2015 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 car was just over $25,000 (constant 2014 dollars).
- In 2014, almost 17% of household expenditures were for transportation
- Over 10 million people were employed in the transportation industry in 2014.

Light Vehicles

- The top nine manufacturers selling vehicles in the U.S. in 2014 produced 51% of the world's vehicles.
- U.S. new light truck sales volumes rose each year from 2011 to 2015 while new car sales declined slightly from 2014 to 2015.
- Sales-weighted data on new light vehicles sold show a 125% increase in horsepower and a 47% decrease in 0-60 time from 1980 to 2015, with the fuel economy of vehicles improving 29%.
- More than 26% of new cars sold in 2015 had continuously variable transmissions.
- More than 50% of new light vehicles sold in 2015 have transmissions with 6 speeds.

Heavy Trucks

- Class 8 combination trucks consumed an average of 6.5 gallons per thousand ton-miles (2010 data).
- Class 3 truck sales in 2015 are 45% higher than 2011.
- Sales of class 4-7 trucks increased in 2015 and were 49% above the 2011 level.
- Class 8 truck sales increased by 45% from 2011 to 2015.
- Diesel comprised 74% of the class 3-8 trucks sold in 2014.
- In 2014, combination trucks were driven an average of almost 66,000 miles per year.
- Idling a truck-tractor's engine can use half a gallon of fuel per hour or more.
- There are over 110 electrified truck stop sites across the country to reduce truck idling time.

Technologies

- About 384,000 hybrid vehicles were sold in 2015.
- In 2015, plug-in vehicle sales totaled over 115,000 units.
- At least 24 different models of plug-in vehicles are available or coming soon to the market.
- Seventy-one flex-fuel vehicle models were offered in model year 2015.
- There are about 30,000 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

- Plug-in hybrids and electric vehicle purchasers receive a Federal tax credit of up to $7,500 for select 2008-2015 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.

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2015 VEHICLE TECHNOLOGIES MARKET REPORT

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Introduction

Welcome to the *2015 Vehicle Technologies Market Report*. This is the seventh edition of this report, which details the major trends in U.S. light-duty vehicle and medium/heavy truck markets as well as the underlying trends that caused them. 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 22 and 23 show U.S. employment in the automotive sector. The following section examines Light-Duty Vehicle use, markets, manufacture, and supply chains. Figures 27 through 63 offer snapshots of major light-duty vehicle brands in the United States and Figures 70 through 81 examine the performance and efficiency characteristics of vehicles sold. The discussion of Medium and Heavy Trucks offers information on truck sales (Figures 90 through 94) and fuel use (Figures 97 through 100). The Technology section offers information on alternative fuel vehicles and infrastructure (Figures 105 through 118), and the Policy section concludes with information on recent, current, and near-future Federal policies like the Corporate Average Fuel Economy standard (Figures 130 through 137).

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,

Jacob Ward
Analysis Manager
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 2014, 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%). Over the last five years, the energy sources have not changed significantly, although renewable fuel use has grown slightly in each sector.

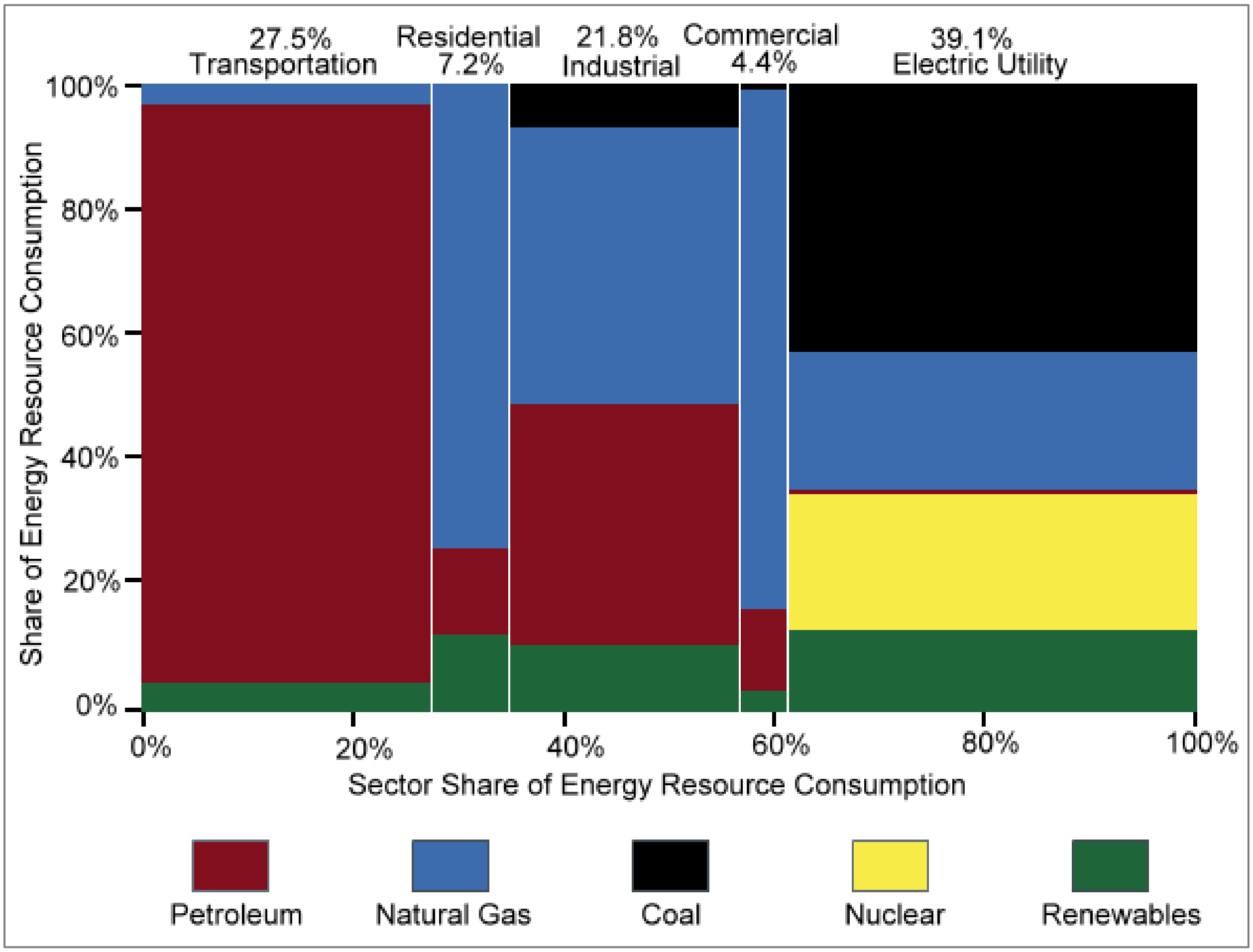


FIGURE 1. U.S. Energy Consumption by Sector and Energy Source, 2014

Source:

Energy Information Administration, *Monthly Energy Review, October 2015*, 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 almost 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 production will be 16 million barrels per day in 2040.

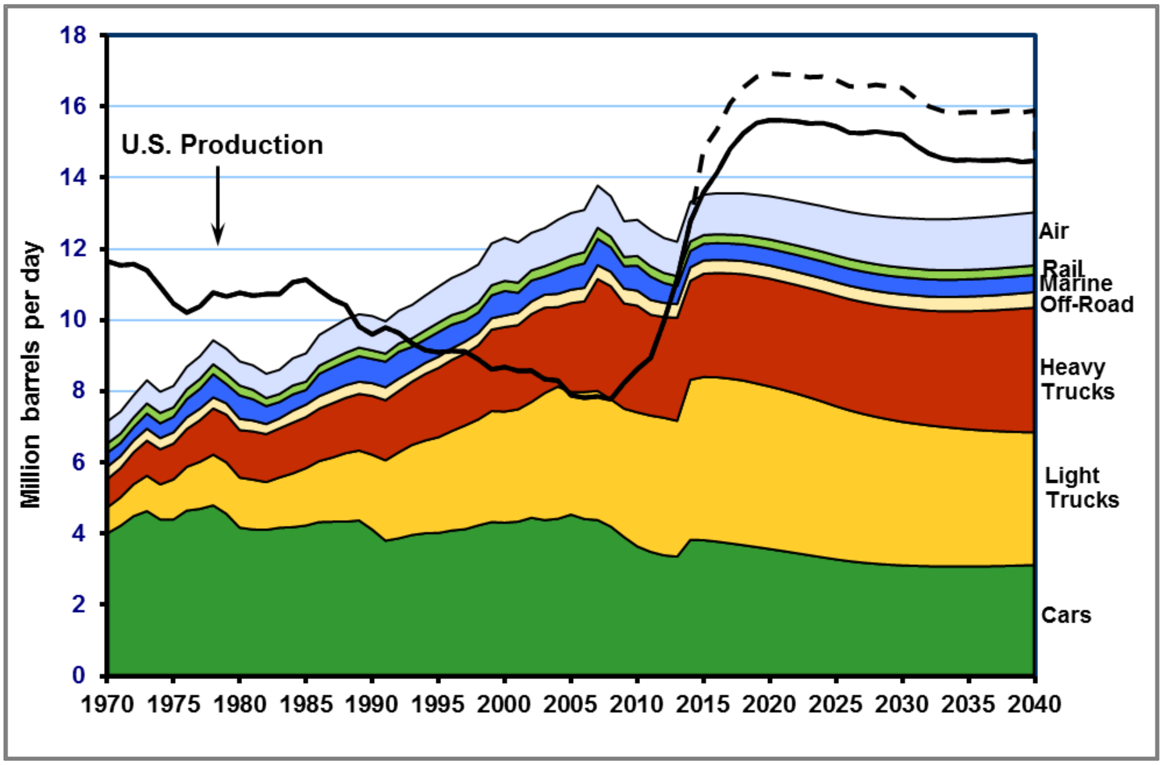


FIGURE 2. Transportation Petroleum Use by Mode and the U.S. Production of Petroleum, 1970-2040

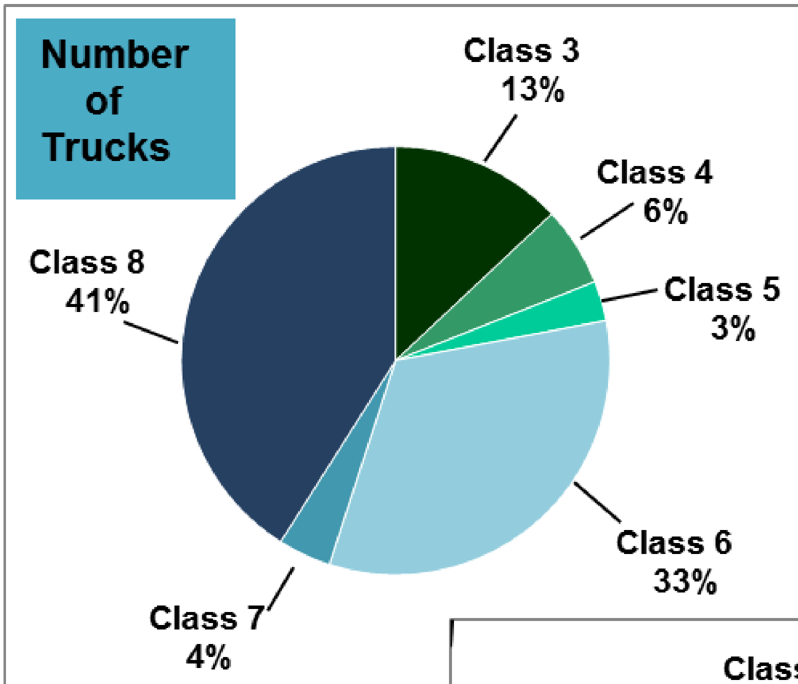
Note: The U.S. production has two lines after 2011. The solid line is conventional sources of petroleum, including crude oil, natural gas plant liquids, and refinery gains. The dashed line adds in other non-petroleum sources, including ethanol, biomass, liquids from coal, other blending components, other hydrocarbons, and ethers. The sharp increase in values between 2013 and 2014 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:

1970-2009: Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 34*, Oak Ridge, TN, 2015. http://cta.ornl.gov/data

2010-2040: Energy Information Administration, *Annual Energy Outlook 2015*, Washington, DC, 2015. 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.

Note: See page 109 for truck class definitions. Data for 2002 are the latest available.

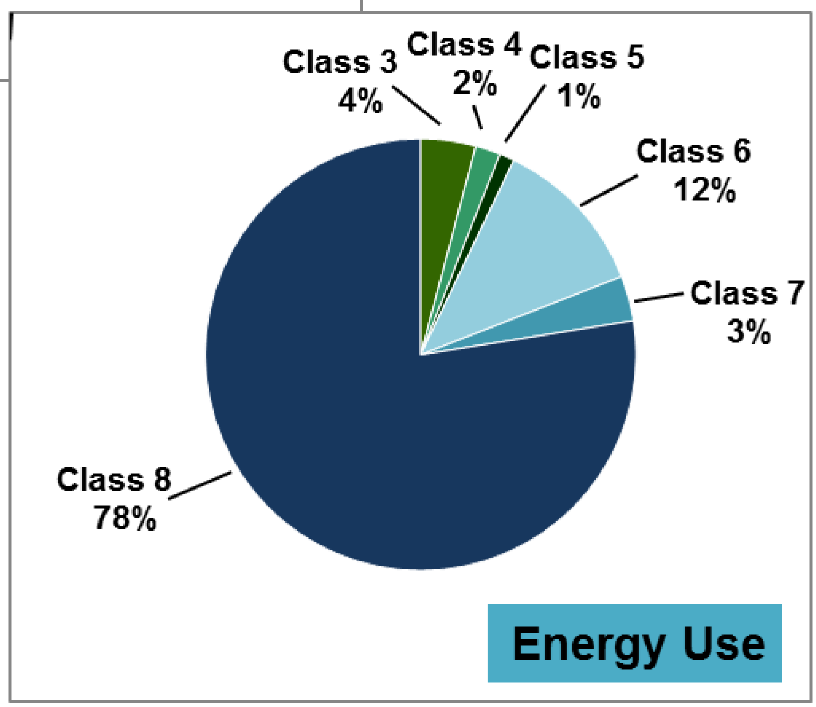


FIGURE 3. Medium and Heavy Truck Fleet Composition and Energy Usage, 2002

Source:
Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 34*, Oak Ridge, TN, 2015. 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.

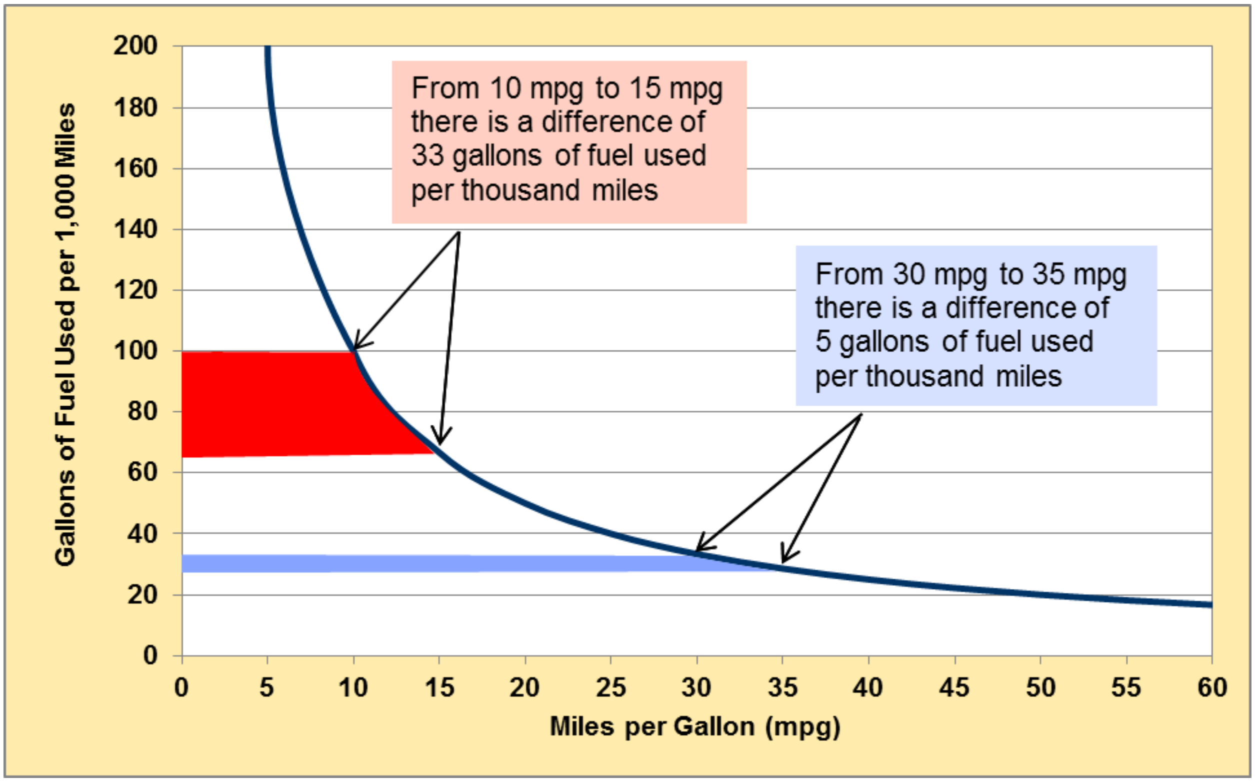


FIGURE 4. Fuel Use versus Fuel Economy

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 Decreased from 2007

Carbon dioxide (CO_2) emissions decreased by 9% from a high of 1,895 million metric tons (mmt) in 2007 to 1,722 mmt in 2013. Improvements in vehicle efficiency and changes in vehicle travel have likely contributed to this decrease. The increased use of ethanol in gasoline may also have played a role in lowering CO_2 emissions.

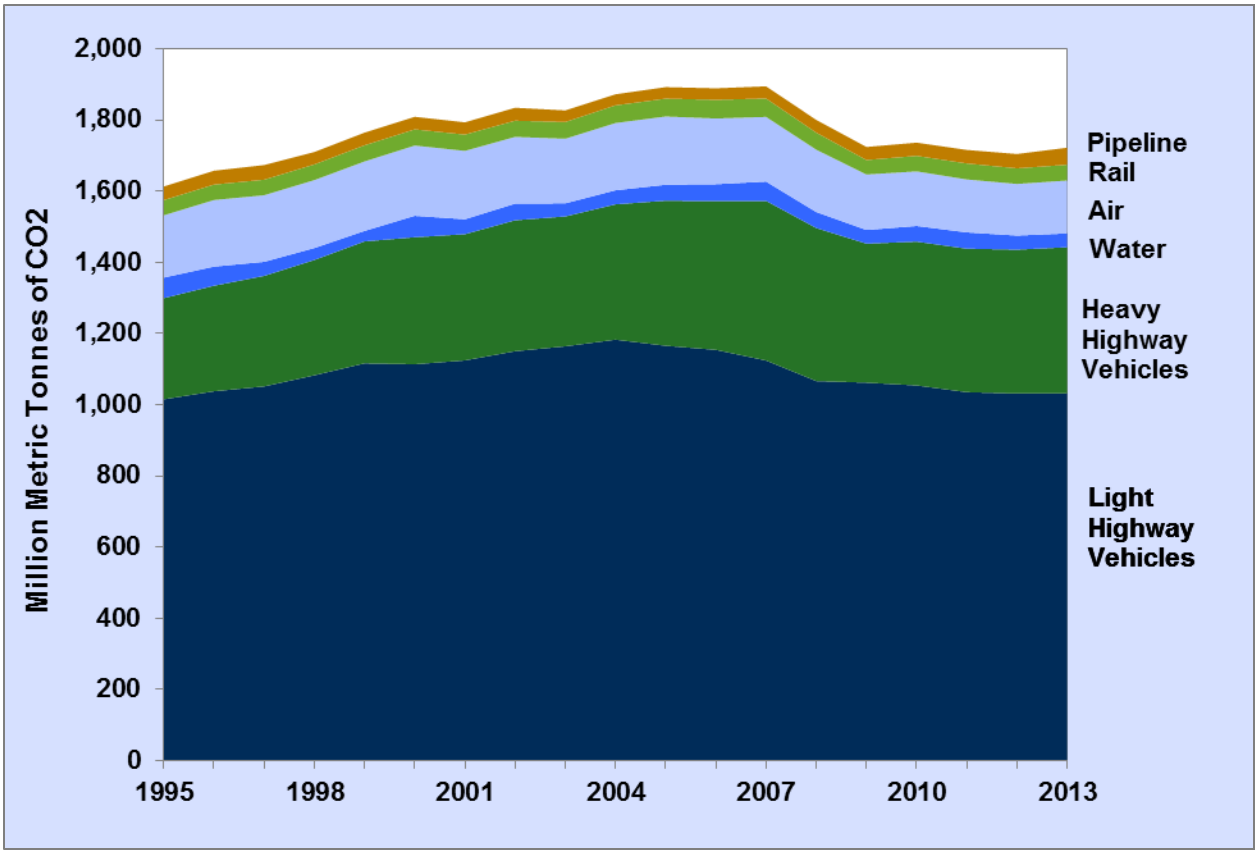


FIGURE 5. Transportation Carbon Dioxide Emissions, 1995-2013

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*: 1990-2013, Table 3-12, April 2015. http://epa.gov/climatechange/ghgemissions/usinventoryreport.html

Many Cars 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) 2015 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 Ford Taurus had the largest decline in CO_2 emissions in the ten-year period, and the Nissan Sentra had the greatest increase in interior volume while still reducing CO_2 emissions.

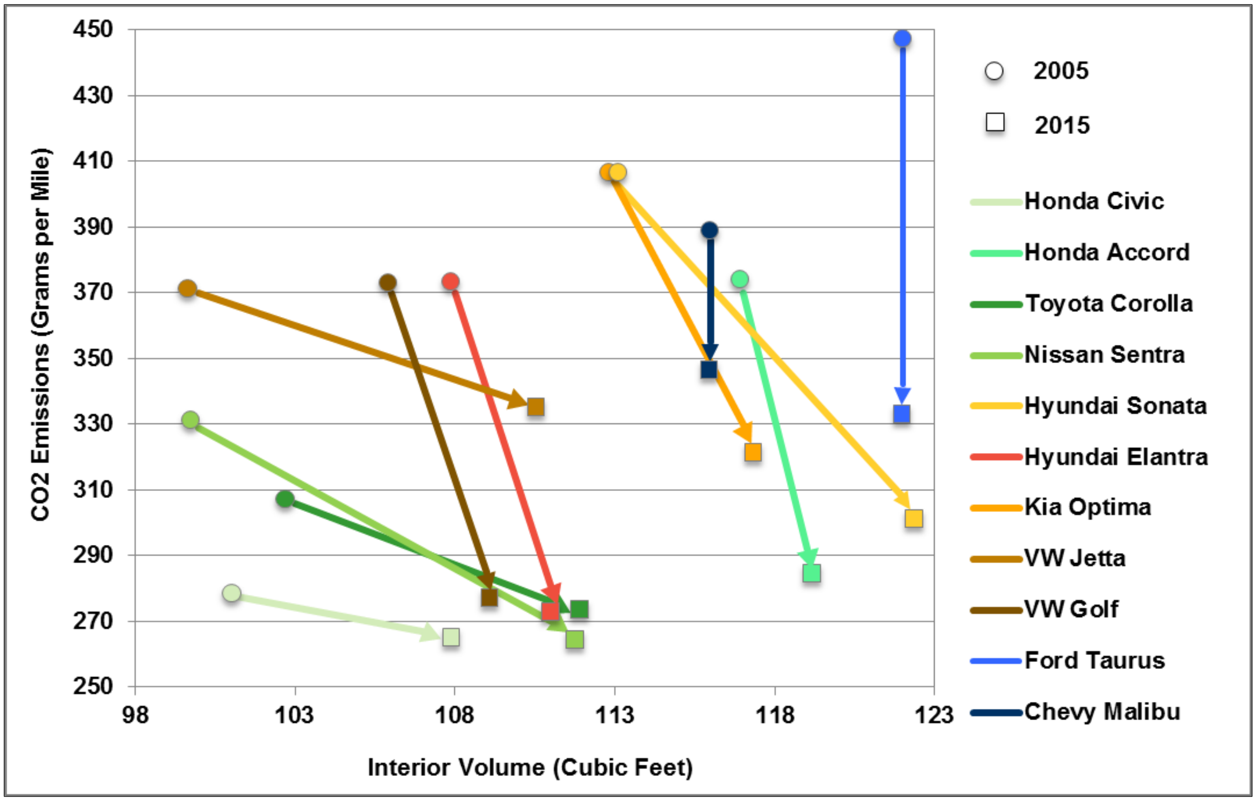


FIGURE 6. Carbon Dioxide Emissions versus Interior Volume for Selected MY 2015 Cars

Source:

U.S. Department of Energy, Fuel economy data, http://www.fueleconomy.gov. Data accessed December 2015.

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) 2015 the sales-weighted average of CO_2 emitted by new cars was 5.8 metric tons annually per car. For new light trucks, the average was 8.2 metric tons annually per truck.

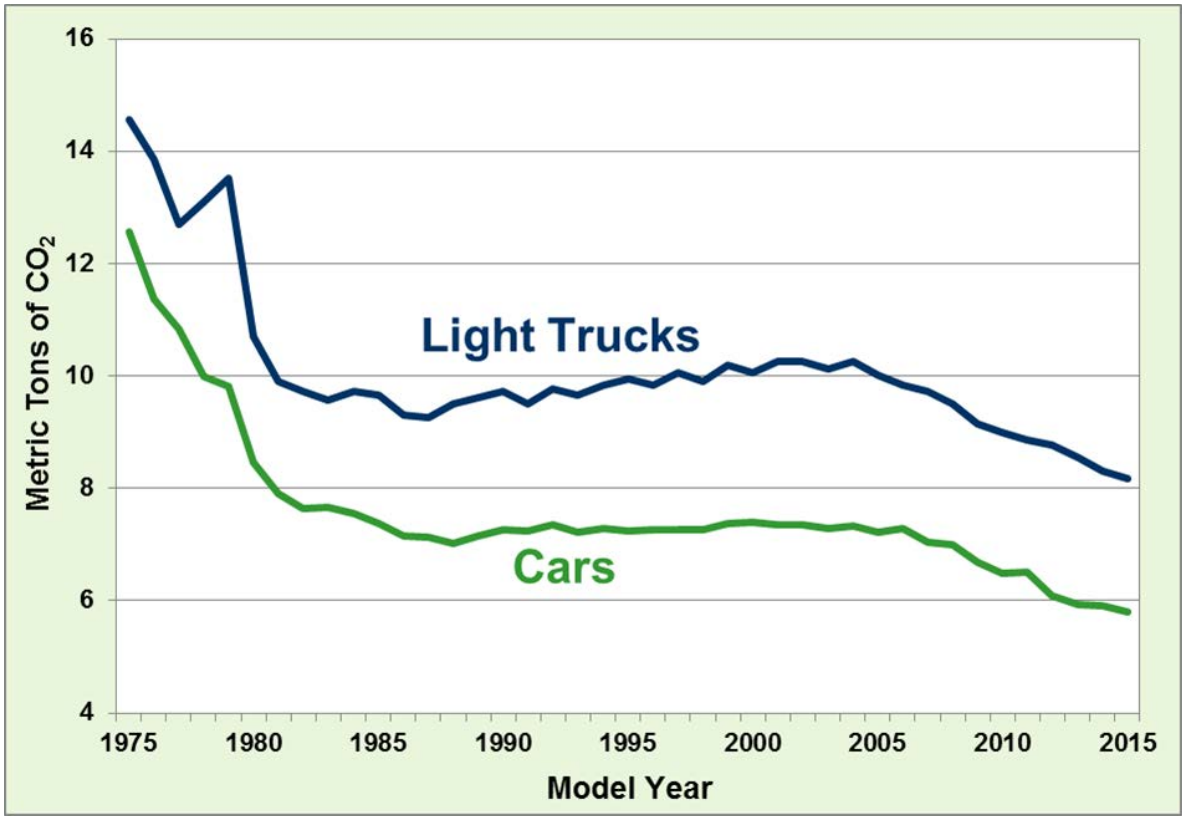


FIGURE 7. Average Carbon Footprint for Cars and Light Trucks Sold, MY 1975-2015

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 2015*, EPA-420-S-15-001, December 2015. 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 2014, carbon monoxide (CO) emissions declined by 51%; nitrogen oxide (NOx) emissions declined by 53%; volatile organic compound (VOC) emissions declined by 44%; and particulate matter emissions less than 10 microns (PM-10) emissions declined 36%.

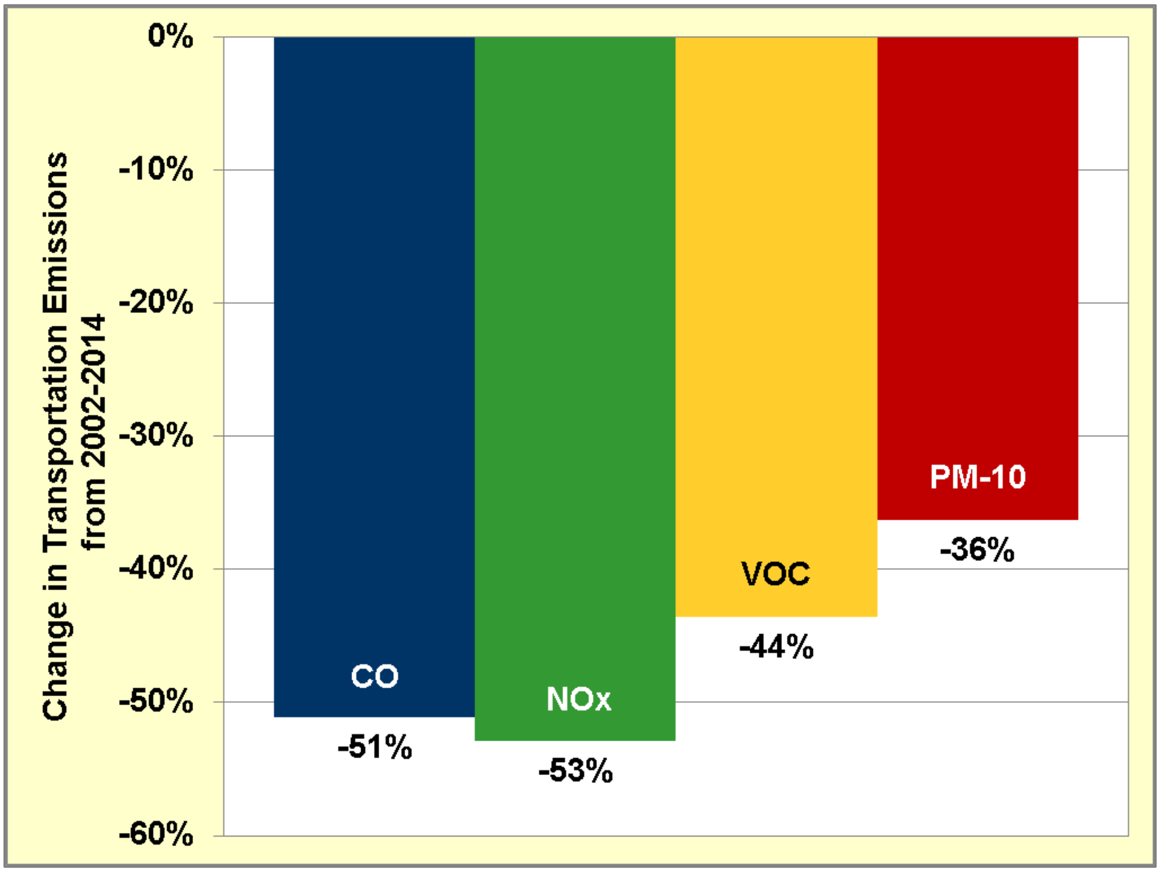


FIGURE 8. Change in Total Transportation Pollutant Emissions from 2002-2014

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 2014 that fell to 33%. The share of transportation's nitrogen oxide (NOx) emissions from highway vehicles experienced a decline from 43% in 2002 to 36% in 2014. The highway share of volatile organic compound (VOC) emissions declined by 6% during this same period. Highway vehicles contributed less than 5% of all particulate matter (PM) emissions.

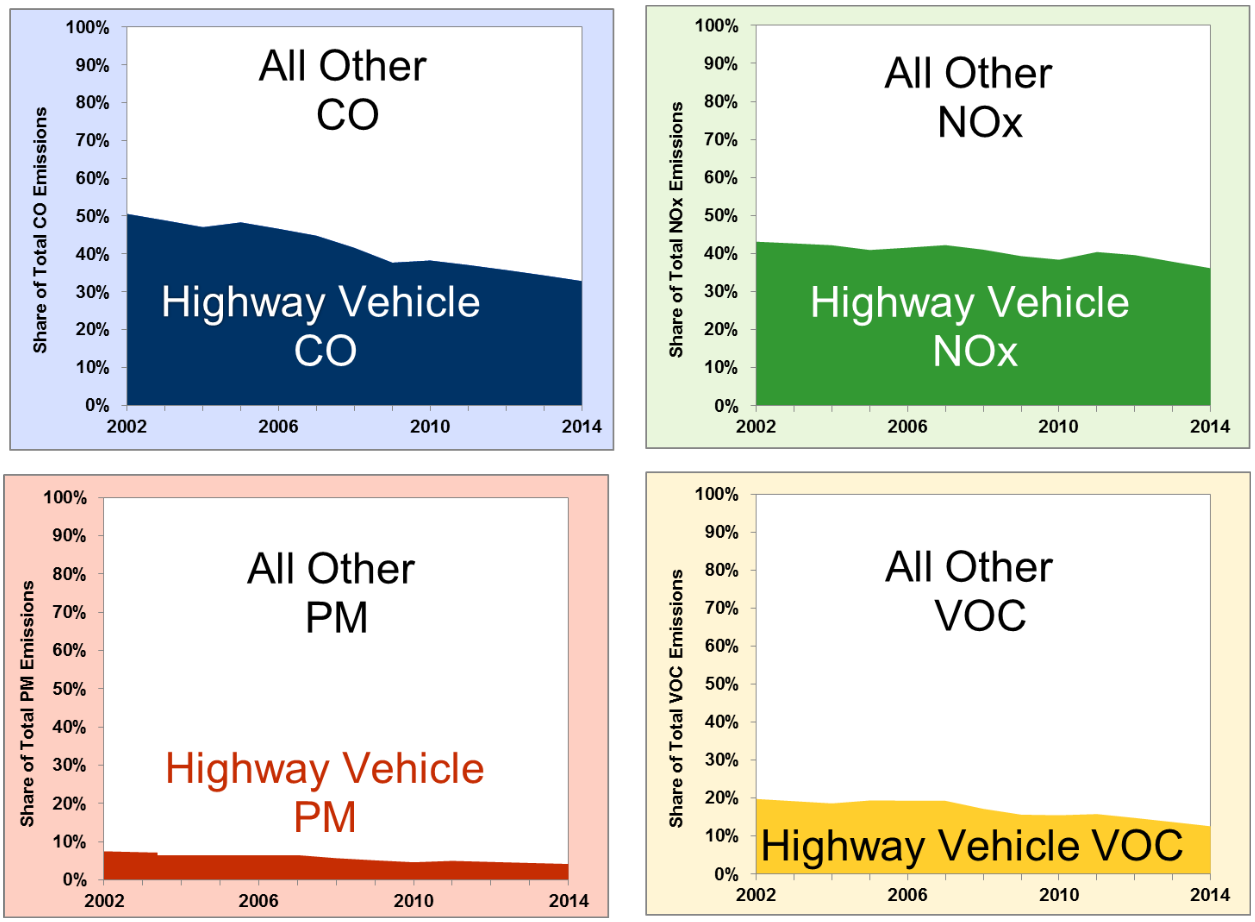


FIGURE 9. Highway and Nonhighway Share of Transportation Pollutant Emissions, 2002-2014

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 27% from 1970-1990, but the gallons per mile changed little from the early 1990's to 2014.

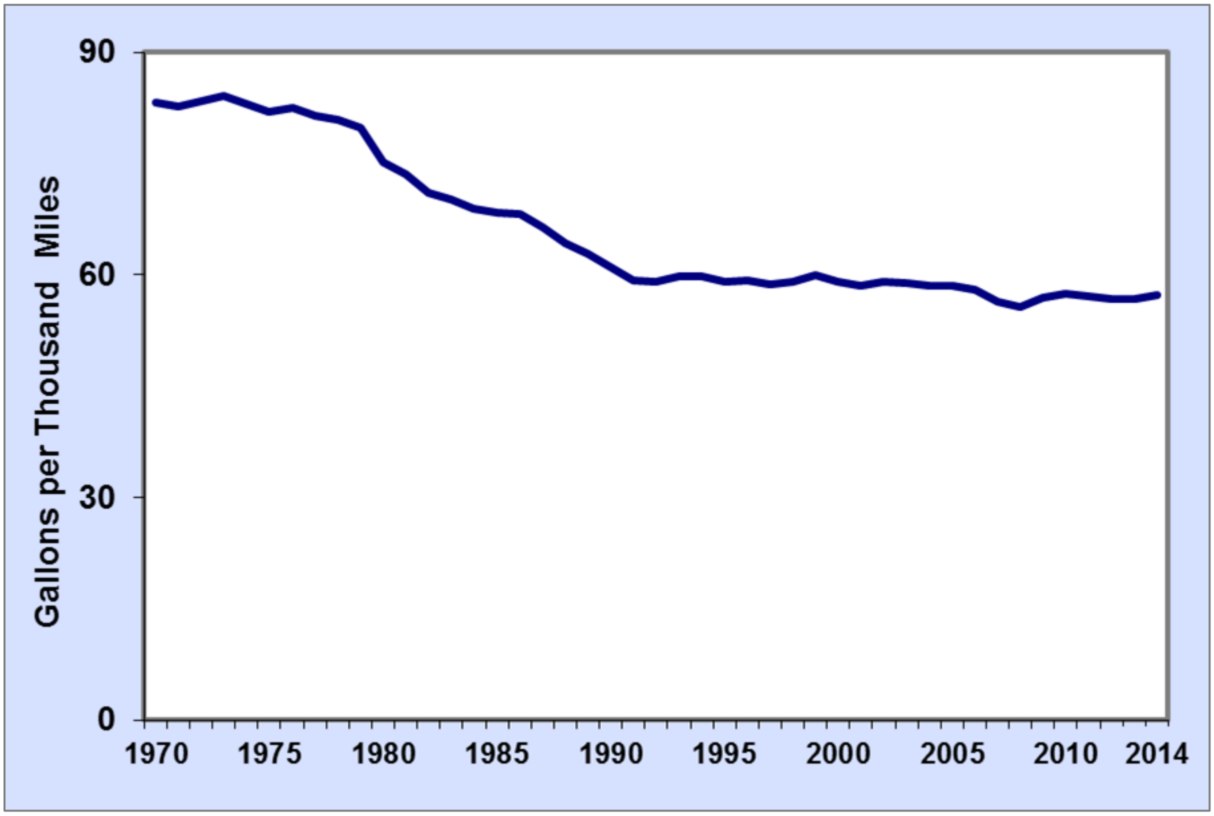


FIGURE 10. Fuel Use per Thousand Miles on the Highways, 1970-2014

Note: Includes travel by cars, light trucks, heavy trucks, buses and motorcycles.

Sources:

Federal Highway Administration, *Highway Statistics 2014*, Table VM-1 and previous annual editions. http://www.fhwa.dot.gov/policyinformation/statistics/2014

Vehicle Miles and Gross Domestic Product Both Grew in 2015

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. The distance between the two series narrowed in 2015 for the first time since the Great Recession in 2009.

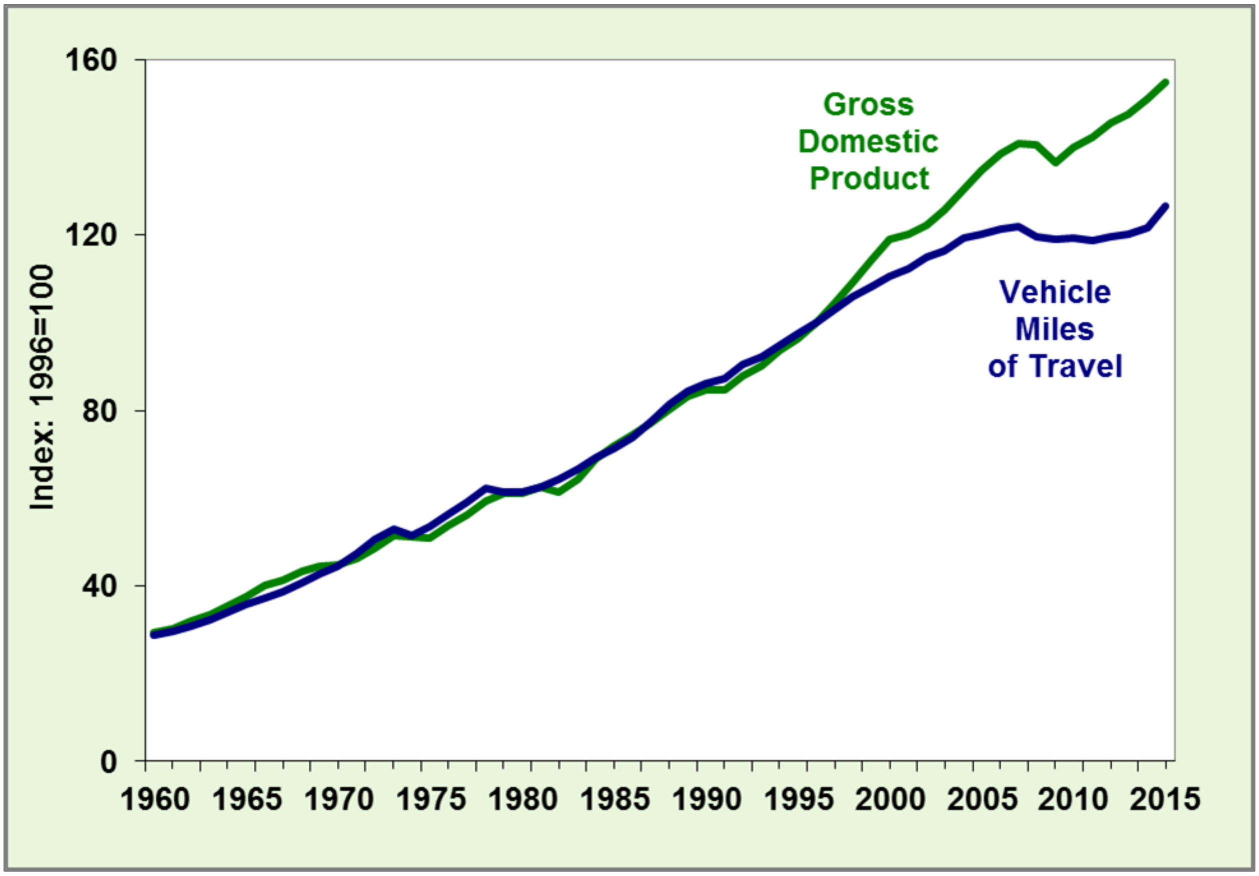


FIGURE 11. Relationship of VMT and GDP, 1960-2015

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 2014*, Table VM-1 and previous annual editions.
http://www.fhwa.dot.gov/policyinformation/statistics/2014

Federal Highway Administration, *Traffic Volume Trends*, December 2015.
http://www.fhwa.dot.gov/policyinformation/travel_monitoring/15dectvt

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.

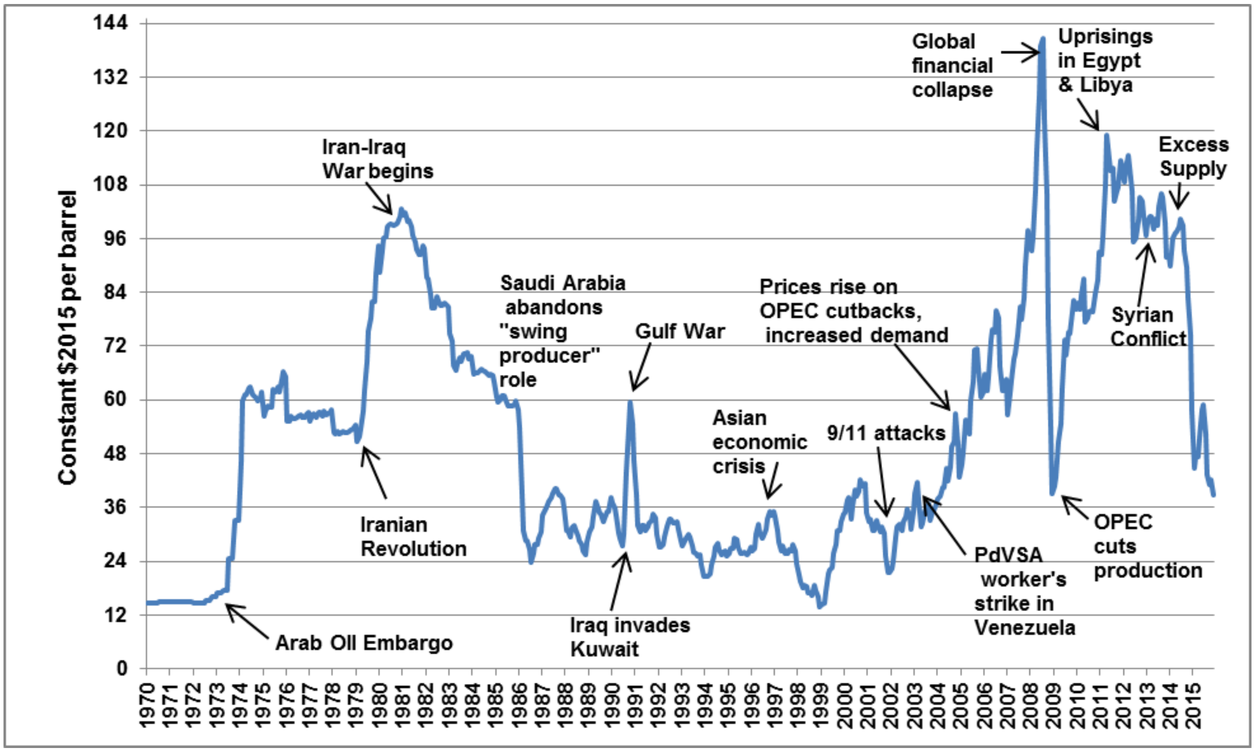


FIGURE 12. World Crude Oil Price and Associated Events, 1970-2015

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, 2015. 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 five times in the past 30 years (1973-74, 1979-80, 1990-91, 1999-2000, and 2008). Most of the oil price shocks have been followed by an economic recession in the United States.

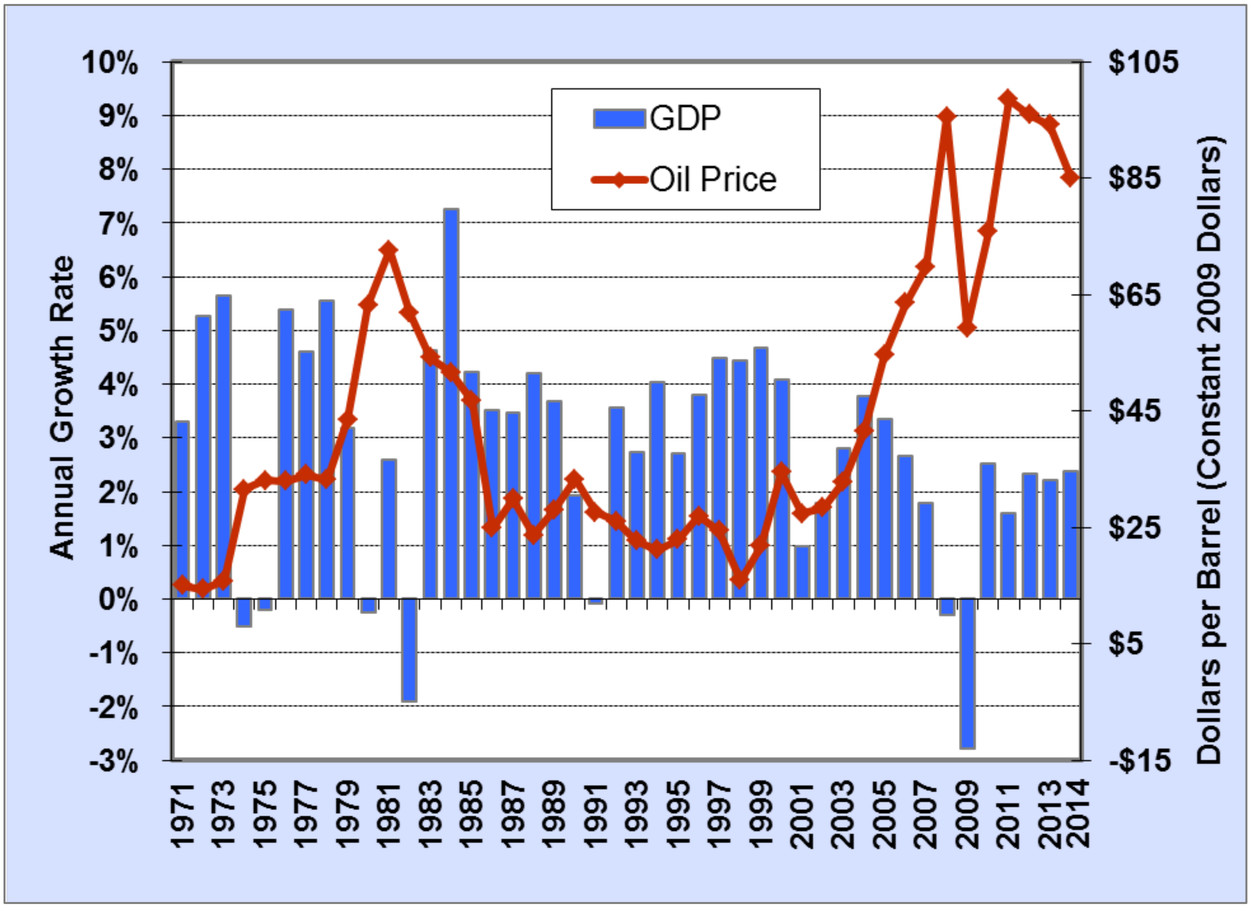


FIGURE 13. The Price of Crude Oil and Economic Growth, 1971-2014

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

Sources:

Energy Information Administration, *Monthly Energy Review, November 2015*, 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 2015. http://bea.gov/iTable/index_nipa.cfm

ORNL Estimates that 2014 Direct and Indirect Oil Dependence Costs Were $116 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 over 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 2014 the total cost was about $116 billion.

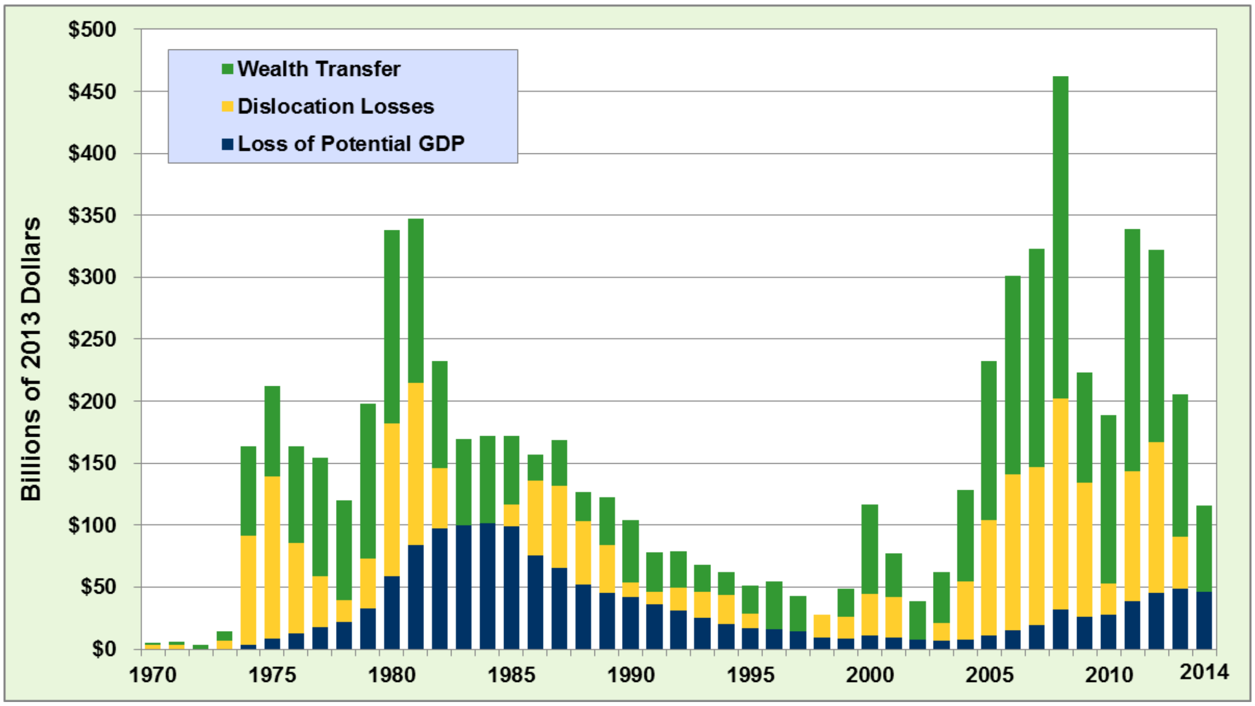


FIGURE 14. Costs of Oil Dependence to the U.S. Economy, 1970-2014

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 Changzheng Liu.

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.

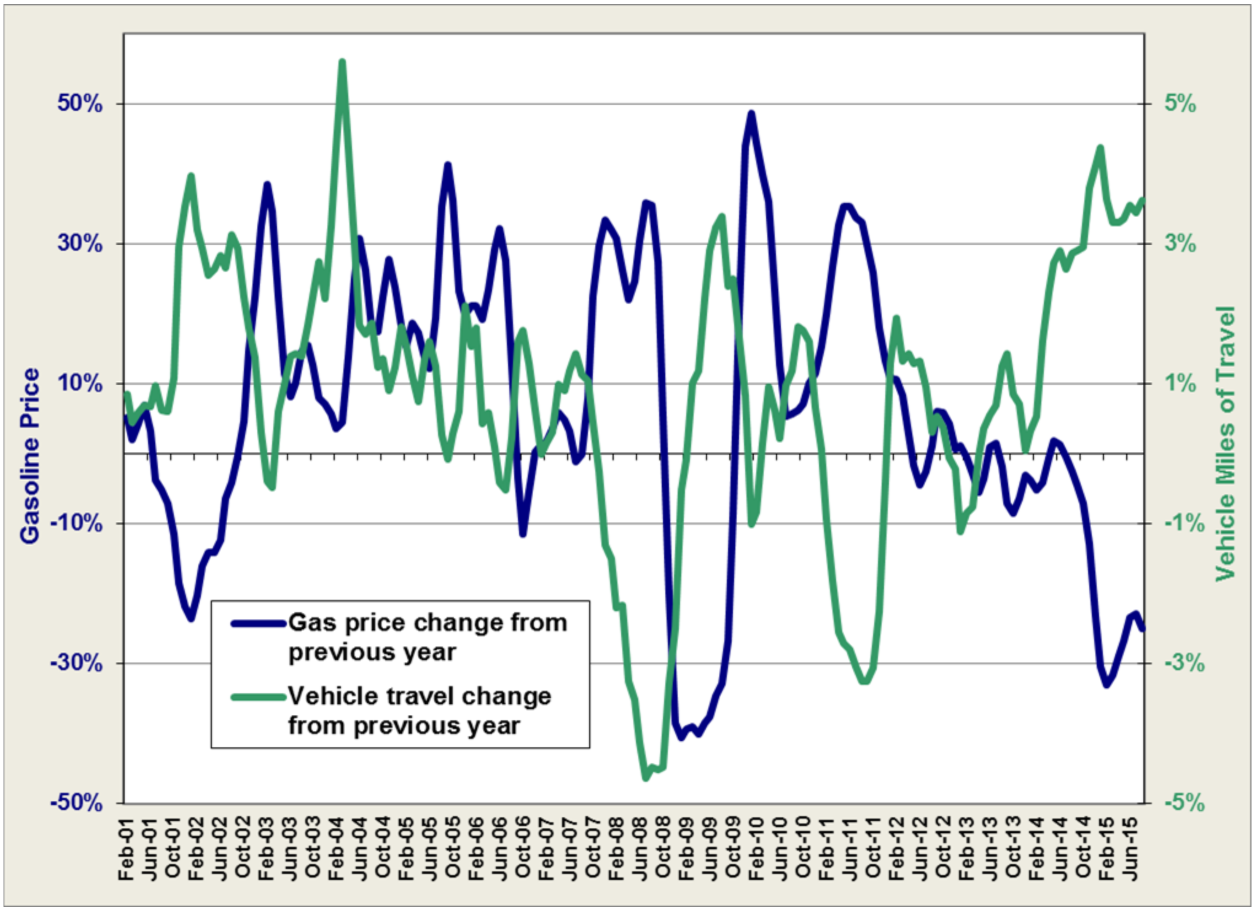


FIGURE 15. Relationship of Vehicle-Miles of Travel and the Price of Gasoline, 2001-2015

Sources:

Federal Highway Administration, *September 2015 Traffic Volume Trends,* and previous monthly editions. http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm

Energy Information Administration, *Monthly Energy Review, November 2015*, Table 9.4. http://www.eia.gov/totalenergy/data/monthly

The Average Price of a New Car Is Just over $25,000

The average price of a new car in 2014 was $25,287, a little lower than the 2013 average (constant 2014 dollars). That price continues to fall from a high of $29,402 in 1999, mainly driven by the high price of import cars. The price of imports peaked in 1998 at $41,676. Until 1981, domestic cars were more expensive than imports.

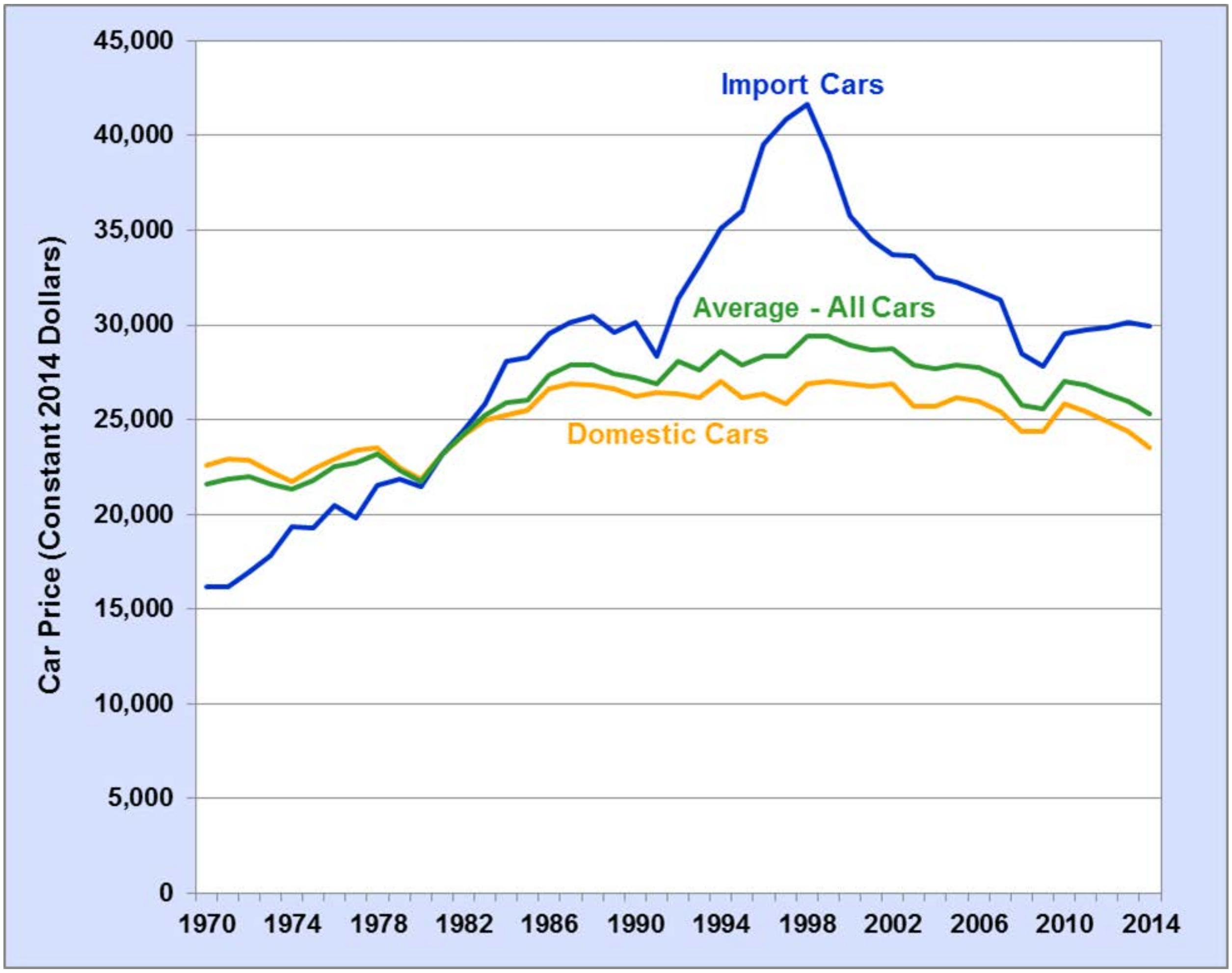


FIGURE 16. Average Price of a New Car, 1970-2014

Note: Data exclude light trucks.

Source:
U.S. Department of Commerce, Bureau of Economic Analysis, *National Income and Product Accounts*, underlying detail estimates for Motor Vehicle Output, Washington, DC, 2015.

The Highest Selling Light Vehicles of 2014 Were In the $25-$30,000 Price Range

In 2014, there were about 5.6 million light vehicles sold with prices ranging from $25-30,000, which was the category with the highest sales volume. The second highest category was $35-40,000. The 2009 and 2014 sales trends by price are similar, considering that about 10 million light vehicles were sold in 2009 and over 16 million were sold in 2014.

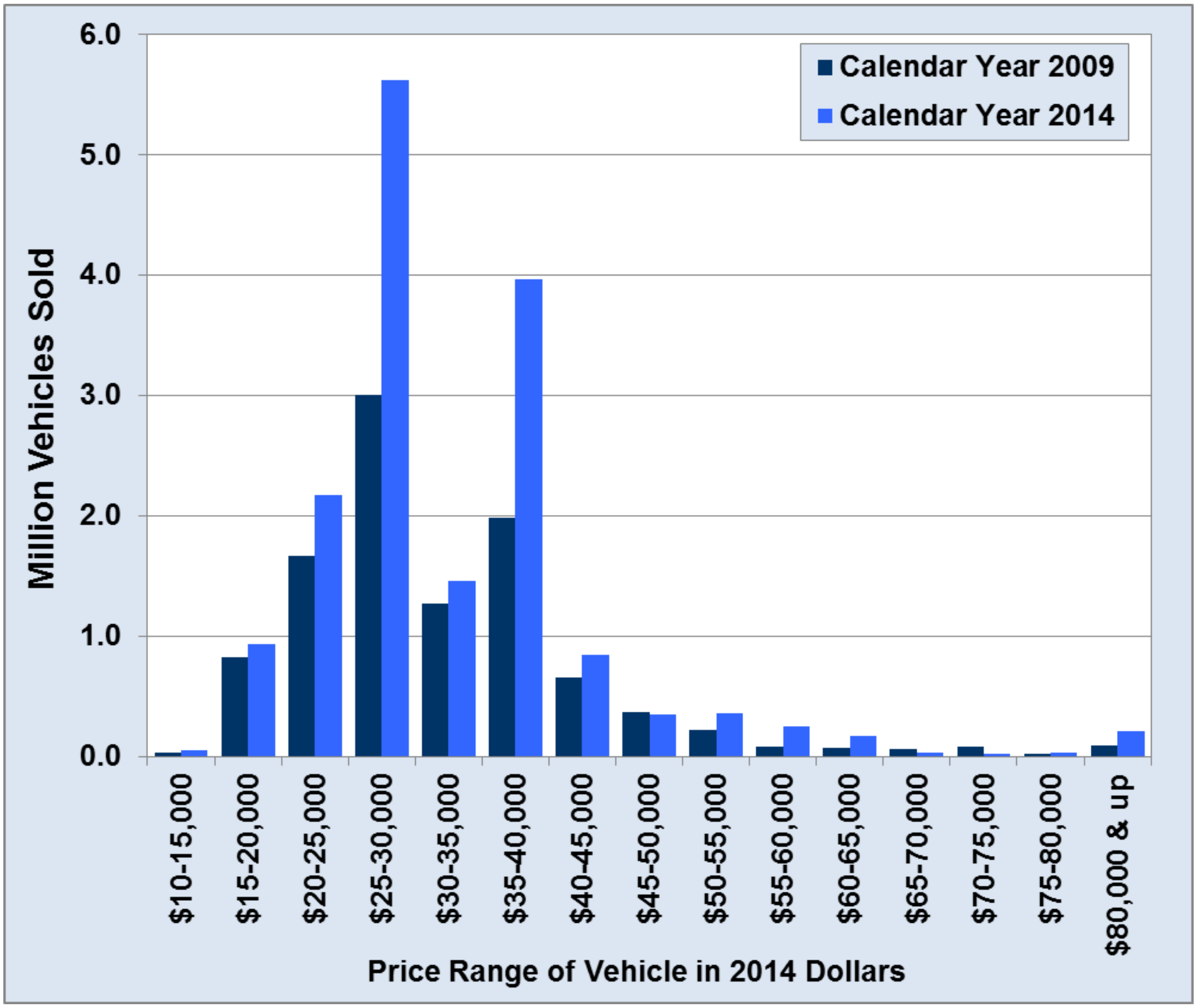


FIGURE 17. Light Vehicle Sales by Price Range, Calendar Years 2009 and 2014

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

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

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

A 2015 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 2015, 31% of the survey respondents indicated that dependability would be the most important vehicle attribute while 13% of the survey respondents chose fuel economy—the lowest share since 2005.

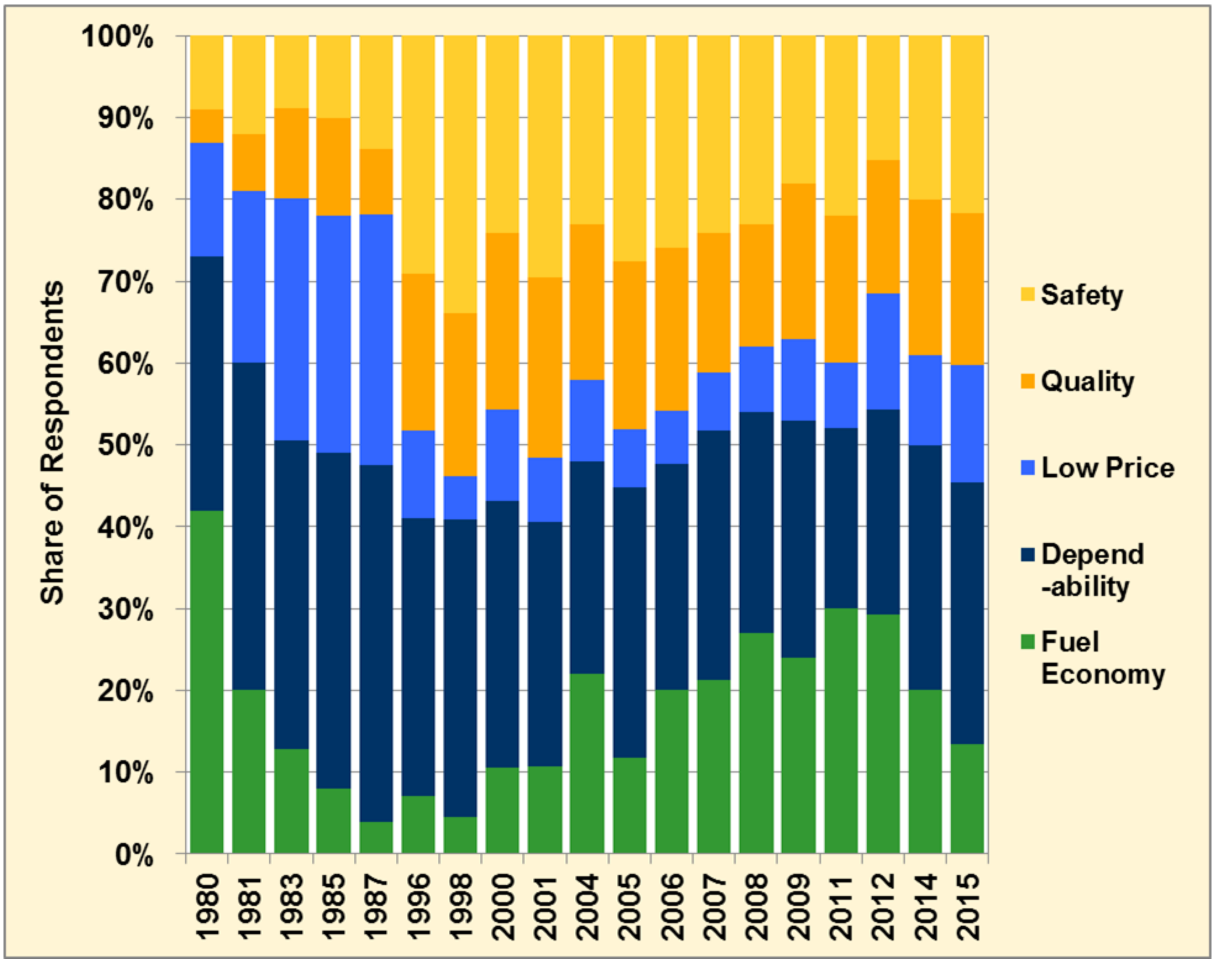


FIGURE 18. Most Important Vehicle Attribute, 1980-2015

Sources:

1980-87: J. D. Power (based on new car buyers). 1998-2015: Opinion Research Corporation International for the National Renewable Energy Laboratory (Sample size ≈ 1,000 in the general population).

Study Finds More than Half of All Age Groups Use the Internet to Find a Car Dealer

According to an AutoTrader-commissioned study of people who purchased vehicles within the past 12 months, the Internet is the source most used when finding a car dealer. However, the study revealed generational differences among vehicle buyers. Millennials were more likely than Baby Boomers or Generation Xers to use a referral from family or friends while Baby Boomers were more likely to rely on prior experience with a dealer, a newspaper or other media sources. Millennials and Generation Xers were more likely to use the Internet.

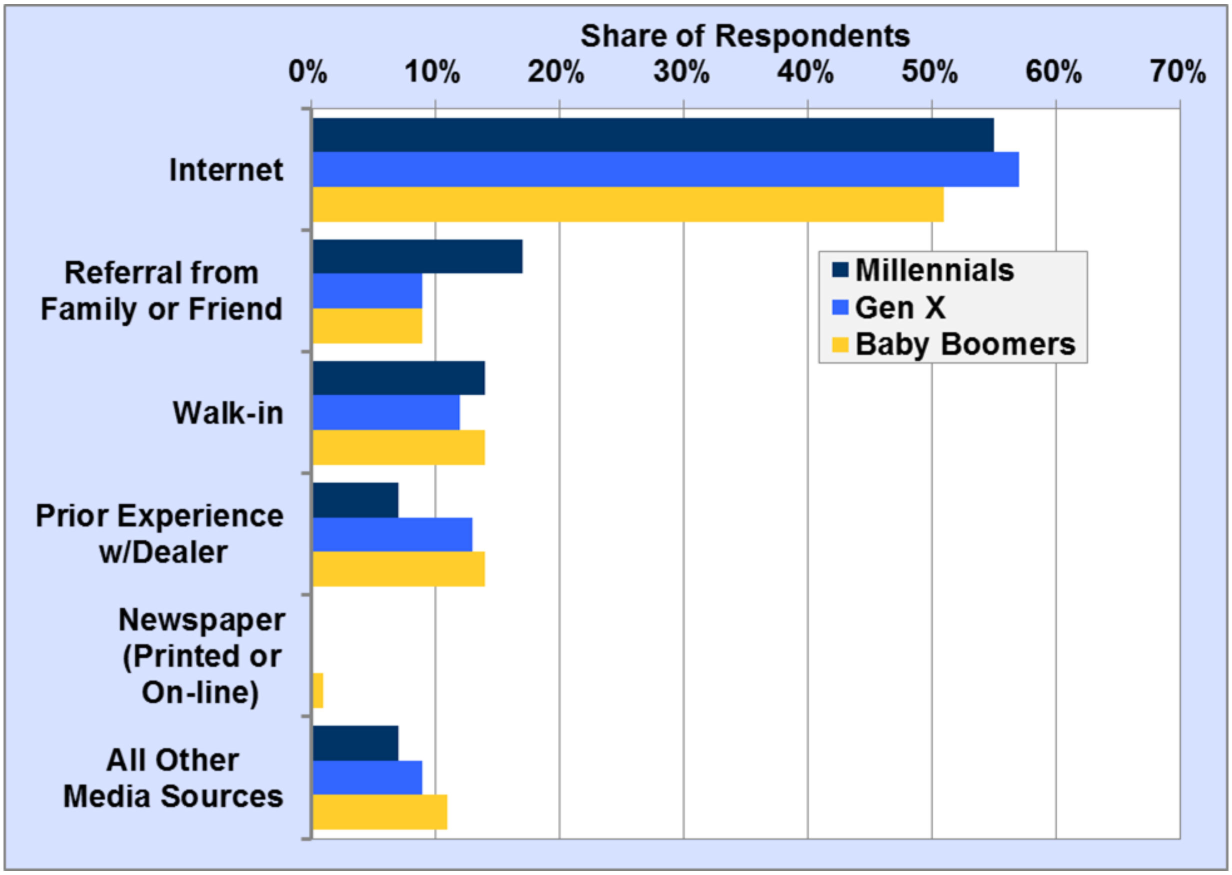


FIGURE 19. Most Influential Sources Leading to a Car Dealer, 2015

Notes: Internet includes on-line news sites. All Other Media Sources include television, direct mailings, outdoor ads, radio, and magazines. Although the original study did not specify exact definitions, Baby Boomers are those born from 1946 to 1964; Generation Xers are those born from 1964 to about 1980; and Millennials are those born from about 1980 to the mid-2000's. Sample size was about 2,300 buyers.

Source:
IHS Automotive/Polk, *2015 Automotive Buyer Influence Study* for AutoTrader.com, 2015.
http://agameautotrader.com/insights/view/2015-automotive-buyer-influence-study-1

Hybrid Vehicles Can Save Money over Time

A selection of hybrid vehicles was paired with a comparably equipped non-hybrid vehicle 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 2015 national average fuel price of $2.52 per gallon of regular.

