2014 Vehicle Technologies Market Report

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE US DEPARTMENT OF ENERGY

Quick Facts

Energy and Economics

- Transportation accounts for 28% of total U.S. energy consumption.
- According to one study, dependence on oil cost the U.S. economy $200 billion in 2013.
- The average price of a new car is just over $25,000 (not including light trucks).
- Almost 18% of household expenditures are for transportation.
- Over 9 million people are employed in the transportation industry.

Light Vehicles

- The top nine manufacturers selling vehicles in the U.S. produce 52% of the world's vehicles.
- U.S. sales volumes increased by nearly 50% from 2009 to 2013.
- Sales-weighted data on new light vehicles sold show a 124% increase in horsepower and a 47% decrease in 0-60 time from 1980 to 2014, with the fuel economy of vehicles improving 27%.
- More than 18% of cars sold in 2013 have continuously variable transmissions.
- More than 90% of new light vehicles sold in 2014 have transmissions with more than 5 speeds.

Heavy Trucks

- Class 8 combination trucks consume an average of 6.5 gallons per thousand ton-miles.
- Class 3 truck sales increased by 95% from 2009 to 2013.
- Sales of class 4-7 trucks in 2014 were more than 65% above the 2009 level.
- Class 8 truck sales (combination trucks and single-unit trucks) decreased 5% from 2012 to 2013 but were still 95% higher than in 2009.
- Diesel comprised 72% of the class 3-8 trucks sold in 2013, up from 69% in 2009.
- Combination trucks are driven an average of over 66,000 miles per year.
- Idling a truck-tractor's engine can use more than a gallon of fuel per hour.
- There are 113 electrified truck stop sites across the country to reduce truck idling time.

Technologies

- From 1999 (when hybrid vehicles were first sold) to 2014, there have been 3.5 million hybrid sales, with almost 450,000 in 2014 alone.
- From the first plug-in vehicle sales in 2011 to 2014 about 287 million vehicles have been sold, with just over 118,000 units in 2014.
- At least 22 different models of plug-in vehicles are available or coming soon to the market.
- Seventy-two flex-fuel vehicle models were offered in model year 2014.
- There are more than 10,700 electric vehicle charging stations throughout the nation.
- 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 2010-2015 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.

ORNL/TM-2015/85

2014 VEHICLE TECHNOLOGIES MARKET REPORT

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Introduction

Welcome to the *2014 Vehicle Technologies Market Report*. This is the sixth 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 21 and 22 show U.S. employment in the automotive sector. The following section examines Light-Duty Vehicle use, markets, manufacture, and supply chains. Figures 24 through 51 offer snapshots of major light-duty vehicle brands in the United States and Figures 58 through 68 examine the performance and efficiency characteristics of vehicles sold. The discussion of Medium and Heavy Trucks offers information on truck sales (Figures 76 through 81) and fuel use (Figures 84 through 87). The Technology section offers information on alternative fuel vehicles and infrastructure (Figures 92 through 104), and the Policy section concludes with information on recent, current, and near-future Federal policies like the Corporate Average Fuel Economy standard (Figures 113 through 118).

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 2013, the transportation sector used 27.1 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.

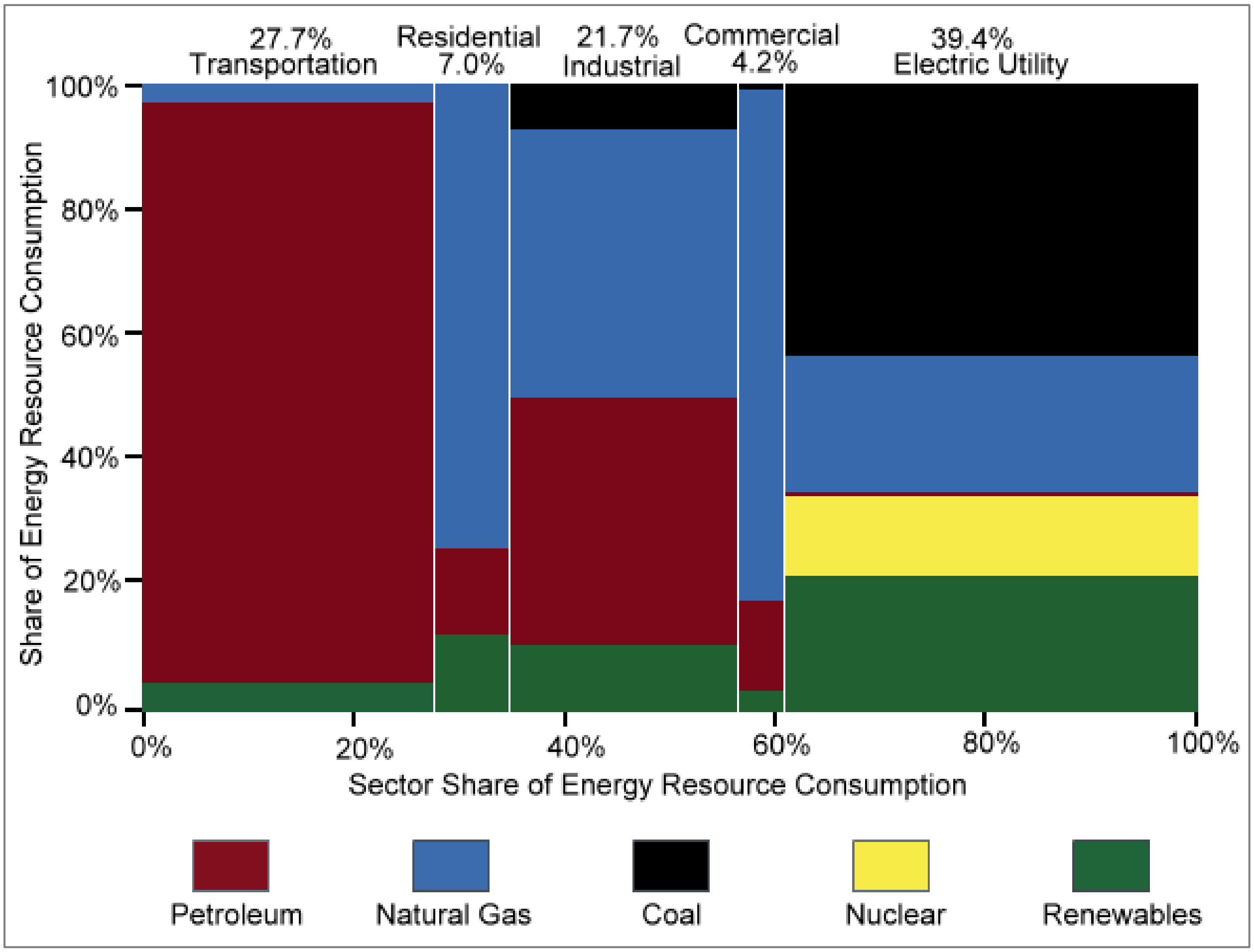


FIGURE 1. U.S. Energy Consumption by Sector and Energy Source, 2013

Source:

Energy Information Administration, *Monthly Energy Review, September 2014*, Tables 2.2, 2.3, 2.4, 2.5, and 2.6., http://www.eia.gov/totalenergy/data/monthly

The Transportation Sector Currently Uses More Petroleum than the United States Produces

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. The projections of U.S. oil production have changed significantly over the years — current projections show that by 2020, conventional sources of petroleum will meet transportation demand, but by 2040 the production will fall short. However, with non-petroleum sources, such as ethanol, biomass, and liquids from coal, the production will meet transportation demand in 2040.

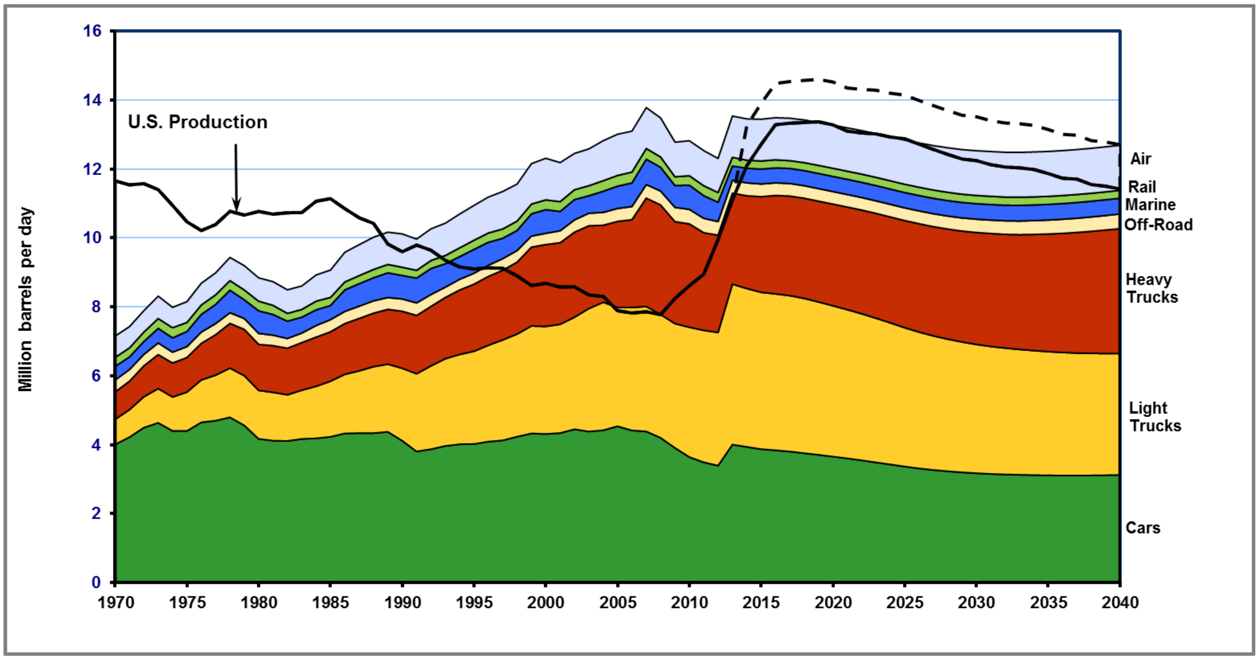


FIGURE 2. Transportation Petroleum Use by Mode and the U.S. Production of Petroleum, 1970-2040

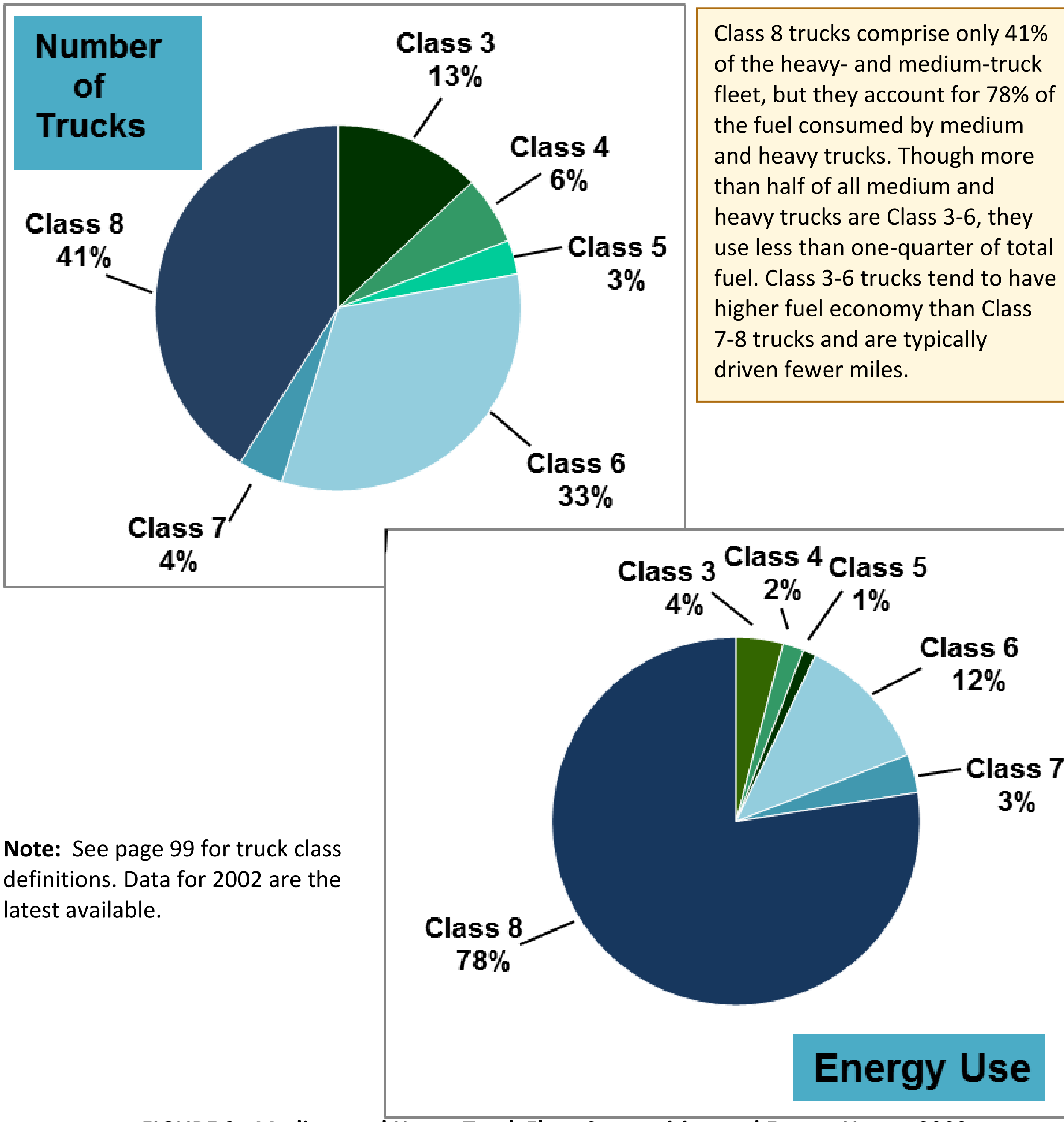
Note: The U.S. production has two lines after 2011. The solid line is conventional sources of petroleum, including crude oil, natural gas plant liquids, and refinery gains. The dashed line adds in other non-petroleum sources, including ethanol, biomass, liquids from coal, other blending components, other hydrocarbons, and ethers. The sharp increase in values between 2012 and 2013 is caused by the data change from historical to projected values. The sharp increase in the value 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 33*, Oak Ridge, TN, 2014. http://cta.ornl.gov/data

2010-2040: Energy Information Administration, *Annual Energy Outlook 2014*, DOE/EIA-0383(2014), Washington, DC, 2014. http://www.eia.gov/forecasts/aeo/

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 99 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 33*, Oak Ridge, TN, 2014. 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.

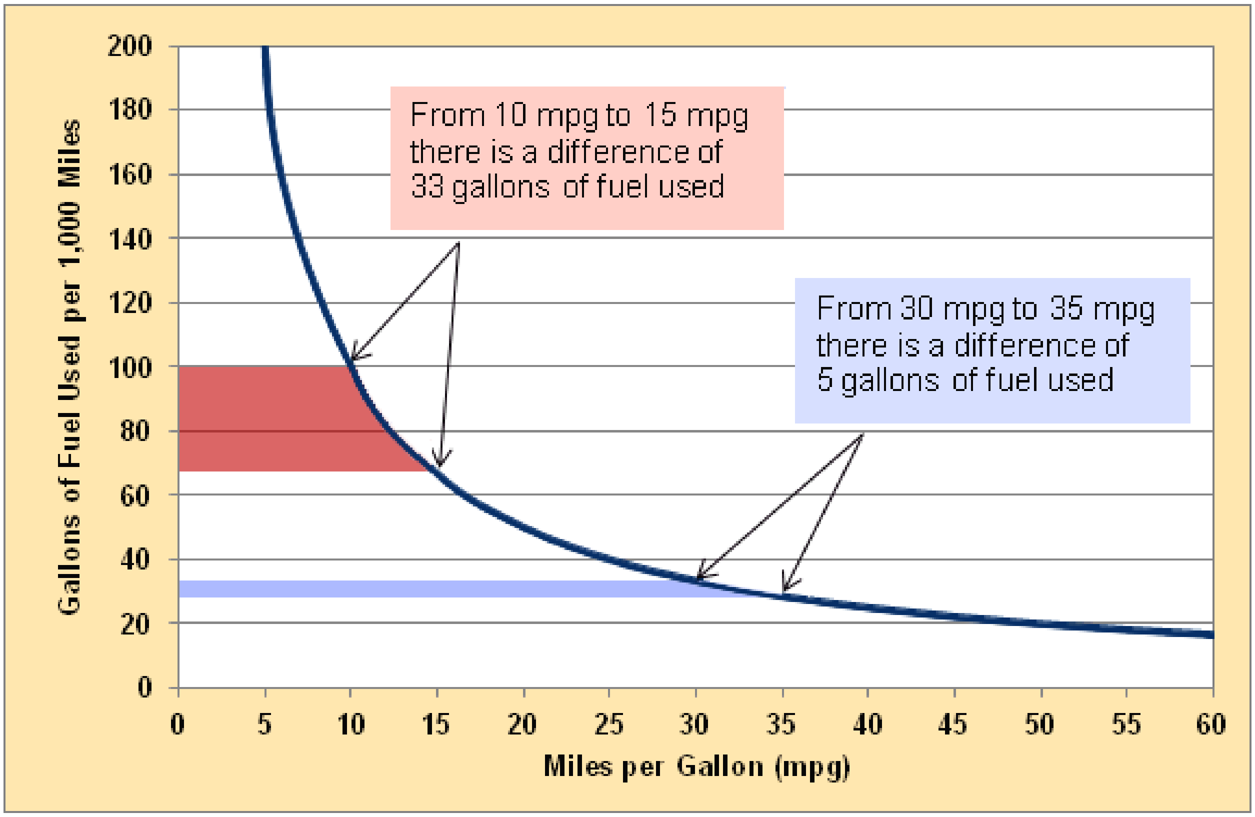


FIGURE 4. Fuel Use versus Fuel Economy

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

Source:
Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov

Carbon Dioxide Emissions from Transportation Decreased from 2007

Carbon dioxide (CO_2) emissions decreased by 9% from a high of 1,910 million metric tons (mmt) in 2007 to 1,743 mmt in 2012. 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.

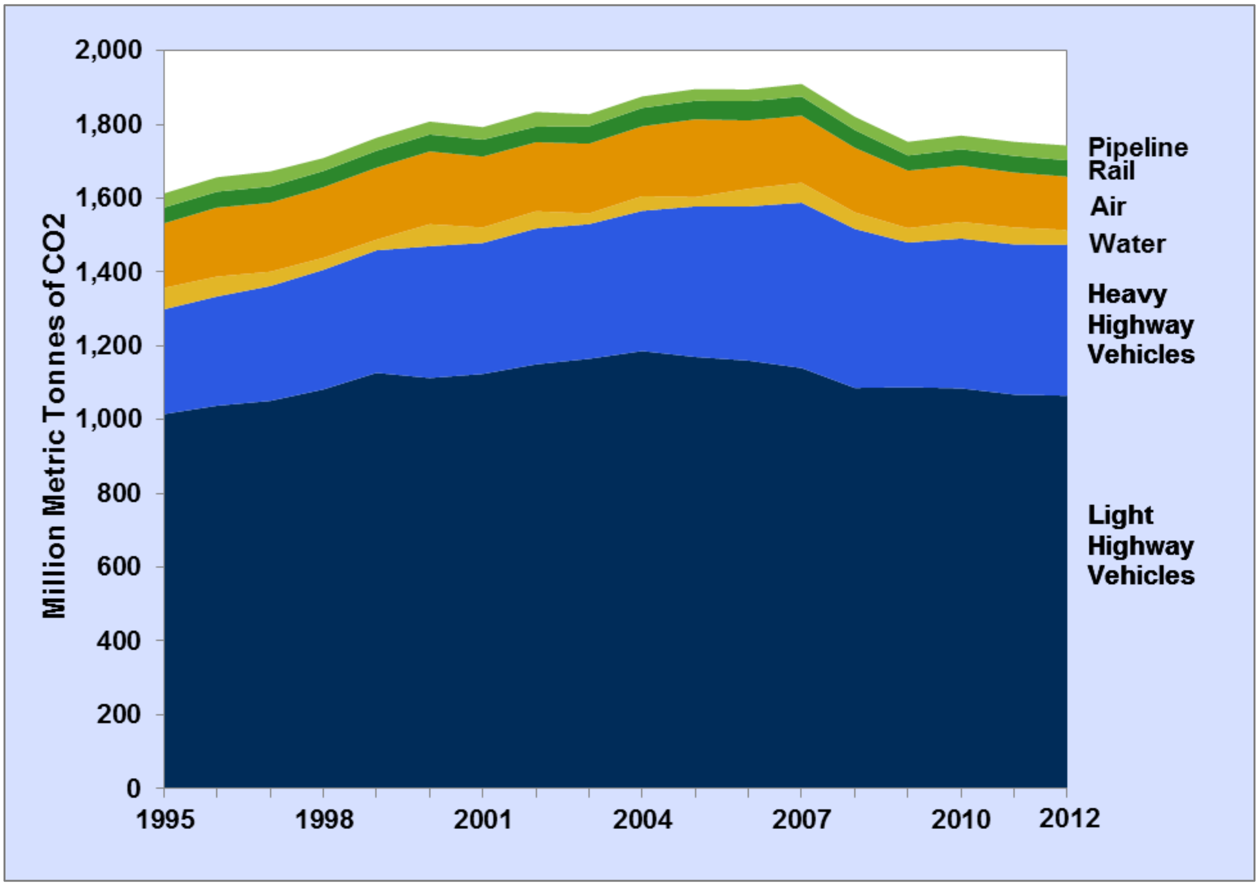


FIGURE 5. Transportation Carbon Dioxide Emissions, 1995-2012

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: 1990-2000*, Table 2-7, April 2002; 1990-2005, Table 3-7, April 2007; and 1990-2012, Table 3-12, April 2014. http://epa.gov/climatechange/emissions/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) 2014 cars that have decreased the amount of CO_2 they produce (in grams per mile) despite the fact that they are larger (in interior volume) than they were ten years ago. Of the examples, the Hyundai Sonata 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.

