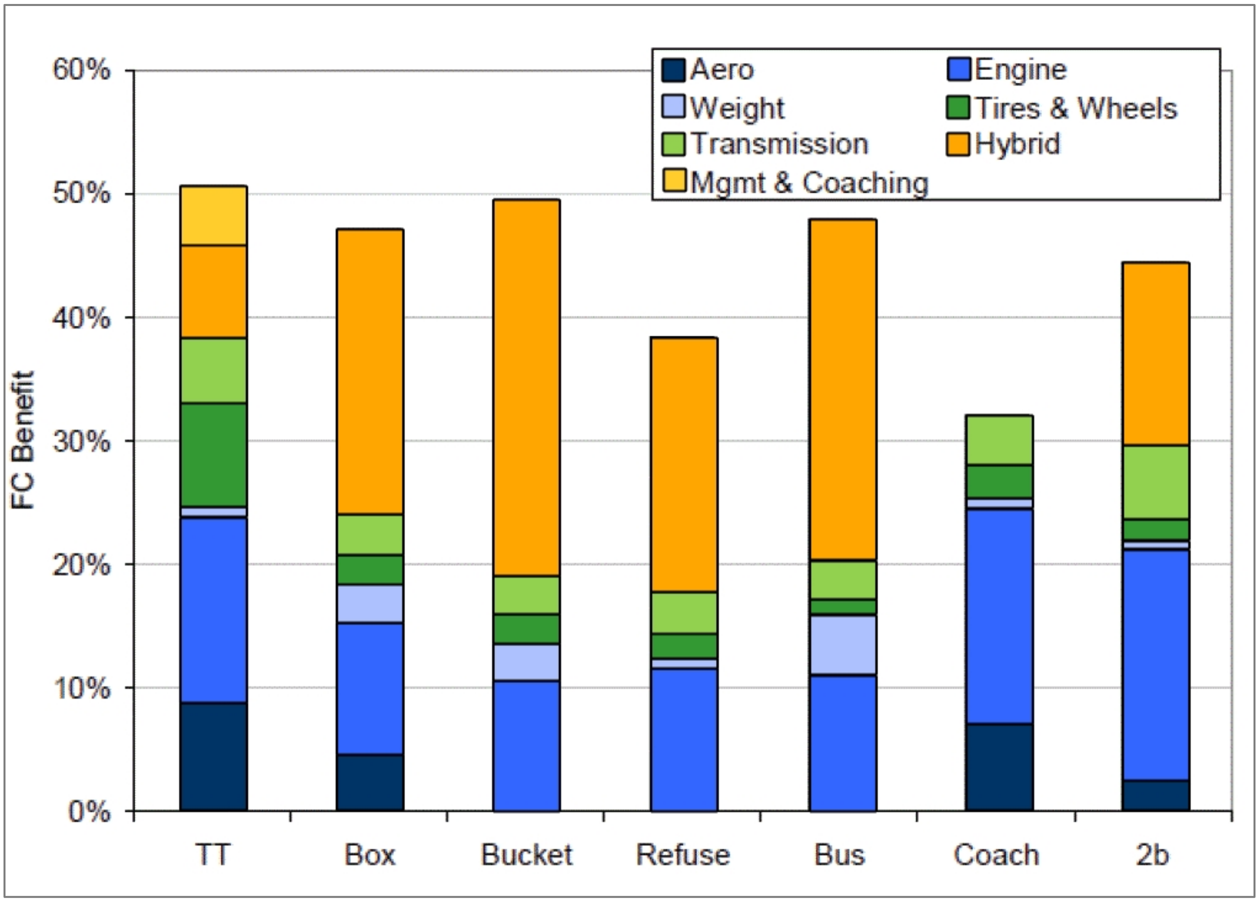


FIGURE 125. Comparison of 2015-2020 New Vehicle Potential Fuel Saving Technologies

Notes: FC Benefit = fuel consumption benefit; TT = tractor-trailer; Box = Class 3-6 box truck; Bucket = Class 3-6 bucket truck; Refuse = Class 8 refuse truck; Bus = transit bus; Coach = motor coach; 2b = Class 2b pickups and vans; Areo = aerodynamics; Mgmt = management.

Source:

TIAX, LLC. As shown in the National Research Council and Transportation Research Board*, Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*, 2010. http://www.nap.edu/catalog.php?record_id=12845

Heavy Vehicles Use Hybrid Technologies in Different Ways

FIGURE 126. Hybrid Bucket Truck

Hybridization of medium and heavy trucks can lead to significant gains in efficiency but optimum configuration of the hybrid system and potential gains in efficiency are highly dependent on the application. Bucket trucks that spend much of their time in a stationary position but running the engine to power the boom could benefit greatly from separating driving power requirements from stationary operation requirements. Engine run time could be drastically reduced through the electrification of auxiliary equipment.

Other heavy vehicles that operate at low speed and with frequent stops like a city bus or refuse truck may benefit more from a hydraulic hybrid system. Still in the prototype phase of development, the EPA claims a potential decrease in fuel consumption by as much as 50%. The hydraulic hybrid system is particularly well suited to heavy truck applications because the hydraulic system can recapture about 70% of the kinetic energy while the storage system is very efficient. This favors a duty cycle that involves a high degree of regenerative breaking but lower sustained power requirements.

FIGURE 128. Hybrid Bus

FIGURE 127. Tractor Trailer

Long-haul class 8 tractor-trailers have a unique set of requirements that favors a different approach to hybridization. The duty cycle involves long periods of sustained work followed by long periods at rest. While driving, tractor trailers can benefit from the electrification of engine driven devices like air conditioning, power steering, water pumps and fans that are normally belt driven. Accessories which are connected to the engine by a belt create a parasitic loss on the engine while it is running. Electrically-powered accessories only draw power when in use, which can provide fuel savings, especially for devices with intermittent use.

When stopped overnight, trucks are often left to idle in order to power the cabin accessories while the driver is at rest. This consumes up to one gallon of diesel per hour. Some truck stops have begun providing external power services in an attempt to reduce overnight idling. Another approach is to integrate smaller heating and cooling systems into the truck that use considerably less fuel than the regular engine.

Source:

National Research Council and Transportation Research Board, *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*, 2010.

(Pictures from the National Renewable Energy Laboratory.)

SmartWay Technology Program Promotes More Efficient Transport Through Heavy Truck Technologies

As part of SmartWay Transport Partnership, begun in 2004, the U.S. Environmental Protection Agency (EPA) certifies tractors and trailers that incorporate efficient technologies. When manufacturers equip tractors and trailers with certified SmartWay specifications and equipment, they are given a SmartWay designation

An EPA-certified SmartWay **tractor** is characterized by a model year 2007 or later engine; integrated sleeper-cab high roof fairing; tractor-mounted side fairing gap reducers; tractor fuel-tank side fairings; aerodynamic bumper and mirrors; options for reducing periods of extended engine idling (auxiliary power units, generator sets, direct-fired heaters, battery-powered HVAC system, and automatic engine stop-start system); and options for low-rolling resistance tires (single wide or dual) mounted on aluminum wheels.

An EPA-certified SmartWay **trailer** is characterized by side skirts; weight-saving technologies; gap reducer on the front or trailer tails (either extenders or boat tails); and options for low-rolling resistance tires (single wide or dual) mounted on aluminum wheels.

TABLE 43. SmartWay Certified Tractor and Trailer Manufacturers

Tractors	Trailers
Daimler	Great Dane Trailers
International	Hyundai Translead
Kenworth	Manac Inc.
Mack	Stoughton Trailers, LLC
Navistar	Strick Trailers, LLC
Peterbilt	Utility Trailer Manufacturing Company
Volvo	Vanguard National Trailer Corporation
Western Star	Wabash National Corporation
	Wilson Trailer Co.

Certain tires, known as low rolling resistance tires, can reduce nitrogen oxide emissions and fuel use by three percent or more. Currently, the EPA has 278 different brands of tires on their list of verified low rolling resistance tires.

Source:
U.S. Environmental Protection Agency, SmartWay Technology Program. http://www.epa.gov/smartway/forpartners/technology.htm

Hybrid Technologies Improve Fuel Economy

There are many different implementations of hybrid technology but most fall within these basic technologies.

TABLE 44. Hybrid Technologies

Technology	Description
Integrated Starter/Generator	Often referred to as "stop-start" or "mild hybridization", this system shuts off the engine during deceleration and when stopped but instantly restarts the engine when the brake is released or the accelerator is depressed. This type of system can be integrated with regenerative braking.
Parallel Hybrid	A parallel hybrid system is one where the wheels of the vehicle can be turned by either the gasoline engine or an electric motor or both simultaneously. The Toyota Prius is an example of a parallel hybrid.
Series Hybrid	A series hybrid is only propelled by a single source, typically an electric motor while electricity is supplied by an engine that acts as a generator. The Chevrolet Volt functions primarily as a series hybrid when the gasoline engine is required.
Dual Mode Hybrid	A dual-mode or two-mode hybrid can operate in either parallel or series hybrid configuration depending on the circumstances. The dual-mode hybrid is well suited for heavy applications like busses and light vehicles where towing is a consideration.
Plug-in Hybrid	A plug-in hybrid is often referred to as an extended range electric vehicle because of its ability to charge from a wall outlet and run entirely on electricity until the battery pack is depleted, at which time an internal combustion engine is used to power the vehicle.
Hydraulic Hybrid	Hydraulic hybrid technology is well suited for heavy duty vehicles in urban settings with frequent stops such as refuse trucks and city buses. Due to the heavy weight of these vehicles, a tremendous amount of energy is lost during frequent starts and stops during driving. A hydraulic system can recapture large amounts of energy very quickly and efficiently.
Electric Continuously Variable Transmission (eCVT)	The eCVT transmissions are designed for hybrid vehicles that require multiple combinations of inputs to drive the wheels whether an electric motor, gasoline engine or both. The eCVT transmission uses a combination of gears to provide variable gear ratios rather than a belt and cones or pulleys used in standard CVT transmissions.

Source:
Compiled from published sources by Bob Boundy, Roltek, Inc., Clinton, TN, 2017.

Much of the Highway Operational Energy Losses for Class 8 Trucks Are from Aerodynamics

For Class 8 long-haul tractor trailers, the engine accounts for more than half of the energy losses, whether the truck is traveling over the highway or in the city. Operational losses, however, are vastly different depending on whether the truck is on the highway or in the city. Overcoming aerodynamic drag is the greatest burden from an energy loss standpoint on the highway, followed by rolling resistance. In city driving, the braking (loss of inertia) plays a much bigger role in energy losses.

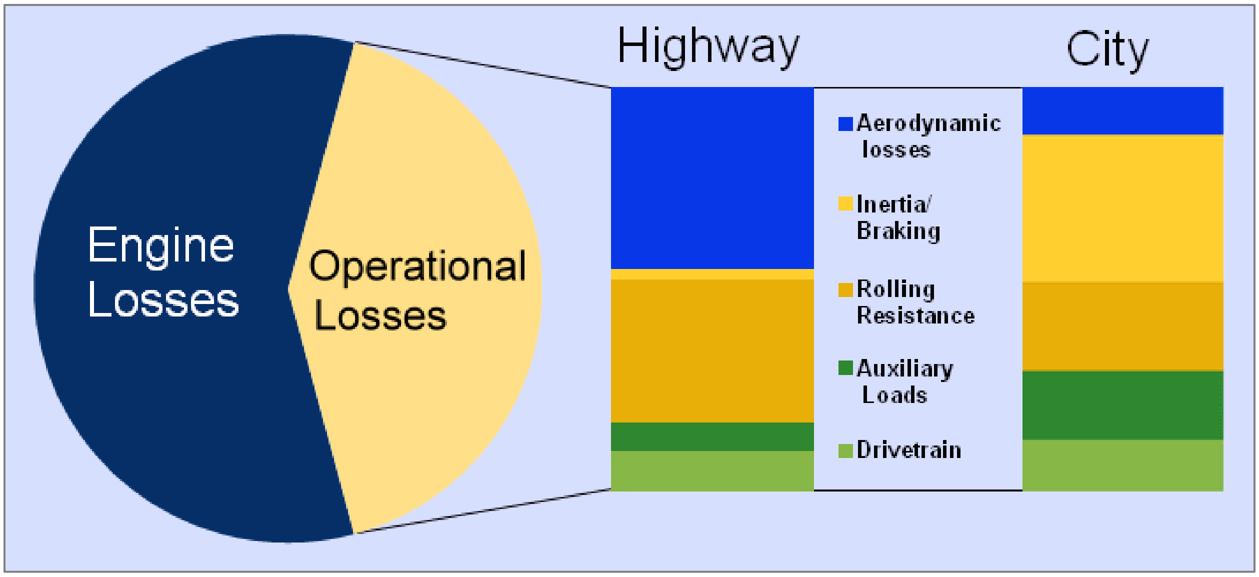


FIGURE 129. Class 8 Truck-Tractor Energy Losses

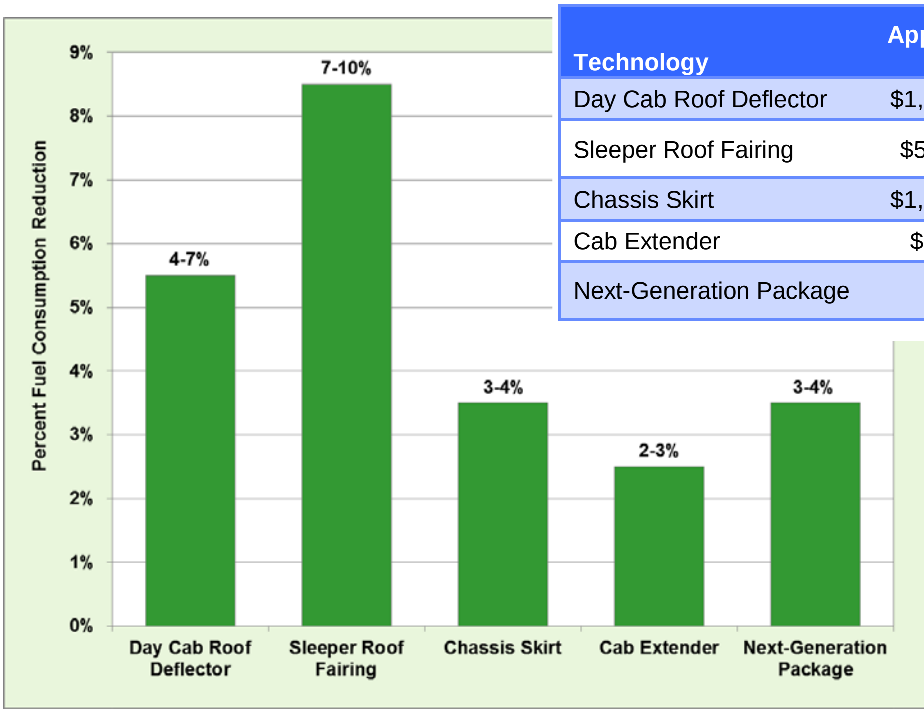
Note: Applies to Class 8 tractor with sleeper cab and van-type trailer at 65 miles per hour with a gross vehicle weight of 80,000 pounds.

Source:

National Research Council and Transportation Research Board, *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*, 2010. http://www.nap.edu/catalog.php?record_id=12845

Some Aerodynamic Technologies Are Widely Adopted

Aerodynamic drag is a large energy loss point for Class 8 tractor-trailers. Aerodynamic devices like cab fairings that do not hinder performance and are usually free from accidental damage have been widely adopted. Other devices like chassis skirts that are more prone to road damage or gap reducers that reduce the gap between the cab and trailer to improve aerodynamics but prevent tight turns have not been as widely adopted. Boat tails that are fitted on the back of a trailer reduce drag but increase the length of the trailer, which can have practical or regulatory implications.



Technology	Approximate Cost	Industry Adoption Rate
Day Cab Roof Deflector	$1,000-1,300	Most
Sleeper Roof Fairing	$500-1,000	Standard equipment
Chassis Skirt	$1,500-2,000	50-60%
Cab Extender	$300-500	80-90%
Next-Generation Package	$2,750	2012 Introduction

FIGURE 130. Fuel Consumption Reduction Rate, Approximate Cost, and Industry Adoption Rate for Aerodynamic Technologies

Though there are potential savings with improved aerodynamics, there are challenges as well. Adding aerodynamic devices to trailers such as skirts or trailer bogies can be challenging; because the trailer and tractor are often owned separately and the fuel savings are realized by the owner of the tractor, there is often little incentive for the trailer owner to invest in fuel saving devices. Also, trailers outnumber tractors and tend to log fewer annual miles than tractors. This extends the payback period for investment in aerodynamic improvements to trailers. Additionally, for every 1,000 lb of weight added, there is a 0.5% penalty in fuel consumption. Trailer skirts alone can add more than 200 lb to the weight of a standard 53-foot trailer.

Note: Next-generation package = features designed and optimized for long-haul tractors in 2012.

Source:

National Research Council and Transportation Research Board*, Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles*, 2010. http://www.nap.edu/catalog.php?record_id=12845

Single Wide Tires Improve Fuel Economy of Class 8 Trucks

A study done by Oak Ridge National Laboratory outfitted Class 8 trucks with monitoring equipment which measured the fuel economy of the vehicle along with many other variables. During the study period, the truck-tractors sometimes had standard dual tires and at other times used single very wide tires on the same roads with similar loads. The results of the study show fuel economy improvements due to single wide tires average 7.1% on flat terrain, but can be as much as 16% improvement on severe downslopes.