TABLE 1. Selected 2015 and 2016 Model Year Hybrid Vehicles Paired with a Comparably Equipped Non-Hybrid Vehicle

Vehicles	EPA MPG	MSRP Difference	Annual Fuel Cost Savings	Years to Payback
2016 Buick LaCrosse eAssist[1]	29	$0	$461	0
2016 Buick LaCrosse	22			
2015 Buick Regal eAssist[1]	29	$0	$378	0
2015 Buick Regal	23			
2016 Lincoln MKZ Hybrid[1]	40	$0	$565	0
2016 Lincoln MKZ FWD	26			
2016 Ford Fusion Hybrid Titanium	42	$310	$615	0.5
2016 Ford Fusion FWD Titanium 4cyl	26			
2015 Toyota Prius Two[2]	50	$1,230	$660	1.9
2015 Toyota Camry LE	28			
2015 Honda Accord Hybrid Touring	47	$1,425	$721	2.0
2015 Honda Accord Touring	26			
2016 Toyota Avalon Hybrid Limited	40	$1,500	$700	2.1
2016 Toyota Avalon Limited	24			
2016 Kia Optima Hybrid	38	$1,105	$395	2.8
2016 Kia Optima EX	28			
2016 Toyota Avalon Hybrid XLE Premium	40	$2,250	$700	3.2
2016 Toyota Avalon XLE Premium	24			
2016 Toyota Avalon Hybrid XLE Plus	40	$2,250	$700	3.2
2016 Toyota Avalon XLE Plus	24			
2016 Ford Fusion Hybrid SE	42	$2,310	$615	3.8
2016 Ford Fusion FWD SE	26			
2016 Lexus ES 300h	40	$2,920	$700	4.2
2016 Lexus ES 350	24			
2015 Toyota Prius Two[2]	50	$2,175	$473	4.6
2015 Toyota Corolla LE Premium	32			
2016 Toyota Prius c One	50	$2,301	$473	4.9
2016 Toyota Yaris 5-Door LE	32			
2016 Ford Fusion Hybrid S	42	$3,075	$615	5.0
2016 Ford Fusion FWD S	26			

[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 5 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, http://www.fueleconomy.gov. Data accessed January 2016.

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.

TABLE 2. Local/Regional Car-Sharing Programs

Organization	City / Region	URL
BlueIndy	Indianapolis, IN	https://www.blue-indy.com/
Capital CarShare	Albany, NY	http://www.capitalcarshare.org/
Car to Go	Aspen, CO	http://www.cartogo.com/
CarShare Vermont	Burlington, VT	http://www.carsharevt.org/
CityCarshare	San Francisco Bay Area, CA	http://www.citycarshare.org/
Dancing Rabbit Vehicle Cooperative	Rutledge, MO	http://www.dancingrabbit.org/drvc/
e-GO CarShare	Boulder, CO	http://carshare.org/
eThos Electric Carshare	Golden, CO	http://ethoscarshare.com/
Ford Car Swap	(Experiment) Dearborn, MI	https://media.ford.com/content/fordmedia/fna/us/en/news/2015/01/06/mobility-experiment-car-swap-dearborn.html
Ford Credit Link	(Experiment) Austin, TX	https://fordcreditlink.com/#/
FunRide	San Luis Obispo, CA	http://myfunride.com/
HOURCAR	Minneapolis, MN	http://www.hourcar.org/
Ithaca Carshare	Ithaca, NY	http://www.ithacacarshare.org/
Maven (GM)	Manhattan, NY & Ann Arbor, MI	https://www.mavendrive.com/
Missoula Urban Demonstration Project Truck Share Program	Missoula, MT	http://www.mudproject.org/
Scoot	San Francisco, CA	http://www.scootnetworks.com/
Smart Commuter Option Of Today (SCOOT)	Kitsap County, WA	http://www.kitsaptransit.com/scoot
Zero Emission Vehicle Network Enabled Transport (ZEV-NET)	(Research) University of California, Irvine, CA	http://www.zevnet.org/

Note: List may not be all-inclusive.

Source:
University of California, Berkeley, Transportation Sustainability Research Center, "Carsharing," website accessed March 18, 2016, and additional research by Oak Ridge National Laboratory staff. http://tsrc.berkeley.edu/carsharing

Car-Sharing and Ride-Summoning Available across the Nation

TABLE 3. 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	FlightCar	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	36	45	20	11	4	5	50	47	32

Note: Turo, formerly RelayRides, cannot operate in the state of New York due to insurance laws.

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

There Were Nearly 1.2 Million Carshare Members and 17,000 Carshare Vehicles in 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.

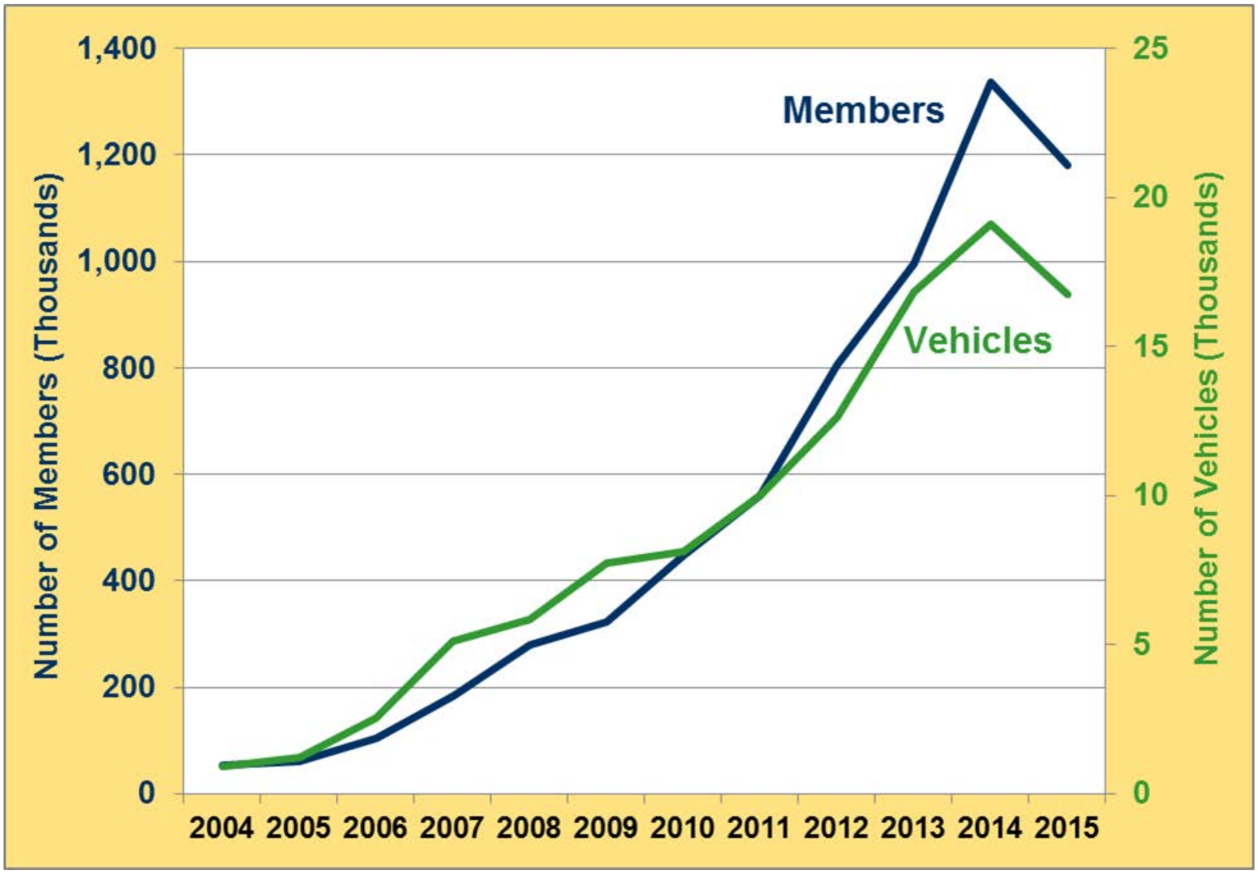


FIGURE 20. Number of Car-Sharing Members and Vehicles, 2004-2015

Source:

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

Almost 17% of Household Expenditures Are for Transportation

Except for housing, transportation was the largest single expenditure for the average American household in 2014. 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%.

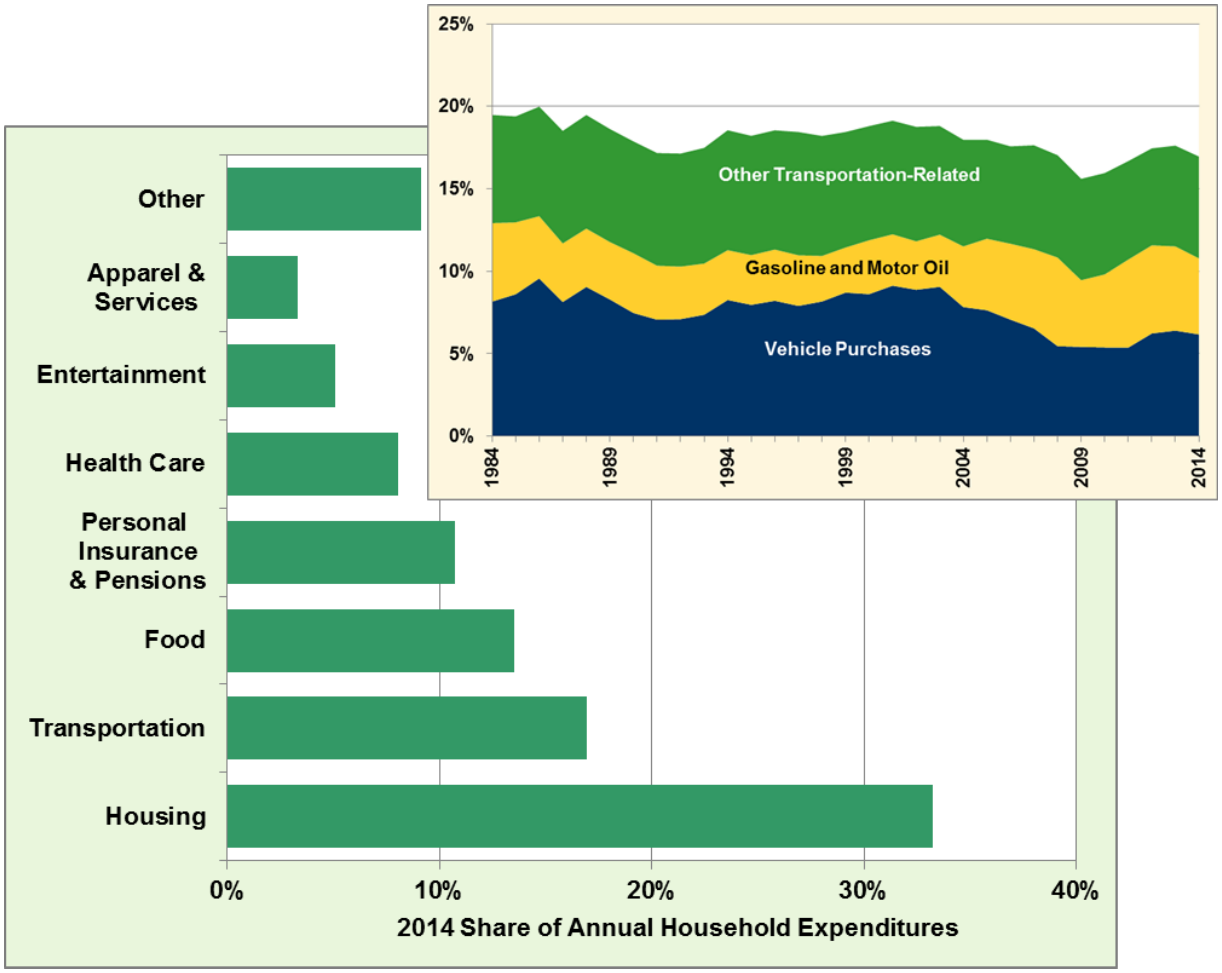


FIGURE 21. Share of Household Expenditures by Category, 2014, and Transportation Share of Household Expenditures, 1984-2014

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 1202, Washington, DC, 2015, 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, 10.3 million people are employed in transportation-related jobs. These transportation-related jobs account for 7.5% of the total non-farm employment. Retail sales of motor vehicles and parts, which include dealerships, retail parts stores, and more, accounts for the most employees. Truck transportation, which includes truck drivers, is the category with the second highest number of employees.

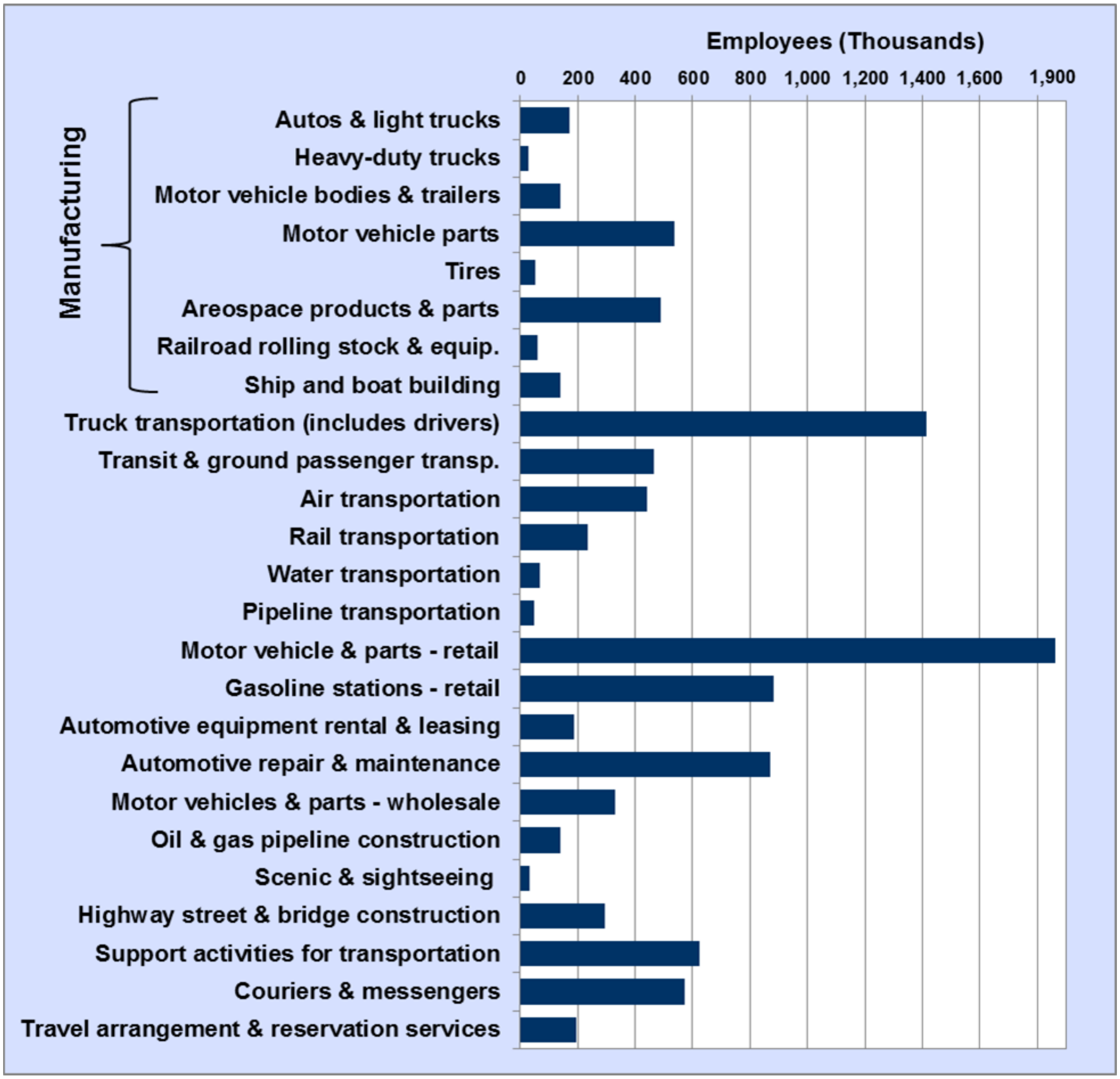
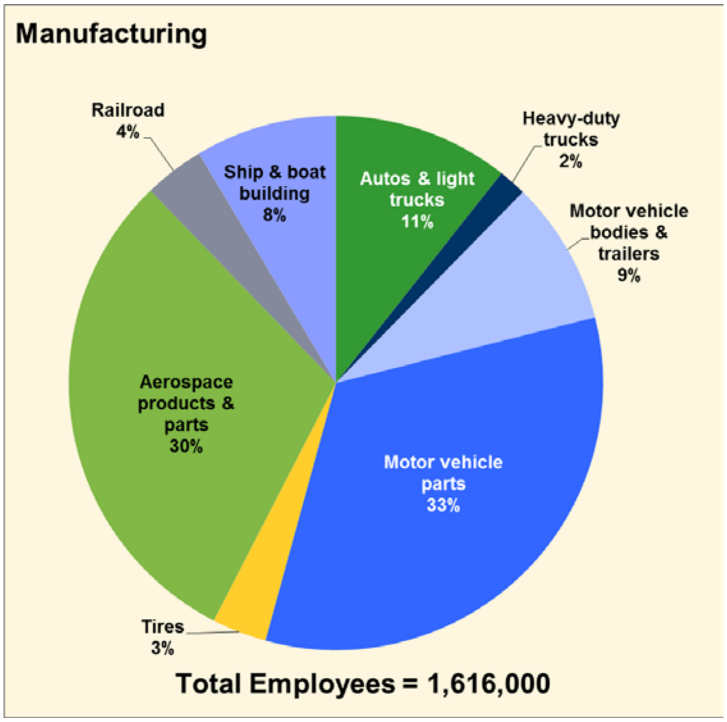


FIGURE 22. Transportation-Related Employment, 2014

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

When looking at jobs related to the movement of people and goods (right), the trucking industry is 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, makes up 17% of the total. Air transportation, which includes everything from pilots to airport workers, is 17% of the total.

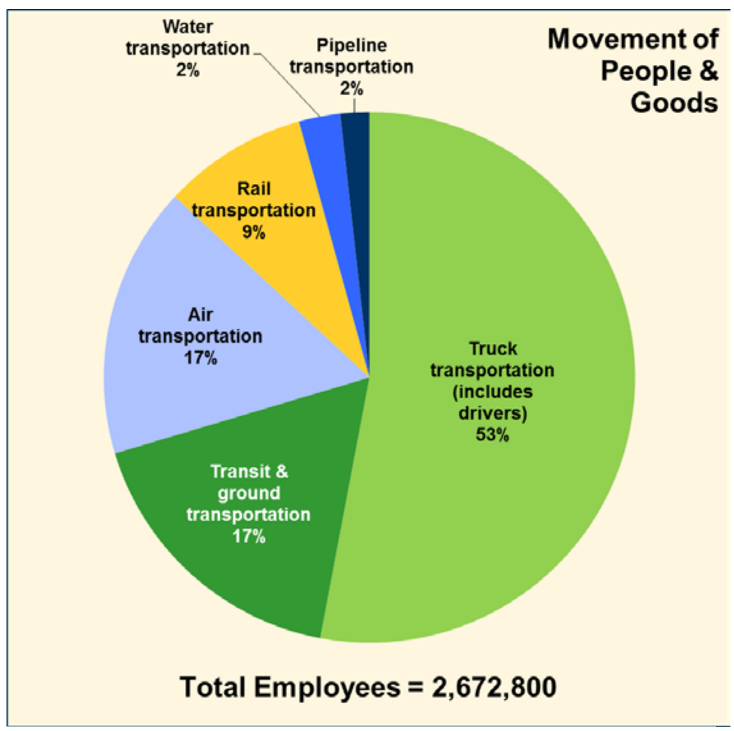


FIGURE 23. Transportation Manufacturing-Related and Mode-Related Employment, 2014

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

The Automotive Industry Spent $109 Billion on Research and Development in 2015

The automotive industry accounted for 16% of all corporate research and development (R&D) in the United States in 2015, totaling $109 billion. Computing & electronics and healthcare were the only two industries where companies spent more on R&D than the automotive industry.

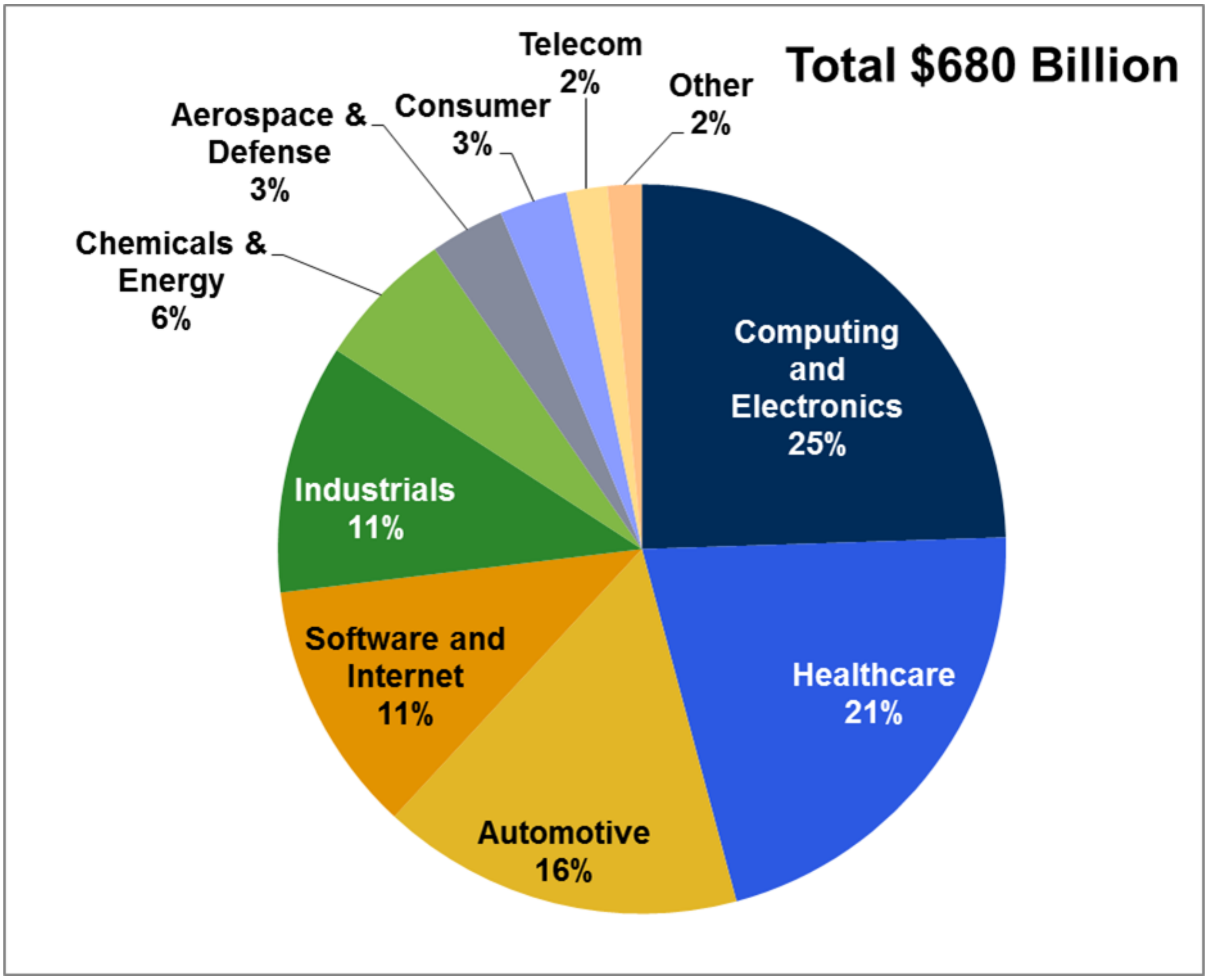


FIGURE 24. Research and Development Spending by Industry, 2015

Source:
PriceWaterhouseCoopers, *The 2015 Global Innovation 1000: Innovation's New World Order*, http://www.strategyand.pwc.com/reports/2015-global-innovation-1000-media-report

VW Tops the List of Automotive Research and Development Expenditures in 2015

Of the top ten companies that spent funds on automotive research and development (R&D), VW is the only company with more than $10 billion of expenditures in 2015. The rest of the companies spent between $3.4 billion (FCA) and 9.2 billion (Toyota) on automotive R&D. Each of the top ten companies is an automotive manufacturer with the exception of Denso, a Tier 1 automotive supplier.

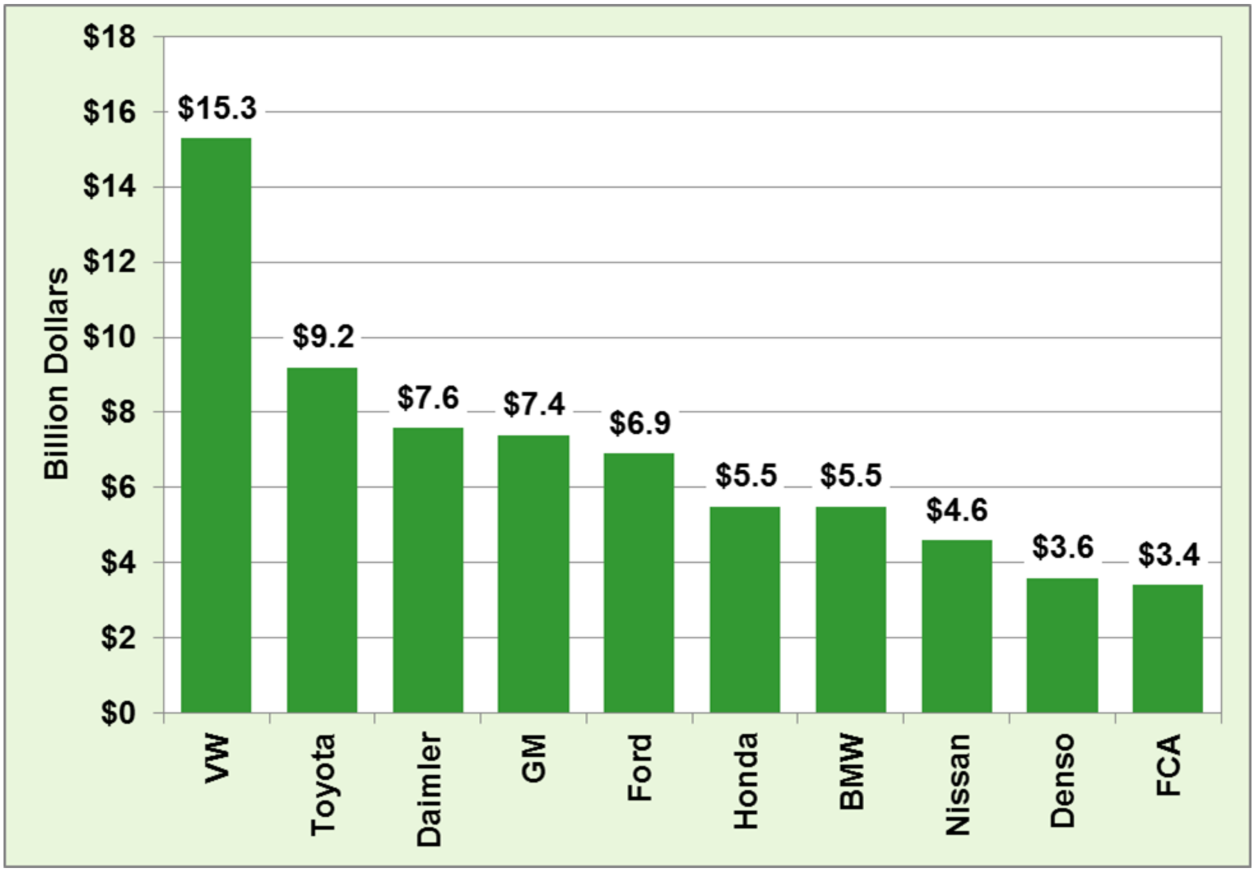


FIGURE 25. Top Ten Companies Investing in Automotive Research and Development, 2015

Source:

Crain Communications, *Automotive News*, February 22, 2016, p. 14.

Original source: PriceWaterhouseCoopers, *The 2015 Global Innovation 1000: Innovation's New World Order*.

Manufacturers' Stock Prices Have Their Ups and Downs

Weekly stock prices are shown on the graph below. Nearly all of the manufacturers show a sharp 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 remained consistently under $40 per share until 2015 when it skyrocketed to $280 per share. Fiat Chrysler Automobiles (FCA) stock began trading in October 2014. General Motors (GM) is shown twice – once before bankruptcy (GM-Old) and after the initial public stock offering in late 2010 (GM-New).

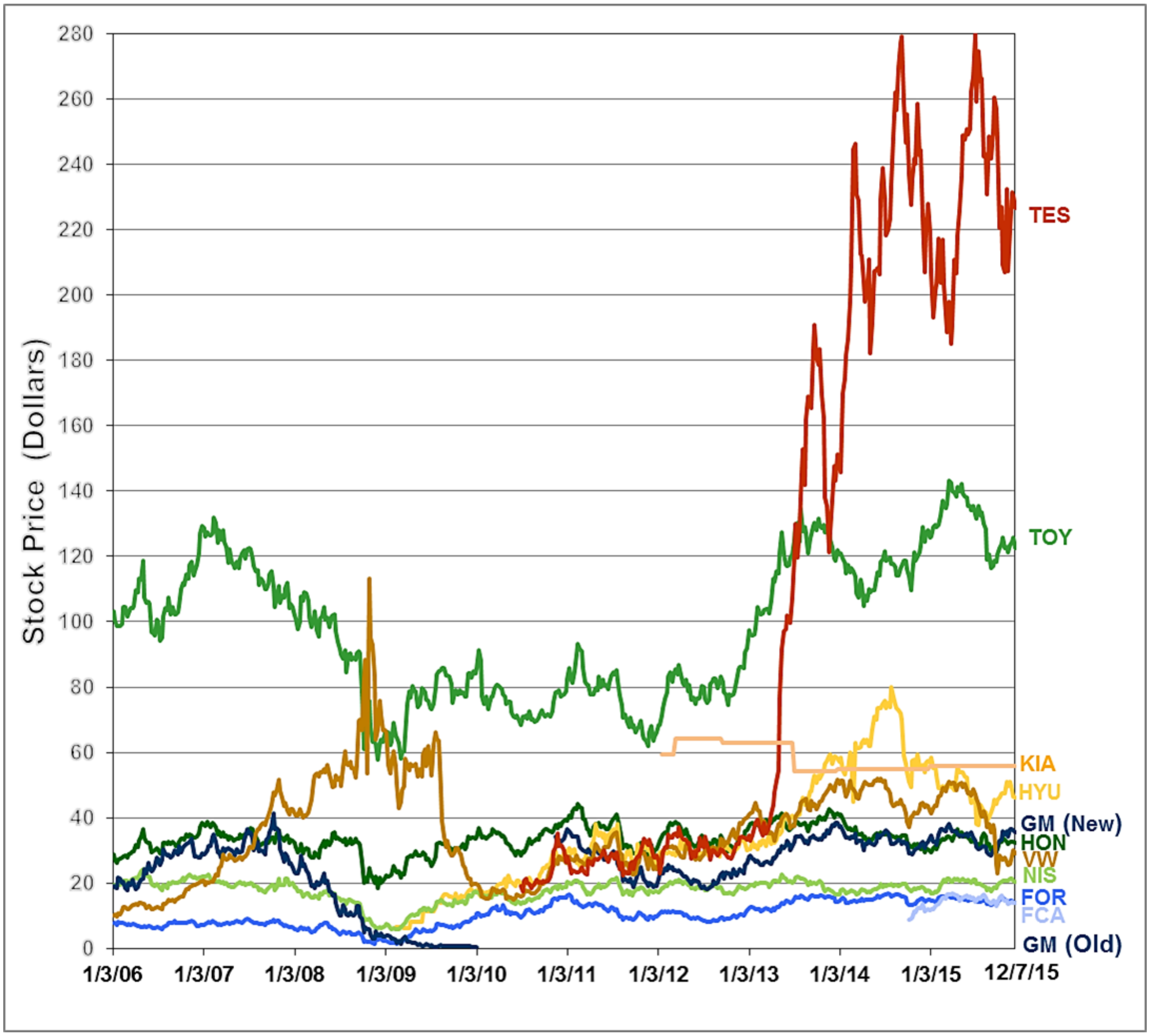


FIGURE 26. Stock Price by Manufacturer, 2006-2015

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

American Full-Size Pickups Top the Most Profitable Vehicles List

Max Warburton and others at Bernstein Research in London developed estimates in 2011 for the vehicles which have made the most money for their companies from the 1990's to 2011. They discovered three categories of vehicles that topped the list: American full-size pickups; German luxury cars; and Japanese mid-size sedans. These vehicles combined high prices, large sales volume and long production periods that spread development costs over a long period. Full-size pickups have a very wide range of extra cost options relative to other vehicle types which contributes to their high ranking on the list.

TABLE 4. List of Twelve Most Profitable Vehicles since the 1990's

Rank	Vehicle Model	Share of Manufacturers' Light Vehicles Sold, 2014	Share of Total Light Vehicles Sold, 2014
1	Ford F series	30%	4%
2	GM Full-Size Pickups	29%	5%
3	Dodge Ram	41%	3%
4	Mercedes S Class	7%	0%
5	BMW 5 Series/X5	25%	1%
6	BMW 3 Series	25%	1%
7	Mercedes E Class	19%	0%
8	Lexus RX SUV	35%	1%
9	Jeep Grand Cherokee	27%	1%
10	Honda Accord	28%	2%
11	Porsche 911	22%	0%
12	Toyota Camry	21%	3%

Note: List compiled in 2011.

Source:
Crain Communications, *Automotive News*, "Cash Cows: The Most Profitable Vehicles Ever," November 21, 2011. http://www.autonews.com/apps/pbcs.dll/article?AID=/20111121/RETAIL07/311219969/1254.
Ward's Automotive Group. http://wardsauto.com

Chapter 2

LIGHT VEHICLES

Page

Contents

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Contents (continued)

Company Profile Section

Company profiles follow for nine different manufacturers.

- 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 brief 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 nine manufacturers for which we have profiles are:

- ❖ three from Detroit
  - Fiat Chrysler Automobiles (FCA),
  - Ford (FOR), and
  - General Motors (GM)
- ❖ three from Japan
  - Honda (HON),
  - Nissan (NIS), and
  - Toyota (TOY),
- ❖ two from Korea
  - Hyundai (HYU), and
  - Kia (KIA), and
- ❖ one from Germany
  - Volkswagen (VW)

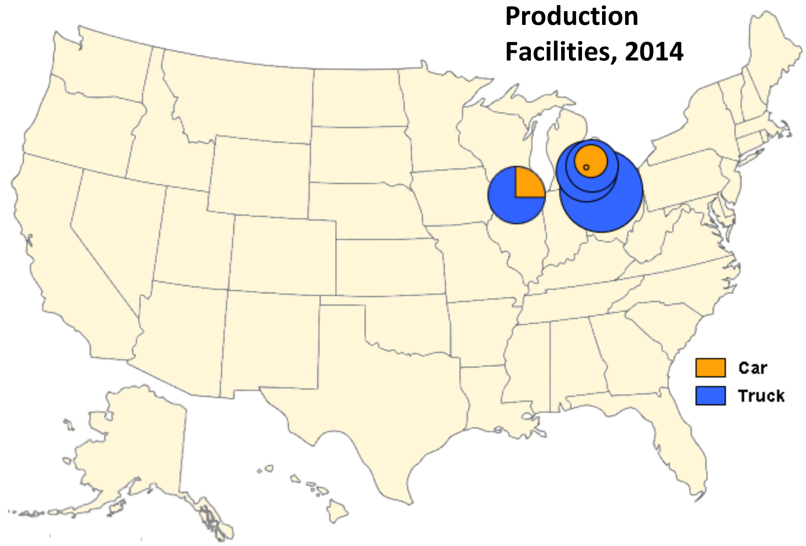
    In future reports some data for VW may be revised. At the current time, data in this report do not reflect any revisions due to the ongoing investigation of VW diesel models.

Fiat Chrysler Automobiles (FCA) Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	31.3 mpg
Import Cars	29.0 mpg
Light Trucks	26.1 mpg

Average Vehicle Footprint, MY 2015	
Cars	46.9 sq ft
Light trucks	53.4 sq ft
All	50.8 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	14
Natural Gas	0
Propane	0
Hybrid-Electric	0
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0



FCA Plants	Type	2014 Production
Toledo, OH - North & South	Truck	510,737
Detroit, MI - Jefferson North	Truck	363,841
Warren, MI	Truck	314,796
Belvidere, IL	Truck	265,774
Sterling Heights, MI	Car	179,528
Belvidere, IL	Car	83,099
Detroit, MI - Conner	Car	549

FIGURE 27. FCA Company Profile

Fuel Saving Technologies

FCA has continued their push toward 8- and 9-speed automatic transmissions in 2015. The all-new 2015 Jeep Renegade became the first small SUV on the market to be offered with a 9-speed transmission; that transmission is also offered on the new Fiat 500x. The “TorqueFlite” 8-speed transmission is now widely used throughout the FCA lineup including sedans, SUVs and pickups and will be used extensively with rear-wheel drive vehicles. FCA estimates a 6-10% improvement in fuel economy over vehicles equipped with the 4-, 5-, and 6-speed predecessors.

Other transmission technologies include the 6-speed automated manual transmission found in the Dodge Dart. Additionally, an all-wheel drive system that automatically disconnects the front or rear axle when not needed reduces mechanical drivetrain losses and improves fuel economy. This axle disconnect technology is installed on a number of vehicles including the new Jeep Renegade and Cherokee, Fiat 500x, Ram 1500, Chrysler 200 and 300, and Dodge Charger. Several new or redesigned engines were also introduced in 2015. The small displacement 1.4L Turbo MultiAir II engine with direct injection was installed on the new 2015 Jeep Renegade and Fiat 500x. The 3.6L Pentastar engine was upgraded for use in model year 2016 vehicles and is expected to deliver fuel economy improvements of about 6%.

Active grille shutters, stop/start, cylinder deactivation and lightweight materials are also employed by FCA. Models like the Ram 1500 EcoDiesel or Dodge Dart Aero make aggressive use of fuel saving technologies. However, even vehicles like the next generation Jeep Wrangler are targeted for weight reduction through greater use of aluminum. For vehicle electrification, there were no hybrid models offered during 2015 and the Fiat 500e, remains the only all-electric vehicle produced by FCA. However, an all-new plug-in hybrid minivan called the Pacifica is planned for late 2016 and is expected to have an all-electric range of about 30 miles.

FCA's Fleet Mix

FCA's vehicle offerings and sales lean heavily toward trucks which tend to have lower fuel economy than cars. The Ram pickup is their largest seller with an EPA-combined fuel economy below 20 mpg. There are three models that average between 25 and 35 mpg (shown in yellow) but they account for a small portion of the overall sales.

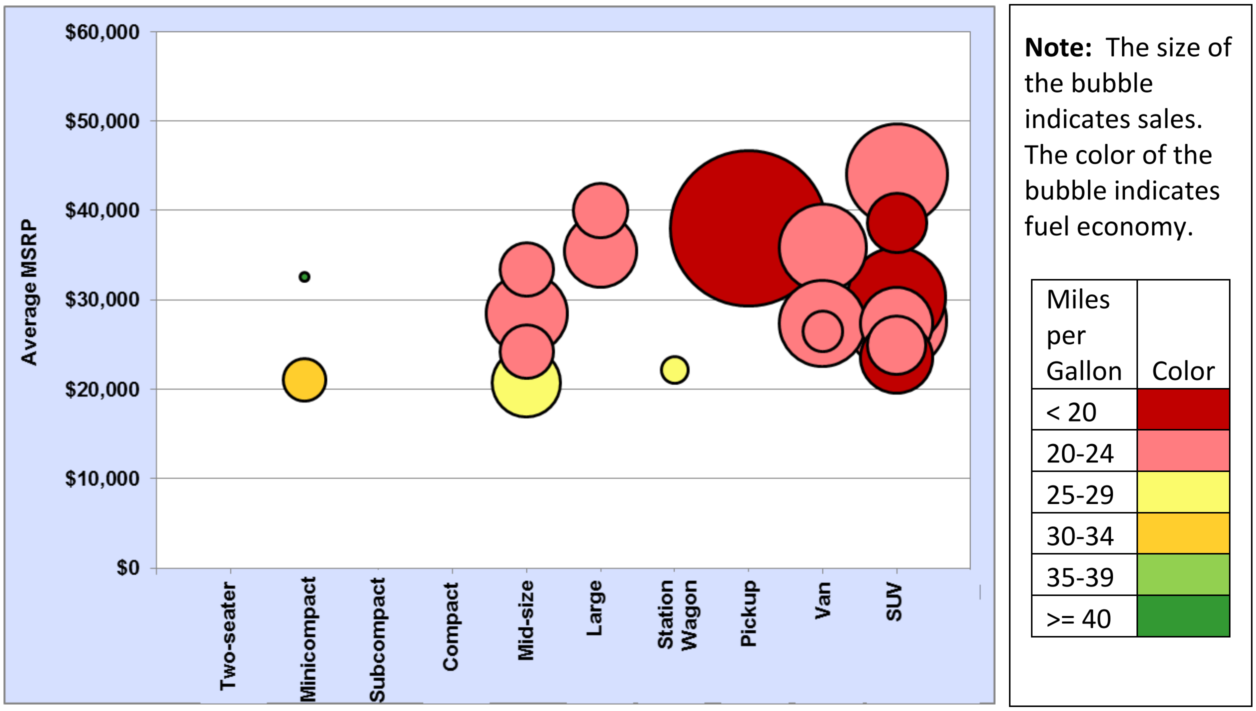


FIGURE 28. FCA Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 5. FCA Models by EPA Size Class, 2014

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

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 about One-Quarter of FCA's Sales in 2014

The combined car market share of Fiat, Chrysler, and Dodge was about 25% of the FCA market share in 2014. The Ram pickup accounted for 21% and the Jeep Grand Cherokee, Cherokee, and Wrangler together accounted for 25%. About 14% of the FCA market was vans.

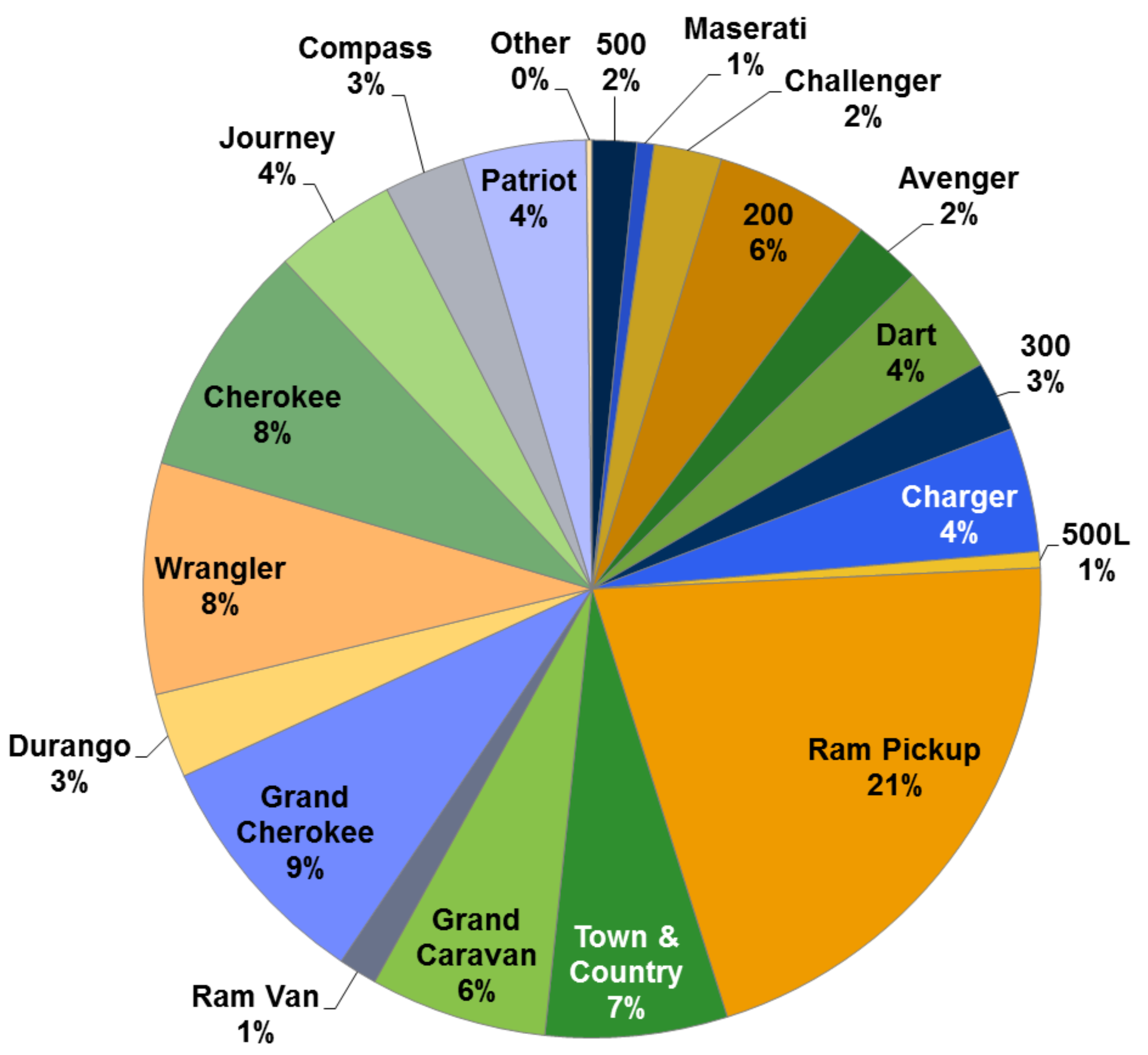


FIGURE 29. FCA Market Share by Model, 2014

Note: "Other" includes the Viper, 500e, and Ferrari. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Fiat 500e Sales More than Doubled in 2015

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 2015, sales increased to nearly 3,500 units. The Fiat 500e was only sold in California and Oregon.

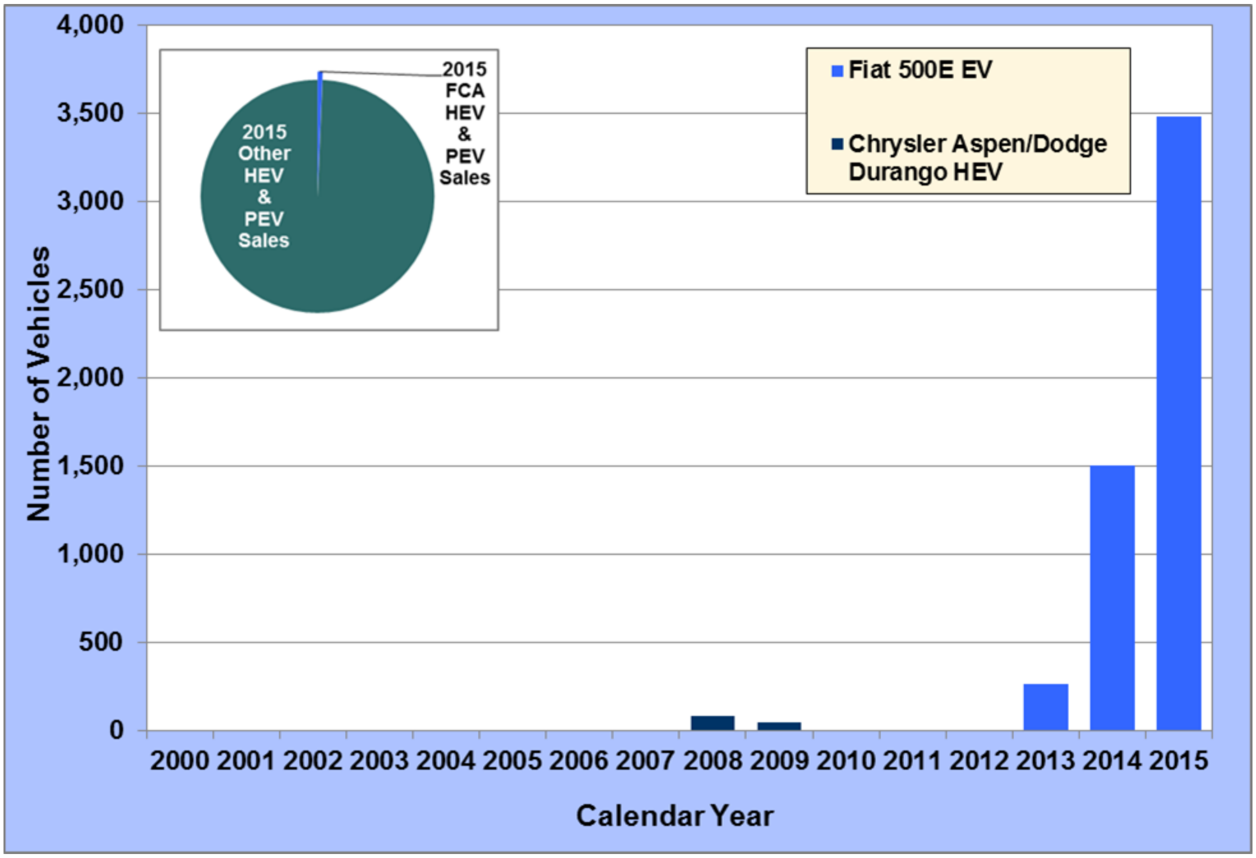


FIGURE 30. FCA Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 Six Other Manufacturers

TABLE 6. FCA Interrelationships with Other Automotive Manufacturers

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

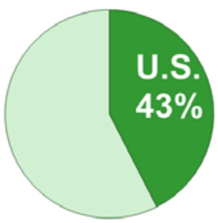
Ford Company Profile

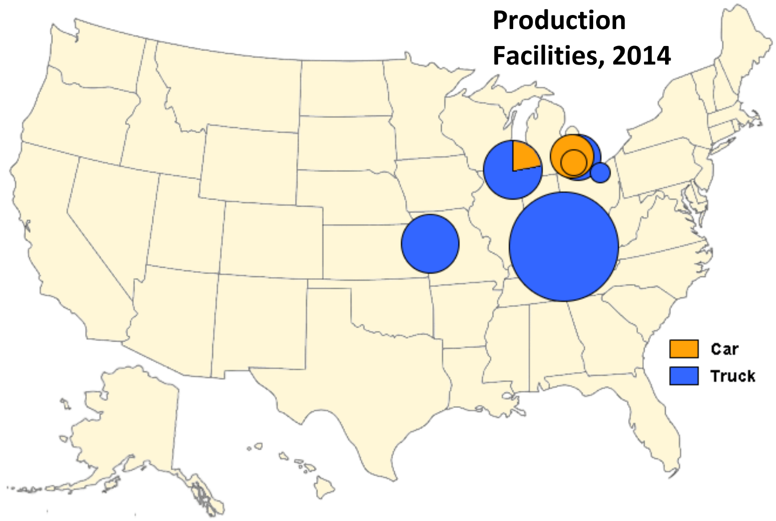
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	36.8 mpg
Import Cars	30.9 mpg
Light Trucks	25.2 mpg

Average Vehicle Footprint, MY 2015	
Cars	46.6 sq ft
Light Trucks	59.0 sq ft
All	52.8 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	5
Natural Gas	0
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	2
Electric	1
Hydrogen	0

World Sales = 5.8 million





Ford Plants	Type	2014 Production
Louisville, KY	Truck	714,469
Kansas City, MO	Truck	367,708
Chicago, IL	Truck	284,951
Dearborn, MI	Truck	275,951
Wayne, MI	Car	262,760
Flat Rock MI	Car	140,910
Avon Lake, OH	Truck	105,487
Chicago, IL	Car	81,679

FIGURE 31. Ford Company Profile

Fuel Saving Technologies

In late 2015, amid low gas prices, Ford announced plans to invest $4.5 billion dollars in vehicle electrification over the next five years. Ford plans to introduce 13 new hybrid or plug-in electric vehicles by 2020 and said that electrification would be an option in 40% of their lineup by that time. Ford is following a strategy of offering a full range of electric configurations including hybrids, plug-in hybrids, and all electric vehicles. Ford is currently installing their hybrid systems in sedans and wagons like the Ford Fusion hybrid, C-Max, and Lincoln MKZ hybrid. Ford's plug-in hybrids – the C-Max Energi and Fusion Energi – offer about 20 miles of electric operation while the Ford Focus electric is Ford's only all-electric vehicle with 76 miles of range.

Following the redesigned aluminum-bodied F-150 pickup which weighed about 700 pounds less than its 2014 predecessor, Ford is expanding its use of aluminum and other lightweight materials. Ford announced that it would be producing aluminum-bodied Super Duty trucks for 2017. The Super Duty trucks will use a thicker gauge of aluminum than the F-150 and more high strength steel will be used in the frame so the weight savings will be about half as much or about 350 lbs. lighter than the models they will be replacing. In 2015 Ford also announced a collaboration with DowAksa to speed production of high-volume, low-cost carbon fiber. A blended carbon fiber and aluminum wheel will be used on the Shelby GT350R. In an industry first, Ford and Corning have developed a lightweight hybrid windshield made from Gorilla glass and regular glass which is 12 pounds lighter and will be used in the GT super car.

Ford 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 2015.

Ford's Fleet Mix

Ford Motor Company has a fairly even distribution of models from the subcompact segment to sport utility vehicles. The Ford F-150 is by far their largest selling model. Of the car models that Ford sells, the majority have an average fuel economy of 25 mpg or higher with six models exceeding 40 mpg.

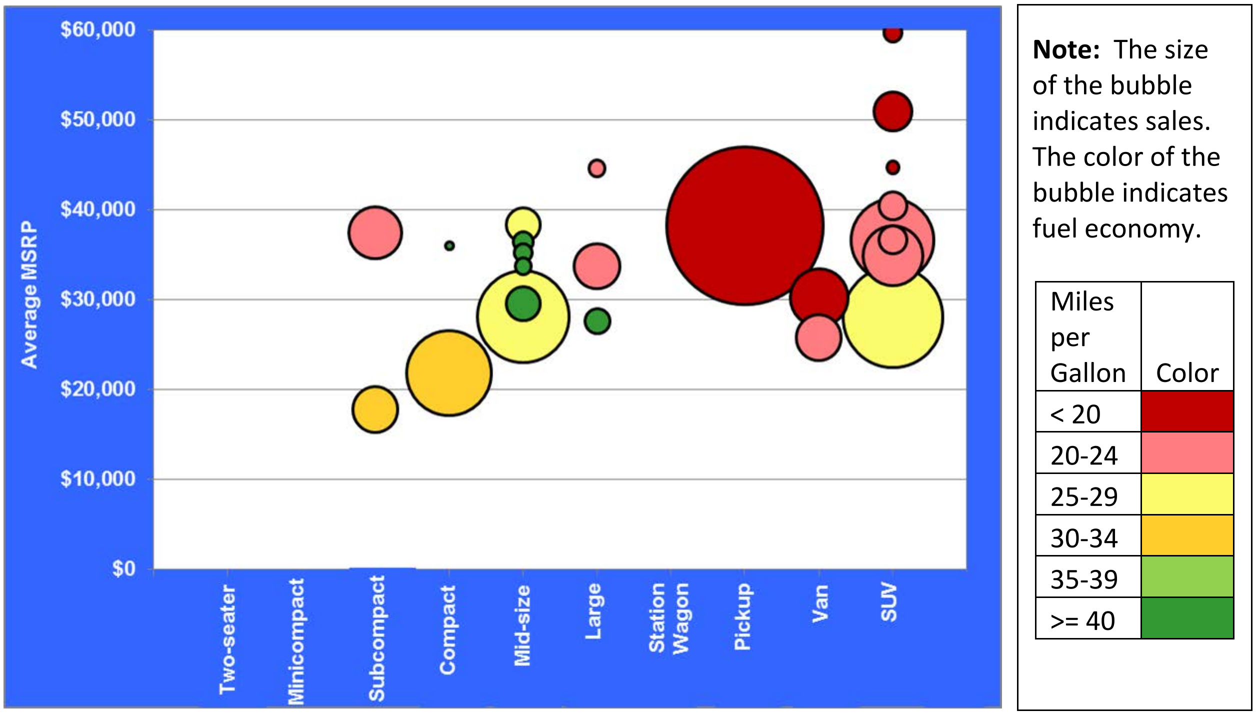


FIGURE 32. Ford Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 7. Ford Models by EPA Size Class, 2014

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

Note: Includes Ford and Lincoln.

The F-Series Accounted for Nearly One-Third of Ford's Sales in 2014

Thirty-one percent of Ford's 2014 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 9-12% of Ford's sales.

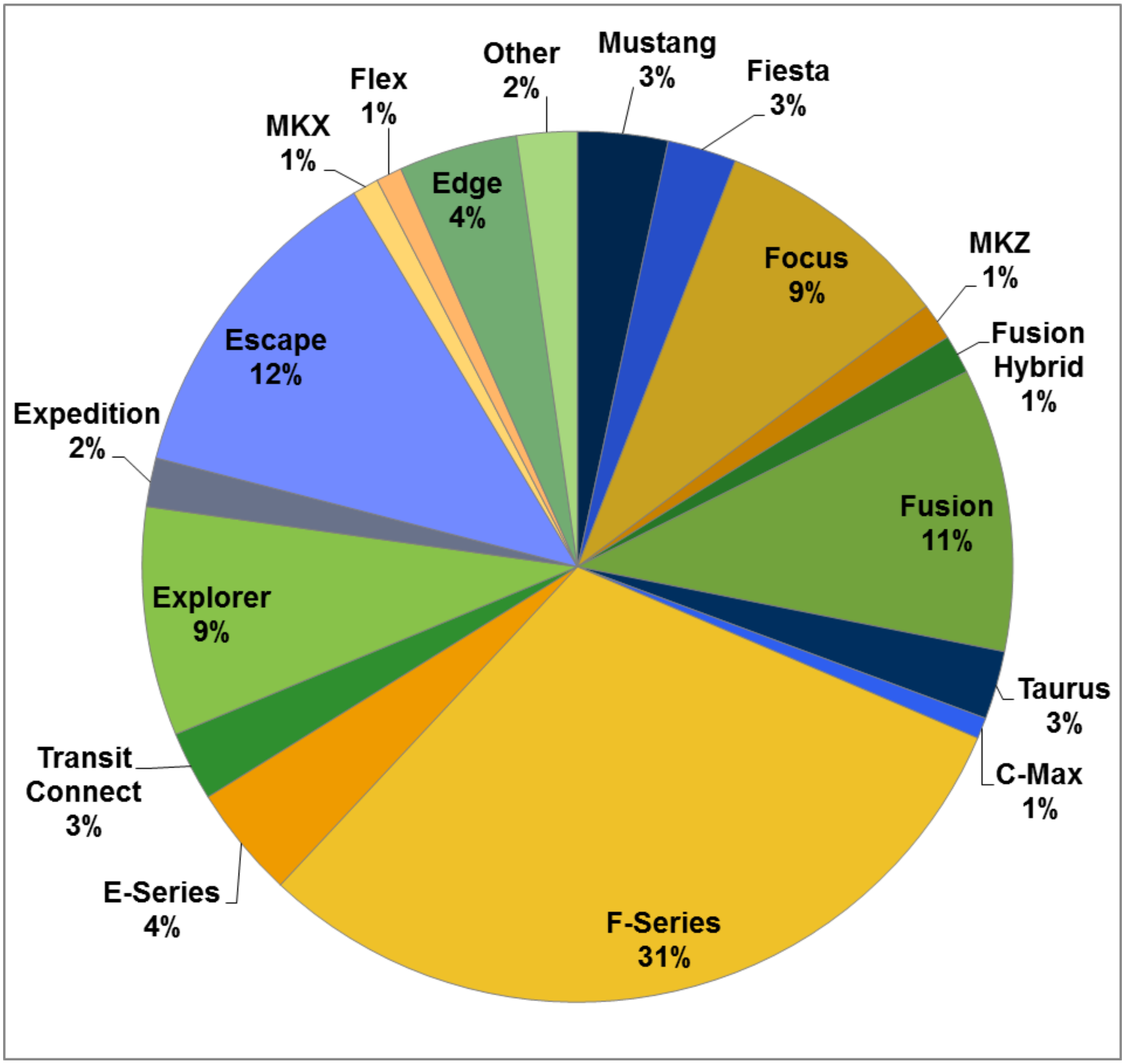


FIGURE 33. Ford Market Share by Model, 2014

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

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Ford Hybrid and Plug-In Vehicle Sales Declined in 2015

After more than doubling in 2013, Ford hybrid and plug-in vehicle sales declined in 2015. 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 (13%) of the hybrid-electric (HEV) and plug-in (PEV) market.

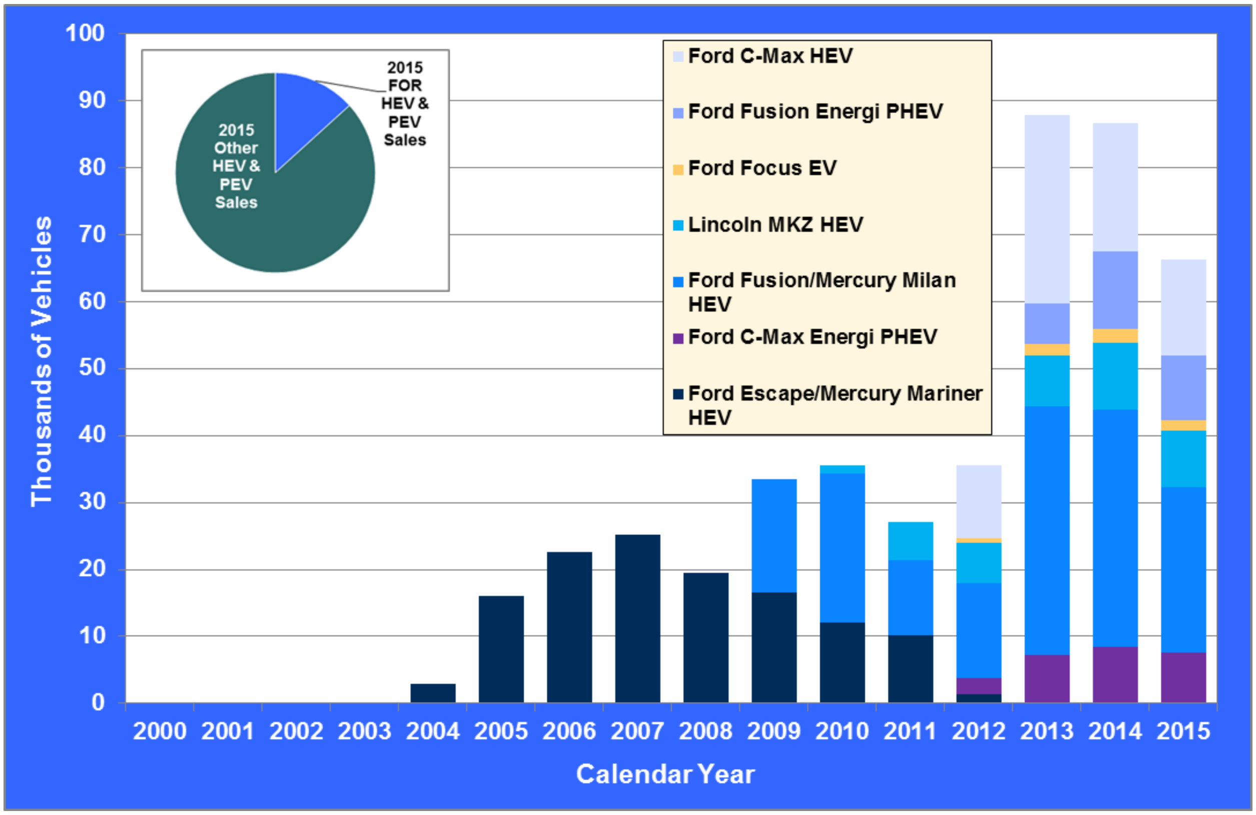


FIGURE 34. Ford Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 8. Ford Interrelationships with Other Automotive Manufacturers

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, Ford, 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

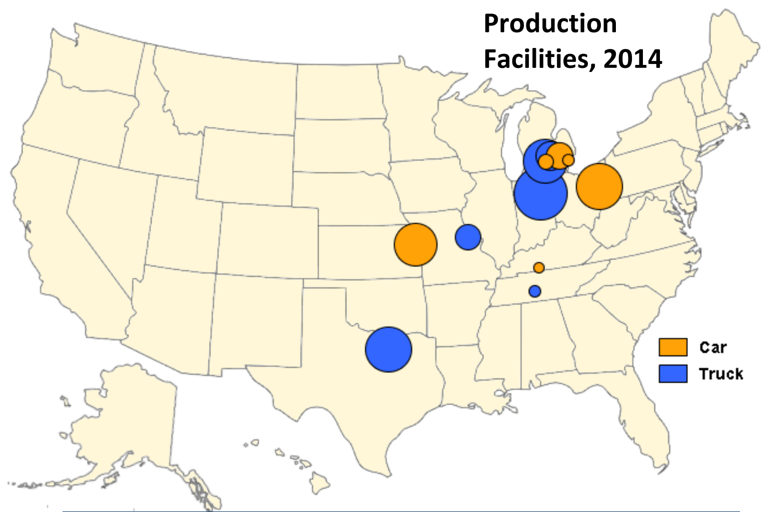
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015.
http://wardsauto.com

General Motors (GM) Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	33.8 mpg
Import Cars	39.8 mpg
Light Trucks	25.2 mpg

Average Vehicle Footprint, MY 2015	
Cars	46.8 sq ft
Light Trucks	63.0 sq ft
All	55.3 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	19
Natural Gas	1
Propane	0
Hybrid-Electric	2
Plug-In Hybrid-Electric	2
Electric	1
Hydrogen	0



GM Plants	Type	2014 Production
Fort Wayne, IN	Truck	332,744
Lordstown, OH	Car	290,028
Arlington, TX	Truck	284,424
Lansing, MI - Delta	Truck	269,997
Fairfax, KS	Car	262,080
Flint, MI	Truck	165,189
Orion, MI	Car	152,680
Wentzville, MO	Truck	141,066
Lansing, MI - Grand River	Car	69,409
Hamtramck, MI	Car	47,368
Spring Hill, TN	Truck	44,319
Bowling Green, KY	Car	39,918

FIGURE 35. GM Company Profile

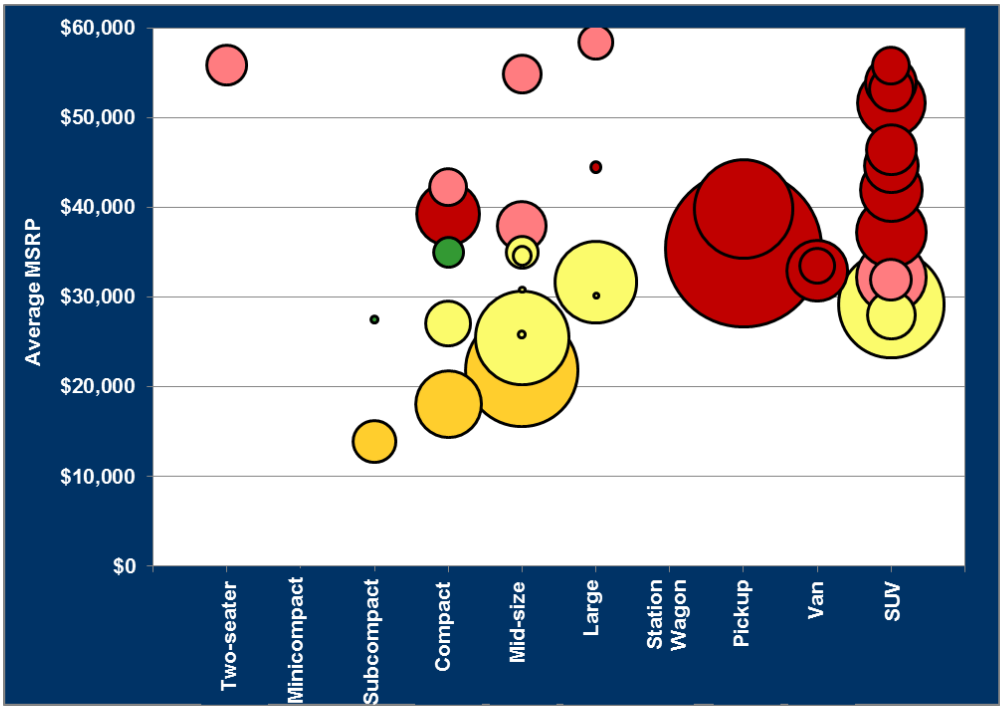
Fuel Saving Technologies

At the 2015 Detroit Auto Show, GM made headlines when they revealed the 200-mile range all-electric Chevrolet Bolt concept with plans for production by 2017 and a projected price of about $30,000 with incentives. Until the Chevrolet Bolt arrives, the Chevrolet Spark remains GM's only all-electric vehicle. GM further demonstrated their commitment to vehicle electrification with several passenger car introductions. Most notable is the redesigned 2016 Chevrolet Volt plug-in hybrid. The 2016 Volt has an all-electric range of 53 miles versus 38 for the 2015 model. GM also revealed the 2016 Chevrolet Malibu Hybrid, which uses an adaptation of the drivetrain from the Chevrolet Volt but with a 1.5 kWh battery pack and no plug. It is expected to deliver a fuel economy rating in excess of 45 mpg. For improved aerodynamics the new Malibu Hybrid will have active grille shutters and a reduced ride height. A first for GM, the 2016 Malibu Hybrid will also use 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 and Start/Stop became standard on the 2015 Chevrolet Impala. An advanced form of Start/Stop that uses ultra-capacitors to augment battery power will begin appearing on several Cadillac models in 2016 including the ATS and CTS models.

In pursuit of mass reduction, 2016 Camaro and Cadillac CT6 are both about 200 pounds lighter than the outgoing models due to extensive use of aluminum in the body structures and body panels. GM has not adopted aluminum body panels on their trucks but has increased the use of high strength steels. The all-new midsized 2015 Chevrolet Colorado and GMC Canyon pickup trucks have sold well and will be offered with a 4-cylinder, 2.8 liter diesel option for the 2016 model year. GM's full-sized pickups with 8-cylinder engines rely on cylinder deactivation or "Active Fuel Management" for 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 is the highest selling car with a combined fuel economy of more than 30 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 36. GM Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 9. GM Models by EPA Size Class, 2014

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

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 2014

With 16 different SUV models, GM's SUVs accounted for more than 38% of GM sales in 2014. The Chevrolet Equinox was the only SUV with more than a 4% share. The Chevrolet Silverado and GMC Sierra pickup trucks were 25% of GM's sales.

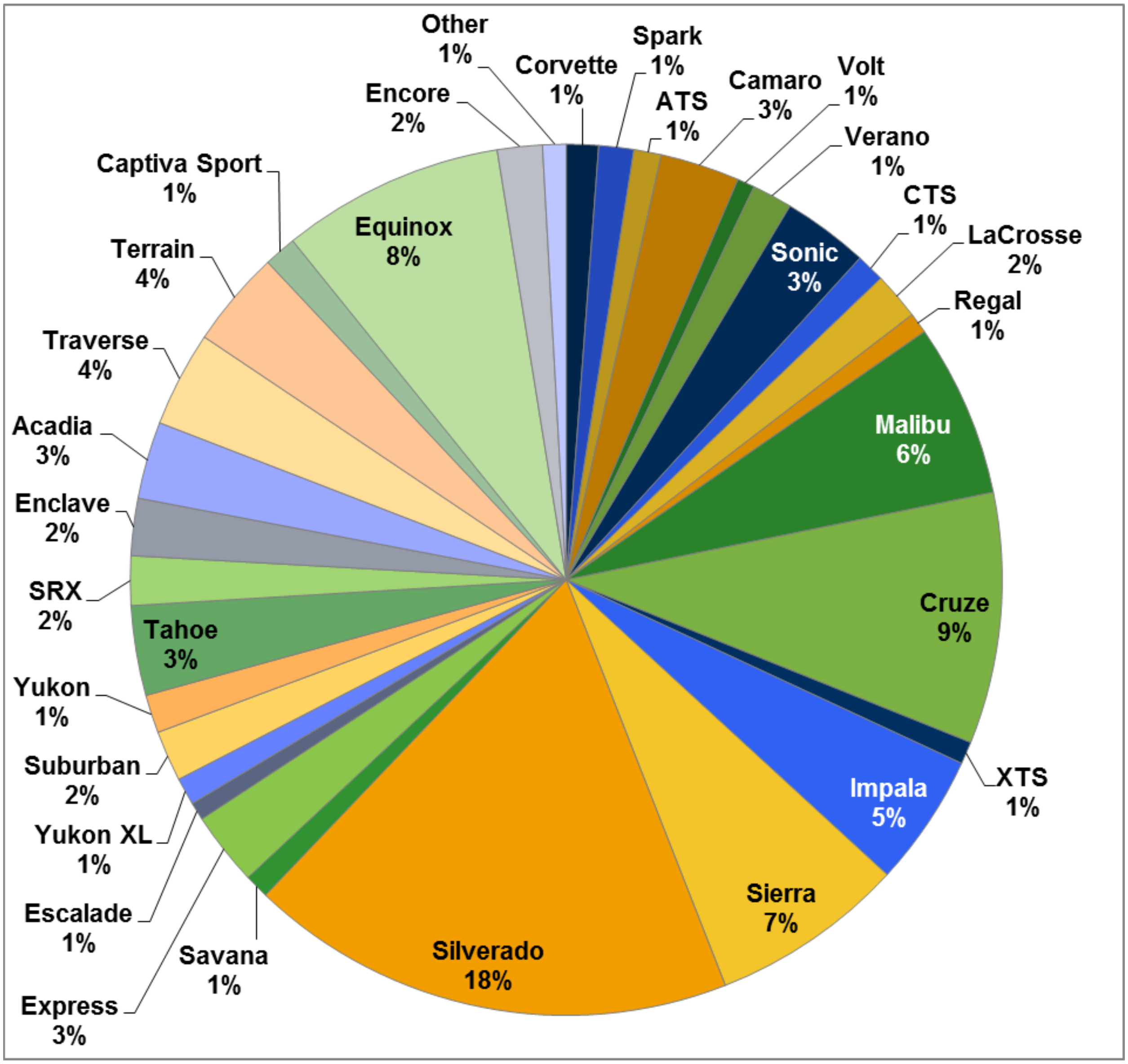


FIGURE 37. GM Market Share by Model, 2014

Note: "Other" includes the ELR, Spark EV, LaCrosse, Regal eAssist, Malibu eAssist, SS, Impala eAssist, and Escalade ESV. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Chevrolet Volt Accounted for More than Half of GM's 2015 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 5% of all hybrid and plug-in vehicle sales.