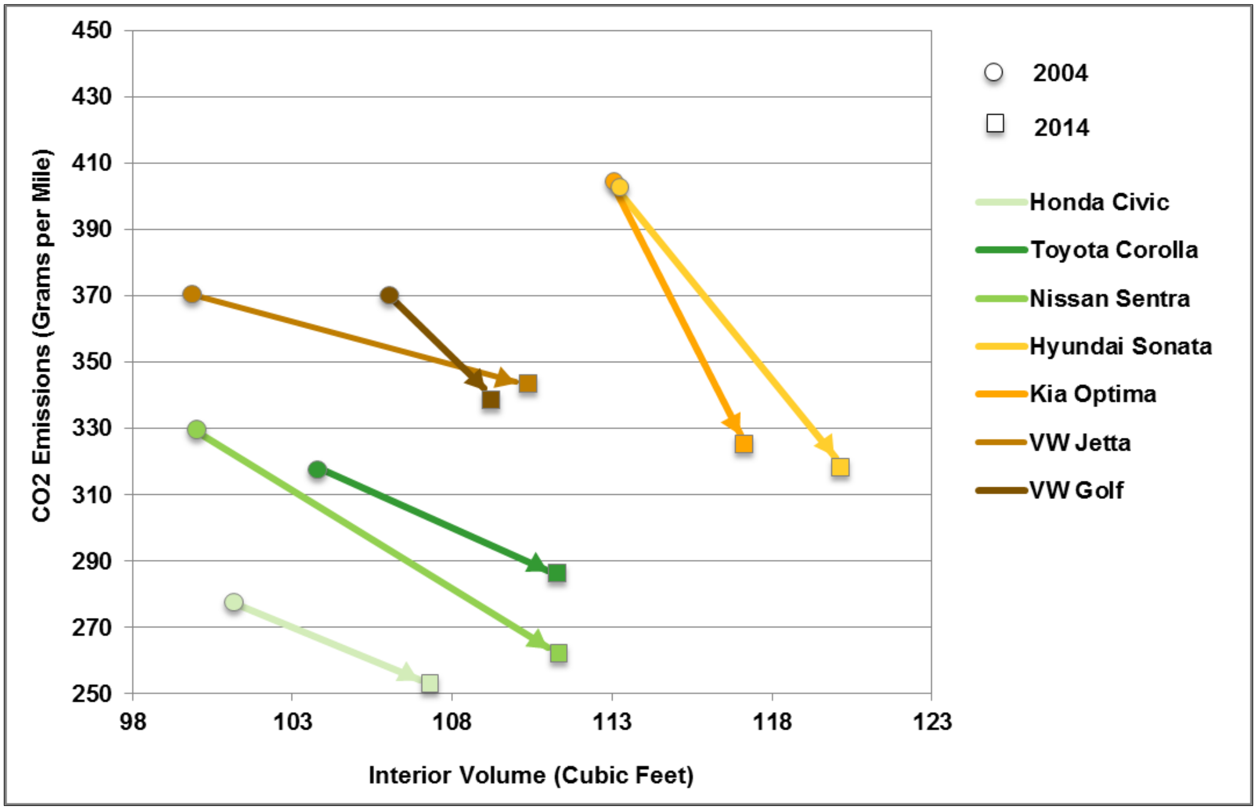


FIGURE 6. Carbon Dioxide Emissions versus Interior Volume for Selected MY 2014 Cars

Source:
Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov – Data accessed October 2014.

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) 2014 the sales-weighted average of CO_2 emitted by cars was 6.7 tons annually per car. For light trucks, the average was 9.3 tons annually per truck.

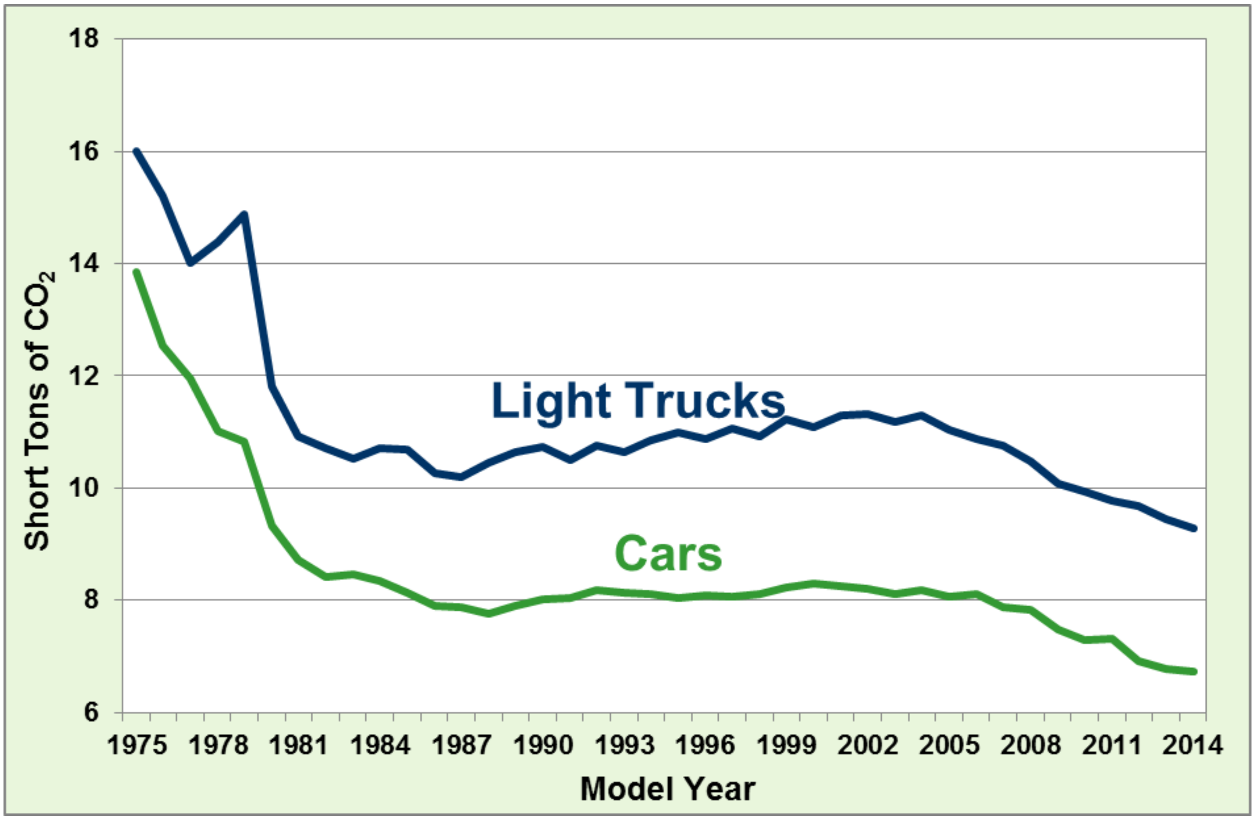


FIGURE 7. Average Carbon Footprint for Cars and Light Trucks Sold, 1975-2014

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.

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

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 2014*, EPA-420-R-14-023a, October 2014. 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 2013, carbon monoxide (CO) emissions declined by 47%; volatile organic compound (VOC) emissions declined by 41%; particulate matter emissions less than 10 microns (PM-10) declined 39%; and nitrogen oxide (NOx) emissions declined by 49%.

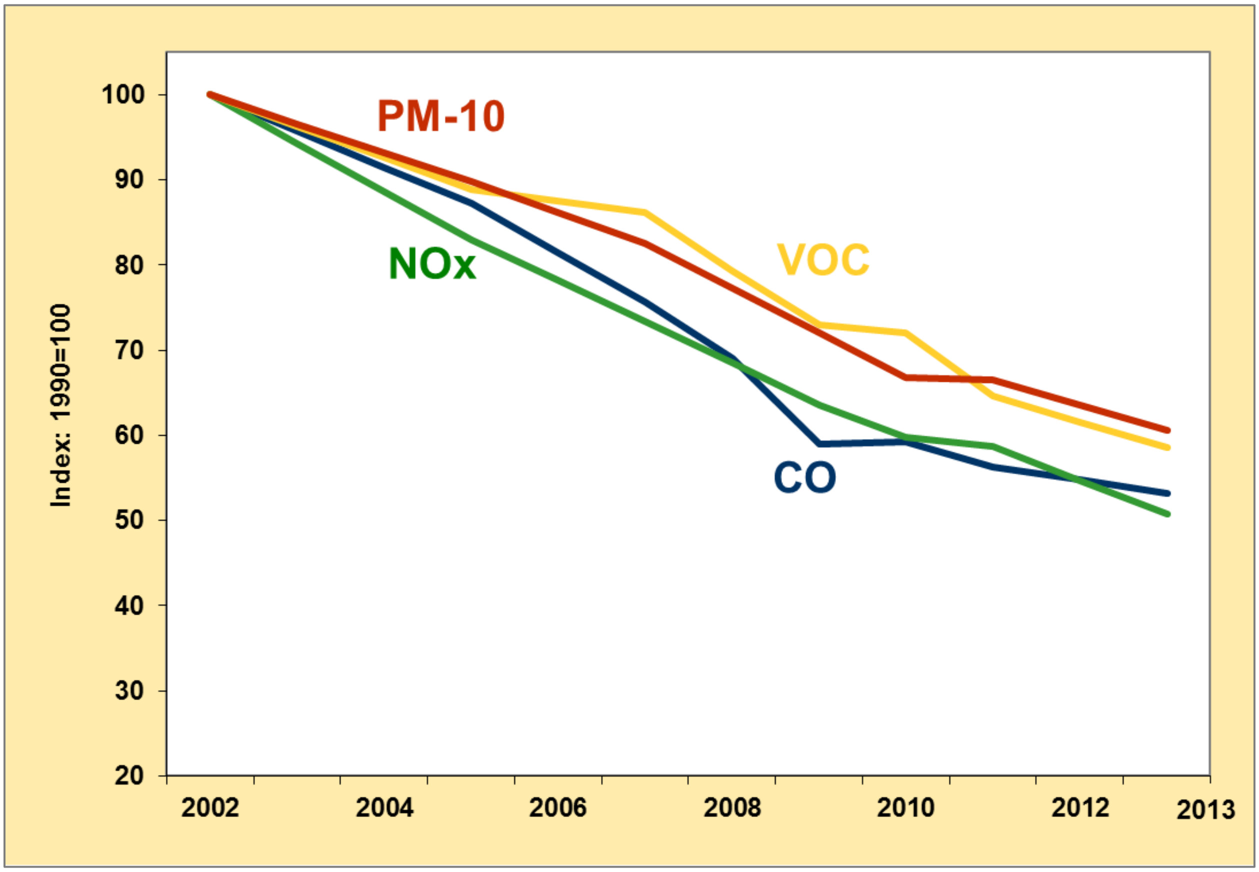


FIGURE 8. Total Transportation Pollutant Emissions, 2002-2013

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/ttn/chief/trends/index.html

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 2013 that fell to 34%. The share of transportation's nitrogen oxide (NOx) emissions from highway vehicles experienced a decline from 43% in 2002 to 39% in 2013. The highway share of volatile organic compound (VOC) emissions declined by 7% during this same period. Highway vehicles contribute less than 10% of all particulate matter (PM) emissions.

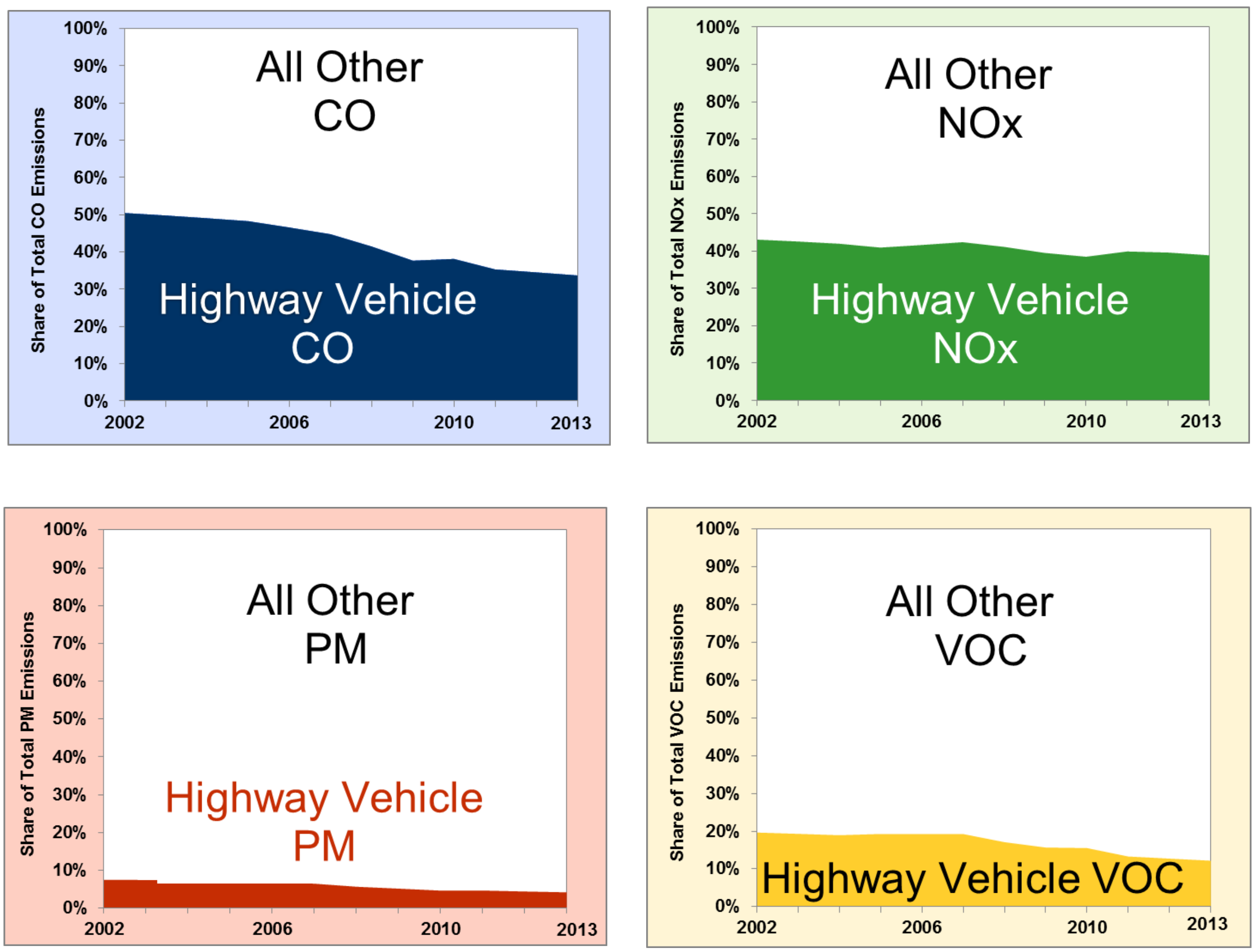


FIGURE 9. Highway and Nonhighway Share of Transportation Pollutant Emissions, 2002-2013

Source:

U.S. Environmental Protection Agency, National Emissions Inventory Air Pollutant Emissions Trends Data. http://www.epa.gov/ttn/chief/trends/index.html

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. However, the gallons per mile changed little from the early 1990's to 2013.

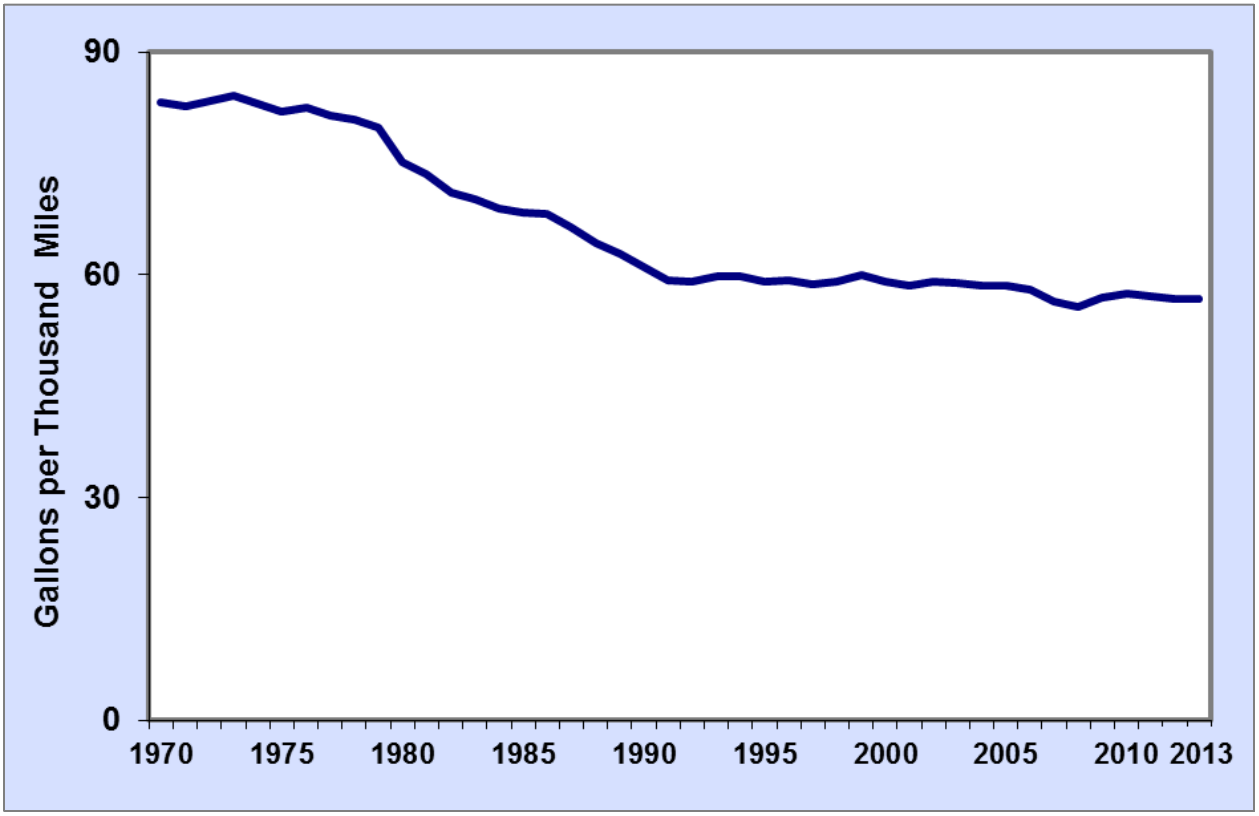


FIGURE 10. Fuel Use per Thousand Miles on the Highways, 1970-2013

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

Sources:

Federal Highway Administration, *Highway Statistics 2013*, Table VM-1 and previous annual editions. http://www.fhwa.dot.gov/policyinformation/statistics/2013

Vehicle Miles Are Increasingly Disconnected from the Economy

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. Though the distance between the two series has widened in recent years, they continue to follow the same trend showing that there continues to be a relationship between the U.S. economy and the transportation sector.

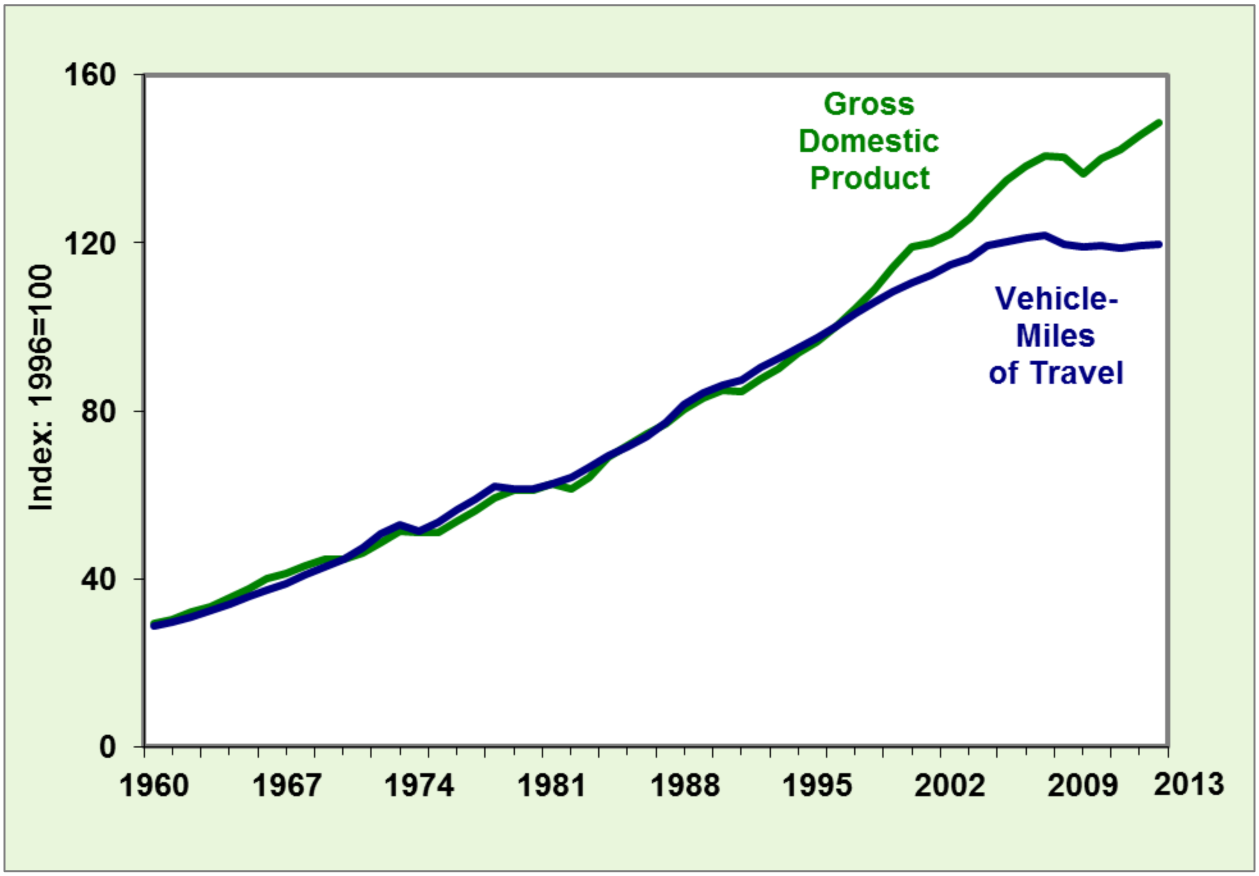


FIGURE 11. Relationship of VMT and GDP, 1960-2013

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 2012*, Table VM-1 and previous annual editions.
http://www.fhwa.dot.gov/policyinformation/statistics/2012

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. An oil glut in 2014 caused the most recent decline in crude oil prices.

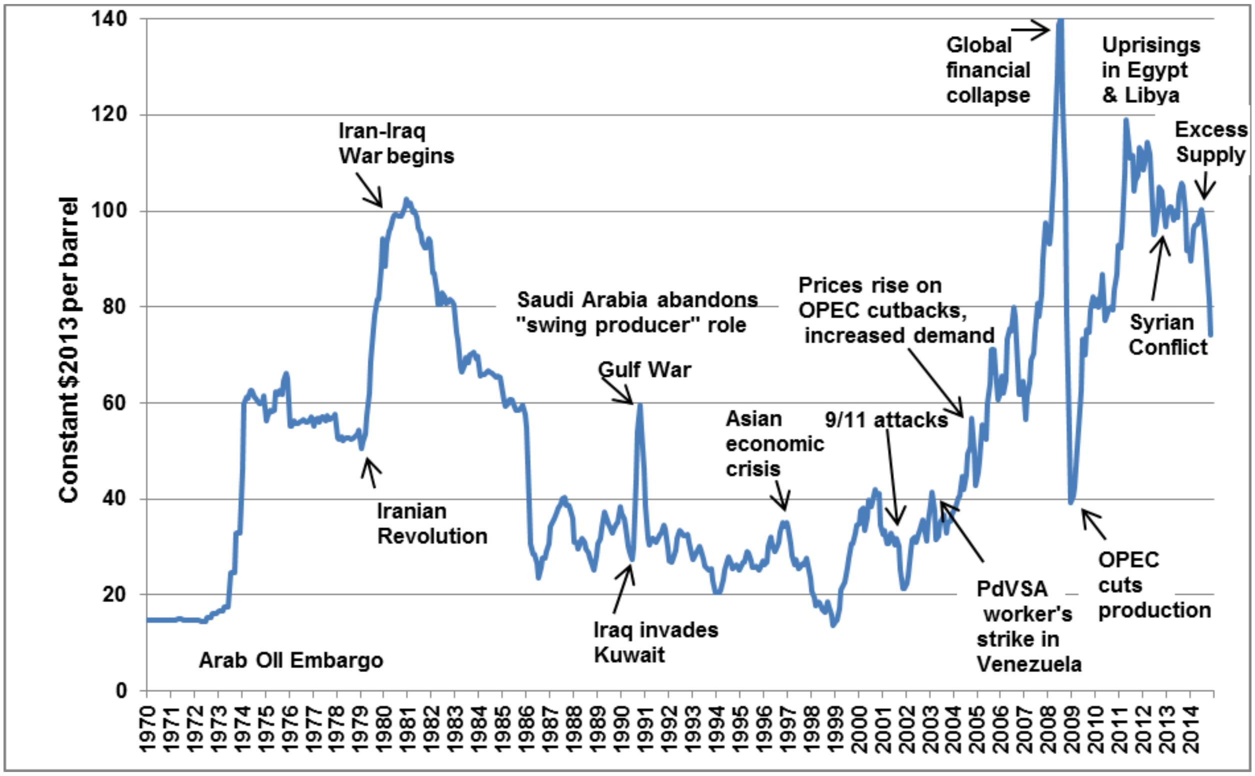


FIGURE 12. World Crude Oil Price and Associated Events, 1970-2014

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, 2014. 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.