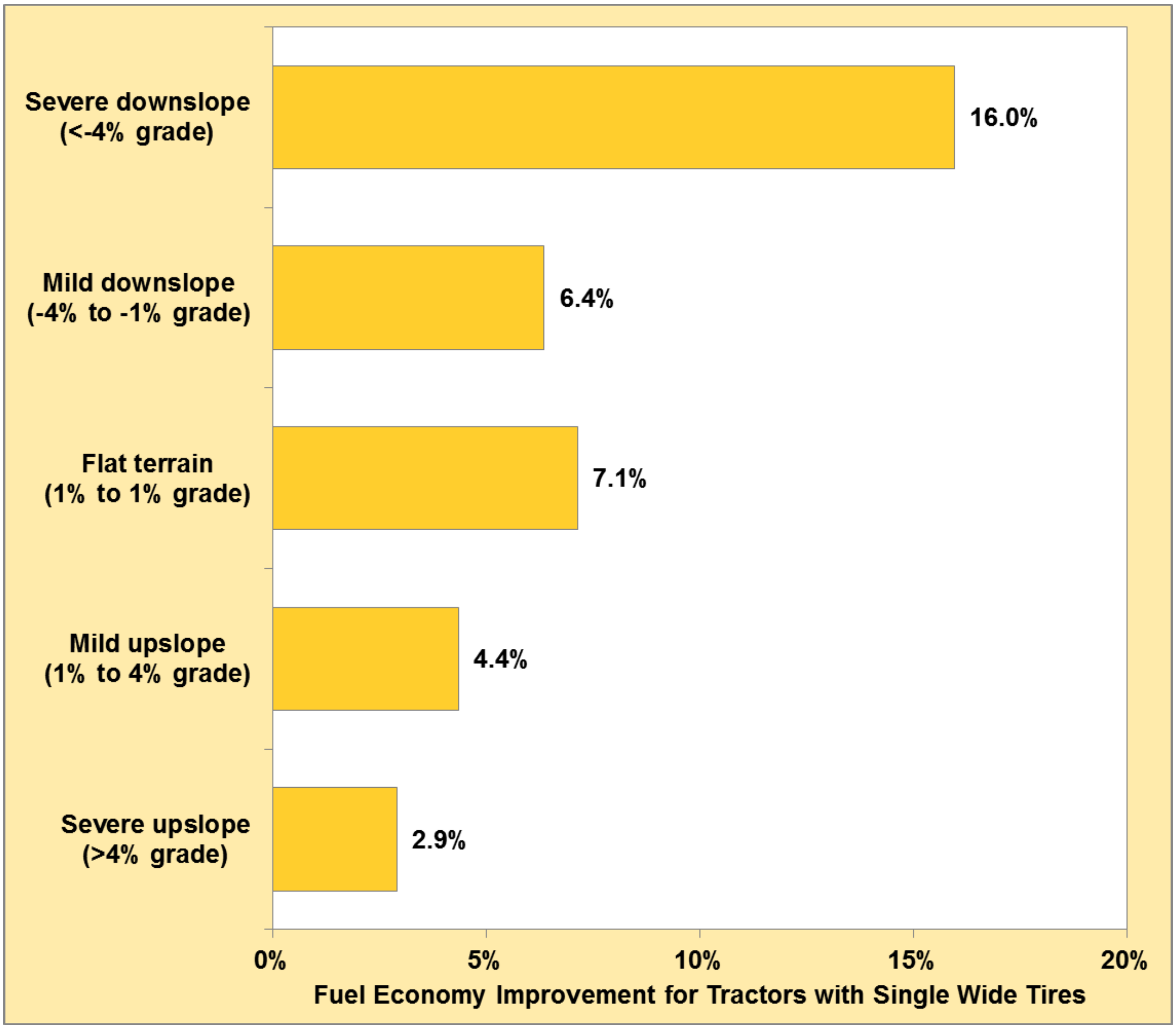


FIGURE 131. Fuel Economy Improvement for Class 8 Tractors with Single Wide Tires

Source:

Franzese, Oscar, *Effect of Weight and Roadway Grade on the Fuel Economy of Class-8 Freight Trucks*, Oak Ridge National Laboratory, ORNL/TM-2011/471, October 2011. http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2011_471.pdf

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CHAPTER 6

POLICY

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Federal Tax Credits Encourage the Purchase of Advanced Technology Vehicles

The Federal Government encourages the use of different transportation fuels by allowing tax credits on vehicle purchases. Between 2005 and 2010, those who purchased hybrid vehicles or vehicles that ran on alternative fuels, such as natural gas, methanol, and hydrogen, received Federal tax credits. Now, electric vehicles (EVs) and plug-in hybrid-electric vehicles (PHEVs) are the only vehicles for which a Federal tax credit is available – up to $7,500.

TABLE 45. Federal Government Tax Incentives for All-Electric Vehicles and Plug-In Hybrid Electric Vehicles, Model Years 2015-2017

Maximum Credit Amount	Vehicle Type	Vehicles Currently Eligible for a Tax Credit
$7,500	EV	2015–17 BMW i3 Sedan
	EV	2017 BMW i3 Sedan (w/ 60 amp-hr battery)
	EV	2015 BYD e6 Electric Vehicle
	EV	2015–17 Fiat 500e
	EV	2015–16 Ford Focus EV
	EV	2017 Chevrolet Bolt
	EV	2015–16 Chevrolet Spark EV
	EV	2015–16 Kia Soul Electric
	EV	2015–17 Mercedes-Benz B-Class EV
	EV	2016-17 Mitsubishi i-MiEV
	EV	2015–16 Nissan Leaf
	EV	2015–16 smart fortwo electric vehicle
	EV	2015–16 Tesla Model S
	EV	2016 Tesla Model X
	EV	2015–16 VW e-Golf
	PHEV	2015–16 BMW i3 Sedan w/ Range Extender
	PHEV	2016 Cadillac ELR
	PHEV	2015–17 Chevrolet Volt
$5,335.60	PHEV	2015 Porsche Cayenne S E-Hybrid
$4,919	PHEV	2016 Hyundai Sonata Plug-in Hybrid Electric Vehicle
$4,751.80	PHEV	2015 Porsche Panamera S E-Hybrid
$4,668	PHEV	BMW 2016–17 X5 xDrive40e
$4,668	PHEV	BMW 2017 740e
$4,585	PHEV	2016-17 Volvo XC-90 T8 Twin Engine Plug in Hybrid
$4,502	PHEV	2016-17 Audi A3 e-tron
$4,502	PHEV	2017 Toyota Prius Prime Plug-in Hybrid
$4,084.60	PHEV	2016-17 Mercedes-Benz GLE550e 4matic
$4,042.90	PHEV	2015-16 Mercedes-Benz S500e Plug-in Hybrid
$4,007	PHEV	2015–16 Ford C-Max Energi
$4,007	PHEV	2015–17 Ford Fusion Energi
$4,001	PHEV	BMW 2016–17 330e
$3,793	PHEV	BMW 2015-17 i8
$3,667	PHEV	2015 Porsche 918 Spyder
$2,500	PHEV	2015 Toyota Prius Plug-in Hybrid

Note: The credit is equal to $2,500 plus, for a vehicle which draws propulsion energy from a battery with at least 5 kilowatt hours of capacity, $417, plus an additional $417 for each kilowatt hour of battery capacity in excess of 5 kilowatt hours. The total amount of the credit allowed for a vehicle is limited to $7,500.

Source:

U.S. Department of Energy fuel economy data, accessed January 19, 2016.
http://www.fueleconomy.gov/feg/taxcenter.shtml.

California Had the Highest State Incentive for Plug-In Vehicles in 2016

In addition to a Federal government tax credit up to $7,500, consumers who purchase plug-in electric vehicles (PEVs) may also receive state government incentives which vary by state. Shown below are state incentives that can be quantified, such as tax credits and rebates, sales and use tax exemptions, reduced license taxes, title tax exemptions, and reduced registration fees. California, Colorado, and Illinois have the highest incentives for tax credits. New Jersey and Washington State offer sales and use tax exemptions; and DC offers the only title tax exemption and reduced registration fee.

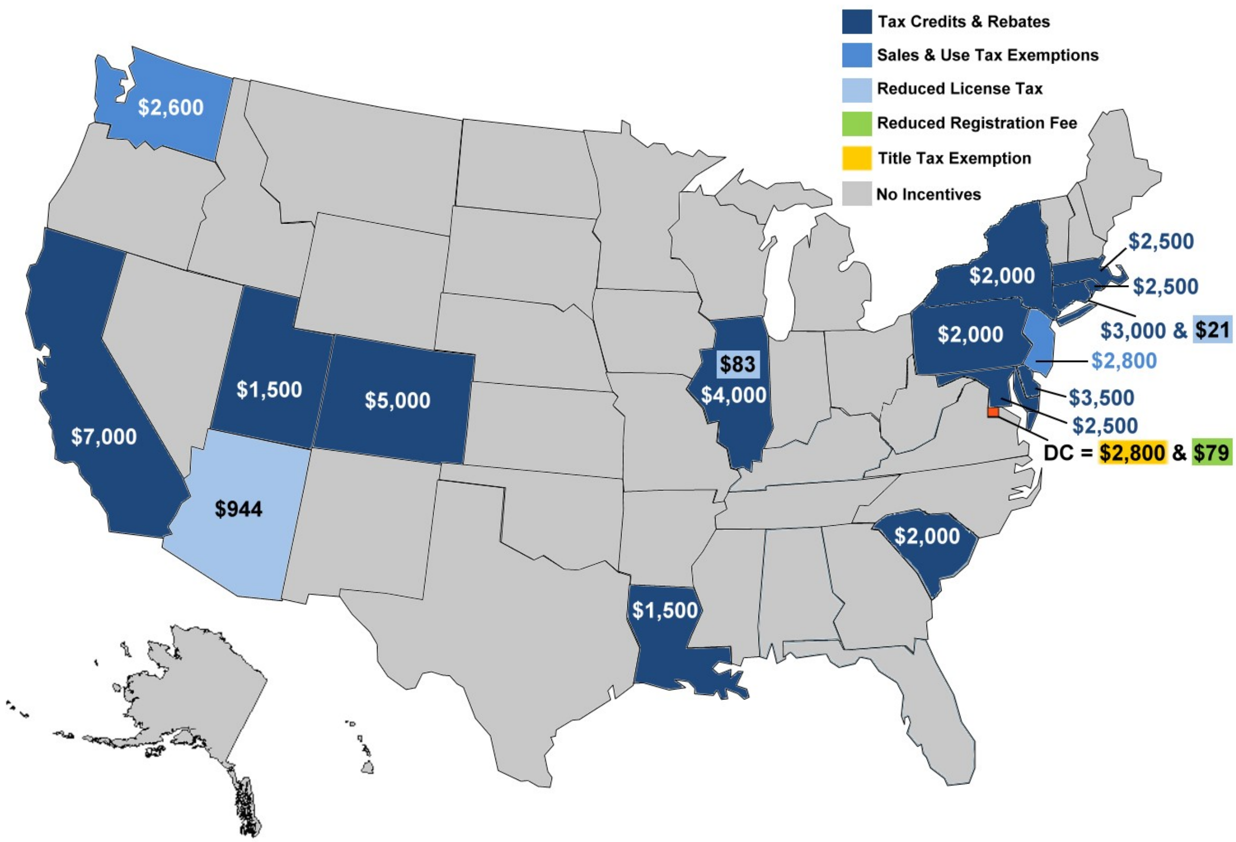

FIGURE 132. Plug-In Electric Vehicle Incentives by State, December 2016

Notes: For calculation purposes, e.g., sales tax exemptions, the vehicle was assumed to have a value of $40,000, a weight of 3,500 lb, and a 20 kWh battery capacity. Other state incentives, such as high-occupancy vehicle lane exemptions and reduced toll rates are not included. Also, incentives on the charging equipment, electricity discounts, etc., are not included.

Source:
Alternative Fuels Data Center, accessed December 2, 2016. http://www.afdc.energy.gov/laws

States Tax Gasoline at Varying Rates

In addition to the 18.4 cents per gallon federal gasoline tax, the states also tax gasoline at varying rates. Some states have sales taxes added to gasoline taxes while others have inspection fees, environmental fees, leaking underground storage tank (LUST) taxes, etc. The Federation of Tax Administrators has estimated the gasoline excise taxes, along with other state taxes and fees, to arrive at an estimate of the amount of state taxes consumers are paying per gallon. According to those estimates, Pennsylvania currently has the highest per gallon tax rate for gasoline; the Pennsylvania rate includes the Oil Franchise Tax for Maintenance and Construction, a variable rate tax adjusted annually. Alaska, with an 9-cent gasoline tax rate, has by far the lowest gasoline tax rate of any state.

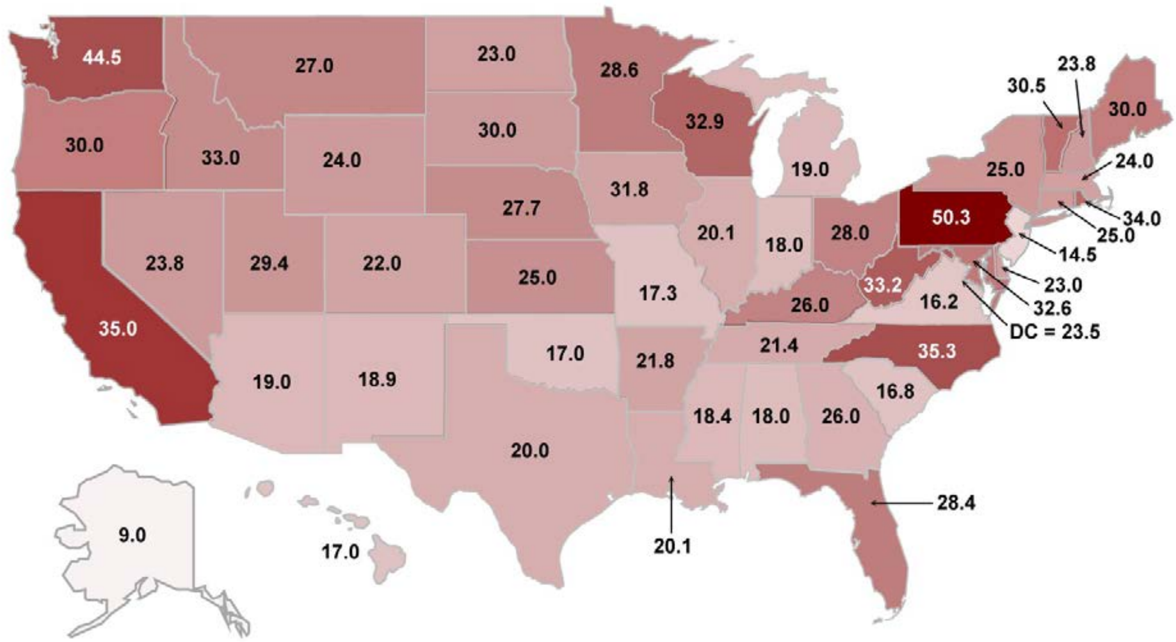

FIGURE 133. State Gasoline Tax Rates, 2016 (Cents per Gallon)

Note: See source for additional specifics on individual state rates.

Source:

Compiled by Federation of Tax Administrators from various sources, January 2016, data accessed December 6, 2016. http://www.taxadmin.org/tax-rates

States Assessing Fees on Electric Vehicles in an Attempt to Make Up for Lost Fuel Tax Revenue

The maintenance of our highways has traditionally been funded from a combination of Federal and state taxes collected at the pump from the sale of motor fuels. Because plug-in electric vehicles (PEVs or EV) do not refuel at pumps that collect state and Federal fuel taxes, they do not contribute to the upkeep of the highways. This has caused many states to rethink how funds are collected to support the highway infrastructure. Eleven states currently assess fees on electric vehicle owners in lieu of traditional fuel taxes. Georgia has the highest annual fee among states that have currently enacted fees for electric vehicles.

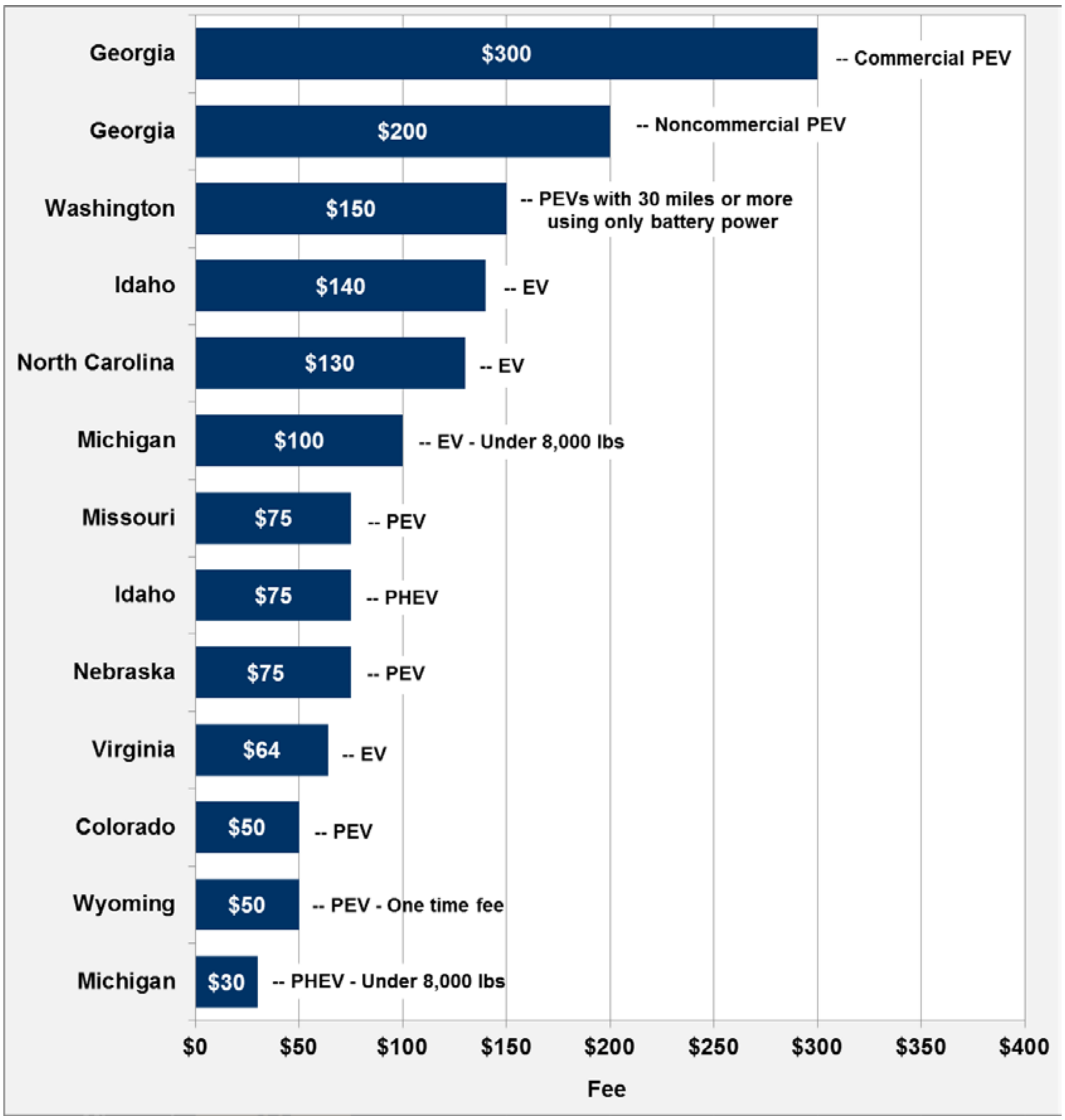

FIGURE 134. Annual State Fees for Electric Vehicle Owners as of April 2017

Source:

Alternative Fuels Data Center, U.S. Department of Energy, Federal and State Laws and Incentives, data accessed April 19, 2017. http://www.afdc.energy.gov/laws

Corporate Average Fuel Economy: Historical Standards and Values

The Corporate Average Fuel Economy (CAFE) is the sales-weighted harmonic mean fuel economy of a manufacturer's fleet of new cars or light trucks in a certain model year (MY). First enacted by Congress in 1975, the standards for cars began in MY 1978 and for light trucks in MY 1979. In general, the average of all cars and all light trucks has met or exceeded the standards each year, although the 2016 estimates based on product plans show a short fall for light trucks. However, standards must be met on a manufacturer level – some manufacturers fall short of the standards while others exceed them. Legislation passed in December 2007 raised the CAFE standards beginning in MY 2011 – for cars, this was the first increase since 1990.