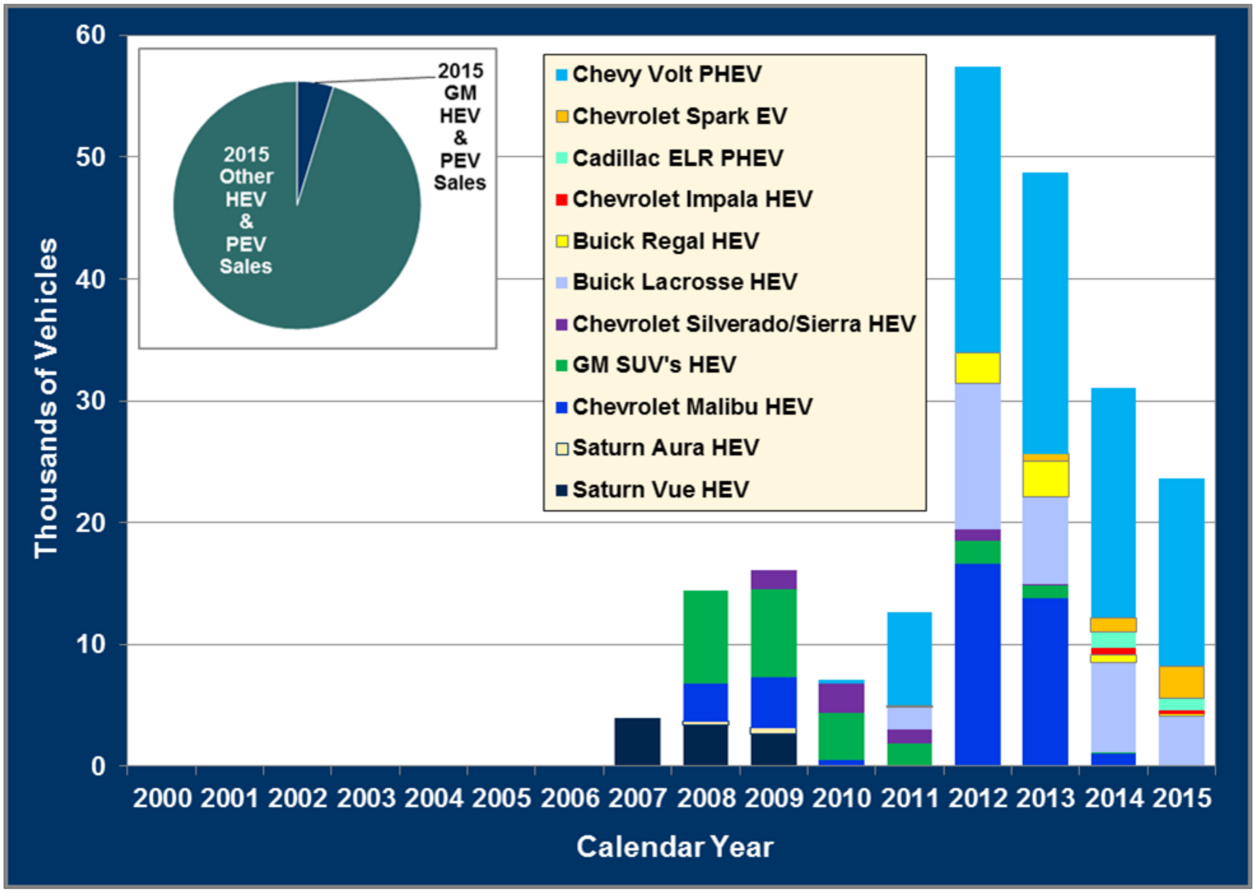


FIGURE 38. GM Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 10. GM Interrelationships with Other Automotive Manufacturers

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

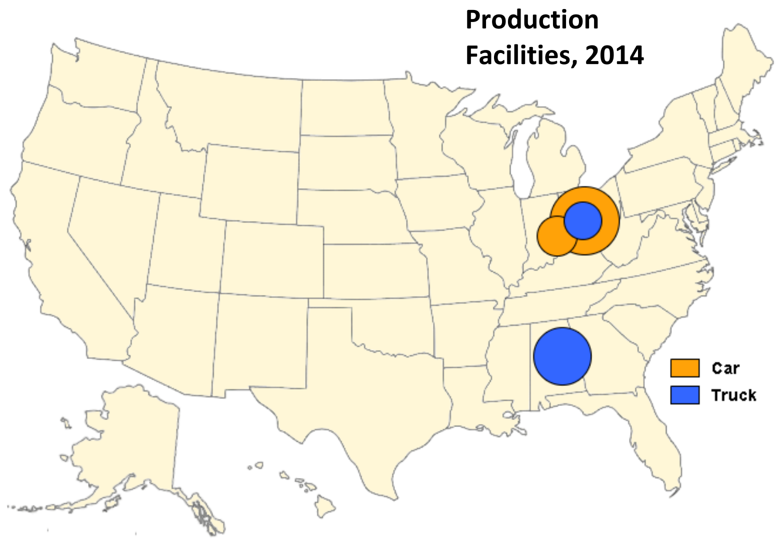
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Honda Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	39.6 mpg
Import Cars	42.0 mpg
Light Trucks	28.8 mpg

Average Vehicle Footprint, MY 2015	
Cars	45.3 sq ft
Light Trucks	49.4 sq ft
All	46.4 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	0
Natural Gas	1
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	0
Electric	0
Hydrogen	0



Honda Plants	Type	2014 Production
Marysville, OH	Car	442,135
Lincoln, AL	Truck	363,419
Greensburg, IN	Car	242,061
East Liberty, OH	Truck	221,289

FIGURE 39. Honda Company Profile

Fuel Saving Technologies

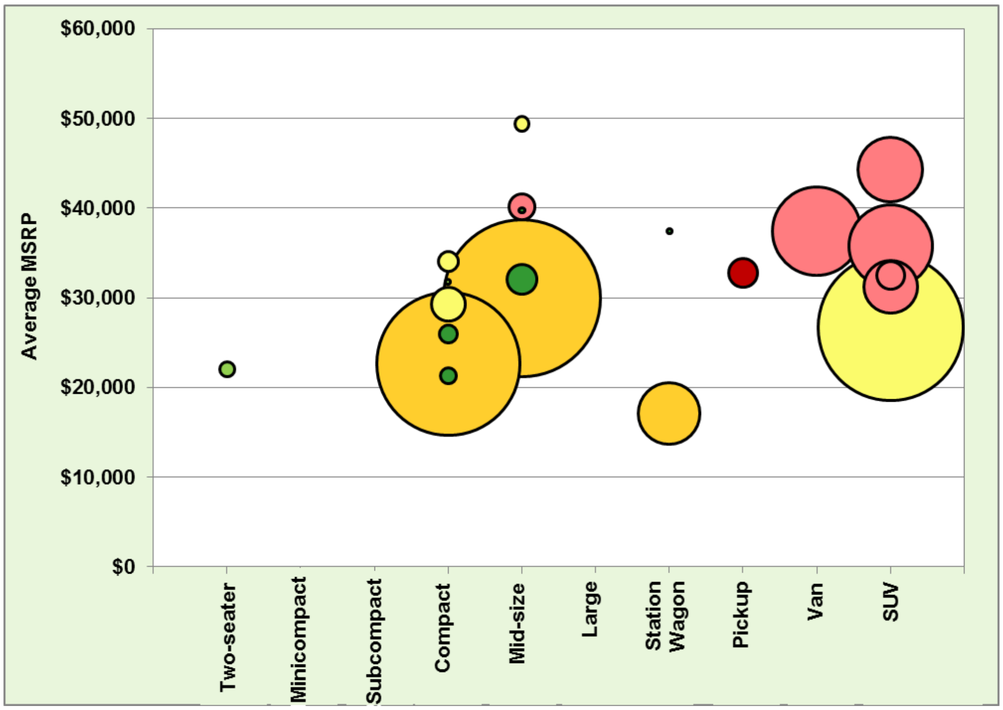
For the 2015 model year, Honda discontinued both the Fit EV and the Honda Accord Plug-in Hybrid. The Fit EV was a compliance car, sold only in California and the Accord Plug-in Hybrid was rated at just 13 miles of electric range. However, Honda remains committed to hybrid and electric technologies, offering hybrid drive trains in the CR-Z sport hybrid and on versions of the Civic, Accord and Acura RLX. Honda also announced that a plug-in hybrid offering about 40 miles of electric range was planned as is an all-electric model.

Honda unveiled the production version of the all-new Clarity Fuel Cell sedan which replaces the FCX Clarity. Initially, it will only be available in selected areas of California beginning in late 2016. The new Clarity has a fuel cell stack that is 33% smaller than the previous fuel cell stack while producing 60% more output. The fuel cell components size reduction allows the entire powertrain to be housed under the hood of the sedan making it possible for Honda to install this technology across a broad range of vehicle types as the cabin space is not compromised. The Honda Civic Natural Gas sedan, which is the only natural gas sedan on the market from a major automaker, will be phased out as Honda concentrates on fuel cell, hybrid, and electric vehicles.

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 was used on the 2016 Pilot, and in late 2015, Honda announced that it is developing a new 10-speed automatic transmission and claims that fuel economy will be improved by about 6% over the models fitted with the current 6-speed transmissions.

Honda's Fleet Mix

Honda Motor Company has just one model with a combined average fuel economy of less than 20 mpg and it represents a small portion of total sales. Those models that sell in the greatest number have combined fuel economies of 25 mpg or higher. The Honda Accord is the highest selling model followed closely by the Civic with a combined average fuel economy of more than 30 mpg. Nearly all of Honda's models have 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 40. Honda Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 11. Honda Models by EPA Class, 2014

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

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

The Accord, CR-V, and Civic Combined Were Two-Thirds of Honda's Sales in 2014

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

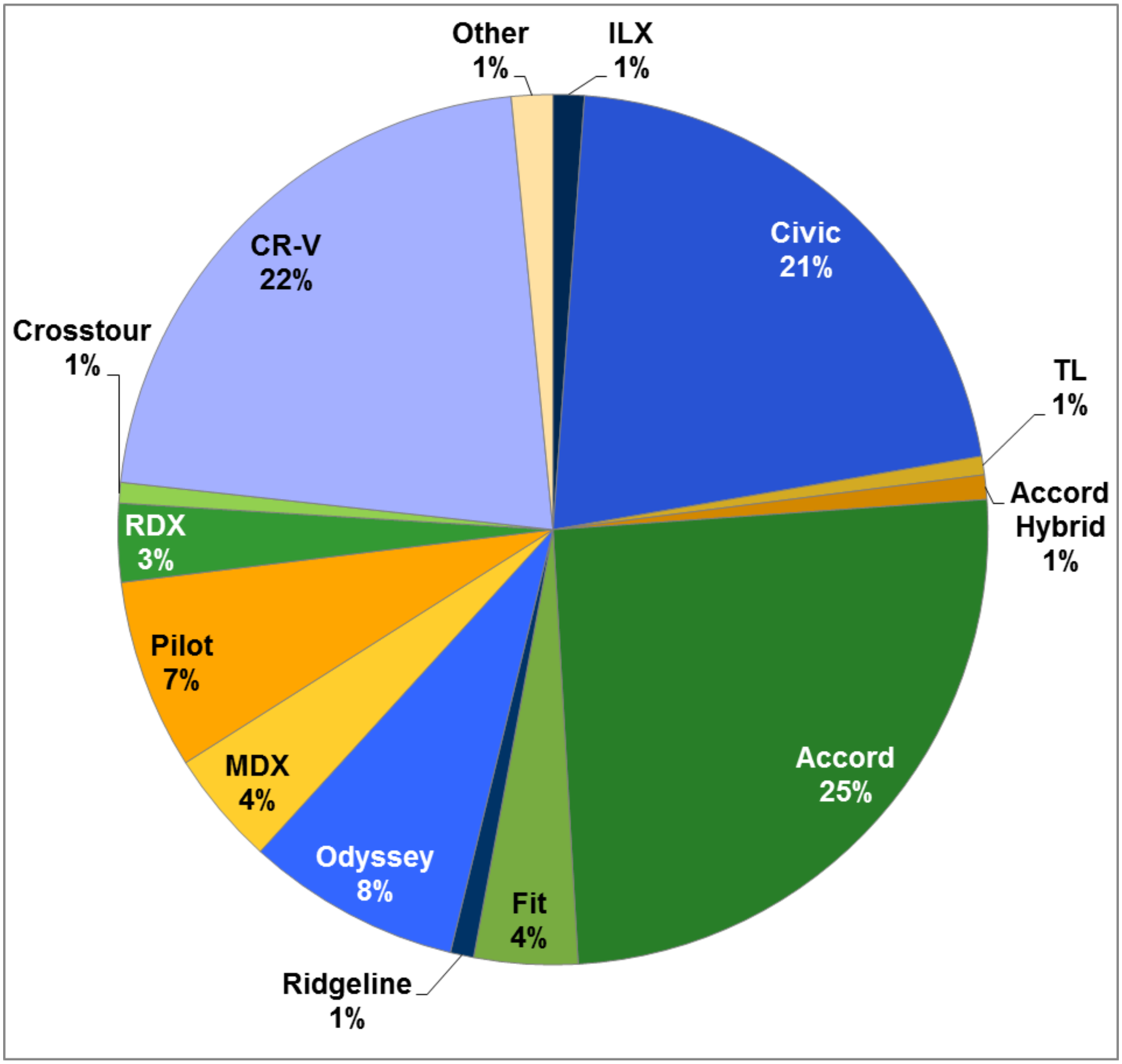


FIGURE 41. Honda Market Share by Model, 2014

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

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Honda Discontinues Five Hybrid and Plug-In Models

Honda announced in 2014 that the Honda Fit EV, Honda Insight and Acura ILX Hybrid would be discontinued for model year 2015. The discontinuation of the Honda Civic Hybrid and Honda Accord Plug-in Hybrid was announced in 2015. Because sales are shown on a calendar-year basis, some of the models may have sales in the calendar year after discontinuation. In 2015, Honda sold just over 4% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales.

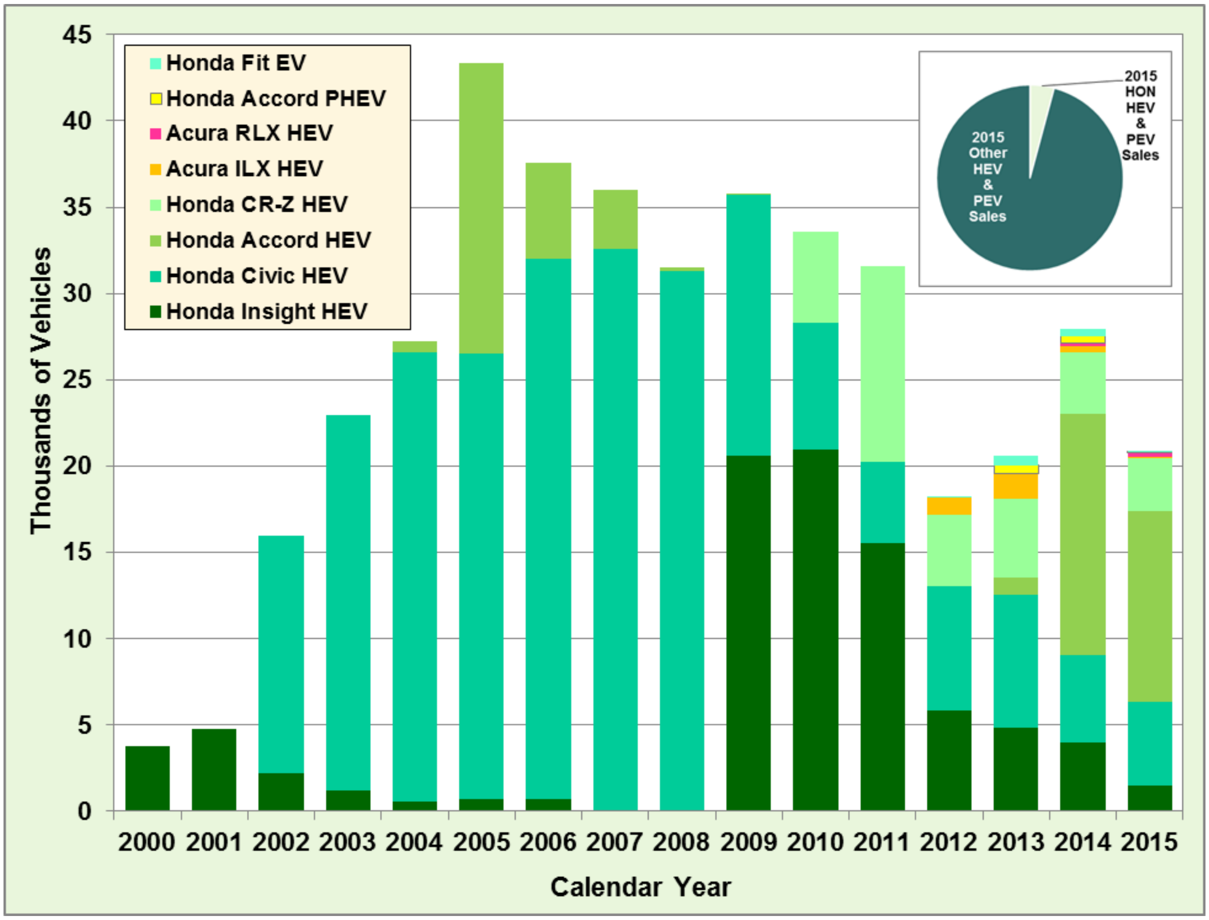


FIGURE 42. Honda Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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

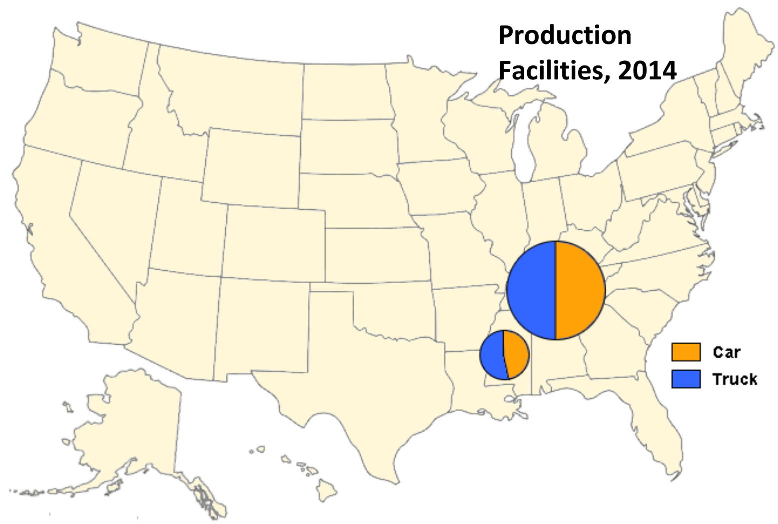
TABLE 12. Honda Interrelationships with Other Automotive Manufacturers

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

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	40.6 mpg
Import Cars	38.8 mpg
Light Trucks	26.7 mpg
Average Vehicle Footprint, MY 2015	
Domestic Cars	45.1 sq ft
Import Cars	50.7 sq ft
Light Trucks	46.9 sq ft
Number of Alternative Fuel Models, MY 2015	
Flex Fuel	2
Natural Gas	0
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0



World Sales = 4.6 million

Nissan Plants	Type	2014 Production
Smyrna, TN	Truck	327,011
Smyrna, TN	Car	321,038
Canton, MS	Truck	158,770
Canton, MS	Car	140,739

FIGURE 43. Nissan Company Profile

Fuel Savings Technologies

Nissan has made several statements in the media this year reaffirming their commitment to bringing affordable all-electric vehicles to market. In 2015, Nissan introduced two battery options for the 2016 Nissan Leaf. A 30 kWh battery pack that delivers 107 miles of range is now available in addition to the 24 kWh battery pack rated at 84 miles. The next generation Nissan Leaf is expected in 2018 with a 60 kWh battery and a range of about 200 miles. Some degree of autonomous driving capability is also expected with the redesigned Leaf. The Nissan Pathfinder Hybrid and Infiniti QX60 Hybrid have been cancelled for the 2016 model year, but Nissan continues to produce hybrid sedans under the Infiniti brand.

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. Nissan's Xtronic CVT is used with engine displacements up to 3.5 liters. For 2015, Nissan introduced an update to their CVT transmission called 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.

Reducing vehicle mass and downsizing engines through direct injection, turbocharging and supercharging are key areas of focus. Nissan has committed to greater use of advanced high tensile strength steel which reduced the weight of the Infiniti Q50 by about 90 pounds. Nissan is planning much greater use of high strength steel beginning in 2017. Engine downsizing and weight reduction are epitomized in the 1.5L turbocharged 3-cylinder engine that weighs just 88 pounds but delivers 400 horsepower and 280 pound-feet of torque. While developed for racing, it demonstrates what is possible and may well influence future production engine design.

Nissan's Fleet Mix

Nissan sells a large number of models that have a combined fuel economy of less than 20 mpg but they sell in relatively low numbers. The compact and mid-size car segments account for a large portion of Nissan's overall sales. The Nissan Versa, Altima, Sentra, and Leaf are the four car models shown in the figure with a combined rating of more than 30 mpg.

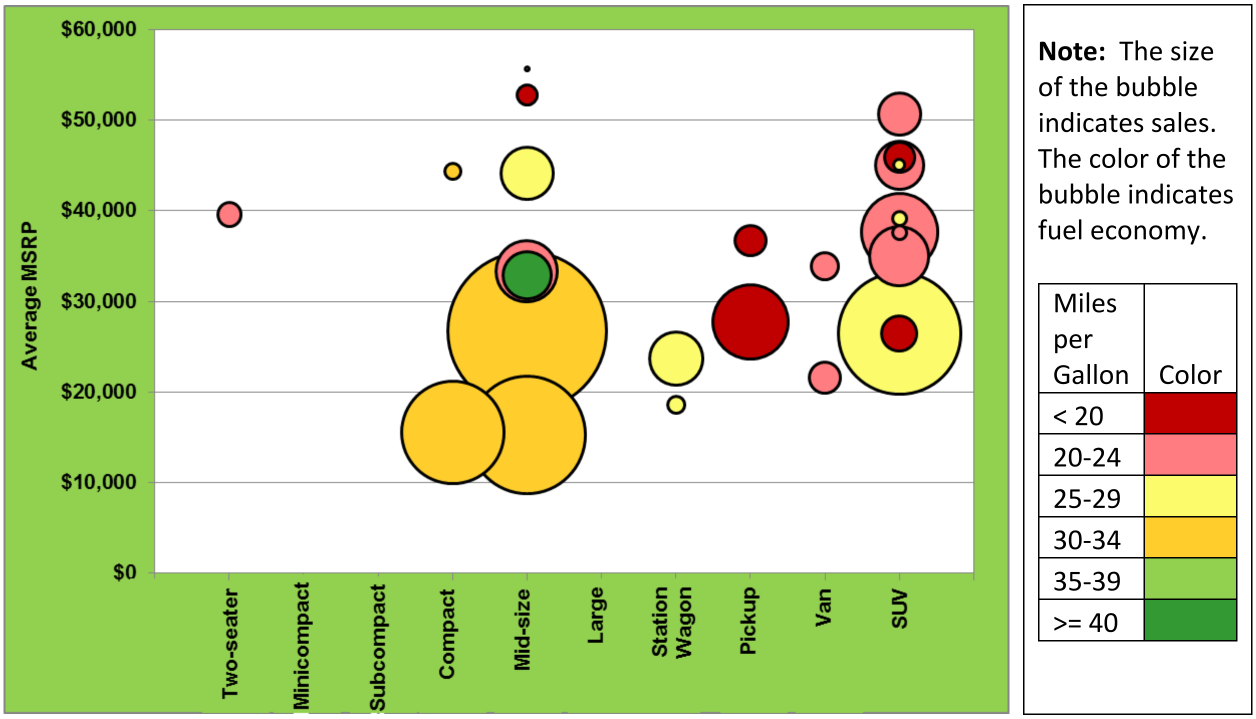


FIGURE 44. Nissan Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 13. Nissan Models by EPA Size Class, 2014

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
370Z		*GT-R*	Q50 Hybrid Versa	Q70-Hybrid Q50 Q60 Leaf Maxima Altima Sentra		Juke Cube	Titan Frontier	Quest NV200	*QX80* QX60 Armada QX60-Hybrid QX70 Pathfinder-Hybrid Pathfinder QX50 Murano Rogue Xterra

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 2014

The Altima was Nissan's best seller in 2014, followed by the Rogue SUV (14%). The Versa and Sentra are the only other models to account for 10% or more. The pickup trucks (Frontier and Titan) held about 6% of Nissan's total sales.

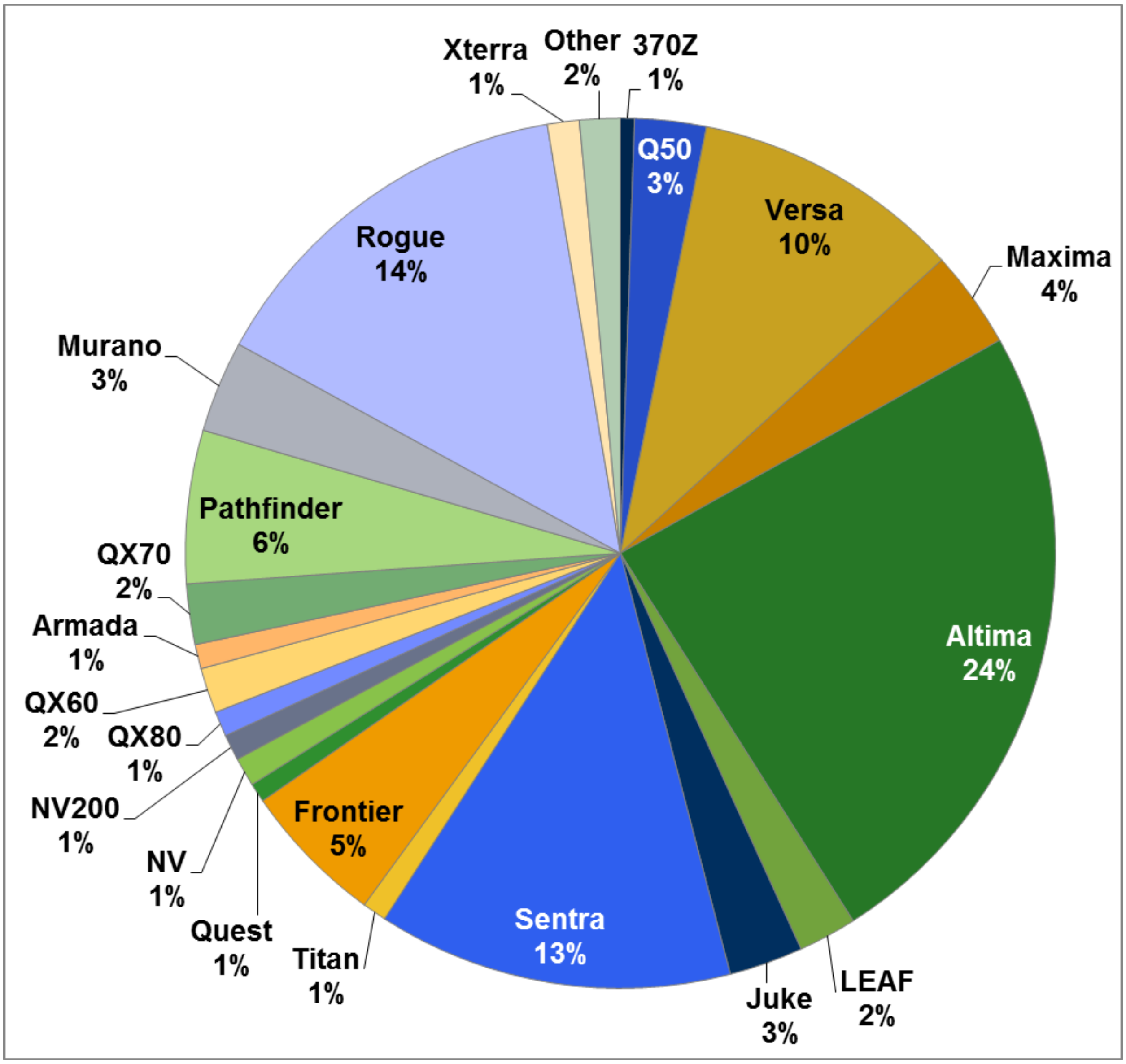


FIGURE 45. Nissan Market Share by Model, 2014

Note: "Other" includes the GT-R, Q50 Hybrid, Q70 Hybrid, Q60, Cube, QX60 Hybrid, Pathfinder Hybrid, and QX50. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Nissan Leaf Was Two-Thirds of Nissan's Hybrid and Plug-In Vehicle Sales in 2015

Nissan Leaf electric vehicle (EV) sales represent two-thirds of Nissan's hybrid-electric (HEV) and plug-in vehicle (PEV) sales. The sales of the Infiniti Q50 and QX60 hybrids grew slightly in 2015, but other hybrid models declined. Nissan is responsible for just over 5% of all HEV and PEV sales.

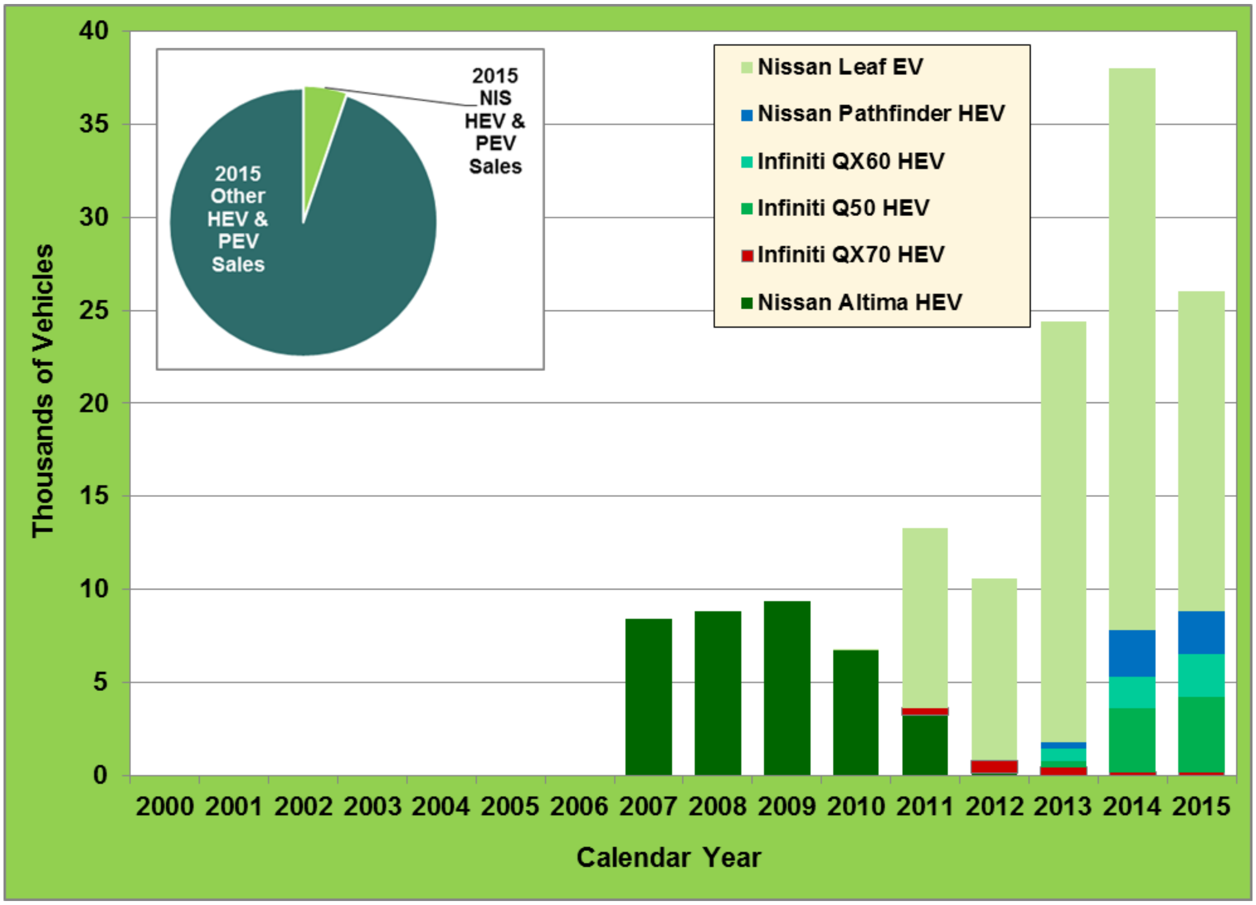


FIGURE 46. Nissan Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 14. Nissan Interrelationships with Other Automotive Manufacturers

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

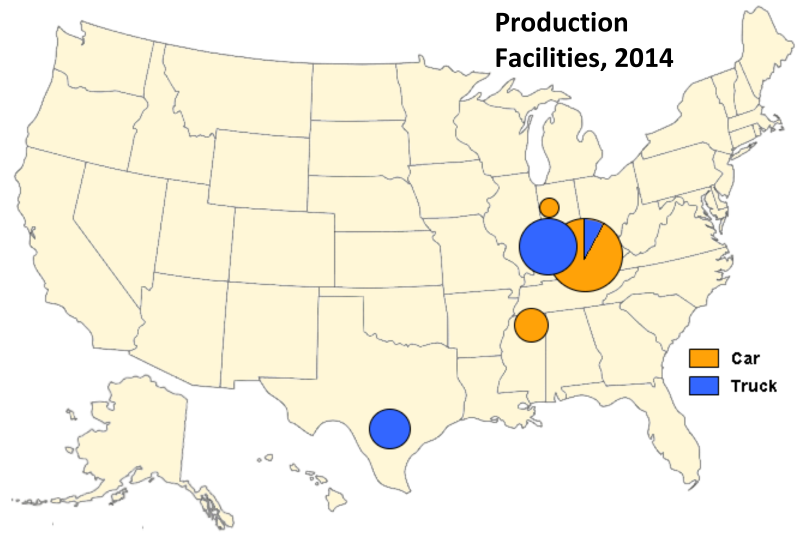
Source: Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015. http://wardsauto.com

Toyota Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	39.1 mpg
Import Cars	44.2 mpg
Light Trucks	25.8 mpg

Average Vehicle Footprint, MY 2015	
Cars	45.5 sq ft
Light Trucks	53.1 sq ft
All	48.6 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	2
Natural Gas	0
Propane	0
Hybrid-Electric	12
Plug-In Hybrid-Electric	1
Electric	2
Hydrogen	0



Toyota Plants	Type	2014 Production
Georgetown, KY	Car	425,705
Princeton, IN	Truck	349,522
San Antonio, TX	Truck	236,668
Blue Springs, MS	Car	189,314
Lafayette, IN	Car	93,476
Georgetown, KY	Truck	40,006

FIGURE 47. Toyota Company Profile

Fuel Saving Technologies

In the Fall of 2015, US sales of the 2016 Toyota Mirai fuel cell sedan began in California with a price of $57,500 before incentives. The Mirai is Toyota's first production fuel cell vehicle and it represents an important step in their strategy for advanced drivetrains. Unlike many manufacturers, Toyota has eschewed all-electric vehicles in favor of hydrogen fuel cell technology. This shift in strategy became clear in 2014 when Toyota revealed production plans for the Mirai while cancelling their all-electric RAV4 EV and Scion IQ EV programs.

Despite these all-electric vehicle cancelations, they remain committed to vehicle electrification by expanding and refining their Hybrid Synergy Drive technology. In fact, the Mirai fuel cell vehicle also incorporates Hybrid Synergy Drive technology. In 2015, Toyota revealed the redesigned fourth-generation Prius. The new 2016 Prius Eco has a combined EPA rating of 56 mpg making it the most fuel-efficient gasoline powered vehicle on the market. Production of the Toyota Prius plug-in hybrid that delivers about 11 miles of electric operation will be temporarily paused after the 2015 model year and a redesigned Prius plug-in hybrid is expected in late 2016, probably as a 2017 model year offering.

Conventional models have also received engine and transmission refinements. Toyota has introduced new engines with increased thermal efficiency and greater use of turbocharging. Toyota has also increased their use of CVT transmissions on models with smaller displacement engines like the Corolla. In the interest of reducing vehicle weight, Toyota is expanding the use of aluminum across their vehicle line-up for hoods, closures, and other parts. Expanded use of high-strength steels, mixed metals and resin-based materials is also planned. The redesigned 2016 Prius is built on the lightweight Toyota New Global Architecture platform and is offered with lithium-ion batteries to improve power density and offset weight on upper trim levels.

Toyota's Fleet Mix

Toyota produces many models and they are fairly evenly split between cars and trucks. Among the truck models, about half achieve a combined fuel economy of more than 20 mpg. Nearly all 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. Ten models (shown in dark green) had a combined average fuel economy of 40 mpg or higher.

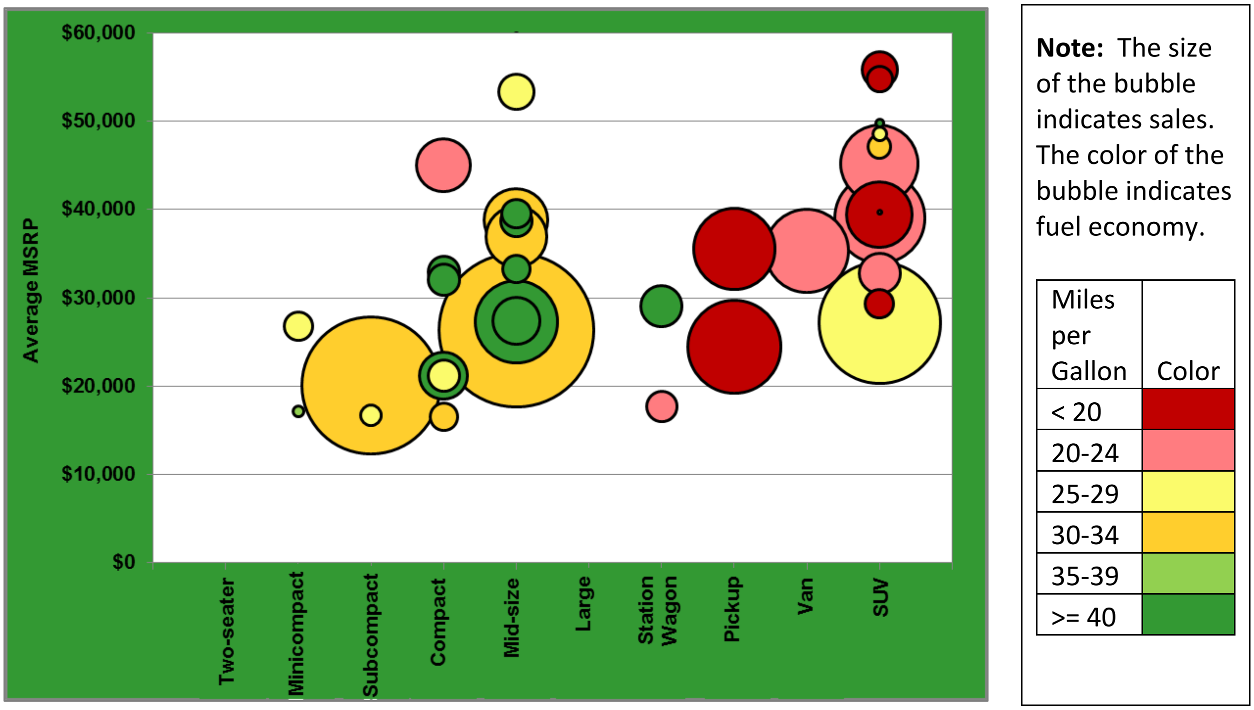


FIGURE 48. Toyota Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 15. Toyota Models by EPA Size Class, 2014

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
LFA	FR-S iQ	Corolla xD	IS CT 200h Prius C tC Yaris	*LS 600h* *LS* *GS 450h* GS ES 300h ES Avalon-Hybrid Avalon Prius-PHEV Camry-Hybrid Prius Camry		Prius v xB	Tacoma Tundra	Sienna	*LX* *Land Cruiser* GX Sequoia RAV4 EV Highlander-Hybrid RX 450h RX NX-Hybrid 4Runner Highlander Venza FJ Cruiser RAV4

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

Together the Toyota Camry and Corolla Were Nearly One-Third of Toyota's Sales in 2014

In 2014, the Camry and Corolla were Toyota's biggest sellers, followed by the RAV4 SUV (11%). Together, the Tacoma and Tundra pickup trucks were 11% of Toyota's market. SUVs make up about one-quarter of Toyota's sales.

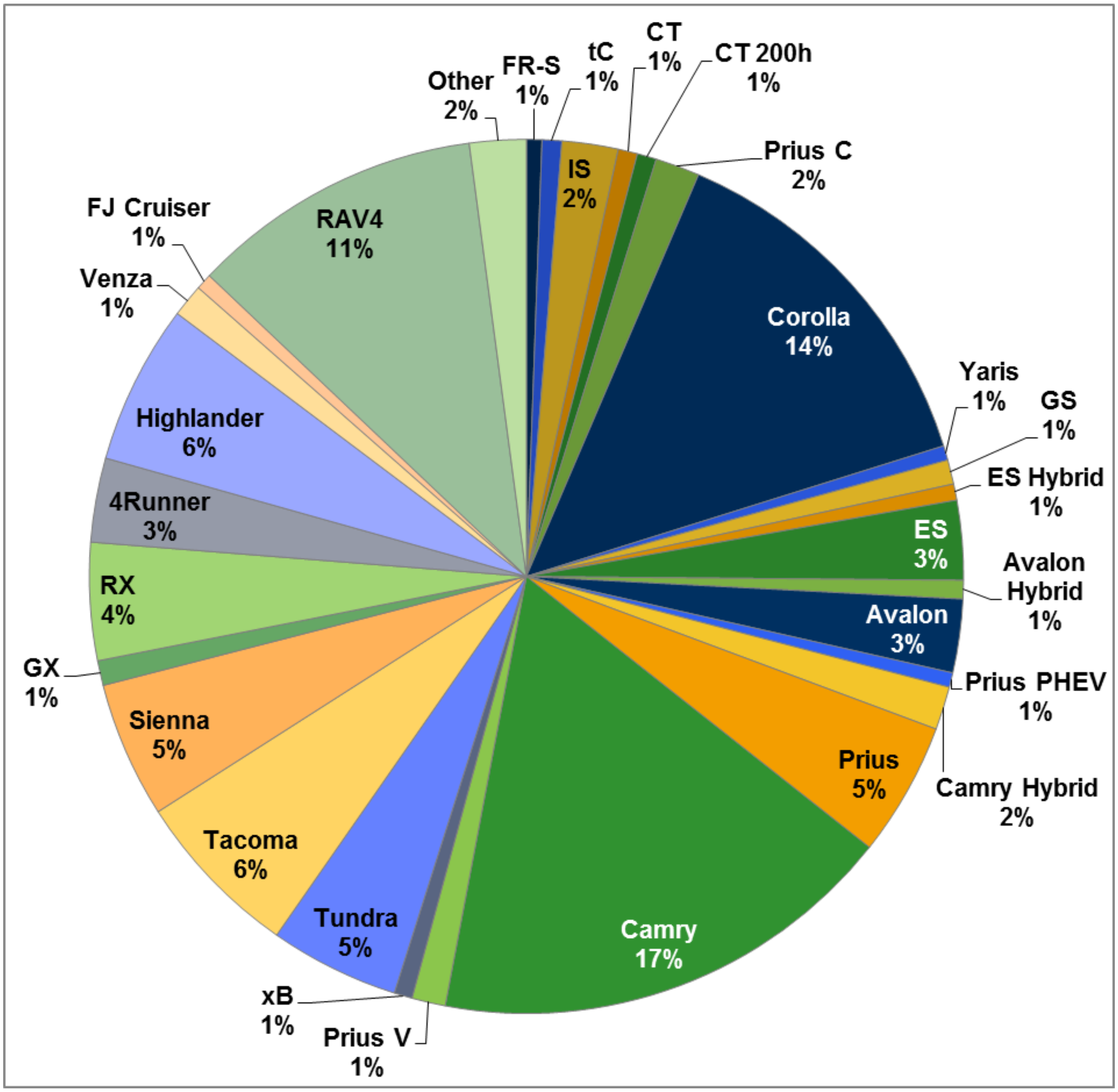


FIGURE 49. Toyota Market Share by Model, 2014

Note: "Other" includes the LFA, iQ, xD, LS 600h, LS, GS 450h, LX, Land Cruiser, Sequoia, RAV4 EV, Highlander Hybrid, Rx450h, and NX Hybrid. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Toyota Accounted for over Half of All Hybrid and Plug-In Vehicle Sales in 2015

Although Prius sales declined by about 7% from 2014 to 2015, 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 2015, with the exception of the Lexus NX Hybrid which debuted in late 2014.

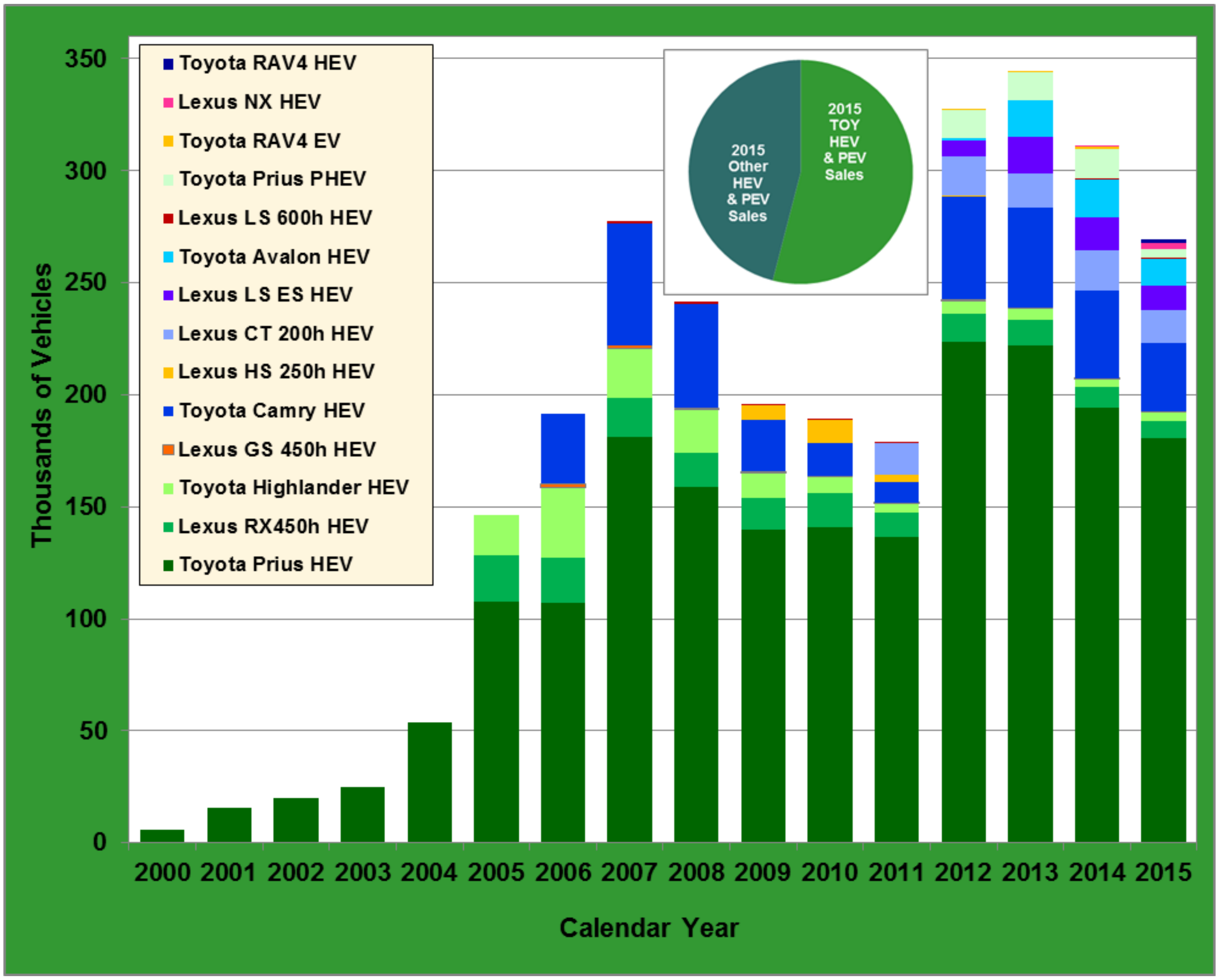


FIGURE 50. Toyota Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 16. Toyota Interrelationships with Other Automotive Manufacturers

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

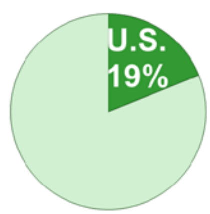
Hyundai Company Profile

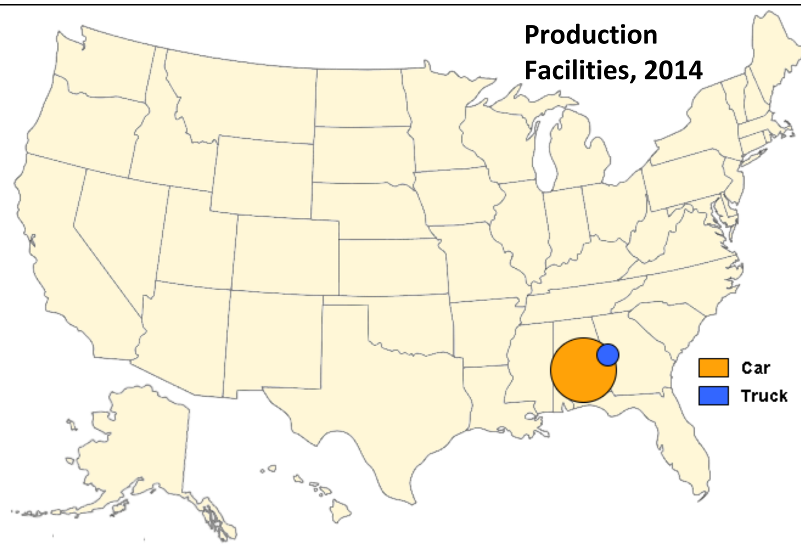
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	None
Import Cars	35.6 mpg
Light Trucks	27.5 mpg

Average Vehicle Footprint, MY 2015	
Cars	46.8 sq ft
Light Trucks	47.5 sq ft
All	46.9 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	0
Hydrogen	1

World Sales = 6.9 million





Hyundai Plants	Type	2014 Production
Montgomery, AL	Car	398,851
West Point, GA	Truck	107,830

Note: World sales figure includes Kia. All other data on the page are Hyundai only. Hyundai vehicles assembled in Alabama in 2014 do not meet CAFE criteria for domestic vehicles due to the low percentage of domestic content.

FIGURE 51. Hyundai Company Profile

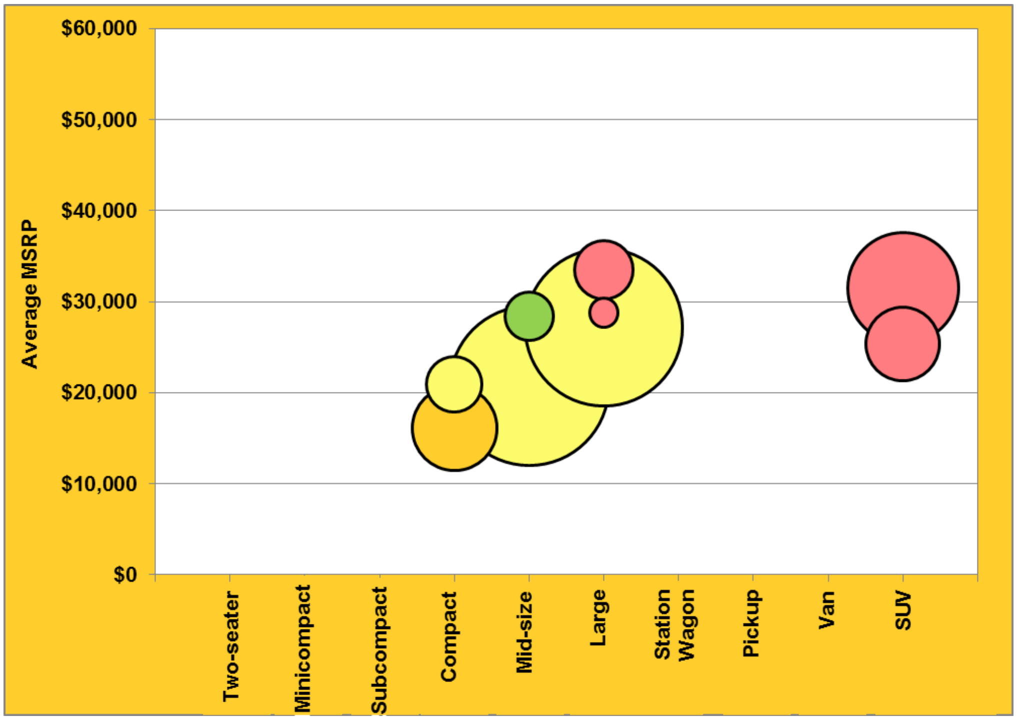
Fuel Saving Technologies

In 2015, Hyundai built on their commitment to vehicle electrification with the introduction of their first plug-in hybrid model. Joining the redesigned 2016 Sonata Hybrid, the 2016 Sonata plug-in hybrid arrived in late 2015 with an all-electric range of 27 miles and a combined electric rating of 99 MPGe and a combined gasoline rating of 40 mpg. The redesigned Sonata Hybrid has an EPA combined fuel economy of 41 mpg versus 38 mpg for the previous model. Hyundai's advanced powertrain offerings have been expanding in recent years. The 2015 Hyundai Tucson fuel cell SUV became available for lease in late 2014 for select residents in Southern California. Hyundai has announced plans to produce an all-new model called the Ioniq which will first appear as a hybrid but will later be offered as a plug-in hybrid and as an all-electric model. The Ioniq will be a hatchback sedan and is expected to arrive in 2017.

Efforts to further downsize engines and reduce vehicle weight are evident in their plans for the new Ioniq hybrid which will be powered by a 1.6 liter GDI engine with a claimed 40% thermal efficiency and it will be paired with an automated manual dual clutch transmission. To reduce weight, 54% of the body structure will be high strength steel while the hood, tailgate, and some suspension components will be made from aluminum. Unlike many manufacturers, Hyundai has not embraced CVT transmissions and is instead favoring fixed gear hydraulic automatic transmissions and automated dual clutch transmissions. At the 2014 Paris Motor Show, Hyundai unveiled their first 7-speed dual clutch automatic transmission which is now available on some 2016 models including the Tucson and Veloster Turbo. Hyundai is also developing a gasoline engine that operates like a diesel, referred to as GDCI or gasoline direct compression ignition. This engine holds the promise of offering diesel efficiency at a lower cost to build and operate than a diesel engine.

Hyundai's Fleet Mix

Hyundai's model offerings, as well as sales, are dominated by cars that have a combined fuel economy of 25 mpg or higher. The mid-size Elantra is the largest seller with an MSRP less than $20,000. All Hyundai vehicles have an MSRP less than $35,000 except the Equus which, due to its high price, is not shown on the figure.



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 52. Hyundai Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 17. Hyundai Models by EPA Size Class, 2014

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
			Accent Veloster	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.

Together the Hyundai Elantra and Sonata Accounted for About 60% of Hyundai's Sales in 2014

The Hyundai Elantra just edged out the Sonata as the top-selling Hyundai model. The company concentrates on car sales—less than 25% of Hyundai's sales were for SUVs and there were no pickup trucks in the current lineup.

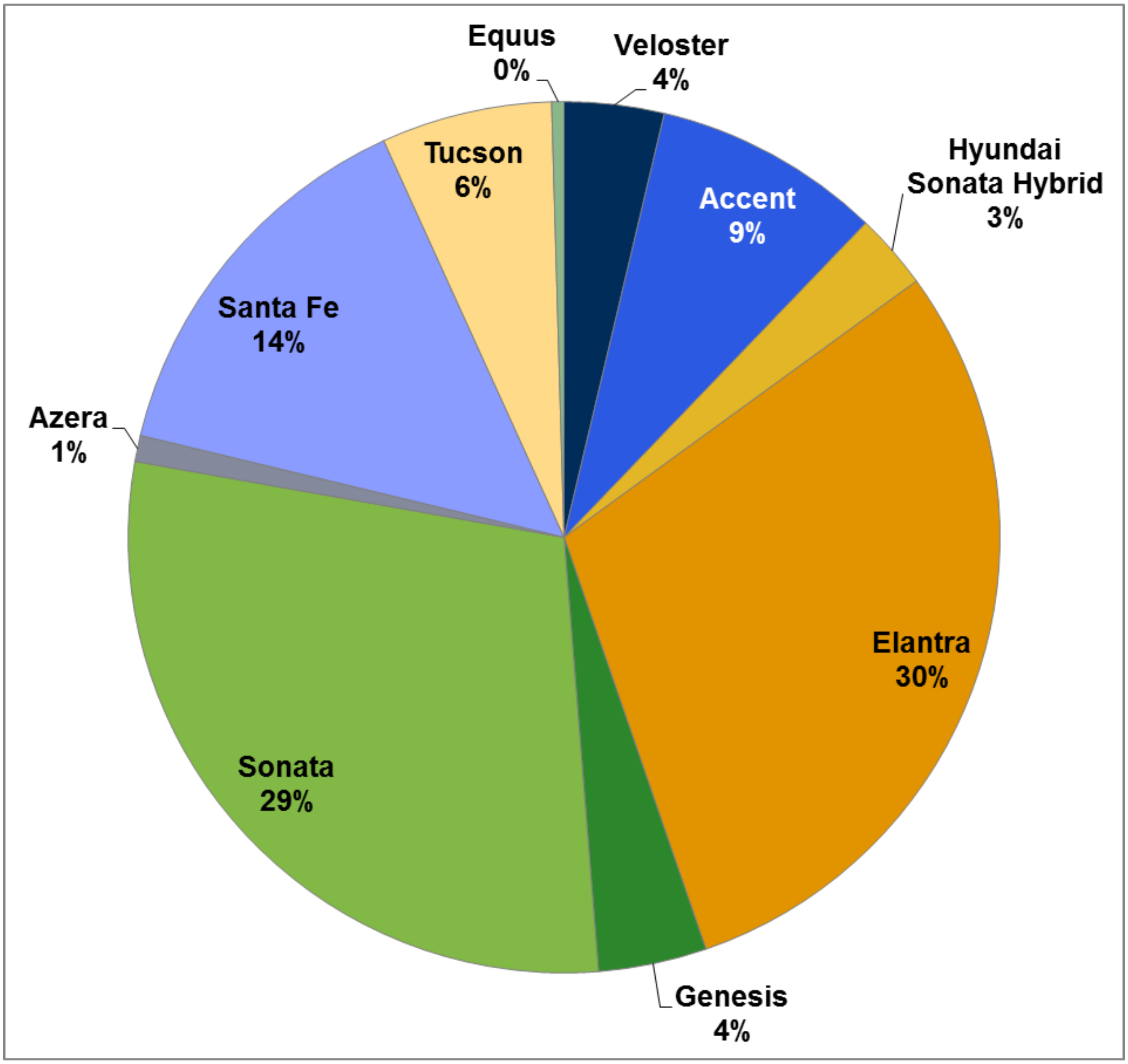


FIGURE 53. Hyundai Market Share by Model, 2014

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Hyundai's Sonata Plug-In Vehicle Debuted in December 2015

The Sonata hybrid-electric vehicle (HEV) has been selling for five years, but the Sonata plug-in hybrid-electric vehicle (PHEV) was available for sale in December of 2015. Sales for the Sonata HEV declined by 5% from 2014 to 2015 but still accounted for about 4% of all HEV and plug-in vehicle (PEV) sales.

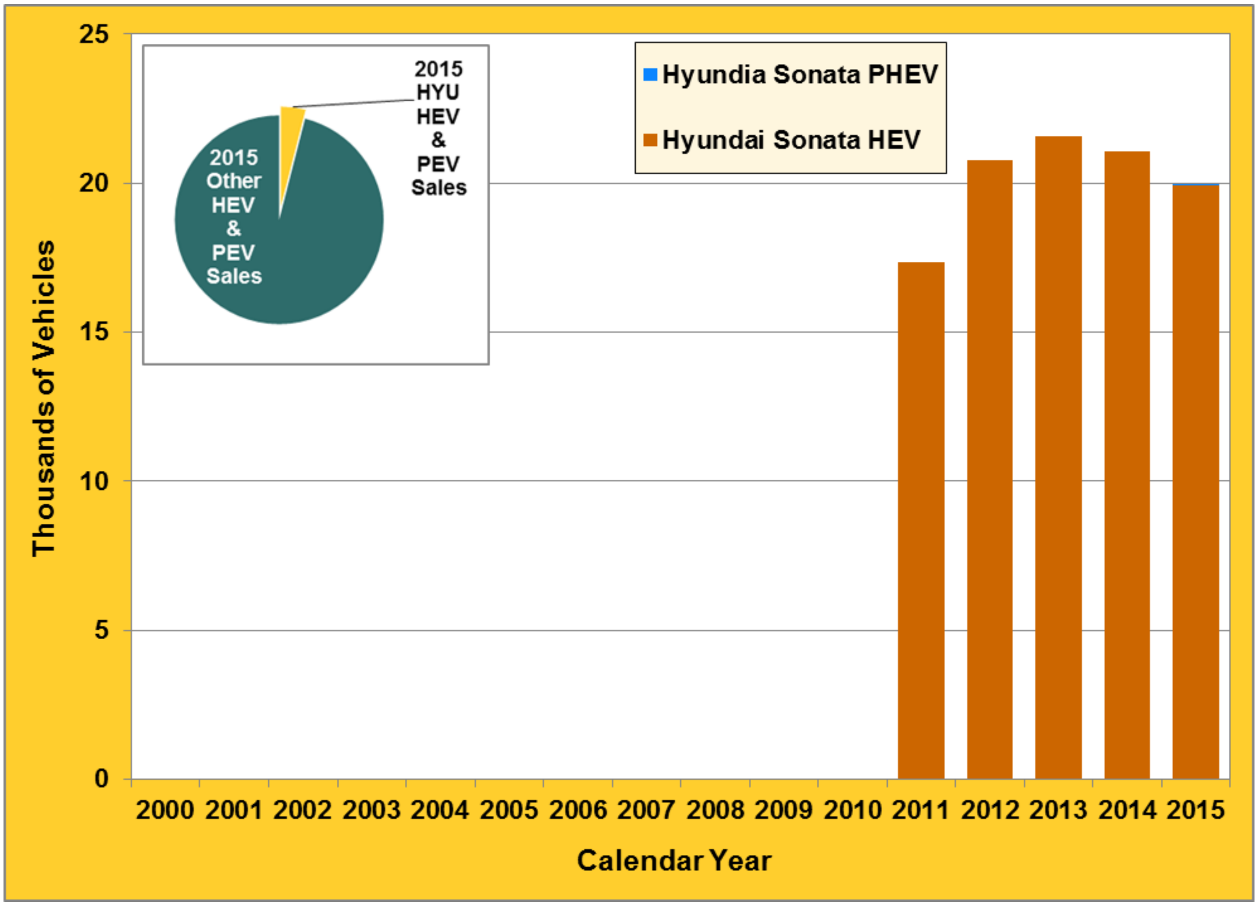


FIGURE 54. Hyundai Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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

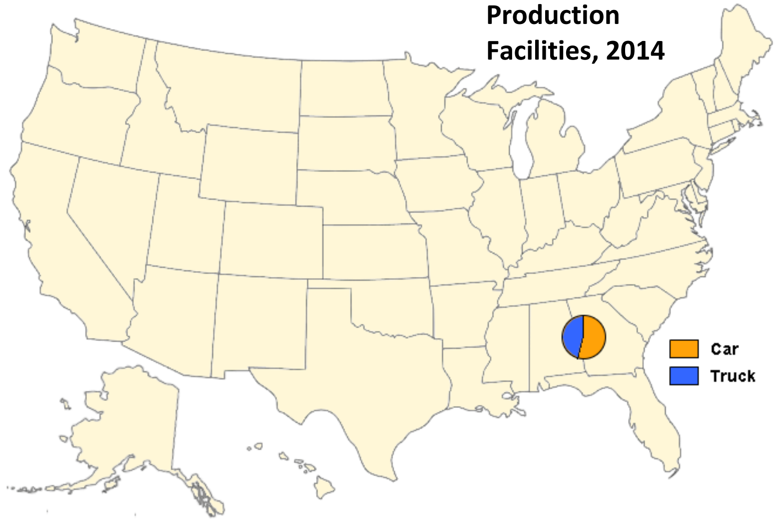
TABLE 18. Hyundai Interrelationships with Other Manufacturers

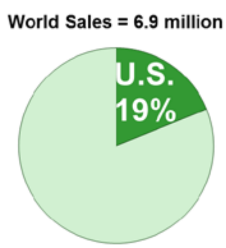
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Beijing Automotive		✓				✓	Car building joint venture
Kia			✓		✓		Share vehicle platforms, components and some R&D resources
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

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	None
Import Cars	33.8 mpg
Light Trucks	26.9 mpg
Average Vehicle Footprint MY 2015	
Cars	46.1 sq ft
Light Trucks	51.1 sq ft
All	46.4 sq ft
Number of Alternative Fuel Models, MY 2015	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0





Kia Plants	Type	2014 Production
West Point, GA	Car	142,561
West Point, GA	Truck	119,119

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 55. Kia Company Profile

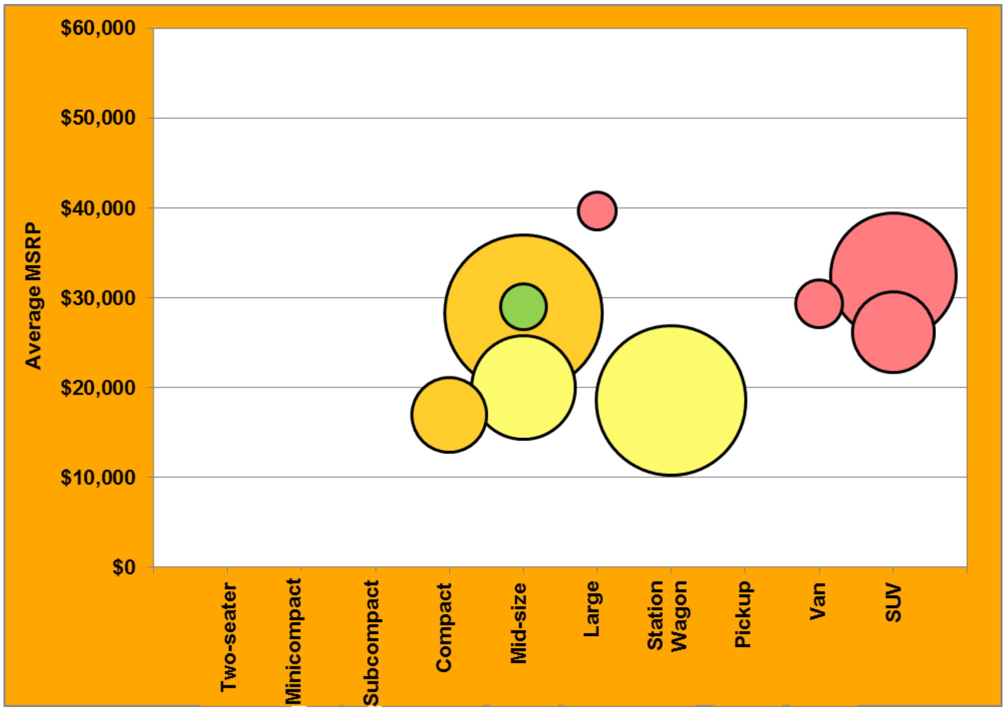
Fuel Saving Technologies

In 2015, Kia announced a $10.2 billion dollar investment in the development of advanced powertrain vehicles over the next five years and is aiming for a 25% increase in Corporate Average Fuel Economy over 2014. 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. Kia's first all-electric vehicle, the 2015 Soul EV arrived at dealerships in the second half of 2014. The first two models to arrive under the new five-year plan are both variants of the Optima. The Optima Hybrid has been redesigned for the 2016 model year with a larger battery pack and redesigned electric motors and transmission. It is expected to be about 10% more efficient than the previous Optima Hybrid models. A plug-in hybrid version of the Optima will arrive in the second half of 2016 and will feature a lithium-polymer battery and a six-speed automatic transmission. It will be Kia's first plug-in hybrid vehicle, with more expected by 2020. The all-new Niro hybrid SUV is expected for 2017 and will be built on Kia's new, dedicated eco-car platform, which has been engineered to accommodate the next generation of advanced powertrains. Kia's target date for a mass produced fuel cell vehicle is 2020.

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, improved aerodynamics, "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 has comparatively few models and all have an average manufacturer's suggested retail price (MSRP) of less than $45,000. About two-thirds of Kia's sales are from models with a combined rating of 25 mpg or higher while none of their models are rated below 20 mpg. About one-third of Kia's models and sales come from 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 56. Kia Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 19. Kia Models by EPA Size Class, 2014

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

Kia Optima and Soul Were over Half of Kia's Sales in 2014

The Kia Optima had the largest market share (27%) of all Kia models in 2014 and the Soul closely followed with a 25% share. The Sorento SUV was 17% of Kia's sales.

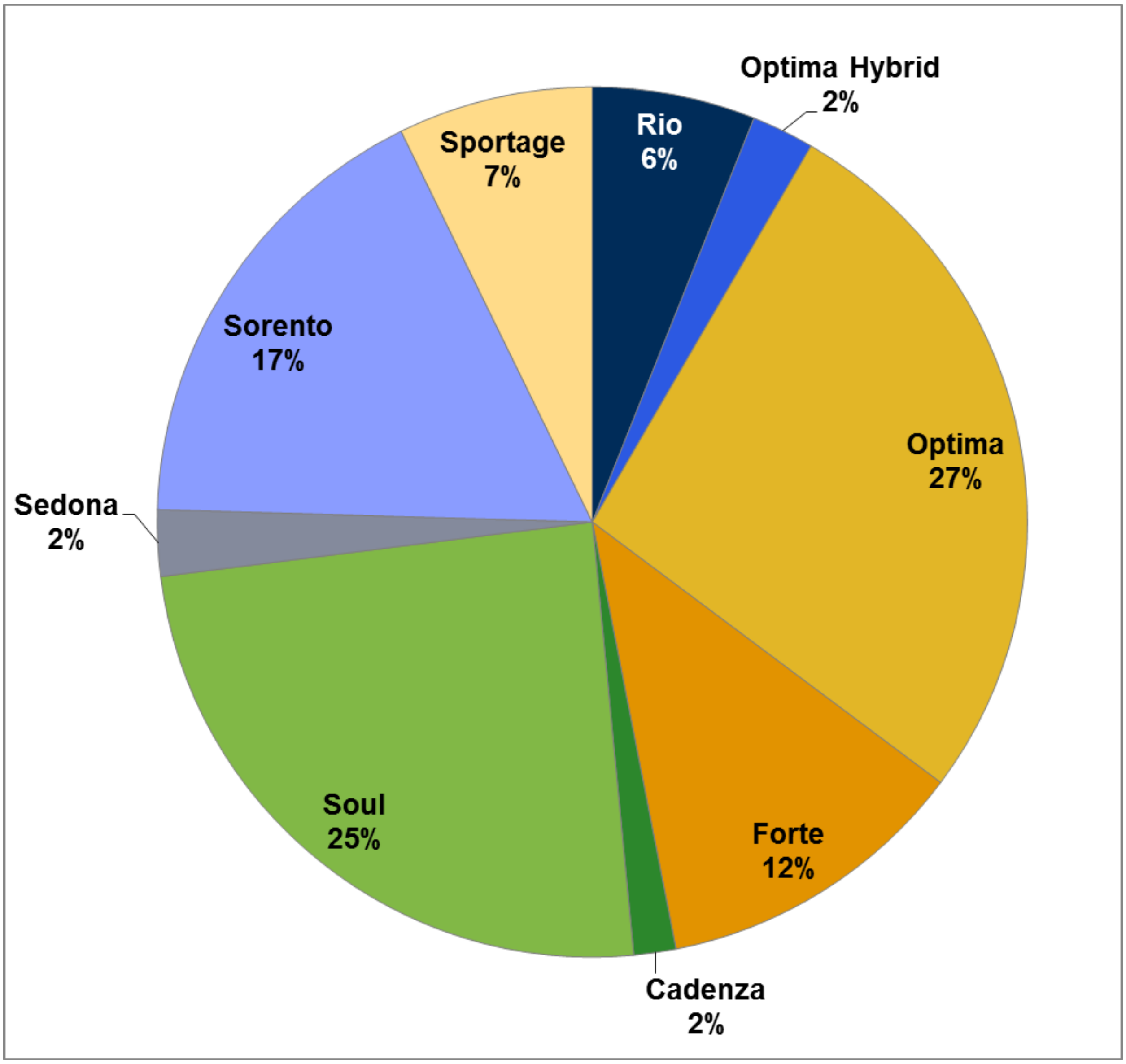


FIGURE 57. Kia Market Share by Model, 2014

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

Kia Soul Electric Vehicle Sales Grew in 2015

The Kia Soul electric vehicle (EV) was introduced in California in 2014 but by the end of 2016, Kia will have 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 in 2015 were small but increased from 2014. The Kia Optima hybrid electric vehicle (HEV) sales declined by about 17% in 2015. Kia is responsible for 3% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales in 2015.