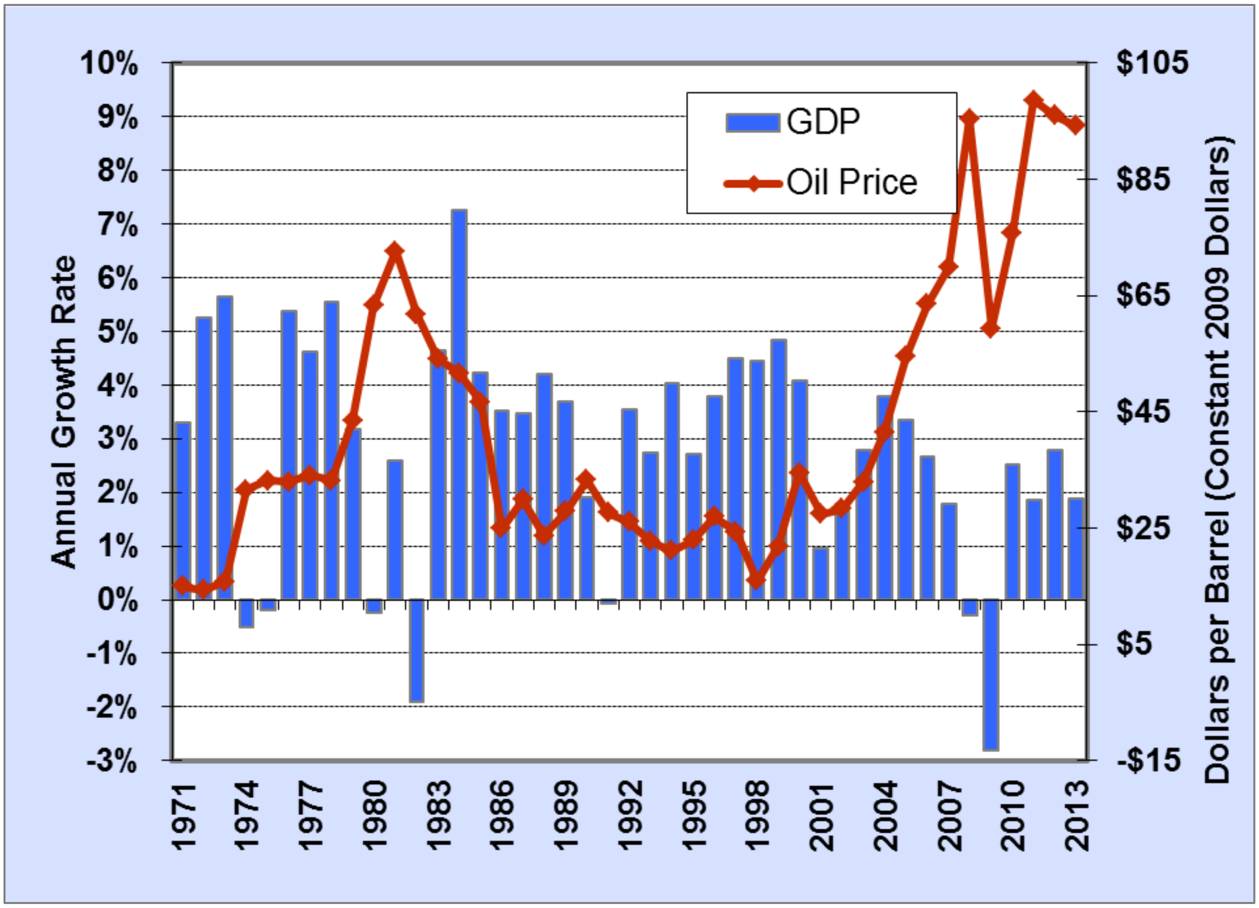


FIGURE 13. The Price of Crude Oil and Economic Growth, 1971-2013

Note: GDP = gross domestic product.

Source:

Greene, D.L. and N. I. Tishchishyna, *Costs of Oil Dependence: A 2000 Update*, Oak Ridge National Laboratory, ORNL/TM-2000/152, Oak Ridge, TN, 2000, and data updates, 2014. http://cta.ornl.gov/data

ORNL Estimates that 2013 Direct and Indirect Oil Dependence Costs $200 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. Oil dependence costs were almost 5.0% of GDP in 1980, but were 2.9% in 2008. Low oil prices in 2009, 2010 and 2013 caused total dependence cost to drop; in 2013 the total cost was about $200 billion.

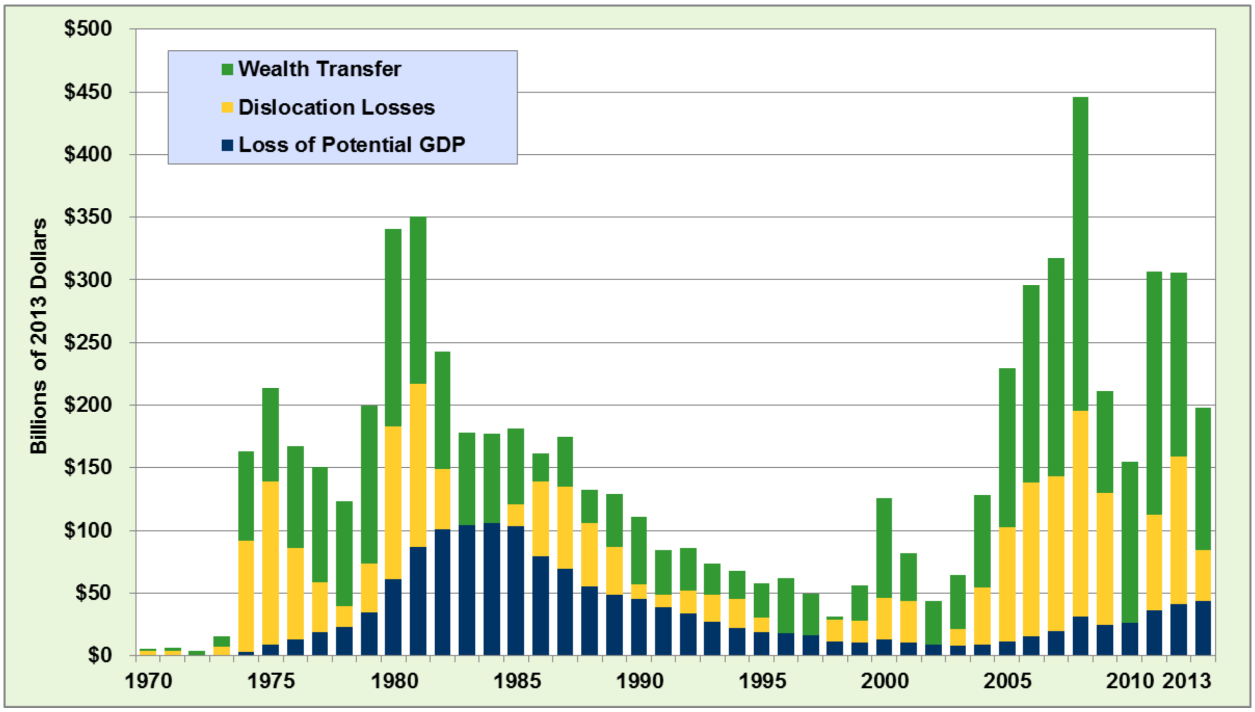


FIGURE 14. Costs of Oil Dependence to the U.S. Economy, 1970-2013

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.

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, the vehicle travel rises. Still, the price of gasoline is just one of the many factors influencing vehicle travel.

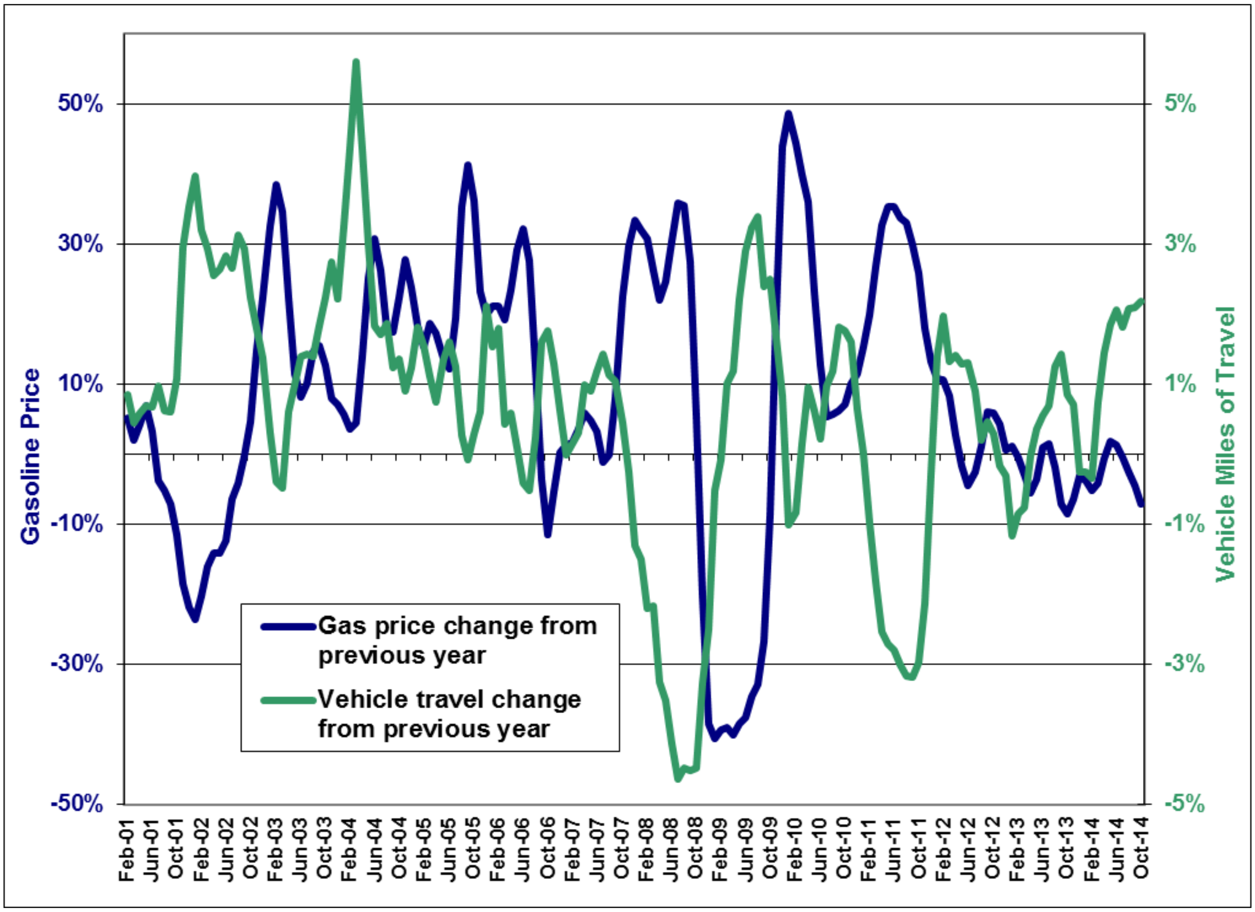


FIGURE 15. Relationship of Vehicle-Miles of Travel and the Price of Gasoline, 2001-2014

Sources:

Federal Highway Administration, *September 2013 Traffic Volume Trends,* and previous monthly editions.
http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm

Energy Information Administration, *Monthly Energy Review, December 2014*, 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 2013 was $25,487, a little lower than the 2012 average (constant 2013 dollars). That price continues to fall from a high of $28,684 in 1998, mainly driven by the high price of import cars. The price of imports peaked in 1998 at $41,010. Until 1981, domestic cars were more expensive than imports.

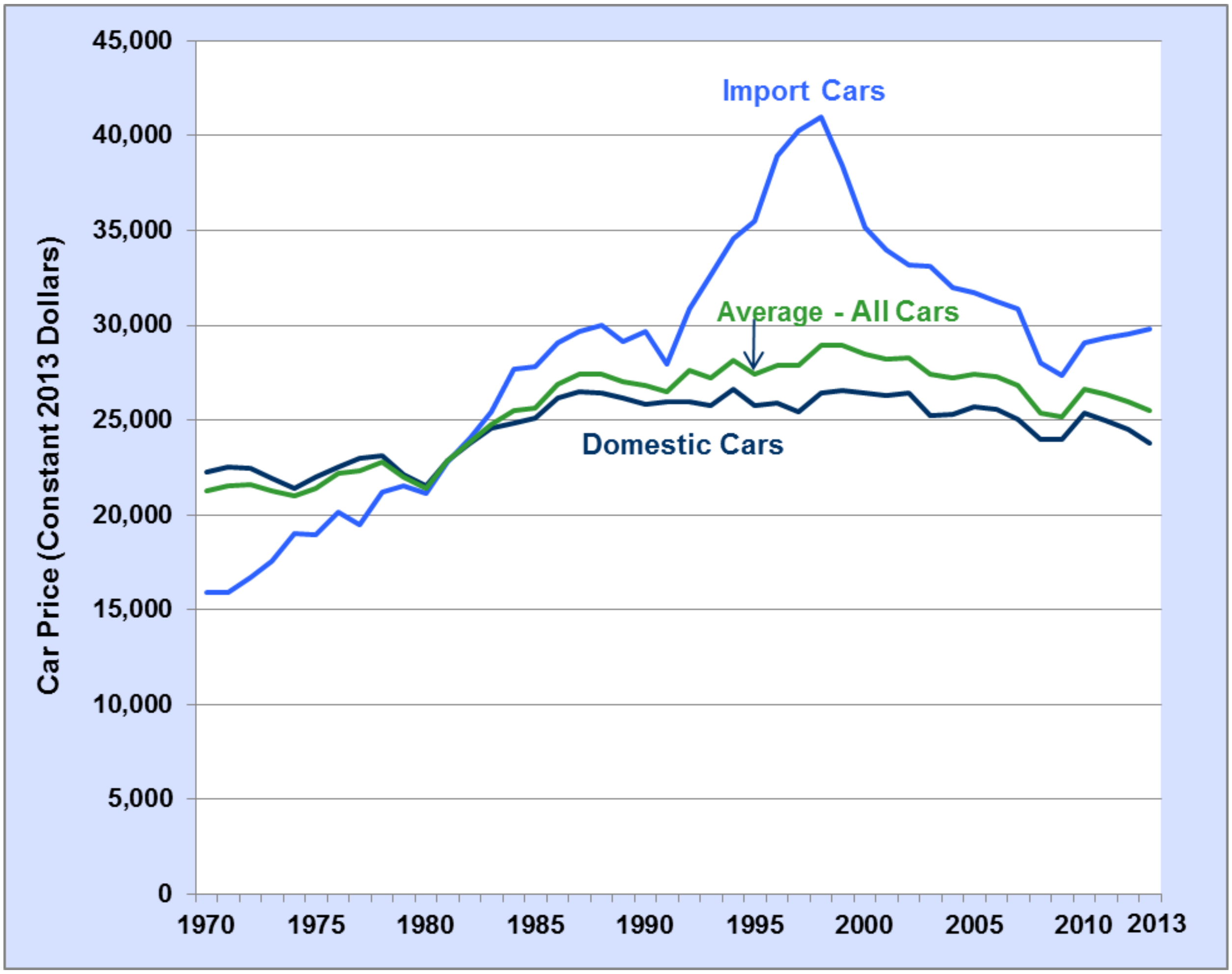


FIGURE 16. Average Price of a New Car, 1970-2013

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, 2014.

Light Vehicles Priced from $30-35,000 Are the Biggest Sellers in 2013

In 2013, there were about 3.8 million light vehicles sold with prices ranging from $30-35,000, which was the category with the highest sales volume. In contrast to 2013, the highest sales volume in 2008 was in the $25-30,000 range. About 3 million more vehicles were sold overall in 2013 compared to 2008. There were more high-priced vehicles sold in 2013, particularly in the $40-45,000 price range.

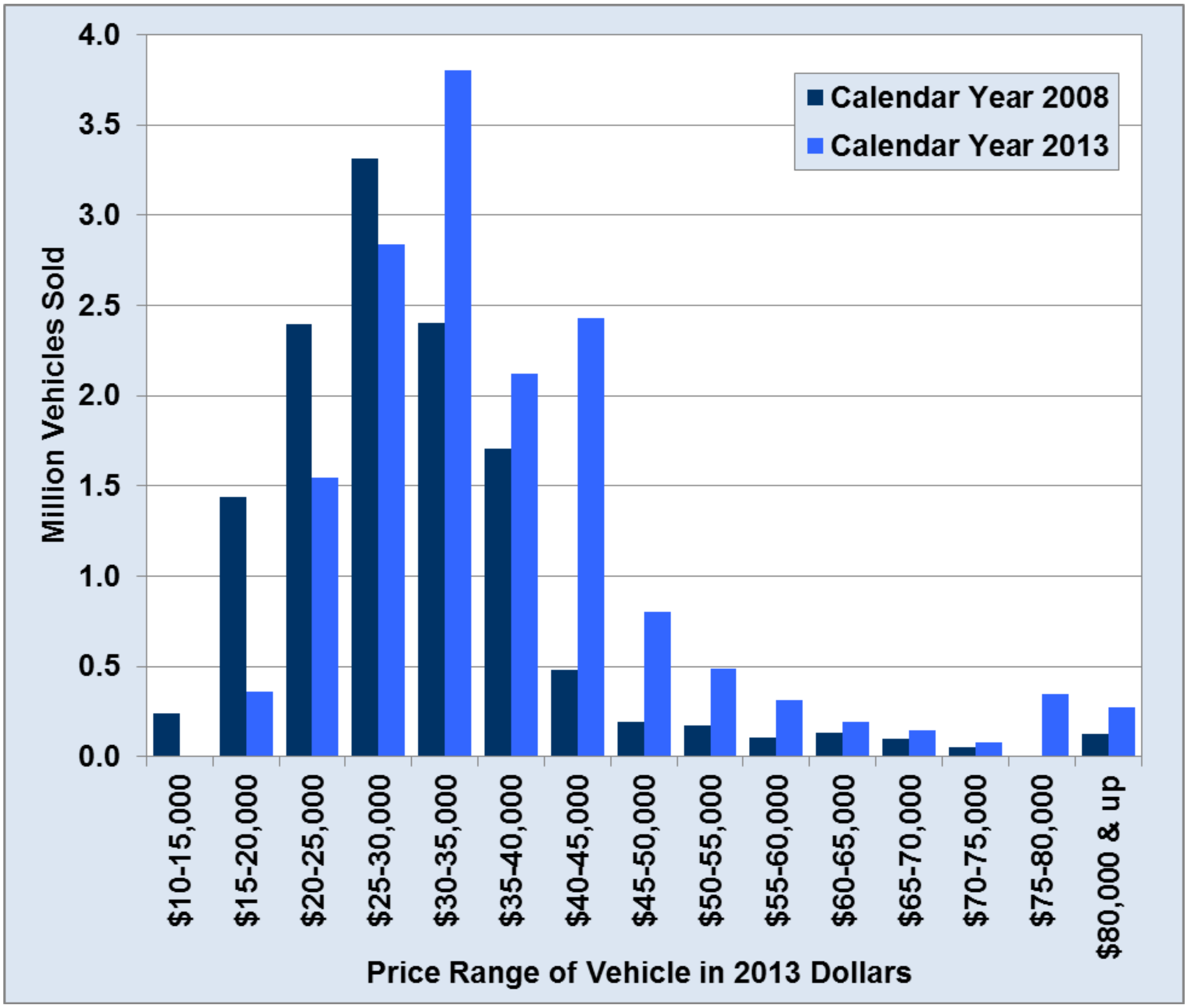


FIGURE 17 . Light Vehicle Sales by Price Range, Calendar Years 2008 and 2013

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

Source:
Provided by Jonathan Ford, SRA International, Inc.

Twenty-Nine Percent of Survey Respondents Consider Fuel Economy Most Important when Purchasing a Vehicle

A 2014 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 2014, 30% of the survey respondents indicated that dependability would be the most important vehicle attribute while 20% of the survey respondents chose fuel economy and another 20% chose safety.

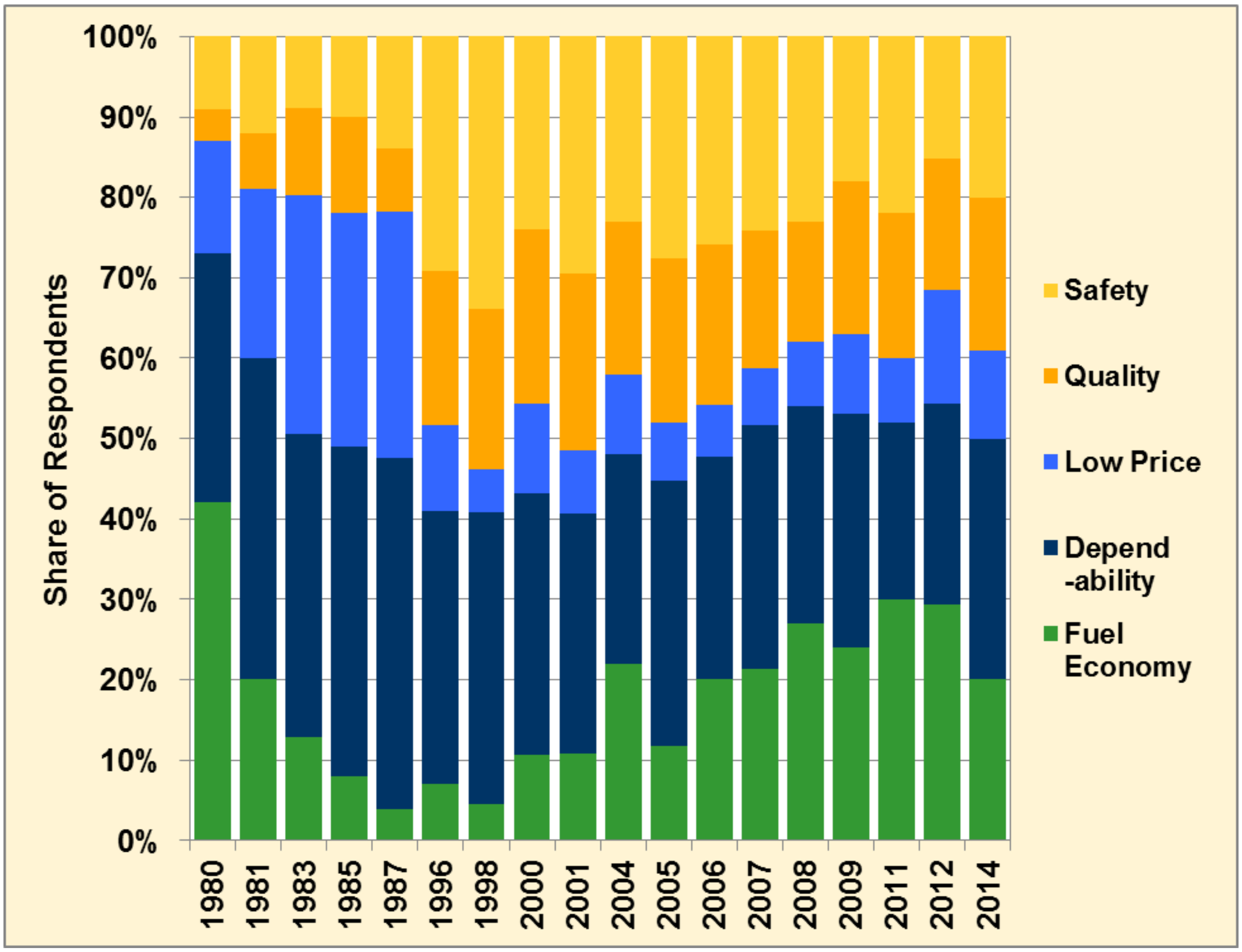


FIGURE 18. Most Important Vehicle Attribute, 1980-2014

Sources:

1980-87: J. D. Power (based on new car buyers). 1998-2014: Opinion Research Corporation International for the National Renewable Energy Laboratory (Sample size ≈ 1,000 in the general population).