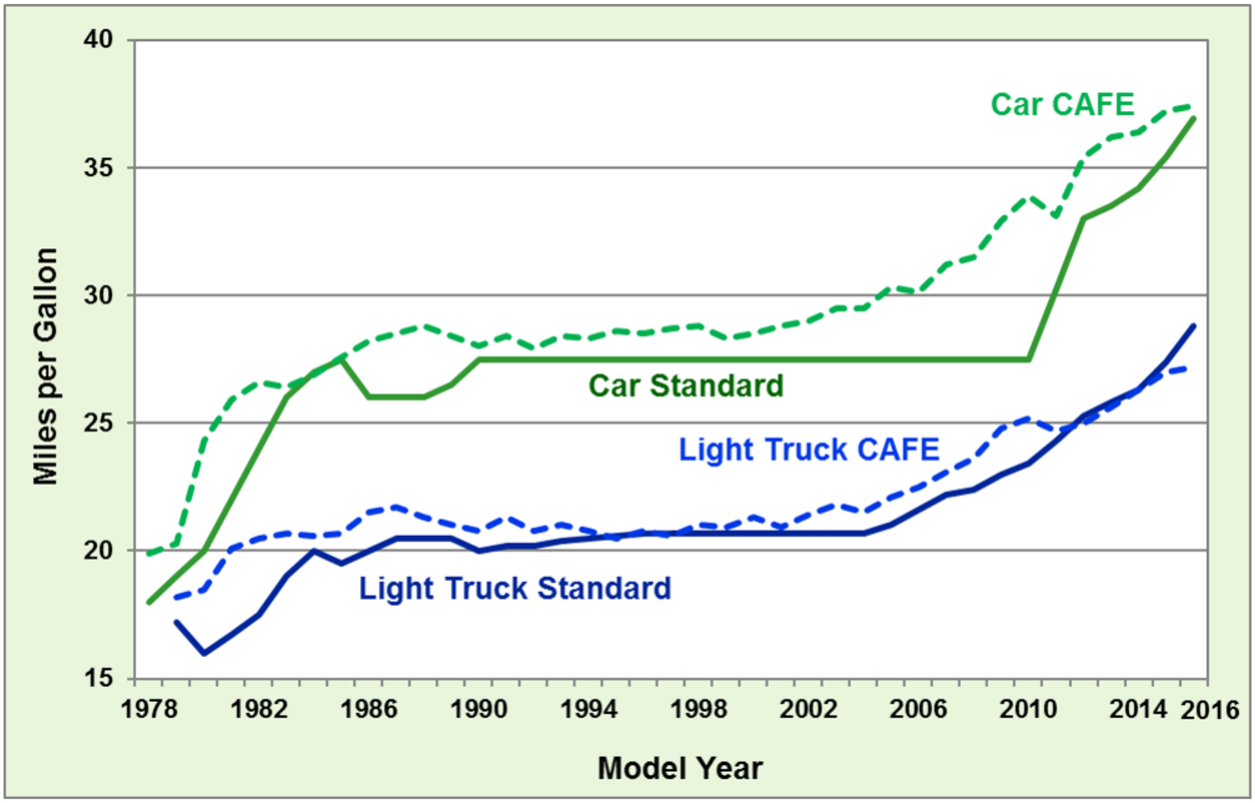

FIGURE 135. CAFE for Cars and Light Trucks, 1978-2016

Note: Light truck standards for MY 2008-2010 are based on "unreformed" standards. MY 2015 and 2016 data are estimates based on product plans.

Source:

National Highway Traffic Safety Administration, CAFE Public Information Center, *Manufacturer Fuel Economy Performance Report*, and *Projected Fuel Economy Performance Report*, February 2017. http://www.nhtsa.gov/fuel-economy

Corporate Average Fuel Economy Improves for All Manufacturers from 2002 to 2016

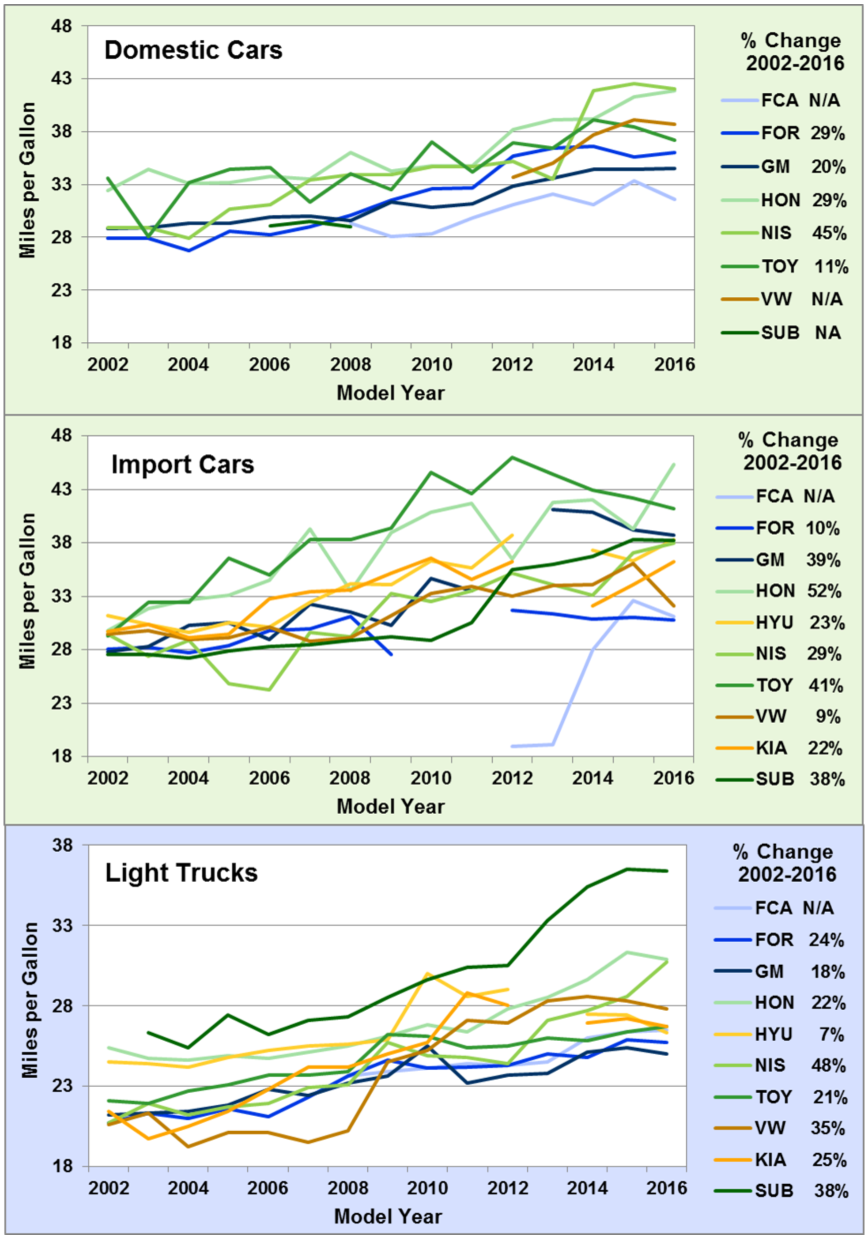

FIGURE 136. Corporate Average Fuel Economy for Domestic and Import Cars and Light Trucks by Manufacturer, 2002-2016

Note: Data for FCA begin in 2008 after the merger with Daimler ended. Ford had no import cars in 2010 and 2011. General Motors had no import cars in 2012. Volkswagen domestic cars begin in 2012. Data were not available for Hyundai and Kia for 2013.

Source:

National Highway Traffic Safety Administration, CAFE Public Information Center, *Manufacturer Fuel Economy Performance Report*, and *Projected Fuel Economy Performance Report*, February 2017. http://www.nhtsa.gov/fuel-economy

Corporate Average Fuel Economy: Average Fleet-Wide Fuel Economies for Future Cars and Light Trucks

The average fleet-wide fuel economies required to meet the Corporate Average Fuel Economy (CAFE) standards are shown below. In May 2010, the final standards were set for model years (MY) 2012 through 2016. In August 2012, the National Highway Traffic Safety Administration (NHTSA) issued final standards for MY 2017 through 2021 and proposed standards for MY 2022 through 2025. These standards apply to cars and pickup trucks less than 8,500 lb gross vehicle weight rating (GVWR), and sport utility vehicles and passenger vans less than 10,000 lb GVWR.

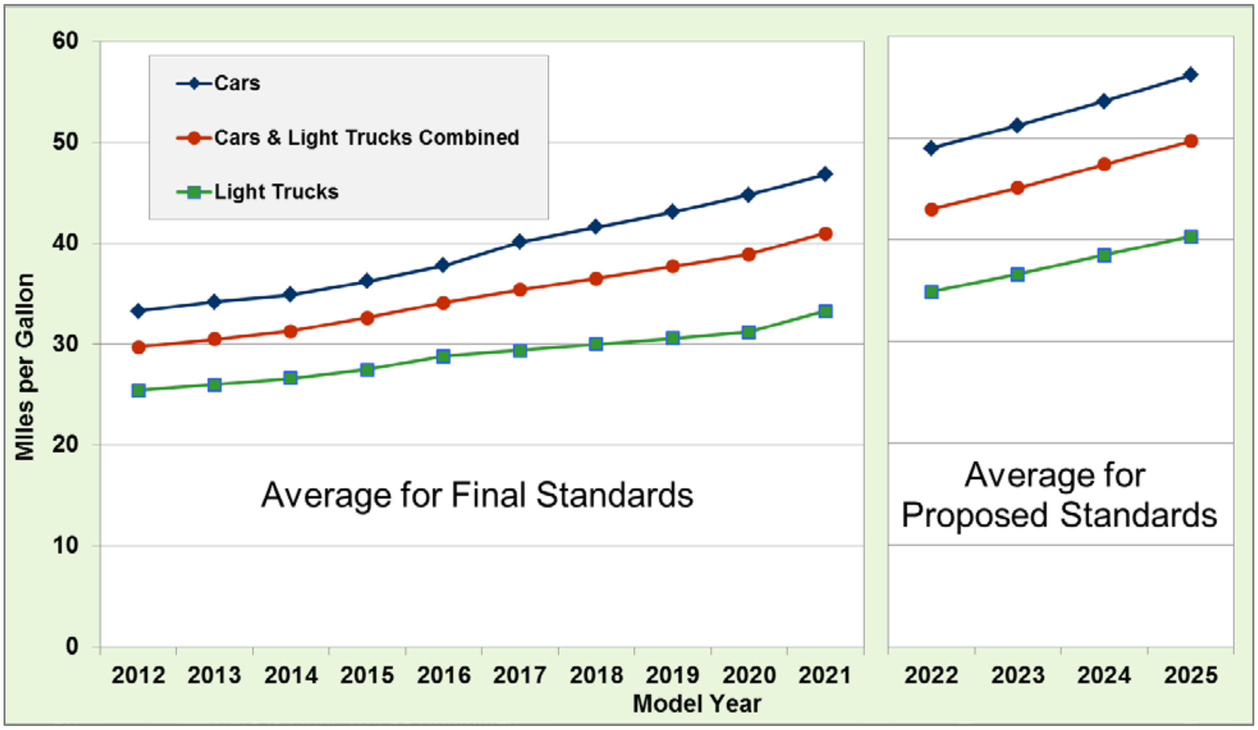

FIGURE 137. Average CAFE Standards for MY 2012-2025

Notes: A MY 2008 baseline was used for MY 2017-2025.

The presented rates of increase in stringency for NHTSA CAFE standards are lower than the Environmental Protection Agency (EPA) rates of increase in stringency for greenhouse gas (GHG) standards. One major difference is that NHTSA's standards, unlike EPA's, do not reflect the inclusion of air conditioning system refrigerant and leakage improvements, but EPA's standards would allow consideration of such improvements which reduce GHGs but generally do not affect fuel economy. The 2025 EPA GHG standard of 163 grams/mile would be equivalent to 54.5 mpg, if the vehicles were to meet this level all through fuel economy improvements. The agencies expect, however, that a portion of these improvements will be made through reductions in air conditioning leakage, which would not contribute to fuel economy.

Sources:

Federal Register, Vol. 75, No. 88, May 7, 2010, pp. 25324-25728.

Final Rule, Docket No. NHTSA-2010-0131, August 28, 2012.

Corporate Average Fuel Economy: Sliding Scale Targets for New Cars and Light Trucks

Corporate Average Fuel Economy (CAFE) standards for light vehicles are defined by target fuel economy values which become increasingly strict each year, and are scaled according to each vehicle's footprint. Vehicles are classified either as a car or truck for regulatory purposes and separate standards apply. Each vehicle model is tested using standardized methods to calculate a miles per gallon (mpg) value which is compared to the appropriate target mpg value for the model year and vehicle's footprint. The manufacturers receive a credit or penalty based on this comparison. The target value curves for years 2022-2025 may be revised during a process known as the "Midterm Evaluation" in which the latest available data will be reviewed and changes made to the curves if appropriate.

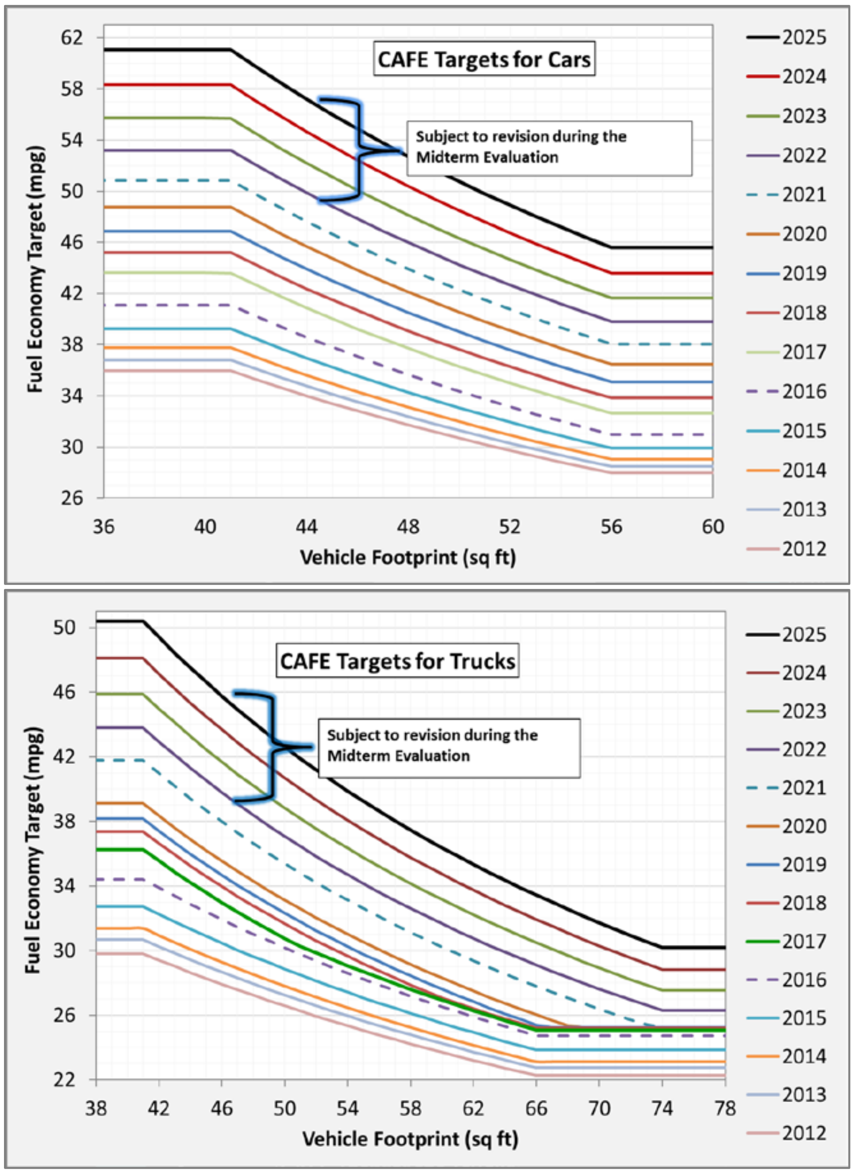

FIGURE 138. CAFE Targets for Cars and Light Trucks, MY 2012-2025

Source:
Final Rule, Docket No. NHTSA-2010-0131, August 28, 2012.

Vehicle Footprints Are Used for Corporate Average Fuel Economy

The vehicle footprint is the area defined by the four points where the tires touch the ground. It is calculated as the product of the wheelbase and the average vehicle track width. The Corporate Average Fuel Economy (CAFE) Standards have fuel economy targets based on the vehicle footprint. The average footprint for all cars sold in model year (MY) 2016 was 46.3 square feet (sq. ft.), up 0.6 sq. ft. from MY 2012. The average footprint for light trucks was 0.3 sq. ft. lower in 2016 than in 2012. The table shows selected vehicles and their MY 2012 footprint with 2025 fuel economy targets.

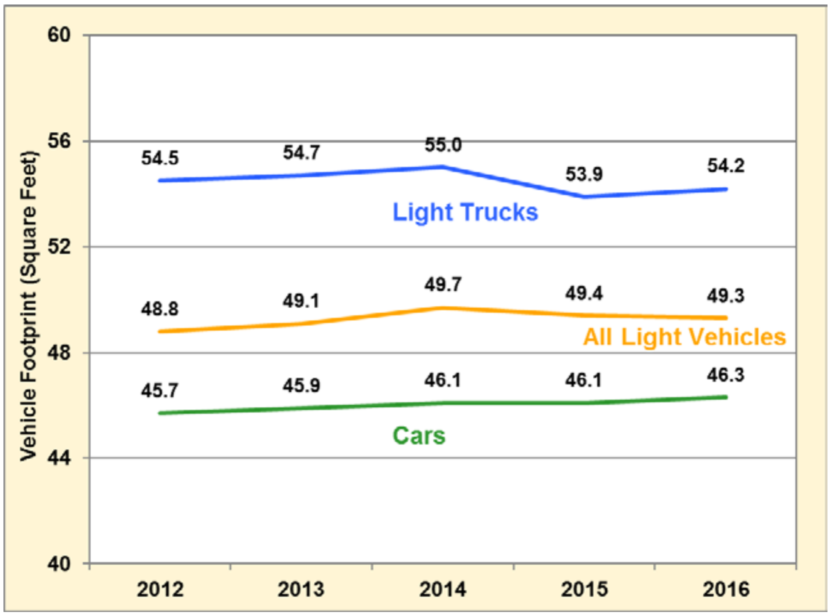

FIGURE 139. Average Vehicle Footprint, MY 2012-2016

TABLE 46. Vehicle Footprint and Fuel Economy Target, MY 2025

Vehicle Type	Example Model (MY 2012 Vehicles)	Footprint (Sq. Ft.)	MY 2025 Fuel Economy Target (mpg)
Cars			
Compact	Honda Fit	40	61.1
Midsize	Ford Fusion	46	54.9
Full-Size	Chrysler 300	53	48.0
Light Trucks			
Small Sport Utility	Ford Escape 4WD	43	47.5
Midsize Crossover	Nissan Murano	49	43.4
Minivan	Toyota Sienna	56	39.2
Large Pickup Truck	Chevrolet Silverado	67	33.0

Sources:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Final Rule, Docket No. NHTSA-2010-0131, August 28, 2012.