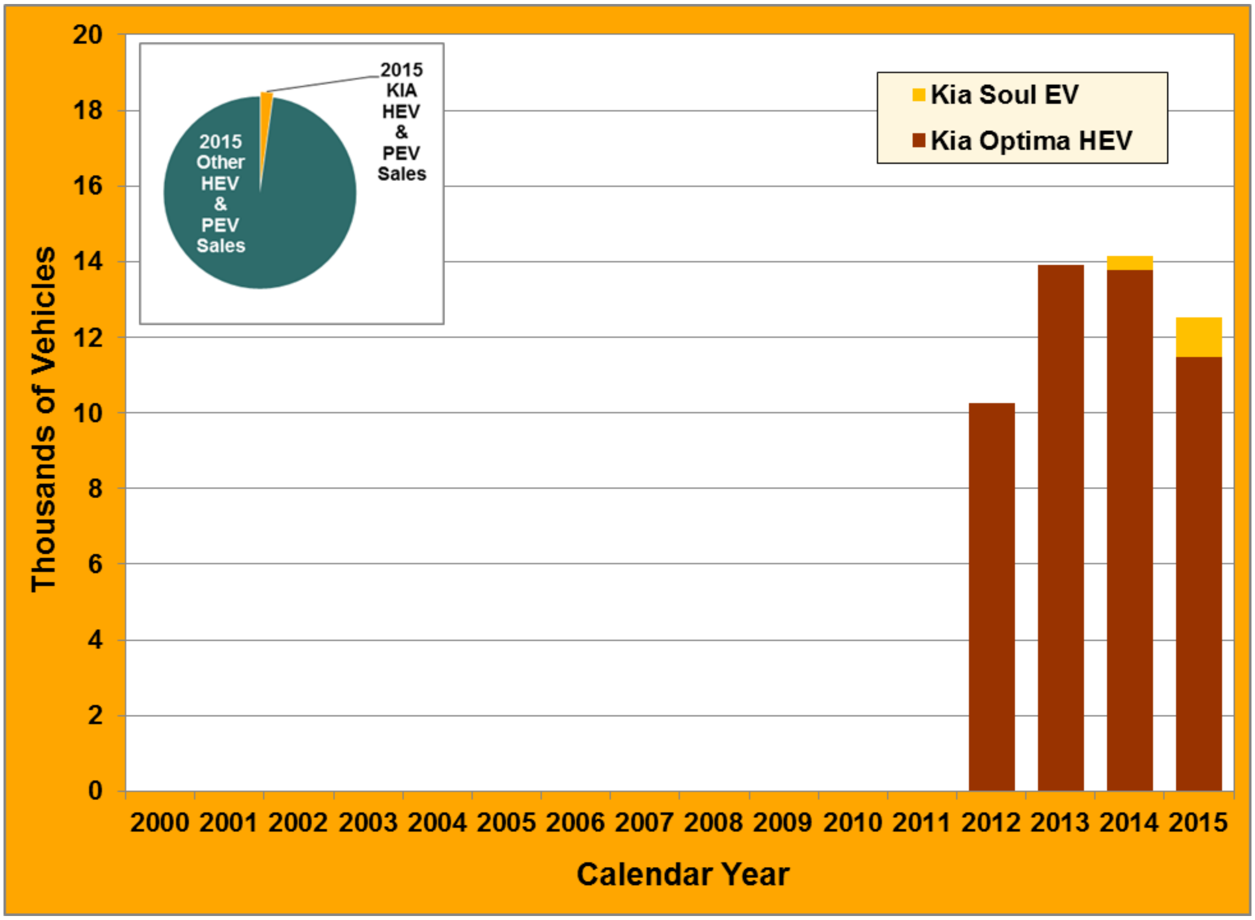


FIGURE 58. Kia Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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 20. Kia Interrelationships with Other Automotive Manufacturers

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

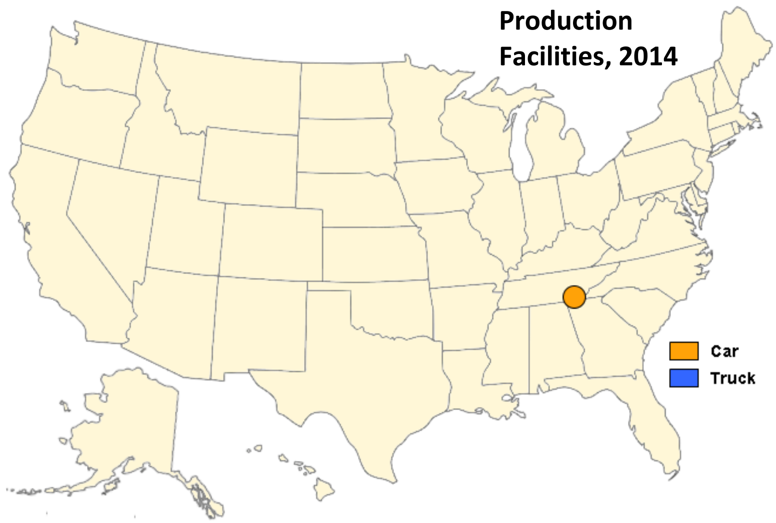
Source:
Ward's Automotive Group, *Interrelationships among the World's Major Auto Makers*, October 2015.
http://wardsauto.com

Volkswagen (VW) Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	33.6 mpg
Import Cars	33.8 mpg
Light Trucks	28.9 mpg

Average Vehicle Footprint, MY 2015	
Cars	45.0 sq ft
Light Trucks	48.5 sq ft
All	45.5 sq ft

Number of Alternative Fuel Models, MY 2015	
Flex Fuel	4
Natural Gas	0
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	0
Electric	1
Hydrogen	0



Volkswagen Plants	Type	2014 Production
Chattanooga, TN	Car	117,628

FIGURE 59. VW Company Profile

Fuel Saving Technologies

After years of leading the diesel light passenger vehicle sales in the US, headlines in 2015 were dominated by the discovery and subsequent admission from Volkswagen that many of their diesel models sold between 2009 and 2015 were installed with “defeat devices” designed to thwart accurate emissions tests. Nearly 600,000 vehicles in the US and as many as 11 million vehicles worldwide were sold with software that detected testing procedures and altered engine operation to restrict emissions only during testing. During normal on-road operation, the software in those same vehicles switched to normal operation and allowed them to exceed emissions standards in real-world driving. Despite the diesel emissions scandal, there are no plans to abandon diesel technology in future models.

Though not turning away from diesels, Volkswagen has since committed to greater focus on vehicle electrification. There have been several all-electric concept models showcased over the years including the Volkswagen e-Up! and Audi R8 e-Tron supercar, but the 2015 e-Golf became Volkswagen’s first all-electric model for the US market. In a 2015 press release Volkswagen announced that the Phaeton luxury sedan would be brought back as a long-range all-electric vehicle. At the 2016 Consumer Electronics Show, 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. Unveiled at the 2016 Detroit Auto Show was the plug-in hybrid Volkswagen Tiguan SUV 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. The fuel economy of Volkswagen’s gasoline and diesel models continue to benefit from engine and transmission refinements including the development of a new 10-speed transmission.

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 are cars in the subcompact, compact, and midsize segments. Although there is only one model 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 are not shown.

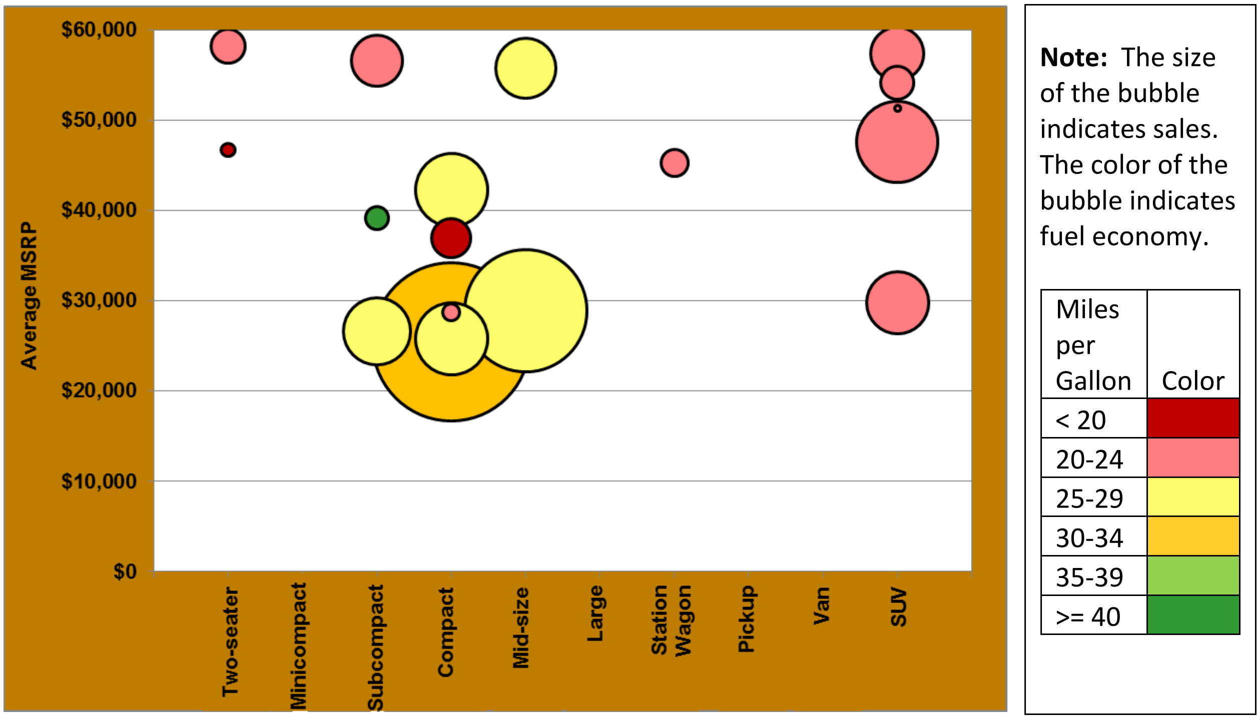


FIGURE 60. VW Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2014

TABLE 21. VW Models by EPA Size Class, 2014

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
Lamborghini R8 Boxster/ Cayman TT	*911 Series*	A5/S5 Eos Beetle	A4/S4 CC Jetta-Hybrid Golf Jetta	A7 A6/S6 Passat	*Bentley* *Panamera* *Panamera S-Hybrid* *A8/S8*	allroad quattro		Routan	*Cayenne* *Cayenne S-Hybrid* *Touareg-Hybrid* Q7 Touareg Q5-Hybrid 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 about One-Quarter of VW's Sales in 2014

The VW Jetta and the VW Passat were the only models to account for more than 8% of VW's market. Two-thirds of VW's sales are cars. The Audi Q5 and the VW Tiguan are the SUVs with the greatest market share.

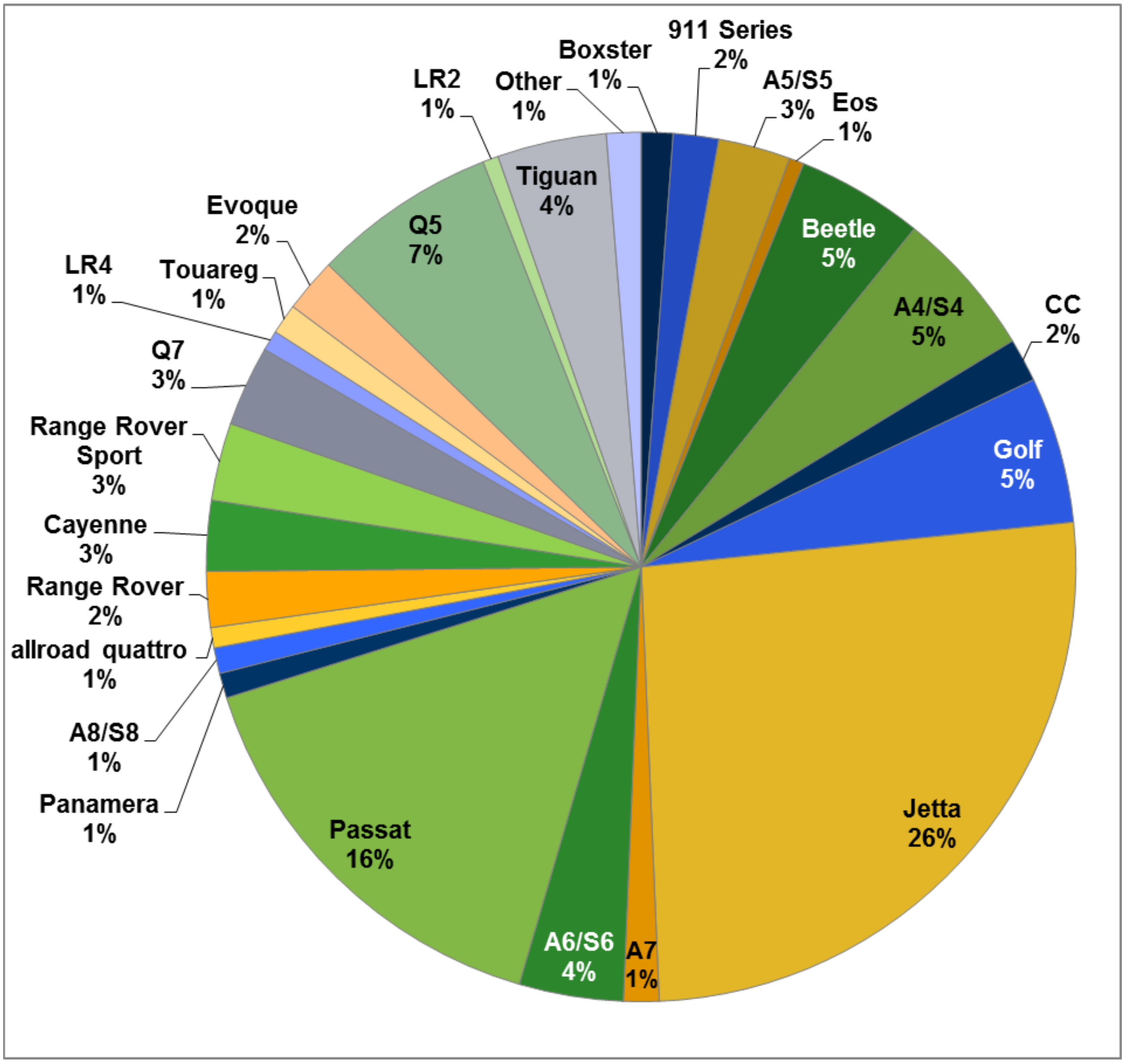


FIGURE 61. VW Market Share by Model, 2014

Note: "Other" includes the R8, TT, Jetta Hybrid, Bentley, Panamera Hybrid, Touareg Hybrid, and Q5 Hybrid. Each vehicle model accounted for less than 1% of the total.

Source:
Ward's Automotive Group, March 2016. http://wardsauto.com

VW Hybrid and Plug-In Vehicle Sales Grew by 57% Due to the e-Golf Sales

Nearly every hybrid-electric vehicle (HEV) and plug-in hybrid-electric vehicle (PHEV) model offered by VW experienced a decline in sales from 2014 to 2015, but the growing sales of the VW e-Golf electric vehicle (EV) more than made up for those declines. Total HEV and plug-in vehicle (PEV) sales for 2015 were up by 57% in 2015. Sales for the Porsche Panamera S E-Hybrid PHEV also increased from 2014 to 2015. VW is responsible for just over 1% of all HEV and PEV sales.

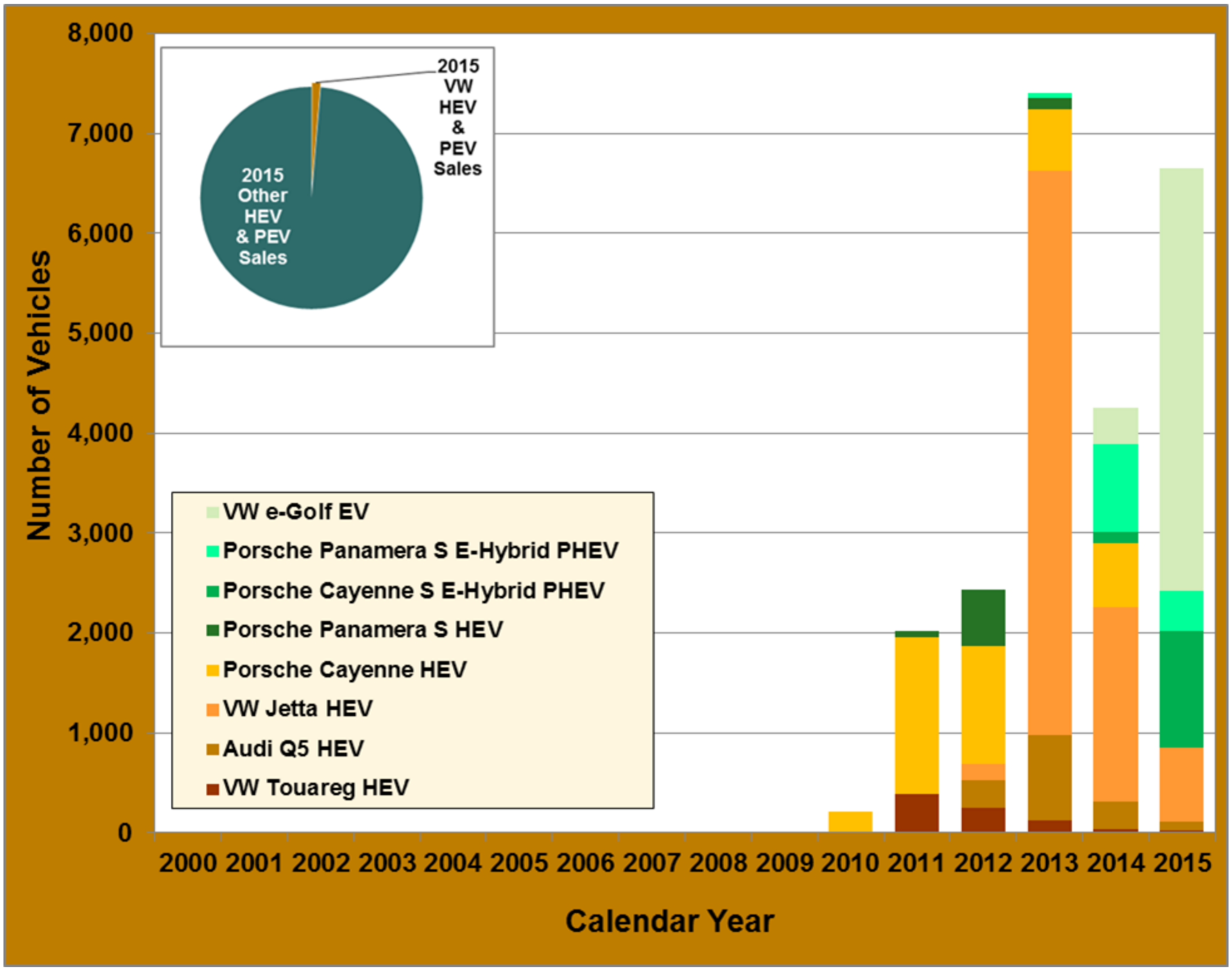


FIGURE 62. VW Hybrid and Plug-In Electric Vehicle Sales, 2000-2015

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) 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

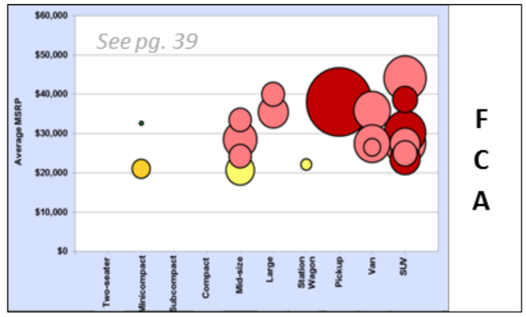
TABLE 22. VW Interrelationships with Other Automotive Manufacturers

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 manufacturer's sales chart shows that GM, Toyota and VW have the most models. Toyota has more fuel efficient models; Hyundai's market is mainly in cars; and FCA's market is mainly light trucks.



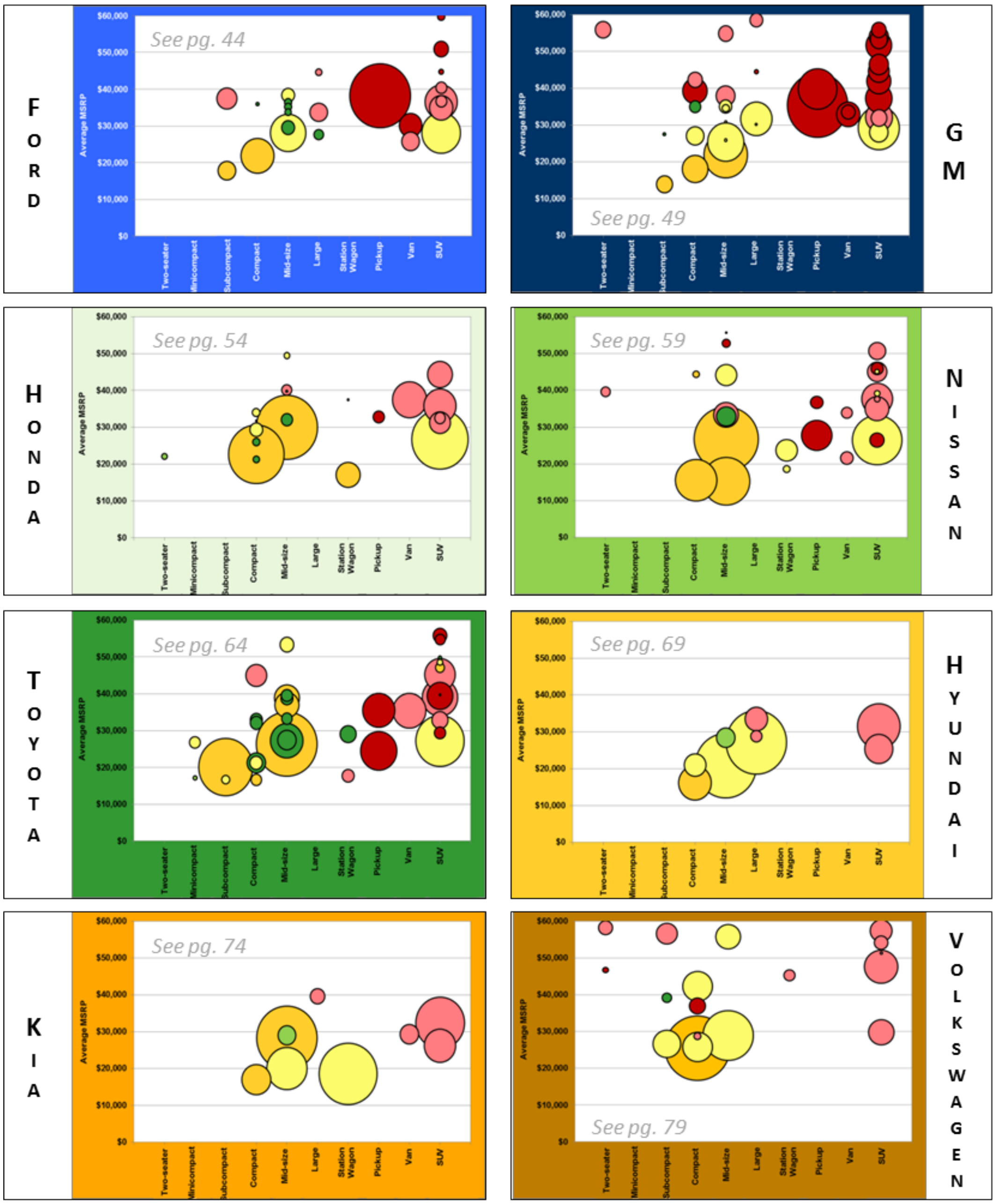


FIGURE 63. Summary Comparison of Manufacturers' Markets, 2014

Top Nine Manufacturers Selling Vehicles in the United States Only Produce a Little More than Half of World's Vehicles

The companies that made 91% of all vehicles produced in the United States in 2014 are together responsible for a little more than half of the vehicles produced worldwide. Volkswagen, which did not produce vehicles in the United States until 2011, held 7% of World production in 2014. Toyota produced 11% in the World as well as 11% in the United States. Many companies, like recent upstarts in China and India, comprise the other 49% of world production. The United States produces about 13% of the world's vehicles.

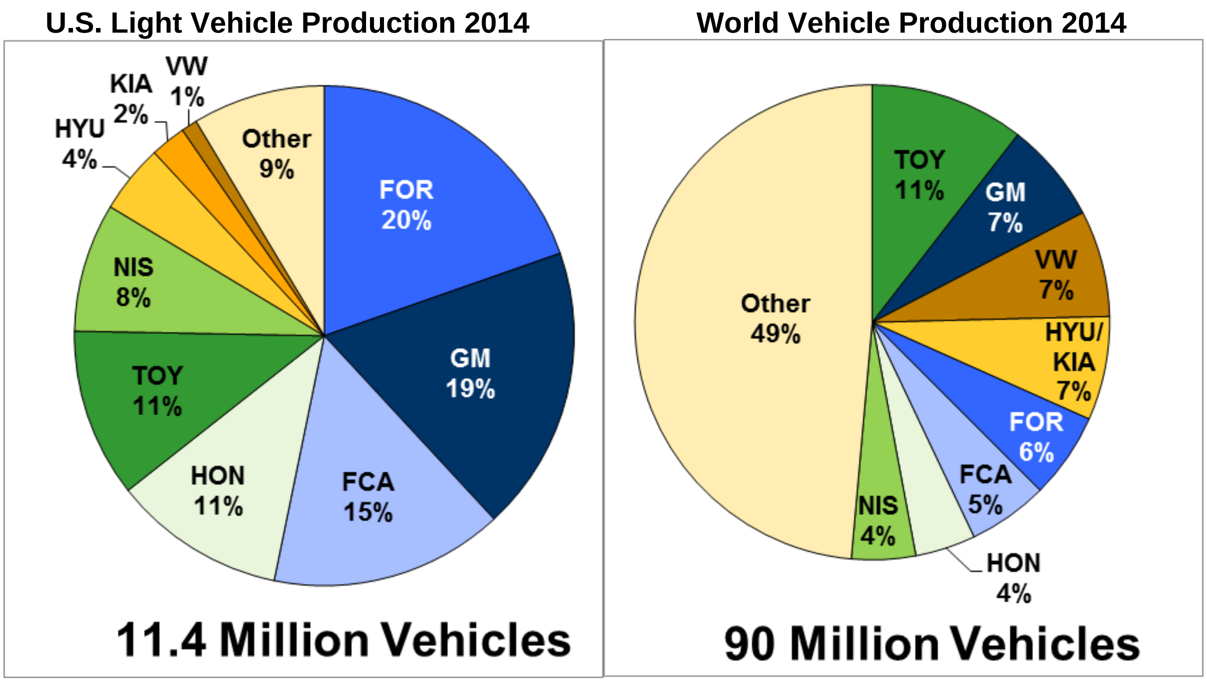


FIGURE 64. Production of United States and World Vehicles in 2014 by Manufacturer

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 6.3% share in 2014.

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

U.S. Light Truck Sales Volumes Continued to Rise in 2015

Sales volumes rose from 2011 to 2015, for light trucks and car sales fell only slightly in 2015. By 2015, sales reached between 7 and 8 million for cars and nearly 10 million for light trucks.

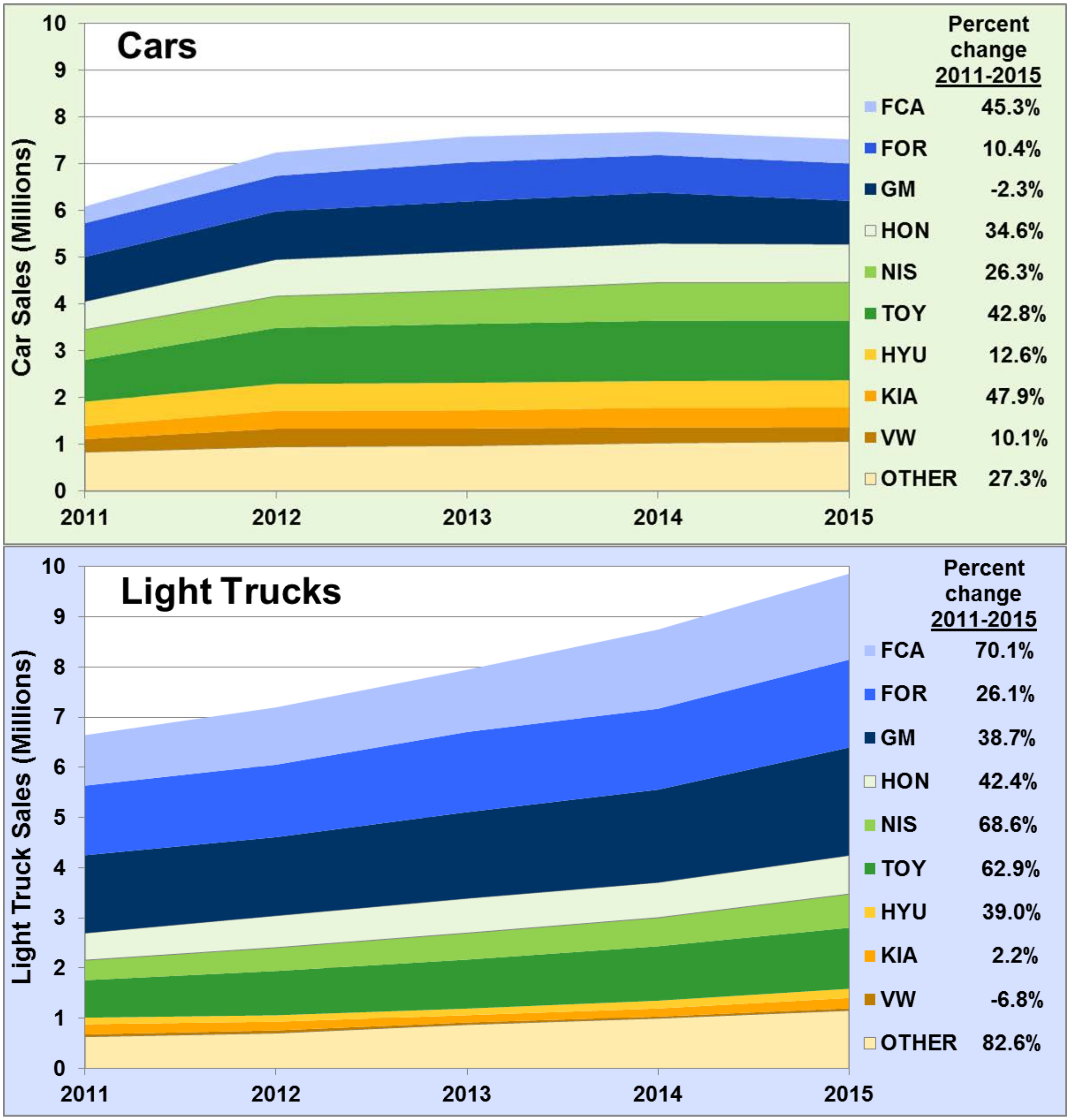


FIGURE 65. New Light Vehicle Sales by Manufacturer, 2011-2015

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

Market Share Shifted among Manufacturers

Kia, FCA, and Honda experienced the largest gains in car market share from 2011-2015. Nissan experienced a slight gain in car market share in the five-year period while the market share declined for Toyota, General Motors, VW, and Ford. The three domestic manufacturers accounted for about 57% of the light truck market share in 2015.

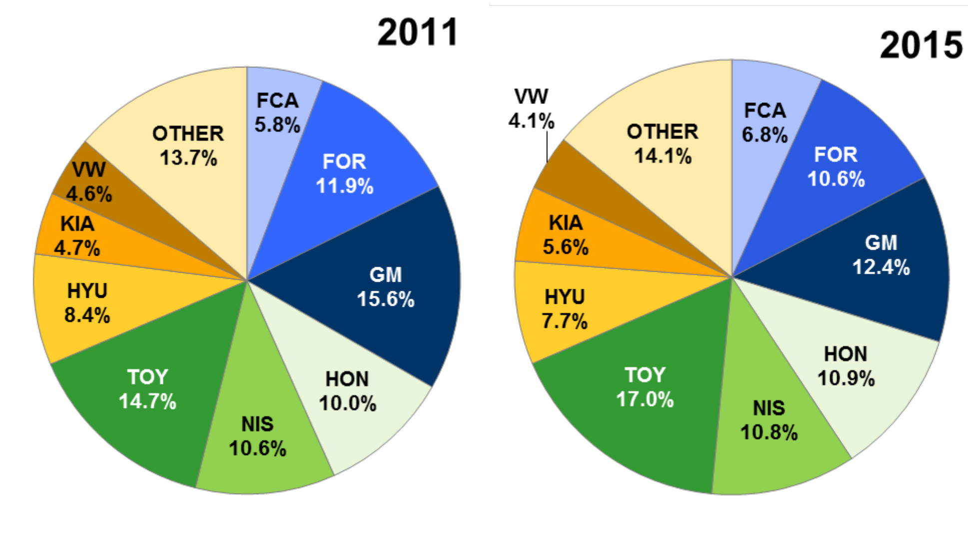


FIGURE 66. New Car Market Share by Manufacturer, 2011 and 2015

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

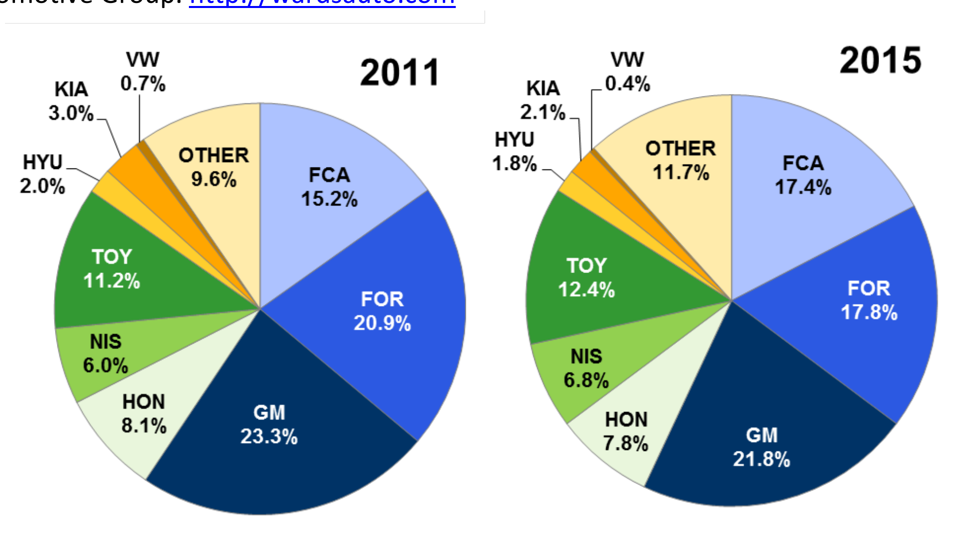


FIGURE 67. New Light Truck Market Share by Manufacturer, 2011 and 2015

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

Share of Import Cars Declined to About 25% of Total Car Sales in 2015

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% but accounted for just 18% in 2015.

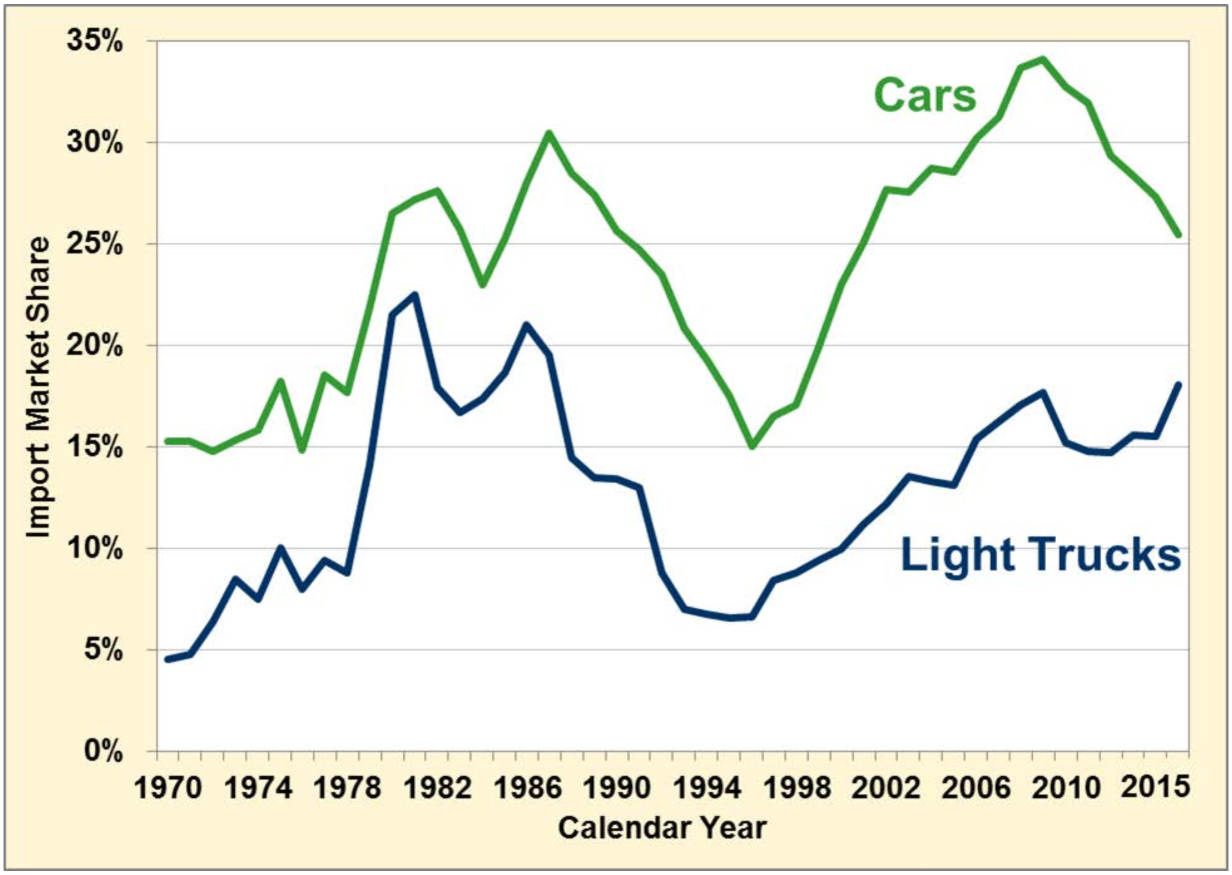


FIGURE 68. Import Market Share of Cars and Light Trucks, 1970-2015

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 nine largest U.S. manufacturers, Toyota sells the most imported light vehicles which accounts for about 29% of their sales. Kia, however, has the highest import share—imports accounted for 58% of Kia light vehicle sales in 2015.

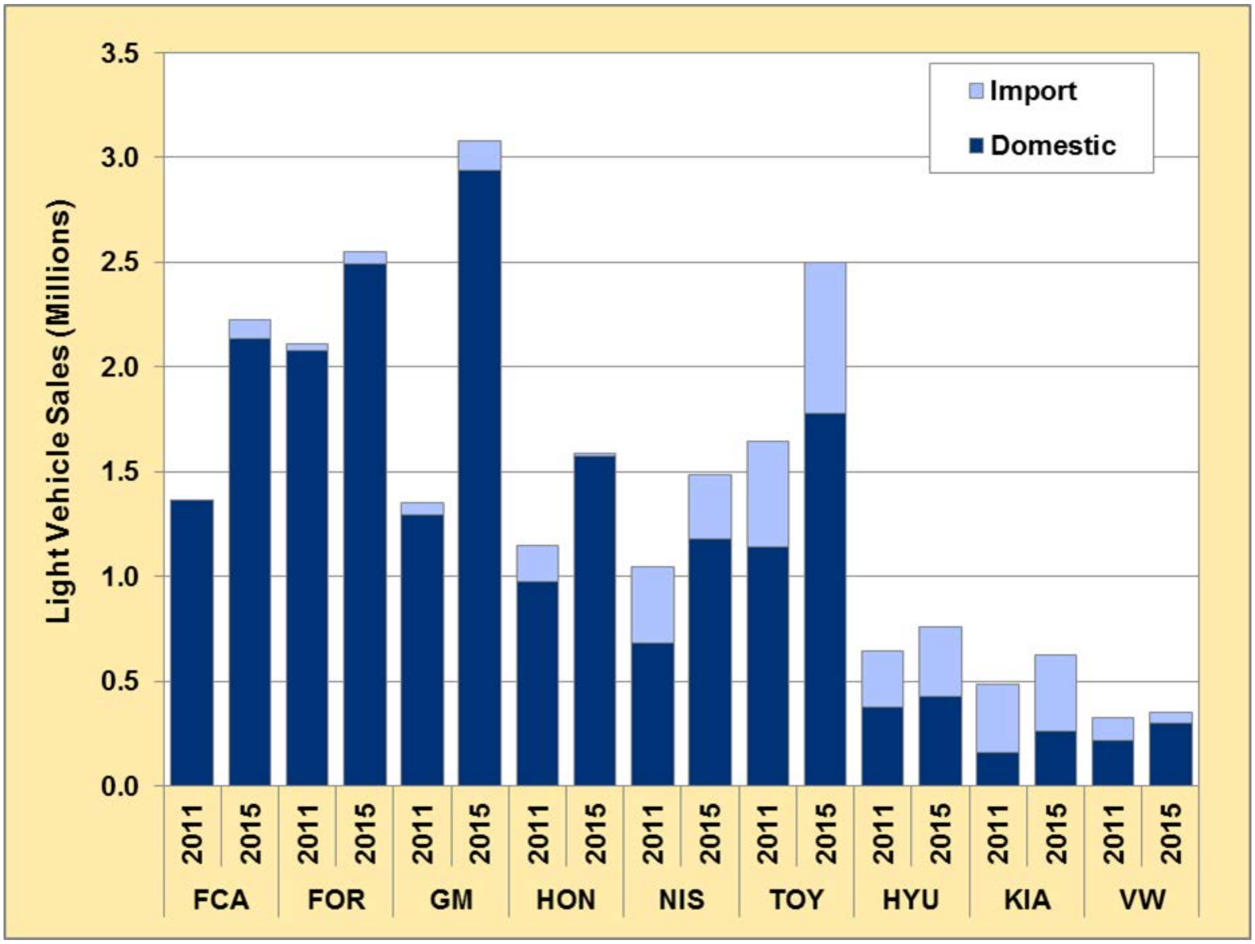


FIGURE 69. Light Vehicle Sales by Source and Manufacturer, 2011 and 2015

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

Engine Displacement for Cars has Declined by 9%

Average sales-weighted engine displacement for all new cars declined 9% from 2011 to 2015. In the same time period, average displacement for light trucks declined by 3%. In general, FCA, General Motors, and Toyota have larger engines than the other major manufacturers. Yearly fluctuations are typically a result of the introduction or elimination of a model.

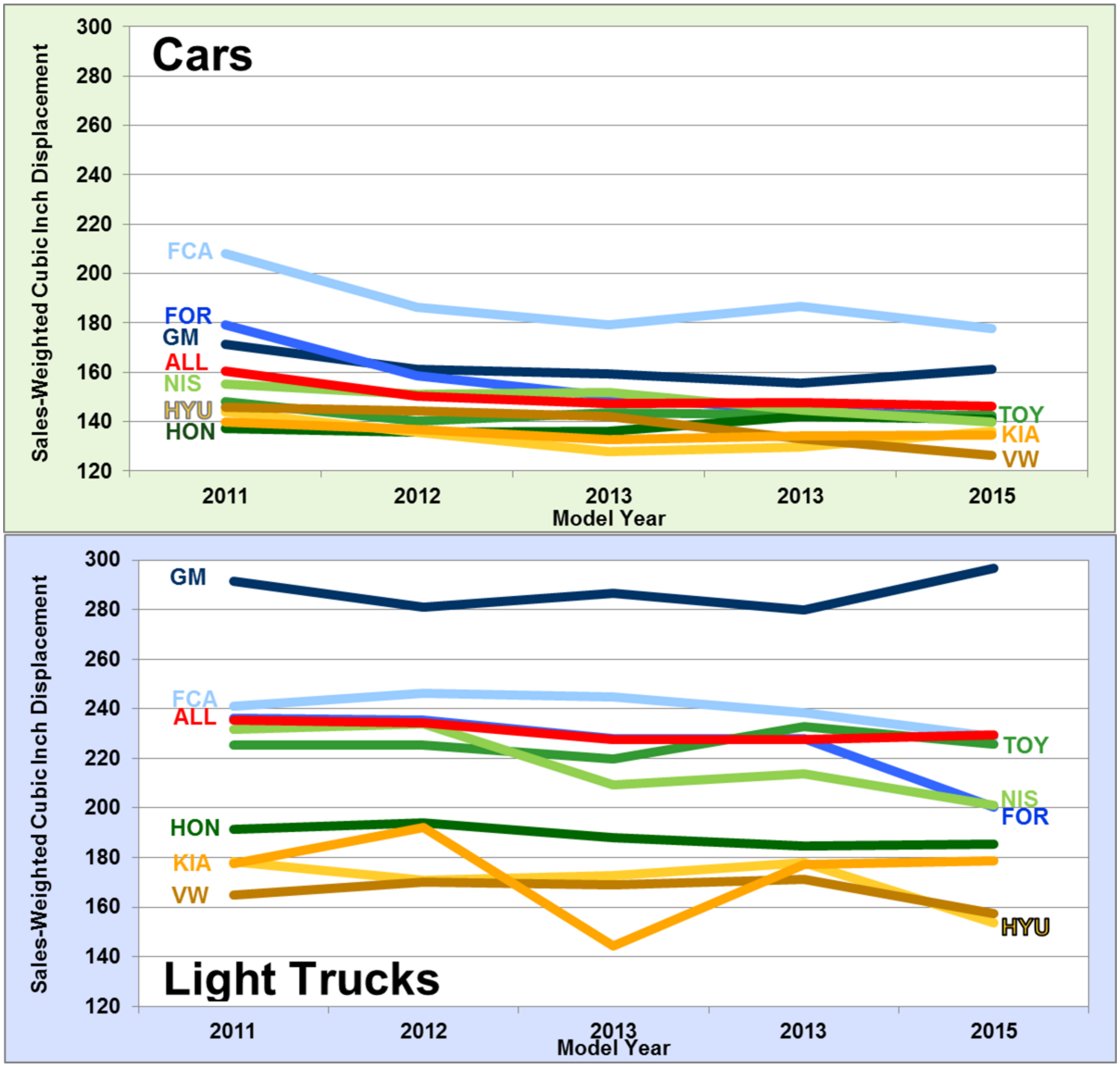


FIGURE 70. Car and Light Truck Engine Size by Manufacturer, 2011-2015

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Light Truck Horsepower Increased by 4% from 2011 to 2015

Advancements in engine design and overall engine technology can increase horsepower without increasing the engine size. Chrysler, General Motors, and Ford, which produce the most trucks, have increased average sales-weighted horsepower from 2011. The noticeable drop in Kia's light truck horsepower in 2013 is likely due to the discontinuation of the Sedona minivan. Average horsepower for cars has stayed about the same over the five-year time period.

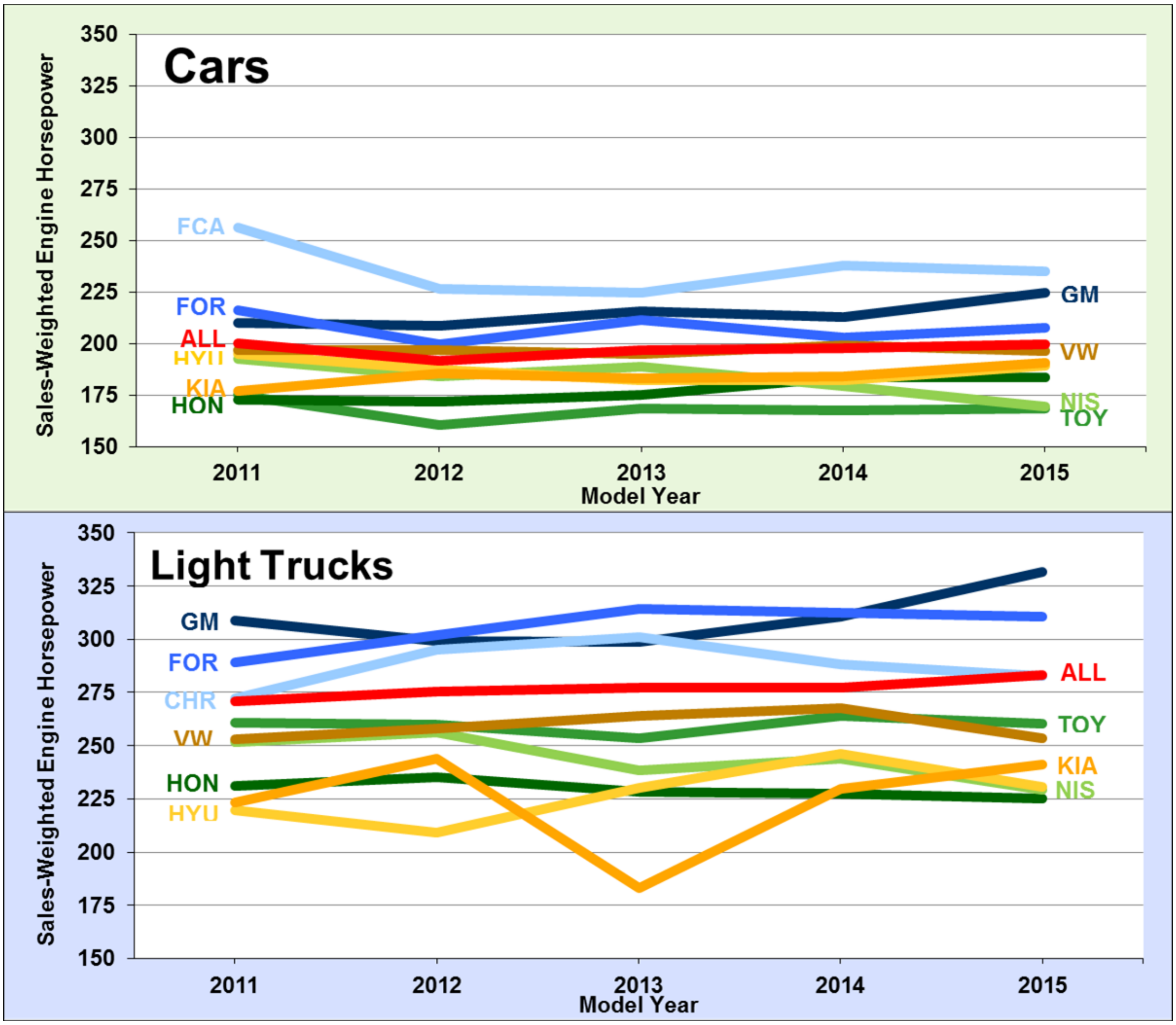


FIGURE 71. Car and Light Truck Horsepower by Manufacturer, 2011-2015

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Technology Has Improved Performance More than Fuel Economy

Despite a 125% increase in horsepower and 47% decrease in 0-60 time from 1980 to 2015, the fuel economy of vehicles improved 29%. All of these data series are sales-weighted averages. The weight of the vehicle appears to have an inverse relationship with fuel economy.

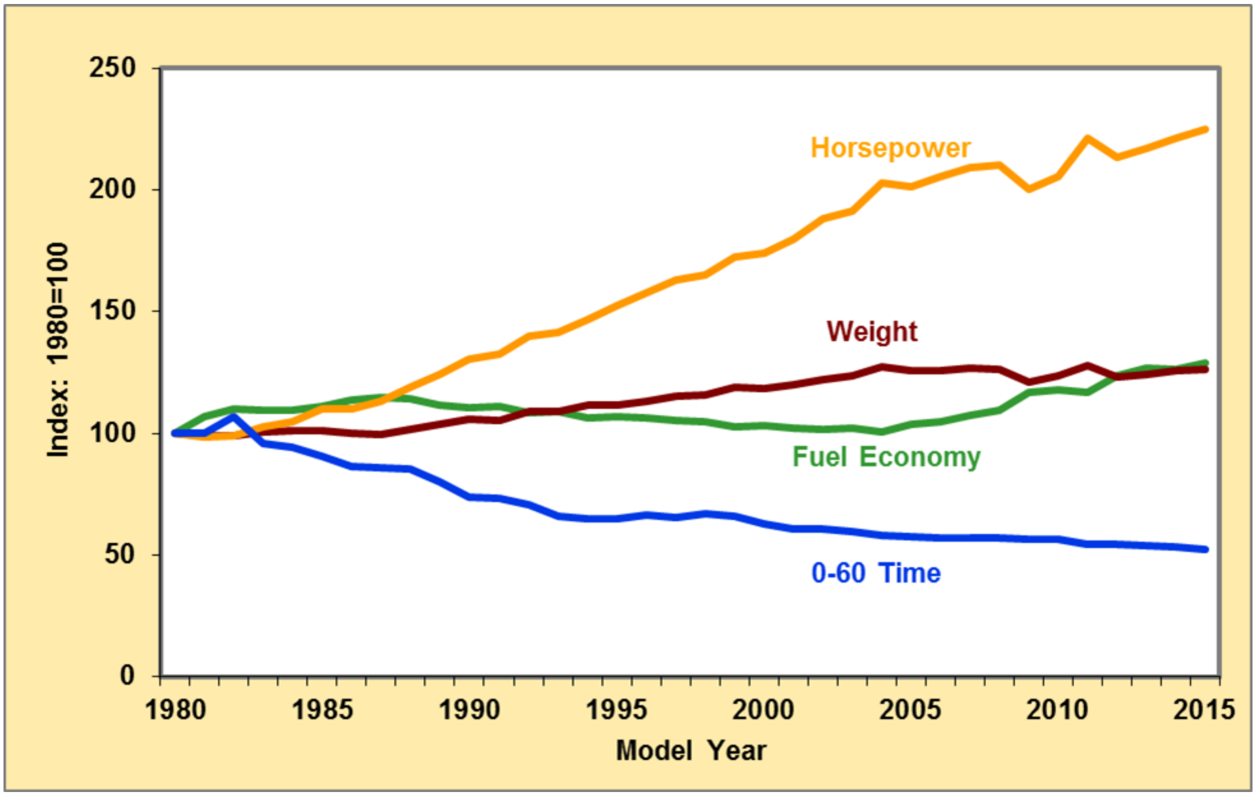


FIGURE 72. Characteristics of Light Vehicles Sold, 1980-2015

Note: Data are sales-weighted.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Horsepower above Fleet Average and Fuel Economy near Fleet Average for Detroit 3 Manufacturers

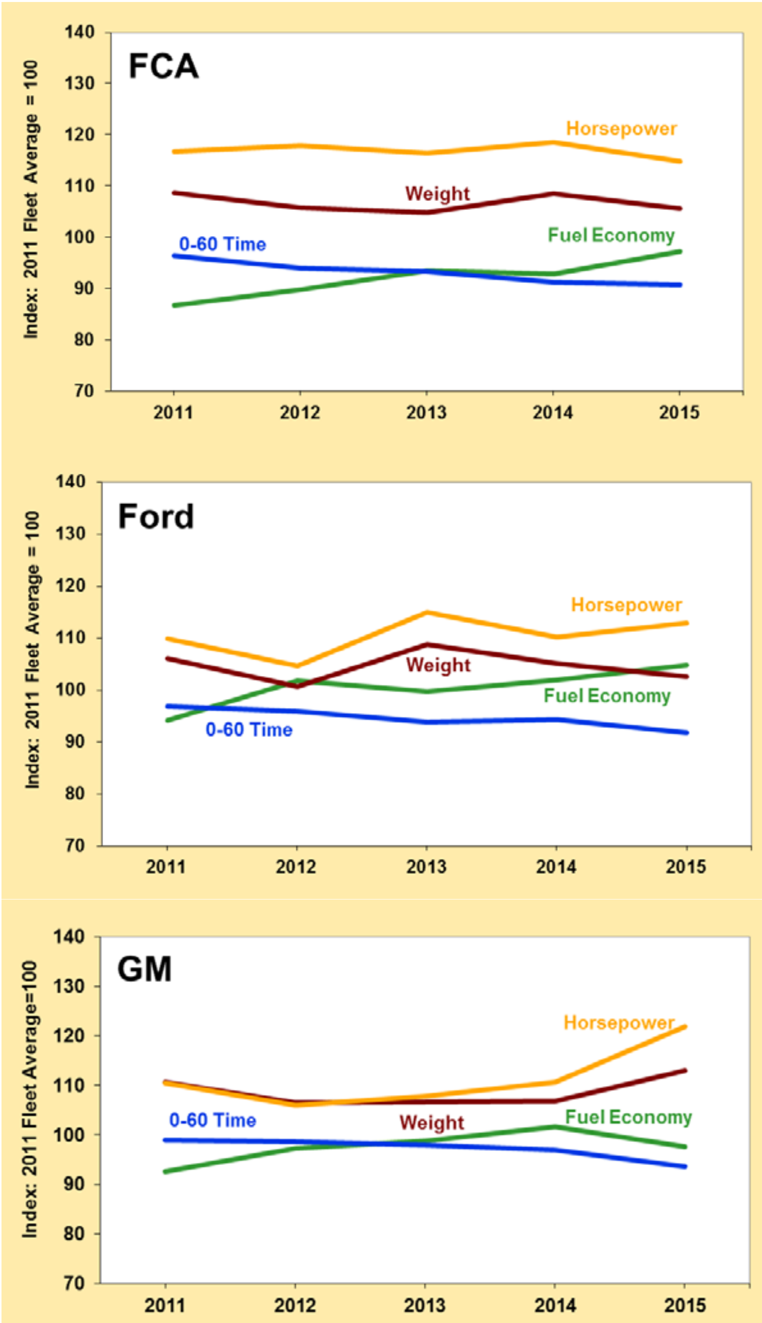


FIGURE 73. Characteristics of Detroit 3 Light Vehicles Sold, 2011-2015

These sales-weighted averages show that all of the Detroit 3 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 made the biggest improvement in fuel economy over the five year period – a 12% improvement from 2011 to 2015. In the same time frame, Ford had an 11% and General Motors (GM) a 5% improvement. Fuel economy in 2015 was below the fleet average (below 100 on the graph) for FCA and GM.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. 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

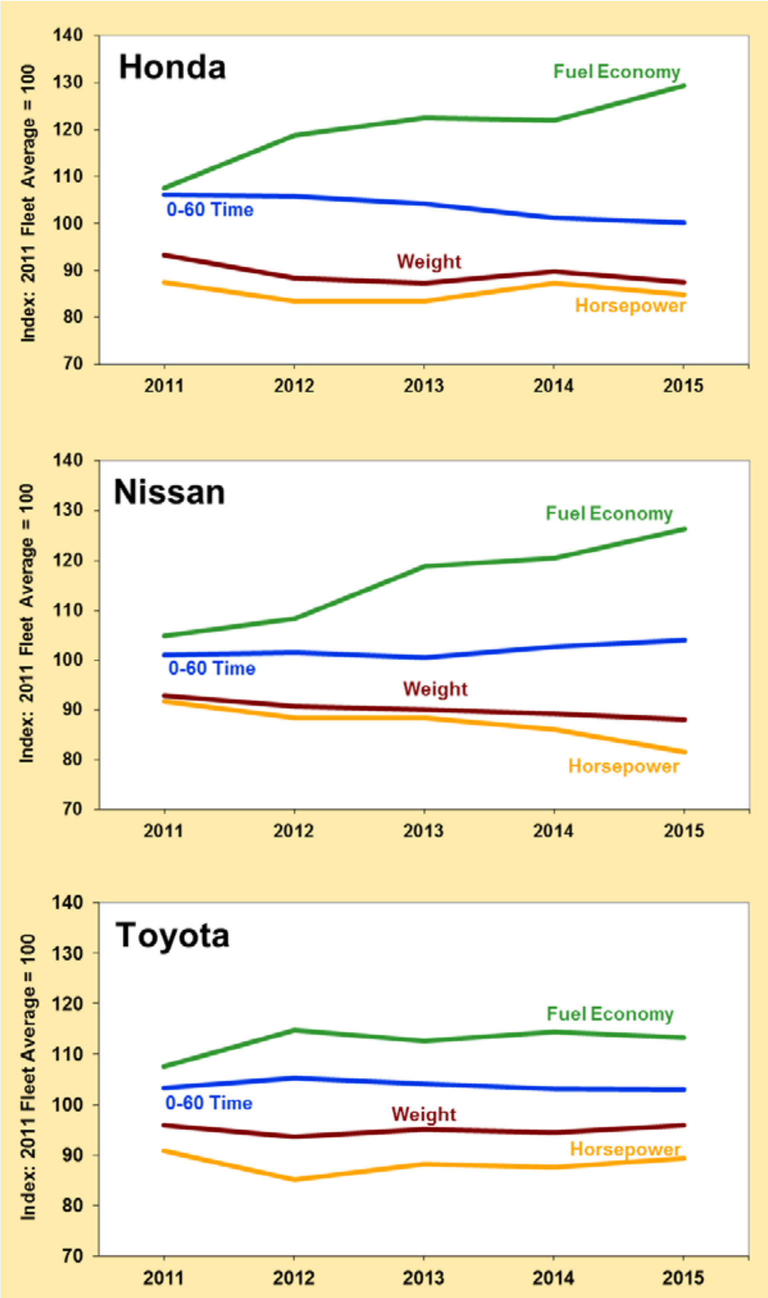


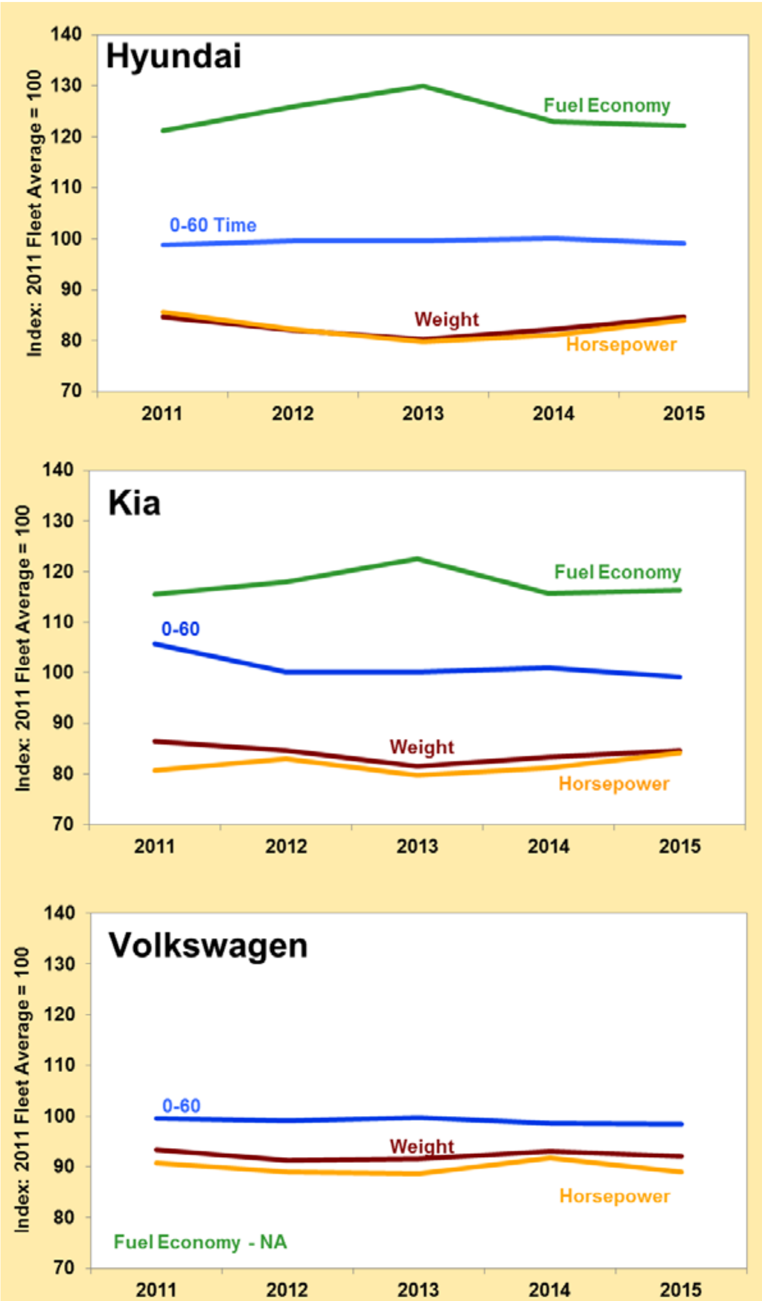
FIGURE 74. Characteristics of Japanese Light Vehicles Sold, 2011-2015

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 – 21% over the five year period – followed by Honda with 20% improvement. While Nissan's fuel economy improved, horsepower declined by 11%. 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 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

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



The fuel economy for Hyundai's and Kia's light vehicles in 2011 was higher than the fleet average (higher than 100 on the graph). Horsepower and weight were below the fleet averages for all three manufacturers. Volkswagen's fuel economy is not available from 2009-on due to the on-going investigation of VW diesel models.

FIGURE 75. Characteristics of Light Vehicles Sold by Other Large Manufacturers, 2011-2015

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. 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 have climbed to 26.3% of car and 12.5% of light truck market share. Nissan sold 32% of cars and 40% of light trucks in 2015 that were equipped with CVT.

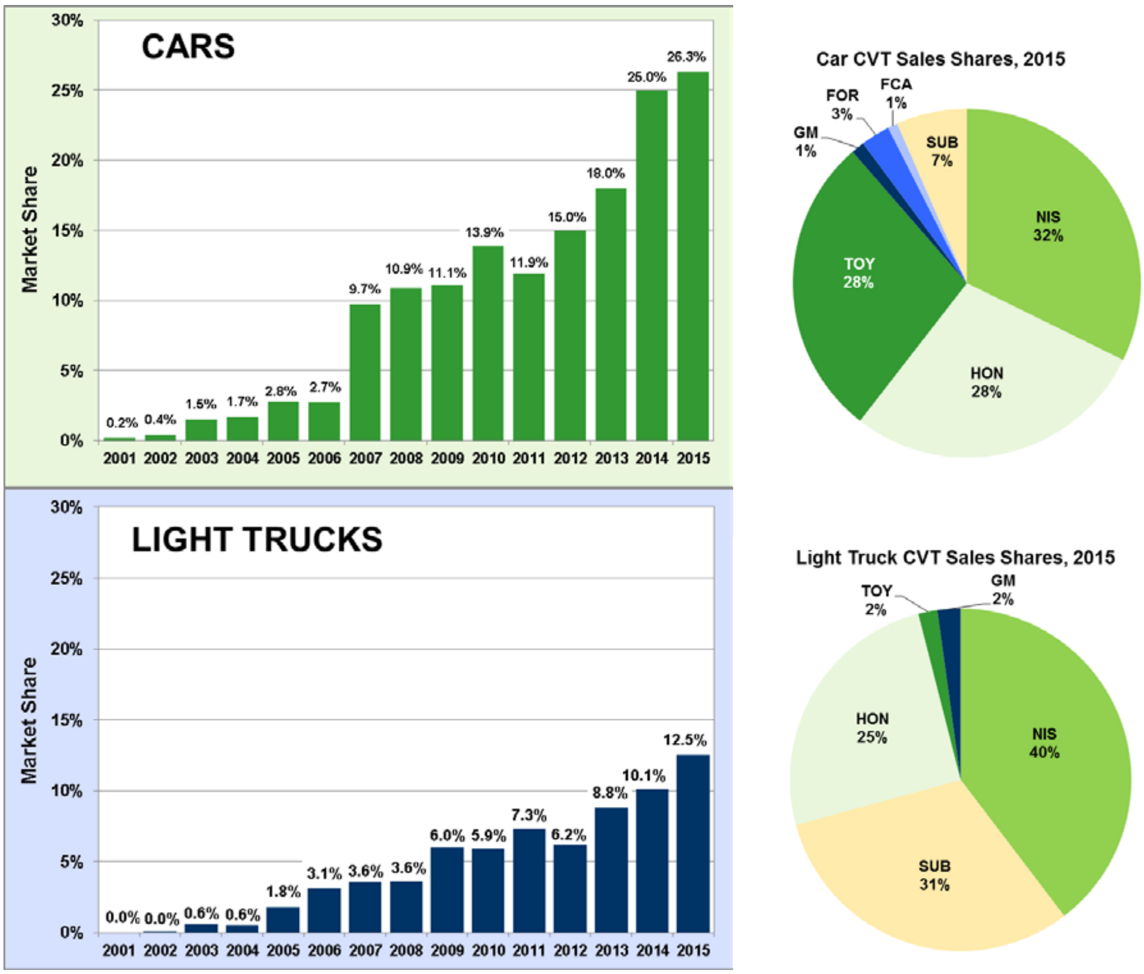


FIGURE 76. CVT Market Share, 2001-2015 and CVT Manufacturers' Share, 2015

Note: SUB = Subaru.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Twenty Percent of New Cars Have Turbochargers

Turbocharging is not a new technology, but has grown in new light vehicle market share over the last five years. In 2015, more than 20% of new cars and nearly 14% of new light trucks had turbocharged engines (turbos). Ford had the greatest share of turbo sales in both cars and light trucks.

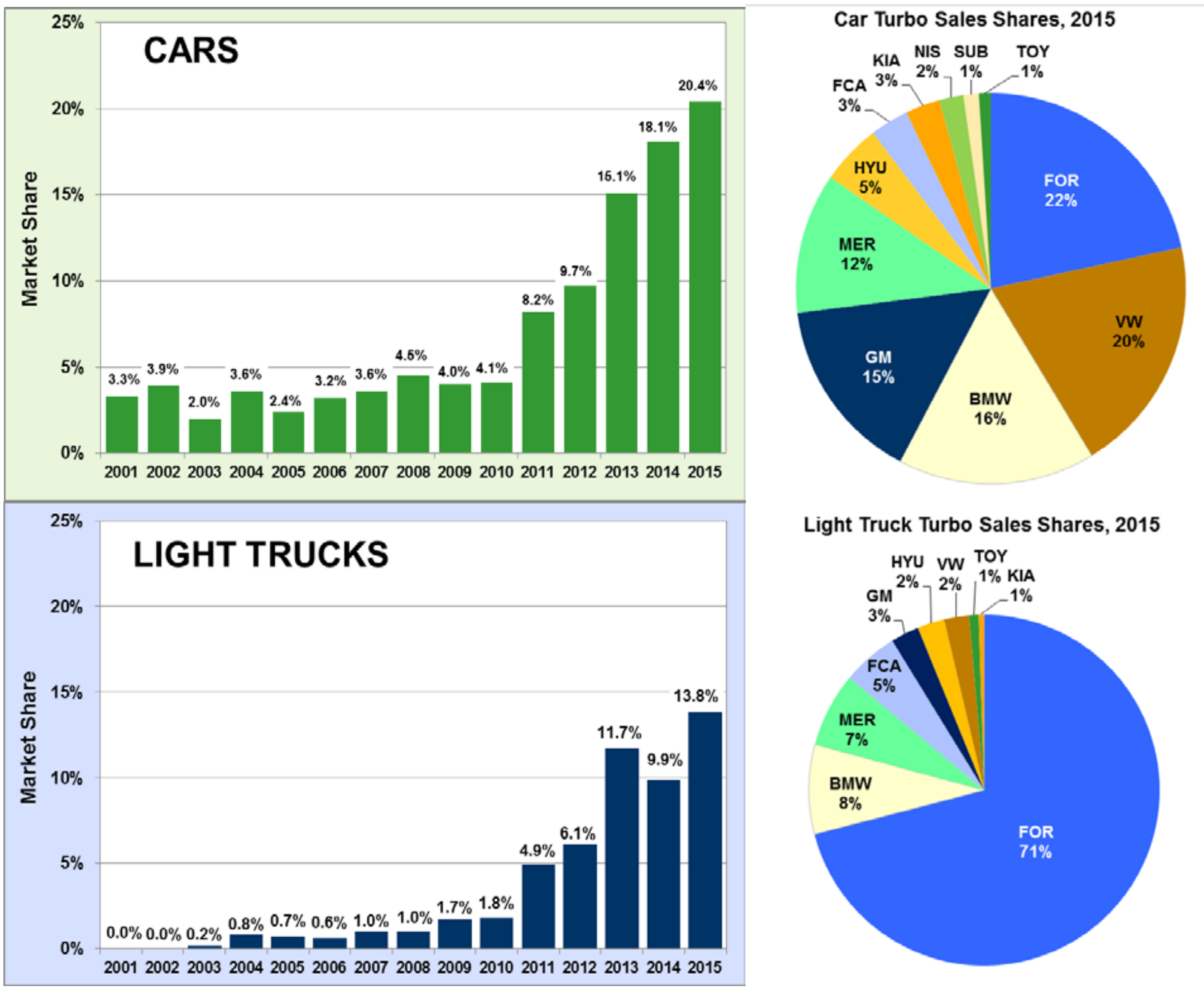


FIGURE 77. Turbo Market Share, 2001-2015 and Turbo Manufacturer's Share, 2015

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

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. 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 2015, the market share for GDI was 46.4% for cars and 43.3% for light trucks. In 2015, half of all light trucks with GDI were sold by GM.

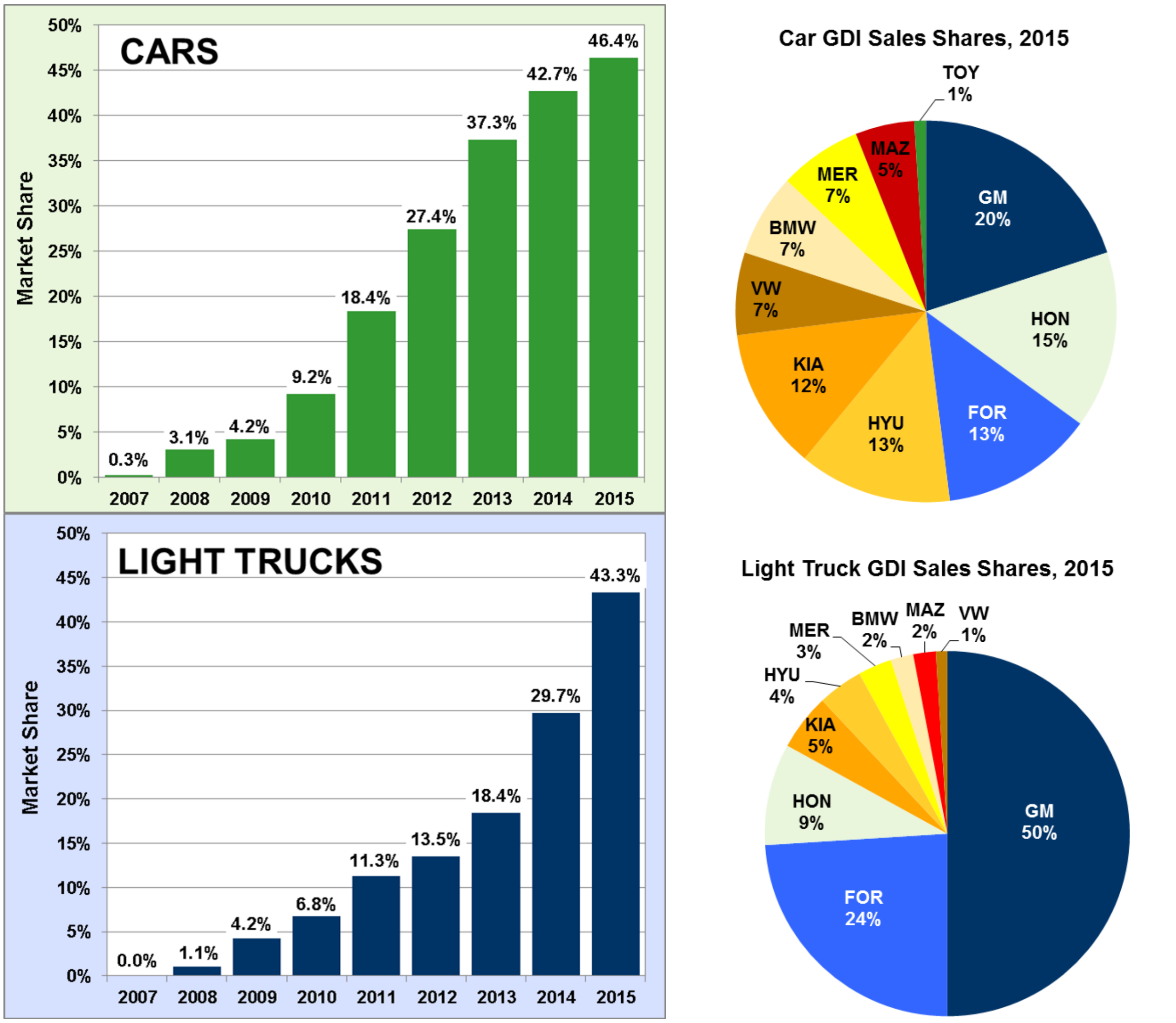


FIGURE 78. GDI Market Share, 2007-2015 and GDI Manufacturer's Share, 2015

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 2015*, EPA-420-S-15-001, December 2015. 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. Also, VW uses CD in cars. Three-fourths of all cars sold with CD were from Honda. GM sold 70% of all light trucks with CD.