Study Finds More than 60% of Millennials and Generation Xers Use the Internet to Find a Car Dealer While Less than Half of Baby Boomers Did

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. Baby boomers were more likely than Millennials or Generation Xers to use a referral from family or friends, a newspaper or other media sources, or have prior experience with a dealer. Millennials and Generation Xers were more likely to use the Internet or simply walk into a dealership than Baby Boomers.

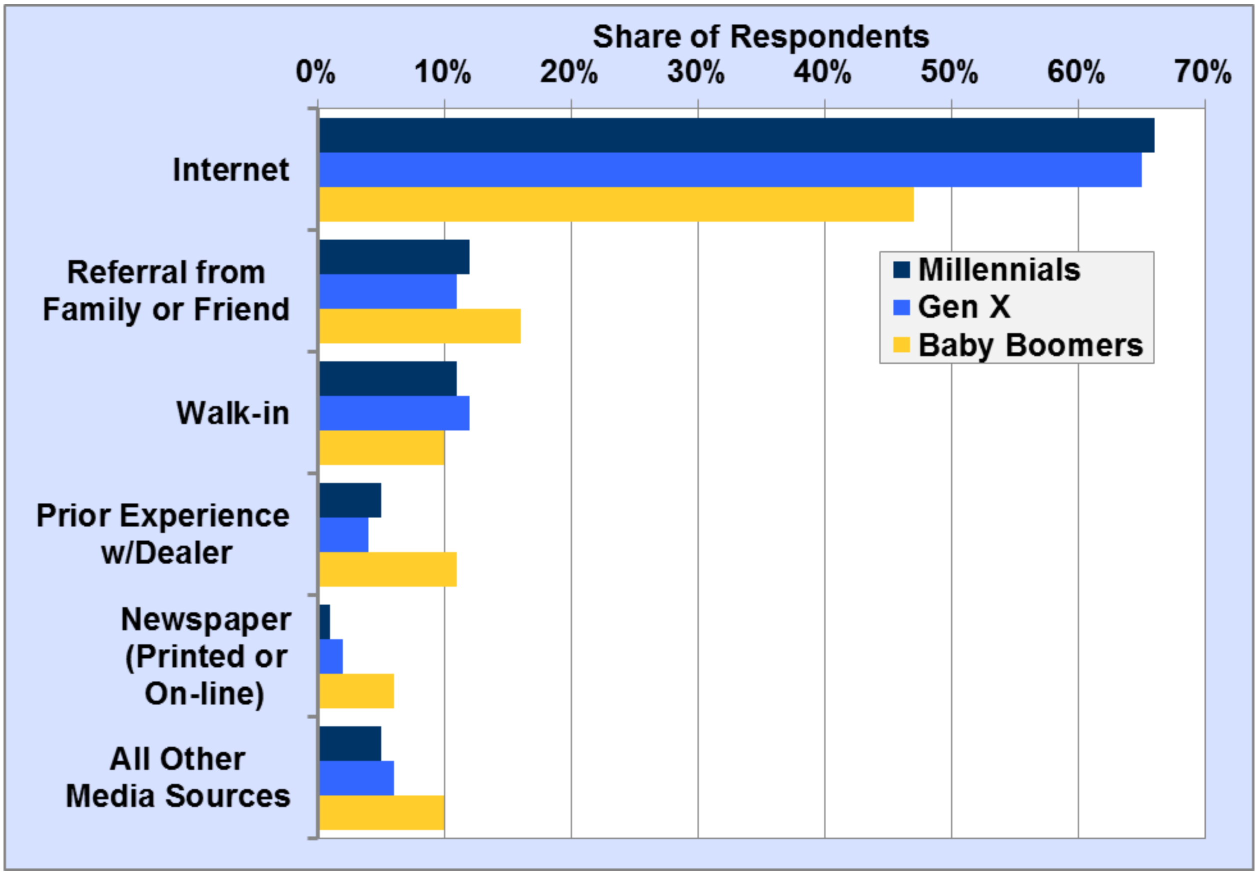


FIGURE 19. Most Influential Sources Leading to a Car Dealer, 2014

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 1,900 buyers.

Source:
IHS Automotive/Polk, *2014 Automotive Buyer Influence Study* for AutoTrader.com, 2014.
http://weworkforyou.com/files/insights/pdf/2014ABISFinal.pdf

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 manufacturer's comparably equipped manufacturer's suggested retail price (MSRP) 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 2014 national average fuel price of $3.37 per gallon of regular.

TABLE 1. Selected 2014 and 2015 Model Year Hybrid Vehicles Paired with a Comparably Equipped Non-Hybrid Vehicle

Vehicles	EPA MPG	MSRP Difference	Annual Fuel Cost Savings	Years to Payback
2015 Buick LaCrosse eAssist[1]	29	$0	$664	0.0
2015 Buick LaCrosse	21			
2015 Buick Regal eAssist[1]	29	$0	$455	0.0
2015 Buick Regal	23			
2015 Lincoln MKZ Hybrid[1]	40	$0	$680	0.0
2015 Lincoln MKZ FWD	26			
2015 Toyota Prius Two[2]	50	$1,230	$794	1.5
2015 Toyota Camry LE	28			
2015 Honda Accord Hybrid Touring	47	$1,425	$869	1.6
2015 Honda Accord Touring	26			
2015 Toyota Avalon Hybrid Limited	40	$1,720	$843	2.0
2015 Toyota Avalon Limited	24			
2015 Toyota Avalon Hybrid XLE Touring	40	$1,720	$843	2.0
2015 Toyota Avalon XLE Touring	24			
2015 Ford Fusion Hybrid Titanium	42	$1,550	$741	2.1
2015 Ford Fusion FWD Titanium 4cyl	26			
2015 Toyota Avalon Hybrid XLE Premium	40	$2,330	$843	2.8
2015 Toyota Avalon XLE Premium	24			
2015 Lexus ES 300h	40	$2,880	$843	3.4
2015 Lexus ES 350	24			
2015 Toyota Prius Two[2]	50	$2,225	$569	3.9
2015 Toyota Corolla LE Premium	32			
2014 Toyota Prius c One[2]	50	$2,261	$569	4.0
2014 Toyota Yaris 5-Door LE	32			
2015 Ford Fusion Hybrid SE	42	$3,345	$741	4.5
2015 Ford Fusion FWD SE	26			
2015 Honda Civic Hybrid	45	$1,895	$408	4.6
2015 Honda Civic EX-L	33			
2015 Honda Civic Hybrid w/ Nav	45	$1,895	$408	4.6
2015 Honda Civic w/ Nav	33			

[1]Hybrid models shown with an MSRP difference of $0 are available to consumers as a no cost option although, performance is not necessarily compatible.

[2]Uses premium gasoline.

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:

Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov – Data accessed February 11, 2014.

Car-Sharing and Ride-Summoning Are a Growing Phenomenon

Car-sharing programs are not new to the United States, but have grown significantly over the last five years in an effort to provide an alternative to car ownership. Typically, car-sharing programs have membership requirements and hourly rates, unlike the rental-car business. Car-sharing programs may have a common vehicle fleet owned by the company or share members' vehicles. In addition, ride-summoning programs are also being used as an alternative to car ownership.

Car-sharing typically falls into two categories:

Types of Car-Sharing	Example Companies
Fleet vehicles provided by the company can be rented by the hour.	Enterprise CarShare ZipCar UHaulCarShare Car2Go
Fleet vehicles owned by members can be rented by other members.	FlightCar RelayRides

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 by Company Type

Organization	City / Region	Company Type
Buffalo CarShare	Buffalo, NY	Non-profit organization
CarShare Vermont	Burlington, VT	Non-profit organization
City CarShare	Berkeley, CA Alameda, CA Oakland, CA San Francisco, CA	Non-profit organization
Community Car	Madison, WI	For-profit company
Dancing Rabbit Vehicle Co-op	Rutledge, MO	Cooperative
eGo Carshare	Denver, CO	Non-profit organization
	Boulder, CO	Non-profit organization
FunRide	San Luis Obispo, CA Paso Robles, CA Santa Maria, CA Ventura, CA Grover Beach, CA	For-profit company
hOurcar	Minneapolis/St. Paul, MN	Non-profit organization
Ithaca CarShare	Ithaca, NY	Non-profit organization
Scoot	Kitsap County, WA	For-profit company
Timecar	Oklahoma City, OK	For-profit company

Source:
Data from CarSharing.Net with additional research by Oak Ridge National Laboratory, November 2014.
http://www.carsharing.net/where.html

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	Hertz 24/7	Car2Go	FlightCar	RelayRides	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	159	55	34	19	11	5	Unknown	128	62

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

Source:
Data from CarSharing.Net with additional research by Oak Ridge National Laboratory, November 2014.
http://www.carsharing.net/where.html

Almost 18% of Household Expenditures Are for Transportation

Except for housing, transportation was the largest single expenditure for the average American household in 2013. Of the transportation expenditures, vehicle purchases and gas and oil were the largest expenditures. In 1984, transportation was closer to 20% of all household expenditures and the share has generally fluctuated between 16% and 20% over time. In 2009, however, the transportation share reached a low of 15.6%.

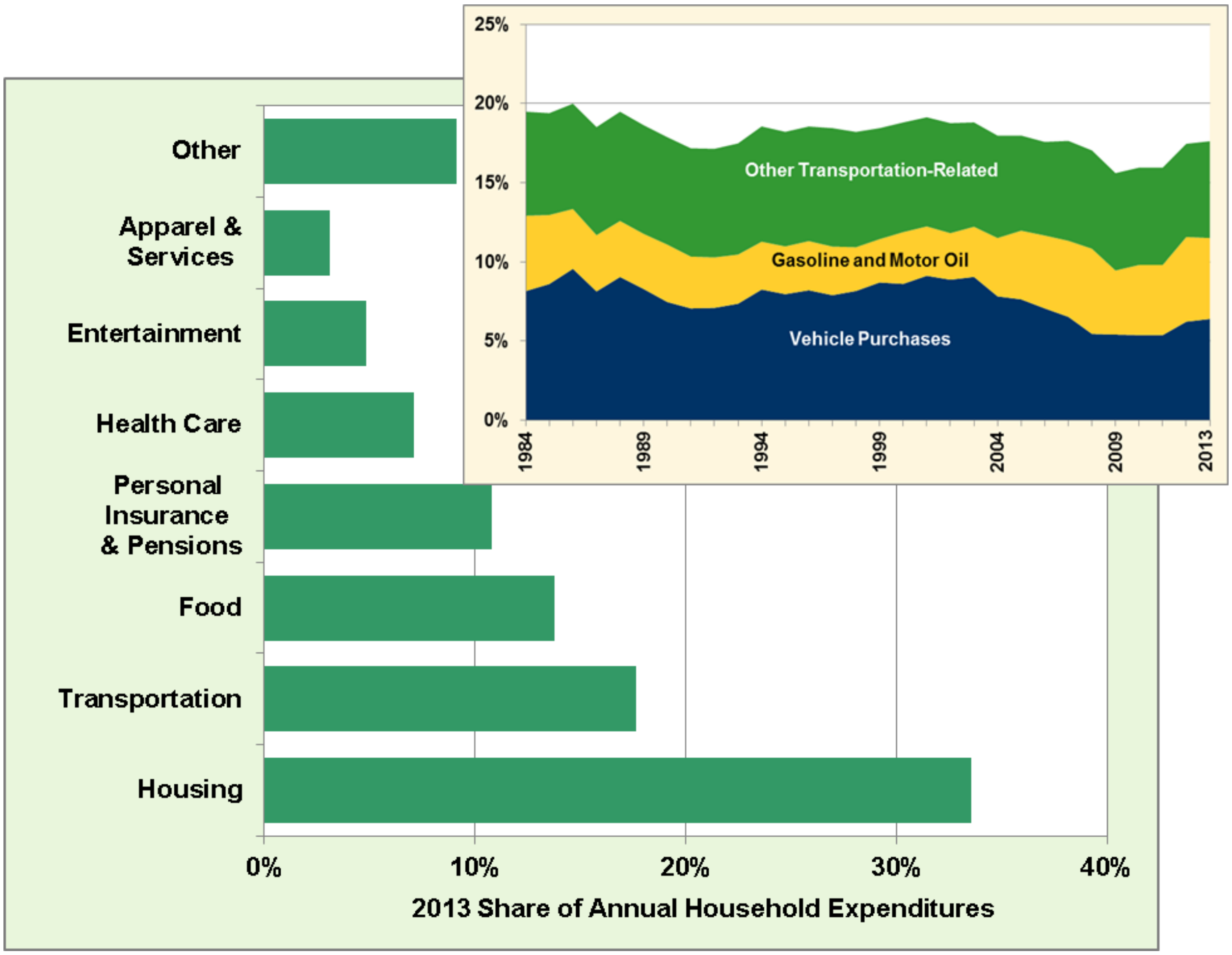


FIGURE 20. Share of Household Expenditures by Category, 2013, and Transportation Share of Household Expenditures, 1984-2013

Sources:

U.S. Department of Labor, *Consumer Expenditure Survey 2013*, Table 1202, Washington, DC, 2014, and multiyear survey tables. http://www.bls.gov/cex/

Almost 10 Million People Are Employed in the Transportation Industry

The transportation industry employs a wide variety of people in many different fields. From the manufacture of vehicles and parts to travel reservation services, 9.9 million people are employed in transportation-related jobs. These transportation-related jobs account for 7.3% 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.

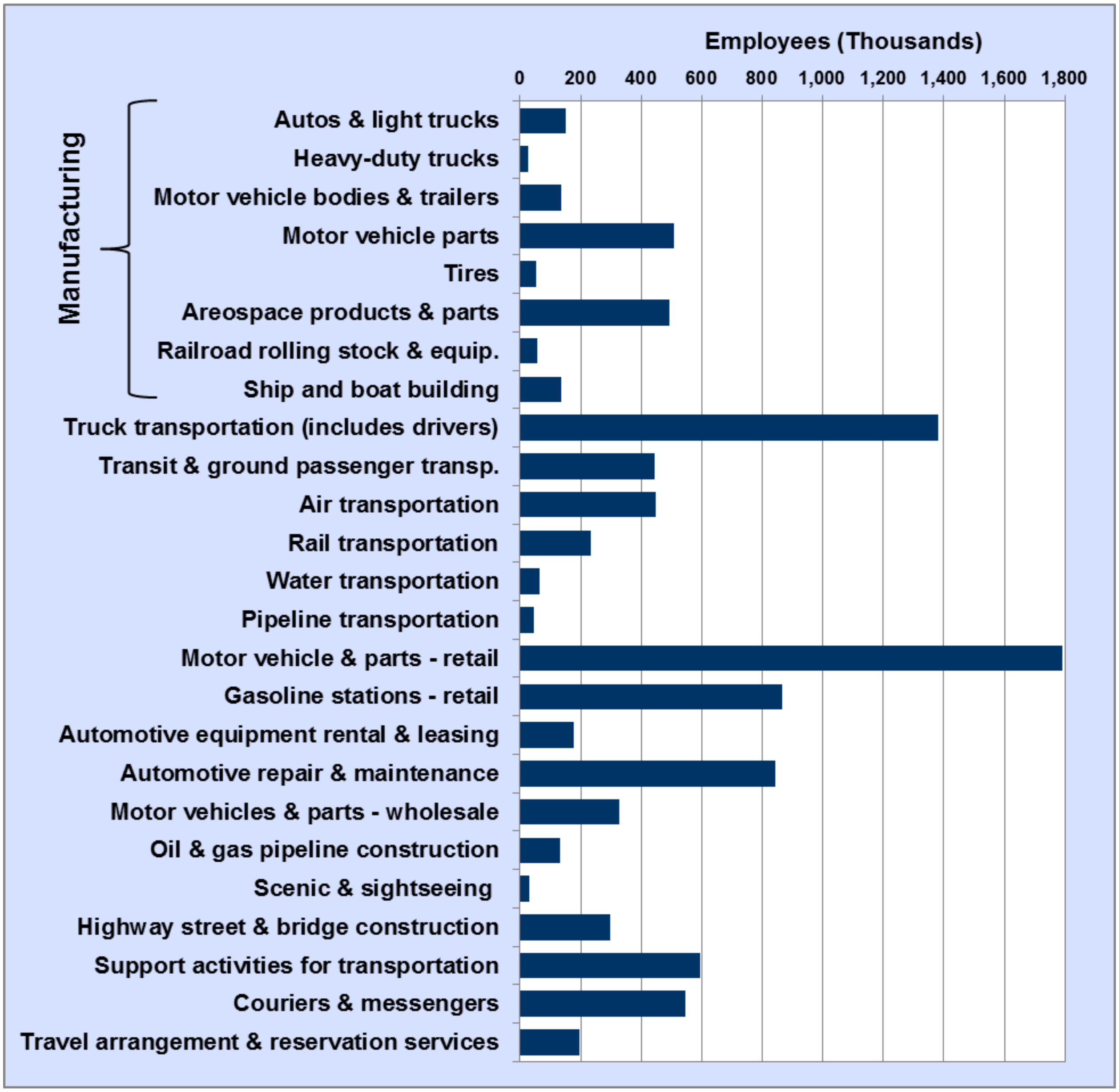
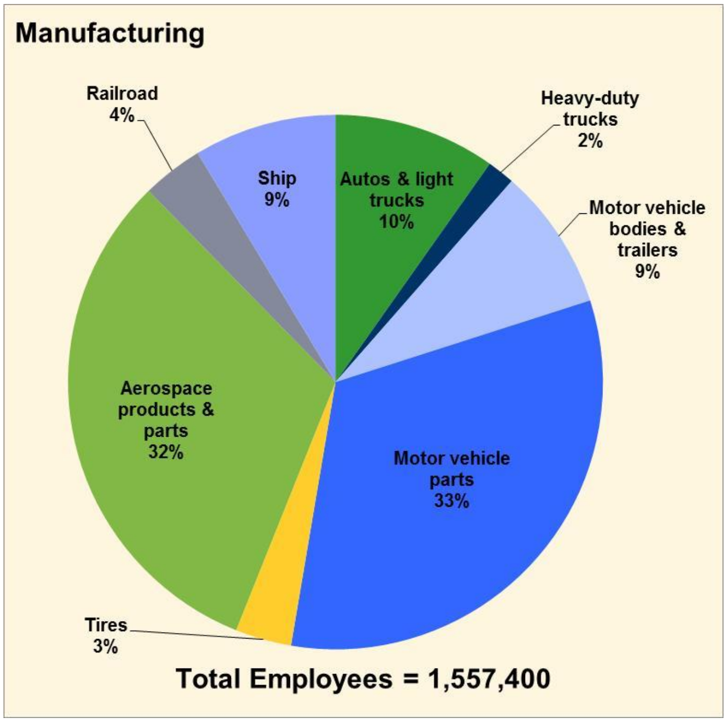


FIGURE 21. Transportation-Related Employment, 2013

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 1.5 million people. The highway mode – vehicles, parts, and tires – accounts for just over 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 2.6 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.

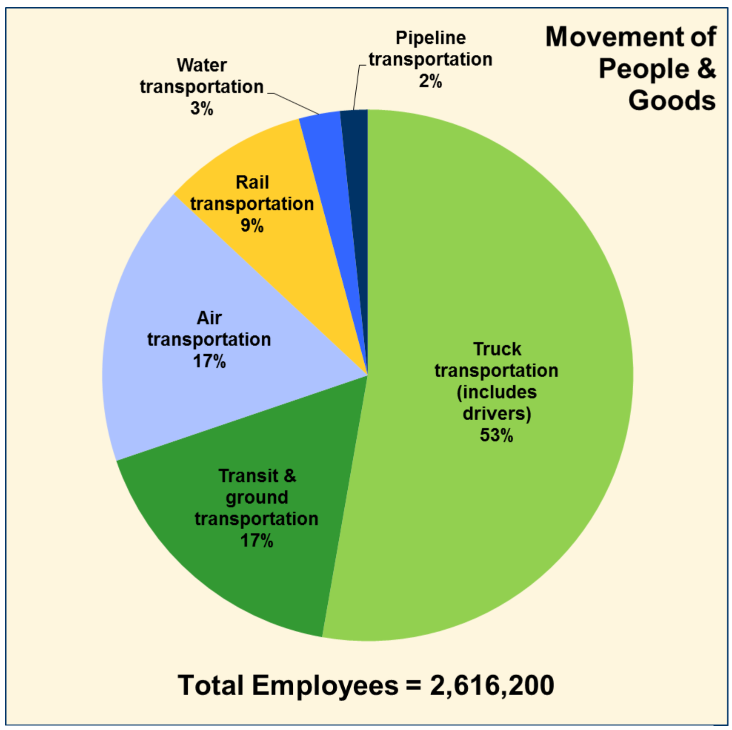


FIGURE 22. Transportation Manufacturing-Related and Mode-Related Employment, 2013

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

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’s stock remained consistently under $40 per share until 2013 when it skyrocketed to $193 per share. Chrysler stock is not currently traded and historical prices are not shown due to company changes from Daimler-Chrysler to Chrysler to Fiat-Chrysler. General Motors (GM) is shown twice – once before bankruptcy (GM-Old) and after the initial public stock offering in late 2010 (GM-New).