GM Has the Highest Light Truck Footprint

The Corporate Average Fuel Economy (CAFE) standards are based on the vehicle's footprint beginning in model year (MY) 2012. For these manufacturers, the footprint for cars has stayed between 45 and 48 sq. ft. from 2012 to 2016. For light trucks, which includes pickups, vans and sport utility vehicles, the difference for manufacturers is more pronounced, with GM having the highest footprint in each year. MY 2016 data are preliminary.

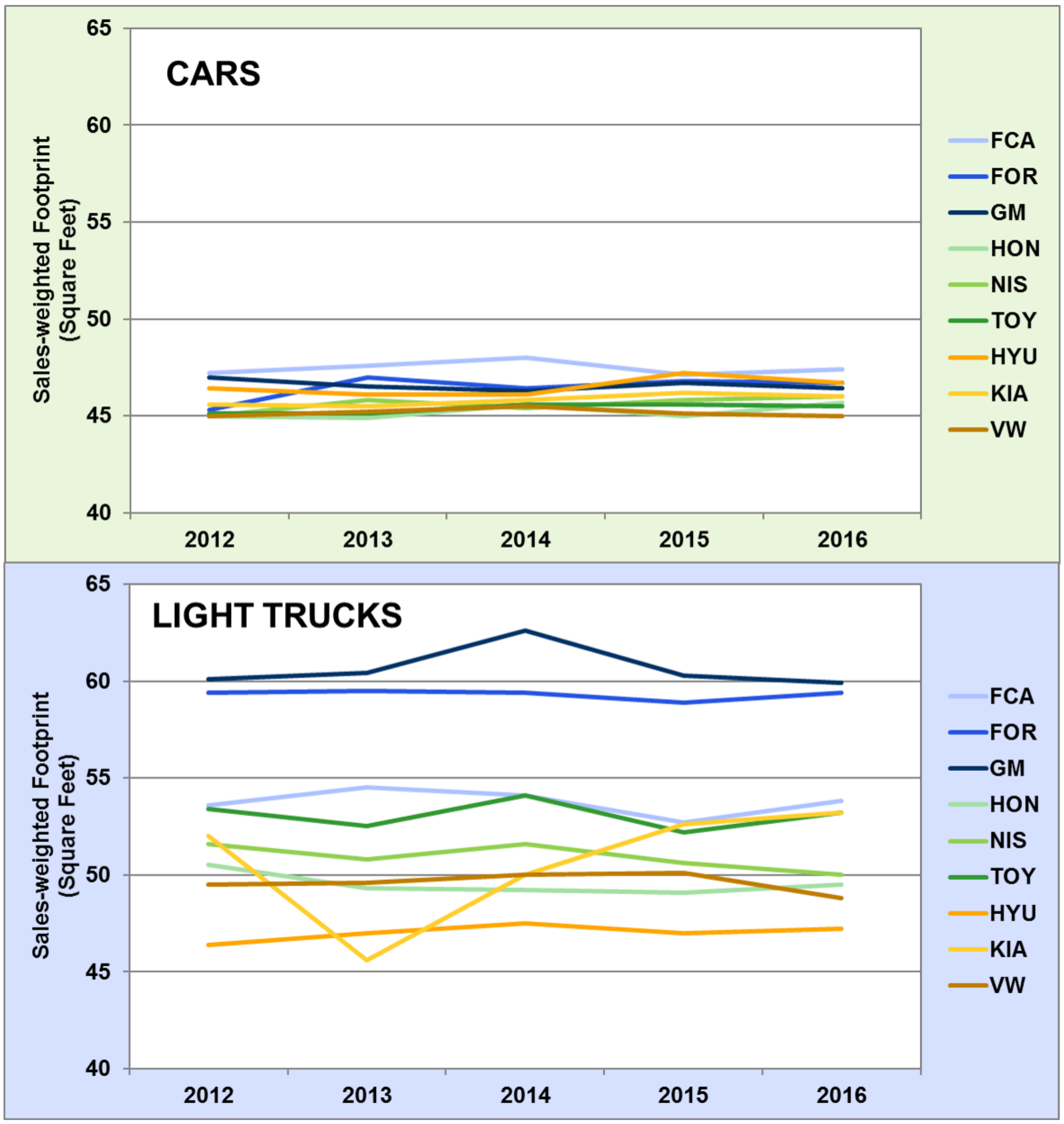

FIGURE 140. Car and Light Truck Footprint by Manufacturer, 2016

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2016*, EPA-420-R-16-010, November 2016. http://www.epa.gov/otaq/fetrends.htm

Honda, Tesla, Toyota, Nissan, and Coda Have Sold CAFE Economy Credits

The rulemaking which established the 2012-2016 Corporate Average Fuel Economy (CAFE) standards included plans for the manufacturers to earn early credits in model years (MY) 2009-2011 as well as credits in MY 2012-2016. As of the end of MY 2015, Honda had sold more than 11 million CAFE credits to other manufacturers. Toyota, Tesla, Nissan, and Coda also sold credits, while eight different manufacturers purchased credits.

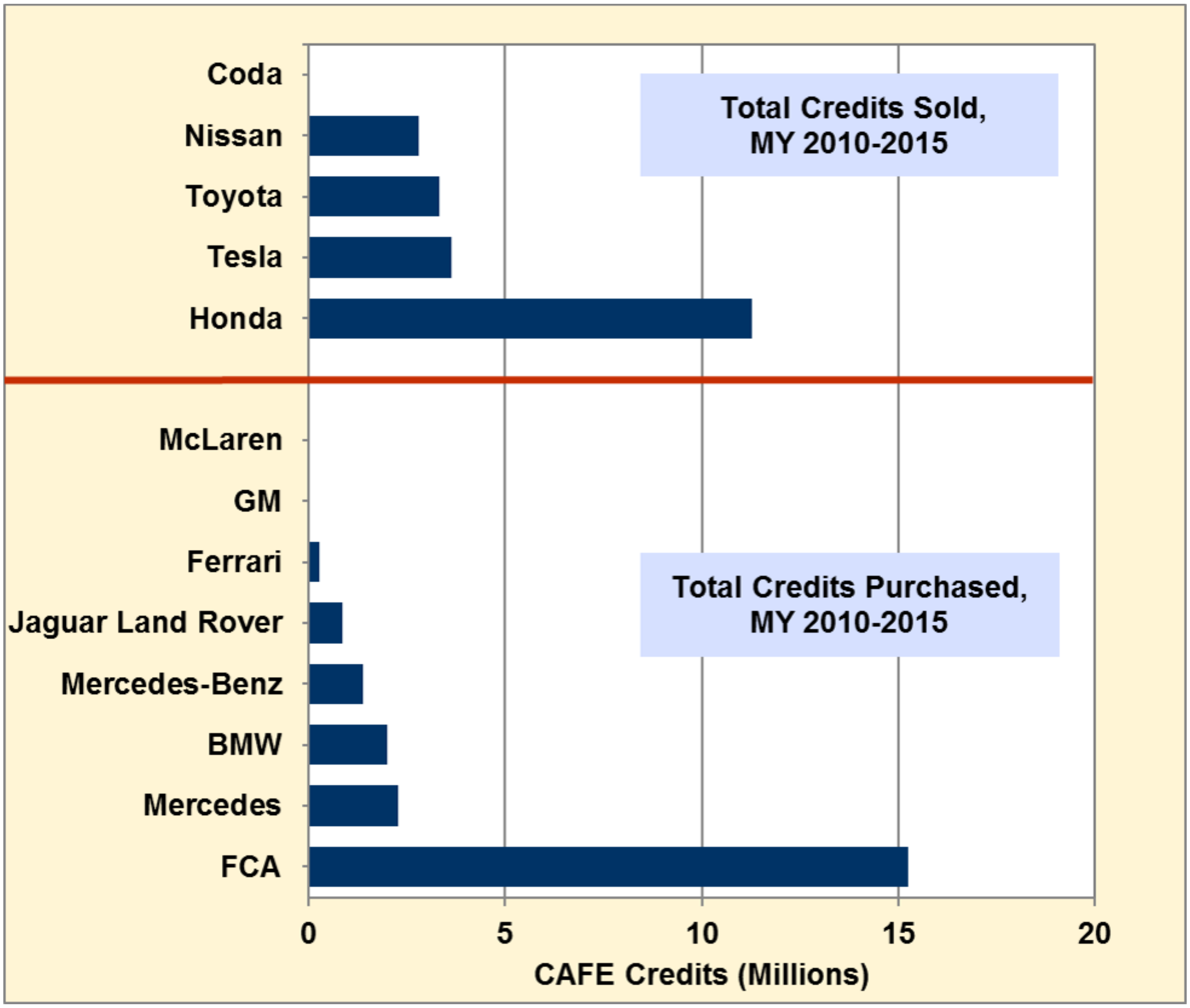

FIGURE 141. Cumulative CAFE Credits Sold and Purchased by Manufacturer at the End of MY 2015

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2015 Model Year*, EPA-420-R-16-014, November 2016. http://www.epa.gov/sites/production/files/2016-11/documents/420r16014.pdf

Nearly All Manufacturers Have CAFE Credits at the End of 2015

Some Corporate Average Fuel Economy (CAFE) credits earned by manufacturers were used to offset deficits in future model years (MY) and some credits were traded among manufacturers. After considering all these credit transactions, as of the end of MY 2015, all manufacturers but Jaguar Land Rover carried a positive balance of credits into MY 2016. This does not, however, mean any manufacturer is out of compliance, as the regulation allows for a deficit to be carried over for up to three model years.

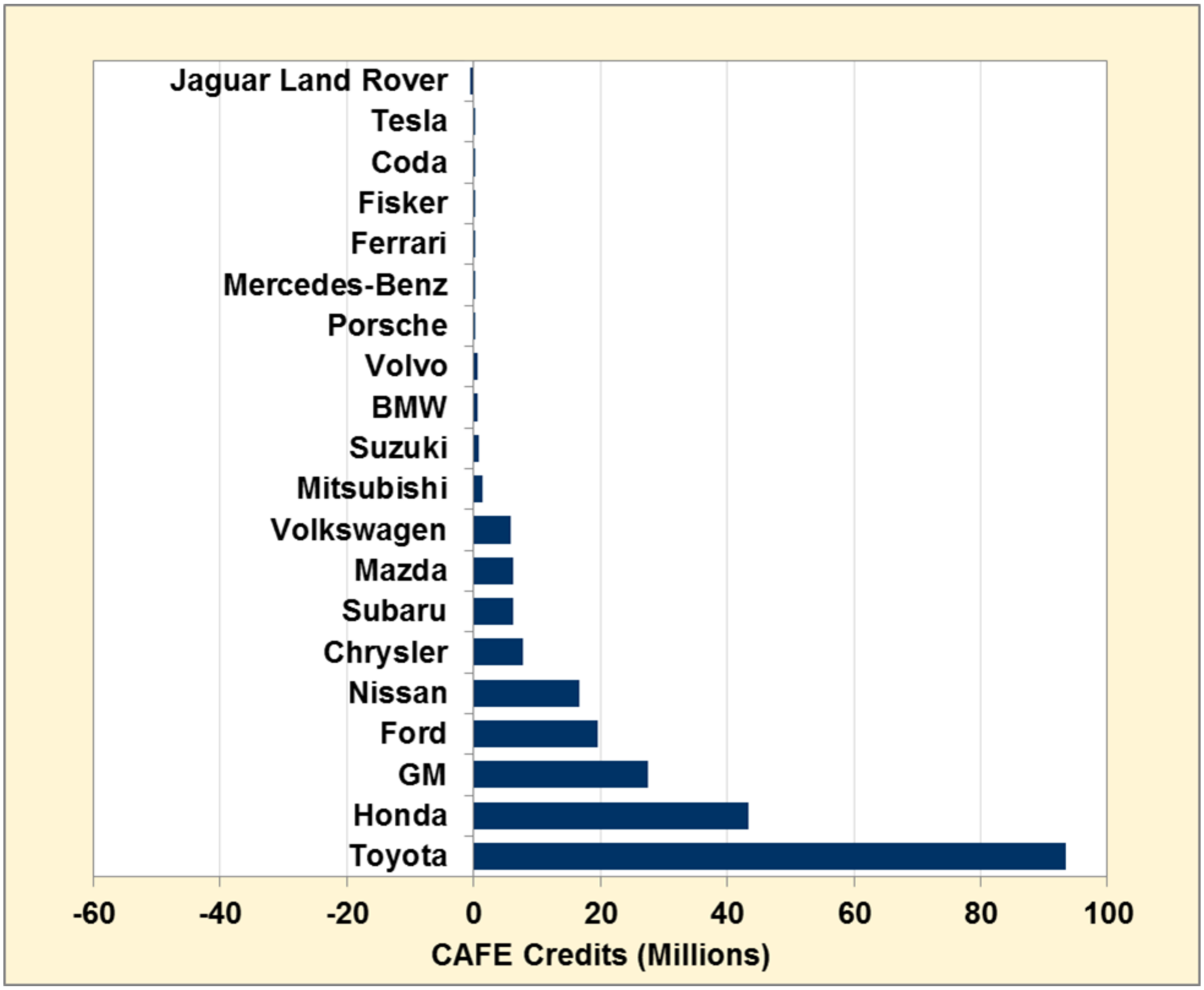

FIGURE 142. Cumulative CAFE Credits by Manufacturer as of the End of MY 2015

Note: VW is not included due to an ongoing investigation.

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2015 Model Year*, EPA-420-R-16-014, November 2016. http://www.epa.gov/sites/production/files/2016-11/documents/420r16014.pdf

Zero-Emission Vehicle Standards in Nine States and Low Carbon Fuel Standards in Development in 13 States

In 2013, the governors of eight states signed the State Zero-Emission Vehicle (ZEV) Programs Memorandum of Understanding to work toward a "collective target of having at least 3.3 million zero-emission vehicles on the road in our states by 2025 and to work together to establish a fueling infrastructure that will adequately support this number of vehicles." All of those states, plus one additional state, have adopted the California ZEV standards. Currently, California is the only state to have adopted a low carbon fuel standard (LCFS), but thirteen other states and the District of Columbia are working towards the development of a LCFS.

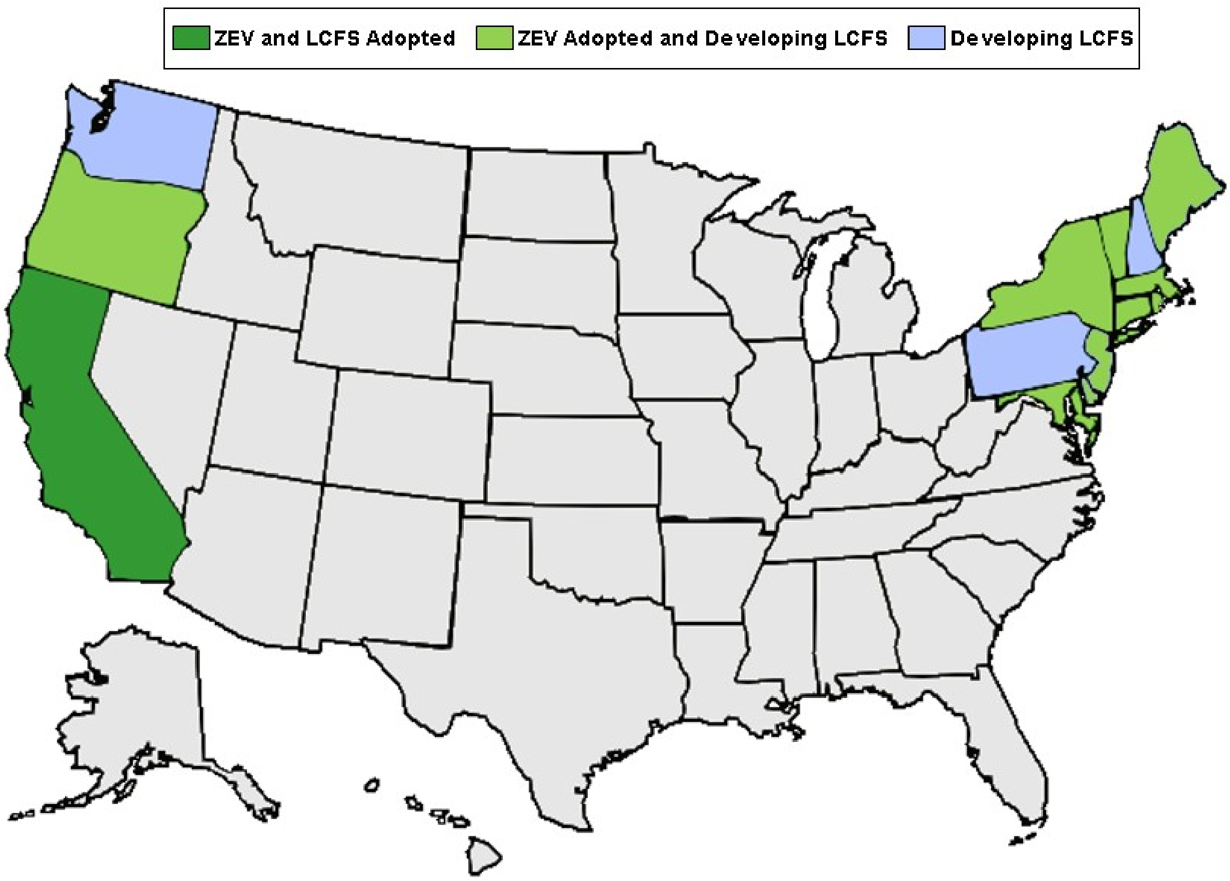

FIGURE 143. States with Zero Emission Vehicle and Low Carbon Fuel Standards

Sources:

State Zero-Emission Vehicle Programs Memorandum of Understanding. http://www.arb.ca.gov/newsrel/2013/8s_zev_mou.pdf

Center for Climate and Energy Solutions, Transportation Sector, ZEV Program and Low Carbon Fuel Standard. http://www.c2es.org/us-states-regions/policy-maps/zev-program-standard

Toyota Has Largest California Zero Emission Vehicle Credit Balance

Taking into account all credit transfers, in and out, California's zero-emission vehicle (ZEV) balances show that Toyota has the largest amount of credit. These credit balances show ZEV regulation compliance through model year 2015. Tesla, the only manufacturer to produce exclusively ZEVs, has transferred many credits to other manufacturers.