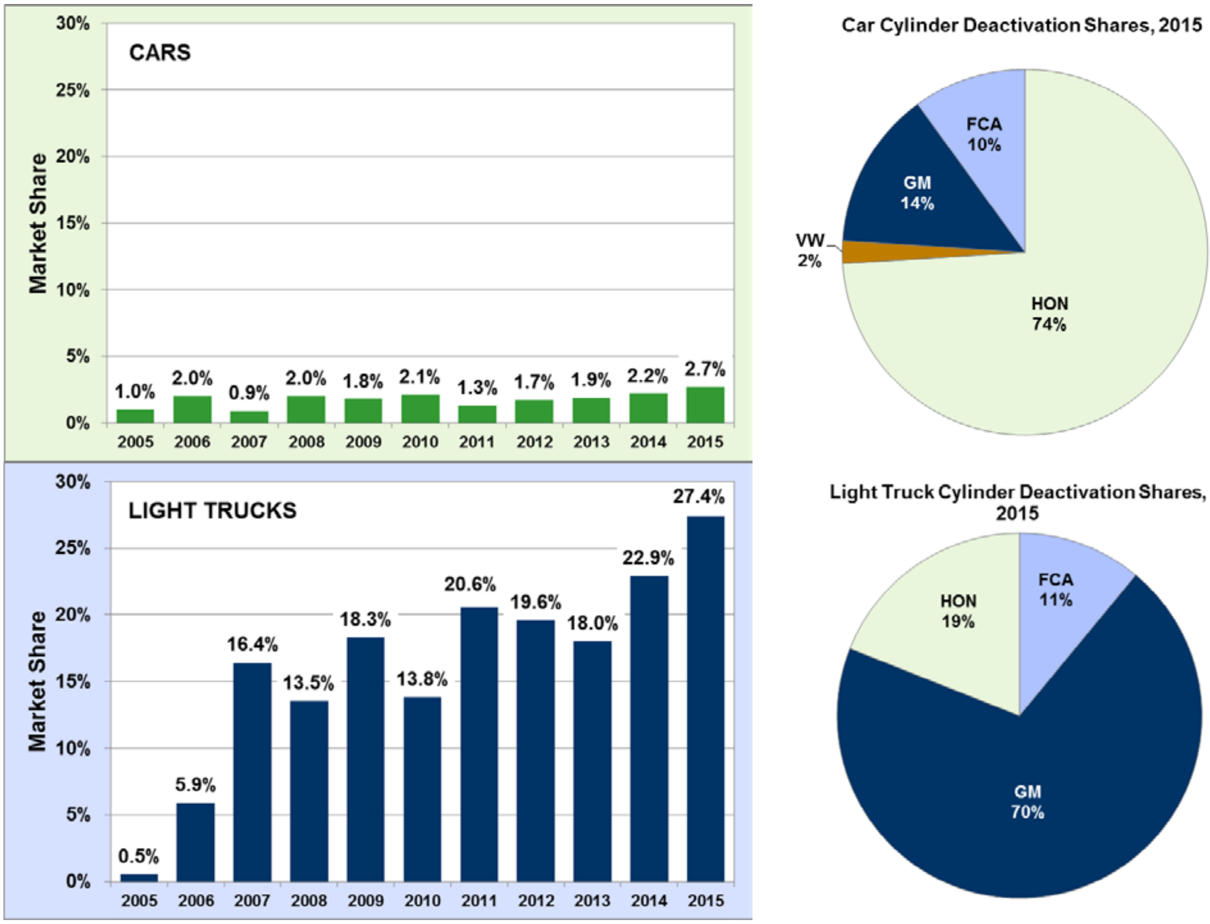


FIGURE 79. Cylinder Deactivation Market Share, 2005-2015 and Manufacturer's Share, 2015

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

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

In 2015 stop-start technology was used by seven different manufacturers as a fuel saving measure. Ford and FCA dominate the stop-start light truck market (87% combined). Mercedes and BMW together make up 70% of the stop-start car market. Stop-start technology penetrated 7.4% of the car market and 5.5% of the light truck market.

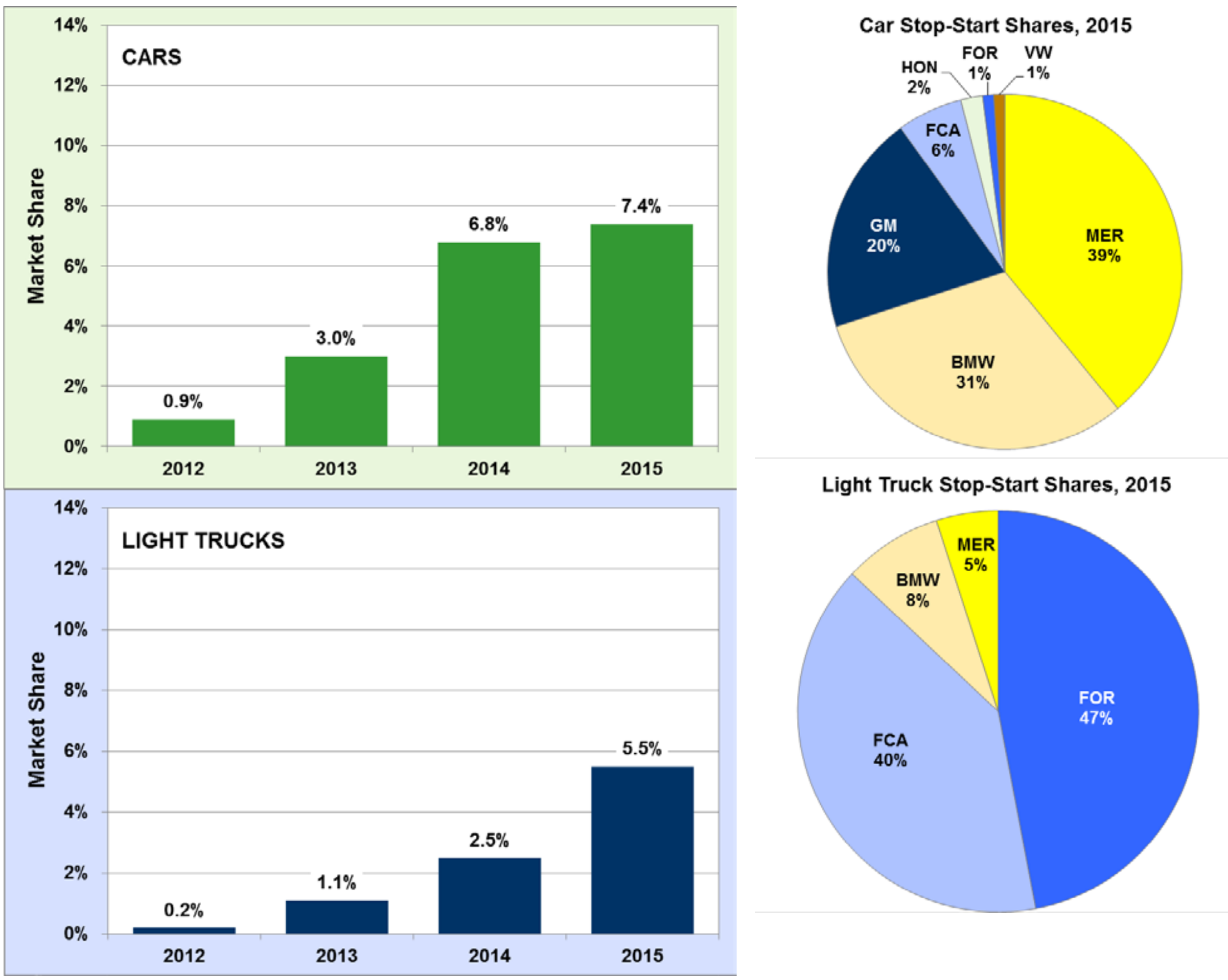


FIGURE 80. Stop-Start Technology Market Share, 2012-2015 and Manufacturer's Share, 2015

Note: MER = Mercedes.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Most Transmissions Are Six-Speed or More

The number of transmission speeds in new light vehicles has been growing. A greater number of gears improve fuel economy and performance by more closely matching the wheel speed to the optimum engine speed. By 2015, over half of all cars and light trucks were 6-speed. The 7-, 8-, and 9-speed transmissions grew to 14% of cars and 19% of light trucks. Continuously variable transmissions (CVTs) were more than one-quarter of the car market and 12.5% of the light truck market.

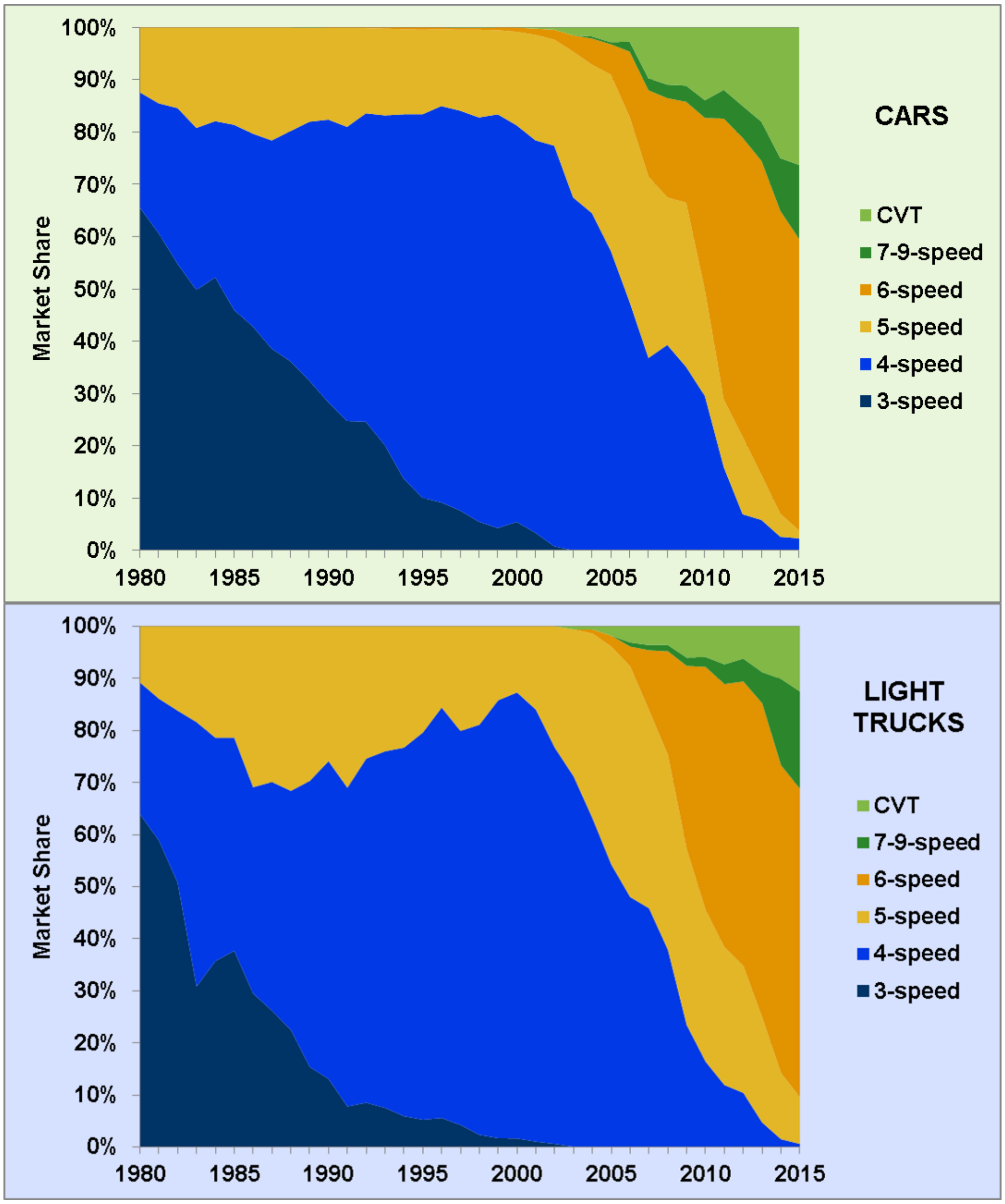


FIGURE 81. Market Share of Transmission Speeds, 1980-2015

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

More than 20 Models of Light Vehicles Were Diesel in Model Year 2015

In the early 1980's gas 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, Volkswagen was the only manufacturer selling diesel light vehicles. Recently, advanced diesel technologies, combined with a nationwide switch to ultra-low-sulfur diesel fuel, have given light vehicle manufacturers new impetus to invest in diesel models. In MY 2015, five different manufacturers have 23 light vehicle models for sale with diesel engines.

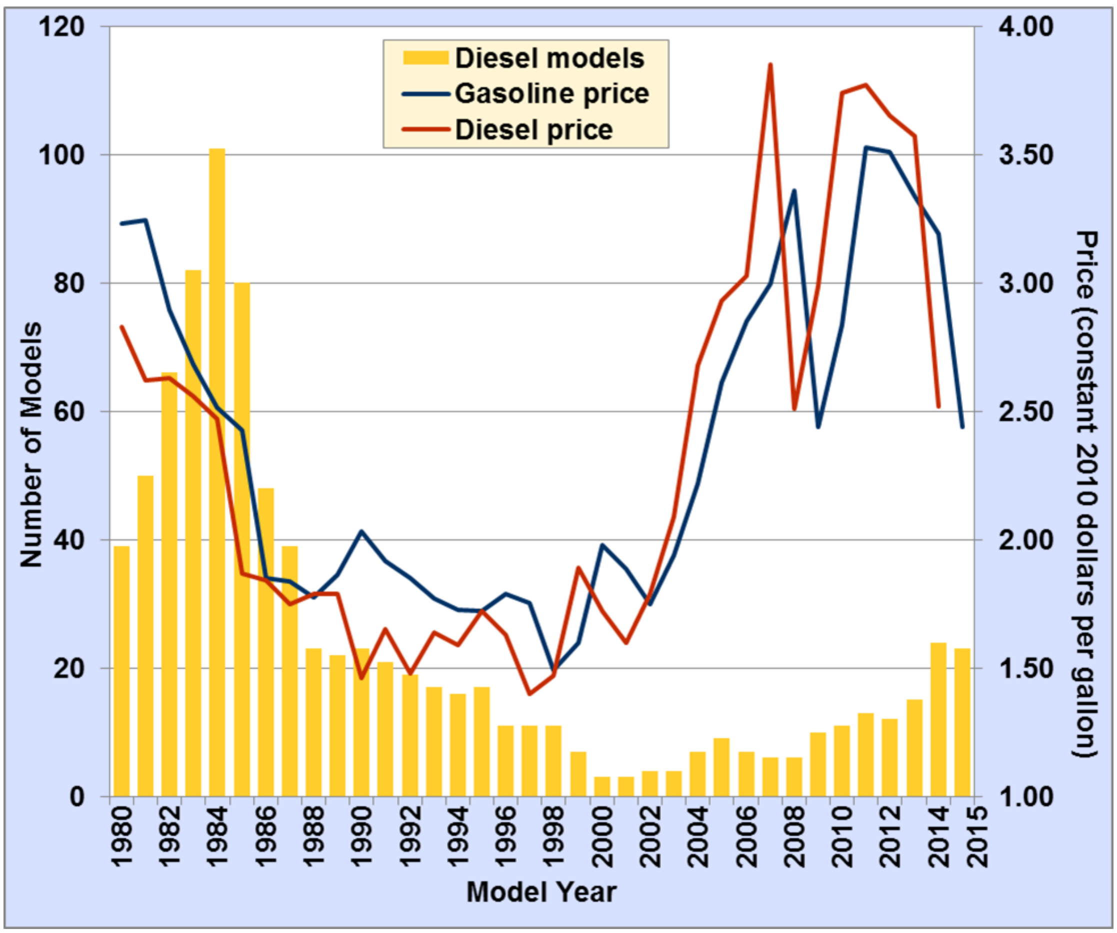


FIGURE 82. Number of Diesel Models and the Price of a Gallon of Gasoline and Diesel, 1980-2015

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

Sources:

U.S. Department of Energy, Fuel economy data, http://www.fueleconomy.gov. Data accessed February 2016.

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

Fleet Sales Are More than 20% of Ford, GM, and FCA Retail Sales

Ford's light vehicle fleet sales were 28% of retail sales in 2014 and 2015. GM and FCA were not far behind. Hyundai/Kia had the largest increase in fleet sales share from 2014 to 2015. GM was the only company shown that decreased the fleet sales share from 2014 to 2015.

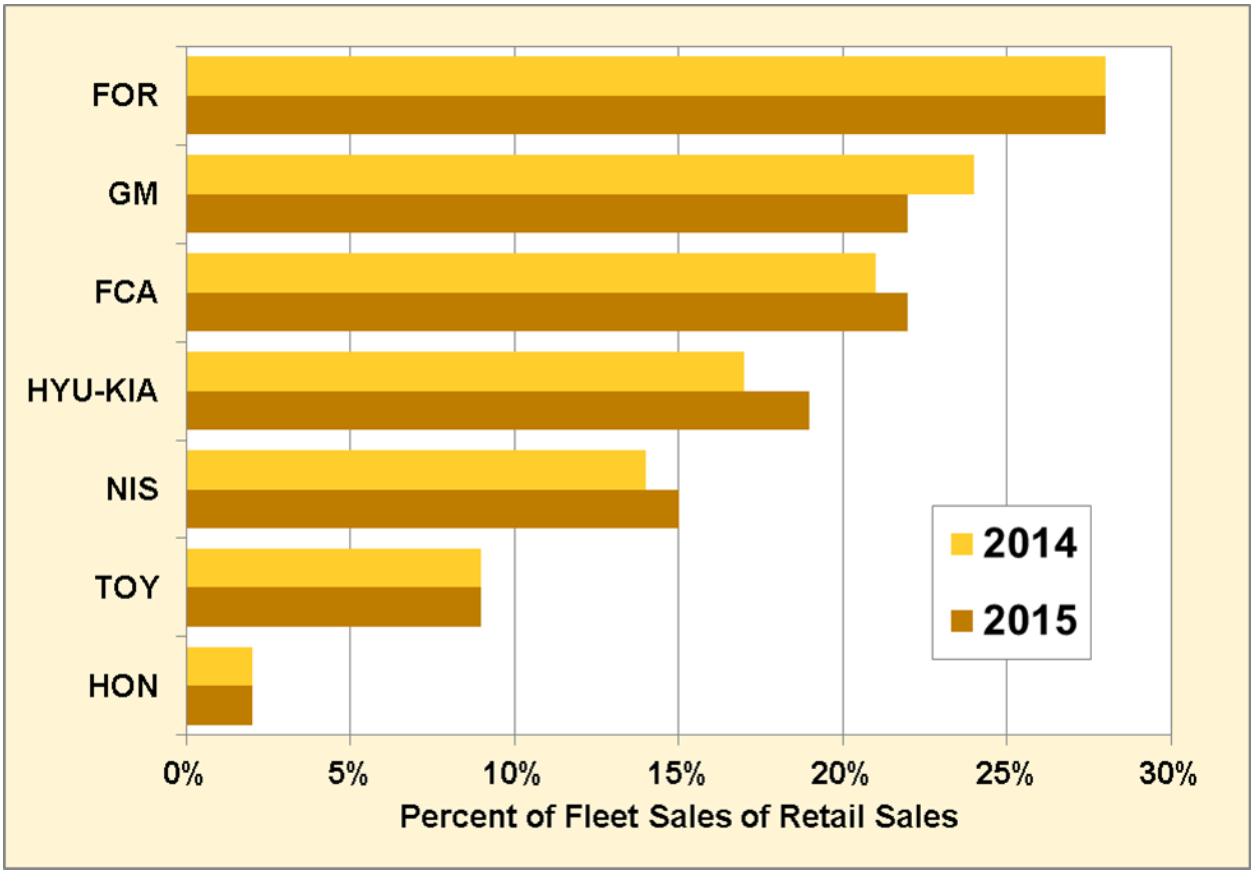


Figure 83. Share of Fleet Vehicle Sales by Manufacturer, 2014 and 2015

Source:

Crain Communications, Automotive News Data Center, U.S. Fleet Sales, January 2016.
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.

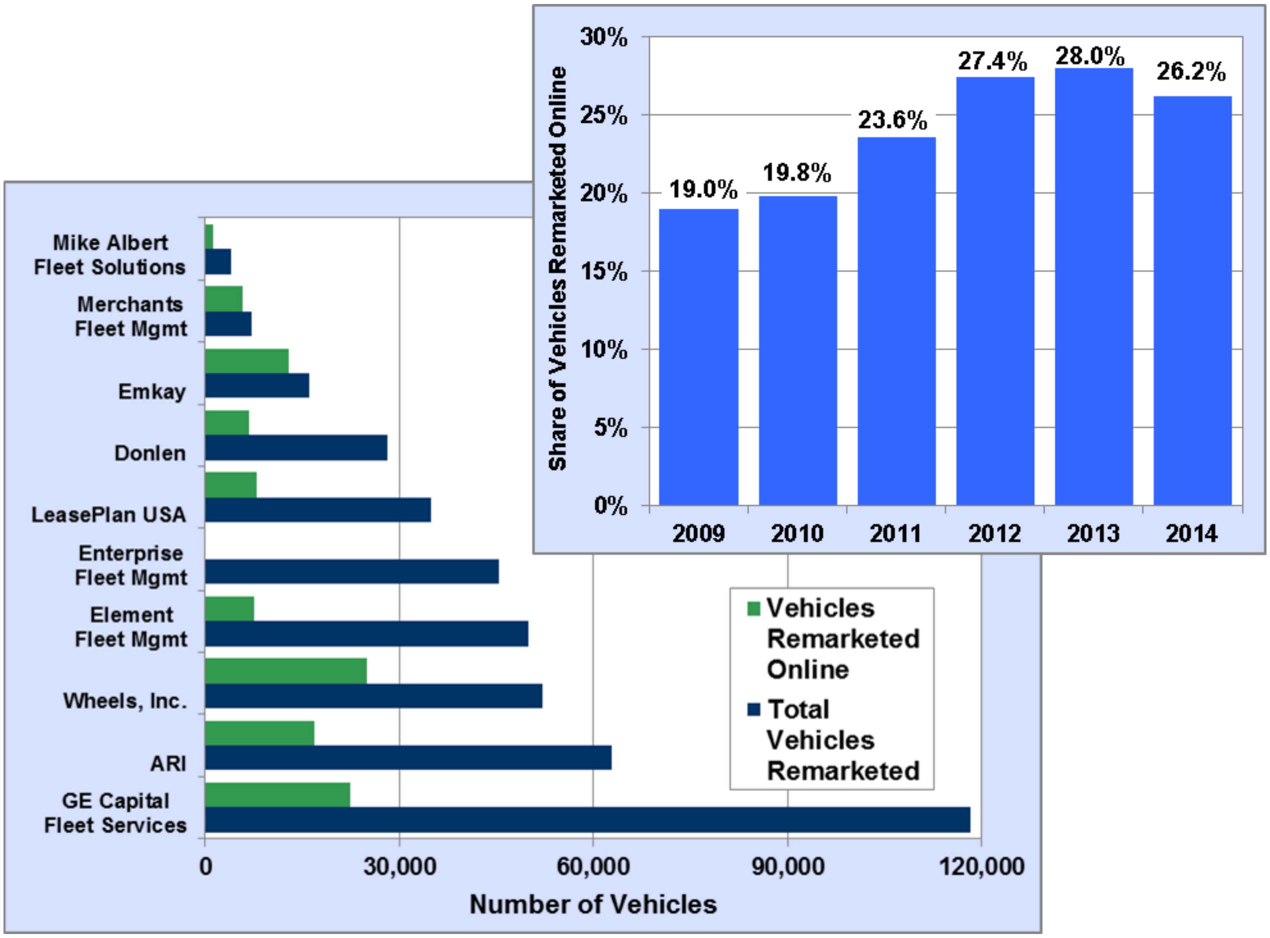
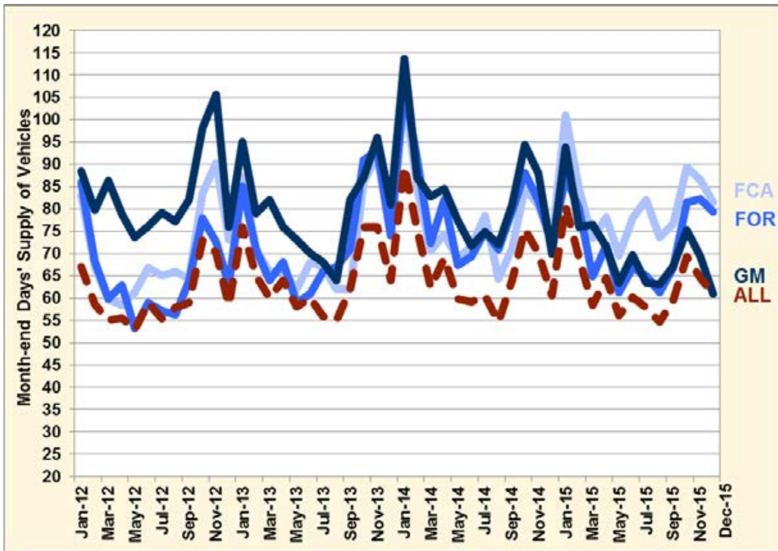


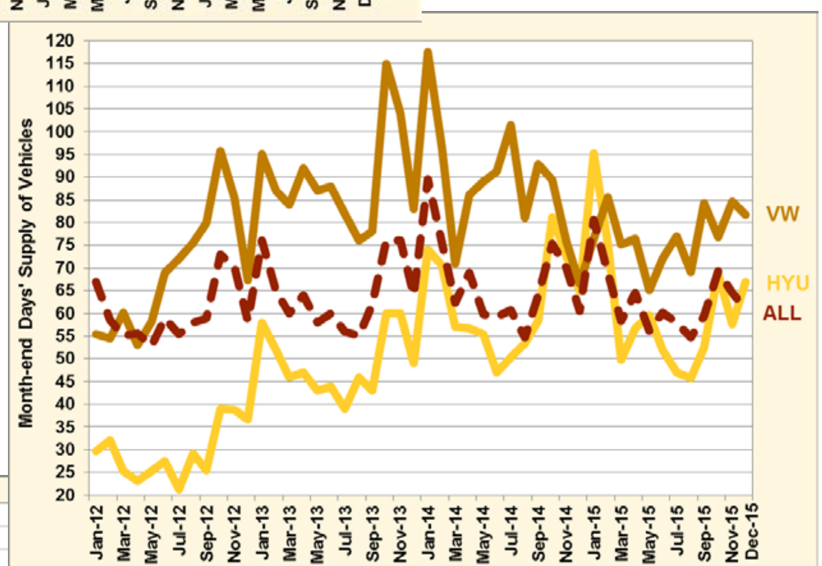
FIGURE 84. Vehicles Remarketed by the Top Ten Fleet Management Companies, 2014, and Share of Vehicles Remarketed On-Line, 2009-2014

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.



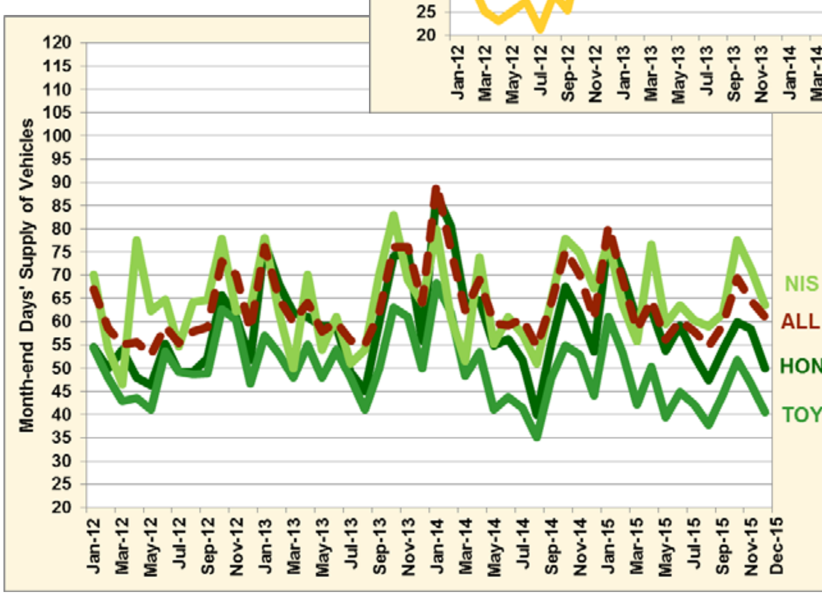


FIGURE 85. Monthly Dealer Supplies by Manufacturer, 2012-2015

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 December 2013 to December 2015, compact trucks had the lowest days to turn. Large cars, for the most part, had the highest days to turn. Large crossover SUVs, particularly in the last year, have seen a decline in days to turn.

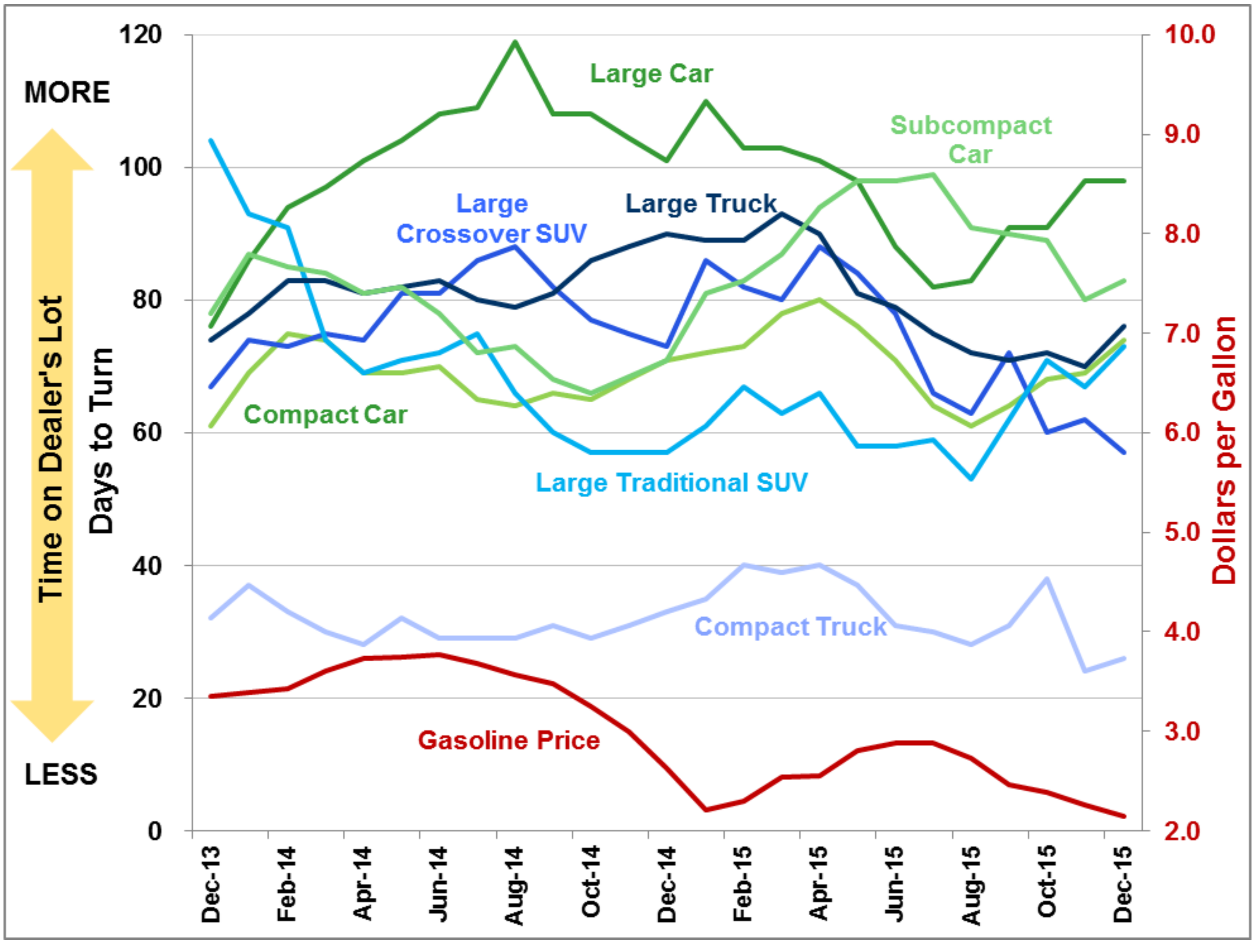


FIGURE 86. Days to Turn Trend by Vehicle Class, 2013-2015

Sources:

Edmunds website data, www.Edmunds.com.

U.S. Department of Energy, Energy Information Administration, International Statistics website, January 2015.

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 2014. Within the top ten suppliers, only one–Magna International, Inc.–has the majority (54%) of its sales to North America. The other companies in the top ten sell to North America, but sell more in Europe and Asia combined.

TABLE 23. List of Top Ten Tier 1 Global Suppliers, 2014

			Market Share				
Rank	**Company**	**Company Headquarters**	**North America**	**Europe**	**Asia**	**Rest of World**	**Total**
1	Robert Bosch GMbH	Germany	19%	50%	28%	3%	100%
2	Magna International, Inc.	Canada	54%	39%	5%	2%	100%
3	Continental AG	Germany	23%	49%	25%	3%	100%
4	Denso Corp.	Japan	22%	12%	64%	2%	100%
5	Aisin Seiki Co., Ltd.	Japan	18%	8%	73%	1%	100%
6	Hyundai Mobis	Korea	20%	11%	68%	1%	100%
7	Faurecia	France	25%	56%	14%	5%	100%
8	Johnson Controls, Inc.	United States	48%	39%	11%	2%	100%
9	ZF Friedrichshafen AG	Germany	20%	56%	20%	4%	100%
10	Lear Corp.	United States	38%	40%	17%	5%	100%

Note: Rank based on total global OEM automotive parts sales in 2014.

Source:
Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2015. http://www.autonews.com/

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

There are ten U.S.-based companies in the top 50 automotive global suppliers. Of these companies, only one (Flex-N-Gate) had more than half of their sales in North America in 2014. Three others—Johnson Controls, Tenneco, and Dana—had nearly half of their sales in North America.

TABLE 24. U.S.-Based Tier 1 Suppliers in the Top 50, 2014

Rank	Company	Percent North America Sales	Products
8	Johnson Controls, Inc	48%	Complete automotive seats & seat components, lead acid & hybrid vehicle batteries
10	Lear Corp.	38%	Seating & electrical distribution systems
12	TRW Automotive Holdings Corp.	41%	Steering, suspension, braking & engine components; fasteners, occupant-restraint systems, electronic safety & security systems
13	Delphi Automotive	35%	Mobile electronics; powertrain, safety, thermal, controls & security systems; electrical/electronic architecture; in-car entertainment technologies
27	Tenneco, Inc.	49%	Emission-control systems, manifolds, catalytic converters, diesel aftertreatment systems, catalytic reduction mufflers, shock absorbers, struts, electronic suspension products & systems
29	BorgWarner, Inc.	29%	Turbochargers, engine valve-timing systems, ignition systems, emissions systems, thermal systems, transmission-clutch systems, transmission-control systems & torque management systems
31	Visteon Corp.	29%	Cockpit electronics, thermal energy management
39	Dana Holding Corp.	47%	Axles, driveshafts, sealing & thermal management products
46	Flex-N-Gate Corp.	91%	Interior & exterior plastics, metal bumpers & hitches, structural metal assemblies, forward & signal lighting, mechanical assemblies, prototyping & sequencing
47	Goodyear Tire & Rubber Co.	36%	Tires

Note: Rank based on total global OEM automotive parts sales in 2014.

Source:
Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2015.
http://www.autonews.com/

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

There are eleven U.S. automotive parts suppliers that sold more than $5 billion in parts to original equipment manufacturers in 2014. 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 and Dana are the only two companies that decreased their sales share to North America between 2010 and 2014. Dana is the only company listed that increased sales share to Europe in the 5-year period.

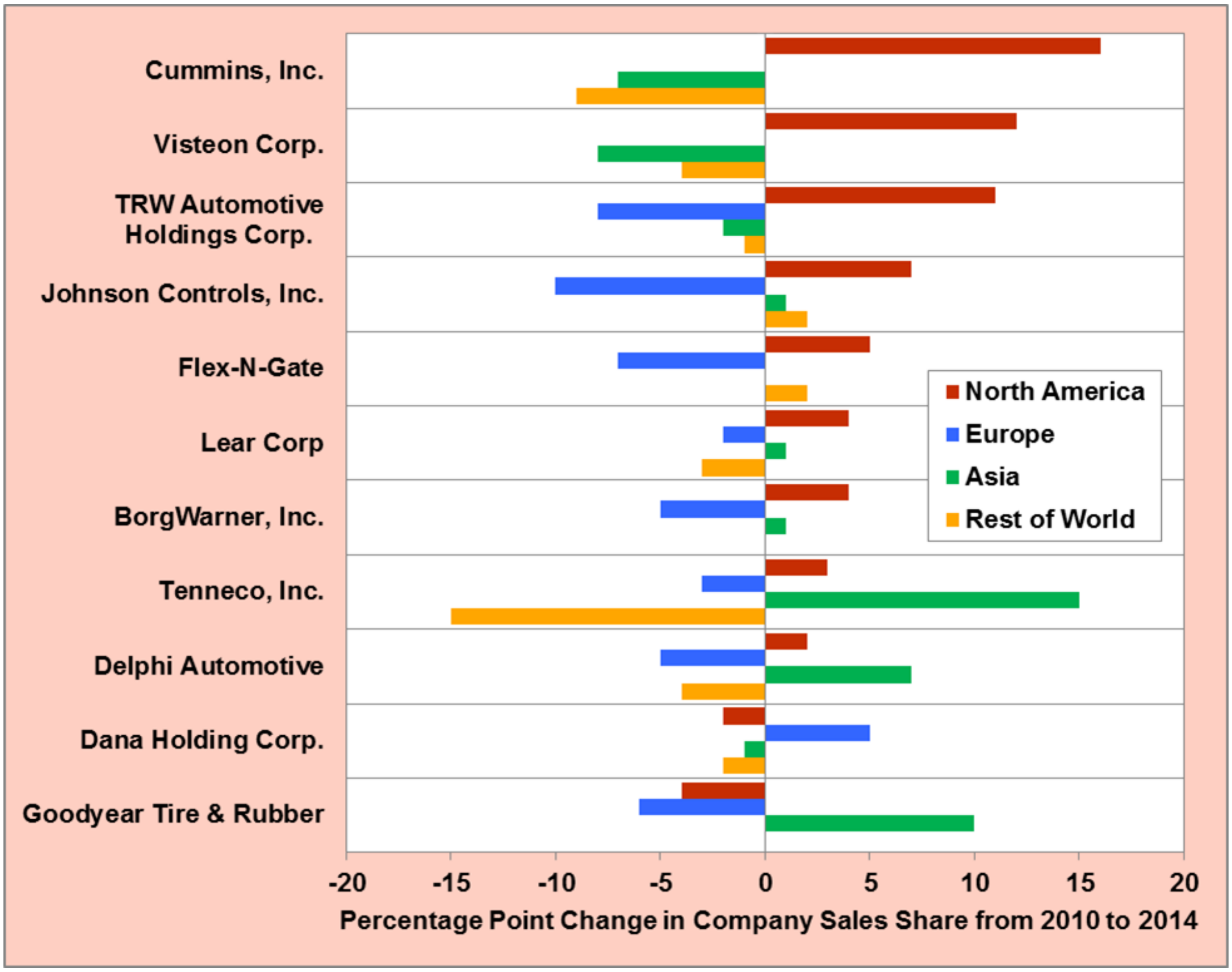


FIGURE 87. Change in Company Sales Share of Top U.S.-Based Tier 1 Suppliers, 2010-2014

Source:

Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2015 and June 2011. http://www.autonews.com/

Chapter 3

HEAVY TRUCKS

Page

Contents

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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.

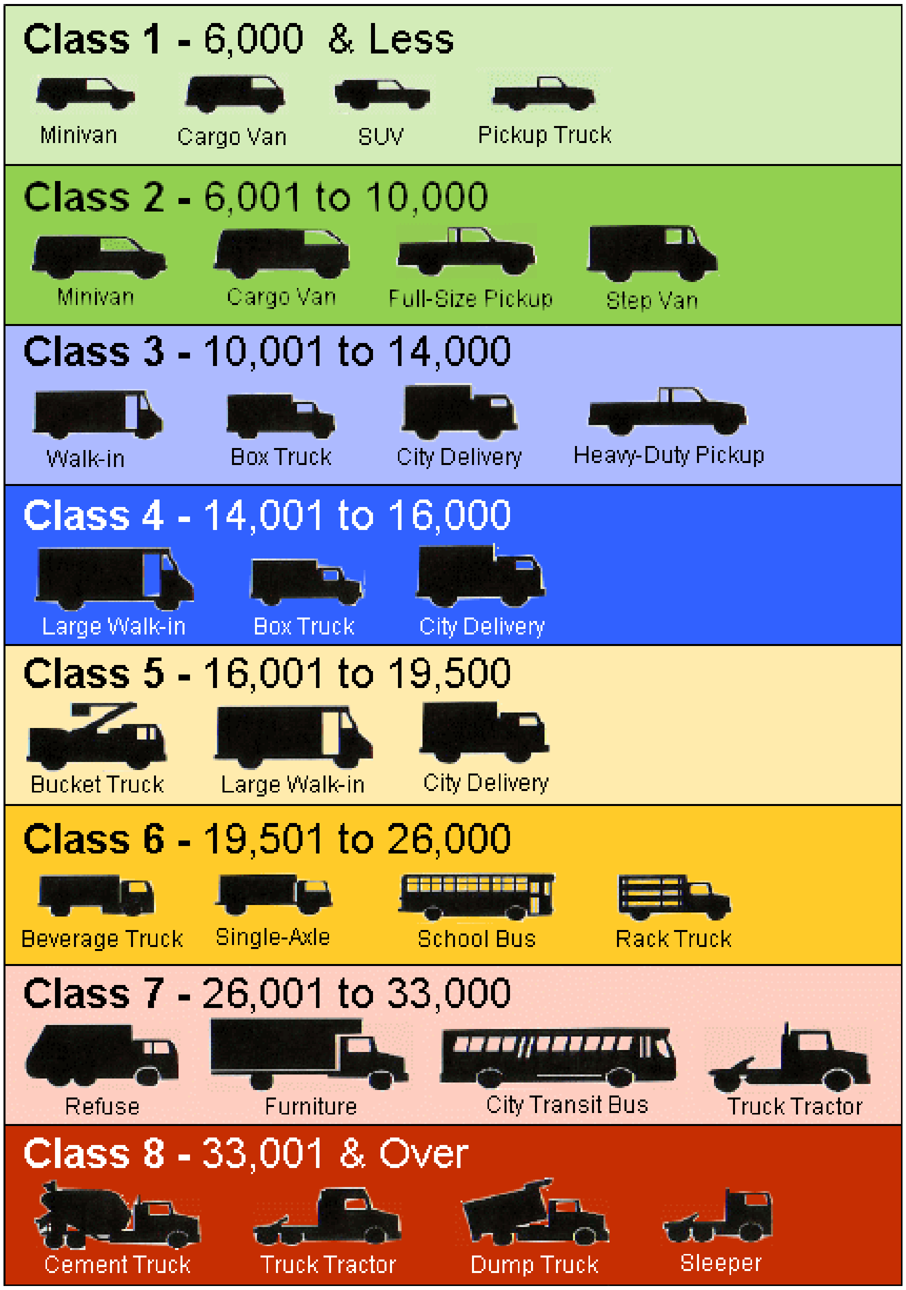

FIGURE 88. Examples of Trucks in Each Truck Class

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 25. Typical Weights and Fuel Use by Truck Class

Class	Applications	Gross Weight Range (lbs.)	Empty Weight Range (lbs.)	Typical Payload Capacity Max (lbs.)	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 61% of Medium/Heavy Truck Production in North America

Nearly 290,000 medium/heavy trucks (Classes 4-8) were produced in the United States in 2014, which is 61% of North American production. Mexico also produced a large number of trucks (37%). The top U.S. producer, Ford, made medium trucks, while the second highest producer, Freightliner, 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 26. North American Production of Medium and Heavy Trucks by Manufacturer, 2014

Manufacturer	Thousands of Trucks				U.S. Share of Total
	United States	Mexico	Canada	Total	
Ford	66.8	0.0	0.0	66.8	100%
Freightliner & Western Star	61.4	82.3	0.0	143.7	43%
Kenworth	38.2	14.3	11.9	64.4	59%
Volvo	33.8	0.2	0.0	34.0	99%
Peterbilt	32.4	0.0	0.0	32.4	100%
Mack	25.7	0.0	0.0	25.7	100%
International	19.4	39.8	0.0	59.2	33%
Hino	8.1	0.5	0.0	8.6	94%
Isuzu	3.5	0.0	0.0	3.5	100%
Blue Diamond	0.0	18.3	0.0	18.3	0%
Dina Camiones	0.0	1.1	0.0	1.1	0%
FCA	0.0	17.2	0.0	17.2	0%
MAN	0.0	1.3	0.0	1.3	0%
Total	289.3	175.0	11.9	476.2	61%

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 Isuzu. 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.

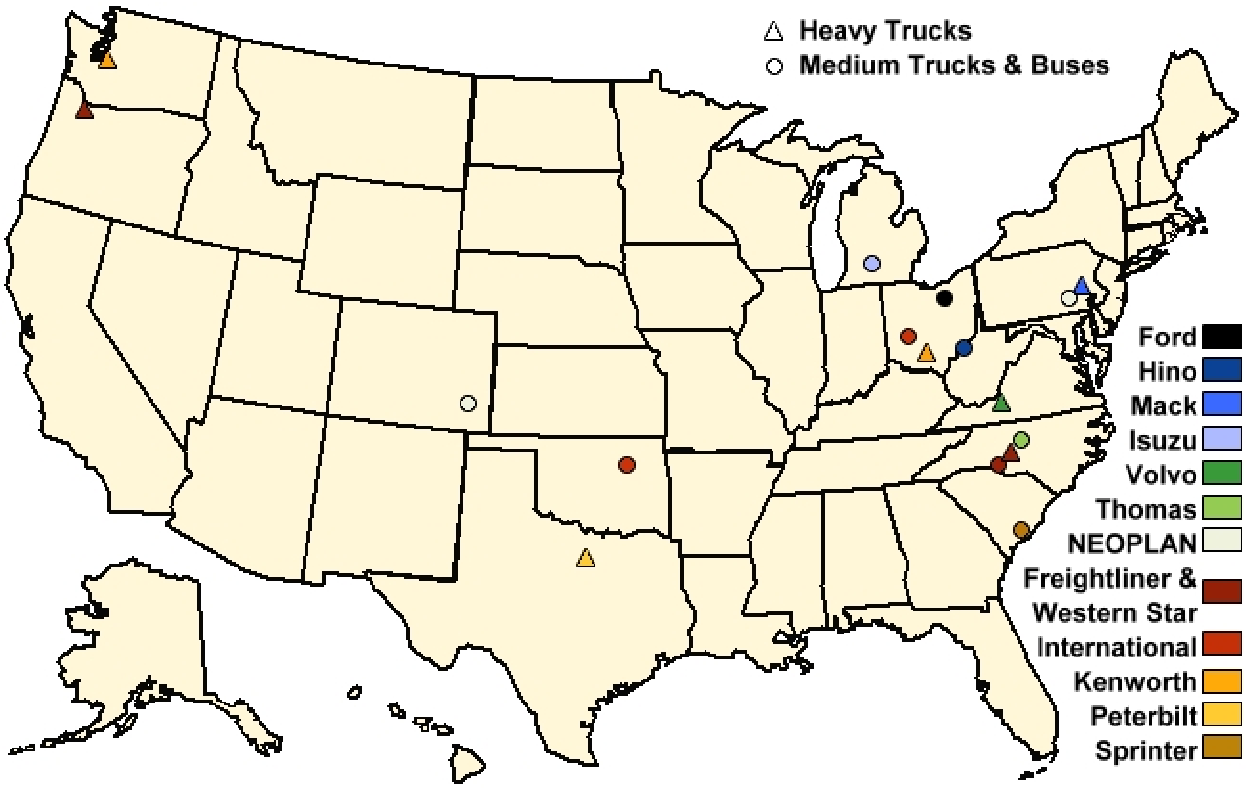

FIGURE 89. Medium and Heavy Truck Manufacturing Plants by Location, 2015

Note: Includes truck Classes 4 through 8.

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

Few Medium/Heavy Trucks Are Imported

Sales of Class 4-8 trucks are overwhelmingly vehicles that are made in North America (domestic). About half of Class 4 trucks and 10% of Class 5 trucks were imported in 2015. 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 3.2% in 2015.

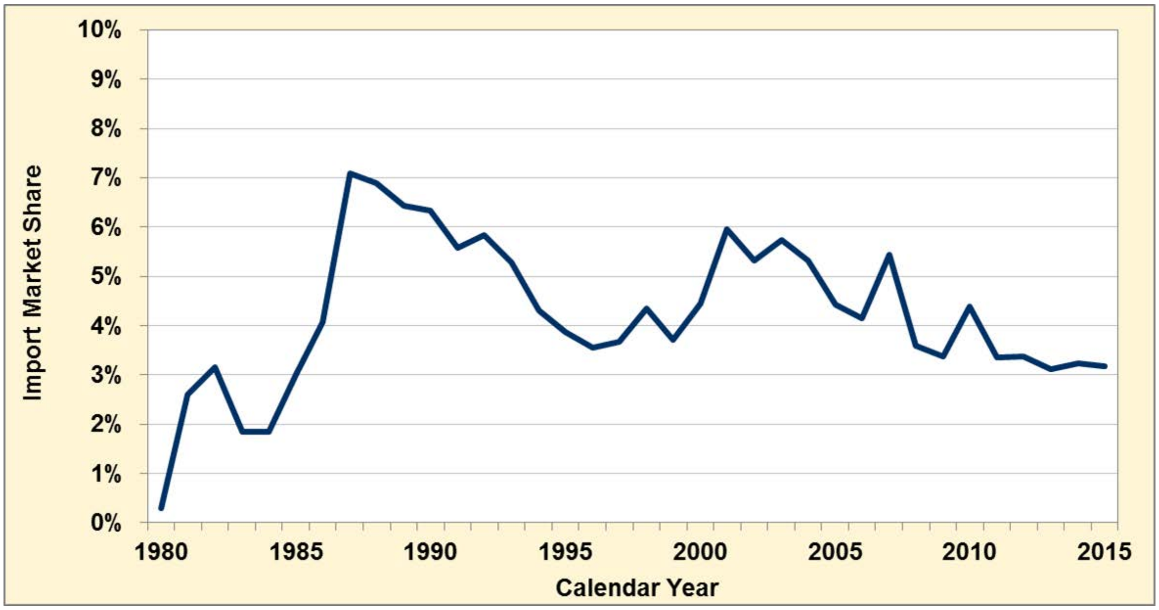

FIGURE 90. Import Share of Medium and Heavy Trucks, 1980-2015

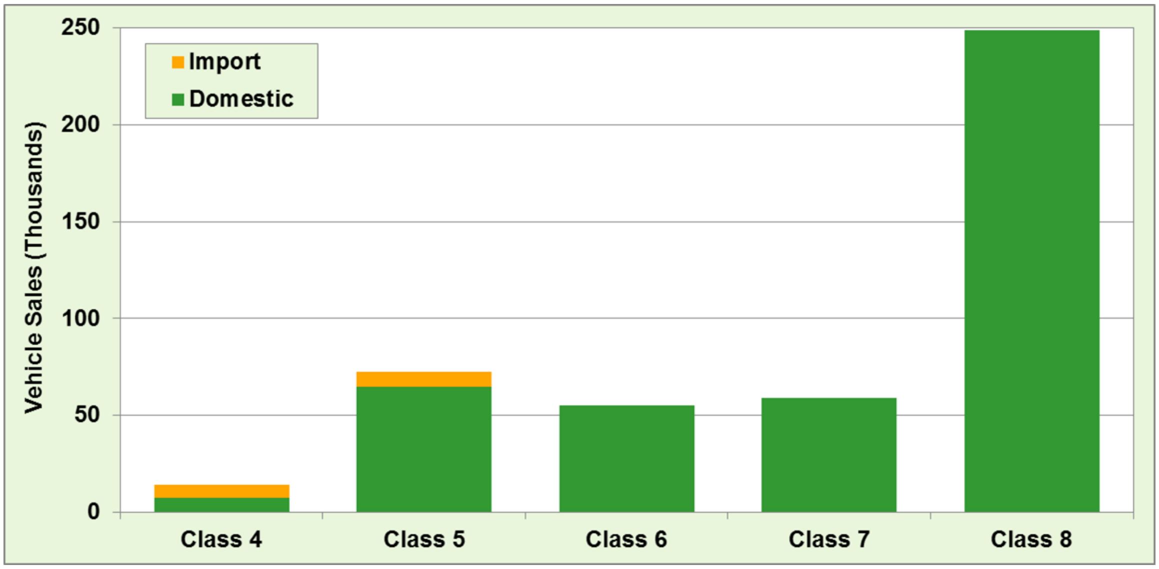

FIGURE 91. Medium and Heavy Trucks Sold by Source and Weight Class, 2015

Note: All trucks made in North America are considered domestic.

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

Class 3 Truck Sales Have Increased by 45% from 2011 to 2015

The Class 3 truck market has grown each year since 2011 and reached 283,000 units by 2015. FCA, Ford, and General Motors dominate the Class 3 market.

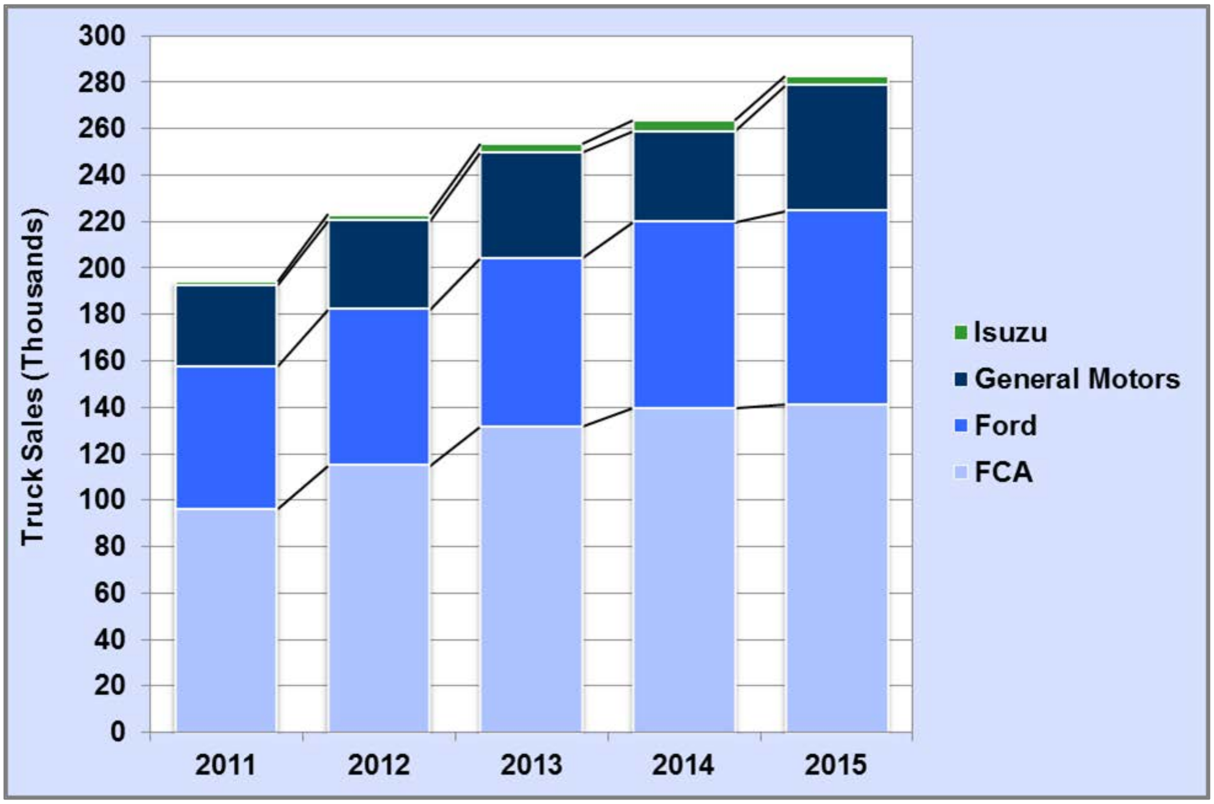

FIGURE 92. Class 3 Truck Sales by Manufacturer, 2011-2015

Note: From 2011 to 2015 Mitsubishi-Fuso sales of Class 3 trucks were between 200 and 400 units. This amount is too small to show on the figure. Also, in 2009 and 2010 International had Class 3 sales of less than 1,000 units.

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2015*, Southfield, MI, 2015.
http://wardsauto.com

Class 4-7 Truck Sales Increased by 49% from 2011 to 2015

The Class 4 truck market has grown to just over 200,000 units in 2015. Many of the manufacturers doubled their sales of Class 4-7 trucks from 2011 to 2015, including Hino, FCA, and Kenworth. The only manufacturers with declining sales in this period were International and Mitsubishi-Fuso.

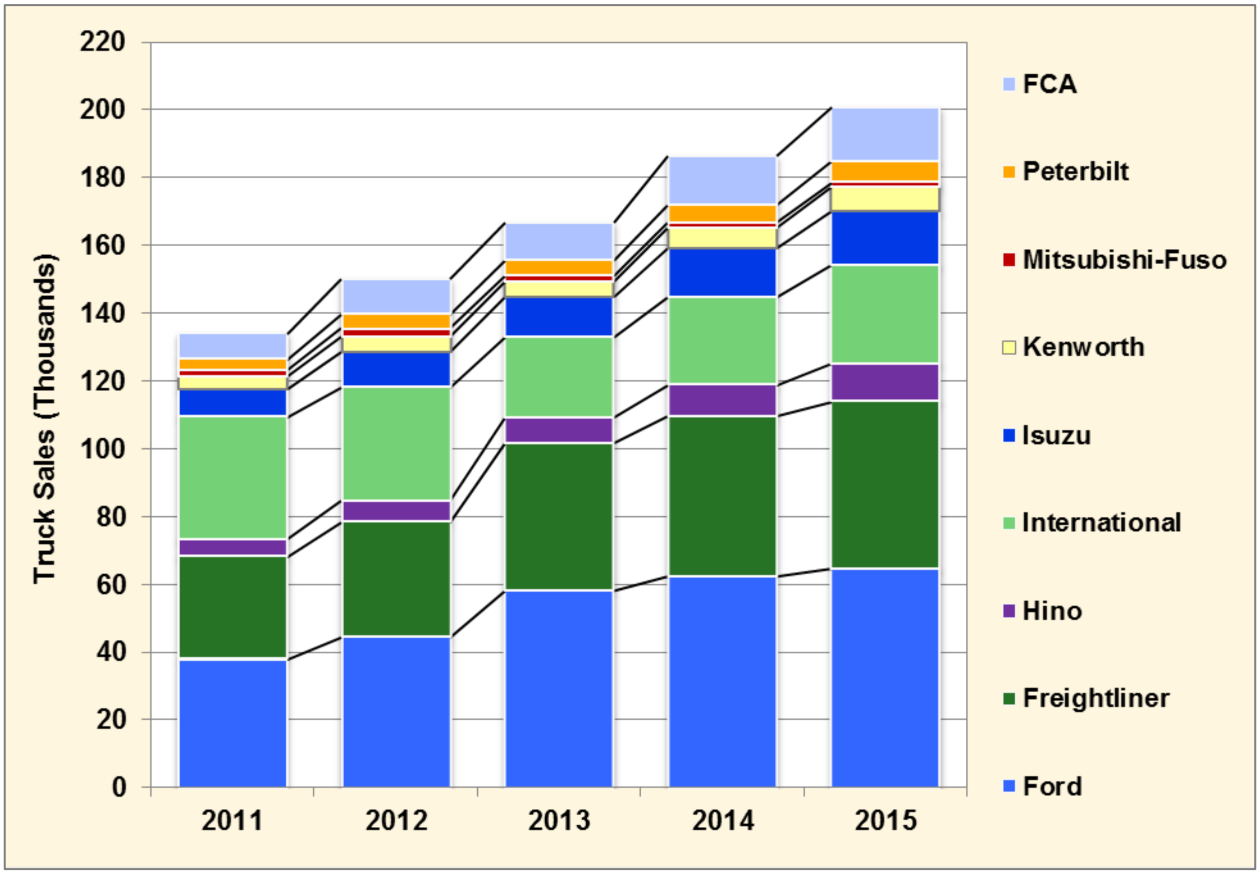

FIGURE 93. Class 4-7 Truck Sales by Manufacturer, 2011-2015

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

Source:

Ward's Automotive Group, *Motor Vehicle Facts and Figures 2015*, Southfield, MI, 2015. http://wardsauto.com

Class 8 Truck Sales Increased 45% from 2011 to 2015

Class 8 truck sales have grown to about 249,000 units in 2015. The market shares by manufacturer were fairly steady from 2011 to 2015, with Freightliner gaining, International losing, and all the rest staying nearly the same. The decline in Class 8 sales from 2012 to 2013 was the only decline in the five-year period.

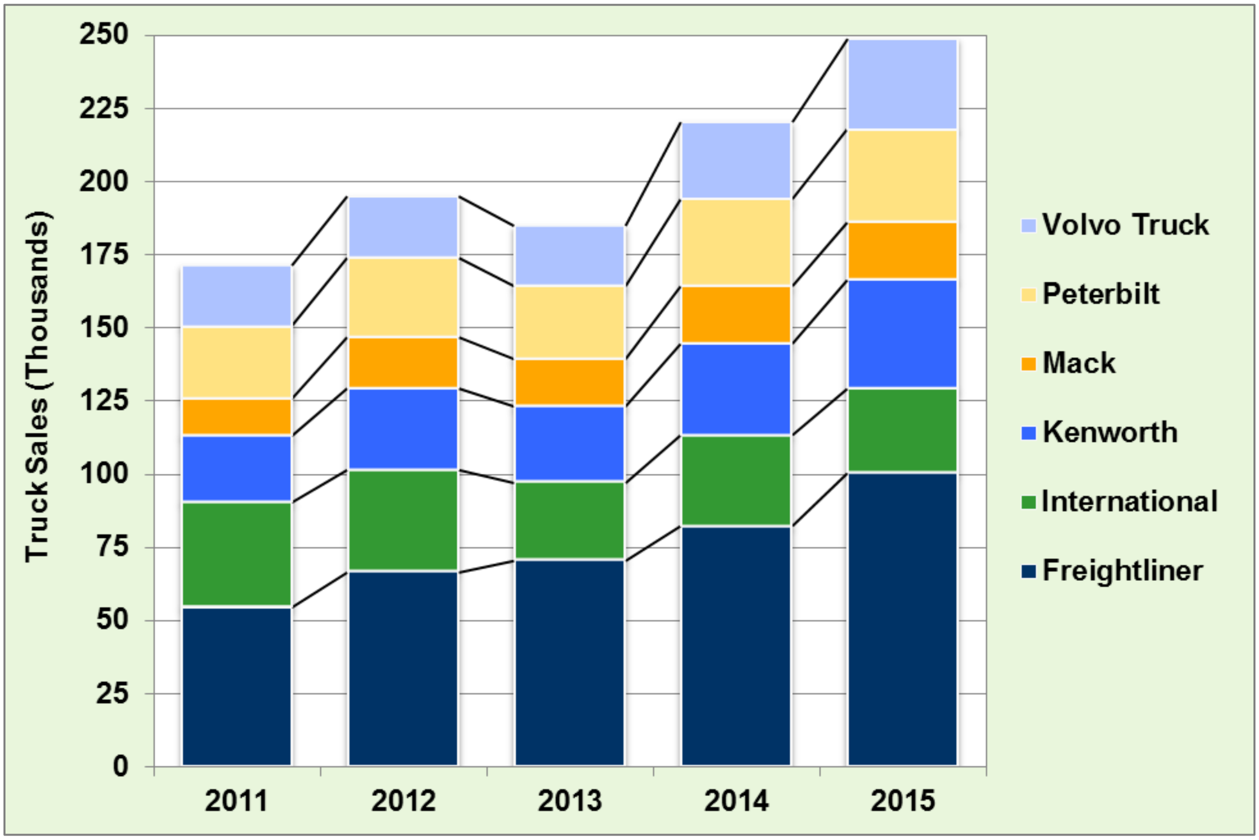

FIGURE 94. Class 8 Truck Sales by Manufacturer, 2011-2015

Note: From 2011 to 2015 sales of Class 8 trucks by "other" manufacturers were less than 100 units. This amount is too small to show on the figure.

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2015*, Southfield, MI, 2015.
http://wardsauto.com

Diesel Engine Use Declines 66% for Class 4 Trucks and Increases 15% for Class 7 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 2010, when truck sales of all classes were low, Classes 4, 5, and 6 each had more than 90% diesel sales share. By 2015, the diesel share of Class 6 trucks continued to be above 90%, while Class 5 share fell to 80% and Class 4 share fell to 32%. The only class to increase diesel sales share from 2010 to 2014 was Class 7.

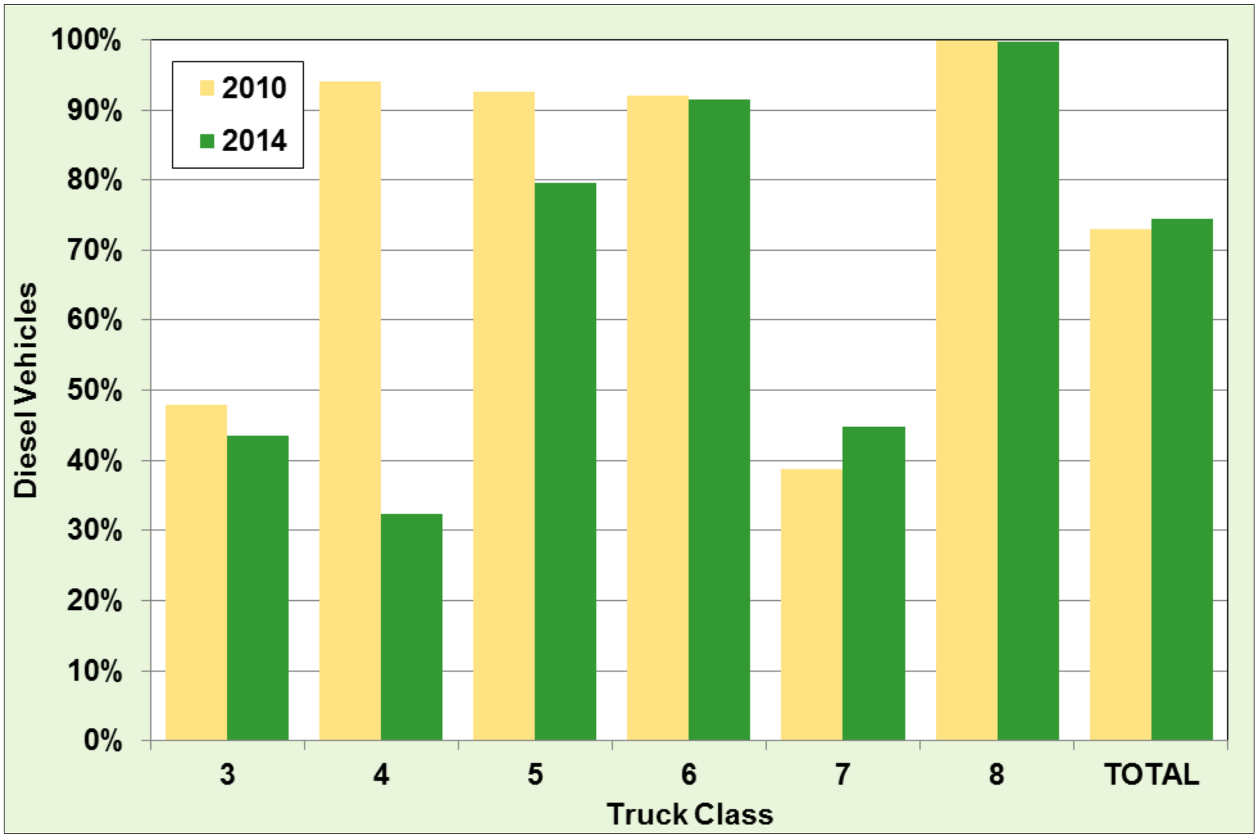

FIGURE 95. Share of Diesel Truck Sales by Class, 2010 and 2014

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

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2015*, Southfield, MI, 2015.
http://wardsauto.com

Many Heavy Truck Manufacturers Supply Their Own Diesel Engines

Though many medium and heavy truck manufacturers 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 27. Diesel Engine Suppliers by Manufacturer, 2014

Make	Engine Manufacturer	Share
Freightliner	Cummins	58.5%
	Detroit Diesel	41.0%
	Mercedes Benz	0.5%
	Total	**100.0%**
Hino	Hino	100.0%
International	Cummins	31.8%
	Navistar	68.2%
	Total	**100.0%**
Kenworth	Cummins	63.2%
	PACCAR	36.8%
	Total	**100.0%**
Mack	Cummins	7.4%
	Mack	92.6%
	Total	**100.0%**
Peterbilt	Cummins	63.0%
	PACCAR	37.0%
	Total	**100.0%**
Volvo	Cummins	8.5%
	Volvo	91.5%
	Total	**100.0%**
Western Star	Cummins	17.2%
	Detroit Diesel	82.6%
	Mercedes Benz	0.2%
	Total	**100.0%**
Other	Cummins	100%

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

In 2010, Navistar held a 23% share of the heavy truck diesel engine market. By 2014, Navistar's share had declined to 5% and Cummins held the largest share of the market (43%).

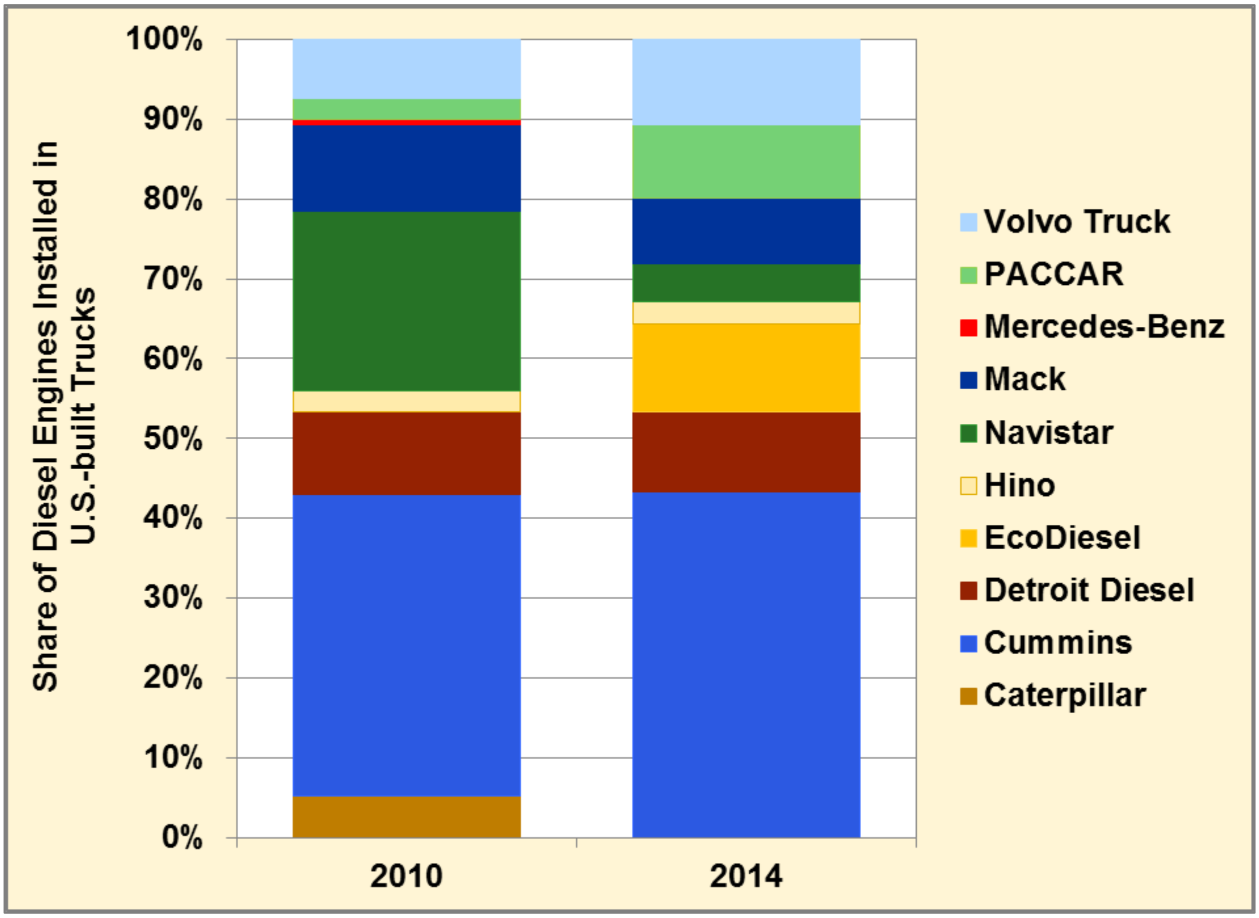

FIGURE 96. Diesel Engine Manufacturers Market Share, 2010 and 2014

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

Combination Trucks Average Almost 66,000 Miles per Year

According to the latest Federal Highway Administration estimates, the average miles traveled per truck was almost 66,000 miles for a combination truck in 2014, 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 7.3 miles per gallon (mpg) in 2014 while the combination truck fuel economy was 5.8 mpg. The combination trucks typically have larger engines to carry heavier loads than the single-unit trucks.