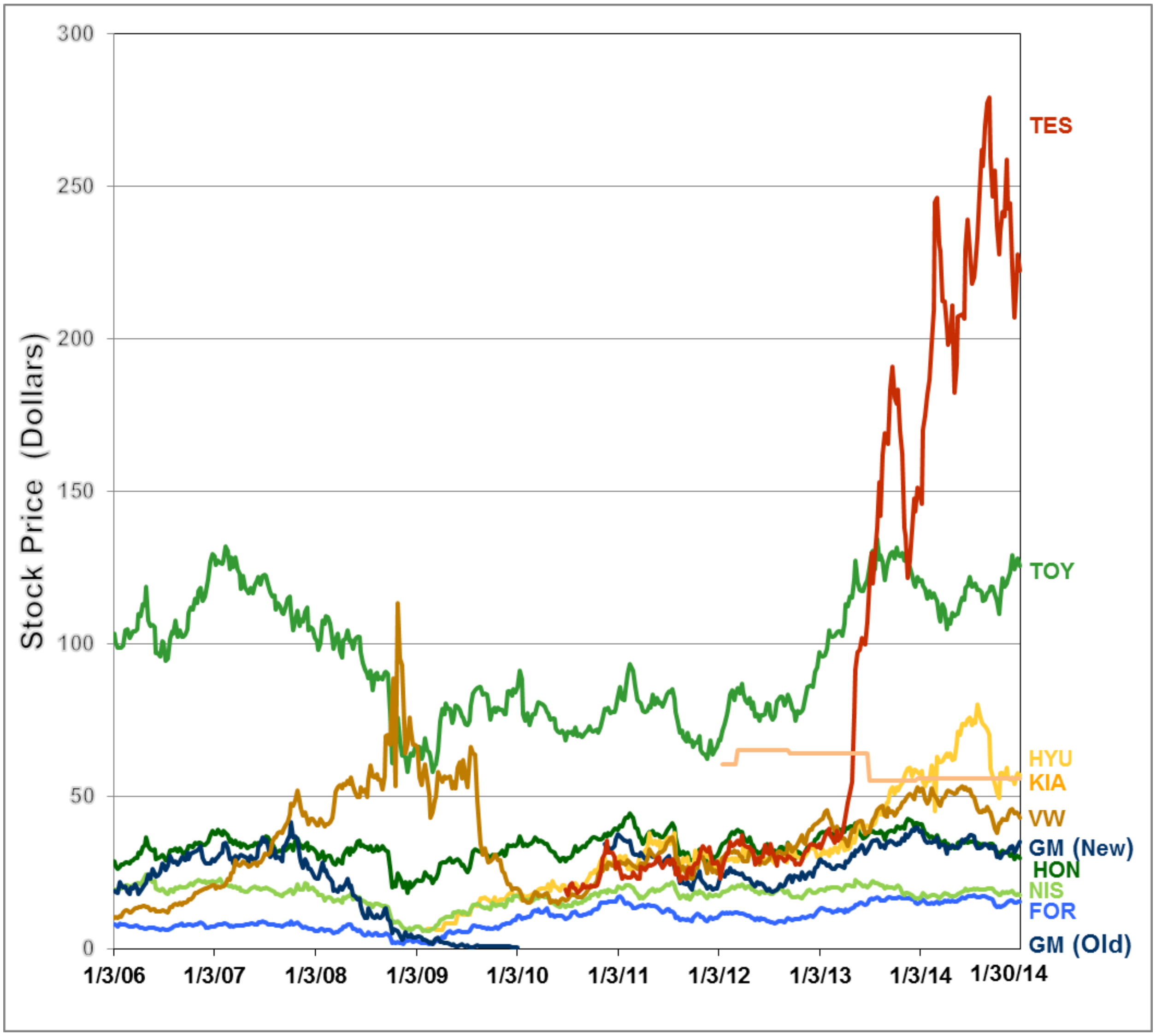


FIGURE 23. Stock Price by Manufacturer, 2006-2014

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 have developed estimates for the vehicles which have made the most money for their companies from the 1990's to today. 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.

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

Rank	Vehicle Model	Share of Manufacturers' Light Vehicles Sold, 2013	Share of Total Light Vehicles Sold, 2013
1	Ford F-Series	29%	5%
2	GM Full-Size Pickups	24%	4%
3	Dodge Ram	19%	2%
4	Mercedes S Class	4%	0%
5	BMW 5 Series/X5	26%	1%
6	BMW 3 Series	30%	1%
7	Mercedes E Class	22%	0%
8	Lexus RX SUV	5%	1%
9	Jeep Grand Cherokee	10%	1%
10	Honda Accord	24%	2%
11	Porsche 911	25%	0%
12	Toyota Camry	18%	3%

Source:
Ward's Autodata. http://wardsauto.com

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Chapter 2

LIGHT VEHICLES

Page

Contents

Page

Contents (continued)

Company Profile Section

Following are company profiles for nine different manufacturers.

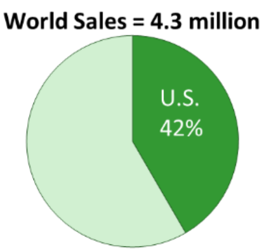
- The first page of each profile is an overview page containing the company's Corporate Average Fuel Economy, average vehicle footprint, number of alternative fuel models, production plant locations, production, and a brief summary of fuel saving technologies.
- The second page of each profile contains 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 includes a figure of hybrid vehicle sales by model and year. Also included is a pie chart depicting the manufacturer's share of the 2013 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.

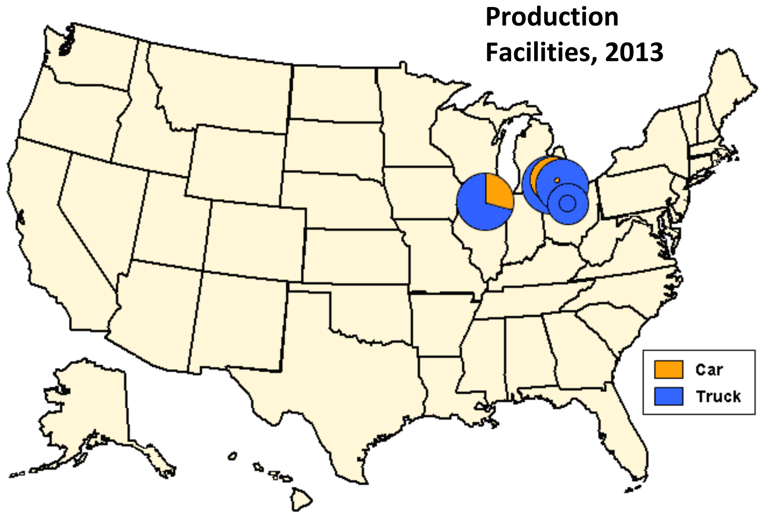
The nine manufacturers for which we have profiles are:

- ❖ three from Detroit
    - Chrysler (CHR),
    - 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)

Chrysler 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 2014	
Cars	47.2 sq ft
Light trucks	50.8 sq ft
All	49.4 sq ft
Number of Alternative Fuel Models, MY 2014	
Flex Fuel	13
Natural Gas	0
Propane	0
Hybrid-Electric	0
Plug-In Hybrid-Electric	0
Electric	1





Chrysler Plants	Type	2013 Production
Detroit, MI - Jefferson North	Truck	331,402
Toledo, OH - North & South	Truck	295,997
Warren, MI	Truck	291,554
Sterling Heights, MI	Car	252,730
Belvidere, IL	Truck	236,149
Belvidere, IL	Car	88,973
Detroit, MI - Conner	Car	1,501

FIGURE 24. Chrysler Company Profile

Fuel Saving Technologies

On December 16, 2014, Chrysler Group LLC was officially renamed FCA US, LLC, to better align with parent company Fiat Chrysler Automobiles NV. There were a number of important announcements in 2014 including the introduction of the 2014 Ram EcoDiesel full-sized truck; an efficient diesel engine, 8-speed transmission, stop-start technology, active grille shutters and aerodynamic under-body panels contributed to its best in class fuel economy for 2014. The use of 8-speed transmissions has also expanded with large investments in the Kokomo, Indiana, transmission plant while another Indiana plant at Tipton produces a 9-speed transmission for the Jeep Cherokee and new 2015 Chrysler 200. The Dodge Dart is available with a 6-speed automated manual dual -clutch transmission.

Besides the technologies that are now widely used like turbocharging, direct injection, active grill shutters, cylinder deactivation and stop-start, it was also announced that the next generation Jeep Wrangler would have an aluminum body in order to reduce weight and improve fuel economy. The new Wrangler will still be built with the body-on-frame architecture so that off-road capability will not be compromised. Although the next generation Wrangler will be made with an aluminum body and reducing weight is a priority, there are no immediate plans to follow Ford with aluminum-bodied Ram pickup trucks.

For vehicle electrification, there were no hybrid models offered during 2014 and the Fiat 500e, which debuted in 2013, remains the only all-electric vehicle produced by FCA. It is only available in select markets. However, CEO Sergio Marchionne confirmed that a plug-in hybrid minivan is planned for late 2015. The plug-in hybrid will be offered as a version of the next Chrysler Town and Country.

Chrysler's Fleet Mix

Chrysler'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.

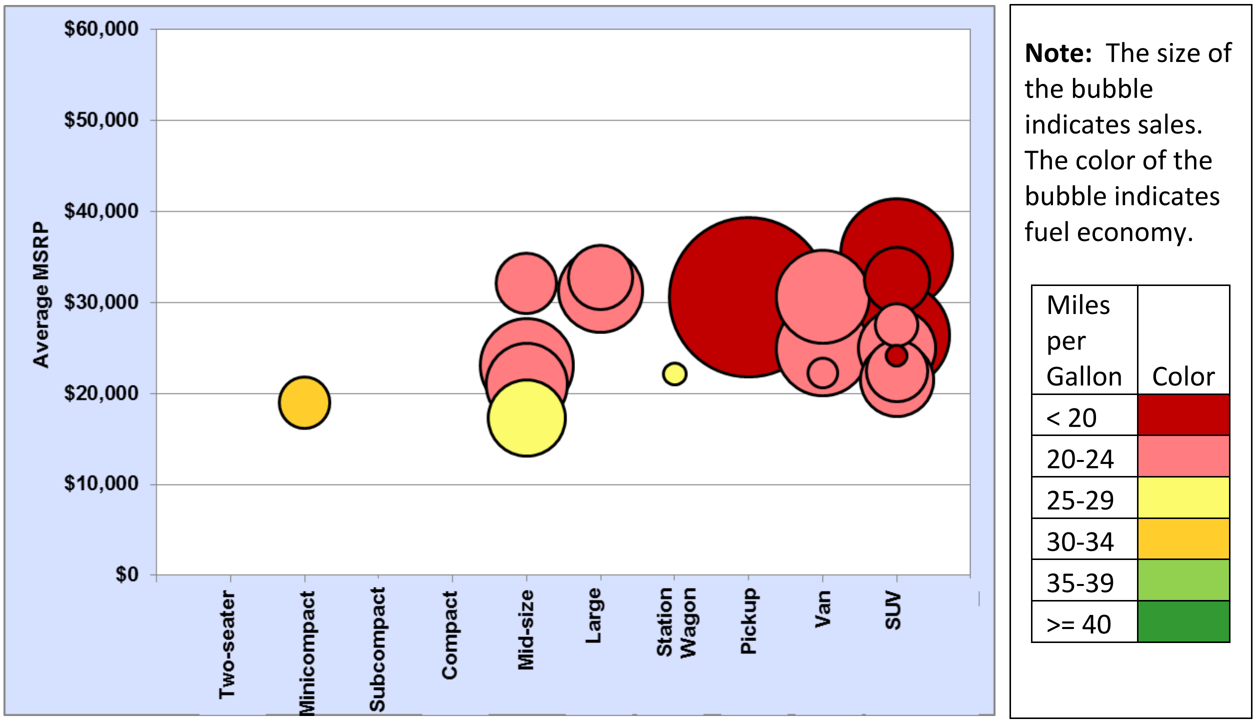


FIGURE 25. Chrysler Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 5. Chrysler Models by EPA Size Class, 2013

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

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

Fiat-Chrysler Debuted the Fiat 500e in 2013

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. The Fiat 500e was only sold in California.

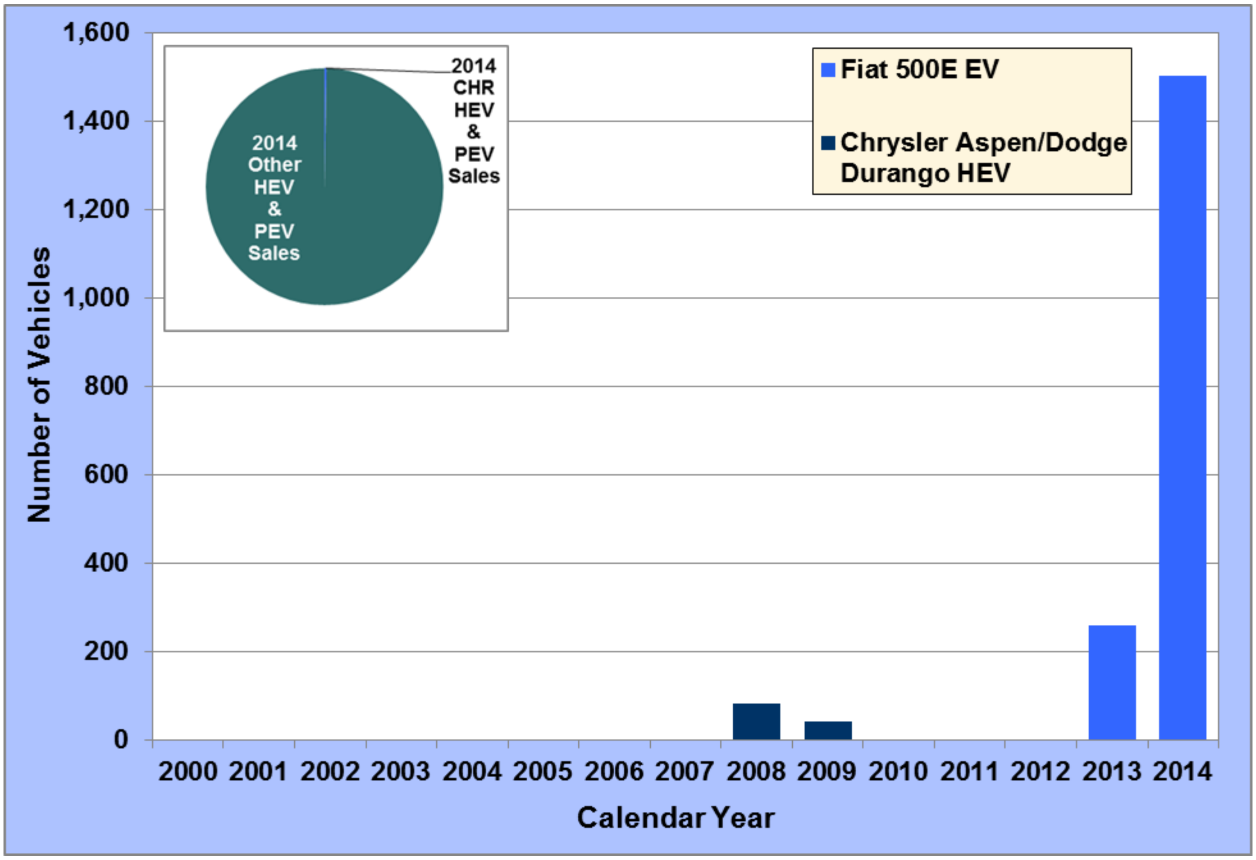


FIGURE 26. Chrysler Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 40, 44, 48, 52, 56, 60, 64, 68) 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.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Fiat Owns All of Chrysler as of January 2014

TABLE 6. Chrysler 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						✓	Manufacturers Chrysler minivans for Taiwanese market
Fiat	✓						Owns 58.5% of Chrysler as of January 2014
Fiat						✓	Builds Jeep vehicles in its Mirafiori, Italy plant
Fiat			✓		✓		Share technology, engines, transmissions & platforms
Fiat				✓			Utilizes Chrysler's distribution network and North American Plants; distributes Chrysler vehicles in overseas markets
GM, Ford					✓		Co-research projects under the USCAR
Hyundai				✓			Sells Hyundai Atos in Mexico as a Dodge
Mitsubishi				✓			Supply its Thai-built Attrage sedan to Chrysler for sale in Mexico

Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

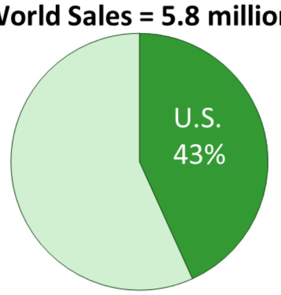
Ford Company Profile

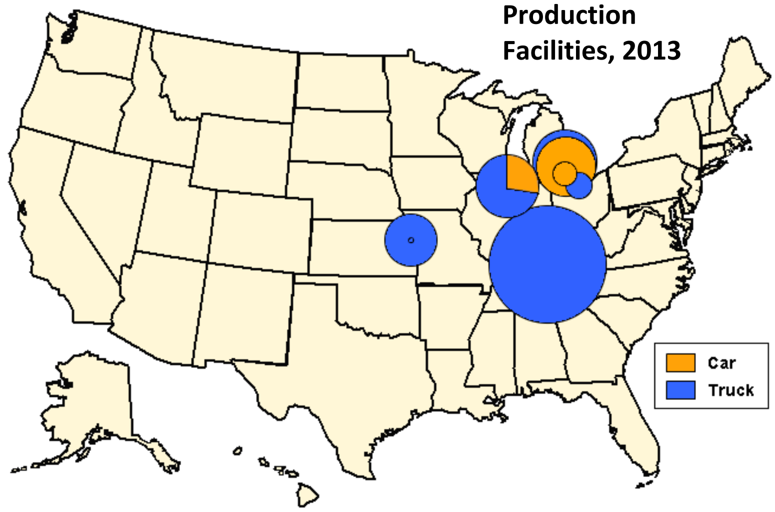
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	36.8 mpg
Import Cars	30.9 mpg
Light Trucks	25.2 mpg

Average Vehicle Footprint, MY 2014	
Cars	46.2 sq ft
Light Trucks	58.4 sq ft
All	51.6 sq ft

Number of Alternative Fuel Models, MY 2014	
Flex Fuel	17
Natural Gas	0
Propane	0
Hybrid-Electric	3
Plug-In Hybrid-Electric	2
Electric	1

World Sales = 5.8 million





Ford Plants	Type	2013 Production
Louisville, KY	Truck	686,613
Dearborn, MI	Truck	358,443
Wayne, MI	Car	331,341
Kansas City, MO	Truck	289,882
Chicago, IL	Truck	246,866
Avon Lake, OH	Truck	132,390
Flat Rock MI	Car	117,297
Chicago, IL	Car	104,808

FIGURE 27. Ford Company Profile

Fuel Saving Technologies

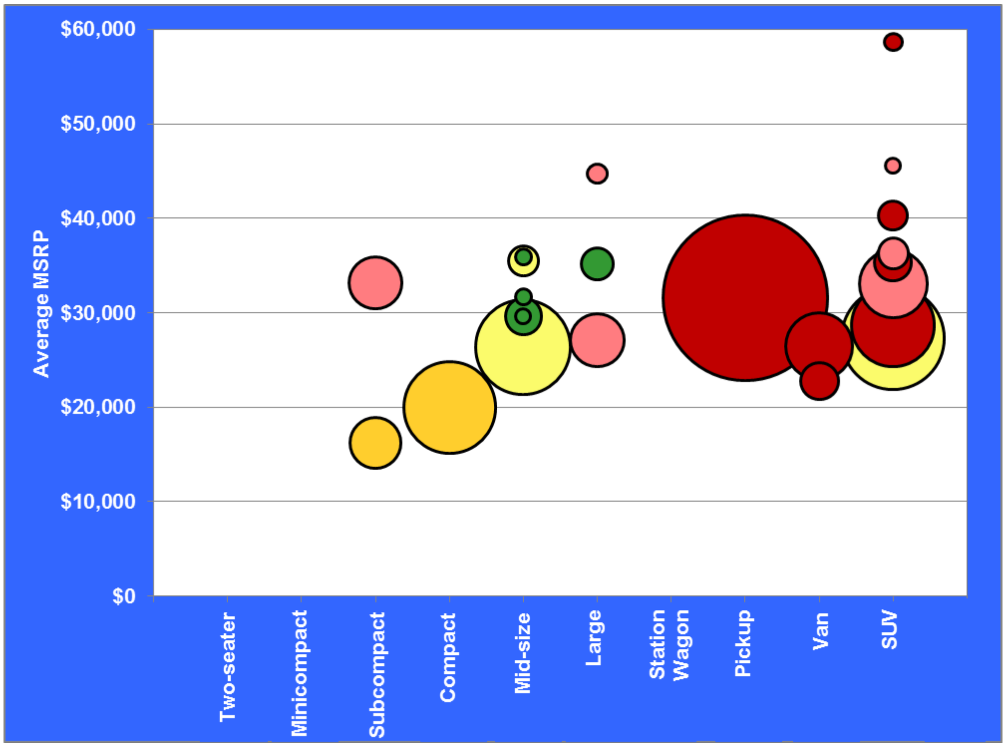
Ford's redesigned F-150 pickup arrived in 2014 (as a 2015 model), weighing about 700 pounds less than its predecessor and became the most fuel-efficient gasoline powered half-ton truck on the market. Weight savings were primarily achieved through the use of aluminum body panels and bed, and greater use of high-strength steel in the frame. Ford expanded the use of EcoBoost technology that uses gasoline direct injection and variable valve timing combined with turbocharging to increase engine output relative to engine displacement. EcoBoost is being deployed throughout Ford's line-up of vehicles from work trucks to their smallest entry-level cars. Ford introduced their smallest displacement engine with the 2014 Ford Fiesta SFE. The three-cylinder, 1.0 liter EcoBoost engine produces 123 horsepower and 125 pound-feet of torque.

Other engine technologies include twin independent variable camshaft timing (Ti-VCT), aggressive deceleration fuel shut-off, and active grille shutters that limit airflow to the engine compartment to improve aerodynamics at high speed. Ford intends to employ greater use of Stop-Start systems on their vehicles. Ford's Auto Start-Stop was added as an option to the 2014 Ford Fusion and will be available on 70% of Ford's North American lineup by 2017.

For vehicle electrification, 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 Ford 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 based on EPA estimates.

Ford's Fleet Mix

Ford Motor Company has a fairly even distribution of vehicles 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 five models exceeding 40 mpg.



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

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

FIGURE 28. Ford Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 7. Ford Models by EPA Size Class, 2013

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

Note: Includes Ford and Lincoln.

Ford Hybrid and Plug-in Vehicle Sales Remain Steady for 2014

After more than doubling in 2013, Ford hybrid and plug-in vehicle sales remained fairly constant in 2014. The Ford Fusion hybrid and Ford Energi plug-in series (Fusion and C-Max) together accounted for the majority of Ford's hybrid and plug-in sales. Ford has the second highest share (15%) of the hybrid-electric (HEV) and plug-in (PEV) market.