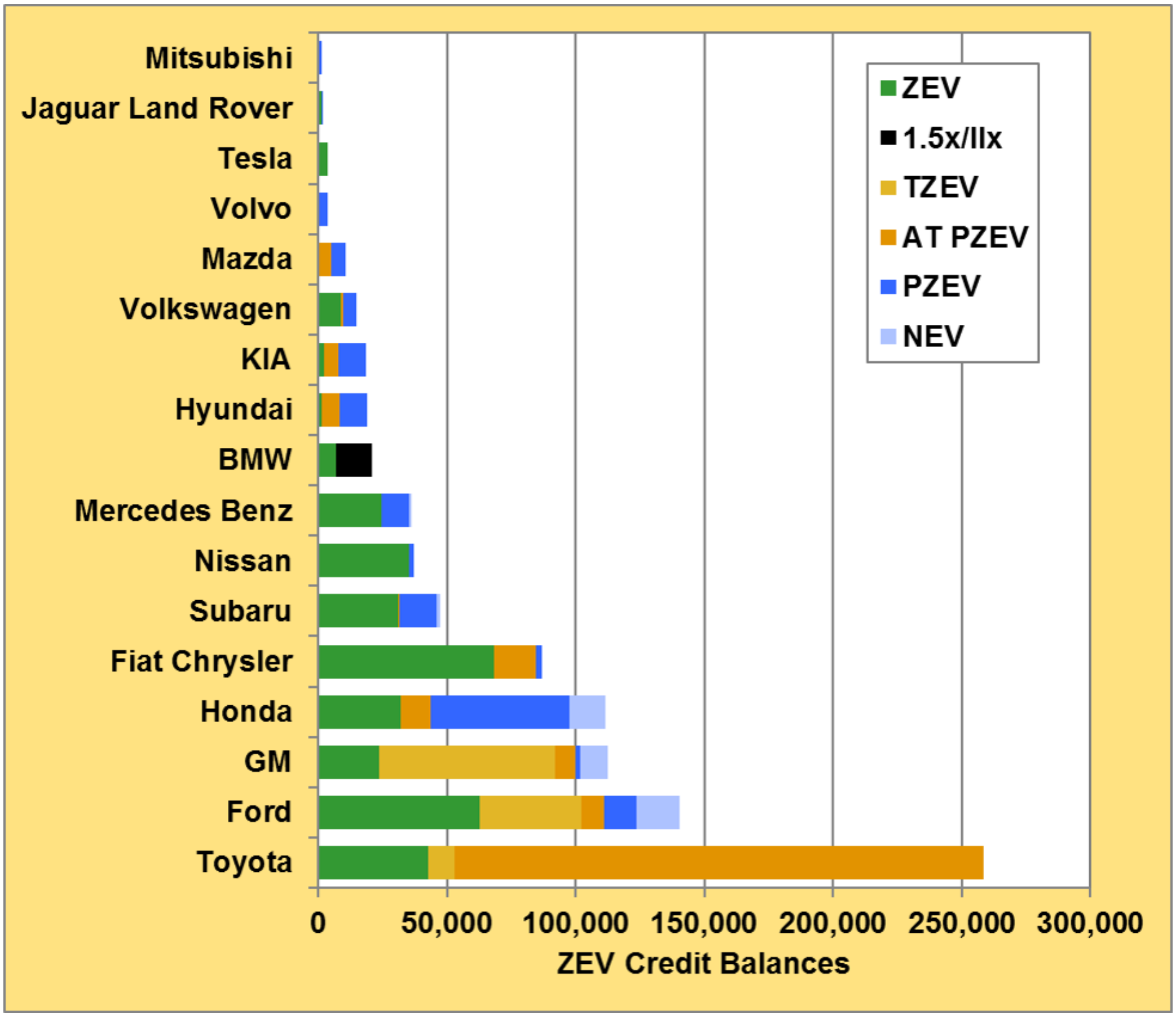

FIGURE 144. California Zero Emission Vehicle Credit Balances by Manufacturer, September 2016

Notes: NEV = Neighborhood electric vehicles; TZEV = Transitional ZEV; PZEV = Partial ZEV; AT PZEV = Advanced technology PZEV; 1.5x/IIx is a type of ZEV defined in the regulation.

Source:
California Air Resources Board, "2015 Zero Emission Vehicle Credits," accessed January 2017. http://www.arb.ca.gov/msprog/zevprog/zevcredits/2015zevcredits.htm

Tesla Transferred Over 80,000 Zero Emission Vehicle Credits to Other Manufacturers

Beginning in 1990, the state of California adopted a Zero Emission Vehicle (ZEV) regulation that affects light vehicle manufacturers. Large and intermediate volume manufacturers are subject to requirements based on a percentage of all light vehicles (up to 8,500 lb) delivered for sale in California. The manufacturers can generate credits by exceeding minimum standards of ZEVs, PZEVs, AT PZEVs, and NEVs. Manufacturers are allowed to transfer credits earned; between October 1, 2015 and September 30, 2016, three manufacturers transferred credits out of their balances, and five more transferred credits into their balances (not including NEV transfers). The transfer of credits allows each manufacturer to strategically comply with the regulation.

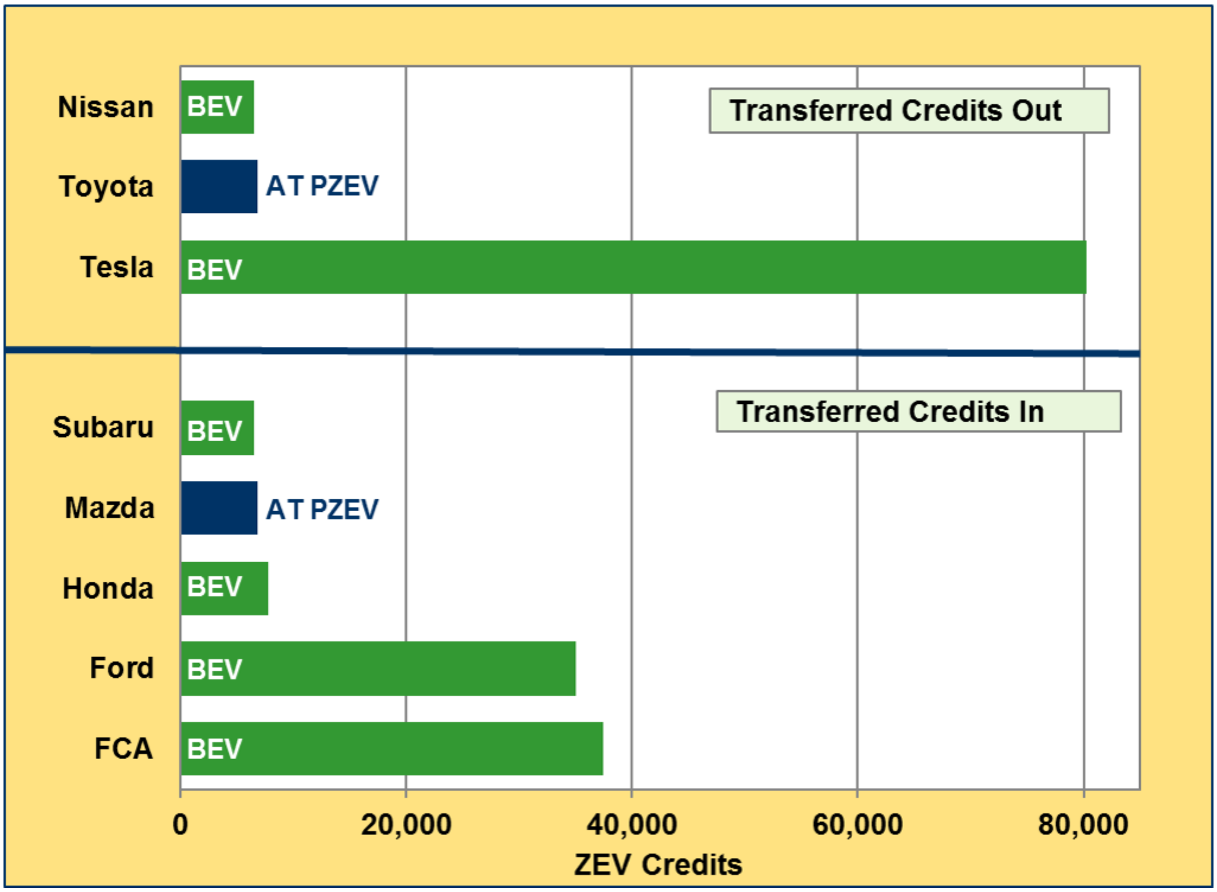

FIGURE 145. California Zero Emission Vehicle Credit Transfers, FY 2016

Note: Transfers between October 1, 2015 and September 30, 2016. PZEV = Partial zero emission vehicle; AT PZEV = Advanced technology partial emission vehicle; NEV = Neighborhood electric vehicle. Polaris and Miles transferred less than 100 NEV credits out; FCA and GM transferred less than 100 NEV credits in.

Source:

California Air Resources Board, "2015 Zero Emission Vehicle Credits," accessed January 2017. http://www.arb.ca.gov/msprog/zevprog/zevcredits/2015zevcredits.htm

Tier 3 Sets New Light Gasoline Vehicle Emission Standards for NMOG+NOx

The Environmental Protection Agency finalized Tier 3 emission standards in a rule issued in March 2014. One effect of the rule is a decrease in the combined amount of non-methane organic gases (NMOG) and nitrogen oxides (NOx) that new light vehicles with gasoline engines are allowed to produce from 2017 to 2025. These standards apply to a corporate average, meaning that some vehicles produced in those model years will emit more than the standard, while others will emit less.

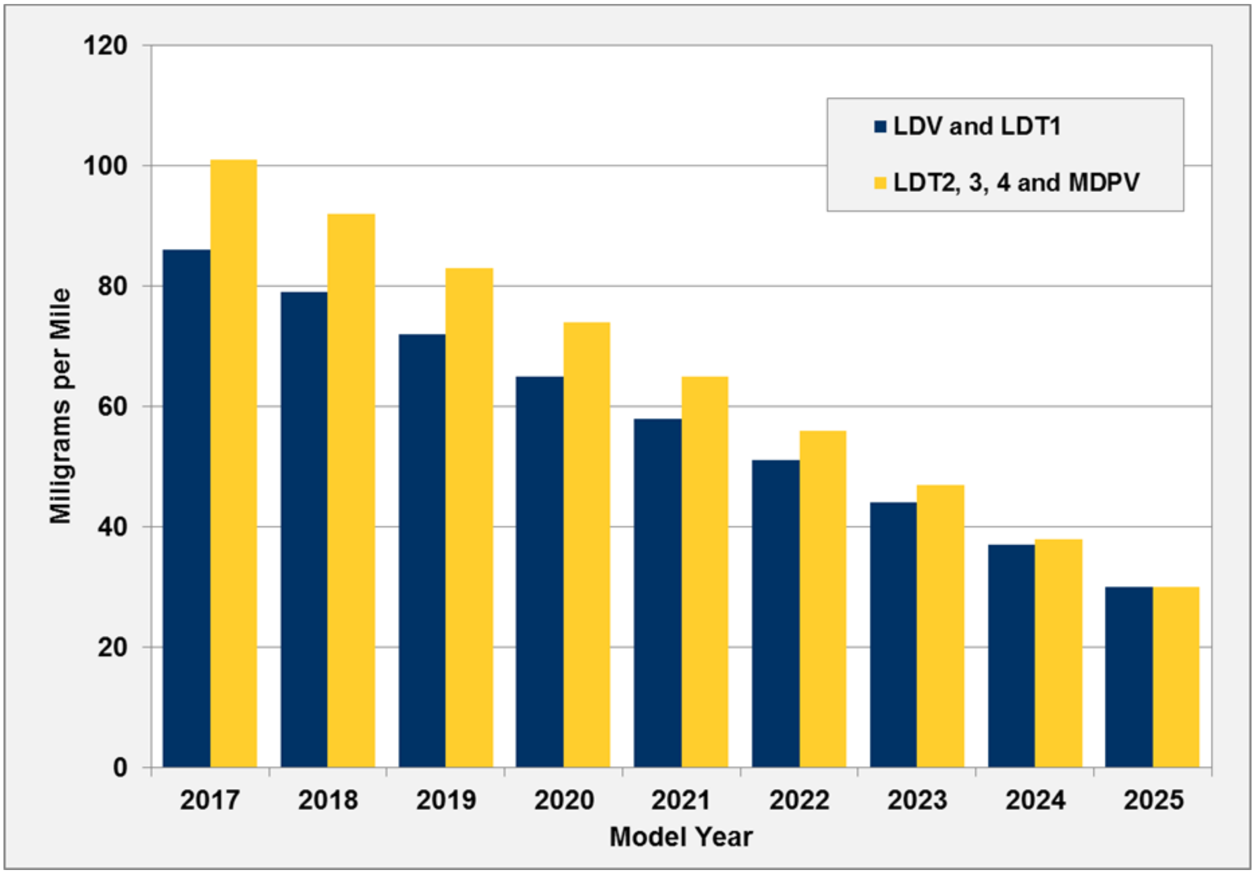

FIGURE 146. Tier 3 NMOG+NOx Emission Standards for Light Gasoline Vehicles, MY 2017-2025

Notes: Standards shown are for the Federal Test Procedure. Different standards apply to the Supplemental Federal Test Procedure. For vehicles over 6,000 lb gross vehicle weight rating (GVWR), the standards apply beginning in MY 2018.
LDV = Light-duty vehicles.
LDT1 = Light trucks less than 6,000 lb GVWR and less than 3,750 lb loaded vehicle weight (LVW).
LDT2, 3, 4 = Light trucks less than 8,500 lb GVWR and more than 3, 750 lb LVW.
MDPV = Medium-duty passenger vehicles.

Source:
U.S. Environmental Protection Agency, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-smog-soot-and-other-air-pollution-passenger.

Tier 3 Particulate Emission Standards for Light Gasoline Vehicles Will Be Phased in Over Six Years

The Environmental Protection Agency finalized Tier 3 emission standards in a rule issued in March 2014. One effect of the rule is a decrease in the amount of particulate matter (PM) that new light vehicles with gasoline engines are allowed to emit from 2017-on. These standards are to be phased in over a six-year period. The first year, only 20% of U.S. sales are mandated to meet the standard. The PM standards are on a "per vehicle" basis, so by 2021, all vehicles sold (100%) must comply with the standards. Both the certification standards and the in-use standards are shown.

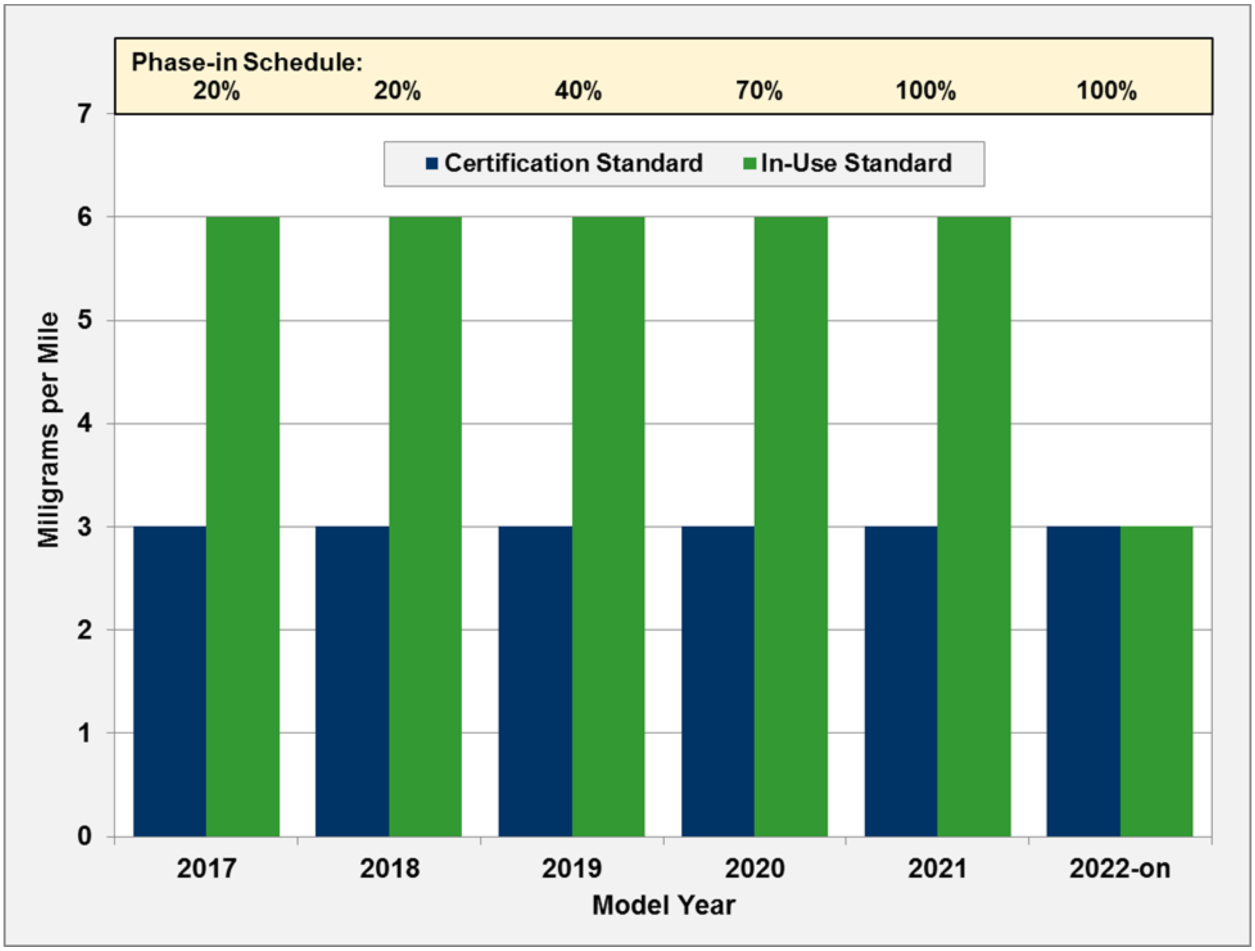

FIGURE 147. Tier 3 Particulate Matter Emission Standards for Light Gasoline Vehicles, MY 2017 and Beyond

Note: Standards shown are for the Federal Test Procedure. The standards apply to all light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles. For vehicles over 6,000 lb gross vehicle weight rating, the standards apply beginning in MY 2018.