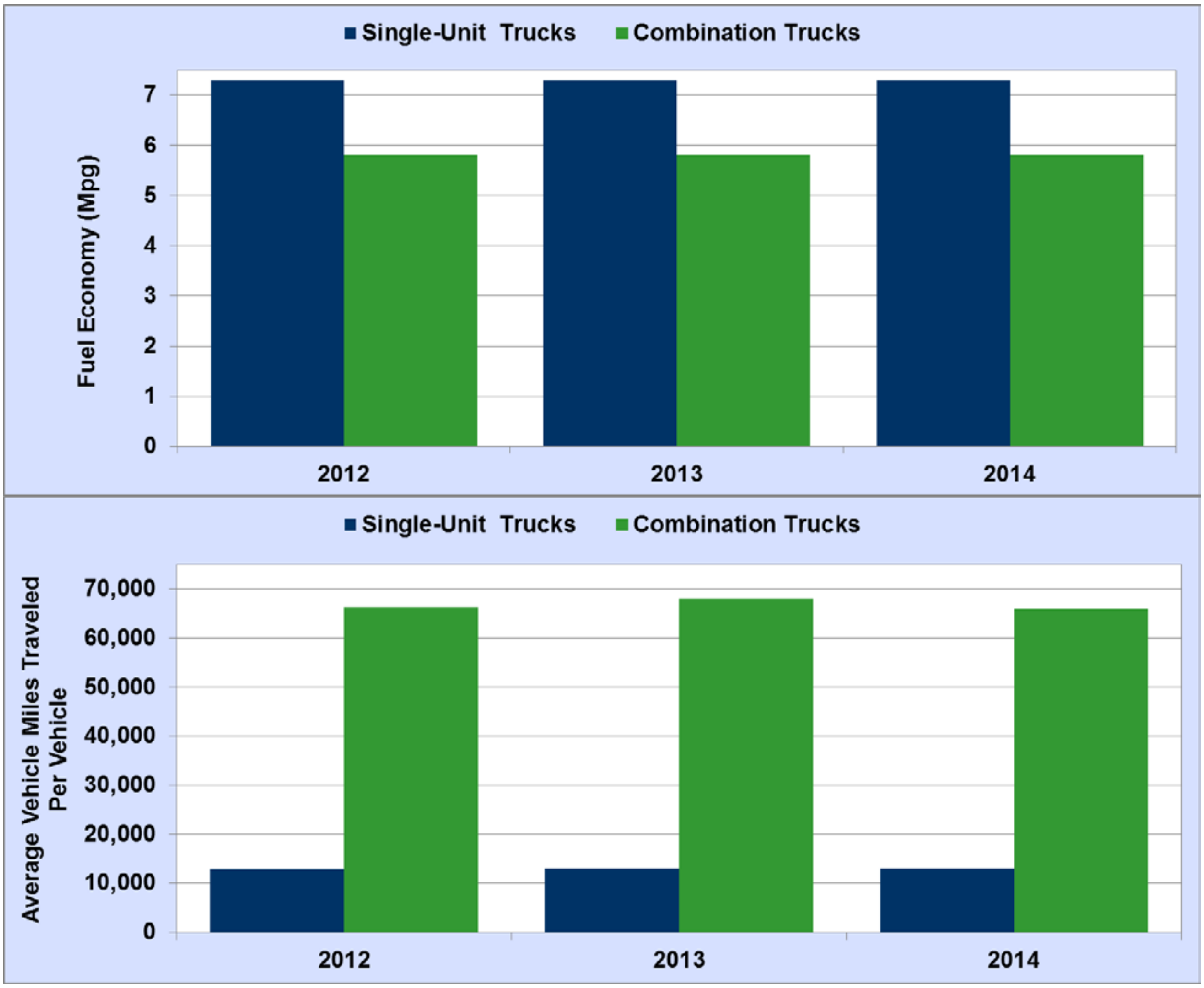

FIGURE 97. Vehicle-Miles of Travel and Fuel Economy for Heavy Trucks, 2012-2014

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 2014*, Table VM-1, 2016. http://www.fhwa.dot.gov/policyinformation/statistics/2014

Study Conducted of Heavy 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 28. Fuel Efficiency of Class 8 Trucks by Vehicle Weight Range on Flat Terrain at 65 mph

Weight Range (Pounds)	Average Weight (Pounds)	Distance Traveled (Miles)	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

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

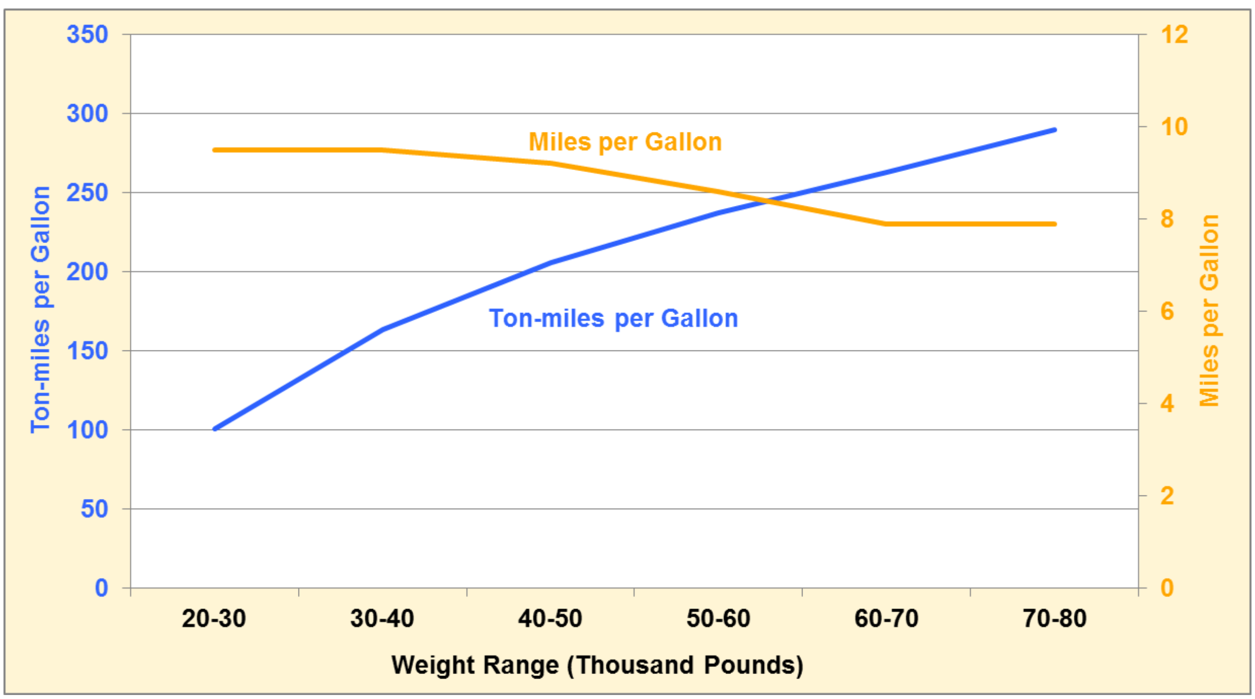

FIGURE 98. Fuel Efficiency of Class 8 Trucks by Vehicle Weight Range on Flat Terrain at 65 mph

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.

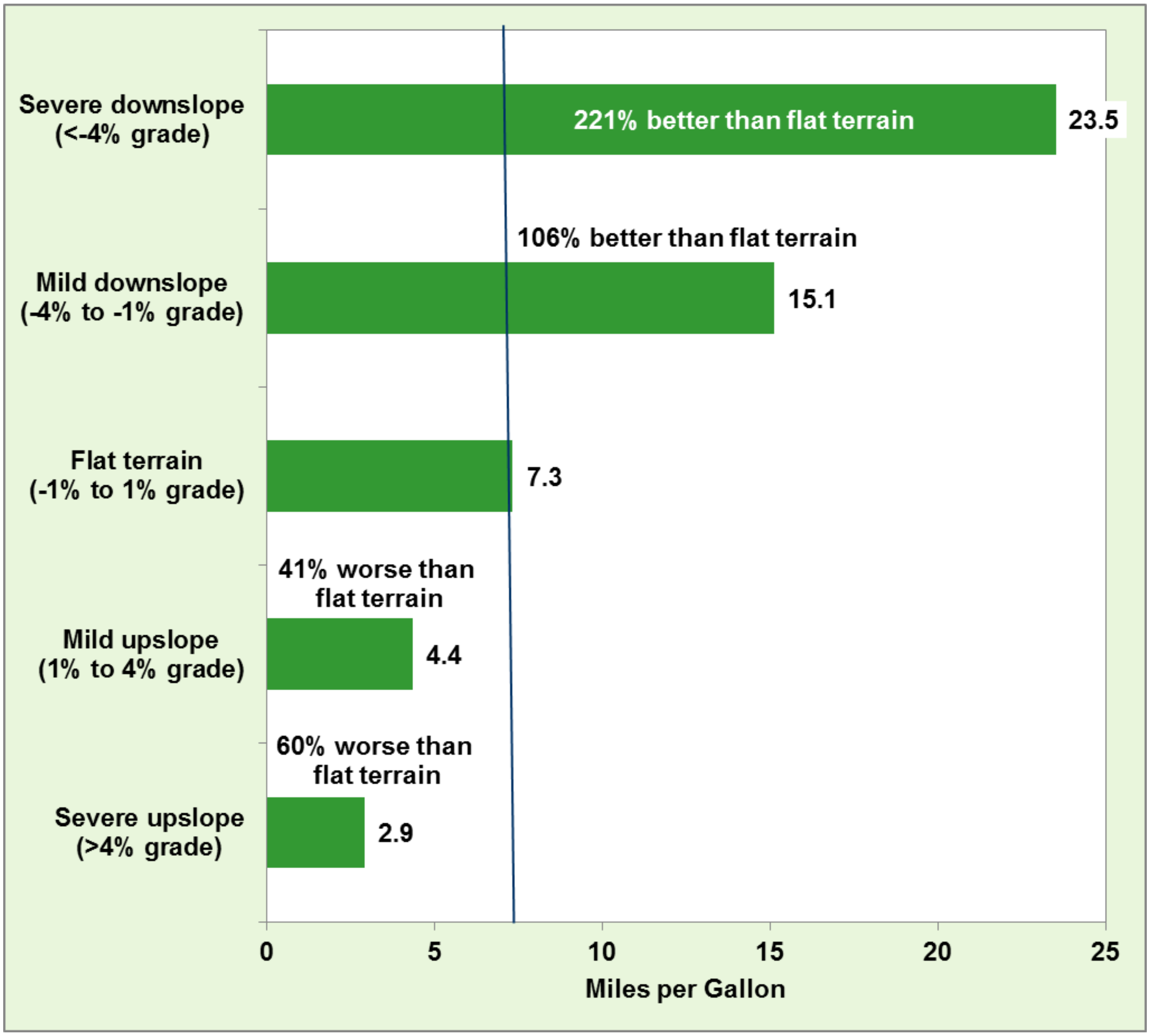

FIGURE 99. Fuel Efficiency of Class 8 Trucks by Roadway Grade

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.

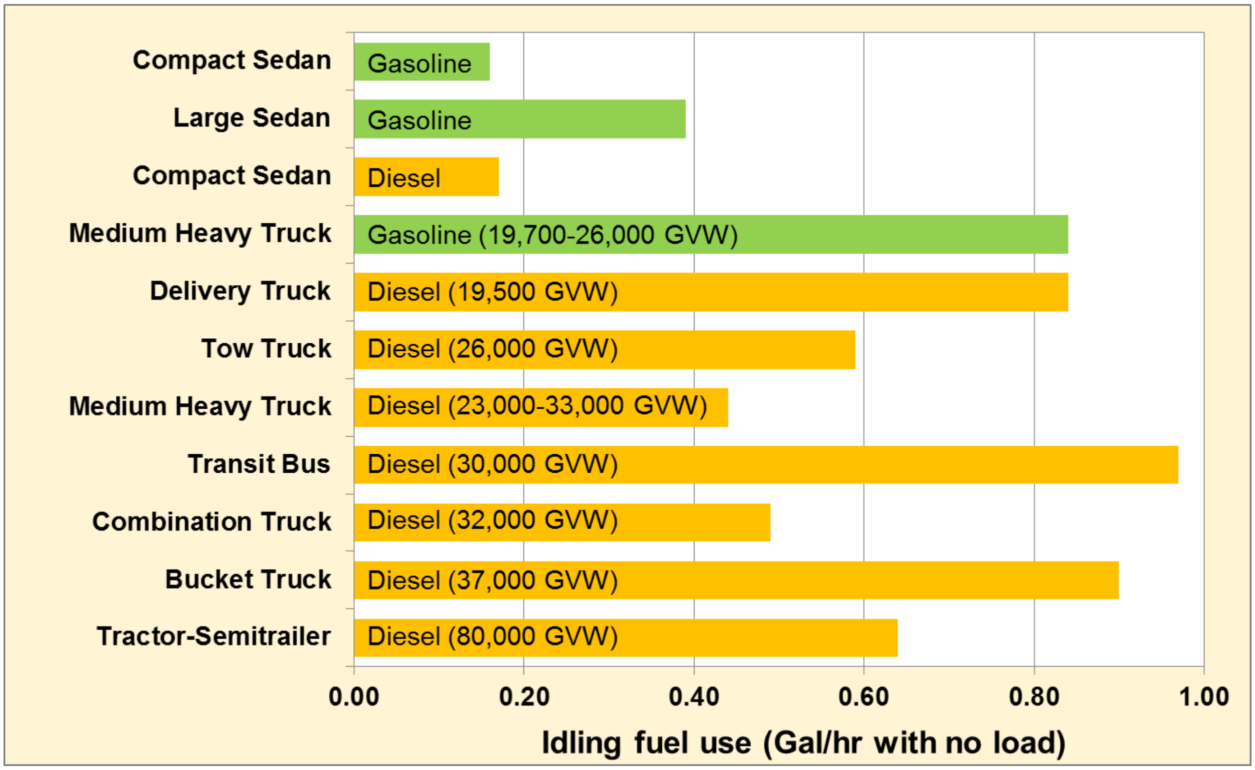

FIGURE 100. Fuel Consumption at Idle for Selected Gasoline and Diesel Vehicles

Note: The passenger car results are from a study by Argonne National Laboratory; the delivery truck results are from a study by the National Renewable Energy Laboratory; the tow truck, transit bus, combination truck and bucket truck results are from a study by Oak Ridge National Laboratory; the tractor-semitrailer results were from a study by the American Trucking Associations; both of the medium heavy truck results were from a study published in the *Journal of the Air & Waste Management Association*. For details on these results, please see the individual studies referenced by the source.

Source:
Argonne National Laboratory, Idling Reduction Savings Calculator, http://www.anl.gov/sites/anl.gov/files/idling_worksheet.pdf, accessed December 2014.

Truck Stop Electrification Reduces Idle Fuel Consumption

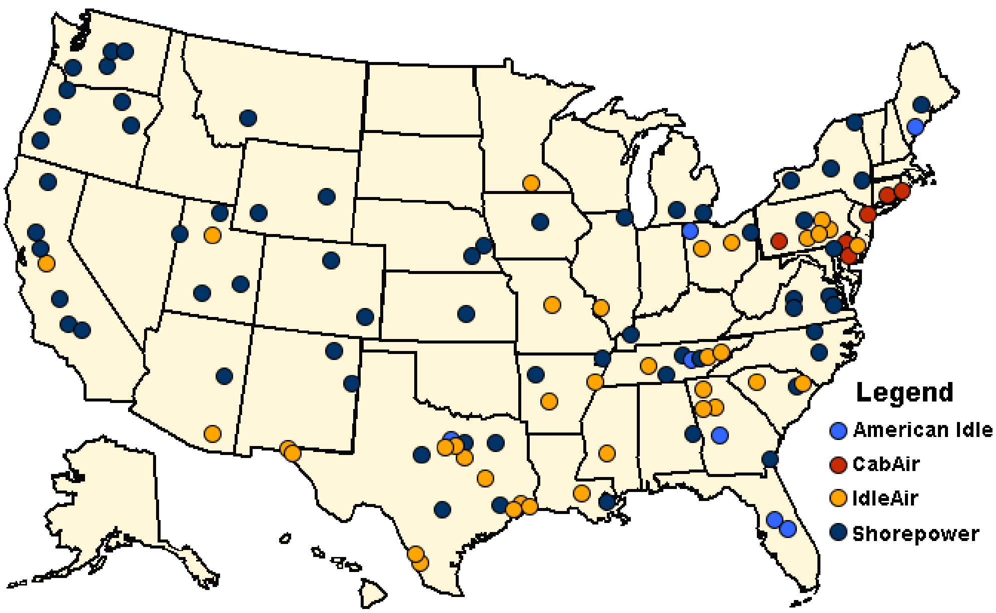

FIGURE 101. Map of Truck Stop Electrification Sites, 2016

TABLE 29. Number of Truck Stop Electrification Sites by State, 2016

State	Number of Sites	State	Number of Sites
Alabama	1	Mississippi	1
Arizona	2	Missouri	2
Arkansas	3	Montana	1
California	7	Nebraska	2
Colorado	2	New Jersey	2
Connecticut	1	New Mexico	2
Delaware	2	New York	4
Florida	2	North Carolina	2
Georgia	5	Ohio	4
Illinois	2	Oregon	5
Iowa	1	Pennsylvania	6
Kansas	1	South Carolina	3
Kentucky	1	Tennessee	7
Louisiana	2	Texas	17
Maine	2	Utah	5
Maryland	1	Virginia	4
Michigan	2	Washington	4
Minnesota	1	Wyoming	2
Total	**111**		

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 111 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 2/12/16).
http://www.afdc.energy.gov/afdc/tse_locator

SuperTruck Project Achieves 12.2 Miles per Gallon

The U.S. Department of Energy partnered with industry to explore fuel economy improvements for class 8 trucks. In February 2015, the Daimler Trucks North America team announced that their fully-loaded class 8 truck achieved a fuel economy of 12.2 miles per gallon, which was a 100% increase in fuel economy and an 115% gain in freight efficiency in testing against a 2009 baseline truck.

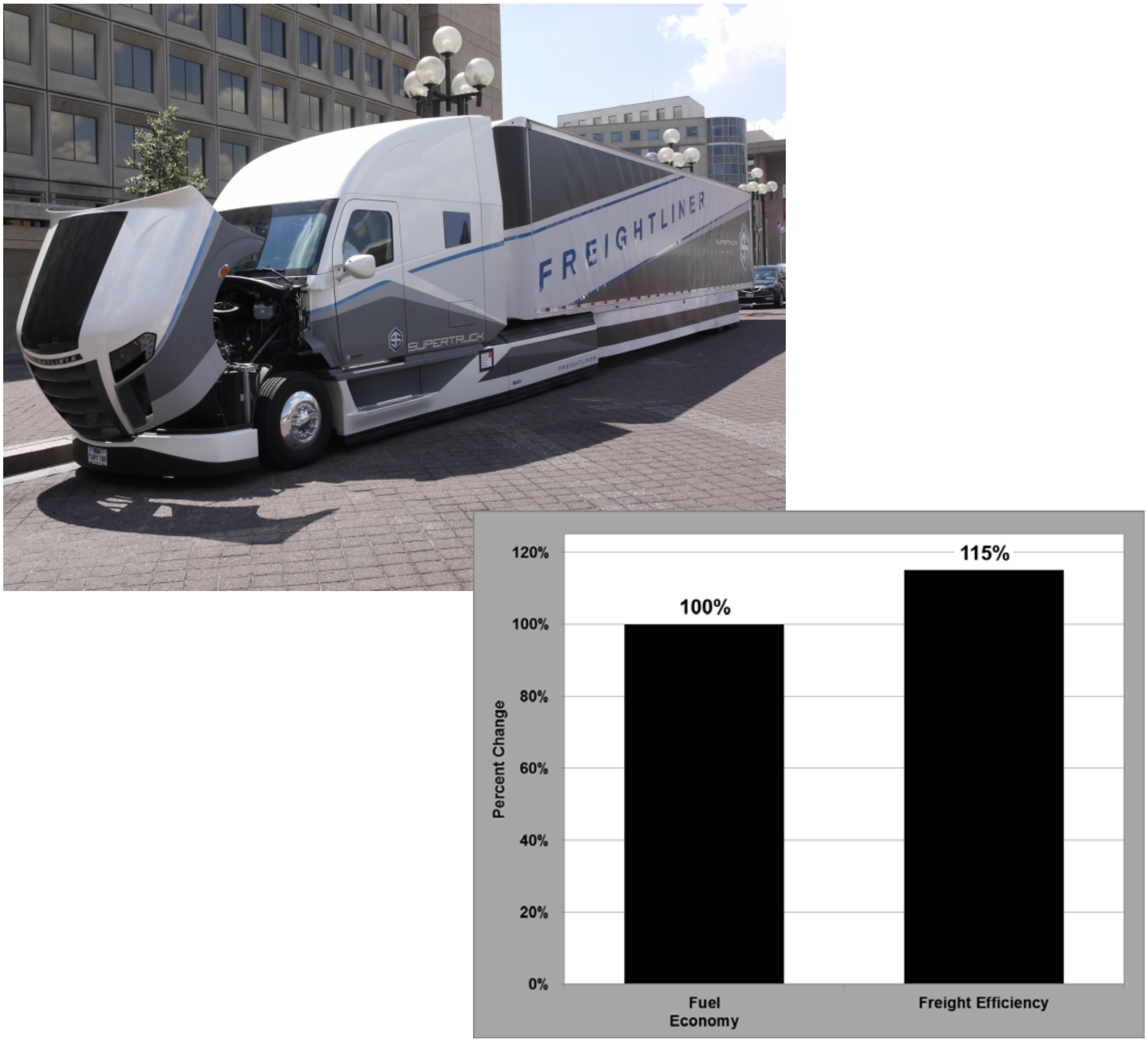

FIGURE 102. Changes in Fuel Economy and Freight Efficiency for the SuperTruck Project, February 2015

Source:

U.S. Department of Energy, "EERE Success Story—SuperTruck Initiative Partner Improves Class 8 Truck Efficiency by 115%" accessed March 10, 2016. http://energy.gov/eere/success-stories/articles/eere-success-story-supertruck-initiative-partner-improves-class-8

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Chapter 4

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 30 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 97% 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.

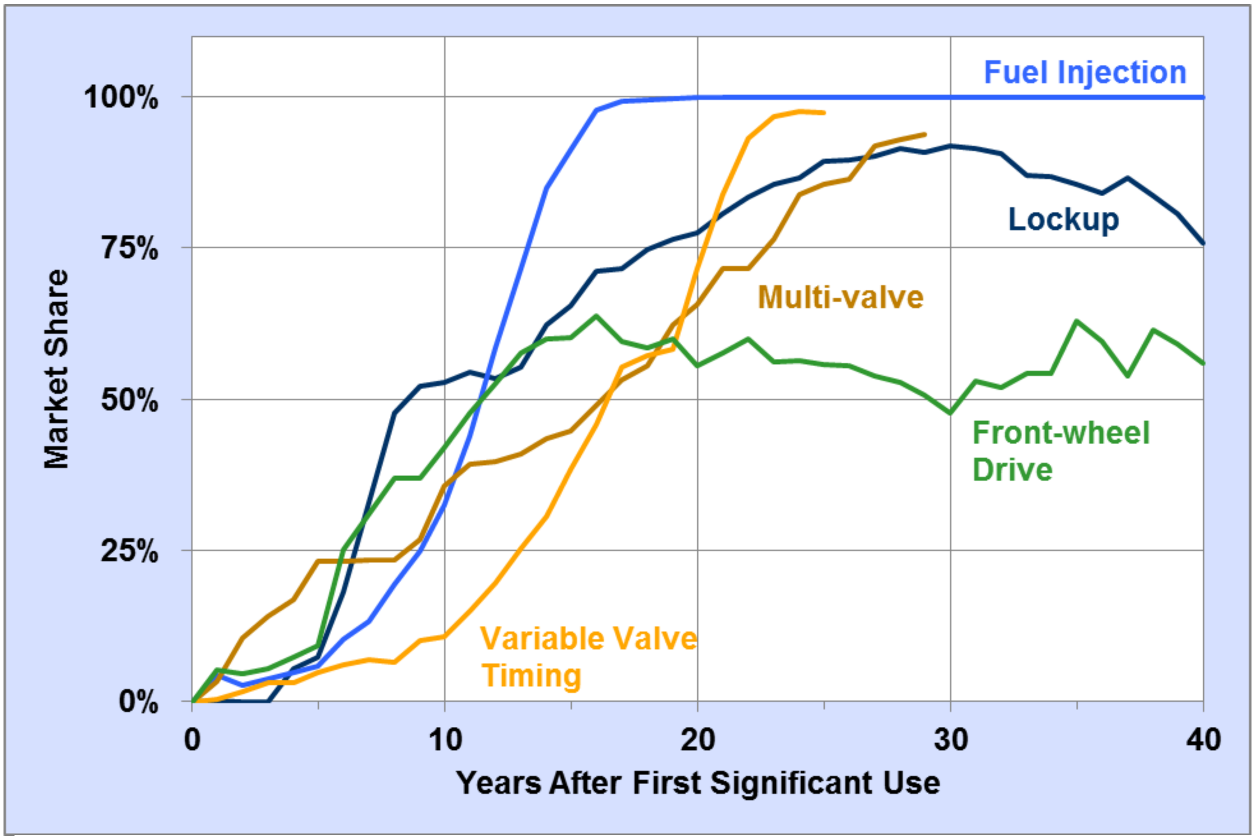

FIGURE 103. Light Vehicle Technology Penetration after First Significant Use

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Gasoline Direct Injection Captures 46% Market Share in Just Eight 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 also seen greater use particularly in the last year, reaching nearly 13% market share. Stop-start technology in non-hybrid vehicles is relatively new in the U.S. market and has only been around for four years since its first significant use. However, in just four years, stop-start has reached almost 7% market share while gasoline hybrids have only grown to 4% market share in the past 16 years.

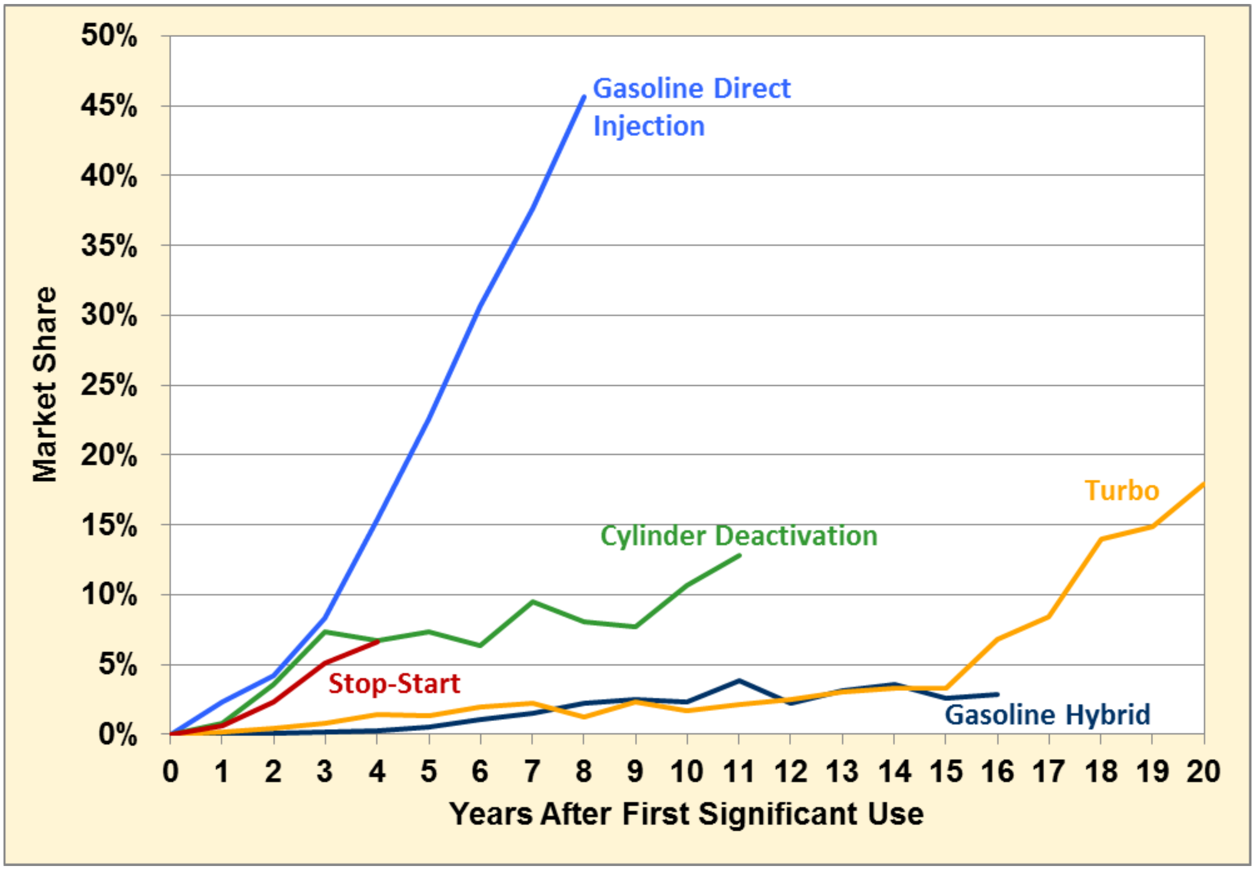

FIGURE 104. New Technology Penetration in Light Vehicles

Note: Stop-start technology data are for non-hybrid vehicles.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Hybrid Sales Decline by 22% from 2013 to 2015

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 in 2014 and 2015 with 2015 sales at about 384,000 vehicles.

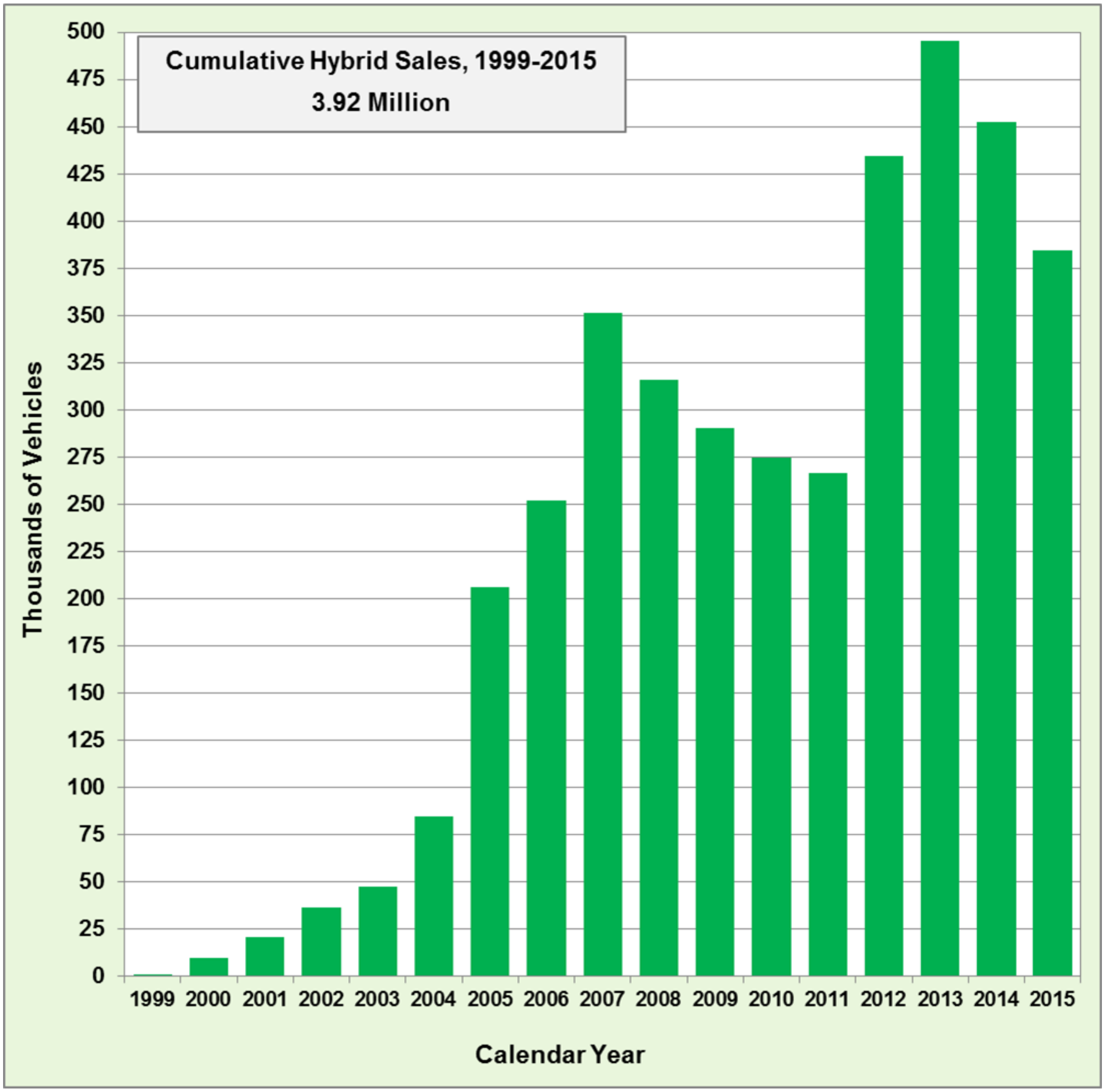

FIGURE 105. Hybrid-Electric Vehicle Sales, 1999-2015

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.

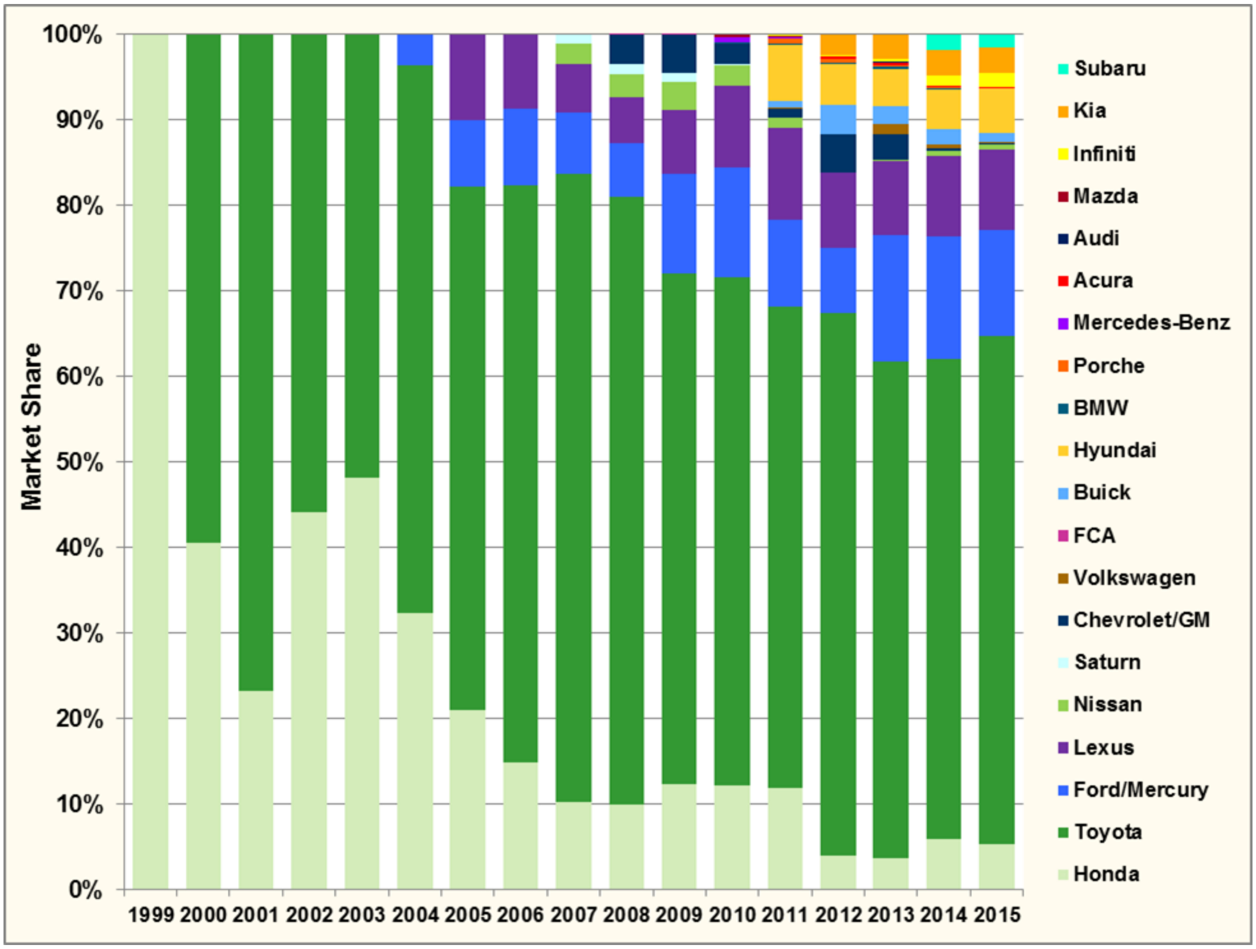

FIGURE 106. Hybrid-Electric Vehicle Market Share, 1999-2015

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.

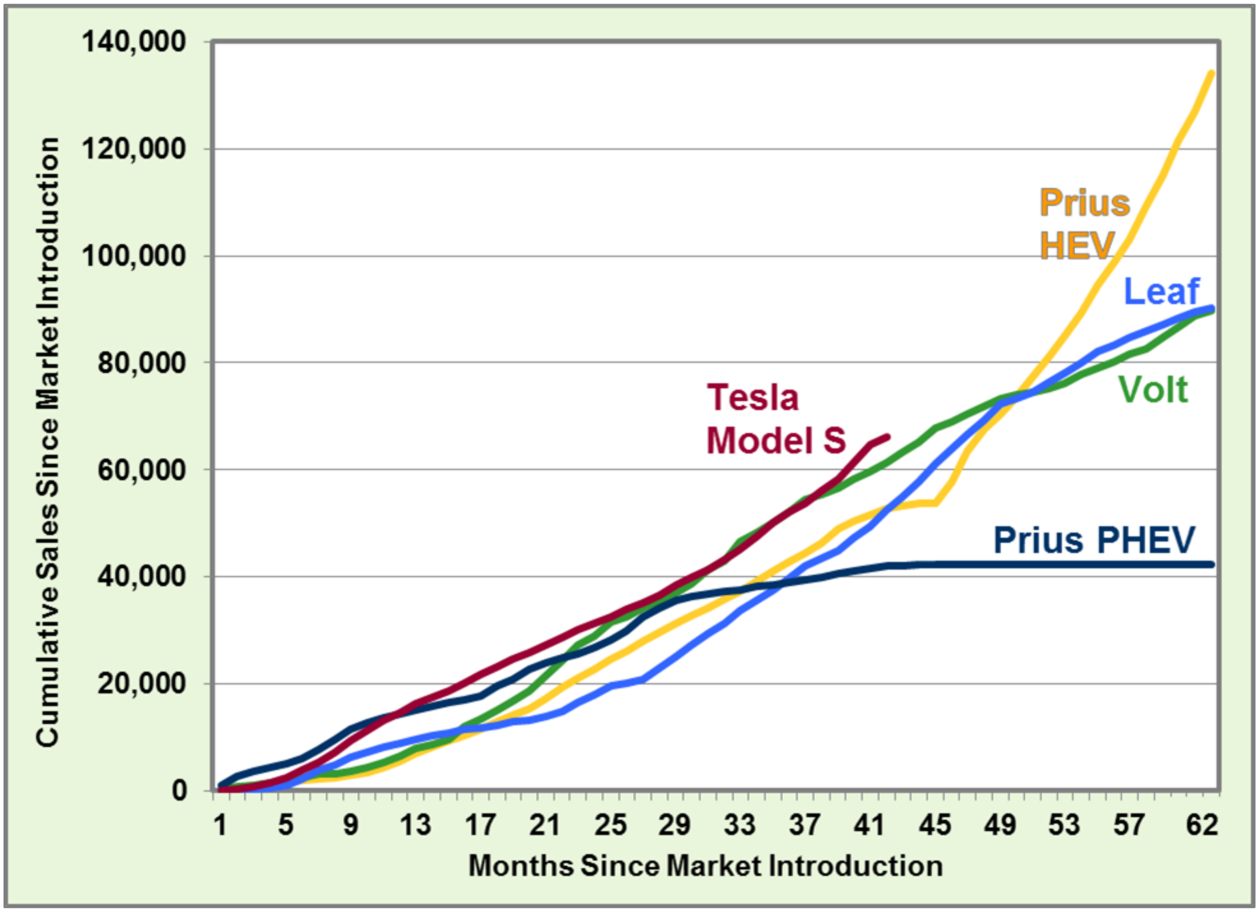

FIGURE 107. Monthly Sales since Market Introduction for Hybrid Vehicles and Plug-In Vehicles

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 Vehicle Sales Total over 115,000 Units in 2015

The number of plug-in vehicles sold in the United States in 2015 fell to a little over 115,000, down from 119,000 the previous year. Nissan and Chevrolet had the best sellers in 2011 with the Leaf and the Volt, but were joined by several other manufacturers in 2012. There were 27 different plug-in models available in 2015, many selling less than 5,000 units. The biggest plug-in sellers in 2015 were the Tesla Model S, Nissan Leaf, Chevrolet Volt, BMW i3, and Ford Fusion Energi.

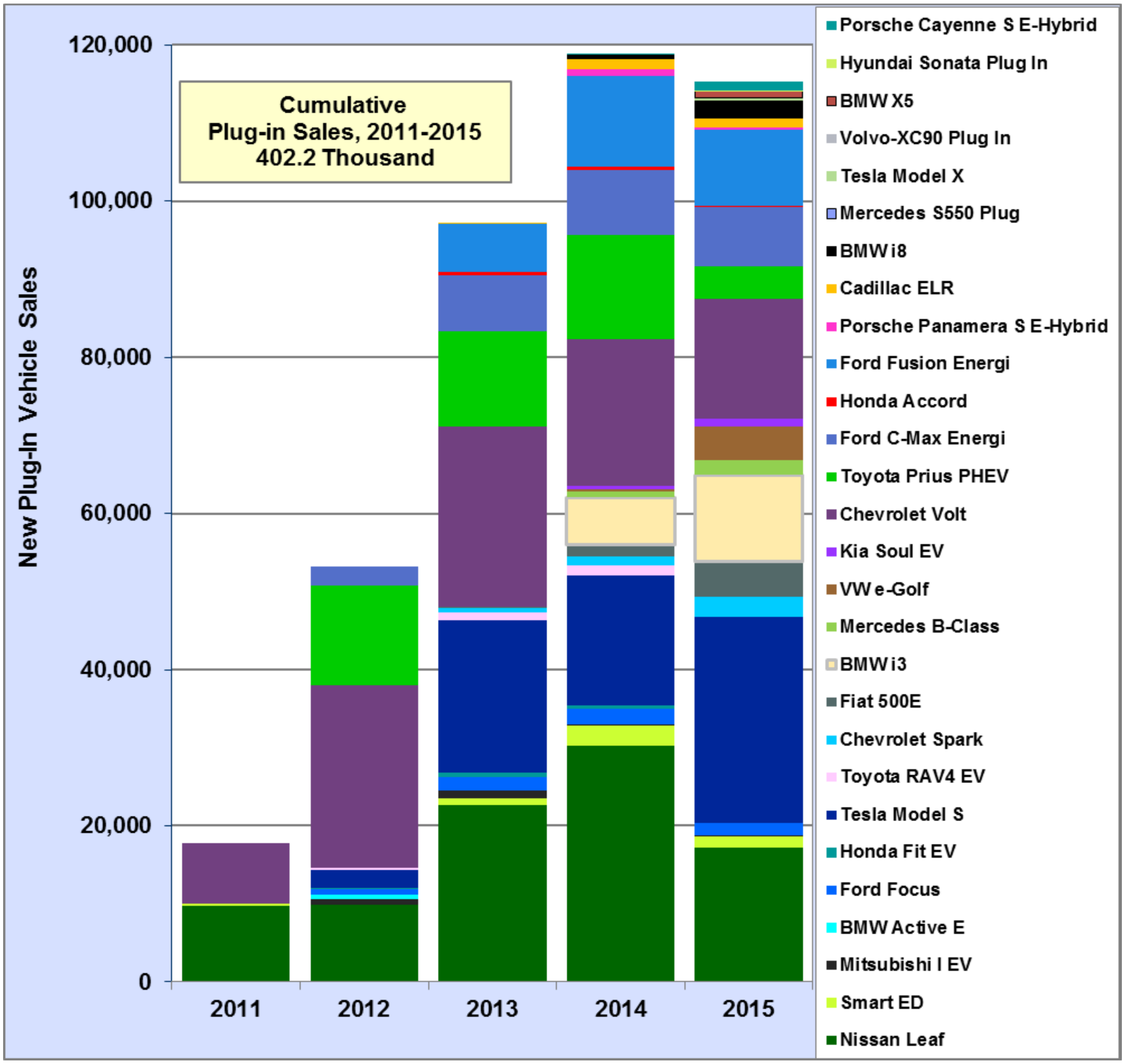

FIGURE 108. Plug-In Vehicle Sales, 2011-2015

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

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

In model year 2016 there are 12 different models that plug into electrical outlets to get all of their fuel and two fuel cell vehicles that use hydrogen. The Tesla Model S has the longest range at 270 miles with the 85 or 90 kW-hr battery pack. The Mitsubishi i-Miev has the shortest range with only 62 miles. The two fuel cell vehicles have ranges from about 250-300 miles.

TABLE 30. Available All-Electric Plug-In and Fuel Cell Vehicles, Model Year 2016

Make and Model	Total Range (Miles)	Time to Charge Battery (Hours at 240V)	Specifications
All-Electric Plug-In Vehicles			
BMW-i3 BEV	81	4.0	125 kW AC Induction
Chevrolet Spark EV	82	7.0	105 kW ACIPM
Fiat 500e	84	4.0	82 kW AC Induction
Ford Focus Electric	76	3.6	107 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	62	7.0	49 kW DCPM
Nissan Leaf, 24 kW-hr 24 kW-hr 30 kW-hr	84 84 107	8.0 (3.6 kW charger) 5.0 (6.6 kW charger) 6.0	80 kW DCPM
smart fortwo electric drive	68	6.0	55 kW DCPM
Tesla Model S, 70 kW-hr	234	10.0 (std. charger) 3.75 (80 amp dual charger)	285 kW AC Induction
Tesla Model S, 85 kW-hr 90 kW-hr	265	12.0 (std. charger) 4.75 (80 amp dual charger)	285 kW AC Induction
Tesla Model S, AWD 70D AWD 85D AWD 90D AWD P85D AWD P90D	240 270 270 253 253	12.0 (std. charger) 4.75 (80 amp dual charger)	70 kW AC Induction 85 kW AC Induction 90 kW AC Induction 193 front, 375 rear, 85 kW 193 front, 375 rear 90 kW
Tesla Model X, AWD 90D AWD P90D	257 250	12.0 (std. charger) 4.75 (80 amp dual charger)	90 kW AC Induction 193 front, 375 rear, 90 kW
Volkswagen e-Golf	83	3.7 (7.2 kW charger) 7.0 (3.6 kW charger)	85 kW AC PMSM
Fuel Cell Vehicles			
Hyundai Tucson Fuel Cell	265	~5 minutes to refuel	180 V Lithium Ion
Toyota Mirai	312	~5 minutes to refuel	245 V NiMH

Notes: AC = Alternative current; ACIPM = Alternating current induction permanent magnet motor; DCPM = Direct current permanent magnet motor; kW = Kilowatt; PMSM = Permanent magnet synchronous motor; V = Voltage; NiMH = Nickel-metal hydride.

Source:
U.S. Department of Energy, Fuel economy data, http://www.fueleconomy.gov. Data accessed March 2016.

Hybrid-Electric Plug-In Vehicles Available from Nine Manufacturers

There are 9 different makes and 13 different models that plug into electrical outlets to get part of their fuel. The BMW i3 REx has the longest all-electric range (72 miles), but the shortest total range (150 miles). The Hyundai Sonata Plug-In Hybrid has the longest total range (600 miles)

Table 31. Available Hybrid-Electric Plug-In Vehicles, Model Year 2016

Make and Model	All-Electric Range (Miles)	Total Range (Miles)	Time to Charge Battery (Hours at 240V)	Specifications
Audi A3 e-tron	16	380	2.5	80 kW electric motor, 1.4 L, 4 cyl
Audi A3 e-tron ultra	17	430	2.5	80 kW electric motor, 1.4L, 4 cyl
BMW i3 REX	72	150	4.0	125 kW electric motor, 0.6 L 2 cyl
BMW i8	15	330	2.0	96 kW electric motor, 1.5L, 3 cyl
BMW X5 XDrive40e	14	540	3.0	83 kW electric motor, 2.0 L, 4 cyl
Cadillac ELR	40	340	5.0	55 and 174 kW electric motor, 1.4 L, 4 cyl
Cadillac ELR Sport	36	320	5.0	55 and 174 kW electric motor, 1.4 L, 4 cyl
Chevrolet Volt	53	420	4.5	48 and 87 kW electric motor, 1.5L, 4 cyl
Ford C-Max Energi Plug-in Hybrid	20	550	2.5	68 kW electric motor, 2.0 L, 4 cyl
Ford Fusion Energi Plug-in Hybrid	20	550	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
Mercedes-Benz S550e	14	450	2.8	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
Porsche Panamera S E-Hybrid	16	560	3.0	70 kW electric motor, 3.0 L, 6 cyl
Volvo XC90 AWD PHEV	14	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, http://www.fueleconomy.gov. Data accessed March 2016.

New Plug-In and Fuel Cell Vehicles Are on the Horizon

There are ten new plug-in vehicles expected in model years 2016-2018 (three all-electric and seven hybrid-electric) and two fuel cell vehicles. The expected ranges of the all-electric vehicles go from 105 miles with the Hyundai Ioniq Electric to 200 miles with the Chevrolet Bolt EV and the Tesla Model 3. The hybrid-electric plug-ins, which also use gasoline, have expected electric ranges of 23-39 miles with total ranges of up to 600 miles. The fuel cell vehicles have ranges similar to conventional vehicles.

TABLE 32. Upcoming Plug-In and Fuel Cell Vehicles

Model Year	Make and Model	All-Electric Range (miles)	Total Range (miles)	Specifications
All-Electric Plug-In Vehicles				
2016	Chevrolet Bolt EV	~200	~200	60 kWh Li-ion battery; 240 volt charging unit; est 200 miles per charge
2017	Hyundai Ioniq Electric	~105	~105	88 kW motor, 28 kWh Li-ion battery pack
2017	Tesla Model 3	~200	~200	N/A
Hybrid-Electric Plug-In Vehicles				
2016	BMW 740e Plug-In Hybrid	23	N/A	2.0 L 4 cyl engine, 250 Nm Li-ion battery,
2016	Cadillac CT6 Plug-In Hybrid	30	N/A	2-motor EVT system, 2.0 L turbocharged 4 cyl engine, 18.4 kWh Li-ion battery
2017	Chrysler Pacifica Mini Van	30	530	3.6 L V6 engine; 16 kWh Li-ion battery pack;
2017	Hyundai Ioniq	~22-26	N/A	1.6 L 4 cyl engine, 43 hp electric motor, Li-ion polymer battery
2017	Kia Optima Plug-In Hybrid	~27	600	2.0 L 4 cyl engine, 50 kW electric motor, 9.8 kWh Lithium-polymer battery pack
2017	Mitsubishi Outlander Plug-In Hybrid	32.5	N/A	2-electric motors, 2.0 L 4 cyl engine, 12 kWh Li-ion battery pack
2018	Honda Accord Plug-In Hybrid	39	N/A	2 motors
Fuel Cell Vehicles				
2017	Mercedes-Benz GLC F-Cell	N/A	250-300	N/A
2016	Honda Clarity	N/A	300+	134 hp

Notes: 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. N/A = not applicable.

Sources:
U.S. Department of Energy, Fuel economy data, http://www.fueleconomy.gov and other industry sources. Data accessed March 2016.

Primearth EV Energy Supplied the Most Batteries by Number but Panasonic Supplied the Most Battery Capacity for Model Year 2015

Primearth EV Energy supplied a majority of the batteries for hybrid vehicles in 2015. While hybrid vehicle sales far outnumber plug-in vehicle sales, the capacity of hybrid batteries average only about 1.2 kW-hrs per battery. Panasonic, while supplying fewer batteries, produced them for plug-in vehicles that have much larger batteries so they supplied the greatest amount battery capacity. The battery capacity for a plug-in vehicle could be as high as 90 kW-hrs–a battery offering for the Tesla models. AESC and LG Chem also produced a substantial amount of battery capacity for plug-in vehicles in that year.

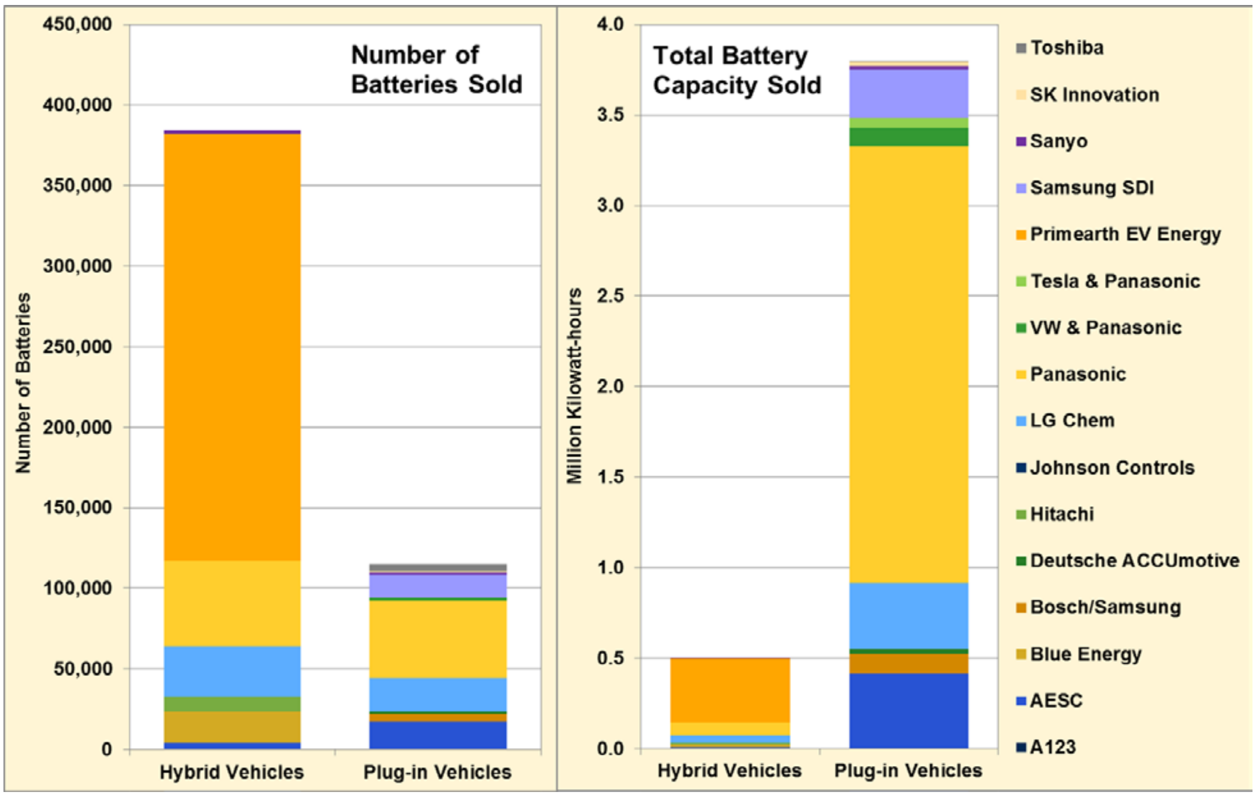

FIGURE 109. Battery Sales Estimates for Hybrid and Plug-In Vehicles, 2015

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 2016.

Battery Capacity Varies Widely for Plug-In Vehicles

The all-electric plug-in vehicles have capacities ranging from 16 kW-hrs in the Mitsubishi iMiev to 90 kW-hrs in the Tesla Model S (and Model X). 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 vehicles currently have lithium-ion (Li-ion) batteries.

TABLE 33. Batteries for Selected Available and Upcoming Plug-in Vehicles, Model Years 2015-2016

Model Year	Vehicle	Battery Capacity (kW-hrs)	Battery Type	Supplier
All-Electric Vehicles				
2015	BMW i3	22	Li-ion	Samsung SDI
2016	Chevrolet Spark EV	18.4	Li-ion	LG Chem
2016	Fiat 500e	24	Li-ion	Samsung, SB LiMotive, Bosch-Samsung partnership
2016	Ford Focus Electric	23	Li-ion	LG Chem
2016	Kia Soul EV	27	Li-ion	SK Innovation
2016	Mercedes-Benz B250e	28	Li-ion	Panasonic
2016	Mitsubishi iMiEV	16	Li-ion	Lithium Energy Japan
2016	Nissan Leaf	24	Li-ion	AESC
2016	Nissan Leaf	30	Li-ion	AESC
2016	Smart For Two Electric Drive	17.6	Li-ion	Deutsche ACCUmotive
2016	Tesla Model S70, S70D	70	Li-ion	Tesla/Panasonic
2016	Tesla Model S85, S85D, P85D	85	Li-ion	Tesla/Panasonic
2016	Tesla Model S90, S90D, P90D	90	Li-ion	Tesla/Panasonic
2016	Tesla Model X 90D, P90D	90	Li-ion	Tesla/Panasonic
2016	Volkswagen e-Golf	24.2	Li-ion	VW & Panasonic
Plug-In Hybrid-Electric Vehicles				
2016	Audi A3 Sportback eTron & etron ultra	8.8	Li-ion	Sanyo
2016	Mercedes-Benz S550e	8.7	Li-ion	Panasonic
2016	BMW X5 xDrive 4.0e	9	Li-ion	Samsung
2015	BMW i3 REX (range extender)	22	Li-ion	Samsung
2015	BMW i8	7.1	Li-ion	Samsung
2016	Cadillac ELR	17.1	Li-ion	LG Chem
2016	Chevrolet Volt	18.4	Li-ion	LG Chem
2016	Ford Fusion Energi	7.6	Li-ion	Panasonic
2016	Ford C-Max Energi	7.6	Li-ion	Panasonic
2016	Hyundai Sonata	9.8	Li-ion	LG chem
2015	Toyota Prius Plug-In	4.4	Li-ion	Panasonic
2016	Porsche Cayenne S e-Hybrid	9.4	Li-ion	Samsung
2016	Porsche Panamera S e-Hybrid	9.4	Li-ion	Samsung
2015	Porsche 918 Spyder	10.8	Li-ion	Samsung
2015	McLaren Automotive P1	6.8	Li-ion	Johnson Matthey Battery Systems
2016	Volvo XC90 T8	9.2	Li-ion	LG Chem

Notes: Automotive Energy Supply Corporation (AESC) is a joint venture between NEC and Nissan. Deutche ACCUmotive is a joint venture between Daimler and Evonik Industries AG. Primearth EV Energy is a joint venture between Panasonic and Toyota. Sanyo is a wholly-owned subsidiary of Panasonic.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2016.

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 34. Batteries for Selected Hybrid-Electric Vehicles, Model Years 2015-2016

Model Year	Vehicle	Battery Capacity (kW-hrs)	Battery Type	Supplier
2016	Acura RLX Hybrid	1.3	Li-ion	Blue Energy
2016	Audi Q5 Hybrid	1.3	Li-ion	Sanyo
2015	BMW ActiveHybrid 3	1.4	Li-ion	A123
2016	BMW ActiveHybrid 5	1.4	Li-ion	A123
2015	BMW ActiveHybrid 7L	1.4	Li-ion	A123
2016	Buick LaCrosse eAssist	0.5	Li-ion	Hitachi
2016	Buick Regal eAssist	0.5	Li-ion	Hitachi
2016	Ford C-Max Hybrid	1.4	Li-ion	Panasonic
2016	Ford Fusion Hybrid	1.4	Li-ion	Panasonic
2015	Honda Accord Hybrid	1.3	Li-ion	Blue Energy
2015	Honda Civic Hybrid	0.7	Li-ion	Blue Energy
2016	Honda CR-Z Hybrid	0.7	Li-ion	Blue Energy
2016	Hyundai Sonata Hybrid	1.6	Li-ion polymer	LG Chem
2016	Inifiniti Q70 Hybrid	1.4	Li-ion	AESC
2015	Inifiniti Q50 Hybrid	1.4	Li-ion	AESC
2015	Inifiniti QX60 Hybrid	0.7	Li-ion	Hitachi
2016	Kia Optima	1.4	Li-ion polymer	LG Chem
2016	Lexus CT 200h	1.3	NiMH	Primearth EV Energy
2016	Lexus ES 300h	1.6	NiMH	Primearth EV Energy
2016	Lexus NX 300h	1.6	NiMH	Primearth EV Energy
2016	Lexus GS 450h	1.9	NiMH	Primearth EV Energy
2016	Lexus LS 600h L	1.9	NiMH	Primearth EV Energy
2015	Lexus RX 450h	1.9	NiMH	Primearth EV Energy
2016	Lincoln MKZ Hybrid	1.4	Li-ion	Panasonic
2015	Mercedes Benz E400 Hybrid	0.8	Li-ion	Panasonic
2015	Nissan Pathfinder Hybrid	0.7	Li-ion	Hitachi
2016	Porsche Cayenne S Hybrid	0.6	NiMH	Panasonic
2016	Suburu XV Crosstrek Hybiid	1.6	NiMH	Primearth EV Energy
2016	Toyota Avalon Hybrid	1.6	NiMH	Primearth EV Energy
2016	Toyota Camry Hybrid	1.9	NiMH	Primearth EV Energy
2016	Toyota Highlander Hybrid	1.3	NiMH	Primearth EV Energy
2016	Toyota Prius Eco	0.7	Li-ion	Toyota/Panasonic
2016	Toyota Prius c	0.9	NiMH	Primearth EV Energy
2016	Toyota Prius v	1.3	NiMH	Primearth EV Energy
2016	Toyota RAV4 Hybrid	1.6	NiMH	Primearth EV Energy
2016	Volkswagen Jetta Hybrid	1.1	Li-ion	Sanyo

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. Sanyo is a wholly-owned subsidiary of Panasonic. Blue Energy is a joint venture between GS Yuasa and Honda.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2016.

Hybrid 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 long-haul trucks.

TABLE 35. Hybrid and Electric Cargo Trucks on the Market

Manufacturer	Model	Category
	Hybrid Electric	
Autocar	E3 Hybrid	Refuse
Champion Bus Inc.	Defender	Shuttle Bus
Collins Bus Corp.	NexBus Gasoline Hybrid	School Bus
Daimler Buses North America	Orion VII Hybrid Low-Floor	Transit Bus
DesignLine Corp.	EcoSaver IV	Transit Bus
Ebus	EBUS22FC	Shuttle Bus
ElDorado National	Axess	Transit Bus
ElDorado National	E-Z Rider II BRT	Transit Bus
Foton America	FCB 30-foot; FCB 35-foot; FCB 40-foot	Transit Bus
Freightliner	M2 106	Tractor
Freightliner	M2 106 Hybrid	TractorVocational/Cab Chassis
Gillig Corp.	Diesel-Electric Hybrid Bus and CNG Bus	Transit Bus
Glaval Bus	Universal	Shuttle Bus
Hino	195h	Vocational/Cab Chassis
IC Bus	HC Hybrid Series	Shuttle Bus
International	DuraStar Hybrid	Vocational/Cab Chassis
Kenworth	T270 Hybrid	TractorVocational/Cab Chassis
Kenworth	T370 Diesel Electric Tractor	Tractor
Kenworth	T370 Hybrid Truck	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	42BRT	Transit Bus
North American Bus Industries	60BRT	Transit Bus
North American Bus Industries	CompoBus	Transit Bus
Nova Bus	LFS Artic HEV	Transit Bus
Nova Bus	LFS HEV	Transit Bus
Nova Bus	LFX	Transit Bus
Peterbilt Motors	330 Hybrid	Vocational/Cab Chassis
Peterbilt Motors	337/338	TractorVocational/Cab Chassis
Peterbilt Motors	386HE	Tractor
Thomas Built Buses	Saf-T-Liner C2e Hybrid	School Bus
Turtle Top	Odyssey XLT	Shuttle Bus
	Hybrid Hydraulic	
Peterbilt Motors	320 HLA	Refuse

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed March 10, 2016. http://www.afdc.energy.gov/vehicles/search

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

There are 19 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 seven hydrogen-fueled medium and heavy trucks on the market.

TABLE 36. Electric and Hydrogen Fuel Cell Medium and Heavy Vehicles on the Market

Manufacturer	Model	Category
Electric		
Balqon	Mule M150	Vocational/Cab Chassis
Balqon	XE-20	Tractor
Balqon	XE-30	Tractor
Boulder Electric Vehicle	DV-500 Delivery Truck	Step Van
BYD (Build Your Dream)	40 ft. Transit Bus	Transit Bus
BYD (Build Your Dream)	60 ft. Transit Bus	Transit Bus
Capacity Trucks	HETT	Tractor
DesignLine Corp.	Eco-Smart 1	Transit Bus
Electric Vehicles International	EVI-MD	Vocational/Cab Chassis
Electric Vehicles International	WI EVI	Step Van
Enova Systems	Enova Ze Step Van	Step Van
GGT Electric	Electric	Vocational/Cab Chassis
Navistar-Modec EV Alliance	eStar	Step Van
New Flyer	Xcelsior	Transit Bus
Proterra	EcoRide BE35	Transit Bus
Smith Electric Vehicles	Newton	Vocational/Cab Chassis
Smith Electric Vehicles	Newton Step Van	Step Van
Trans Tech	ETrans	School Bus
ZeroTruck	ZeroTruck	Vocational/Cab Chassis
Hydrogen Fuel Cell		
Capacity Trucks	ZETT	Tractor
Ebus	EBUS22FC	Shuttle Bus
ElDorado National	Axess	Transit Bus
New Flyer	Xcelsior	Transit Bus
Van Hool	A300L Fuel Cel	Transit Bus
Vision Motor Corp.	Tyrano	Tractor
Vision Motor Corp.	ZETT	Tractor

Source:

U.S. Department of Energy, Alternative Fuels and Advanced Vehicles Data Center, accessed March 10, 2016. http://www.afdc.energy.gov/vehicles/search

Flex-Fuel Vehicle Offerings Decline by 11% for Model Year 2015

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 and Toyota have offered flex-fuel models each of the last five years, too. Other manufacturers, like Volkswagen and Mercedes-Benz expanded their flex-fuel offerings in 2012 through 2013. In 2015 there were 71 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.

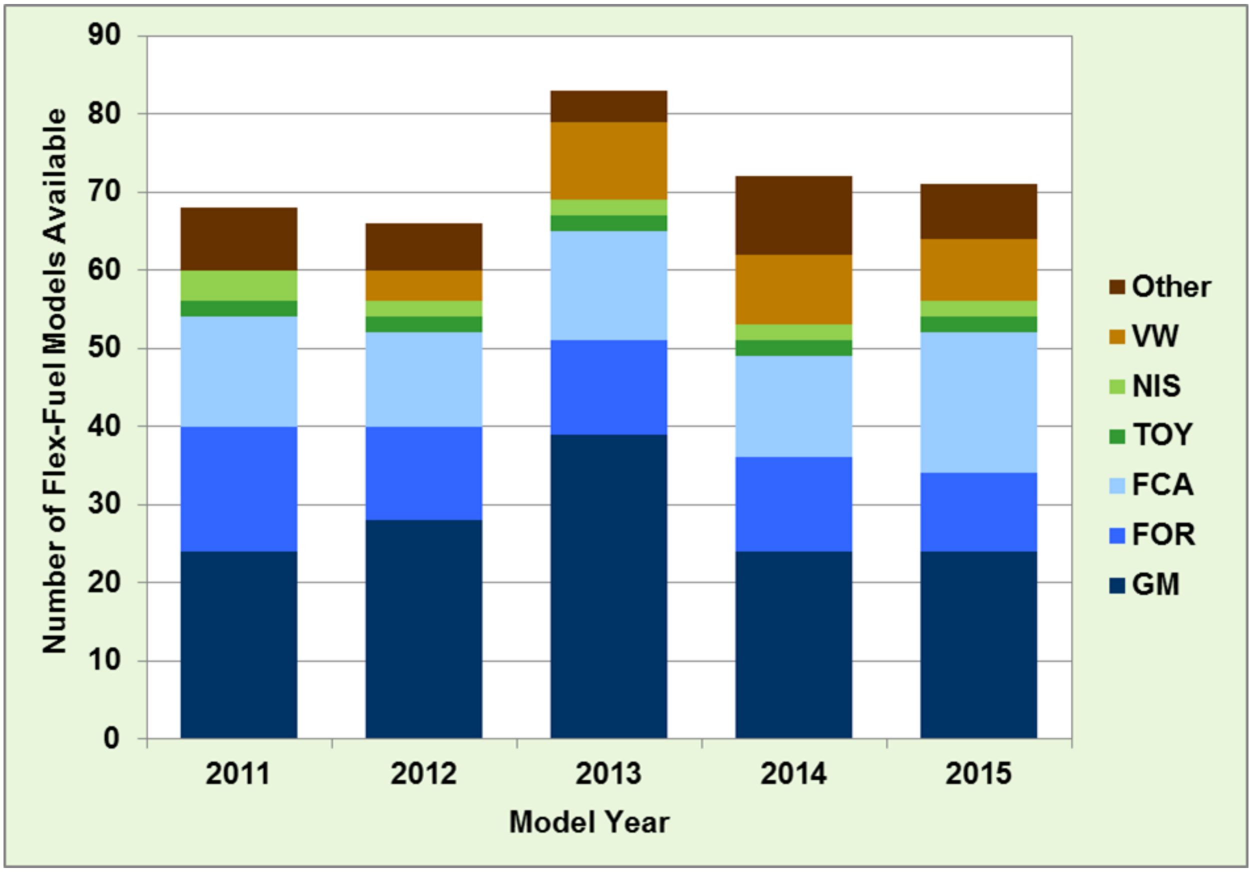

FIGURE 110. Number of Flex-Fuel Models Available, 2011-2015

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

In lieu of "vehicles in use" the Energy Information Administration now publishes the number of vehicles supplied each year from original equipment manufacturers and conversions. These data will more closely align with sales than with vehicle population. Unfortunately there is no estimate of how many flex-fuel vehicles are actually using E85 or how many gallons of E85 are consumed.

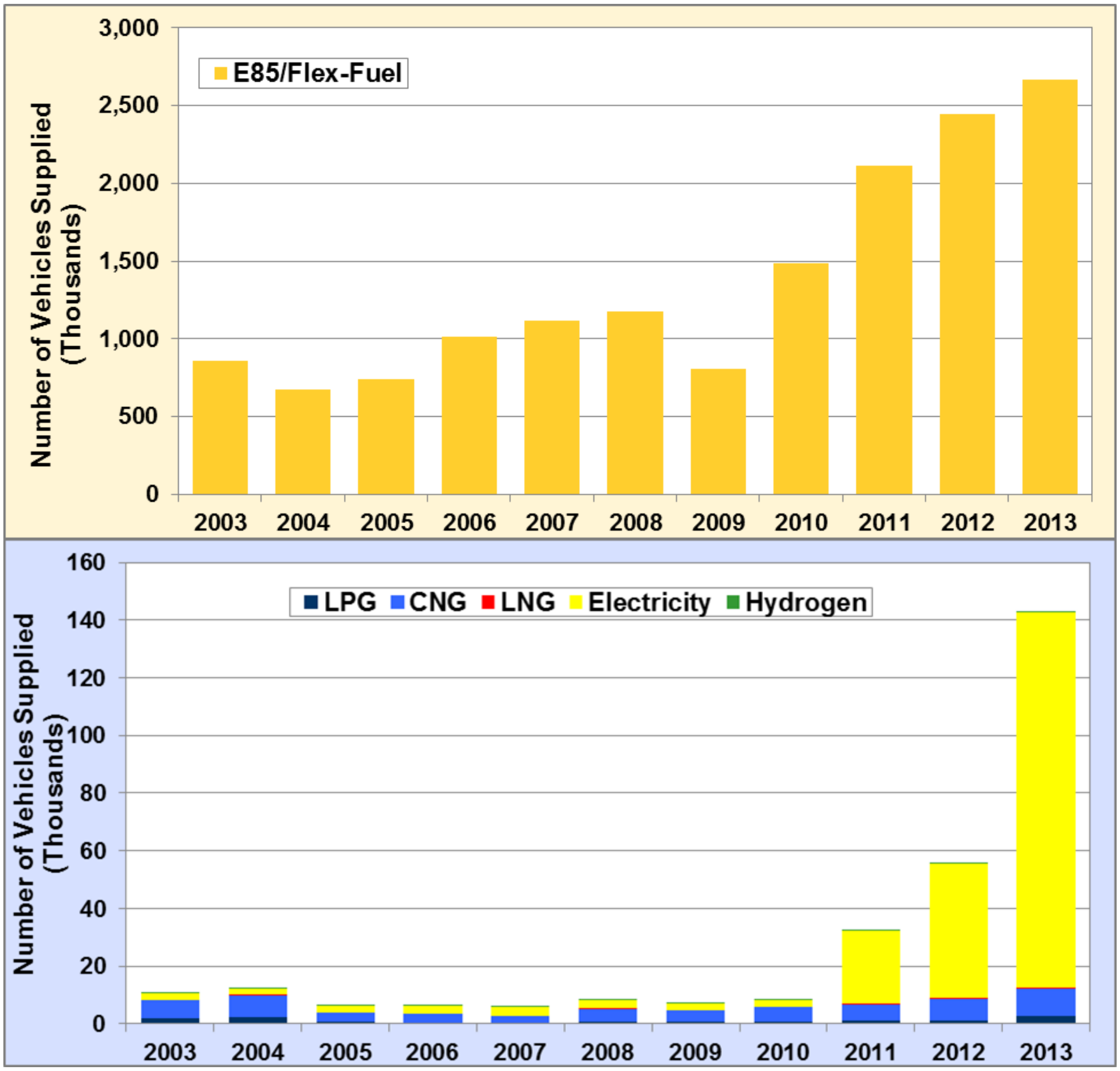

FIGURE 111. Number of Alternative Fuel Vehicles Supplied, 2003-2013

Note: Electricity includes only vehicles that plug into an outlet and does not include low-speed vehicles. LPG = Liquefied petroleum gas; CNG = Compressed natural gas; LNG = Liquefied natural gas.

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 stations (plugs) grew from about 3,500 in 2011 to over 30,000 in 2015. It should be noted that beginning in 2011, electric charging stations 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 about 3,600 propane stations, 3,000 E85 stations, and 1,600 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.