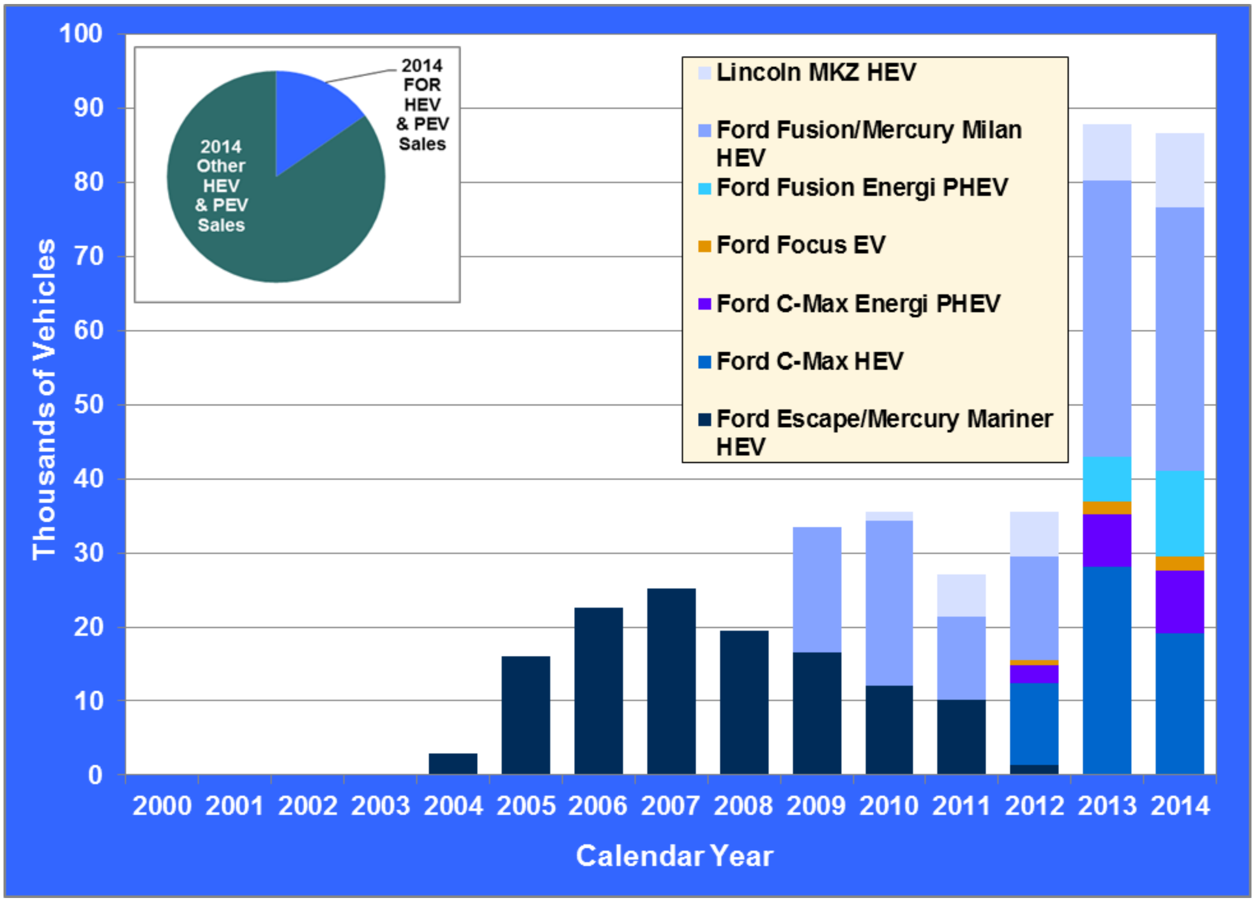


FIGURE 29. Ford Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 44, 48, 52, 56, 60, 64, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

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
Fiat						✓	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:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

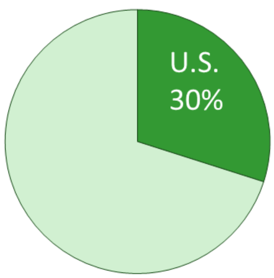
General Motors (GM) Company Profile

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

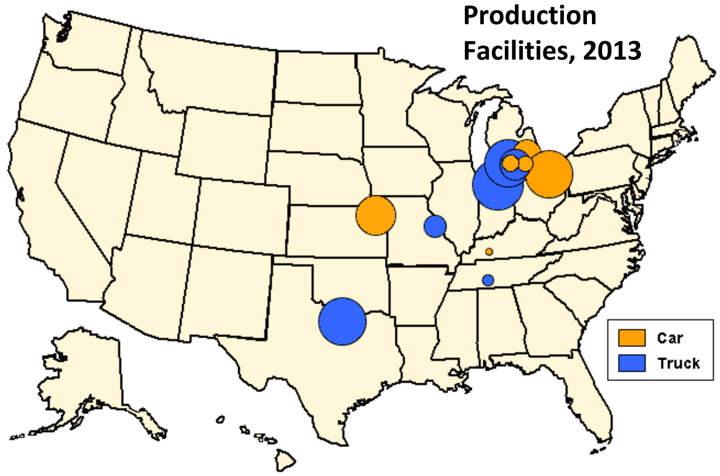
Average Vehicle Footprint, MY 2014	
Cars	46.4 sq ft
Light Trucks	61.1 sq ft
All	52.9 sq ft

Number of Alternative Fuel Models, MY 2014	
Flex Fuel	32
Natural Gas	3
Propane	2
Hybrid-Electric	0
Plug-In Hybrid-Electric	2
Electric	1

World Sales = 9.3 million



Production Facilities, 2013



GM Plants	Type	2013 Production
Fort Wayne, IN	Truck	298,872
Lordstown, OH	Car	282,946
Arlington, TX	Truck	278,346
Lansing, MI - Delta	Truck	278,056
Fairfax, KS	Car	229,155
Flint, MI	Truck	172,350
Orion, MI	Car	147,684
Wentzville, MO	Truck	112,057
Lansing, MI - Grand River	Car	82,606
Hamtramck, MI	Car	73,737
Spring Hill, TN	Truck	40,446
Bowling Green, KY	Car	15,726

FIGURE 30. GM Company Profile

Fuel Saving Technologies

GM introduced two new midsize pickup trucks in 2014 bringing consumers a smaller and more fuel-efficient alternative in a segment dominated by full-sized trucks. The 2015 Chevrolet Colorado and 2015 GMC Canyon pickups come standard with 4-cylinder engines that produce 200 horsepower and an optional 6-cylinder engine producing 305 horsepower. For full-sized pickup trucks GM offers cylinder deactivation termed "Active Fuel Management" for 8-cylinder models.

In 2014, the mild hybrid eAssist system was dropped from the Chevrolet Malibu and Impala in favor of a simple and cost effective stop/start option that is standard on the 2015 Chevrolet Impala. GM is not abandoning the eAssist technology as it is still offered on the Buick Regal and LaCrosse as a no cost option.

The next generation Chevrolet Volt plug-in hybrid neared completion by the end of 2014 and should arrive in 2015 as a 2016 model. GM was able to reduce the battery size, weight, and battery pack cells while increasing energy density by ~20%. The new electric motors are smaller, lighter, more efficient, and will include fewer rare earth metals. The new Volt is expected to have an all-electric range of 50 miles versus 38 for the current model. The Chevrolet Spark remains GM's only all-electric vehicle. However, GM executives have stated their intention to add another all-electric vehicle to their line-up with a range of ~ 200 miles. Aside from expanding the use of direct injection and turbo charging, GM has been collaborating with Honda on the development of fuel cell technology with plans to commercialize fuel cell vehicles by around 2020.

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.

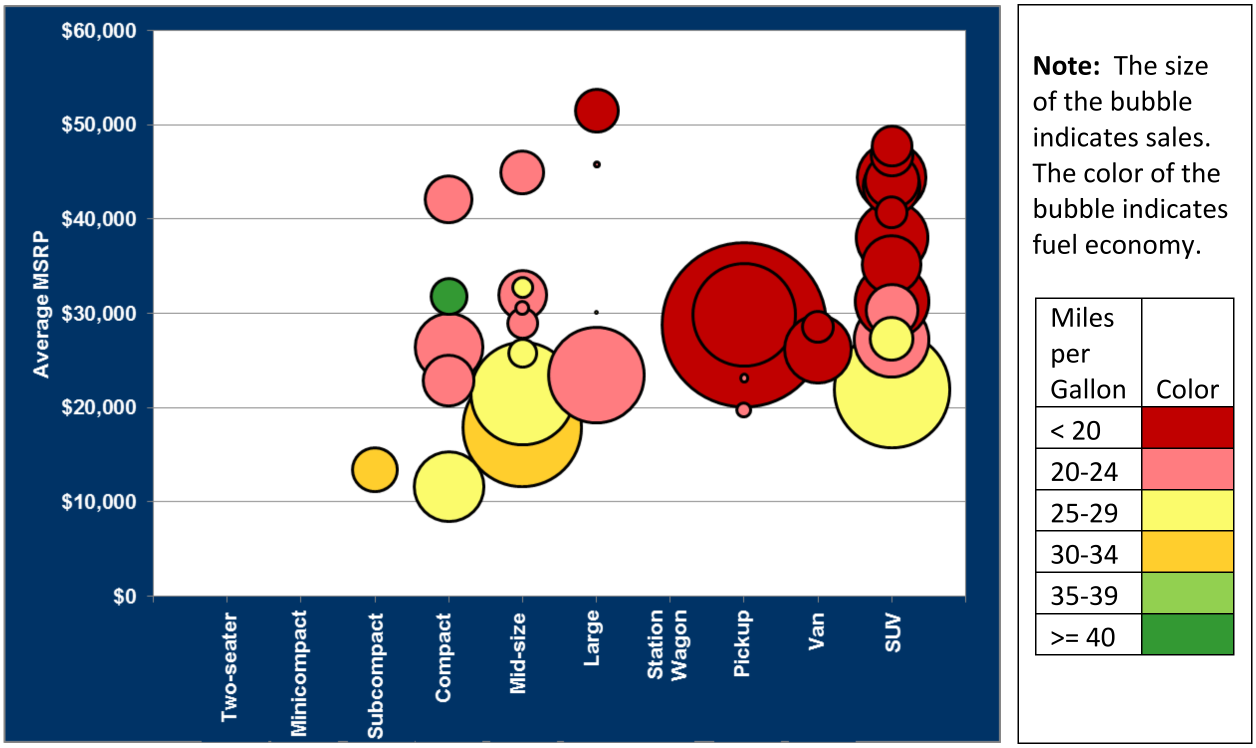


FIGURE 31. GM Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 9. GM Models by EPA Size Class, 2013

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

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

Chevrolet Volt is More than Half of GM's Hybrid and Plug-In Sales in 2014

Cancelation of hybrid truck models and declining sales of the eAssist Chevrolet Malibu contributed to a decline in GM's 2013 and 2014 hybrid sales. Thus, the Chevrolet Volt sales, which declined slightly between 2013 and 2014, accounted for more than half of GM's hybrid and plug-in sales. In 2014 GM sold just over 5% of all hybrid-electric (HEV) and plug-in (PEV) sales.

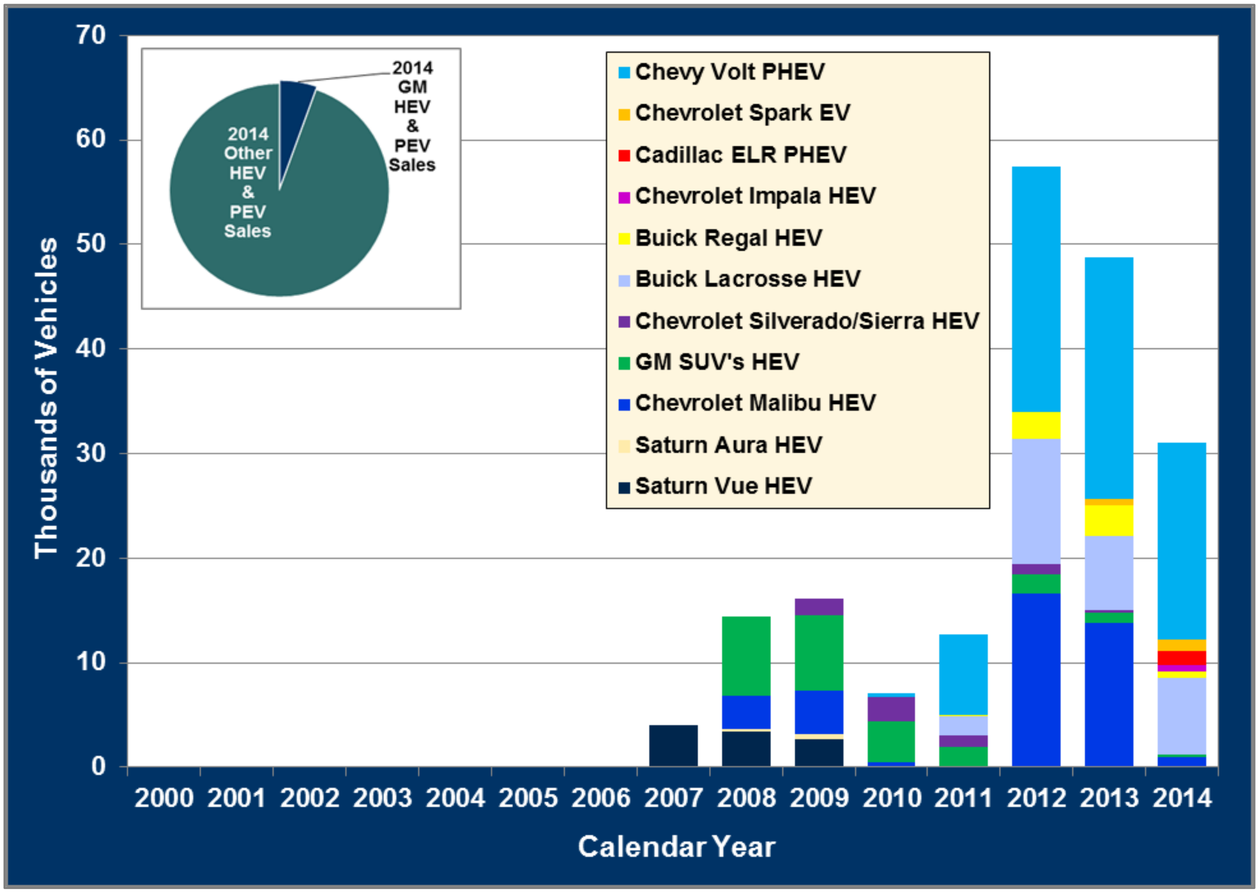


FIGURE 32. GM Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 48, 52, 56, 60, 64, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

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 Chevy 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
Fiat				✓			Supplies light vehicles to Opel to sell as the Combo
Ford					✓		Developing 9- and 10-speed automatic transmissions
Ford & Chrysler					✓		Co-research projects under the USCAR
Gaz						✓	Assembles Chevy 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 Chevy 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 Chevy models

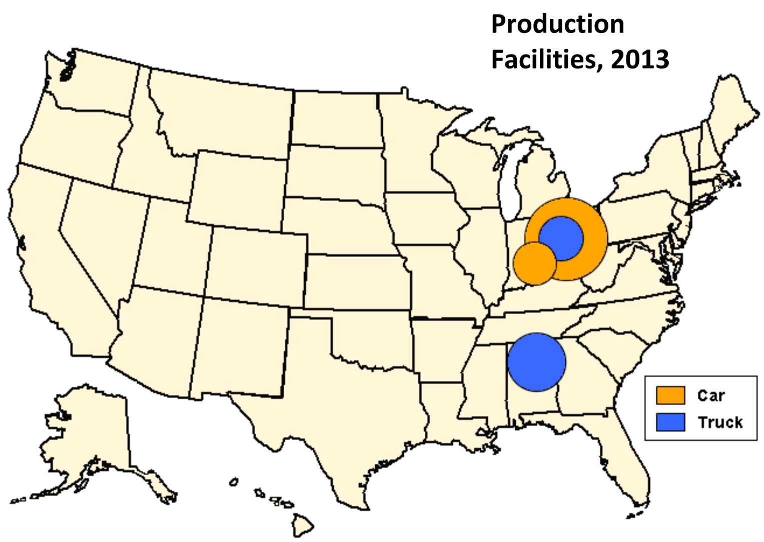
Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

Honda Company Profile

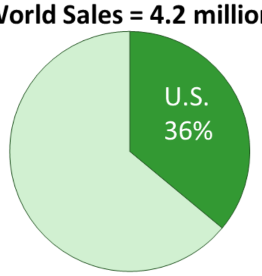
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	39.6 mpg
Import Cars	42.0 mpg
Light Trucks	28.8 mpg

Average Vehicle Footprint, MY 2014	
Cars	45.7 sq ft
Light Trucks	50.4 sq ft
All	47.2 sq ft

Number of Alternative Fuel Models, MY 2014	
Flex Fuel	0
Natural Gas	1
Propane	0
Hybrid-Electric	6
Plug-In Hybrid-Electric	1
Electric	1



World Sales = 4.2 million



Honda Plants	Type	2013 Production
Marysville, OH	Car	492,409
Lincoln, AL	Truck	333,556
East Liberty, OH	Truck	242,363
Greensburg, IN	Car	241,589

FIGURE 33. Honda Company Profile

Fuel Saving Technologies

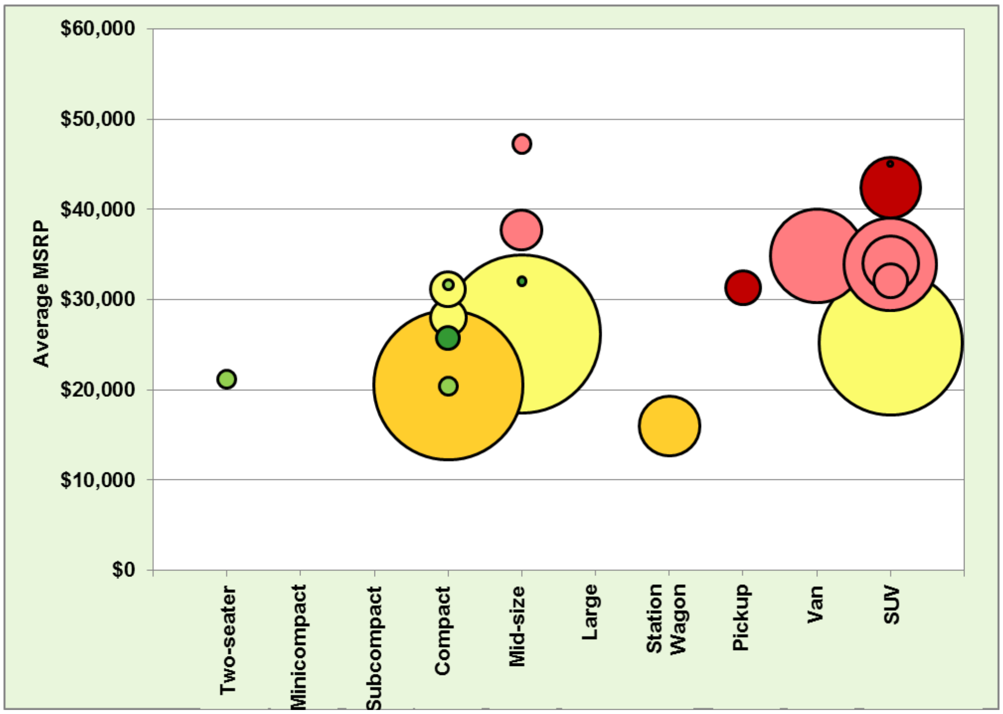
Production of Honda's first hybrid vehicle, the Insight, came to an end in 2014 and Honda also dropped the Acura ILX hybrid. However, Honda remains committed to a range of hybrid technologies, offering hybrid drive trains in the CR-Z sport hybrid and on versions of the Civic, Accord and Acura RLX. The Honda Fit is available as a hybrid in foreign markets but not in the US. For enhanced electrification, Honda also offers a plug-in hybrid version of the Accord that delivers about 13 miles of EV operation. Honda's only all-electric model, the Fit EV which debuted as a 2013 model, was discontinued in 2014 after just two model years.

Other alternative fuel models include the Honda Civic Natural Gas sedan, which continues to be the only natural gas sedan on the market from a major automaker. Also in late 2014, Honda unveiled the all-new FCV concept – a fuel-cell sedan that follows the Honda FCX Clarity, which has been available to customers in California as a lease vehicle since 2008. The new FCV Concept has a fuel cell stack 33% smaller than the previous fuel cell stack while producing 60% more output. The size reduction of the fuel cell components 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 since the cabin space is not compromised.

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.

Honda's Fleet Mix

Honda Motor Company has just three models with a combined average fuel economy of less than 20 mpg and they represent a small portion of their 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. 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 34. Honda Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 11. Honda Models by EPA Class, 2013

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

Note: Includes Honda and Acura.

Honda Hybrid Sales Show Growth in 2014

Hybrid sales for Honda continue to rebound from the low in 2012. The new hybrid Accord is responsible for most of that growth. Honda has two plug-in vehicles, the Accord PHEV and the Fit EV (electric vehicle), which were sold in 2013 and 2014. The Fit EV is only sold in California. In 2014 Honda sold just under 5% of all hybrid-electric (HEV) and plug-in (PEV) sales.

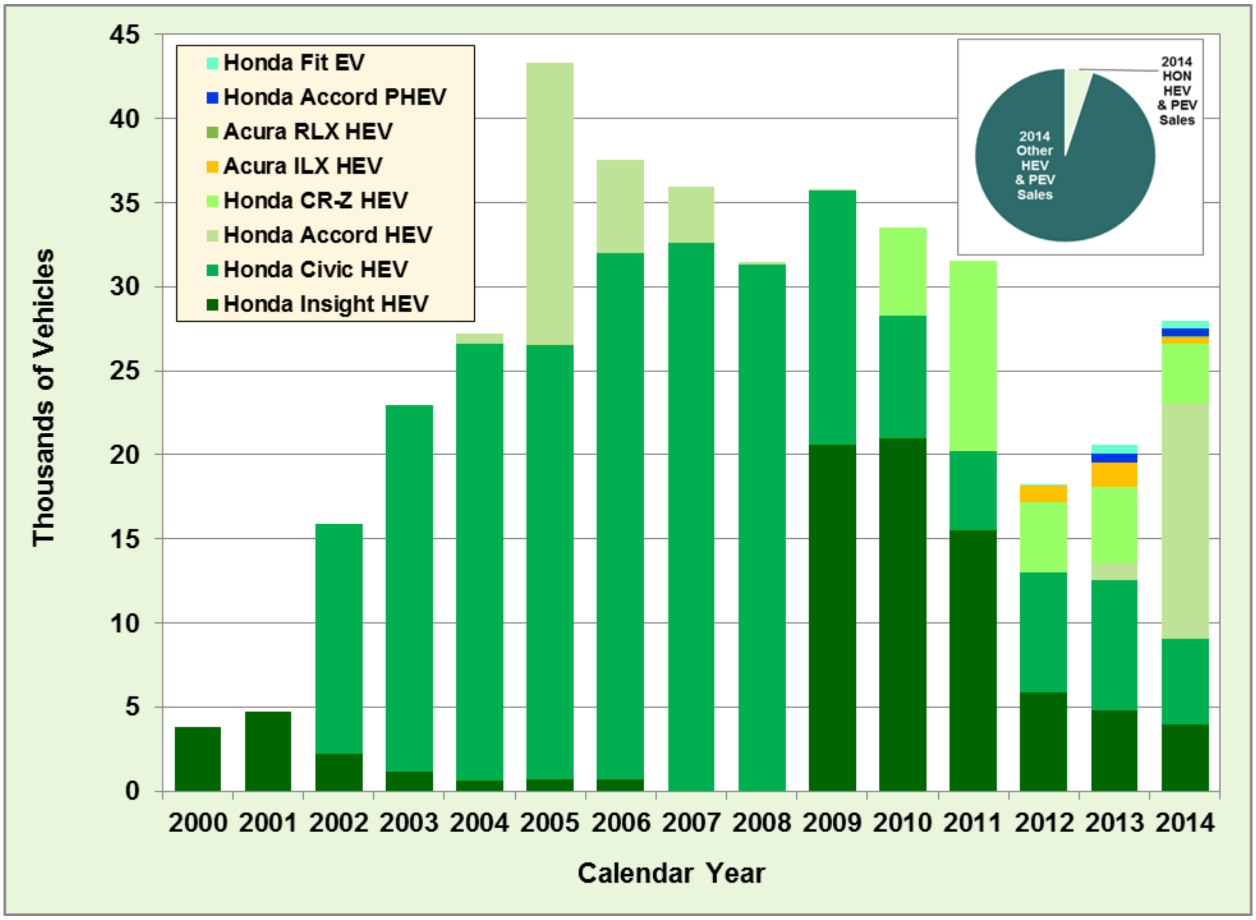


FIGURE 35. Honda Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 52, 56, 60, 64, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Honda Has Few Interrelationships for a Manufacturer of Its Size

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
Proton				✓	✓		Planning partnership to include platform sharing and distribution arrangements

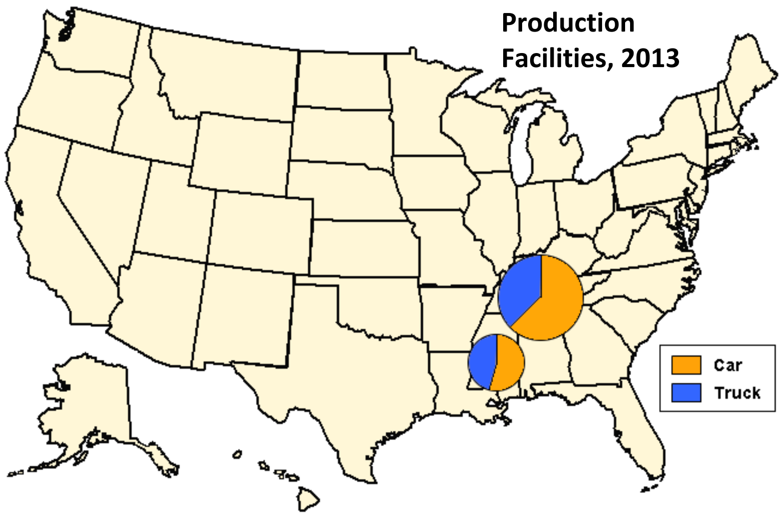
Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

Nissan Company Profile

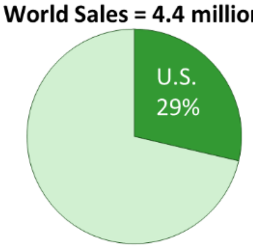
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	40.6 mpg
Import Cars	38.8 mpg
Light Trucks	26.7 mpg

Average Vehicle Footprint, MY 2014	
Domestic Cars	45.5 sq ft
Import Cars	52.7 sq ft
Light Trucks	47.5 sq ft

Number of Alternative Fuel Models, MY 2014	
Flex Fuel	2
Natural Gas	0
Propane	0
Hybrid-Electric	5
Plug-In Hybrid-Electric	0
Electric	1



World Sales = 4.4 million



Nissan Plants	Type	2013 Production
Smyrna, TN	Car	301,733
Smyrna, TN	Truck	182,407
Canton, MS	Car	168,499
Canton, MS	Truck	139,614

FIGURE 36. Nissan Company Profile

Fuel Saving Technologies

Of the major manufacturers, Nissan has been the most aggressive in promoting all-electric vehicles, not only in the U.S., but also around the world. U.S. sales of the all-electric Nissan Leaf topped 30,000 units in 2014 setting a record for annual sales volume of a plug-in vehicle. Nissan also developed a more heat-resistant battery to address concerns of premature battery degradation and range loss in extremely hot climates. The all-electric e-NV200 commercial van began testing in 2014 for a possible U.S. launch, and a luxury EV is still planned for the Infiniti LE sedan. However, the launch date of the Infiniti LE was pushed back until 2017. For the 2014 model year, Nissan also introduced new hybrid technology with the Nissan Pathfinder Hybrid.