Source:
U.S. Environmental Protection Agency, https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-smog-soot-and-other-air-pollution-passenger.

New Fuel Consumption Standards Were Set for Heavy Pickups and Vans in October 2016

The National Highway Traffic Safety Administration (NHTSA) set standards regulating the fuel use of new pickup trucks and cargo trucks over 8,500 lb, and passenger vans over 10,000 lb. Standards were set separately for gasoline and diesel vehicles, on a scale that depends on a "work factor." Standards for model years (MYs) 2014 and 2015 are voluntary, but are mandatory thereafter.

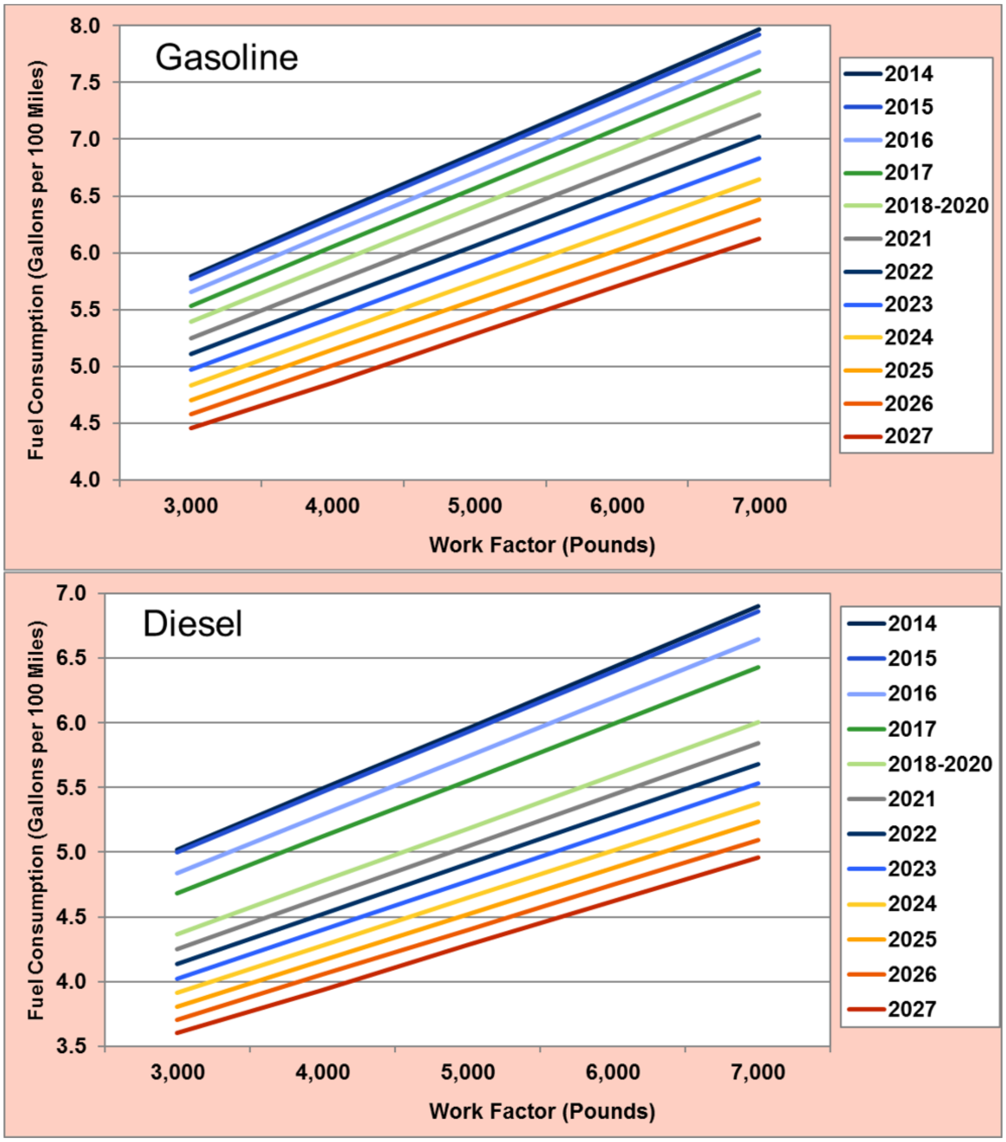

FIGURE 148. Fuel Consumption Target Standards for Gasoline and Diesel Heavy Pickups and Vans, MY 2014 and Later

Note: Work factor is a weighted average of 25% towing capacity and 75% payload capacity. An additional 500 lb is added to payload capacity when the vehicle is four-wheel drive.

Source:
Federal Register, Vol. 81, No. 206, October 25, 2016, p. 73737.

Fuel Consumption Standards for Combination Tractors Vary by Cab Type, Weight Class and Roof Height

The National Highway Traffic Safety Administration (NHTSA) published a final rule setting fuel consumption standards for heavy trucks in September 2011 and again in October 2016. For tractor-trailers, the standards focus on the gallons of fuel per thousand ton-miles. Ton-miles are equal to the weight of a shipment transported multiplied by the distance hauled. Because differences in the tractors create differences in the fuel used, standards were set for varying roof height (low, mid, and high), gross vehicle weight rating (class 7 and 8), and types of tractor (day cab, sleeper cab).

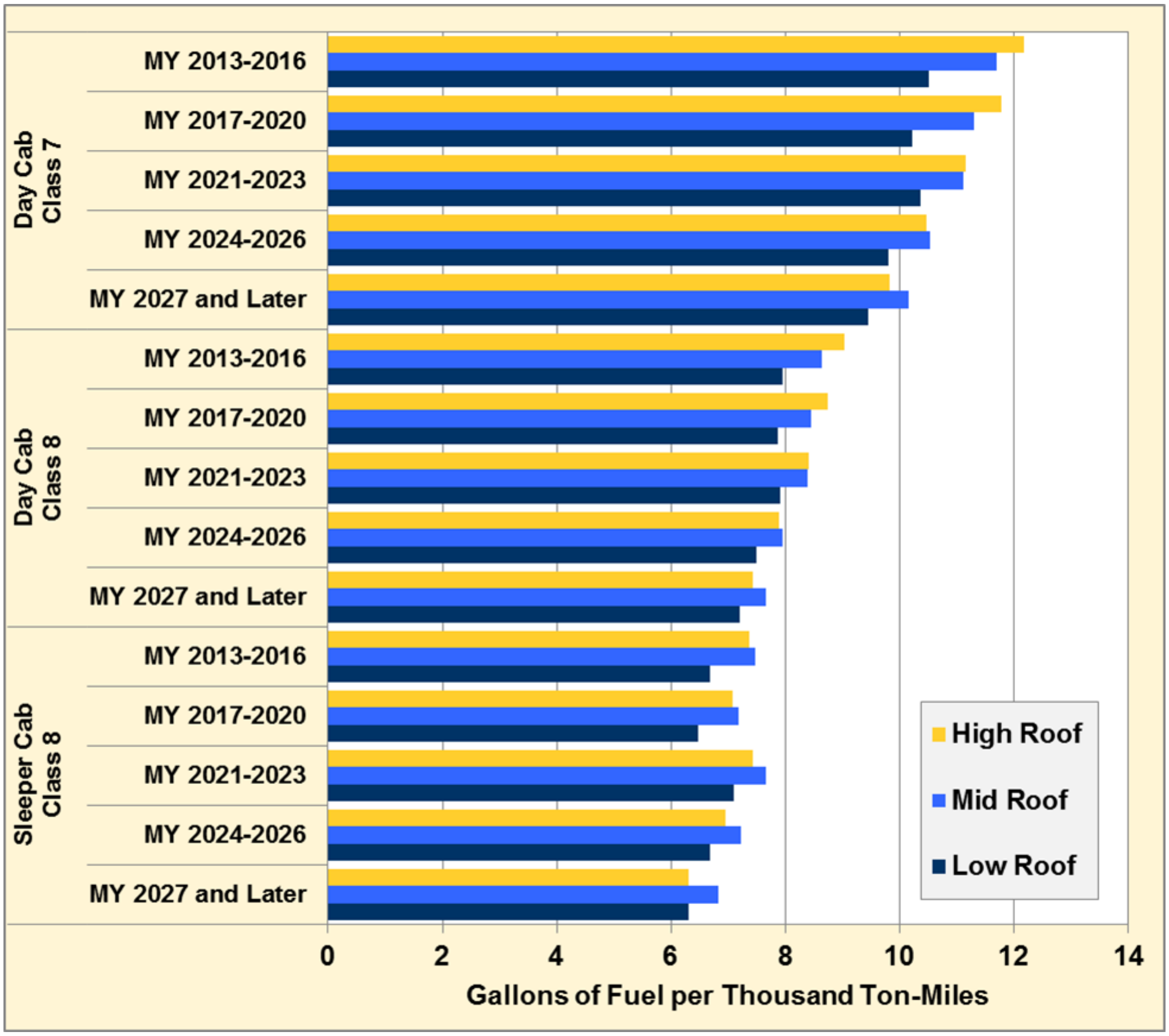

FIGURE 149. Fuel Consumption Standards for Combination Tractors, MY 2013 and Later

Note: The standards for model year (MY) 2013-2015 were voluntary. Class 7 trucks have a gross vehicle weight rating between 26,000 and 33,000 lb Class 8 trucks have a gross vehicle weight rating over 33,000 lb.

Source:
Federal Register, Vol. 81, No. 206, October 25, 2016, p. 74252.

Fuel Consumption Standards for Vocational Vehicles from 2013 to 2020 Vary By Truck Class

The National Highway Traffic Safety Administration (NHTSA) first published fuel consumption standards for heavy vehicles called "vocational" vehicles in 2011. A vocational vehicle is generally a single-unit work vehicle over 8,500 lb gross vehicle weight rating (GVWR) or a passenger vehicle over 10,000 lb GVWR. These vehicles vary in size, and include van trucks, utility ''bucket'' trucks, tank trucks, refuse trucks, urban and over-the-road buses, fire trucks, flat-bed trucks, dump trucks, and others. Often, these trucks are built as a chassis with an installed engine purchased from one manufacturer and an installed transmission purchased from another manufacturer. The chassis is typically then sent to a body manufacturer, which completes the vehicle by installing the appropriate feature—such as dump bed, delivery box, or utility bucket—onto the chassis.

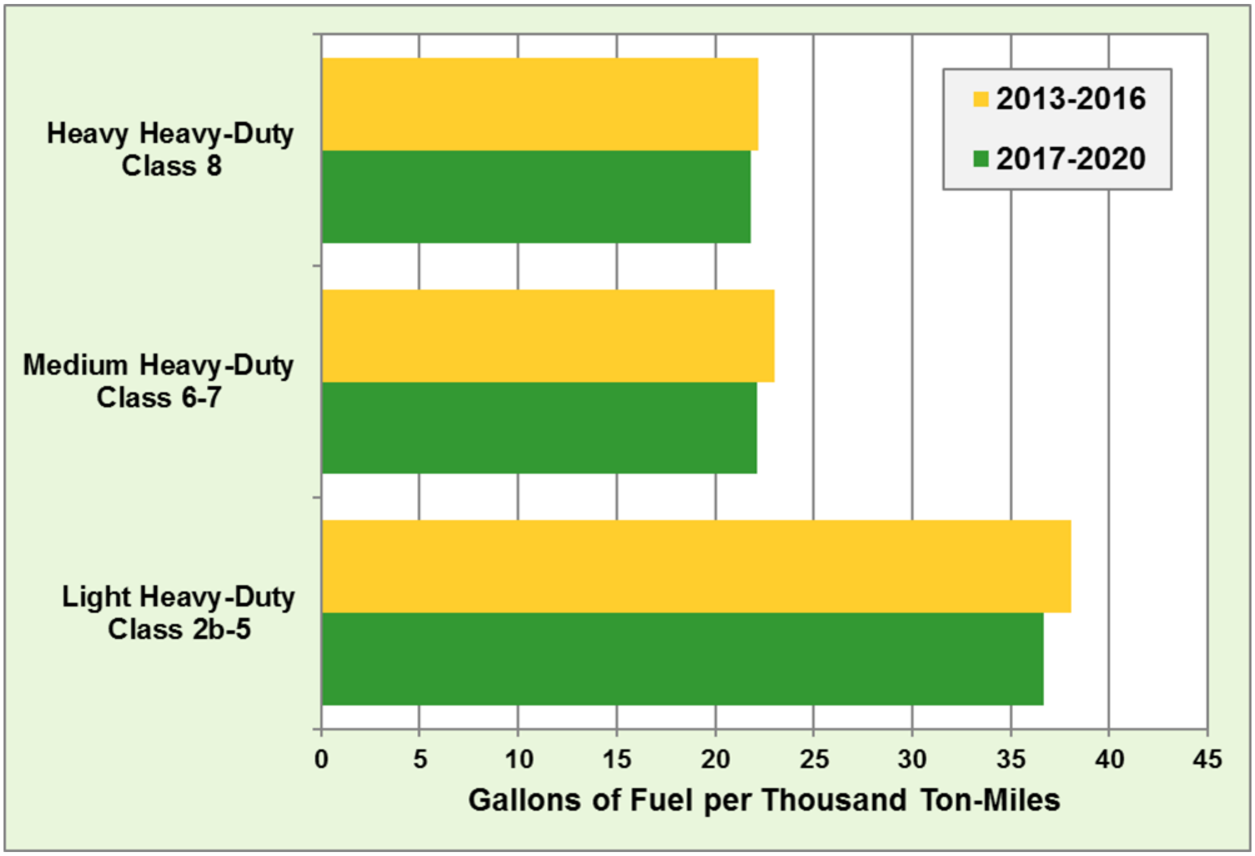

FIGURE 150. Vocational Vehicle Fuel Consumption Standards, MY 2013-2020

Note: Vehicles in classes 2b – 5 are between 8,500 and 19,500 lb GVWR. Vehicles in class 6-7 are between 19,500 and 33,000 lb GVWR. Vehicles in class 8 are above 33,000 lb GVWR. A ton-mile is a measure of shipment weight multiplied by distance traveled.

Source:
Federal Register, Vol. 81, No. 206, October 25, 2016, p. 74248.

Fuel Consumption Standards for Vocational Vehicles Past 2020 Vary By Truck Class, Engine Type, and Duty-Cycle

In 2016 the National Highway Traffic Safety Administration (NHTSA) first published fuel consumption standards for heavy vehicles called "vocational" vehicles for model year (MY) 2021-on. A vocational vehicle is generally a single-unit work vehicle over 8,500 lb gross vehicle weight rating (GVWR) or a passenger vehicle over 10,000 lb GVWR. Standards for these vehicles had previously varied by vehicle size (Light, Medium Heavy), but the standards for MY 2021-on also vary by engine type (compression ignition, spark ignition) and duty-cycle (urban, multi-purpose, regional). Each individual standard is documented in the Federal Register, but only medium trucks are shown below.

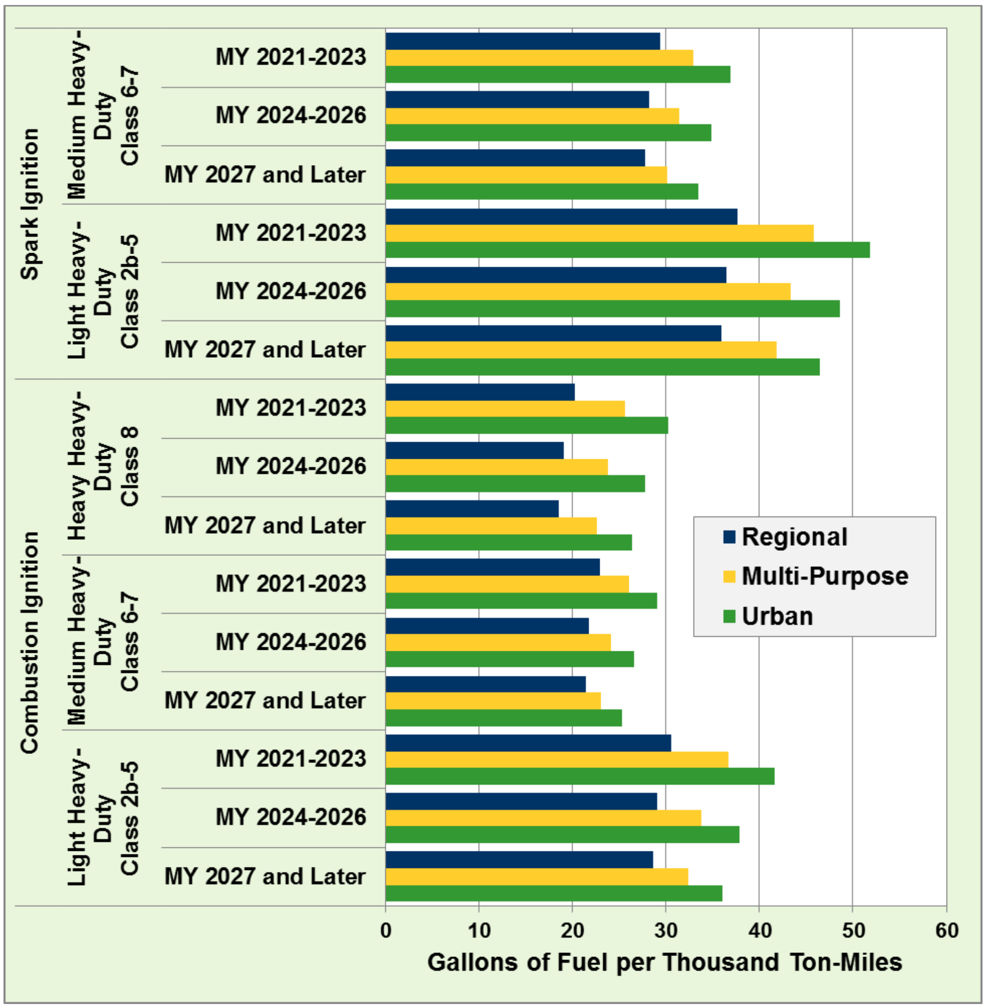

FIGURE 151. Vocational Vehicle Fuel Consumption Standards, MY 2021 and Later

Note: Vehicles in classes 2b – 5 are between 8,500 and 19,500 lb GVWR. Vehicles in class 6-7 are between 19,500 and 33,000 lb GVWR. Vehicles in class 8 are above 33,000 lb GVWR. A ton-mile is a measure of shipment weight multiplied by distance traveled.

Source:
Federal Register, Vol. 81, No. 206, October 25, 2016, pp. 74248 – 74249.