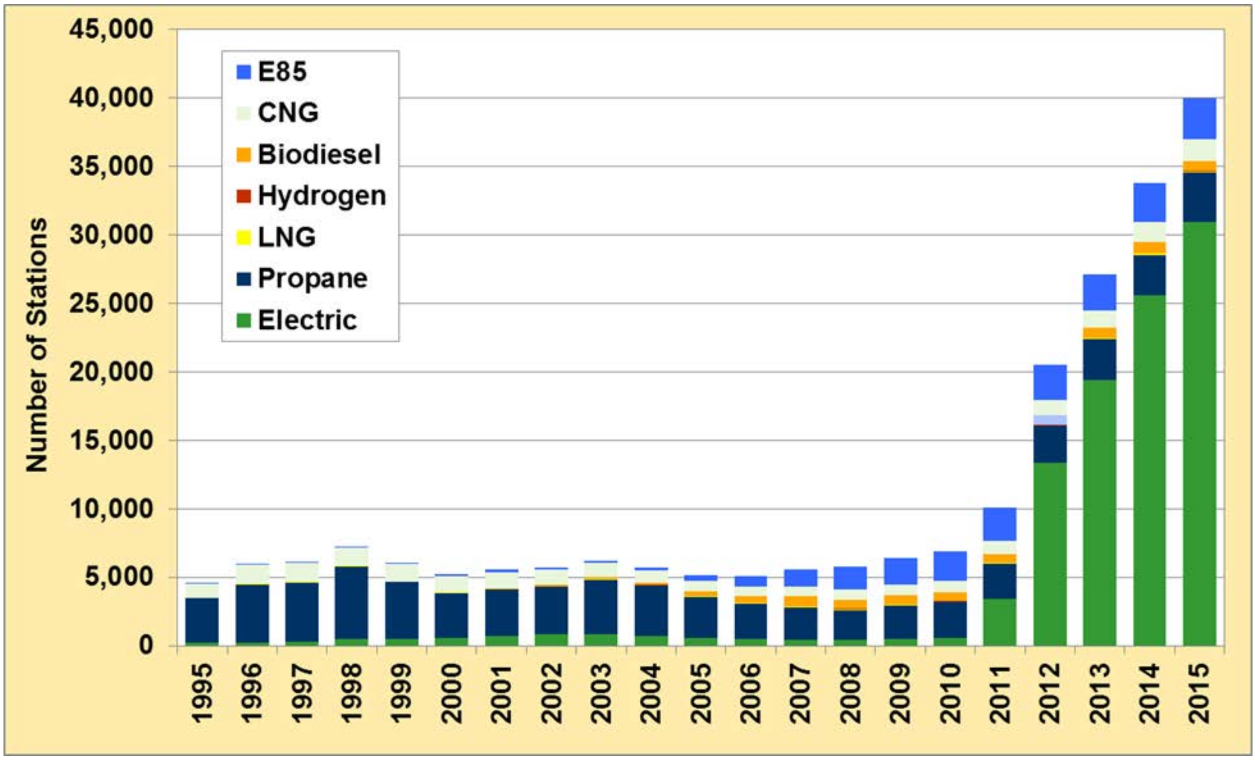

FIGURE 112. Alternative Fueling Stations by Fuel Type, 1995-2015

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 February 2016. 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 3,127 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 712 stations across the country, with the predominance of stations in the Southeast. Data are as of March 9, 2016.

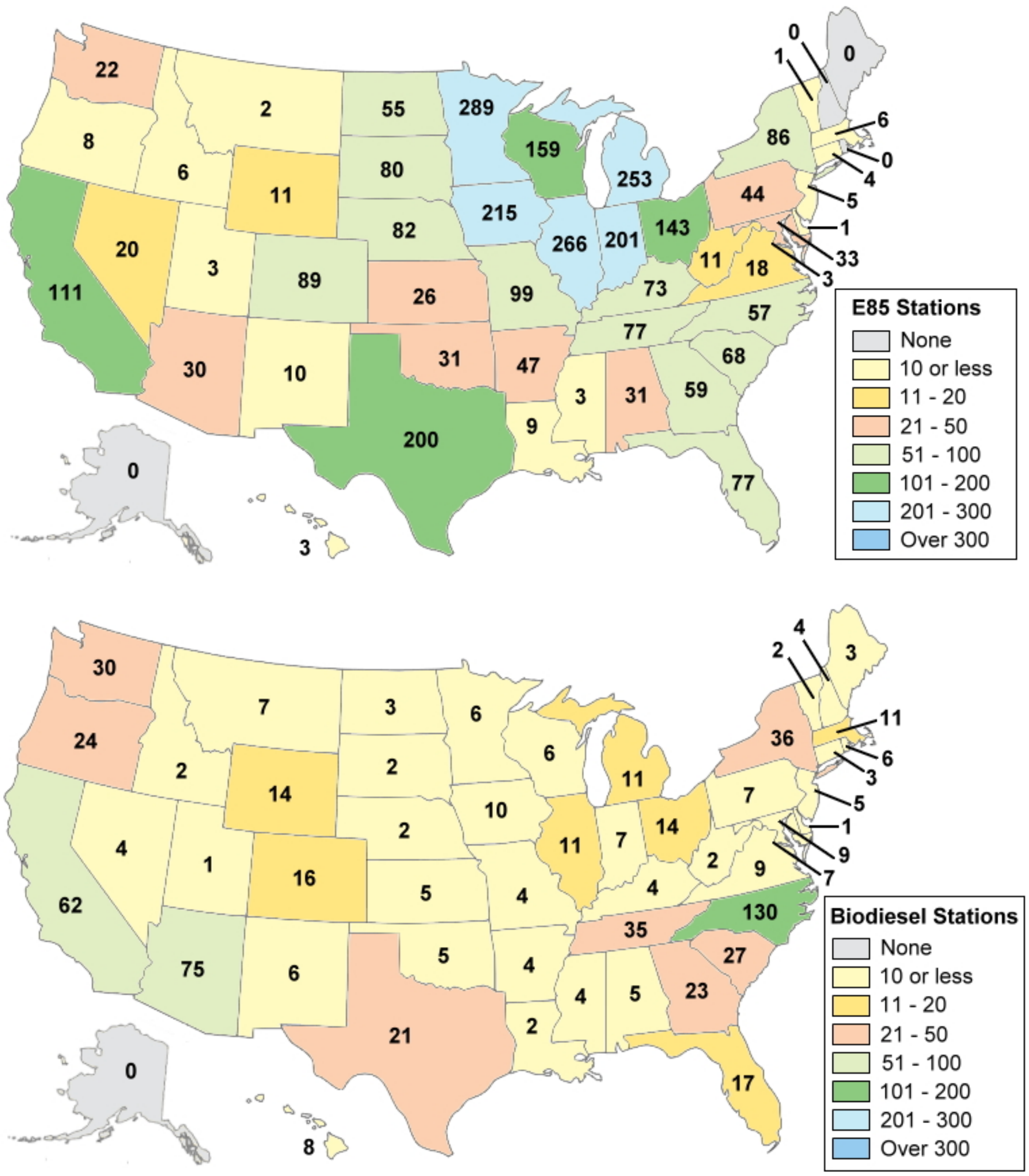

FIGURE 113. Number of E85 (top) and Biodiesel Stations by State, 2016

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 3,759 propane stations across the country. Texas and California together comprise 23% of the propane stations. Natural gas, compressed or liquefied, is not as widely available as many other alternative fuels. There are 1,748 stations nationwide. California and Texas have the most natural gas stations. Data are as of March 9, 2016.

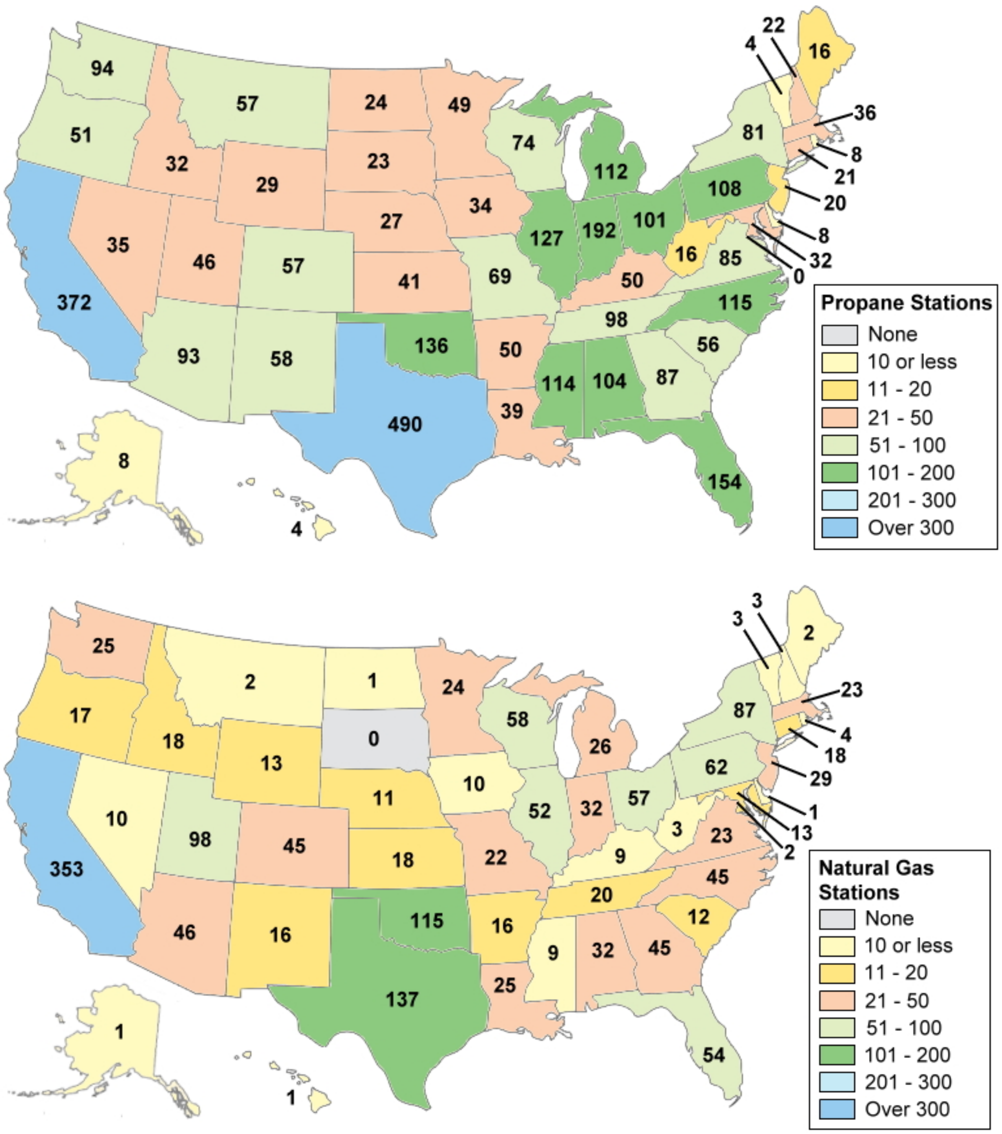

FIGURE 114. Number of Propane (top) and Natural Gas Stations by State, 2016

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 (14,966 stations). The number of charging units is of particular importance for electric vehicles due to the length of time it takes vehicles to charge compared to other types of fueling stations. While most refueling 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 March 9, 2016.

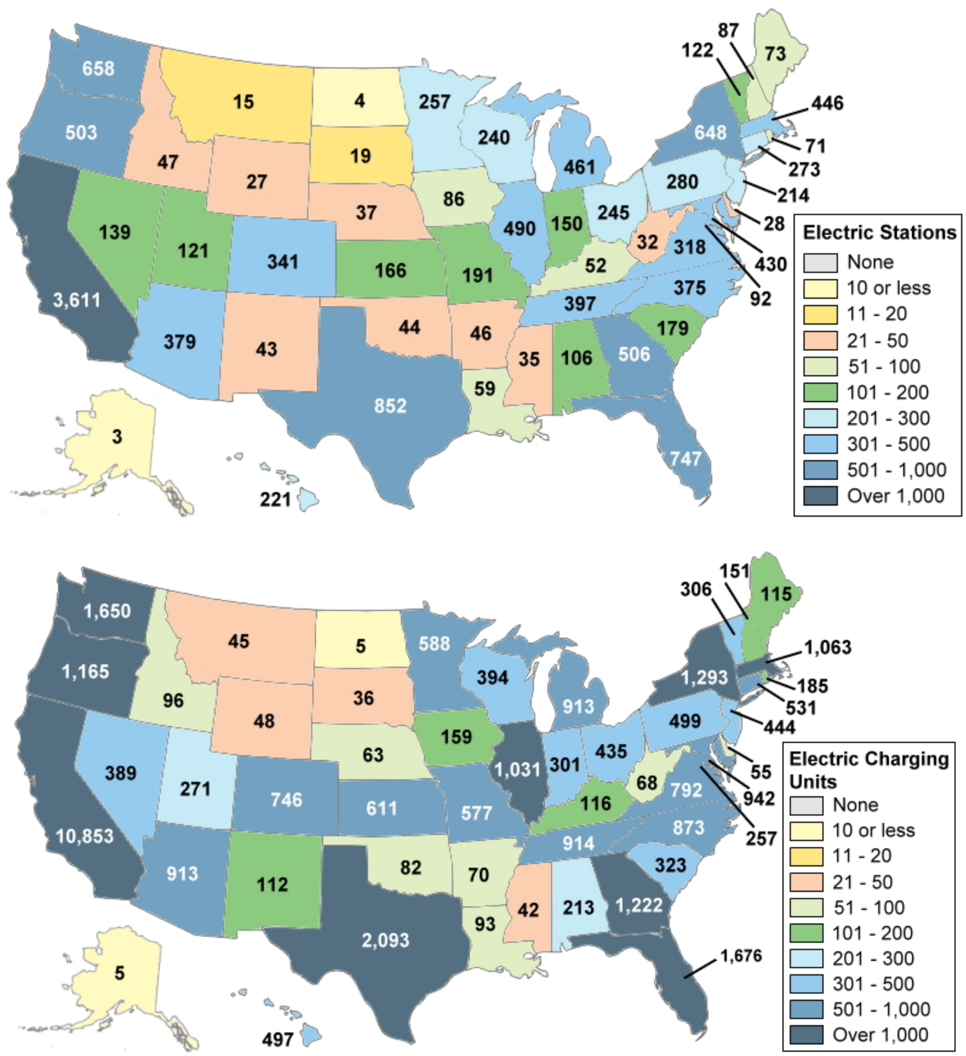

FIGURE 115. Number of Electric Stations (top) and Electric Charging Units by State, 2016

Note: Includes public and private stations and units. About 84% 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

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 March 9, 2016.

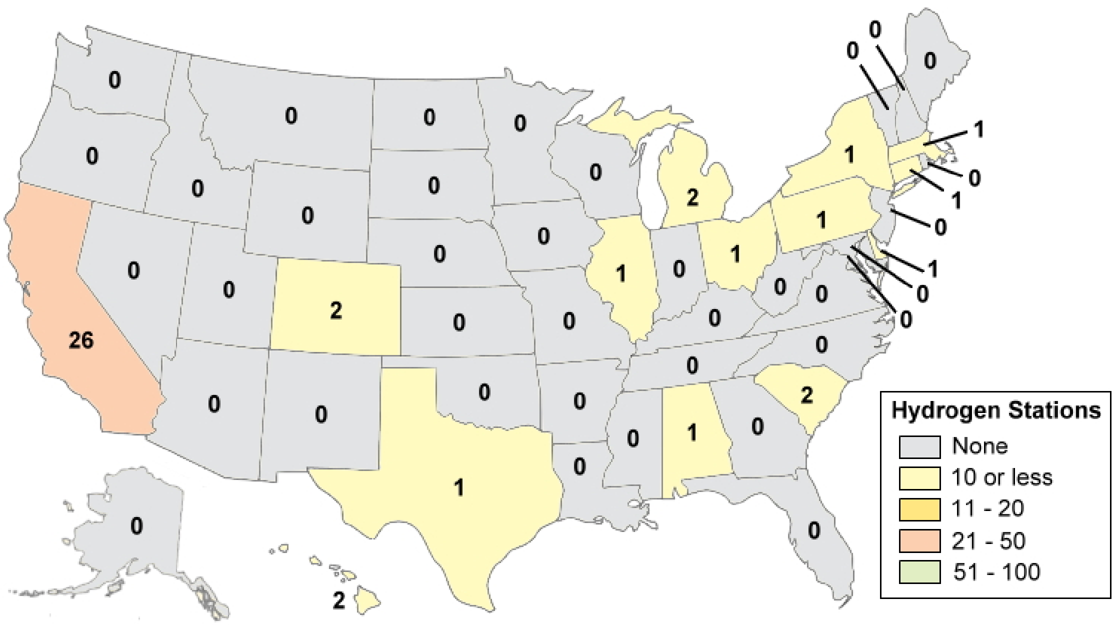

FIGURE 116. Number of Hydrogen Stations by State, 2016

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

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 2014. Federal use of other alternative fuels has been less than one million GGEs combined in 2010-2014. Note the large difference in the scales of the two graphs.

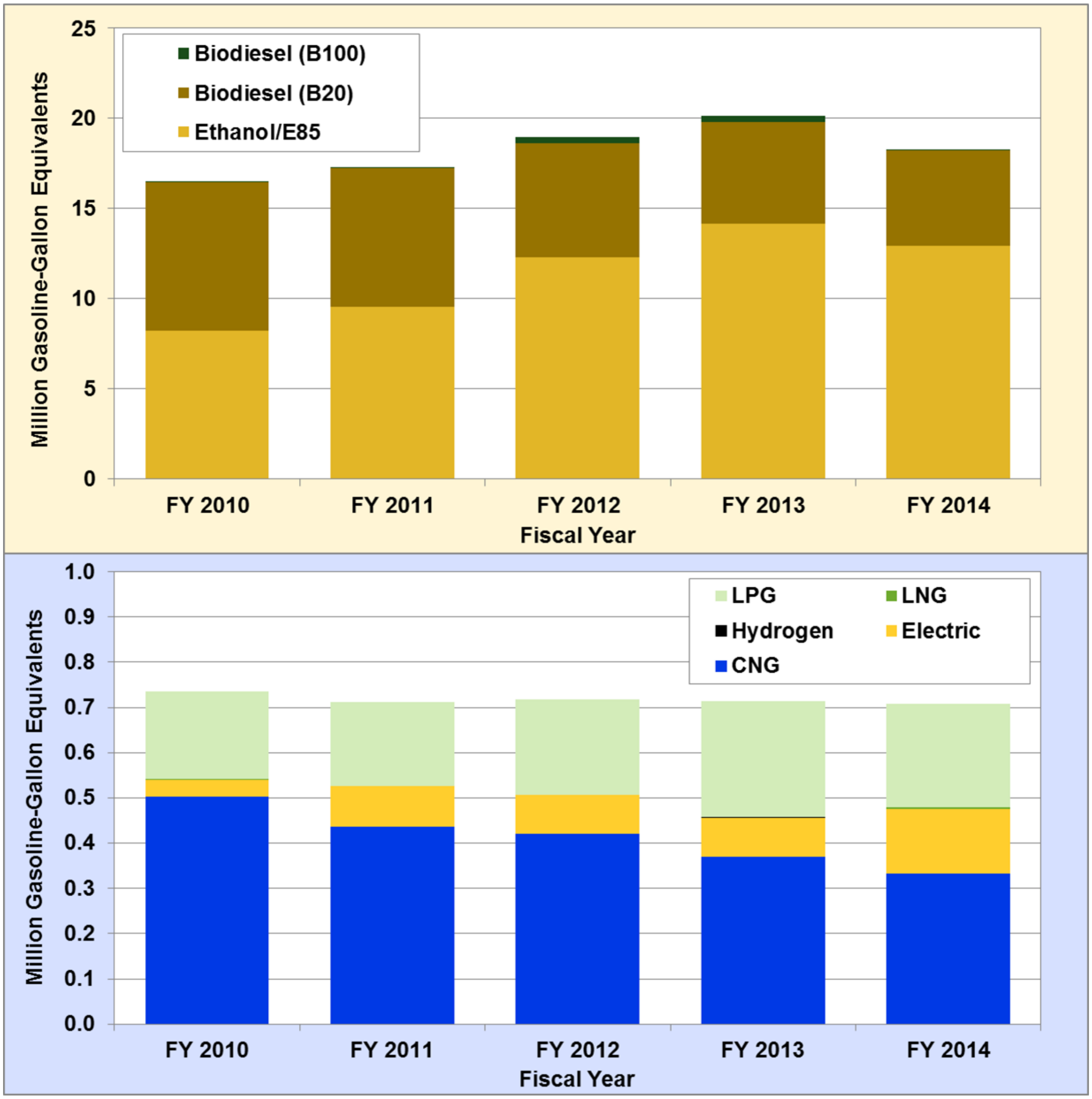

FIGURE 117. Alternative Fuel Use by the Federal Government, 2010-2014

Source:

U.S. General Services Administration, *FY 2014 Federal Fleet Report*, Washington, DC, 2015. 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 and electric vehicles both rose substantially between 2010 and 2014.

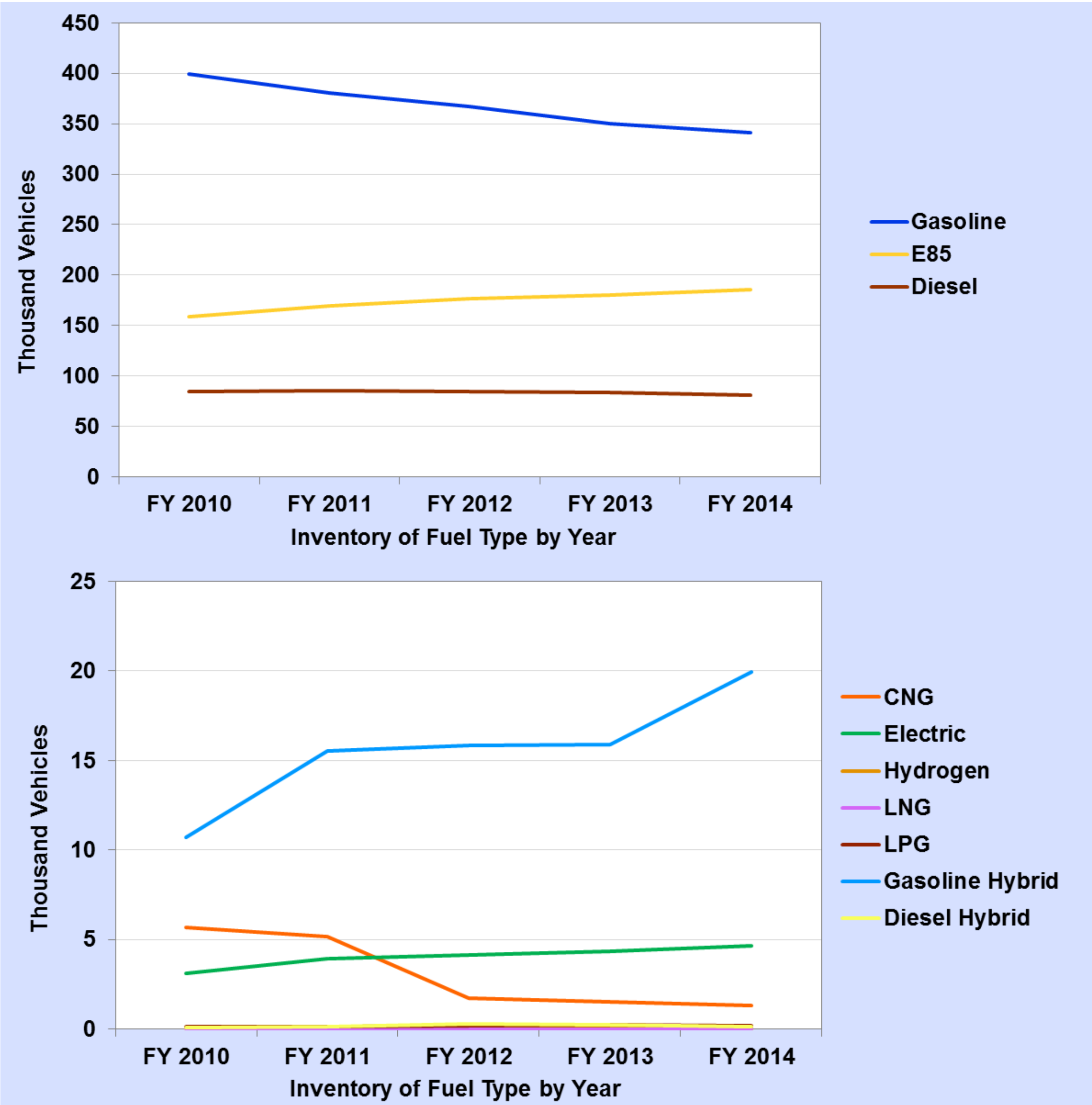

FIGURE 118. Federal Government Vehicles by Fuel Type, 2010-2014

Source:
U.S. General Services Administration, *FY 2014 Federal Fleet Report*, Washington, DC, 2015.
http://www.gsa.gov/portal/content/102943

Commercial Fleets Use Alternative Fuel and Advanced Technology Vehicles

Some commercial fleet owners are realizing the advantages of using alternative fuels and advanced technology vehicles. A list of the top “green” fleets compiled by Bobit Publishing shows that Waste Management uses more than 12,000 alternative fuel vehicles, most of them biodiesel.

TABLE 37. Top 25 Commercial Fleets Using Alternative Fuel and Advanced Technology Vehicles, 2015

	Company	CNG*	Propane*	Flex-Fuel	Biodiesel	Hybrid/ Electric*	Total Alt Fuel
1	Waste Management	933	10	0	11,000	388	12,331
2	AT&T	7,726	0	668	0	2,518	10,912
3	Archer Daniels Midland	0	0	10,214	0	255	10,469
4	Elan Pharmaceuticals	6,051	0	0	0	2,168	8,219
5	Honeywell International, Inc.	514	0	3,500	1,500	1,307	6,821
6	Abbott	1,144	20	2,100	2,300	4	5,824
7	Merck & Co., Inc.	0	0	3,932	0	725	4,657
8	New Jersey Natural Gas Company	3	0	4,402	0	212	4,617
9	AstraZeneca Pharmaceuticals	0	0	1,873	0	2,671	4,544
10	Allergan	0	77	4,175	0	1	4,253
11	Cook's Pest Control, Inc.	200	500	1,000	1,000	1,000	3,800
12	G&K Services	712	0	294	1,201	1,266	3,473
13	Safeway, Inc.	0	0	3,400	0	0	3,400
14	Kraft Foods	0	0	3,000	0	67	3,067
15	Air Products & Chemicals, Inc.	215	118	48	0	2,244	2,631
16	AutoZone	0	0	2,489	0	0	2,489
17	Republic Services	60	0	0	1,741	530	2,331
18	Norfolk Southern Railway Co.	0	0	2,157	0	0	2,157
19	Liberty Mutual Insurance	0	0	0	1,638	504	2,142
20	Yum! Brands Restaurants	0	0	2,000	0	30	2,030
21	Serco Group	30	151	0	0	1,832	2,013
22	McDonald's Corp.	0	0	2,000	0	2	2,002
23	Colgate-Palmolive	0	0	0	0	1,792	1,792
24	Pfizer, Inc.	0	0	1,300	50	35	1,385
25	Aflac	0	0	845	0	0	845

*Includes dedicated and bi-fuel vehicles.

Source:

Bobit Publishing, *Automotive Fleet 500*, “Top 50 Green Fleets,” 2015.
http://digital.automotive-fleet.com/FL5002015

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 200 lb per vehicle from 1995 to 2013 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 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.

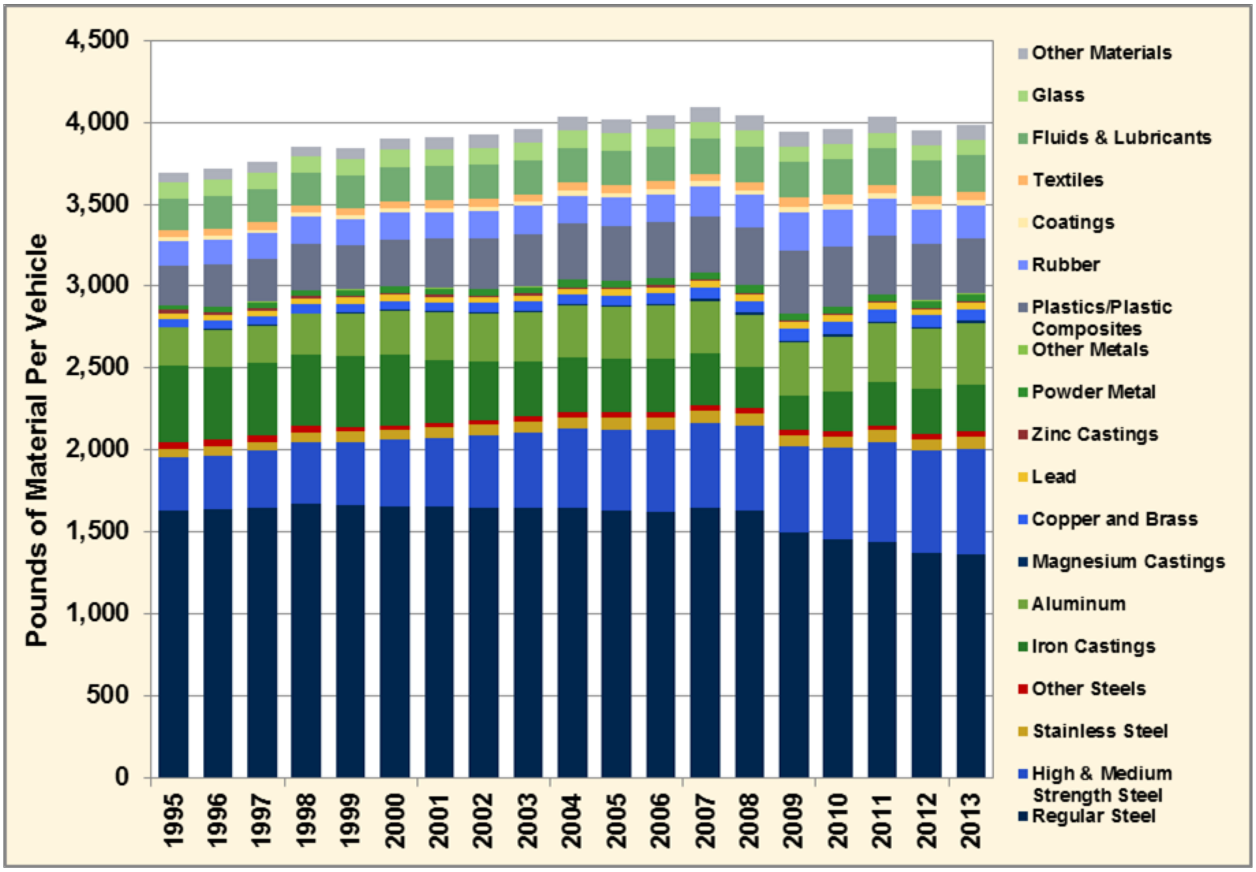

FIGURE 119. Average Materials Content of Light Vehicles, 1995-2013

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

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.

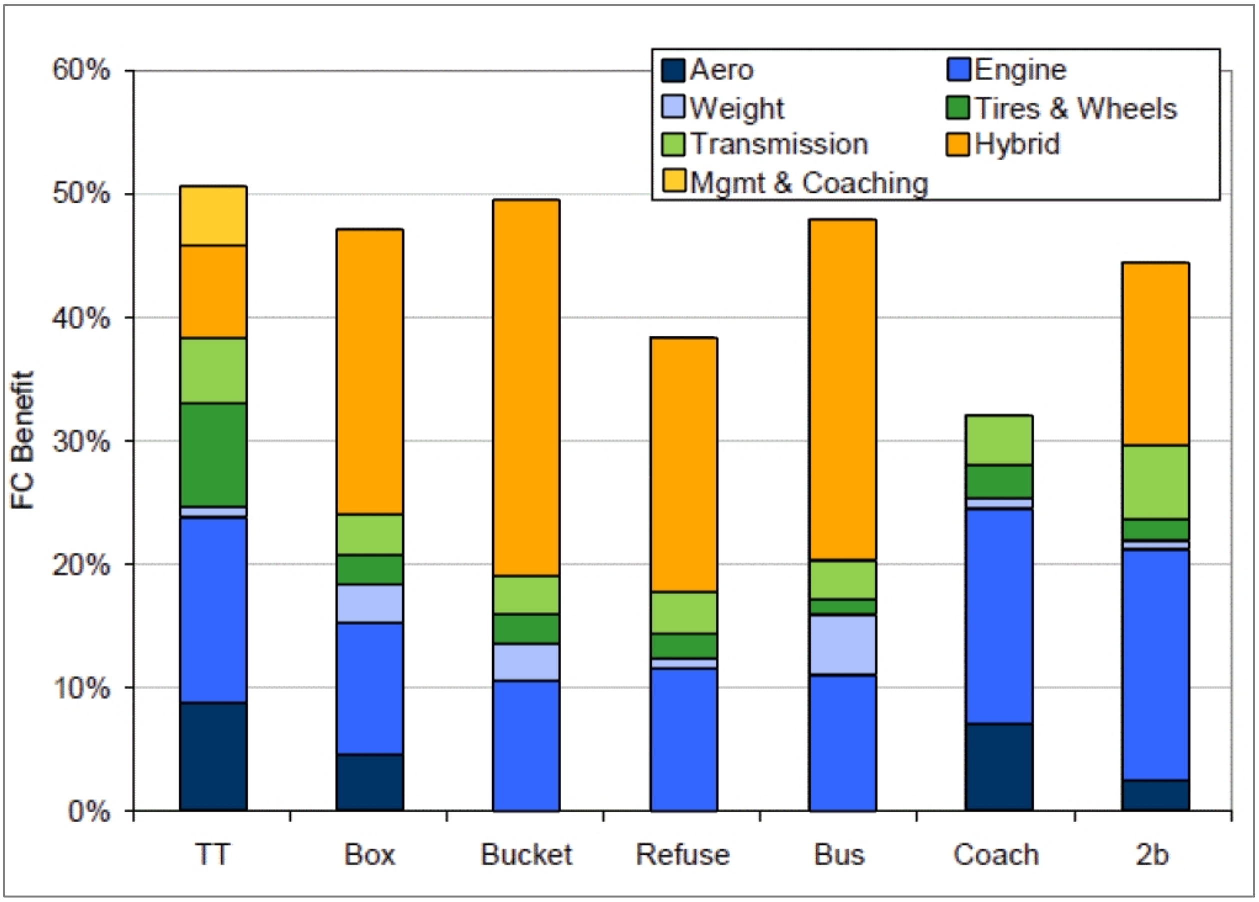

FIGURE 120. Comparison of 2015-2020 New Vehicle Potential Fuel Saving Technologies

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 121. 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 123. Hybrid Bus

FIGURE 122. 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 Encourages Heavy Truck Efficiencies

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 start/stop 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 38. SmartWay Certified Tractor and Trailer Manufacturers

Tractors	Trailers
Daimler	Great Dane Trailers
Kenworth	Hyundai Translead
Mack	Manac Inc.
Navistar	Stoughton Trailers, LLC
Peterbilt	Strick Trailers, LLC
Volvo	Utility Trailer Manufacturing Company
	Vanguard National Trailer Corporation
	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 251 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

New Engine Technologies Can Improve Fuel Economy and Reduce Emissions

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

TABLE 39. 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 39. 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 Have Great Potential for Fuel Savings

TABLE 40. 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 40. 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

Note: OHC = overhead cam; OHV = overhead valve; DOHC = dual overhead cam; AT = automatic transmission; sp = speed.

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 Show Promise

These fuel-saving technologies are currently under development but show promise to improve engine efficiency in the future.

TABLE 41. Fuel-Saving Engine Technologies under Development

Technology	Description
Homogenous Charge Compression Ignition (HCCI)	Homogenous Charge Compression Ignition 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 many of the benefits of a diesel engine such as high efficiency and torque without the emissions drawbacks associated with diesel.
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.

Source:
Compiled from published sources by Bob Boundy, Roltek, Inc., Clinton, TN, 2012.

Hybrid Technologies Can Improve Fuel Economy

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

TABLE 42. 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 break is released or the accelerator is depressed. This type of system can be integrated with regenerative breaking. General Motors has been marketing this system under the name eAssist beginning with 2011 Buick models. Other manufacturers including Ford and Kia are also offering Stop-Start options.
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 at the same time. 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 to 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. Then an internal combustion engine is used to power the vehicle.
Hydraulic Hybrid	Hydraulic hybrid technology is still in the demonstration phase and is well suited to heavy duty vehicles in urban settings with frequent stops like 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. 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, 2012.

Most 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.

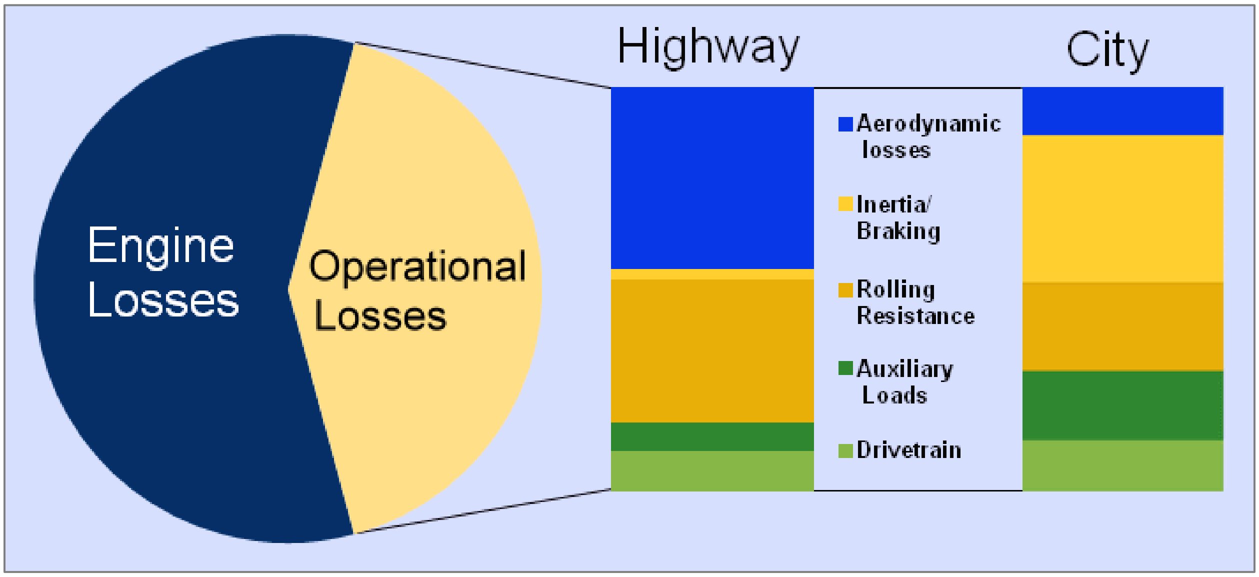

FIGURE 124. Class 8 Truck-Tractor Energy Losses

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

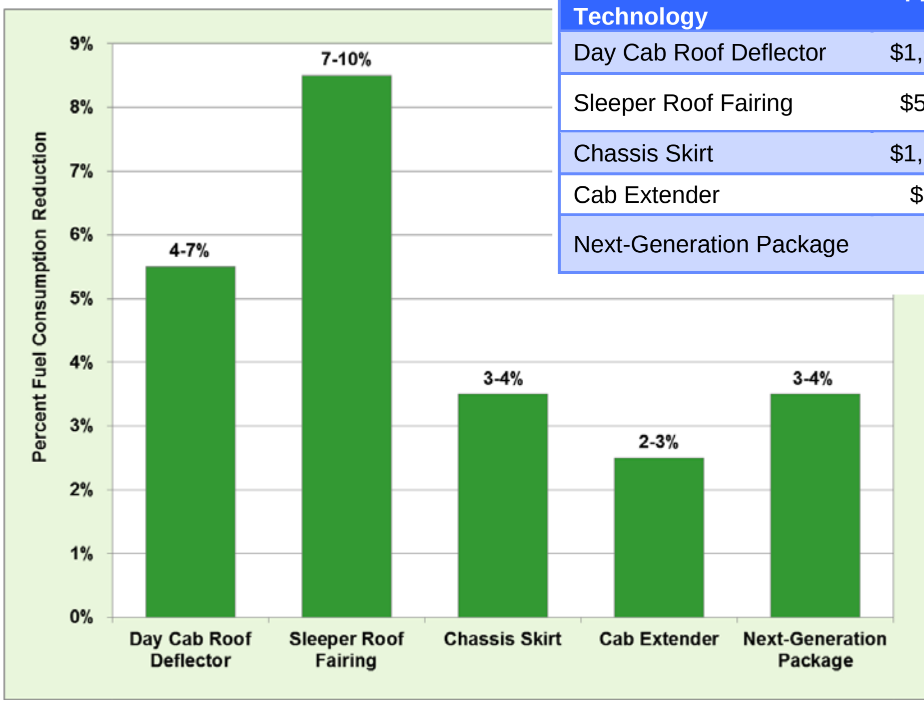

FIGURE 125. Fuel Consumption Reduction Rate, Approximate Cost, and Industry Adoption Rate for Aerodynamic Technologies

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.

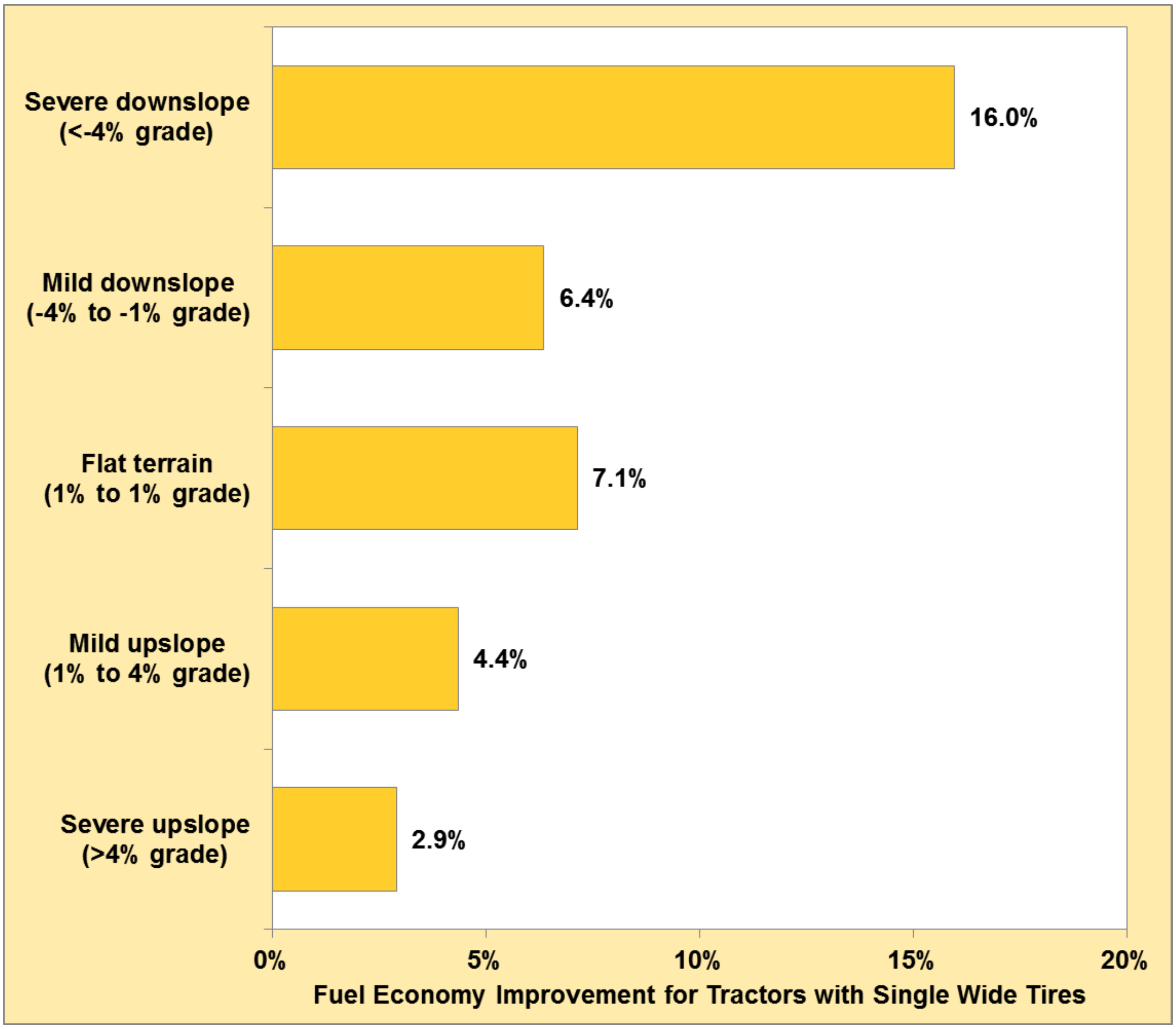

FIGURE 126. Fuel Economy Improvement for Class 8 Tractors with Single Wide Tires

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 5

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 and plug-in hybrid-electric vehicles are the only vehicles for which a Federal tax credit is available – up to $7,500. There are 23 electric vehicles that currently qualify for a credit.

TABLE 43. Federal Government Tax Incentives for All-Electric Vehicles

Calendar Year in which the Vehicle was Purchased	Maximum Credit Amount	Vehicles Currently Eligible for a Tax Credit
2010-on	$7,500	2012 AMP GCE Electric Vehicle
		2012 AMP MLE Electric Vehicle
		2014–16 BMW i3 Sedan
		2012–15 BYD e6 Electric Vehicle
		2010, 2012 CODA Sedan
		2010 Electric Mobile Cars E36 7 Passenger Wagon
		2010 Electric Mobile Cars E36t Pickup Truck
		2010 Electric Mobile Cars E36v Utility Van
		2013–16 Fiat 500e
		2012–16 Ford Focus EV
		2011–12 Ford/Azure Dynamics Transit Connect EV
		2014–16 Chevrolet Spark EV
		2015–16 Kia Soul Electric
		2014–15 Mercedes-Benz B-Class EV
		2012, 2014, 2016 Mitsubishi i-MiEV
		2011–16 Nissan Leaf
		2011, 2013–16 Smart fortwo electric vehicle
		2012–15 Tesla Model S
		2008–11 Tesla Roadster
		2011 Think City EV
		2012–14 Toyota RAV4 EV
		2015–16 VW e-Golf
		2011 Wheego LiFe

Source:

U.S. Department of Energy, Fuel Economy data, http://www.fueleconomy.gov/feg/taxcenter.shtml. Data accessed March 15, 2016.

Battery Capacity Determines Maximum Federal Tax Credit for Plug-In Hybrid Electric Vehicles

The Federal Government encourages the use of plug-in hybrid electric vehicles by allowing tax credits on vehicle purchases. The maximum amount of credit is dependent on the vehicle's battery capacity. There are 19 plug-in hybrid electric vehicles that currently qualify for a credit—eight of them qualify for the highest credit amount of $7,500.

TABLE 44. Federal Government Tax Incentives for Plug-In Hybrid Electric Vehicles

Calendar Year in which the Vehicle was Purchased	Maximum Credit Amount	Vehicles Currently Eligible for a Tax Credit
2010-on	$2,500	2012–15 Toyota Prius Plug-in Hybrid
	$3,626	2014 Honda Accord Plug-in Hybrid
	$3,667	2015 Porsche 918 Spyder
	$3,793	2014–15 BMW i8
	$4,007	2013–16 Ford C-Max Energi
	$4,007	2013–16 Ford Fusion Energi
	$4,042.90	2015 Mercedes-Benz S500e Plug-in Hybrid
	$4,585	2016 Volvo XC-90 T8 Twin Engine Plug in Hybrid
	$4,668	2016 BMW X5 xDrive40e
	$4,751.80	2014–15 Porsche Panamera S E-Hybrid
	$5,335.60	2015 Porsche Cayenne S E-Hybrid
	$7,500	2014–16 BMW i3 Sedan w/ Range Extender
		2012 Fisker Karma Sedan
		2014, 2016 Cadillac ELR
		2011–16 Chevrolet Volt
		2014 2500 VIA Extended Range Electric Passenger Van
		2014 1500 VIA Extended Range Electric Truck 4WD
		2014 2500 Extended Range Electric Cargo Van
		2014 1500 VIA Extended Range Electric Truck 2WD

Source:
U.S. Department of Energy, Fuel Economy data, http://www.fueleconomy.gov/feg/taxcenter.shtml. Data accessed March 15, 2016.

Colorado Had the Highest State Incentive for Plug-In Vehicles in 2015

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. Colorado, Connecticut and Louisiana have the highest incentives for tax credits. New Jersey offers the only sales and use tax exemptions; and DC offers the only title tax exemption and reduced registration fee.

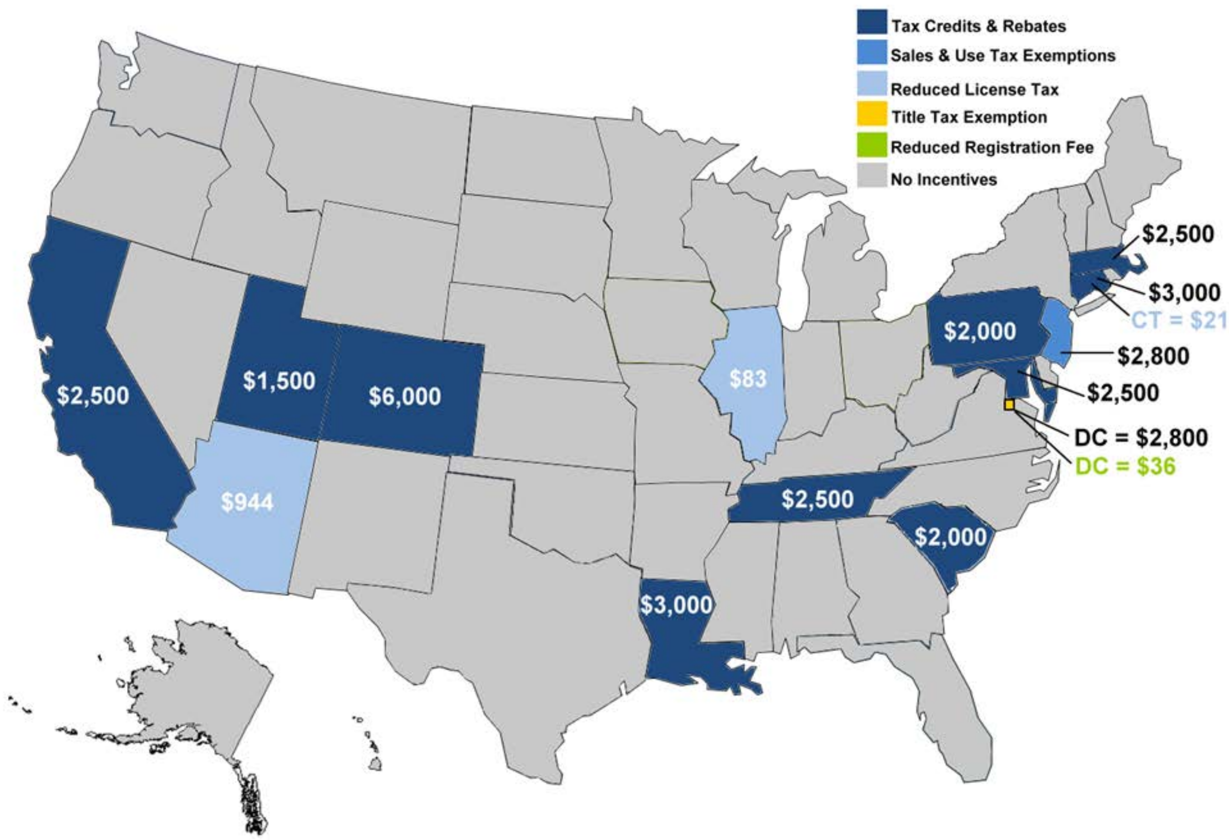


FIGURE 127. Plug-In Electric Vehicle Incentives by State, July 2015

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 lbs., 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 July 20, 2015. http://www.afdc.energy.gov/laws
Data compiled by SRA International, Inc.

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 consumers are paying per gallon in each state. 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 8-cent gasoline tax rate, has by far the lowest gasoline tax rate of any state.

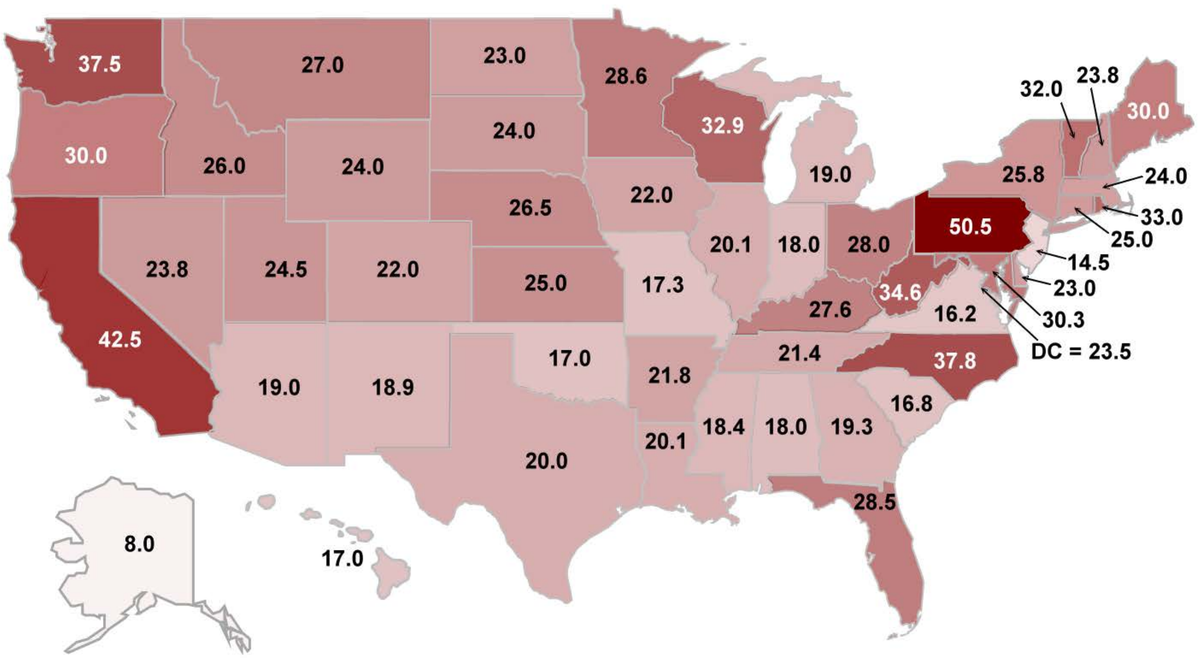


FIGURE 128. State Gasoline Tax Rates, 2015 (Cents per Gallon)

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

Source:

Compiled by Federation of Tax Administrators from various sources, January 2015. Data accessed September 29, 2015. 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.

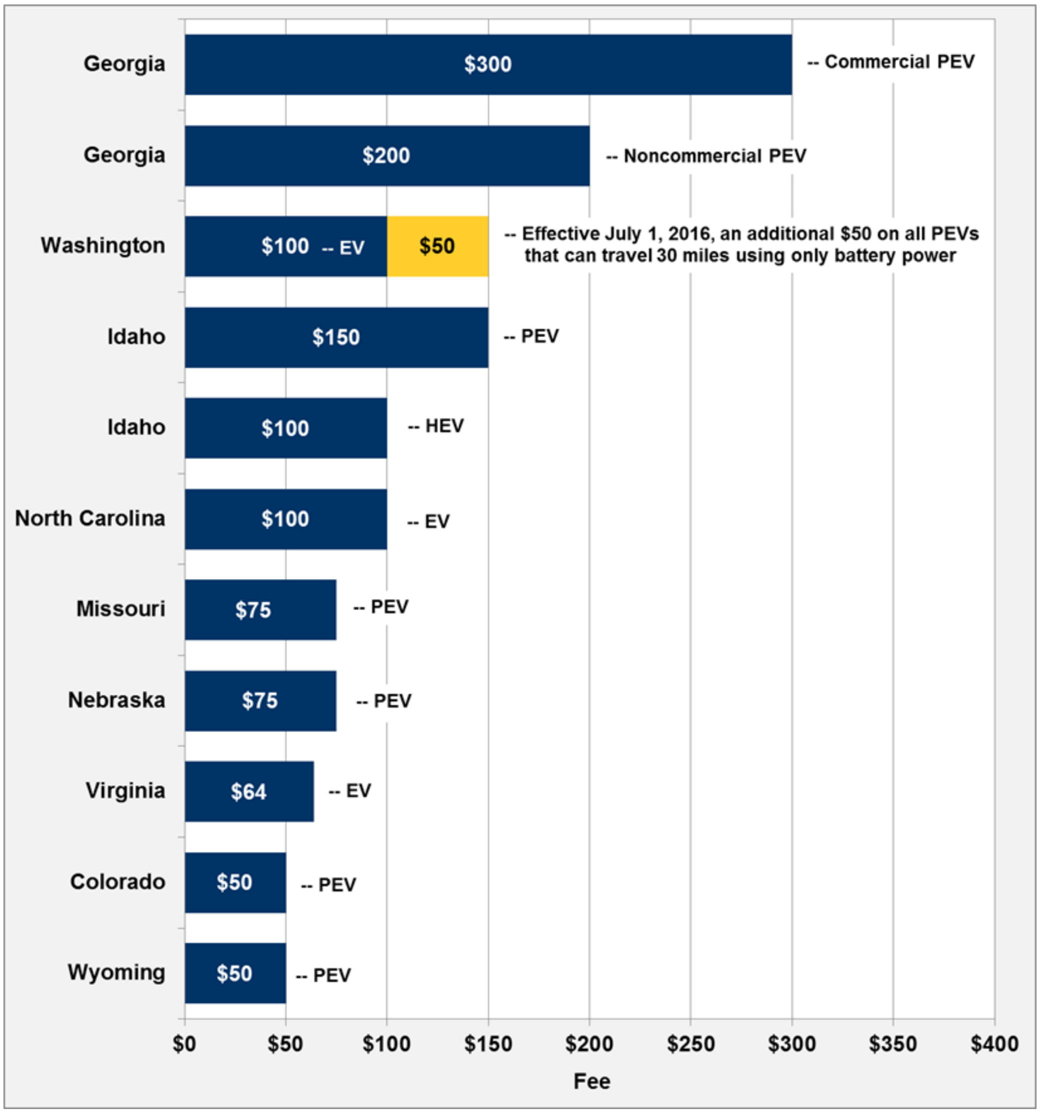


FIGURE 129. Annual State Fees for Electric Vehicle Owners as of September 2015

Source:
Alternative Fuels Data Center, U.S. Department of Energy, Federal and State Laws and Incentives, data accessed September 3, 2015. 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. 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.

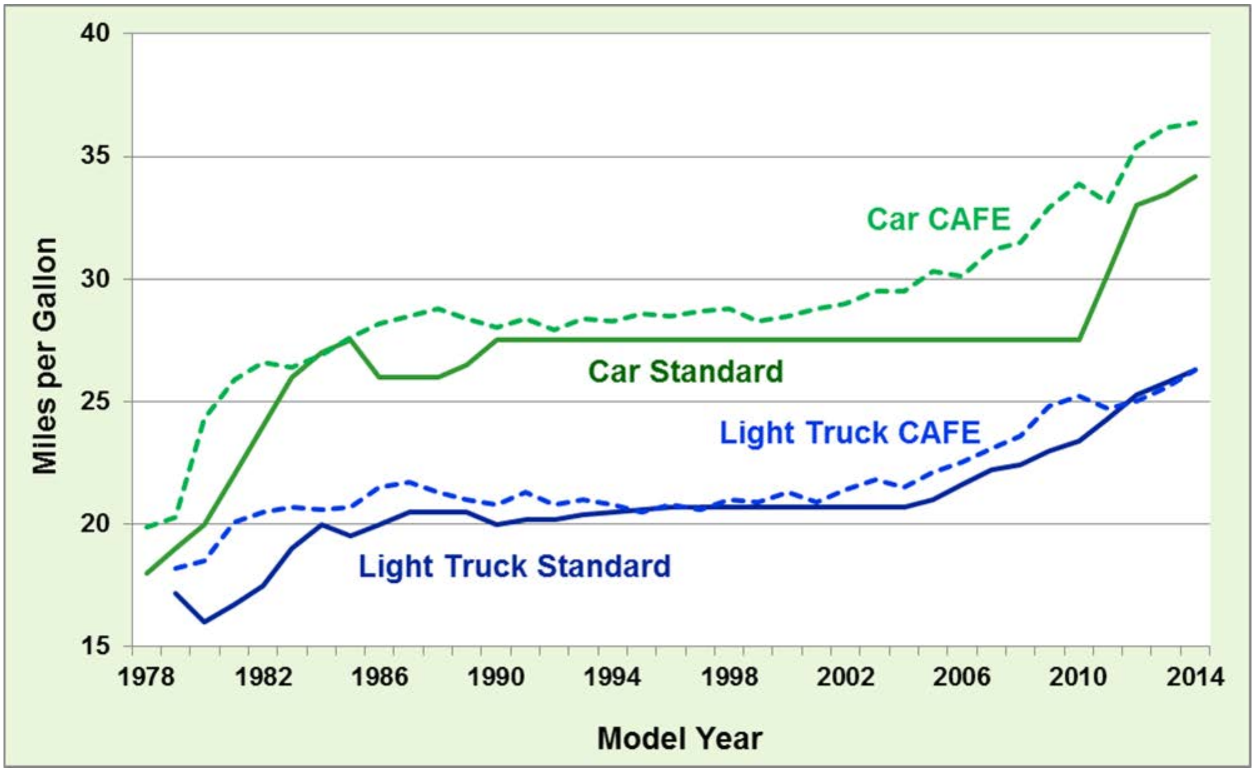


FIGURE 130. CAFE for Cars and Light Trucks, 1978-2014

Note: Light truck standards for MY 2008-2010 are based on "unreformed" standards. MY 2013 and 2014 data are estimates based on product plans.

Source:
National Highway Traffic Safety Administration, "Summary of Fuel Economy Performance," December 2014. http://www.nhtsa.gov/fuel-economy

Corporate Average Fuel Economy (CAFE) Improves for All Manufacturers from 2002 to 2014

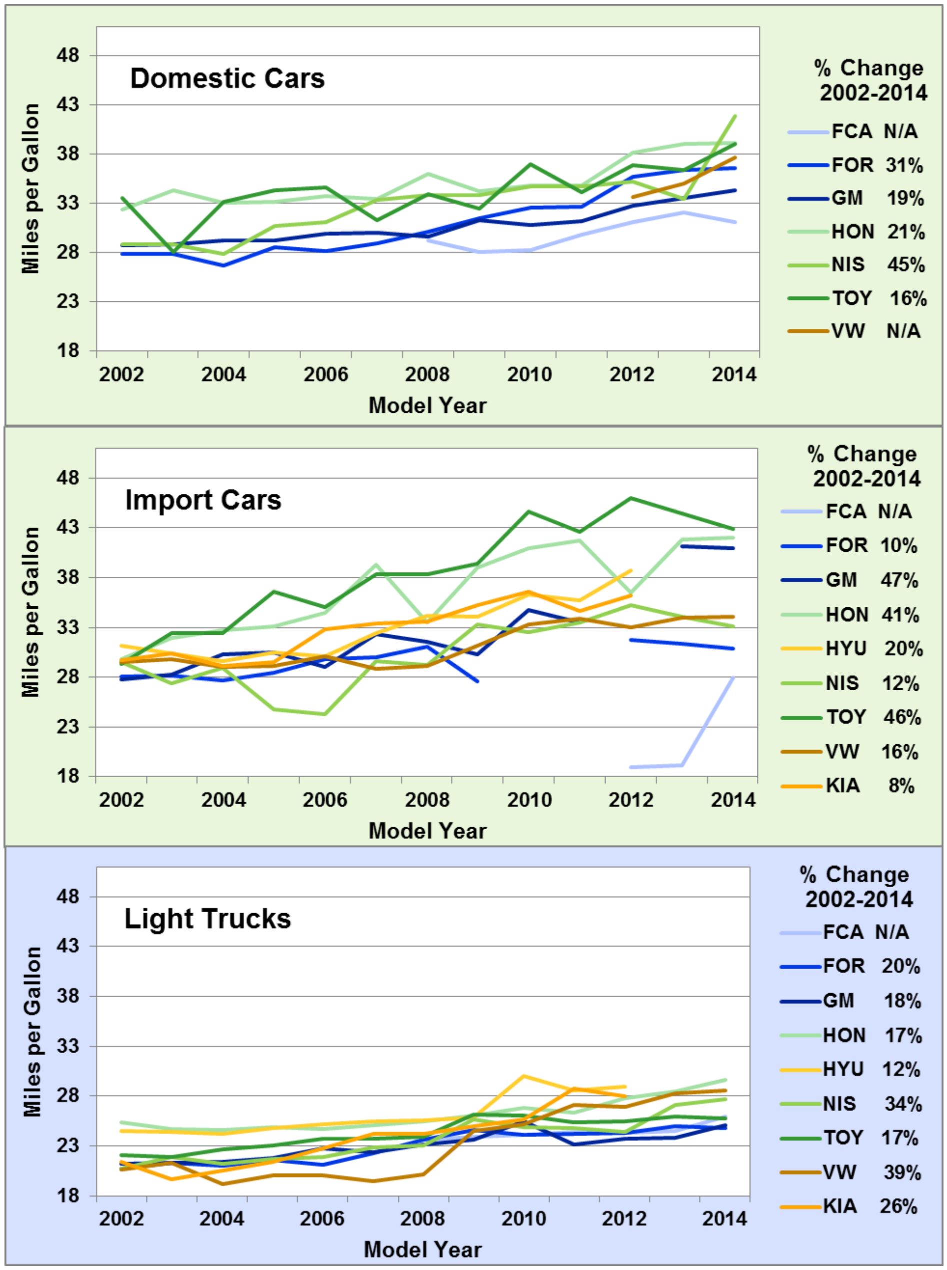


FIGURE 131. CAFE for Domestic and Import Cars and Light Trucks by Manufacturer, 2002-2014

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. 2013 data was not available for Hyundai and Kia.

Source:

National Highway Traffic Safety Administration, "Summary of Fuel Economy Performance," December 2014. 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.

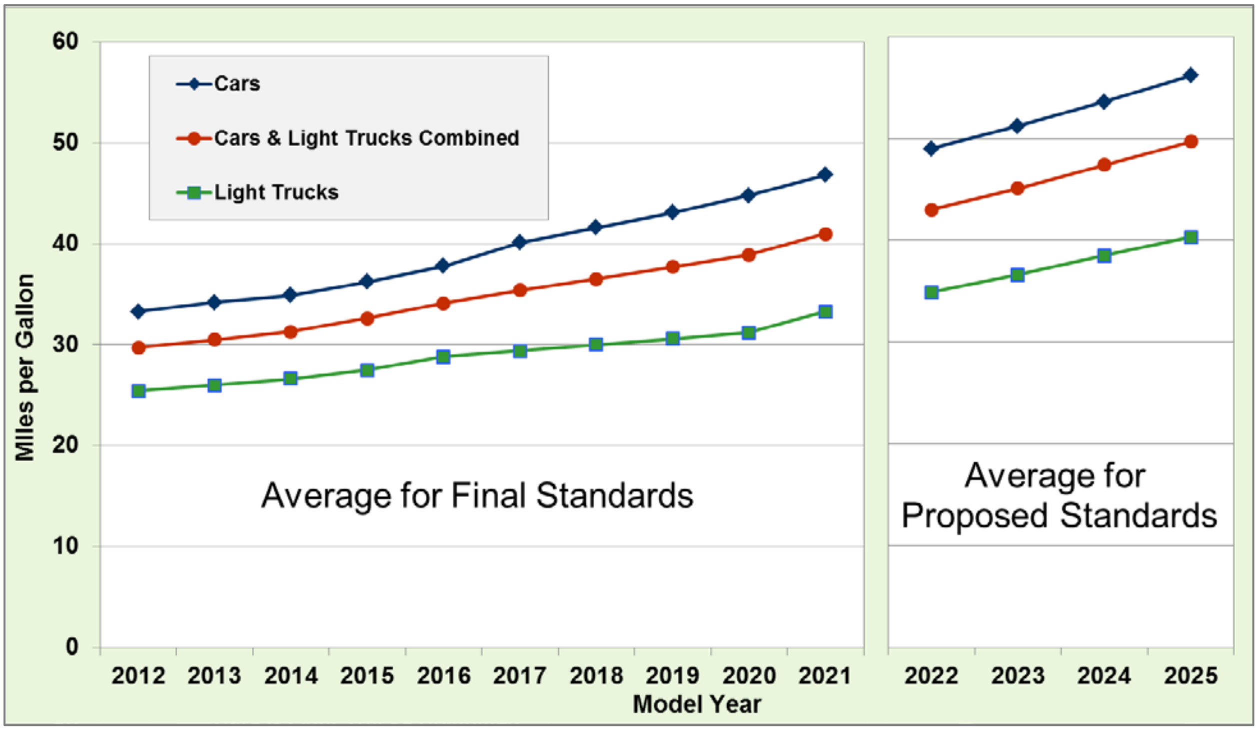


FIGURE 132. Average CAFE Standards for MY 2012-2025

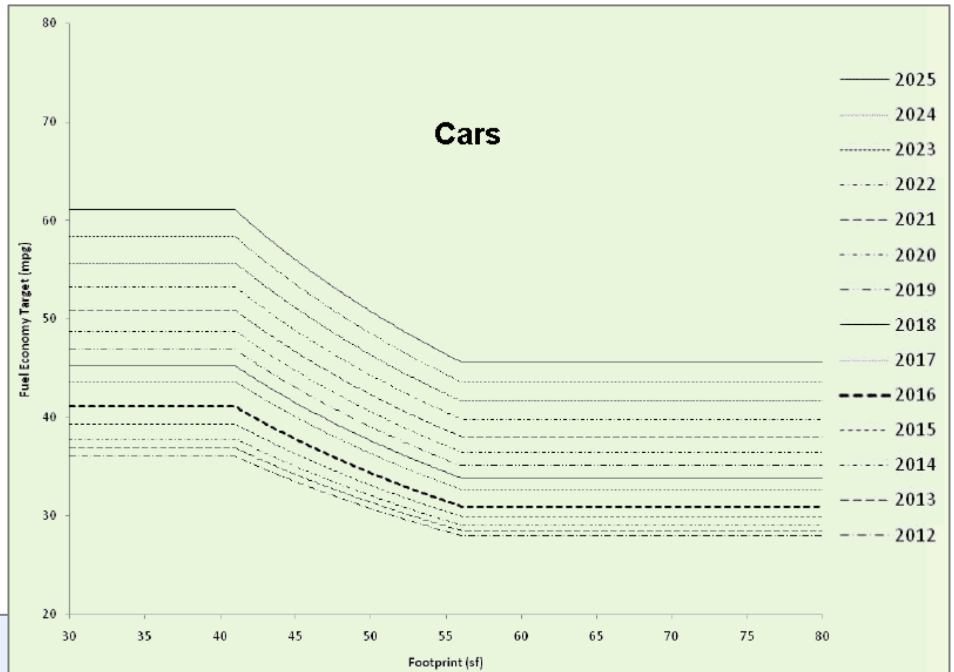
Notes: A MY 2008 baseline was used for MY 2017-2025.
The presented rates of increase in stringency for NHTSA CAFE standards are lower than the Environmental Protection Agency (EPA) rates of increase in stringency for greenhouse gas (GHG) standards. One major difference is that NHTSA's standards, unlike 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 Standards for New Cars and Light Trucks

Beginning in 2012, the Corporate Average Fuel Economy (CAFE) standards are based on a vehicle's footprint, where each vehicle has a different fuel economy target depending on its footprint. The footprint is calculated as the vehicle's track width times the wheelbase (i.e., the distance between the wheels [width] multiplied by the distance between the axles [length]). In general, as the vehicle footprint increases, the fuel economy standard the vehicle has to meet decreases. Footprint-based standards help to distribute the burden of compliance across all vehicles and manufacturers.

Note:
Standards from 2022 to 2025 are proposed standards.



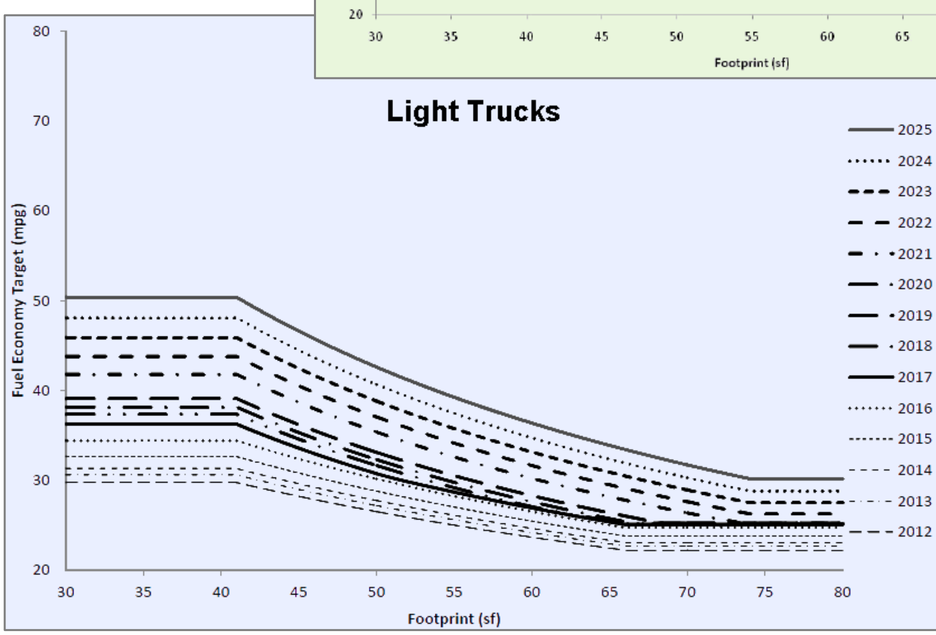


FIGURE 133. CAFE Standards for Cars and Light Trucks, MY 2012-2025

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 Standards have fuel economy targets based on the vehicle footprint. The average footprint for all cars sold in model year (MY) 2014 was 45.9 square feet (sq. ft.), up just 0.5 sq. ft. from MY 2010. The average footprint for light trucks was higher – 54.4 sq. ft. in 2014. The table shows selected vehicles and their MY 2012 footprint with 2025 fuel economy targets.

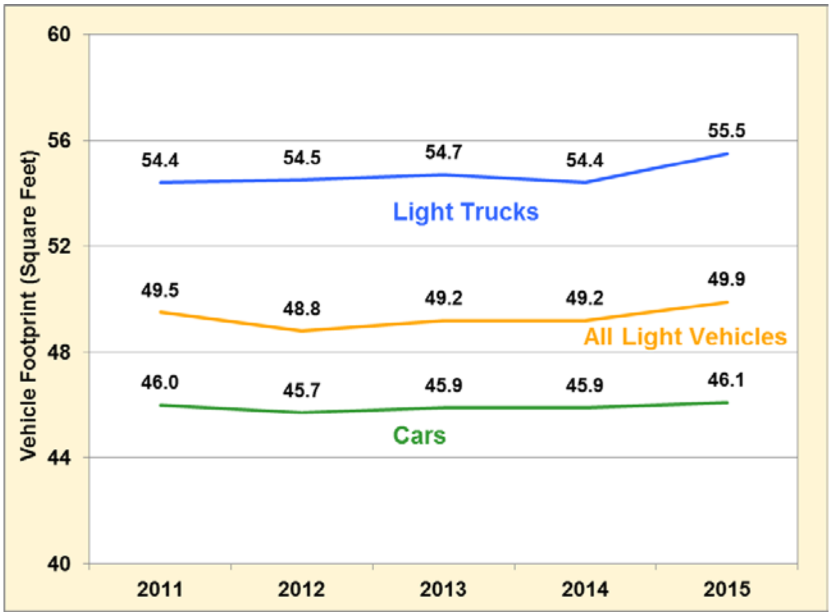


FIGURE 134. Average Vehicle Footprint, MY 2011-2015

TABLE 45. 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 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

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

GM Has the Highest Car and Light Truck Footprint

The Corporate Average Fuel Economy (CAFE) standards are based on the vehicle's footprint beginning in model year (MY) 2012. In MY 2015, GM had the highest sales-weighted average footprint for both cars and light trucks, thus would have the least stringent standards to meet according to the new CAFE methodology. MY 2015 data are preliminary.