Nissan has long been a leader in the development and implementation of continuously variable transmissions (CVTs). Without fixed gear ratios, the CVT provides smooth “stepless” acceleration and Nissan’s XTRONIC CVT offers one of the widest gear ratio ranges in the industry. CVTs are typically used on vehicles with small displacement engines with limited torque. However, Nissan was the first to offer the CVT for engines as large as 3.5 liters and now offers them throughout their line-up including high-powered luxury vehicles.

Nissan made bold commitments in the area of autonomous vehicles with the stated goal of offering commercially-viable autonomous vehicles by 2020. They are working with universities like MIT, Stanford, Oxford, Carnegie Mellon, and the University of Tokyo. Nissan also has a partnership with NASA to speed development of autonomous vehicles; in 2014, they developed a dedicated proving ground for autonomous vehicles in Japan. Although autonomous vehicles are generally discussed from a safety standpoint, they have indirect implications for fuel efficiency as they can affect the patterns of vehicle use and operation.

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.

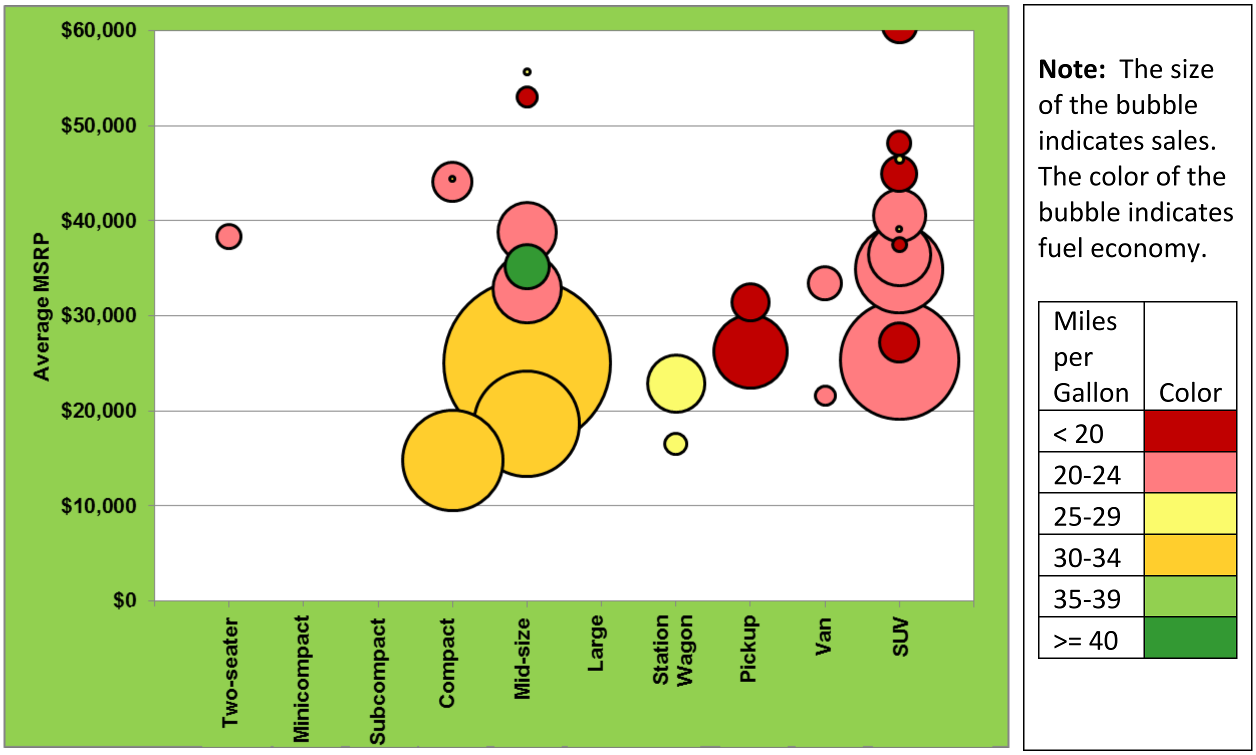


FIGURE 37. Nissan Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 13. Nissan Models by EPA Size Class, 2013

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

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

Nissan Leaf Sales Exceed 30,000 Units in 2014

Sales of the Nissan Leaf electric vehicle (EV) represent the vast majority of Nissan's hybrid and plug-in vehicle sales. Hybrid models, including the Pathfinder, Infiniti Q50 and Infiniti Q60 also grew substantially in 2014. Nissan is responsible for 6.7% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales.

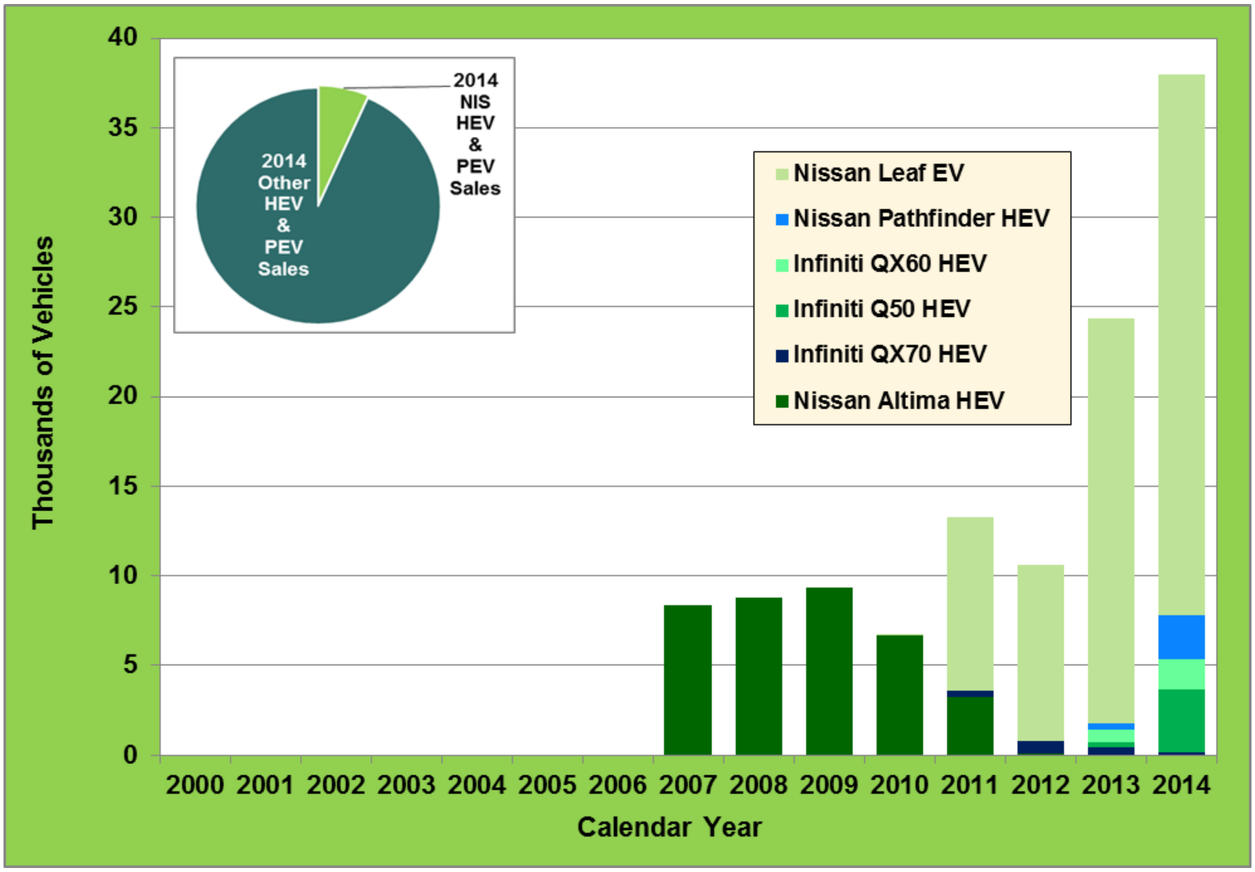


FIGURE 38. Nissan Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Notes: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 48, 56, 60, 64, 68) 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.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Nissan Has Many Manufacturing/Assembly Agreements with Other Manufacturers

TABLE 14. Nissan Interrelationships with Other Automotive Manufacturers

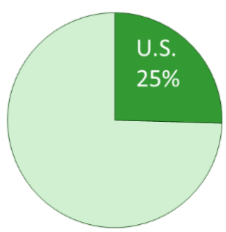
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Avtovaz	✓						Joint venture with Renault-Nissan
Dacia					✓		Co-engineered Nissan Logan platform built by Dacia
Daimler, Ford					✓		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
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

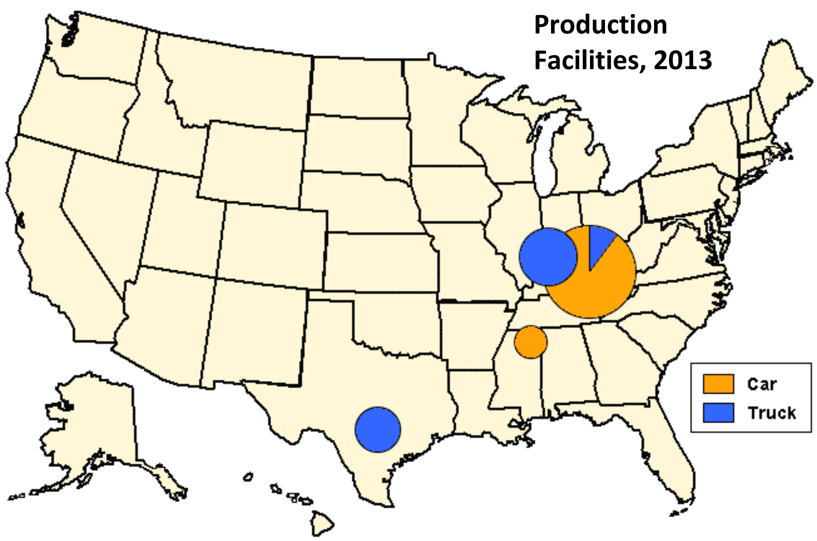
Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

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 2014	
Cars	45.0 sq ft
Light Trucks	53.7 sq ft
All	48.2 sq ft
Number of Alternative Fuel Models, MY 2014	
Flex Fuel	2
Natural Gas	0
Propane	0
Hybrid-Electric	11
Plug-In Hybrid-Electric	1
Electric	2

World Sales = 8.8 million





Toyota Plants	Type	2013 Production
Georgetown, KY	Car	448,976
Princeton, IN	Truck	299,820
San Antonio, TX	Truck	228,983
Blue Springs, MS	Car	158,647
Georgetown, KY	Truck	55,237

FIGURE 39. Toyota Company Profile

Fuel Saving Technologies

During 2014, Toyota built on their commitment to commercialize fuel cell vehicles and revealed the pre-production 2016 Toyota Mirai fuel cell vehicle, a sedan scheduled to go on sale in California in late 2015. Toyota's strategy for fuel cell vehicles differs somewhat from those of other manufactures in that they are combining the efficiency benefits of their electric Hybrid Synergy Drive system with a hydrogen tank and fuel cell stack. The Mirai has a range of about 300 miles and a refueling time of about five minutes.

Toyota's emphasis on fuel cell vehicles coincides with the cancellation of some all-electric vehicle programs. In 2014, they announced that production of the Toyota RAV4 EV would be discontinued, ending their partnership with Tesla for the production of the RAV4 EV powertrain. Toyota also dropped plans to further market the Scion iQ EV micro car that was only sold in limited markets and in very small numbers. Although Toyota cancelled their all-electric vehicle offerings, they remain committed to expanding and refining their Hybrid Synergy Drive technology and they continue to produce the Toyota Prius plug-in hybrid that delivers about 11 miles of EV operation. Conventional models also received engine and transmission refinements. The 2014 Toyota Corolla was offered with a new CVTi-S (intelligent-Shift) transmission, which is a CVT that mimics shifting while still improving fuel economy.

In the interest of reducing vehicle weight, Toyota plans to expand the use of aluminum across their vehicle line-up for hoods, closures, and other parts. The 2016 Lexus RX350 crossover is expected to get an aluminum hood and lift-gate while the higher volume Toyota Camry will also be fitted with an aluminum hood by 2018 according to several media sources. Toyota is also expanding the use of high-strength steels, mixed metals and resin-based materials across their range of vehicles to reduce overall vehicle weight.

Toyota's Fleet Mix

Toyota produces many models and they are fairly evenly split between cars and trucks. Among the truck models, more than half achieve a combined fuel economy of more than 20 mpg. Most of the car models had a combined fuel economy of 25 mpg or higher and those models also represented a large portion of Toyota's overall sales. Eight models (shown in dark green) had a combined average fuel economy of 40 mpg or higher.

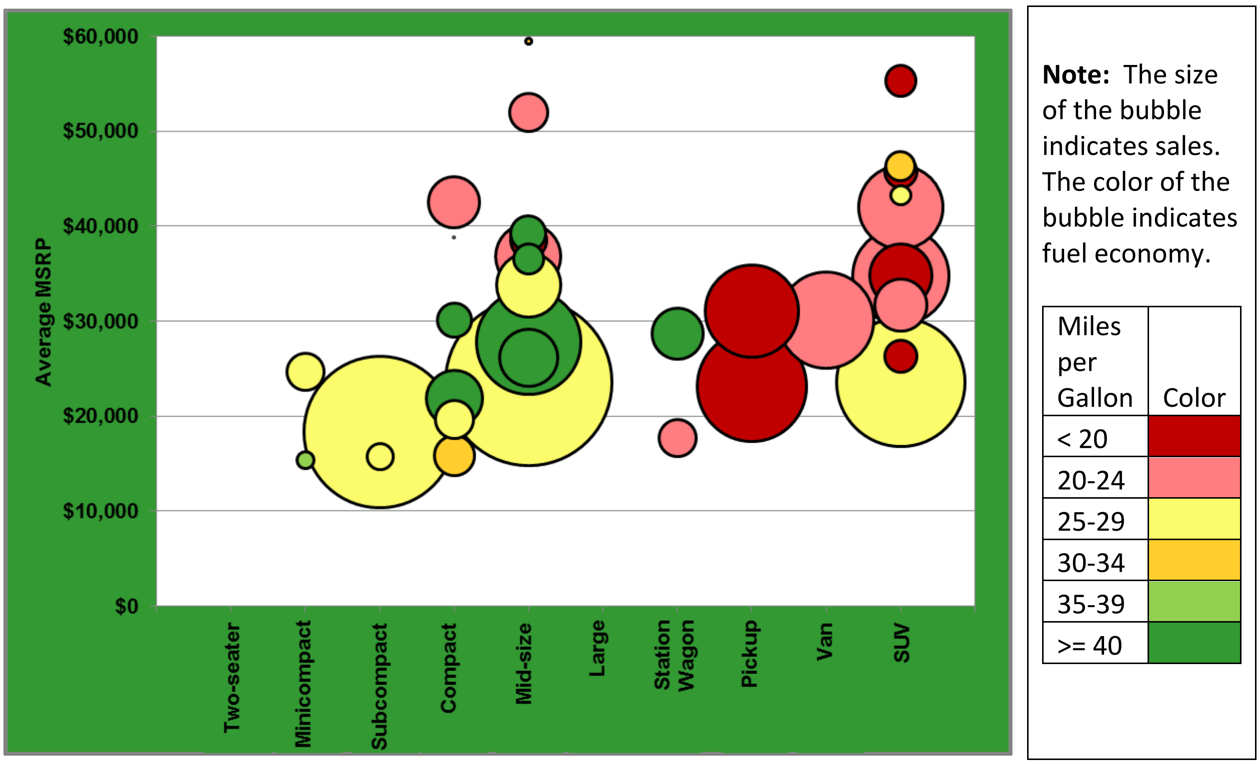


FIGURE 40. Toyota Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 15. Toyota Models by EPA Size Class, 2013

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

Toyota Accounted for over Half of All Hybrid and Plug-In Vehicle Sales in 2014

Although Prius sales declined by about 13% from 2013 to 2014, Toyota remained the dominant manufacturer of hybrid vehicles (HEV). Aside from the Prius, the other hybrid and plug-in vehicles (PEV) from Toyota have remained fairly steady in sales over the last three years.

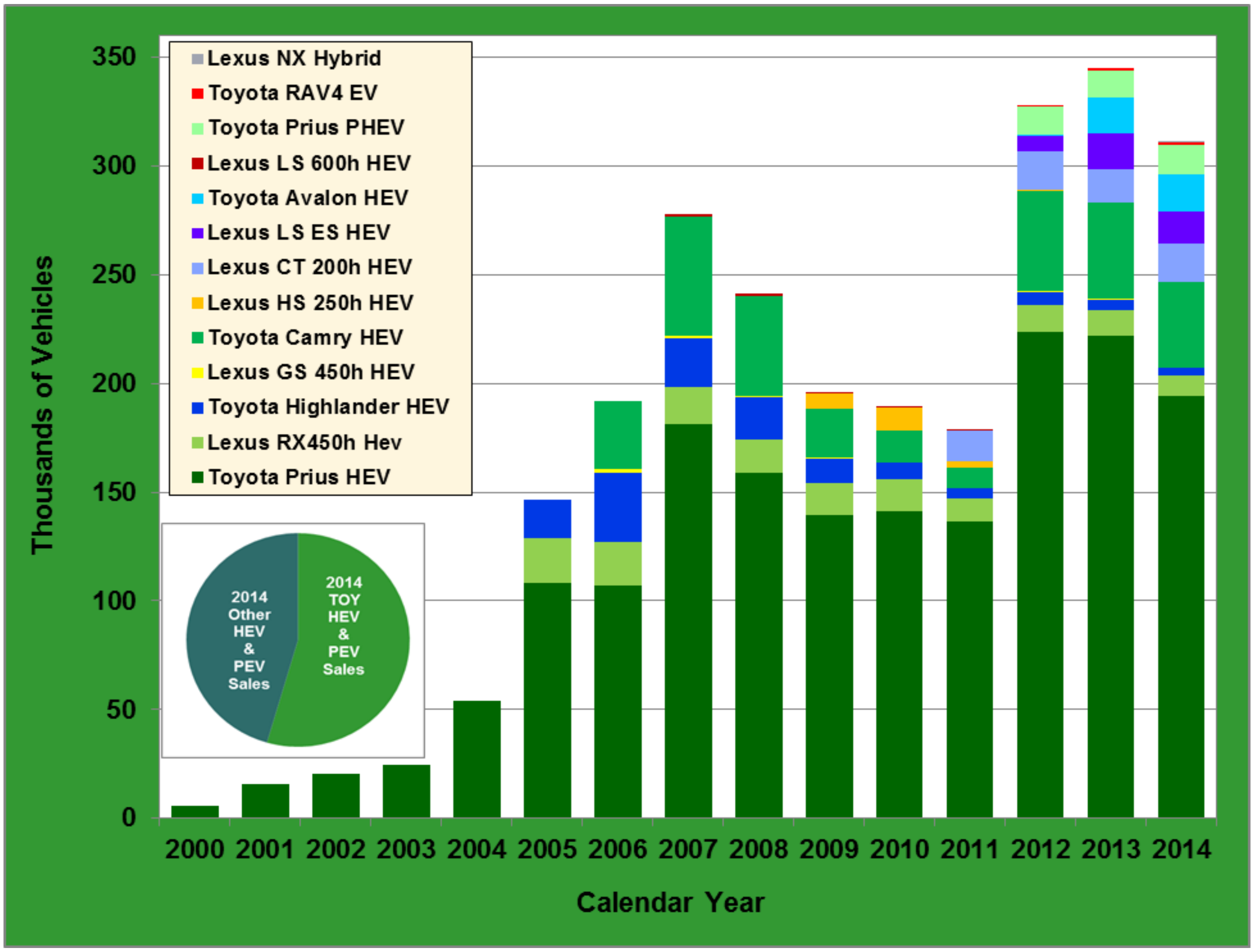


FIGURE 41. Toyota Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 48, 52, 60, 64, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Toyota Has the Most Interrelationships

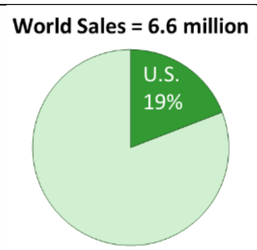
TABLE 16. Toyota Interrelationships with Other Automotive Manufacturers