Diesel Engine Fuel Consumption Standards Were Set for Vocational Vehicles and Truck Tractors

In addition to the combination truck and vocational truck fuel consumption standards, the National Highway Traffic Safety Administration (NHTSA) set fuel consumption standards for diesel engines installed in truck-tractors and vocational vehicles. The standards were set in gallons of fuel used per horsepower hour, which is a measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, differential, water pump, and other auxiliary components for one hour. These standards were voluntary from model year (MY) 2013 through 2016 and mandatory thereafter.

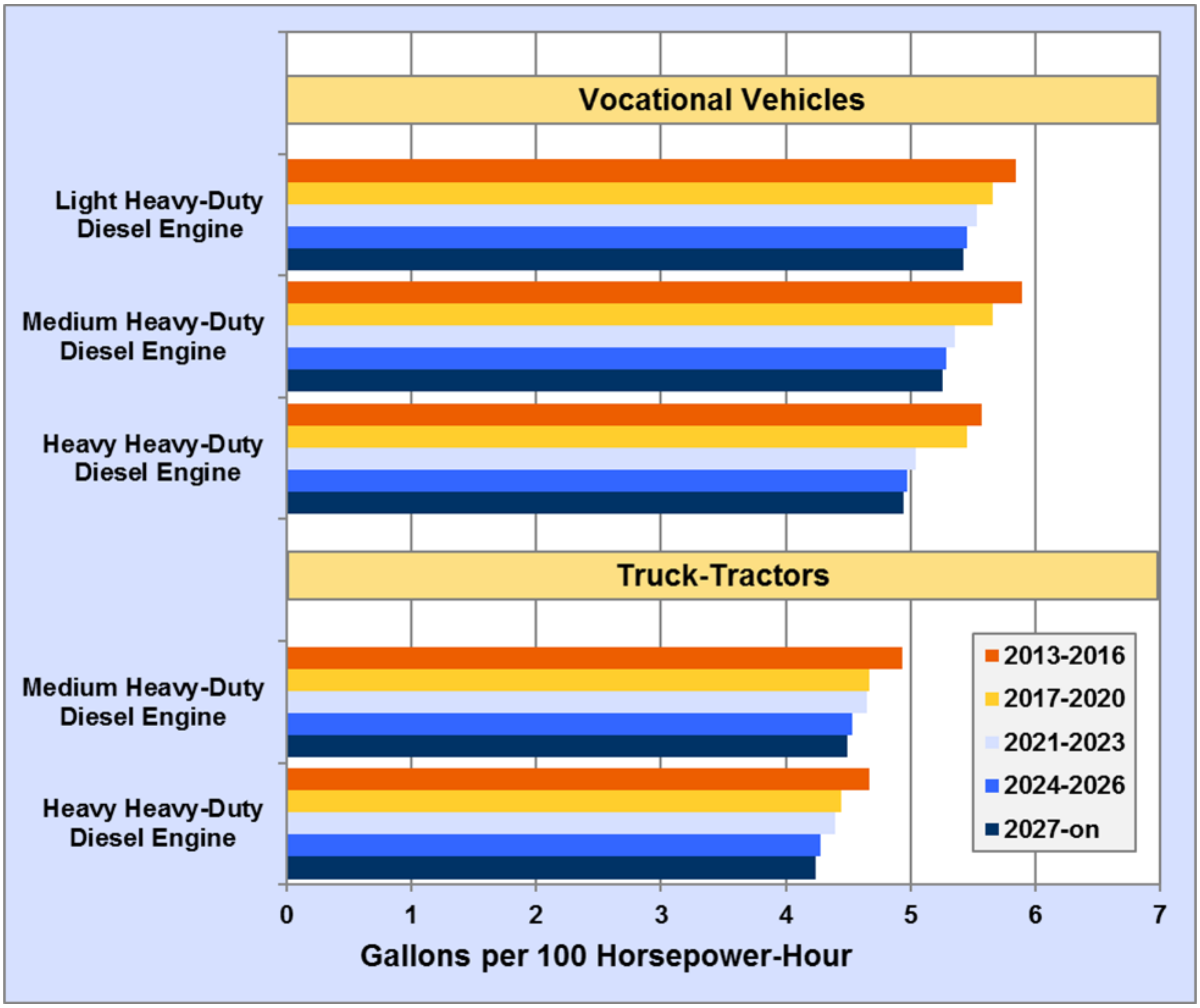

FIGURE 152. Fuel Standards for New Diesel Engines, MY 2013 and Later

Notes: Light Heavy-Duty (Class 2b–5); Medium Heavy-Duty (Class 6–7); and Heavy Heavy-Duty (Class 8).

Source:
Federal Register, Vol. 81, No. 206, October 25, 2016, p. 74254.

Energy Policy Act Encourages Idle Reduction Technologies

In order to encourage the use of idle reduction devices in large trucks, the Energy Policy Act of 2005 allowed for a weight exemption to account for the additional weight of idle reduction technology. States were given the discretion of adopting this exemption without being subjected to penalty. Since then, most states have passed laws which allow trucks to exceed the maximum gross vehicle weight limit by either an additional 400 or 550 lb. Other States have a 400 lb weight allowance which is granted by enforcement personnel. Arkansas allows a 550 lb weight exemption by enforcement policy. Five states plus the District of Columbia have not adopted the weight exemption.

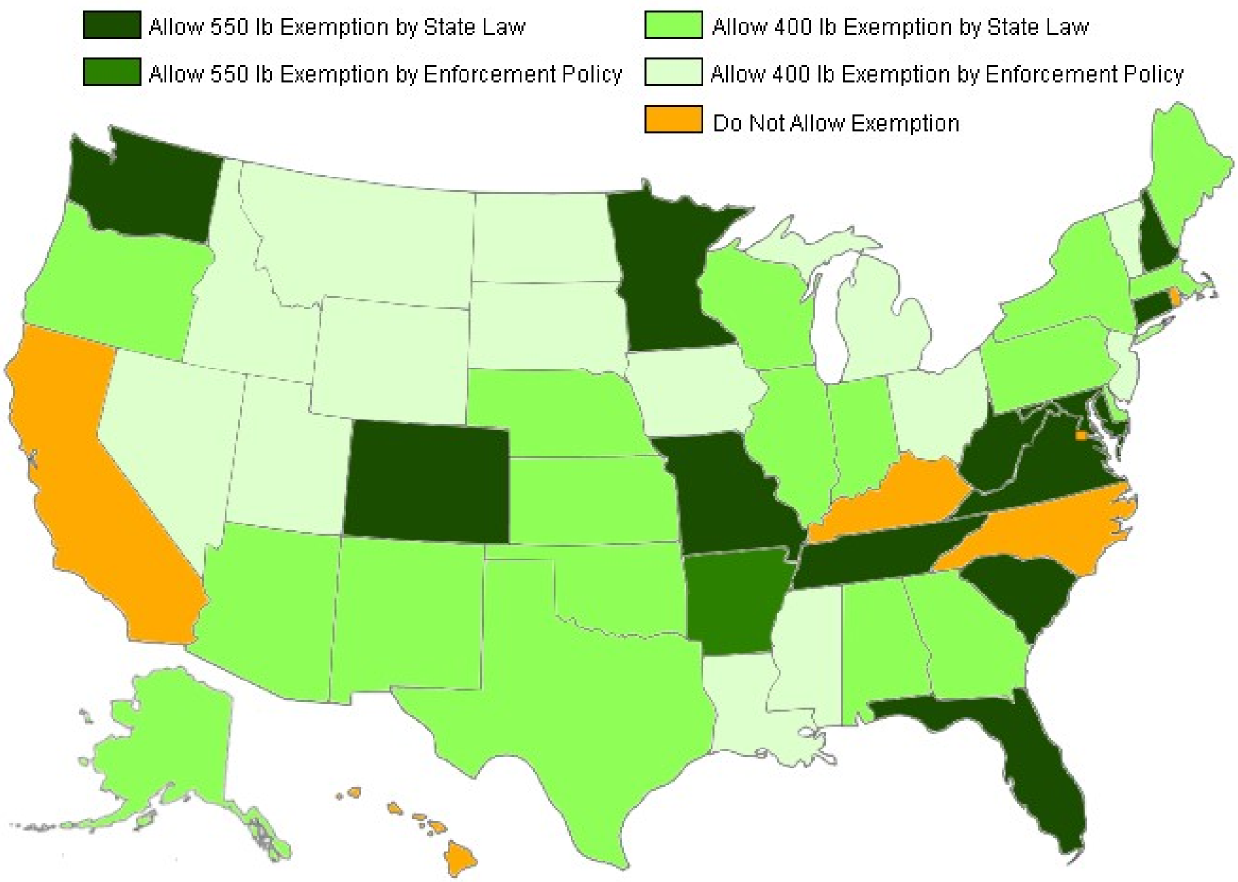

FIGURE 153. States Adopting Weight Exemptions for Idle Reduction Devices, 2017

Source:

U.S. Department of Energy, Energy Efficiency and Renewable Energy, *December 2016 National Idling Reduction News*. http://energy.gov/eere/vehicles/vehicle-technologies-office-national-idling-reduction-network-news

Idle Reduction Technologies Excluded from Federal Excise Taxes

With the passage of the Energy Improvement and Extension Act of 2008, certain idling reduction devices are excluded from Federal excise taxes. The Environmental Protection Agency (EPA) certifies products that are eligible for the exemption. The exemption is only available for EPA-certified idling reduction devices installed on truck tractors. The companies that have devices for highway vehicles certified with the EPA are shown below.

Auxiliary Power Units/ Generator Sets

- ACEMCO Power Systems, LLC
- Airworks Compressors Corp
- Big Rig Products
- Carrier Transicold
- Centramatic
- Diamond Power Systems, LLC
- Dunamis Power Systems
- Hodyon LP
- Kohler
- Life Force
- Mantis Metalworks, LLC
- McMillan Electric Company
- Midwest Power Generators
- Navistar
- Parks Industries, LLC
- Pony Pack, Inc.
- Power Technology Southeast
- RigMaster Power by Mobile Thermo Systems
- Star Class
- Thermo King Corp
- TRIDAKO Energy Systems
- Volvo
- Willis Power Systems

Fuel Operated Heaters

- Automotive Climate Control
- Espar
- Proheat
- Volvo
- Webasto

Battery Air Conditioning/ Heating Systems

- All Around Contracting, LLC
- AuraGen
- Bergstrom, Inc.
- Cool Moves
- Crosspoint Solutions, LLC
- DC Power Solutions
- Diamond Power Systems, LLC
- Dometic Corporation
- Driver Comfort System
- Energy Xtreme
- Freightliner Cascadia
- Hammond Air Conditioning, LTD
- Idle Free Systems
- Indel B Sleeping Well
- NAS, LLC / Comfort Cab
- Navistar
- Paddock Solar
- Peterbilt
- Safer Corporation
- Sobo, Inc./ Kingtec Technologies
- Sun Power Technologies
- Thermo King
- Volvo

Shore Connection Systems

- Comfort
- Freightliner
- Phillips and Temro Industries
- Shurepower, LLC
- Volvo
- Xantrex Technology

Thermal Storage Systems

- Autotherm Division Enthal Sys, Inc.
- Webasto

FIGURE 154. Idle Reduction Technologies which Are Granted Exemption from Federal Excise Taxes

Source:

U.S. Environmental Protection Agency, SmartWay Technology Program, April 2017.
http://www.epa.gov/smartway/forpartners/technology.htm

Longer Combination Trucks Are Only Permitted on Some Routes

Although all states allow the conventional combinations consisting of a 28-foot semi-trailer and a 28-foot trailer, only 14 states and six state turnpike authorities allow longer combination vehicles (LCVs) on at least some parts of their road networks. LCVs are tractors pulling a semi-trailer and trailer, with at least one of them – the semi-trailer, the trailer, or both – longer than 28 feet. The routes that these LCVs can travel have not changed since 1991.

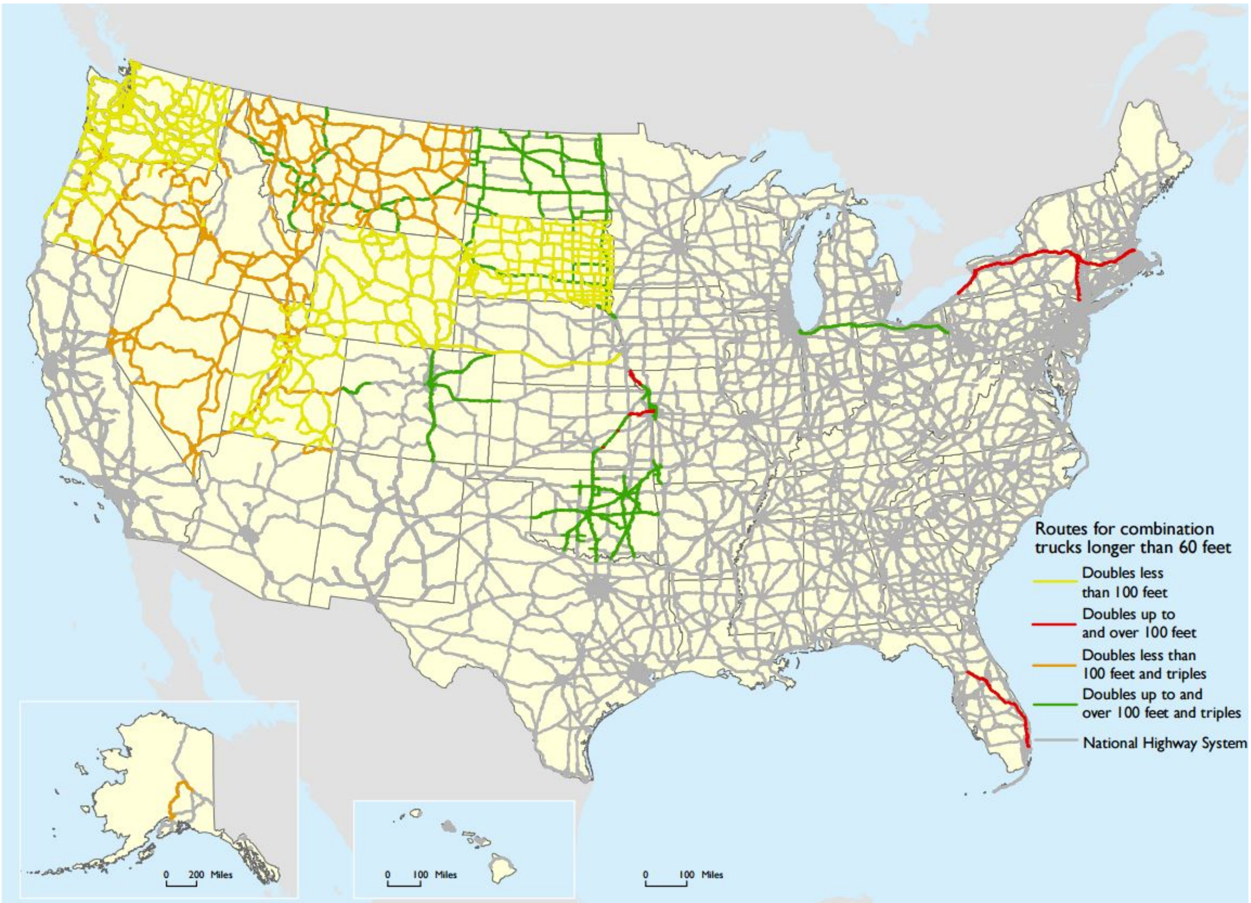

FIGURE 155. Routes Where Longer Combination Vehicles Are Permitted, 2014

Note: Empty triples are allowed on I-80 in Nebraska.

Source:
U.S. Department of Transportation, Federal Highway Administration, *Freight Facts and Figures 2015,* 2015. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/data_and_statistics/by_subject/freight/freight_facts_2015

Heavy Truck Speed Limits Are Inconsistent

Ranging from a speed limit of 55 miles per hour (mph) to 85 mph, the maximum speed limit for trucks varies from state-to-state and sometimes from year to year. Currently, California has the most conservative maximum speed limit for trucks – 55 mph. At the other end of the spectrum, Texas has some roads where the truck speed limit is 85 mph. Because of the varying limits, there is not one common highway speed at which trucks travel. This precludes truck manufacturers from engineering truck engines that peak in efficiency after reaching the speed at which the vehicles most commonly travel. Instead, manufacturers design the vehicle to perform well over the entire range of speeds, which in turn limits engine efficiency.

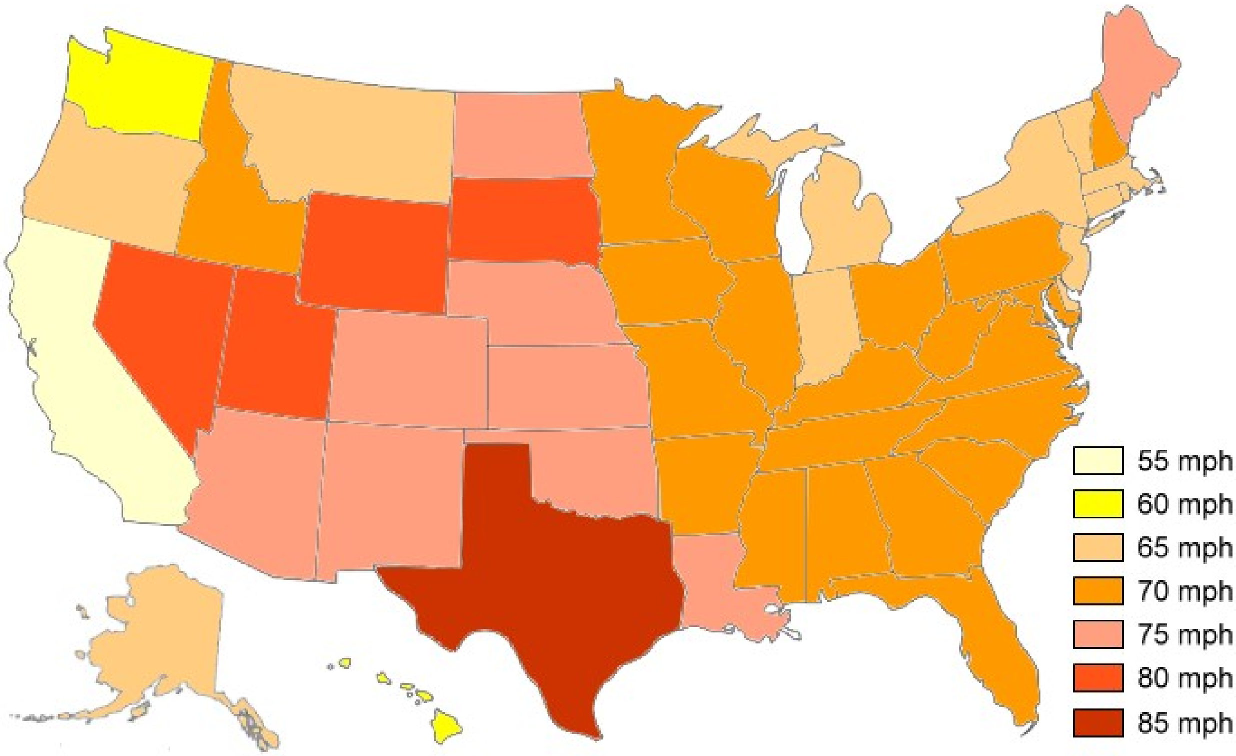

FIGURE 156. Maximum Daytime Truck Speed Limits by State, 2017

Source:
Insurance Institute for Highway Safety, Highway Loss Data Institute, February 2017.
http://www.iihs.org/laws/speedlimits

EPA Finalizes Stricter Standards for Gasoline

Sulfur naturally occurs in gasoline and diesel fuel, contributing to pollution when the fuel is burned and reducing the effectiveness of vehicle emission controls. Beginning in 2004, standards were set on the amount of sulfur in gasoline (Tier 2 standards). Separate standards were set for different entities, such as large refiners, small refiners, importers, downstream wholesalers, etc. In March 2014, Tier 3 standards were finalized by the Environmental Protection Agency (EPA). Tier 3 standards took effect in 2017. Large refinery standards are shown below, both the maximum and average per gallon. See the EPA website for additional details on sulfur standards.