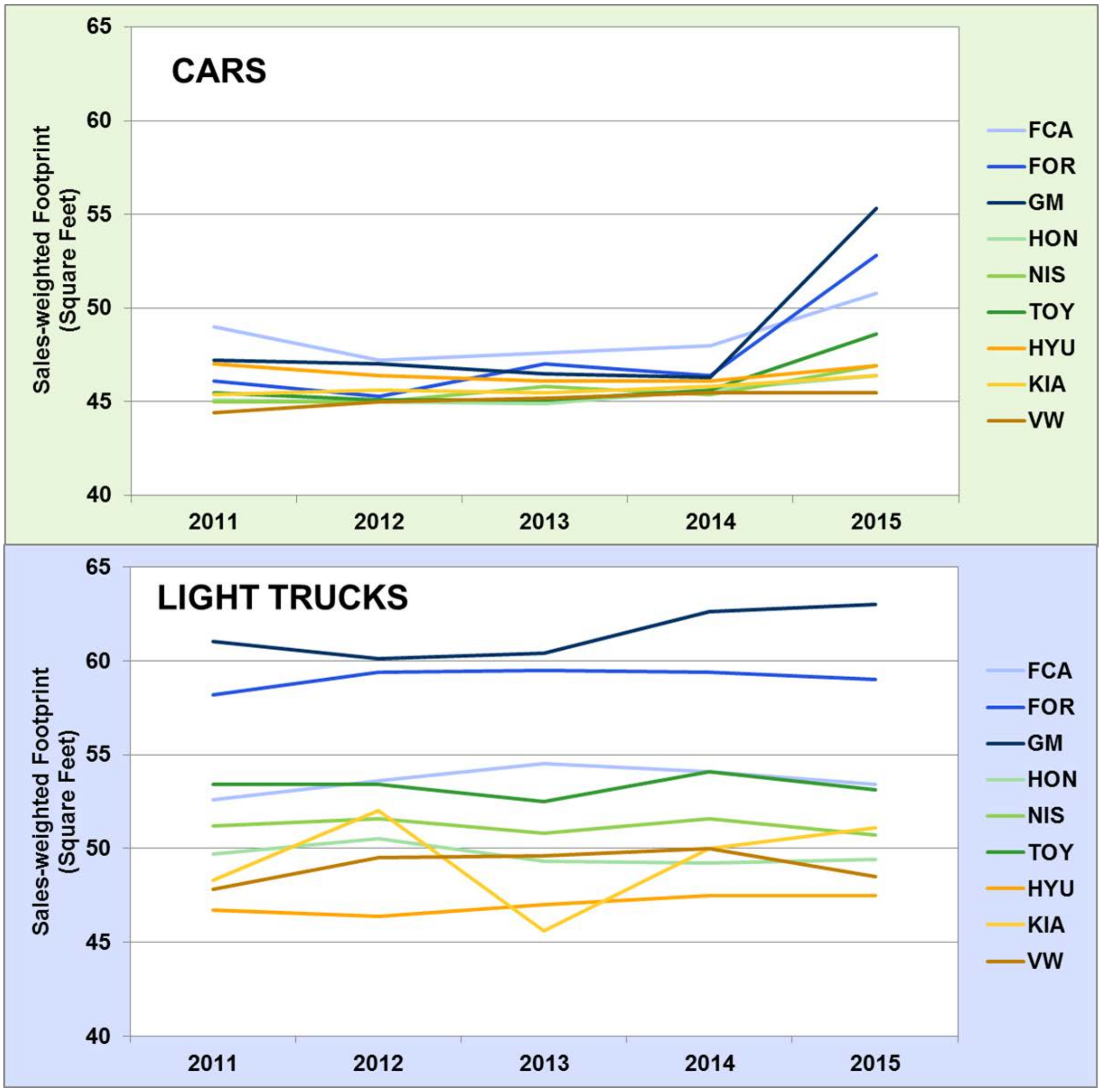


FIGURE 135. Car and Light Truck Footprint by Manufacturer, 2015

Sources:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2015*, EPA-420-S-15-001, December 2015. http://www.epa.gov/otaq/fetrends.htm

Honda, Toyota, Nissan, and Tesla Have Sold CAFE 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 2014, Honda had sold CAFE credits to other manufacturers. Toyota, Tesla, and Nissan also sold credits, while Ferrari, Mercedes-Benz, and FCA purchased credits.

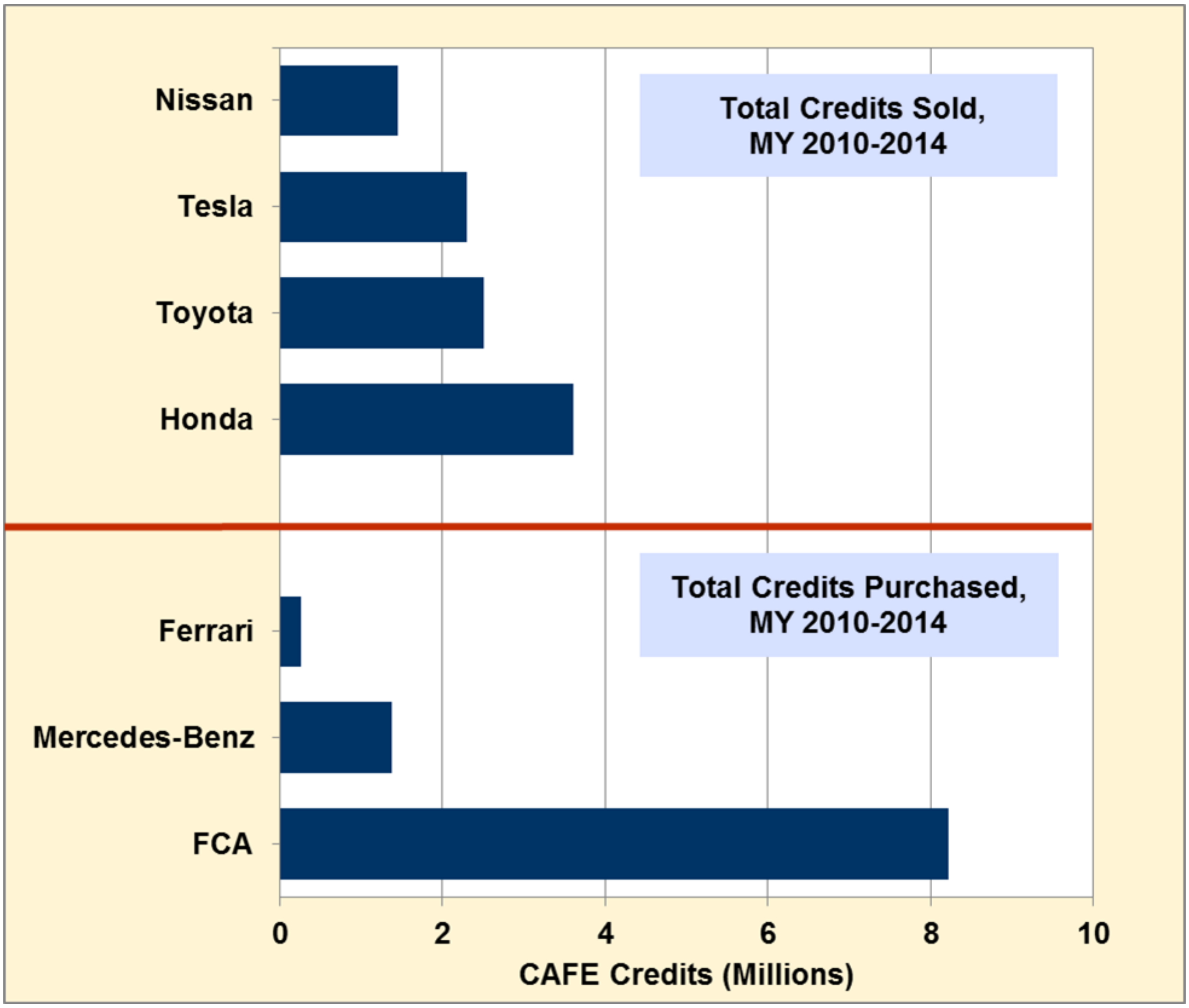


FIGURE 136. Cumulative CAFE Credits Sold and Purchased by Manufacturer at the End of MY 2014

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2014 Model Year*, EPA-420-R-15-026, December 2015. http://www.epa.gov/otaq/climate/documents/420r15026.pdf

Nearly All Manufacturers Have CAFE Credits at the End of 2014

Some 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 2014, all manufacturers but four (Jaguar Land Rover, Aston Martin, McLaren, and Lotus) carried a positive balance of credits into MY 2015. This does not, however, mean any manufacturer is out of compliance, as the regulation allows for a deficit to be carried over up to three model years.

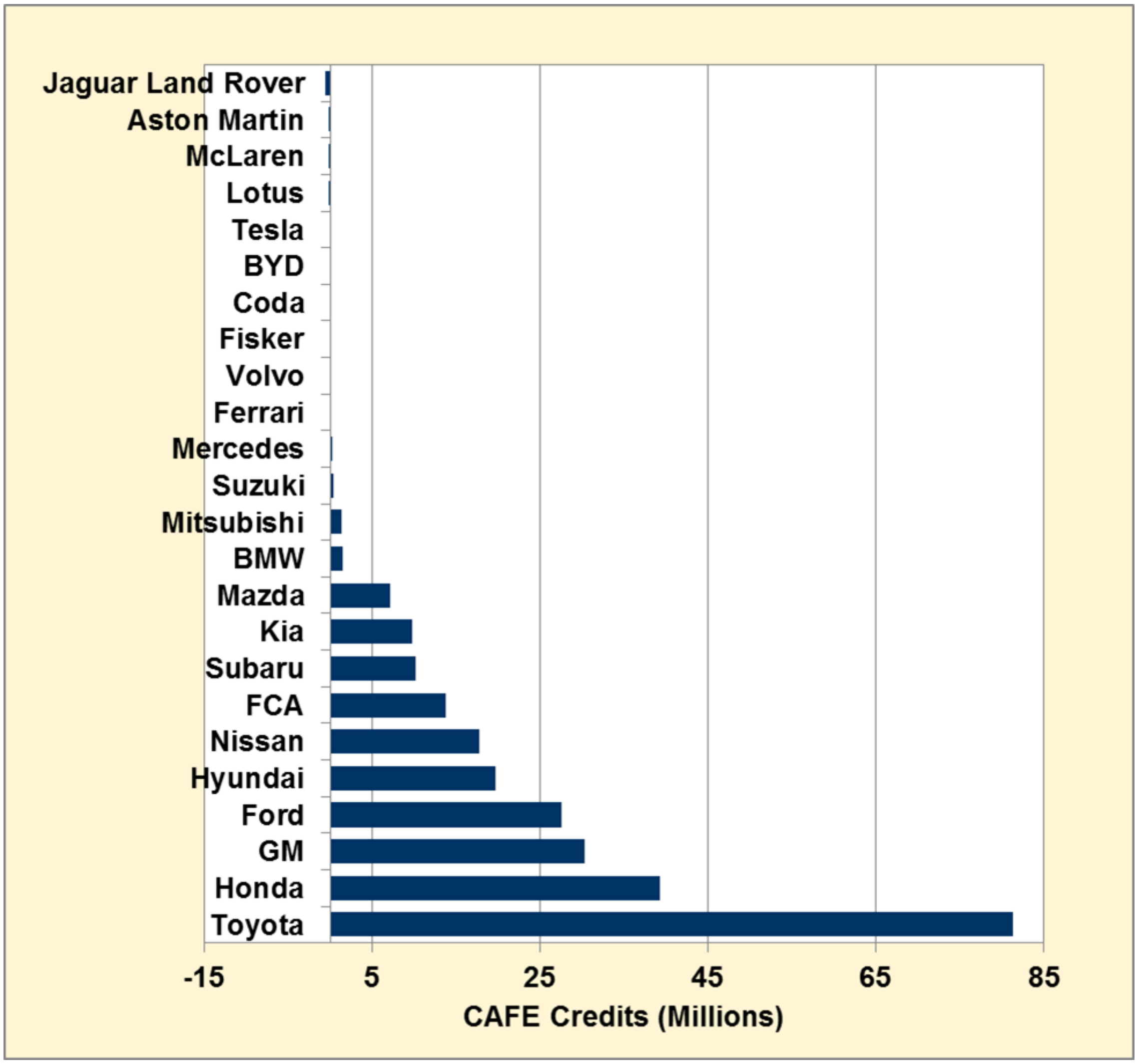


FIGURE 137. Cumulative CAFE Credits by Manufacturer as of the End of MY 2014

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2014 Model Year*, EPA-420-R-15-026, December 2015. http://www.epa.gov/otaq/climate/documents/420r15026.pdf

Zero-Emission Vehicle Standards in Eight 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." 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.

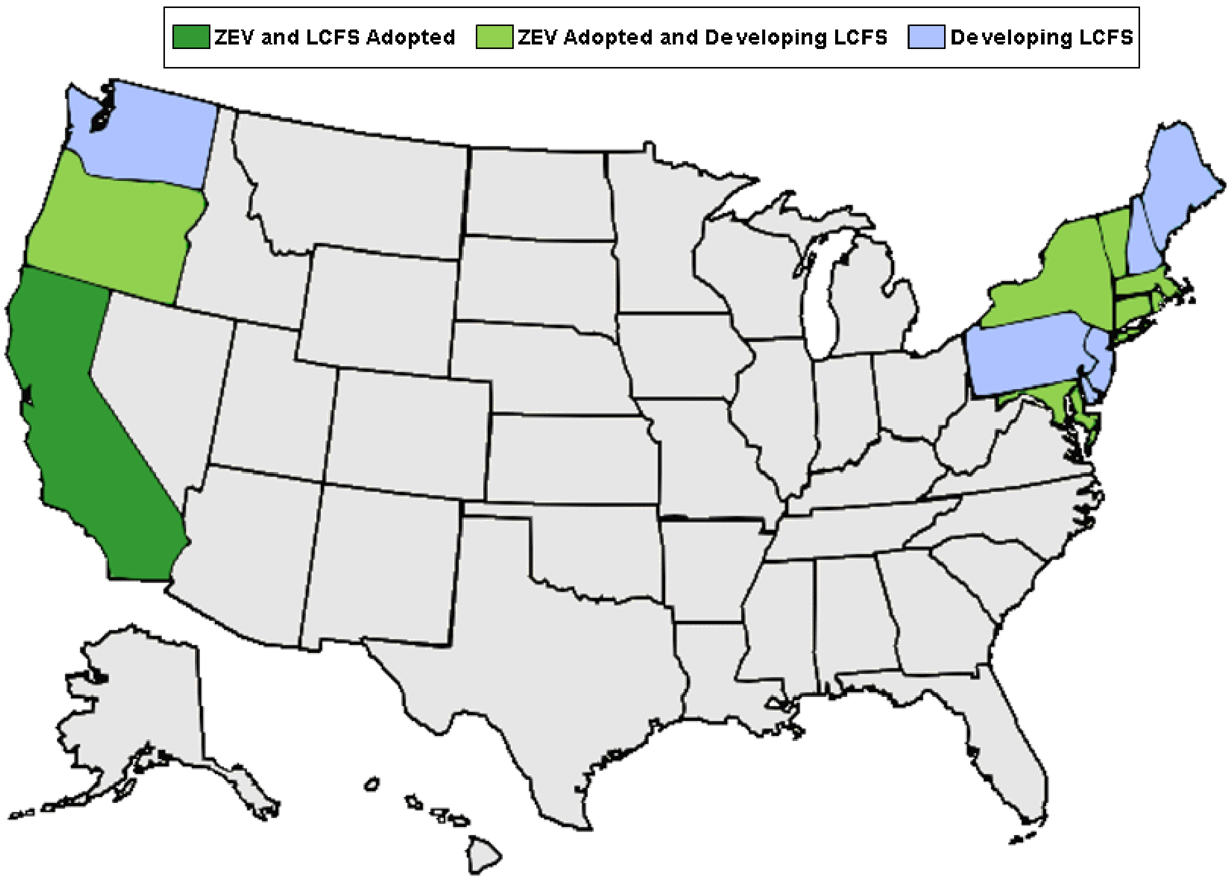


FIGURE 138. States with Zero Emission Vehicle and Low Carbon Fuel Standards

Source:
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, Low Carbon Fuel Standard.
http://www.c2es.org/us-states-regions/policy-maps/low-carbon-fuel-standard

Tesla Transferred Over 1,500 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, 2014 and September 30, 2015, seven manufacturers transferred credits out of their balances, and seven more transferred credits into their balances. The transfer of credits allows each manufacturer to strategically comply with the regulation.

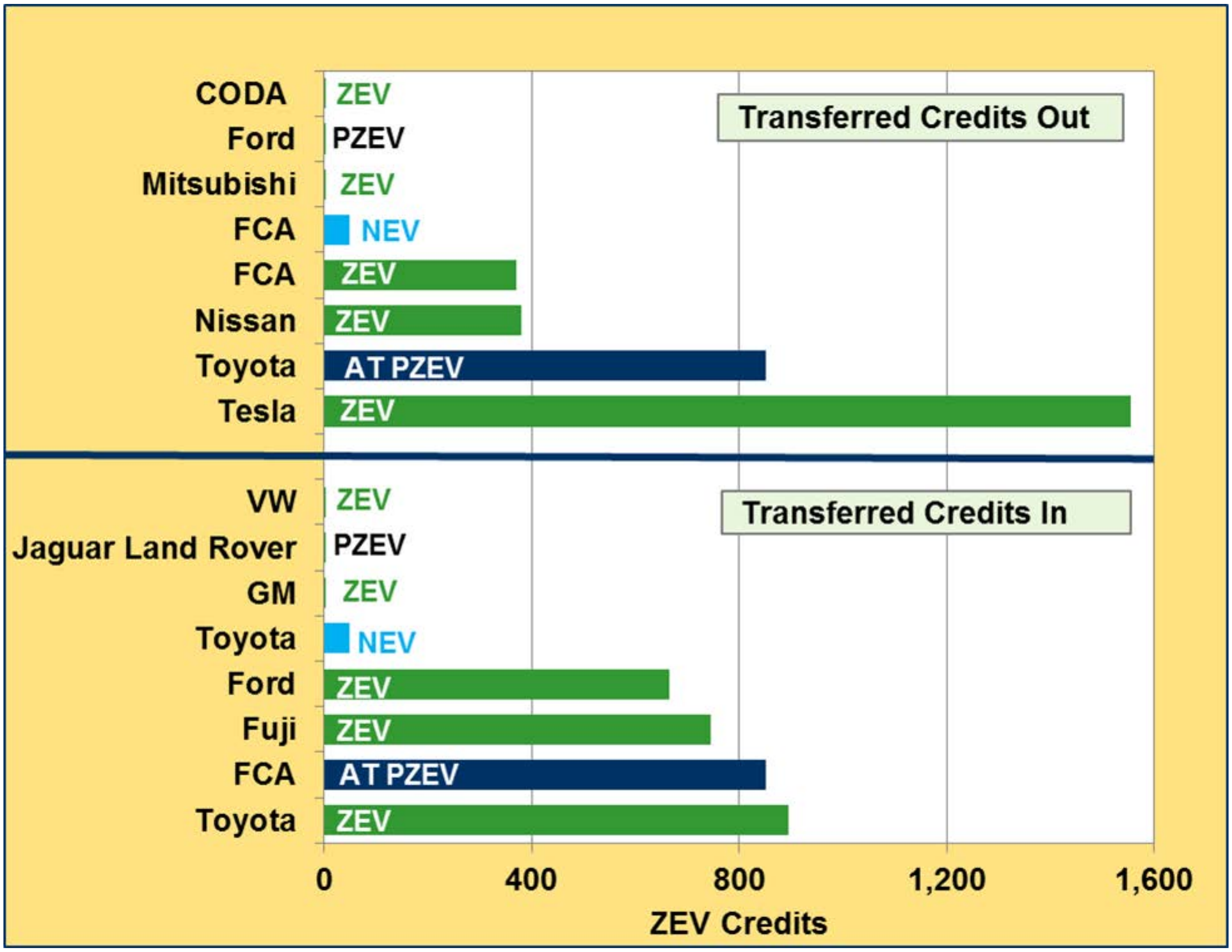


FIGURE 139. California Zero Emission Vehicle Credit Transfers, FY 2015

Note: Transfers between October 1, 2014 and September 30, 2015. PZEV = Partial zero emission vehicle; AT PZEV = Advanced technology partial emission vehicle; NEV = Neighborhood electric vehicle.

Source:

California Air Resources Board, "2014 Zero Emission Vehicle Credits," http://www.arb.ca.gov/msprog/zevprog/zevcredits/2014zevcredits.htm, accessed March 17, 2016.

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 2014. Tesla, the only manufacturer to produce exclusively ZEVs, has transferred many credits to other manufacturers.

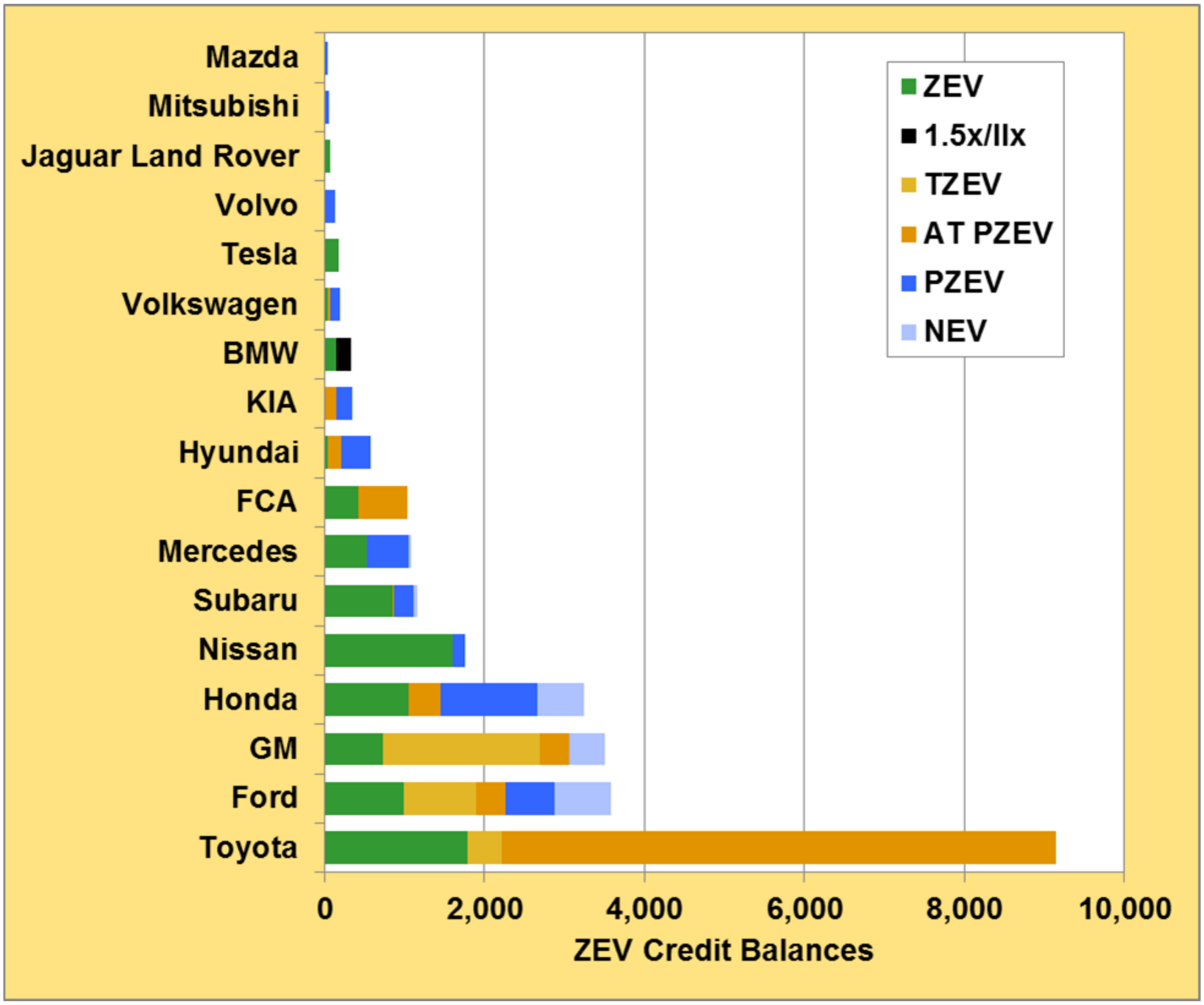


FIGURE 140. California Zero Emission Vehicle Credit Balances by Manufacturer, September 2015

Note: 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, "2014 Zero Emission Vehicle Credits," http://www.arb.ca.gov/msprog/zevprog/zevcredits/2014zevcredits.htm, accessed March 17, 2016.

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.

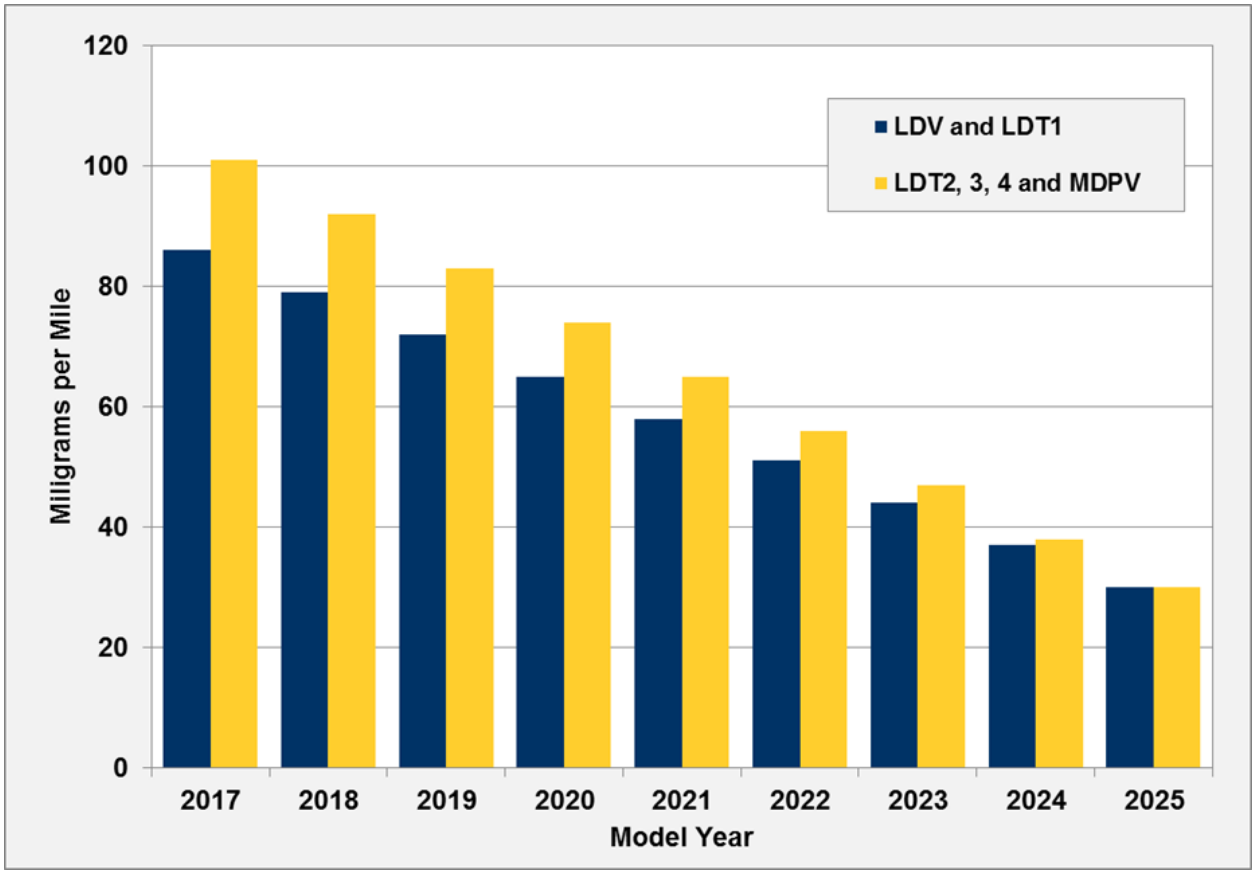


FIGURE 141. Tier 3 NMOG+NOx Emission Standards for Light Gasoline Vehicles, MY 2017-2025

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

Source:
U.S. Environmental Protection Agency, http://www.epa.gov/otaq/tier3.htm.

Tier 3 Particulate Emission Standards for Light Gasoline Vehicles Are 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.

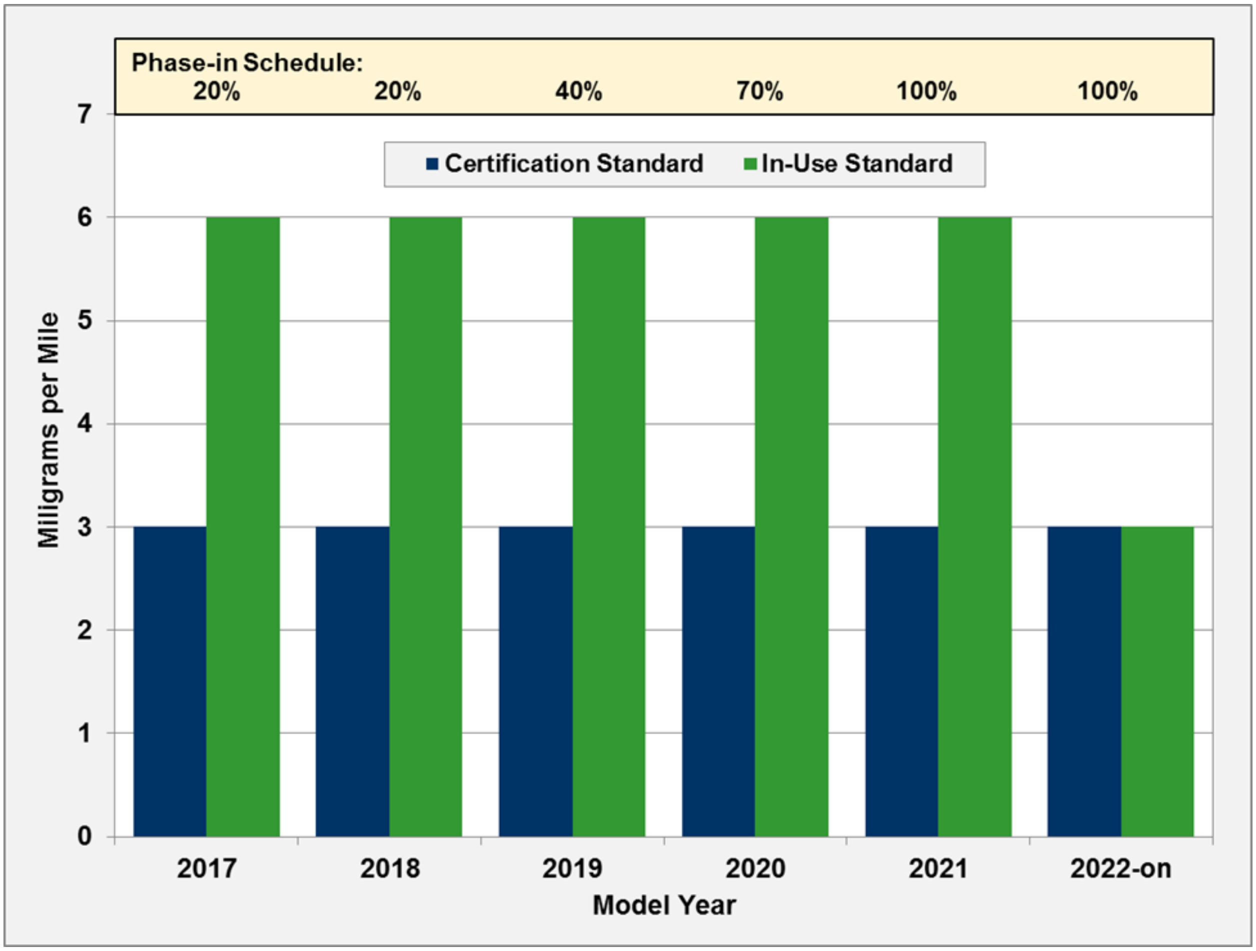


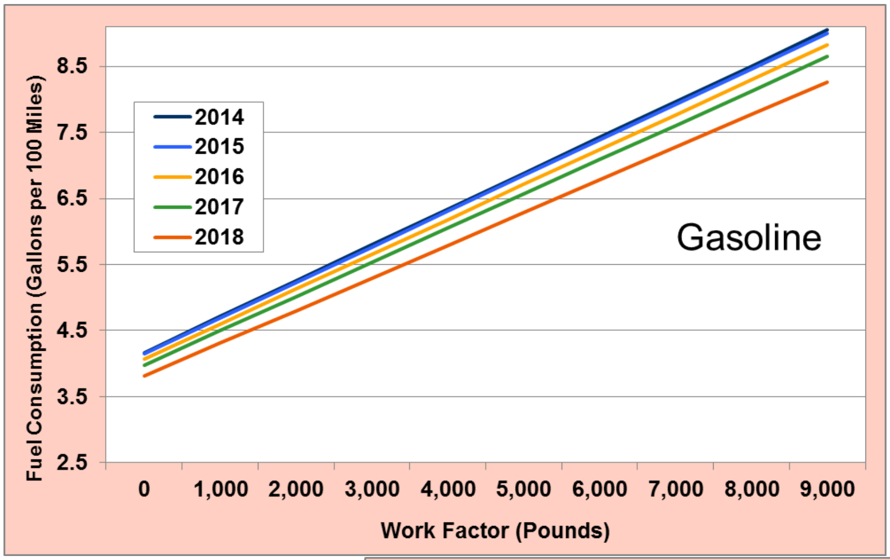
FIGURE 142. Tier 3 Particulate Matter Emission Standards for Light Gasoline Vehicles, MY 2017 and Beyond

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 lbs. gross vehicle weight rating, the standards apply beginning in MY 2018.

Source:
U.S. Environmental Protection Agency, http://www.epa.gov/otaq/tier3.htm.

Fuel Consumption Standards Set for Heavy Pickups and Vans through 2018 and Standards Proposed through 2027

In September 2011 the National Highway Traffic Safety Administration (NHTSA) issued the final rule to set standards regulating the fuel use of new vehicles—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. In July 2015, NHTSA proposed standards through MY 2027 in Federal Register Vol. 80, No. 133, pp. 40137-40766. Final standards have not been set.



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.

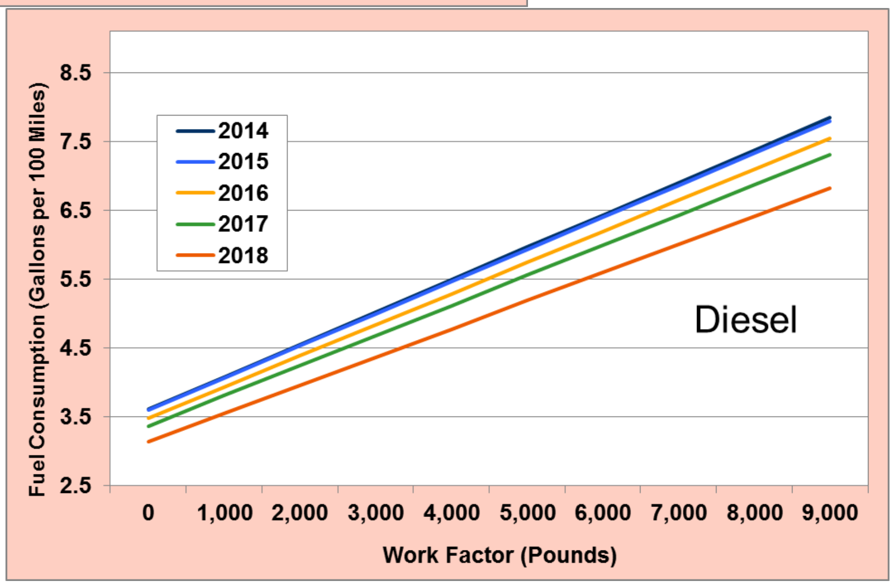


FIGURE 143. Fuel Consumption Target Standards for Gasoline and Diesel Heavy Pickups and Vans, MY 2014-2018

Source:
Federal Register, Vol. 76, No. 179, September 15, 2011, pp. 57105 - 57513.

Fuel Consumption Standards Set for Combination Tractors through 2017 and Standards Proposed through 2027

The National Highway Traffic Safety Administration (NHTSA) published a final rule setting fuel consumption standards for heavy trucks in September 2011. 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). Standards for model years (MY) 2018-2027 were proposed by NHTSA in July 2015 but final standards have not been set.

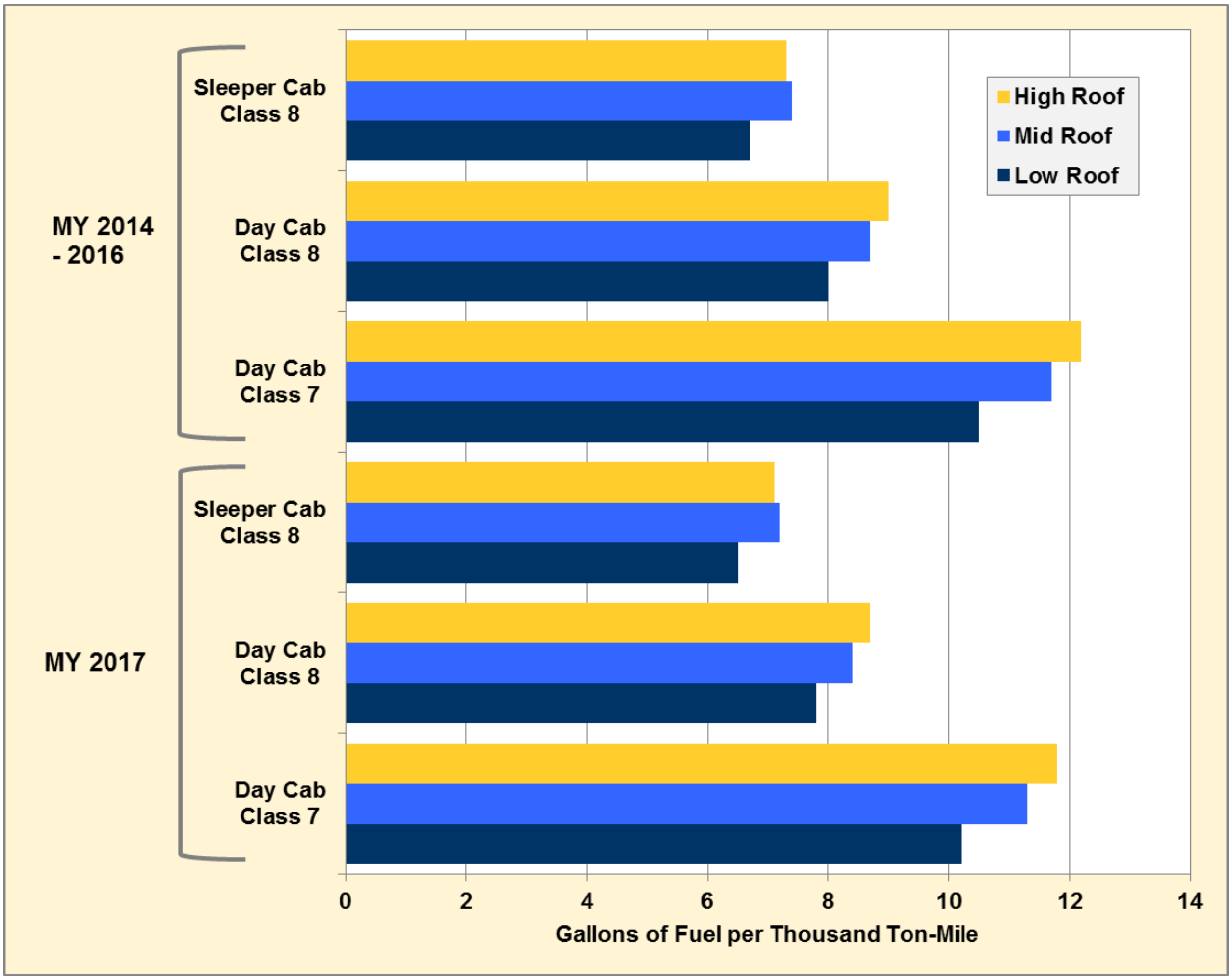


FIGURE 144. Fuel Consumption Standards for Combination Tractors, MY 2014-2017

Note: The standards for 2014 and 2015 are voluntary. Class 7 trucks have a gross vehicle weight rating between 26,000 and 33,000 lbs. Class 8 trucks have a gross vehicle weight rating over 33,000 lbs.

Source:
Federal Register, Vol. 76, No. 179, September 15, 2011, pp. 57105 - 57513.

Fuel Consumption Standards Set for Vocational Vehicles through 2017 and Standards Proposed through 2027

The National Highway Traffic Safety Administration (NHTSA) published final 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. Because of the complexities associated with the wide variety of body styles, NHTSA decided to finalize a set of standards beginning in 2016 for the chassis manufacturers of vocational vehicles. NHTSA-proposed standards from MY 2018-2027 were published in the Federal Register on July 13, 2015.

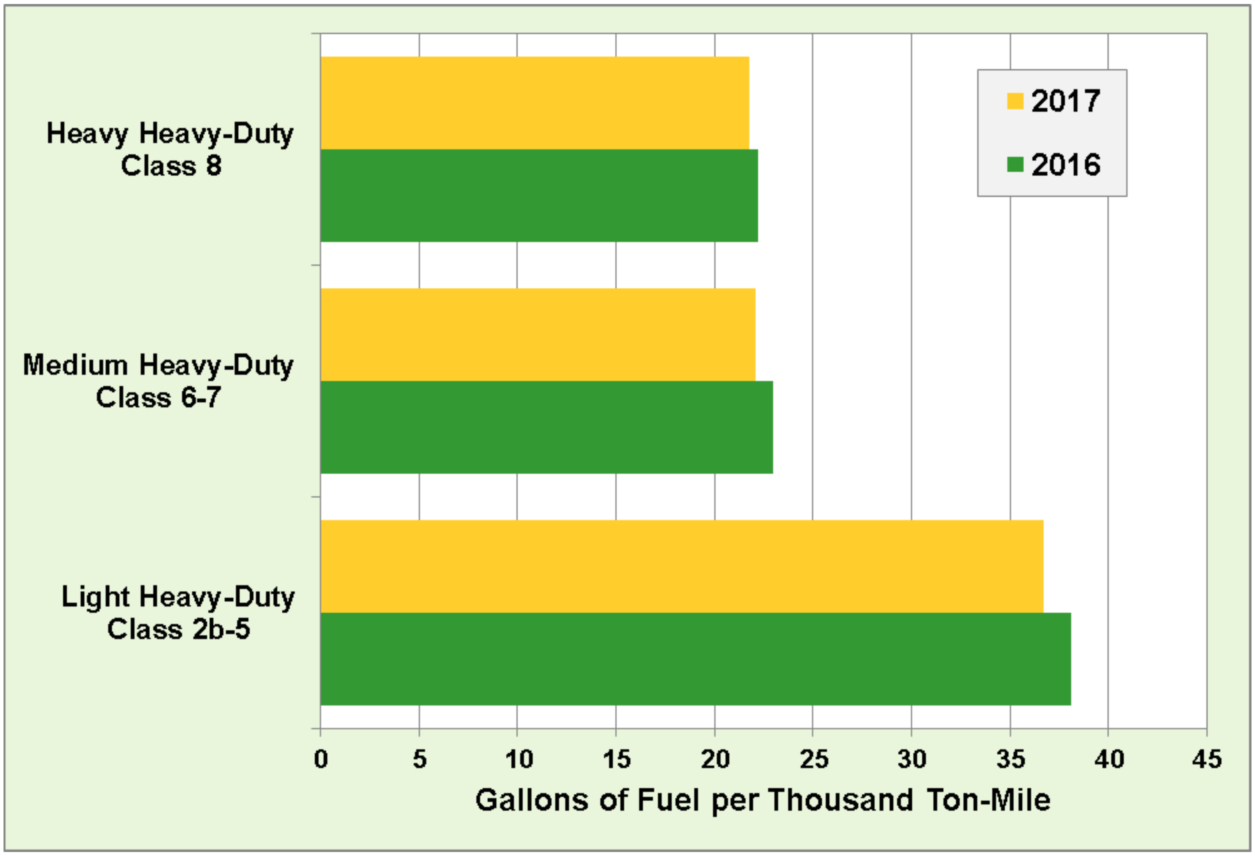


FIGURE 145. Vocational Vehicle Fuel Consumption Standards, MY 2016 and 2017

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

Source:
Federal Register, Vol. 76, No. 179, September 15, 2011, pp. 57105 - 57513.

Diesel Engine Fuel Consumption Standards Are Set through 2020 and Standards Proposed through 2027

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 brake-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) 2014 through 2016 and mandatory thereafter. The standards proposed by NHTSA in July 2015 begin with MY 2021 and end in MY 2027.

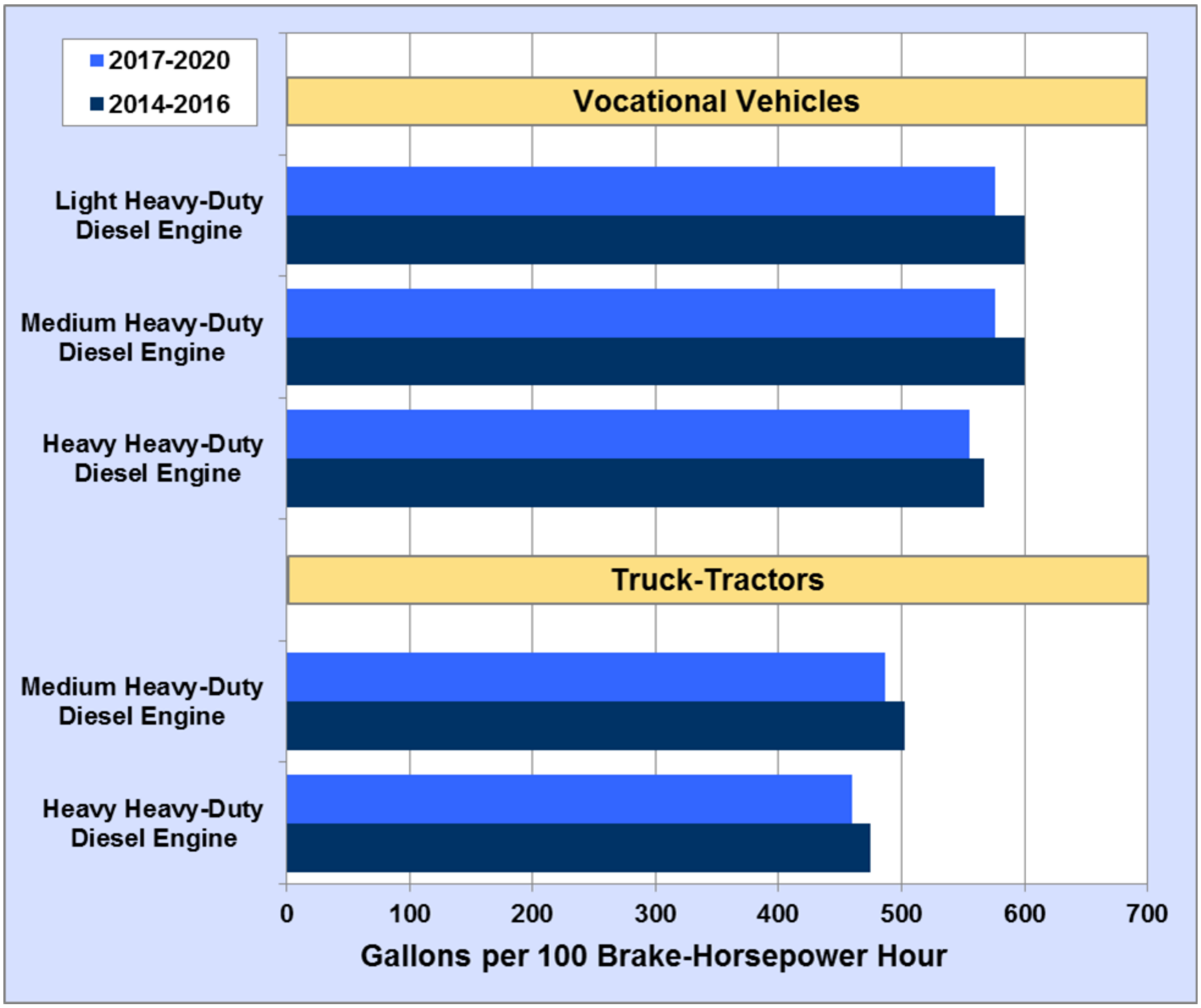


FIGURE 146. Fuel Standards for New Diesel Engines, MY 2014-2020

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

Source:
Federal Register, Vol. 76, No. 179, September 15, 2011, pp. 57105 - 57513.

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 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.

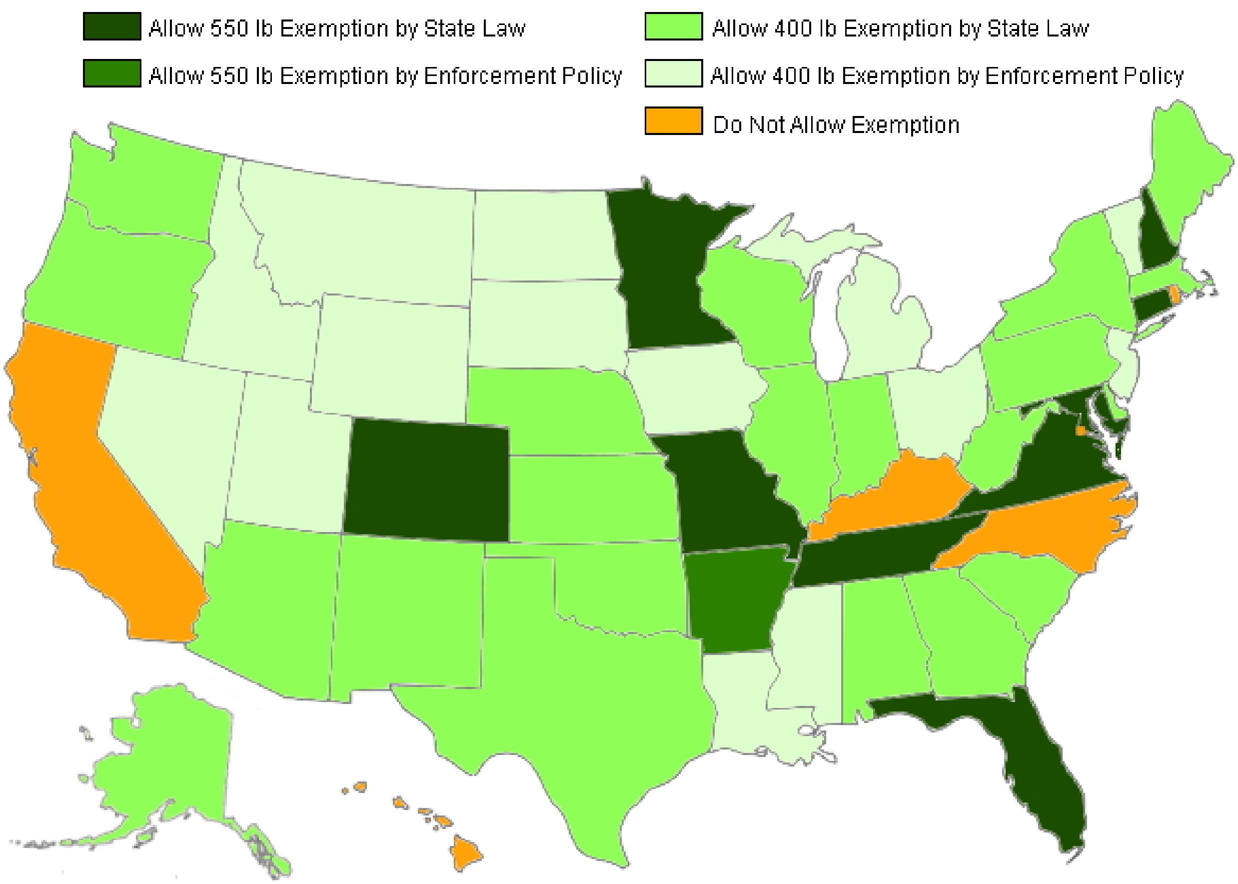


FIGURE 147. States Adopting Weight Exemptions for Idle Reduction Devices, 2016

Source:

U.S. Department of Energy, Energy Efficiency and Renewable Energy, *February 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
- 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
- DC Power Solutions APU
- Diamond Power Systems
- Dometic Corporation
- Driver Comfort System
- EnergyXtreme
- Freightliner
- Hammond Air Conditioning, LTD
- Idle Free Systems
- Indel B Sleeping Well
- NAS, LLC
- Navistar
- Paddock Solar
- Peterbilt
- Safer Corporation
- Sobo, Inc.
- 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 148. Idle Reduction Technologies which Are Granted Exemption from Federal Excise Taxes

Source:
U.S. Environmental Protection Agency, SmartWay Technology Program, March 2016.
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.

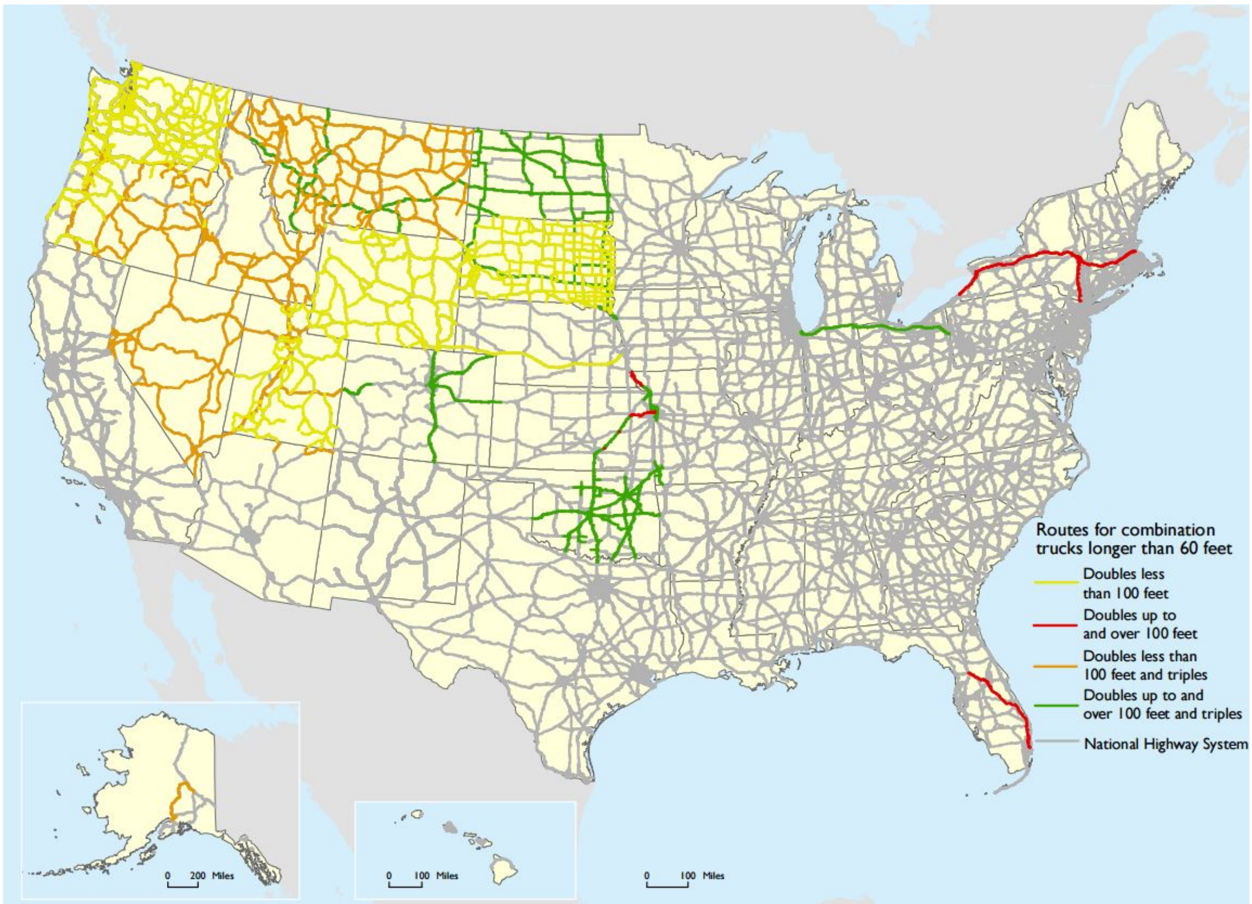


FIGURE 149. Routes Where Longer Combination Vehicles Are Permitted, 2014

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.

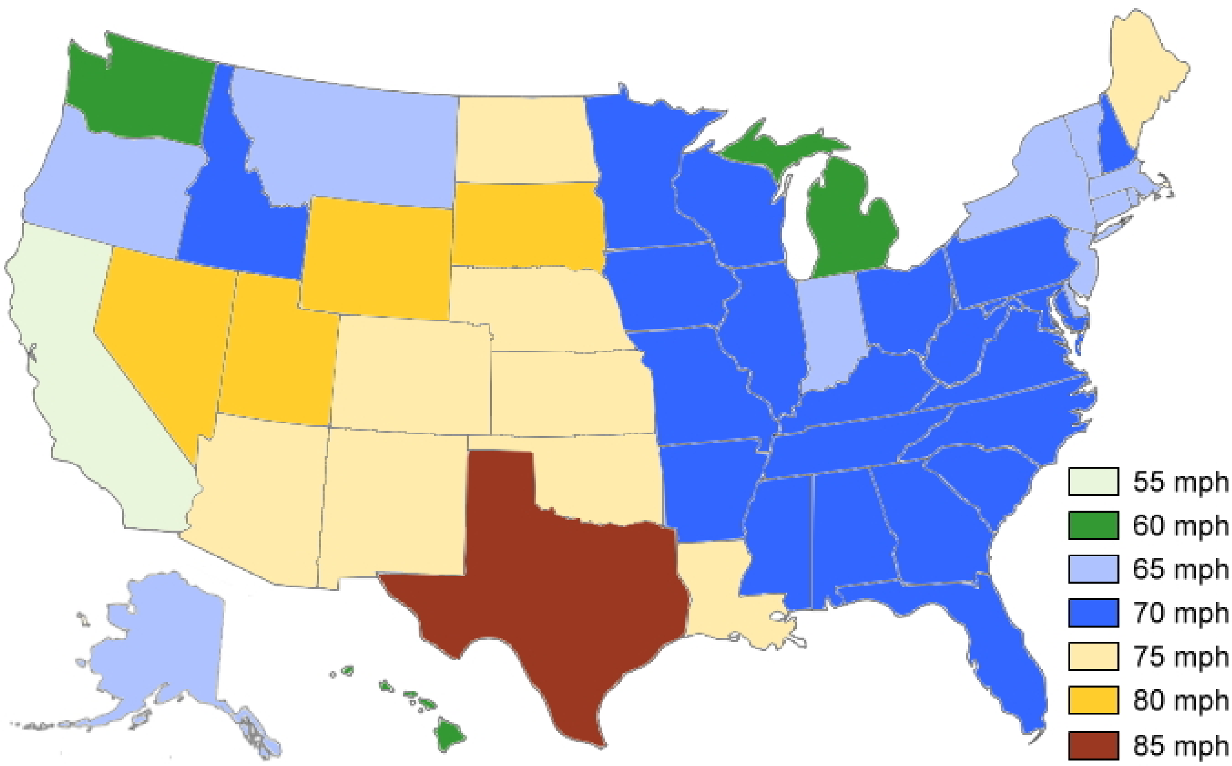


FIGURE 150. Maximum Daytime Truck Speed Limits by State, 2016

Source:
Insurance Institute for Highway Safety, Highway Loss Data Institute, March 2016.
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 take 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.

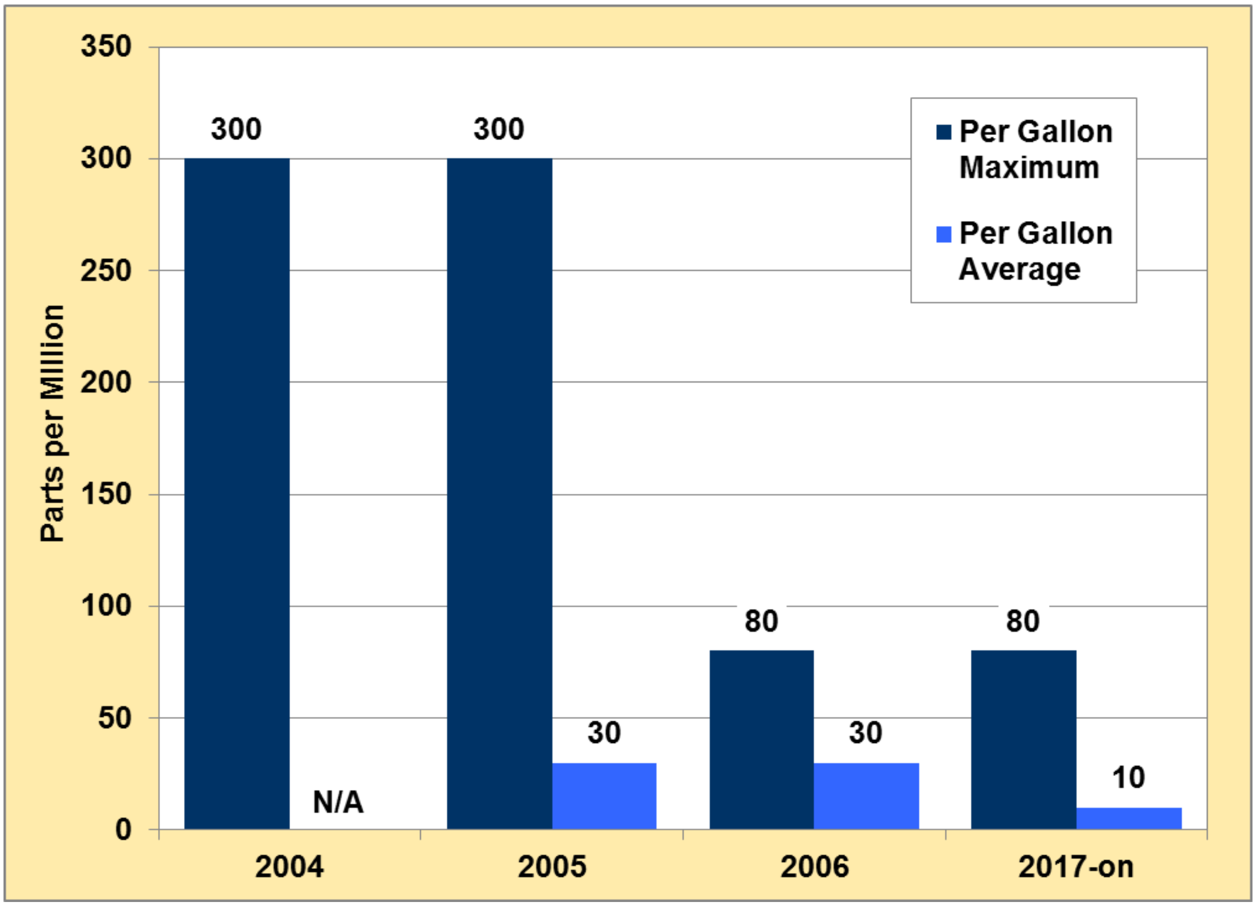


FIGURE 151. Gasoline Sulfur Standards, 2004-on

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.

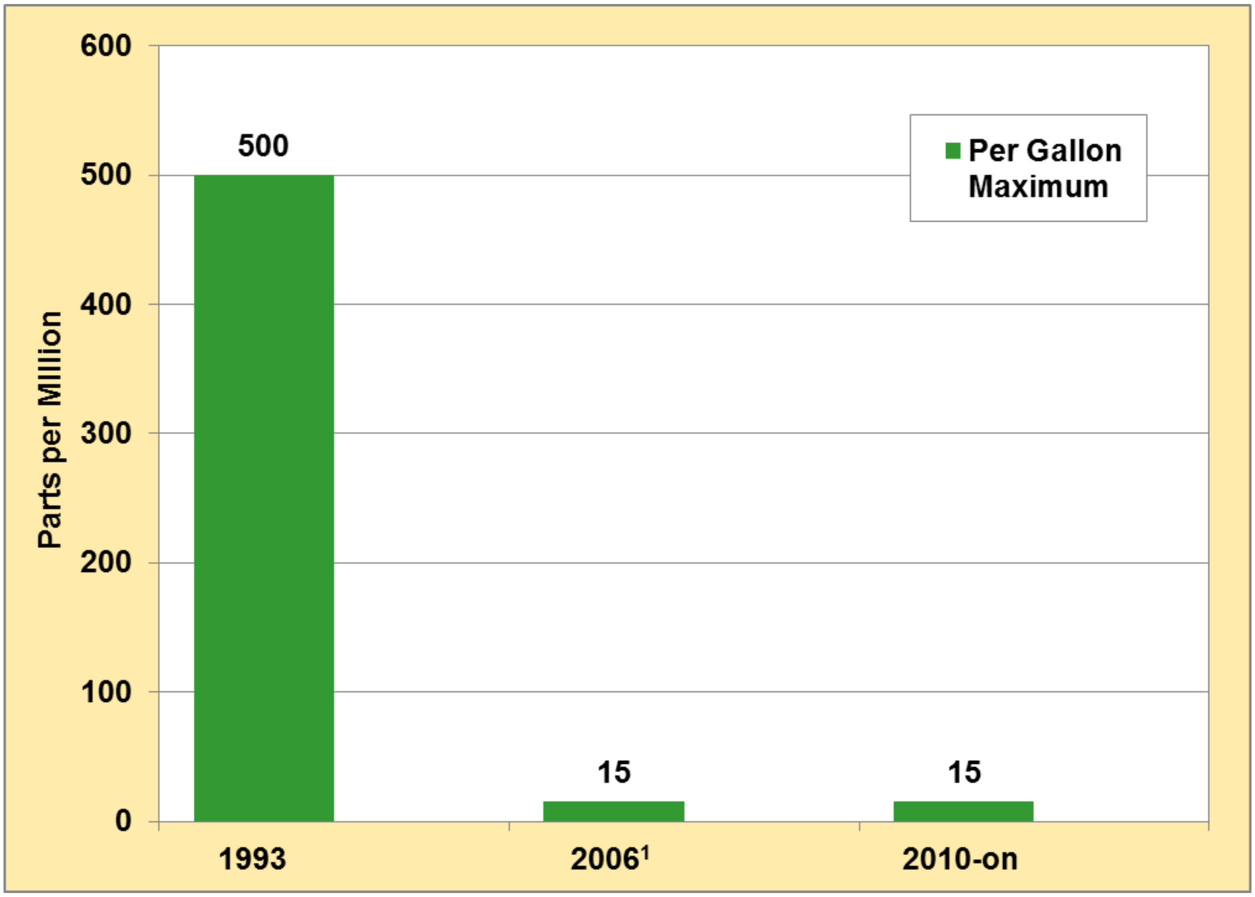


FIGURE 152. Diesel Sulfur Standards, 1993-on

[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://www3.epa.gov/otaq/highway-diesel/regs.htm.

Emission Standards on Diesel Engines Are More Strict

In 1994, the emission standards for new heavy-duty highway diesel vehicles was 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 are meeting these standards by using technologies such as selective catalytic reduction and exhaust gas recirculation in combination with diesel particulate filters.

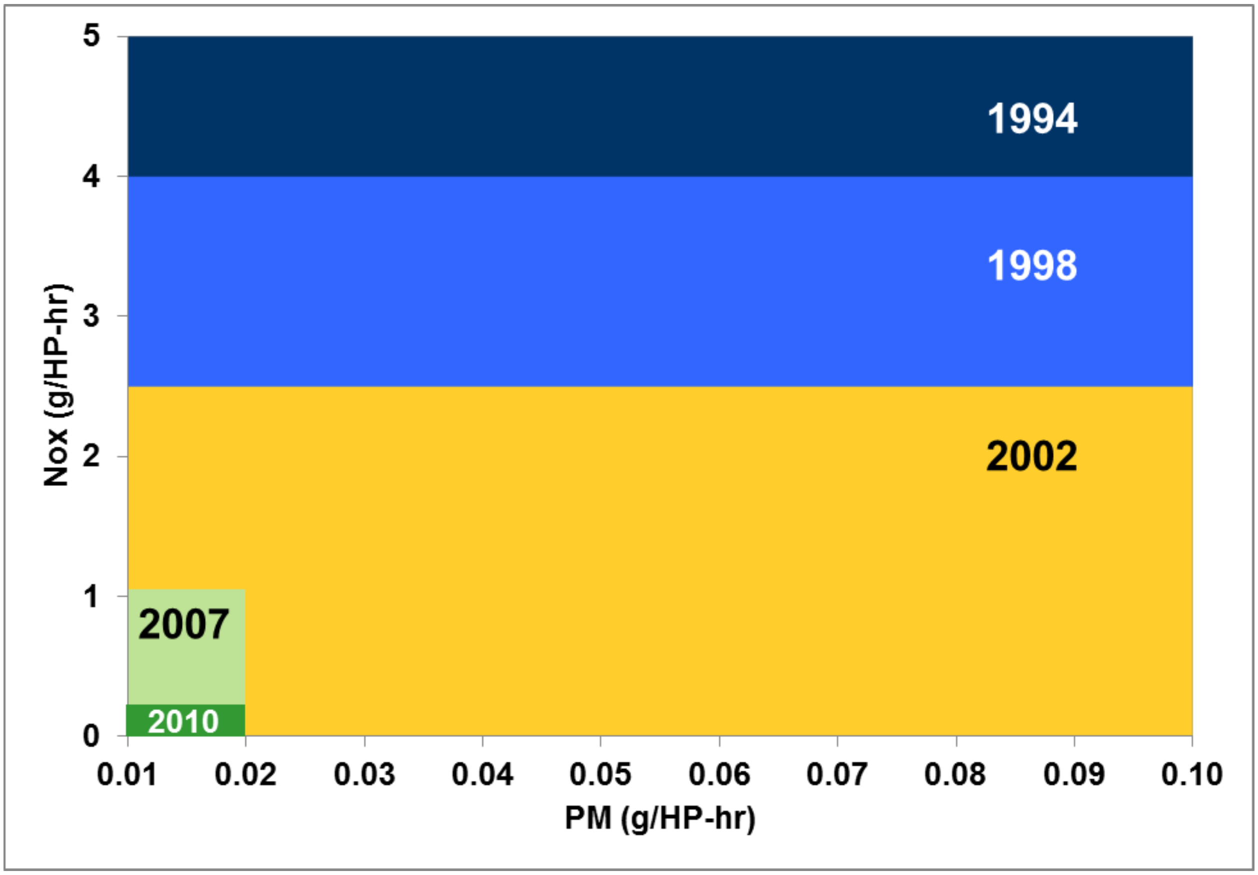


FIGURE 153. Diesel Emission Standards, 1994-2010

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, http://www.epa.gov/otaq/hd-hwy.htm.

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 surely 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.

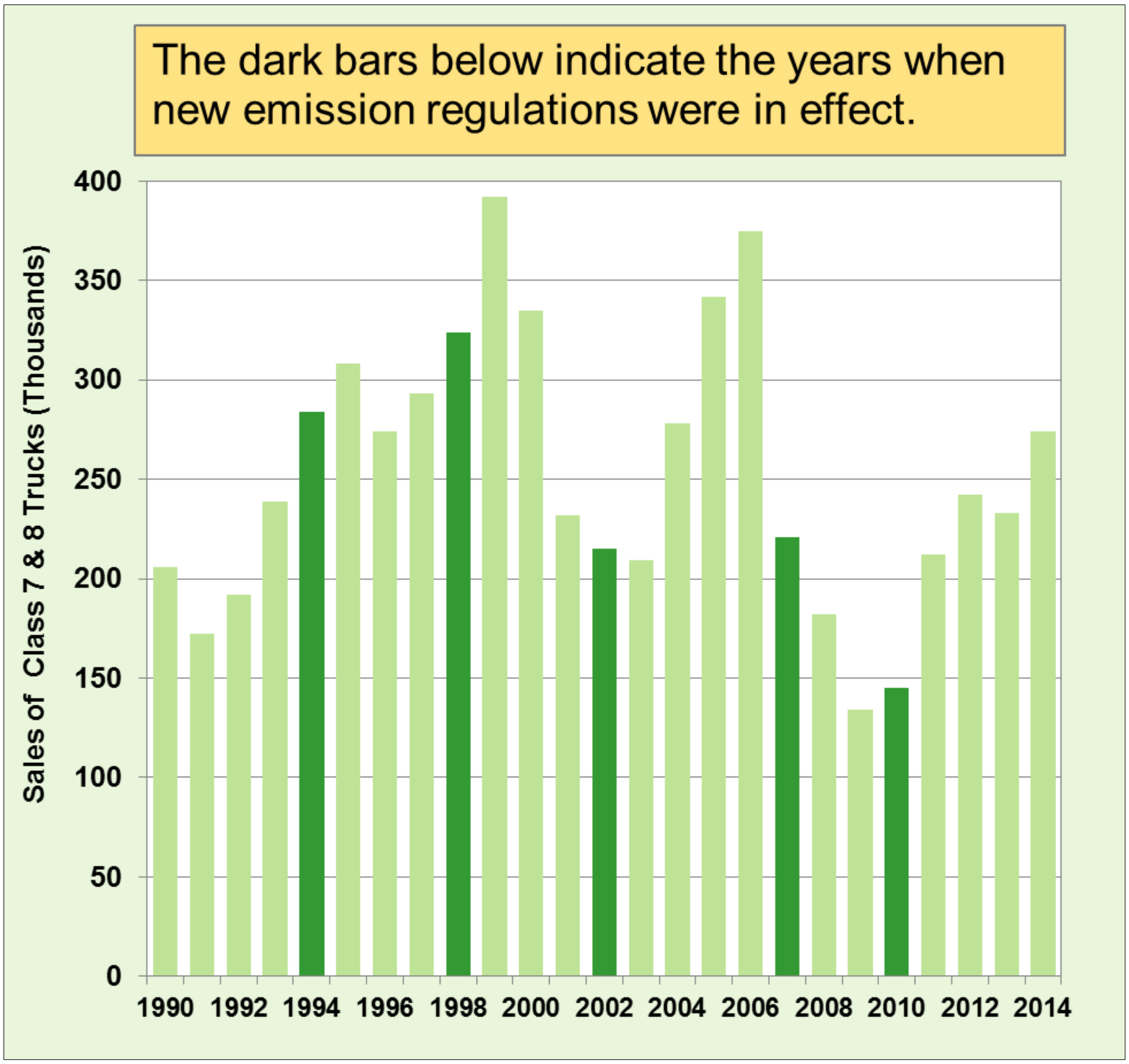


FIGURE 154. Class 7 and 8 Truck Sales, 1990-2014

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2015*, Southfield, MI, 2015.
http://wardsauto.com