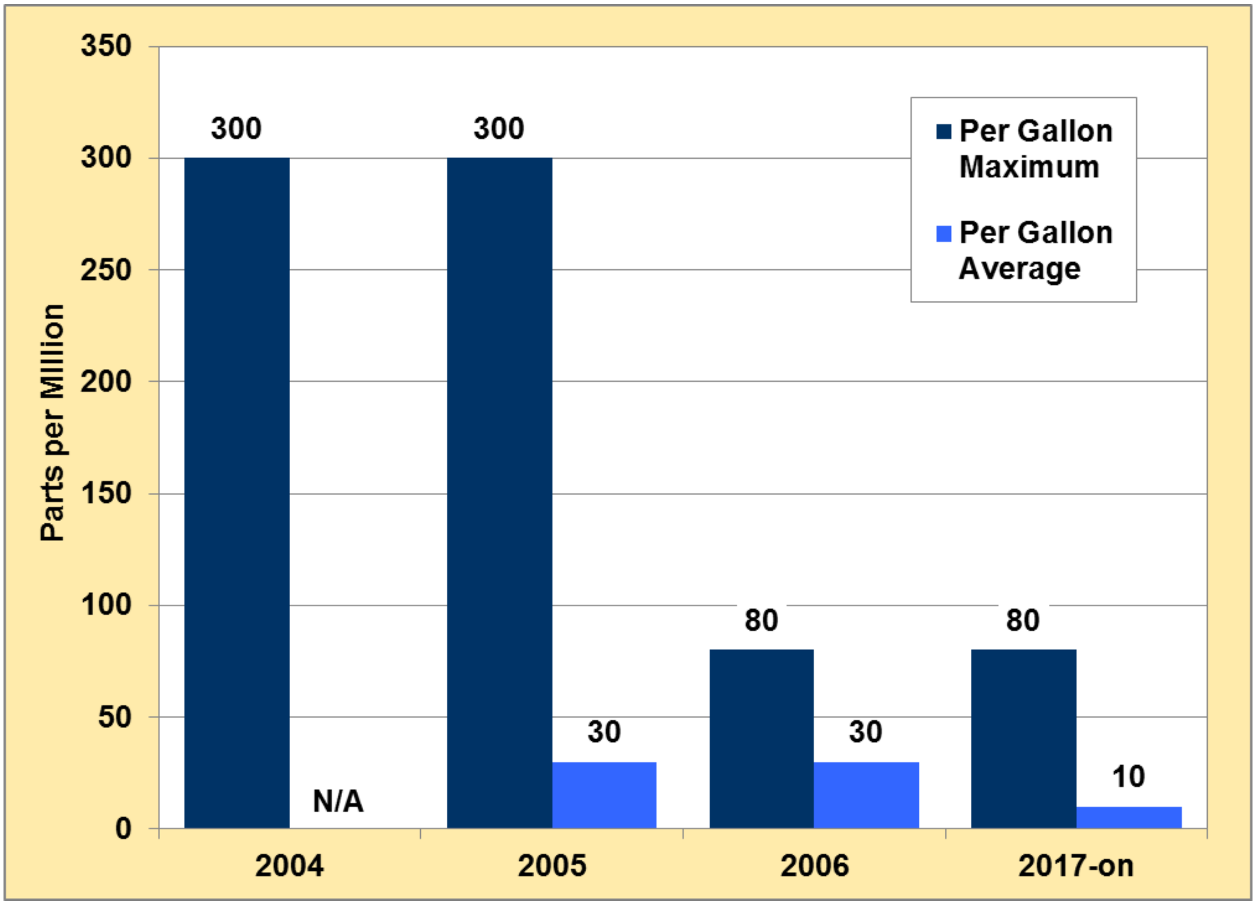

FIGURE 157. Gasoline Sulfur Standards Since 2004

Note: N/A = not applicable.

Source:

U.S. Environmental Protection Agency, Gasoline Sulfur. http://www.epa.gov/gasoline-standards/gasoline-sulfur.

Diesel Sulfur Standards Set at 15 Parts per Million

Sulfur naturally occurs in diesel fuel, contributing to pollution when the fuel is burned and reducing the effectiveness of vehicle emission controls. Low-sulfur diesel (500 parts per million (ppm) began in 1993 as a result of the 1990 Clean Air Act Amendments. By October 2006, 80% of the diesel fuel produced was ultra-low sulfur diesel (ULSD) which is 15 ppm. By 2010, all diesel fuel produced was ULSD. Separate standards were created for highway and non-highway diesel fuel. The standards for highway diesel from large refineries are shown here; see the Environmental Protection Agency website for additional details on sulfur standards.

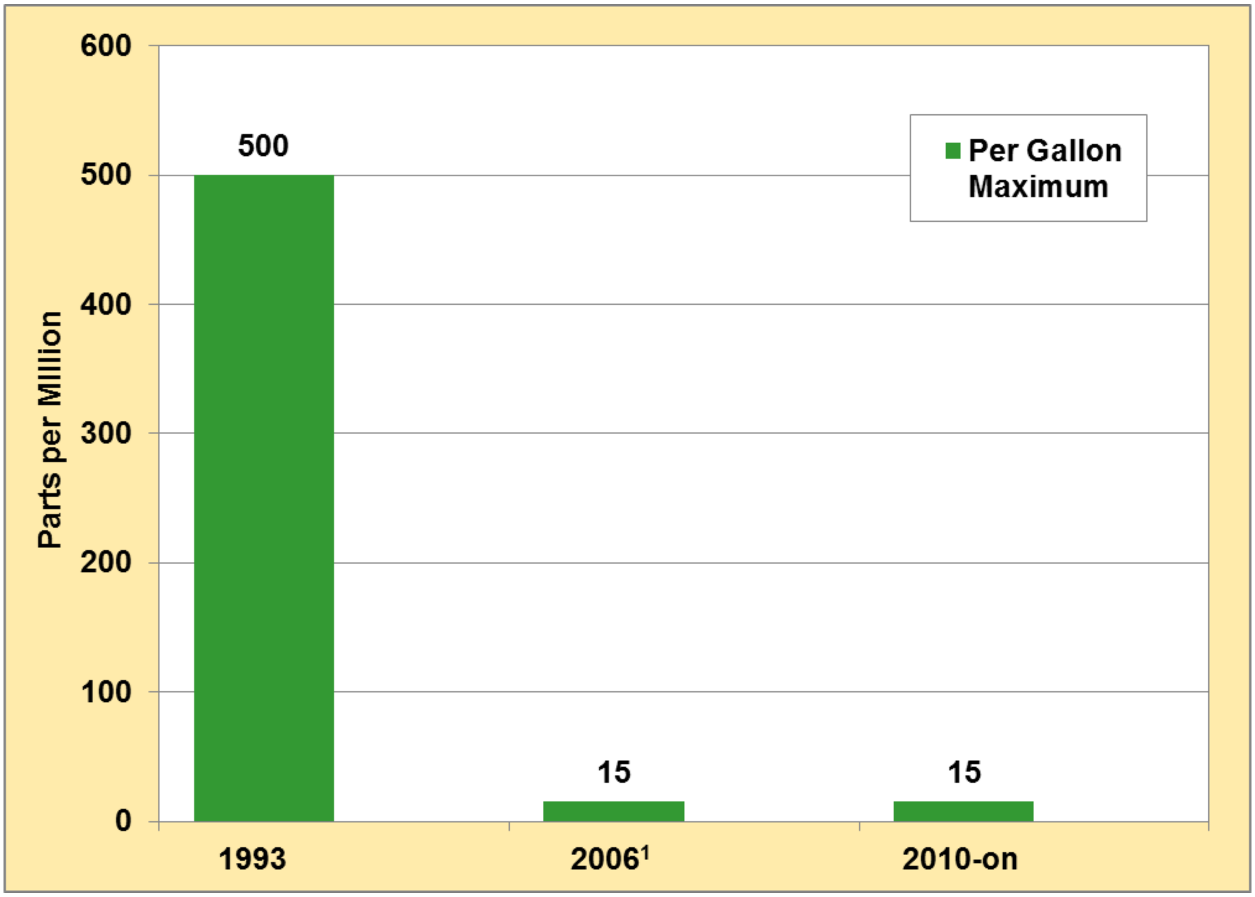

FIGURE 158. Diesel Sulfur Standards, 1993 to Present

[1] By October 2006 80% of the diesel fuel produced was required to be 15 ppm. In 2010, 100% produced was required to be 15 ppm.

Source:
U.S. Environmental Protection Agency, Heavy-Duty Highway Diesel Program. https://www.epa.gov/diesel-fuel-standards.

Emission Standards on Diesel Engines Are More Strict

In 1994, the emission standards for new heavy-duty highway diesel vehicles were five grams per horsepower-hour (g/HP-hr) of nitrogen oxides (NOx) and 0.1 g/HP-hr of particulate matter (PM). The units of measure, g/HP-hr, describes the grams of the pollutant as a result of the use of the energy equivalent to 1 horsepower for one hour. Since 1994, the standards for NOx have been reduced four times, in 1998, 2002, 2007, and 2010. By 2010, the NOx standard was reduced to 0.2 g/HP-hr. For PM, the standards changed from 0.1 g/HP-hr in 2002 to 0.01 g/HP-hr in 2007 and beyond. New medium and heavy trucks meet these standards by using technologies such as selective catalytic reduction and exhaust gas recirculation in combination with diesel particulate filters.

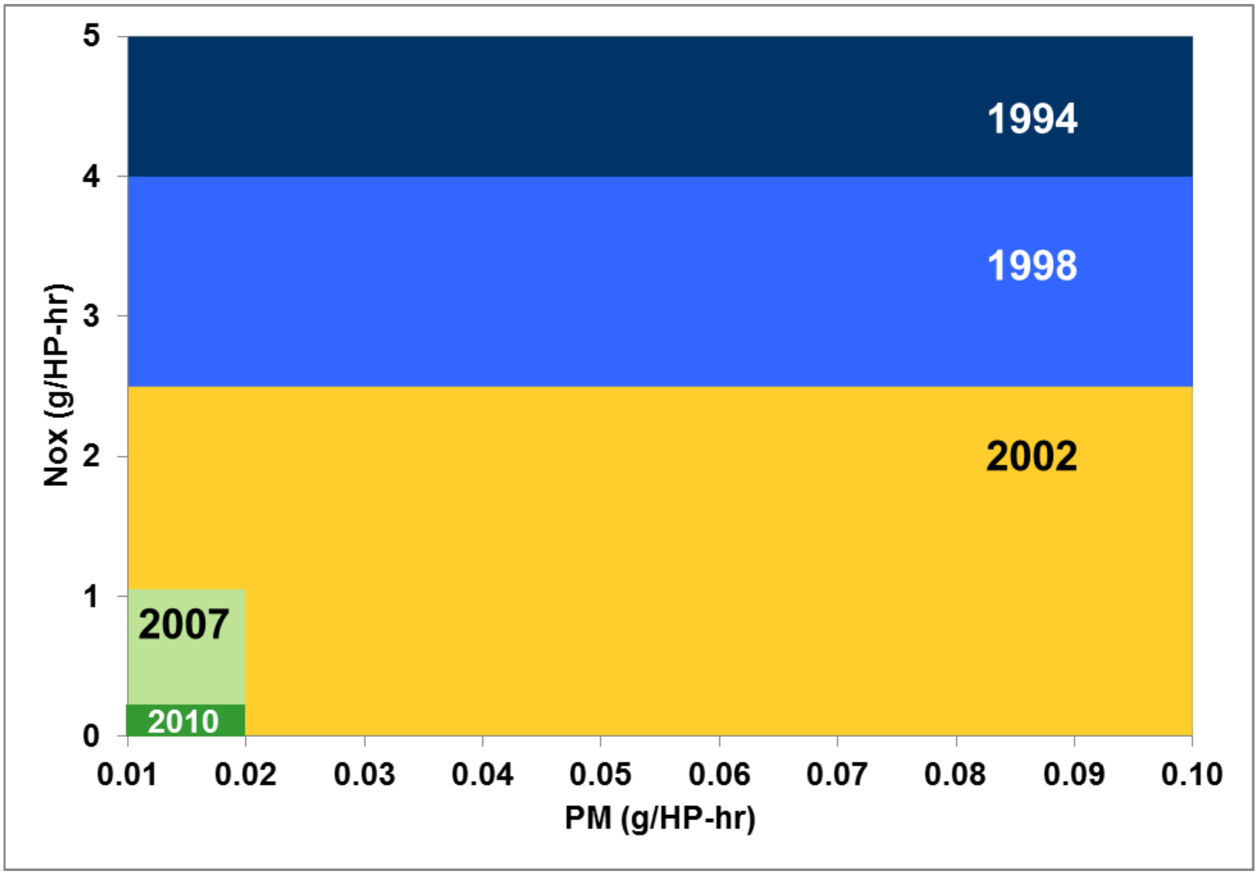

FIGURE 159. Changes in Diesel Engine Emission Standards, 1994 to Present

Note: All standards apply to vehicle model years, not calendar years. In 2015, manufacturers may choose to certify engines to the California Optional Low NOx Standards of 0.10, 0.05, or 0.02 g/hp-hr.

Source:

U.S. Environmental Protection Agency. https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-smog-soot-and-other-air-pollution-commercial.

Effect of Emission Standards on Heavy Truck Sales

It is often thought that stricter emission standards on diesel engines largely affect the sales of heavy trucks. Companies may purchase a greater amount of new heavy trucks just before the stricter emission standard takes effect, thus avoiding the added expense of new engines which meet the regulations. Though this purchase pattern is likely true for many companies, the overall annual sales patterns do not reflect this trend, likely due to the fact that the economy's impact on truck sales dwarfs the effect from emission standards. Also, the calendar year sales may not show the effects of regulations that apply to model years.

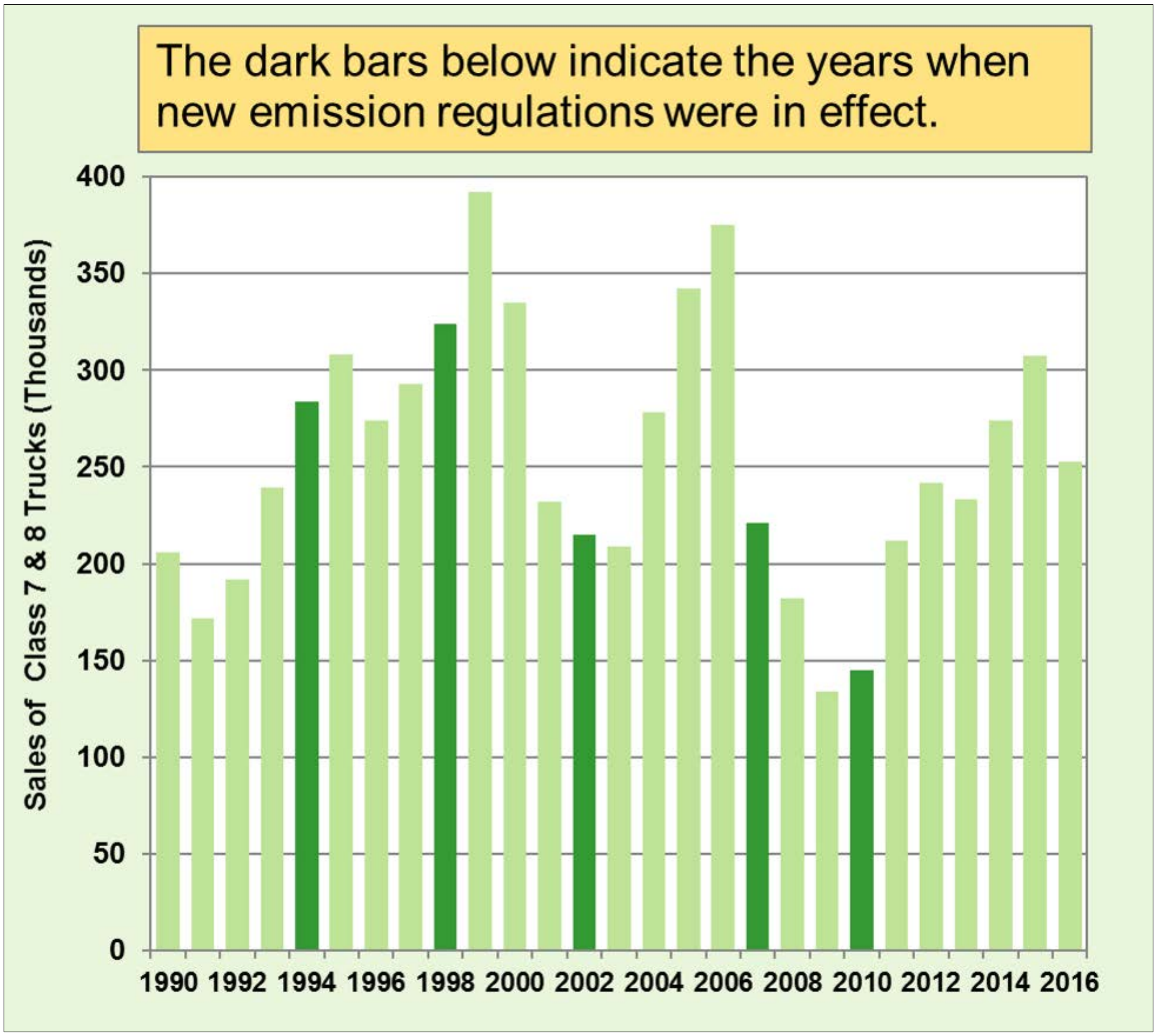

FIGURE 160. Class 7 and 8 Truck Sales, 1990-2016

Source:
Ward's Automotive Group. http://wardsauto.com