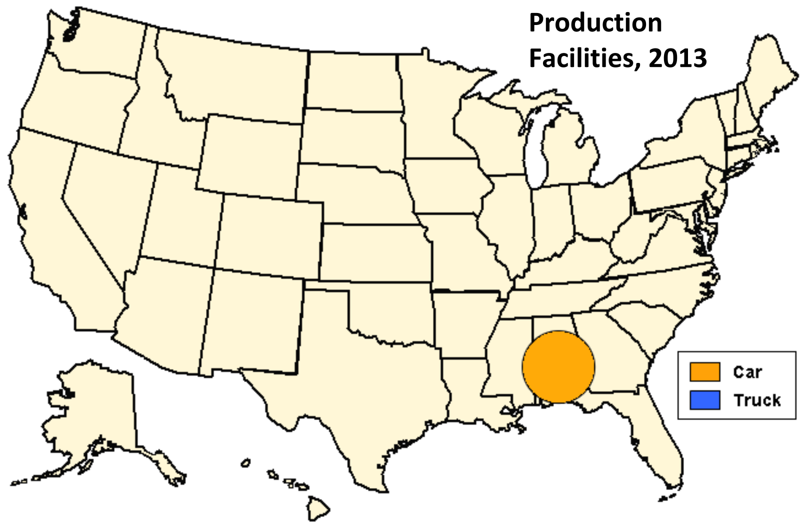
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
BMW, Ford Daimler, GM, Honda, Toyota, VW					✓		Partners in Clean Energy Partnership
BMW					✓		Jointly developing a 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
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

Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

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 2014	
Cars	45.9 sq ft
Light Trucks	46.5 sq ft
All	46.0 sq ft
Number of Alternative Fuel Models, MY 2014	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	0





Hyundai Plants	Type	2013 Production
Montgomery, AL	Car	399,495

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

FIGURE 42. Hyundai Company Profile

Fuel Saving Technologies

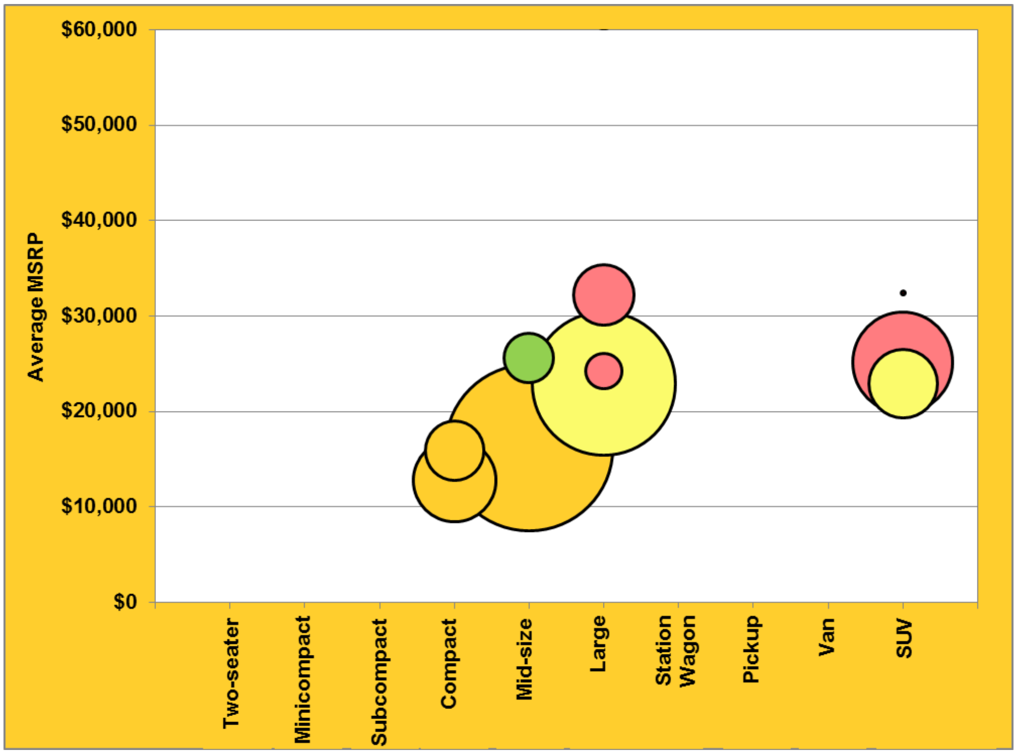
In 2014, the Hyundai Tucson Fuel Cell SUV became available for lease as a 2015 model for select residents in Southern California. A range of 265 miles is claimed with a refuel time of less than 10 minutes from empty. The Tucson Fuel Cell SUV employs regenerative breaking and a stop-start mode that shuts down the fuel cell stack under idle conditions to improve efficiency in urban driving. Accessories are powered by battery when the fuel cell stack is shut down.

Hyundai is employing a wide array of other technologies to achieve their goals for higher fuel economy. A key component for achieving greater fuel economy is downsizing their engine offerings. In order to do this while still meeting consumer expectations for performance, Hyundai is combining weight reduction with high output turbocharged direct injection engines. 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. 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.

At the 2015 Detroit Auto Show, Hyundai revealed the next generation Sonata Hybrid. The midsize hybrid sedan is expected to be about 10 percent more efficient than the outgoing model. Also announced was the all-new Hyundai Sonata Plug-in hybrid which will offer about 22 miles of all-electric operation. The 2016 Sonata hybrid and plug-in hybrid models are expected to arrive at dealerships toward the end of 2015.

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. Over half of their car models have a combined rating of 30 mpg or higher. Only two models, the Equus large sedan and Veracruz SUV, fall below 20 mpg and they have very low sales. The Veracruz was discontinued after the 2012 model year and the Equus does not appear in the figure because it has an MSRP over $60,000.



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 43. Hyundai Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 17. Hyundai Models by EPA Size Class, 2013

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

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

Hyundai Hybrid Sales Remain Strong

After four years the Sonata remains the only hybrid vehicle offered by Hyundai but the sales of that vehicle account for nearly 4% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales. Sales have been fairly consistent over the last three years; above 20,000 units annually.

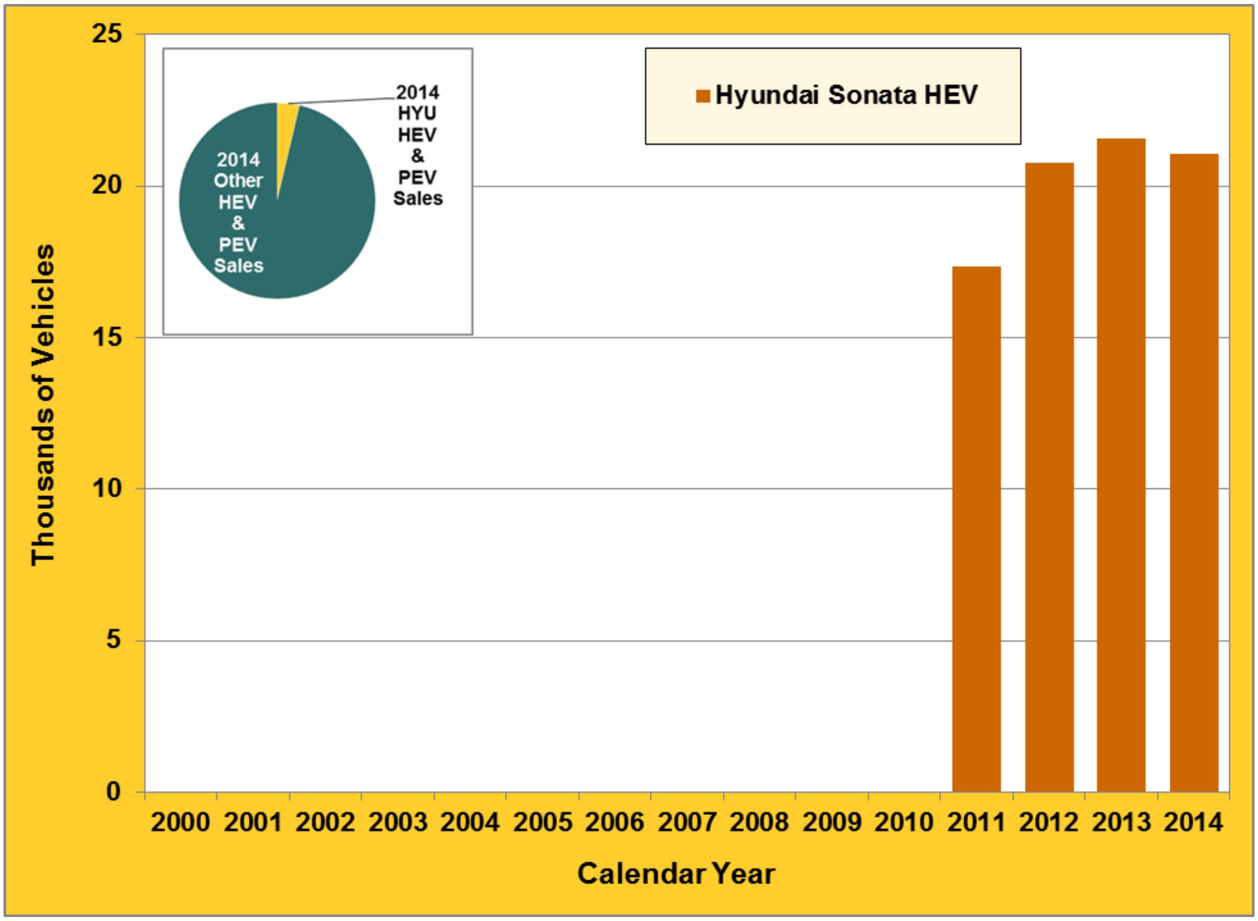


FIGURE 44. Hyundai Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 48, 52, 56, 64, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Hyundai Has a Joint Venture in China

TABLE 18. Hyundai Interrelationships with Other Manufacturers

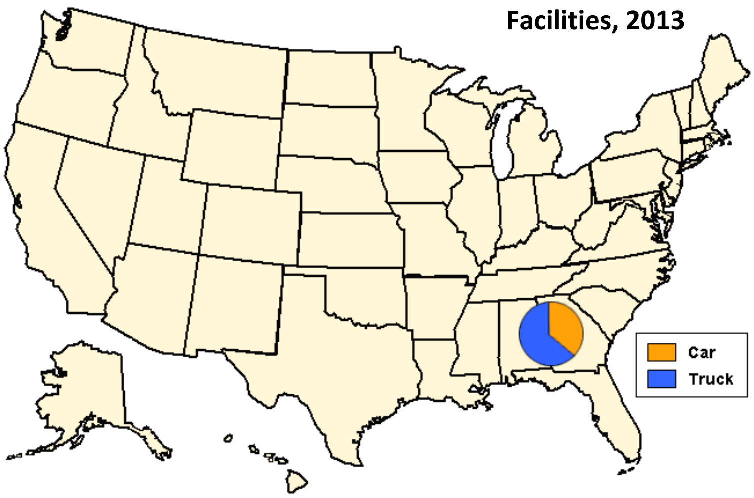
Company	Equity Arrangement	Joint Venture	Supplies/ Buys Major Components	Marketing/Distribution Arrangement	Technology/ Design Arrangement	Manufacturing/ Assembly Agreement	Description
Beijing Automotive		✓				✓	Car building joint venture
Chrysler				✓			Sells Hyundai Atos in Mexico as a Dodge
Kia		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

Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

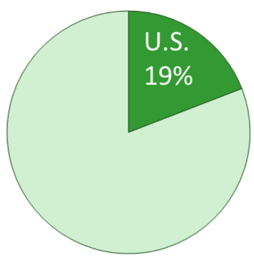
Kia Company Profile

Corporate Average Fuel Economy, MY 2014	
Domestic Cars	None
Import Cars	33.8 mpg
Light Trucks	26.9 mpg
Corporate Average Fuel Economy, MY 2014	
Cars	45.5 sq ft
Light Trucks	49.9 sq ft
All	45.8 sq ft
Number of Alternative Fuel Models, MY 2014	
Flex Fuel	0
Natural Gas	0
Propane	0
Hybrid-Electric	1
Plug-In Hybrid-Electric	0
Electric	0

Production Facilities, 2013



World Sales = 6.6 million



Kia Plants	Type	2013 Production
West Point, GA	Truck	235,559
West Point, GA	Car	133,946

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 45. Kia Company Profile

Fuel Saving Technologies

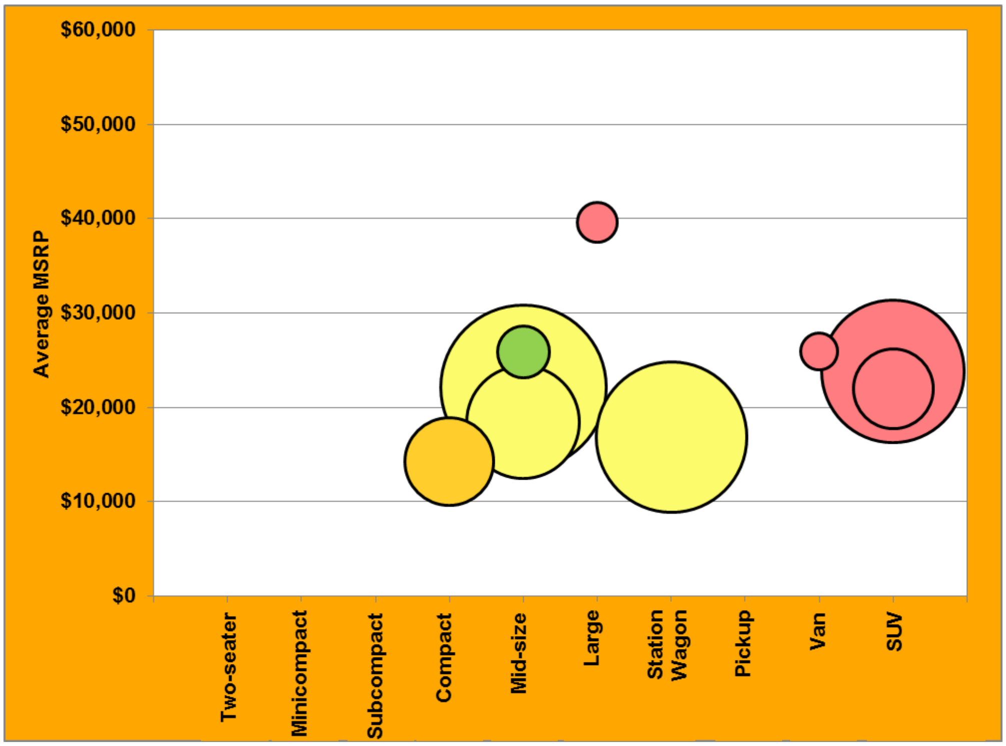
Kia's first all-electric vehicle, the 2015 Soul EV arrived at dealerships in the second half of 2014. The Soul EV has an EPA-rated range of 93 miles and a starting MSRP of $33,700 before the $7,500 Federal tax credit is applied. Although sales began in California and will likely follow in select markets, nationwide sales will be considered as demand dictates. Kia's only other electrified model is the Optima hybrid, which is a midsized hybrid sedan offered since the 2011 model year. Vehicle electrification continues to be an important part of Kia's advanced powertrain strategy and will likely be expanded into future models.

There are a number of other approaches that Kia is taking to increase fuel economy including weight reduction, aerodynamics and "Idle Stop & Go" or ISG. This is a simple system that reduces unnecessary idle time by shutting down the engine when a vehicle comes to a stop. Kia estimates that ISG reduces fuel consumption by 10 to 15% in city driving and is offering it on several models including the Rio and Soul.

Like other manufacturers, Kia has embraced gasoline direct injection (GDI) for maximizing engine performance and fuel economy. Other notable technologies for improved fuel economy include 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 Advanced Smart Cruise Control improves efficiency by adapting the vehicle speed to that of the vehicle in front to achieve the optimal speed. Kia's Eco Driving Point System rates the efficiency of a driver and provides user feedback to encourage more efficient driving behavior.

Kia's Fleet Mix

Kia has comparatively few models and all have an average manufacturer suggested retail price (MSRP) of less than $40,000. 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 46. Kia Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 19. Kia Models by EPA Size Class, 2013

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's First All-Electric Vehicle Debuted in 2014

The all-electric Kia Soul EV (electric vehicle) was introduced in the California market in 2014. Kia Optima HEV sales have remained nearly unchanged at just under 14 thousand units. Kia is responsible for 2.5% of all hybrid-electric (HEV) and plug-in vehicle (PEV) sales in 2014.

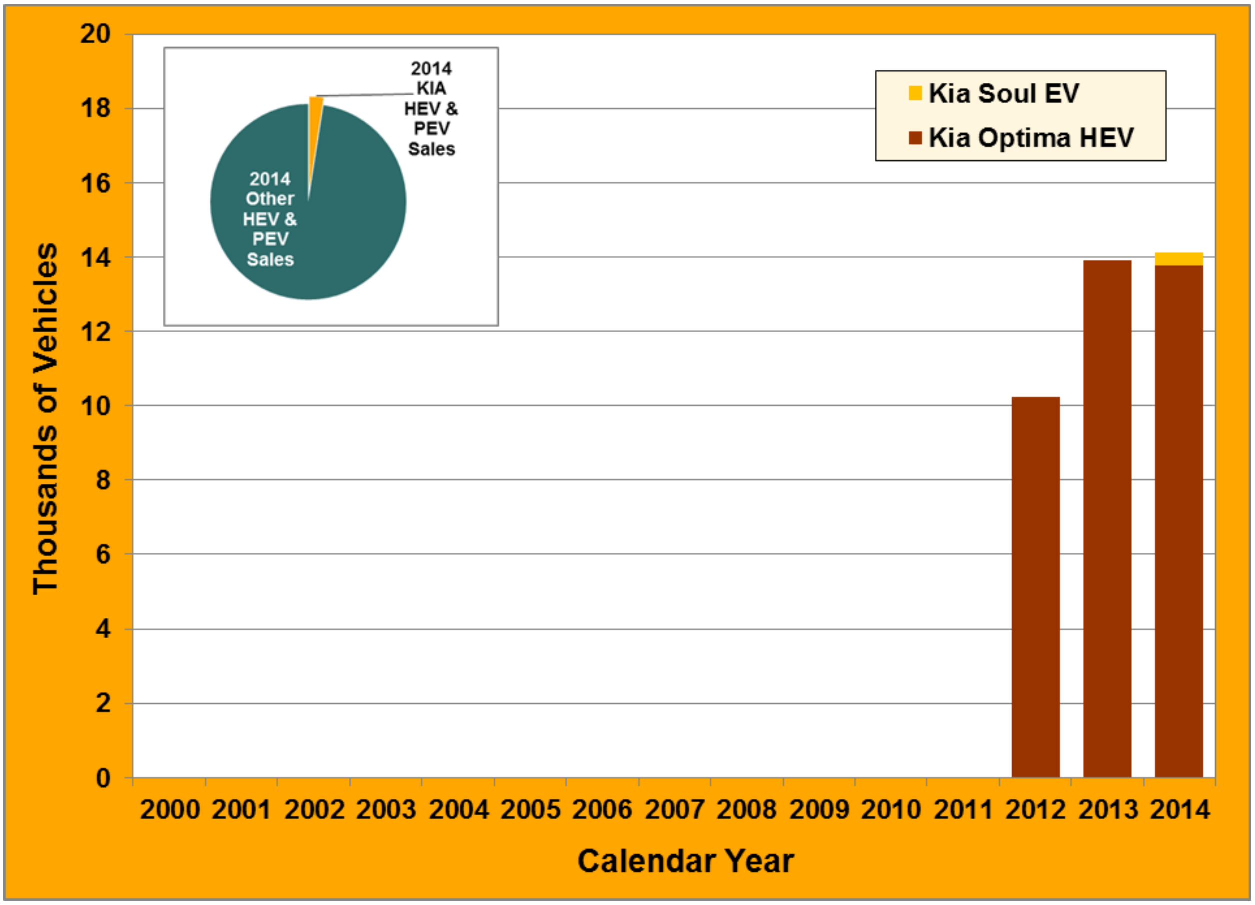


FIGURE 47. Kia Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 48, 52, 56, 60, 68) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

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

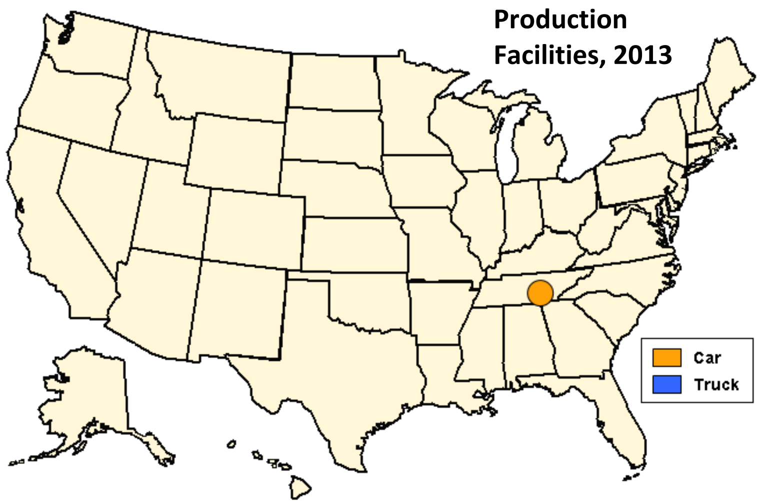
Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

Volkswagen (VW) Company Profile

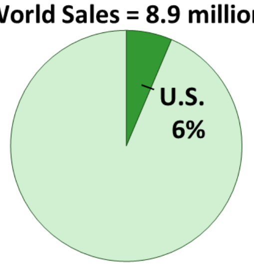
Corporate Average Fuel Economy, MY 2014	
Domestic Cars	33.6 mpg
Import Cars	33.8 mpg
Light Trucks	28.9 mpg

Average Vehicle Footprint, MY 2014	
Cars	45.3 sq ft
Light Trucks	48.9 sq ft
All	45.8 sq ft

Number of Alternative Fuel Models, MY 2014	
Flex Fuel	5
Natural Gas	0
Propane	0
Hybrid-Electric	4
Plug-In Hybrid-Electric	1
Electric	0



World Sales = 8.9 million



Volkswagen Plants	Type	2013 Production
Chattanooga, TN	Car	133,141

FIGURE 48. VW Company Profile

Fuel Saving Technologies

The 2015 e-Golf became Volkswagen's first all-electric model for the U.S. market when it went on sale at the end of 2014. The e-Golf is a compact hatchback with an EPA rated range of 83 miles and a starting MSRP of $35,445 (before $7,500 Federal tax credit). Other all-electric vehicles that Volkswagen has showcased include the e-Up! and Audi R8 e-Tron Supercar. Volkswagen also produces a range of hybrid models including the Volkswagen Jetta hybrid, Touareg hybrid, and Audi Q5 Hybrid. Volkswagen is also developing diesel hybrid vehicles to combine the benefits of both diesel and hybrid technologies. Plug-in hybrid models like the Audi A3 Sportback are also under development.

Volkswagen has long been dominant in producing light-vehicle diesel models for the U.S. market and is currently pushing a range of fuel-efficient TDI diesel technologies under the name "BlueMotion." The Volkswagen Jetta uses a self-cleaning diesel emissions filter while the Tourareg uses the urea system to control NOx emissions. Volkswagen (including Audi) uses turbo charging and direct injection with both diesel and gasoline engines.

The TSI engines developed by Volkswagen use turbo charging and a supercharger with direct injection making it possible to downsize engines while meeting consumer expectations for performance. They are not only more efficient than traditional port injection engines but also lighter with maximum torque at lower engine speeds. This technology combined with Volkswagen's 7-speed dry dual-clutch automatic transmission offers greater efficiency and uninterrupted torque between the engine and wheels. At the 2014 International Motor Symposium, Volkswagen introduced the world's first 10-speed dual-clutch automatic transmission with plans to use the new transmission throughout its future vehicle lineup to boost fuel economy.

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 separately from their conventional gasoline counterparts.

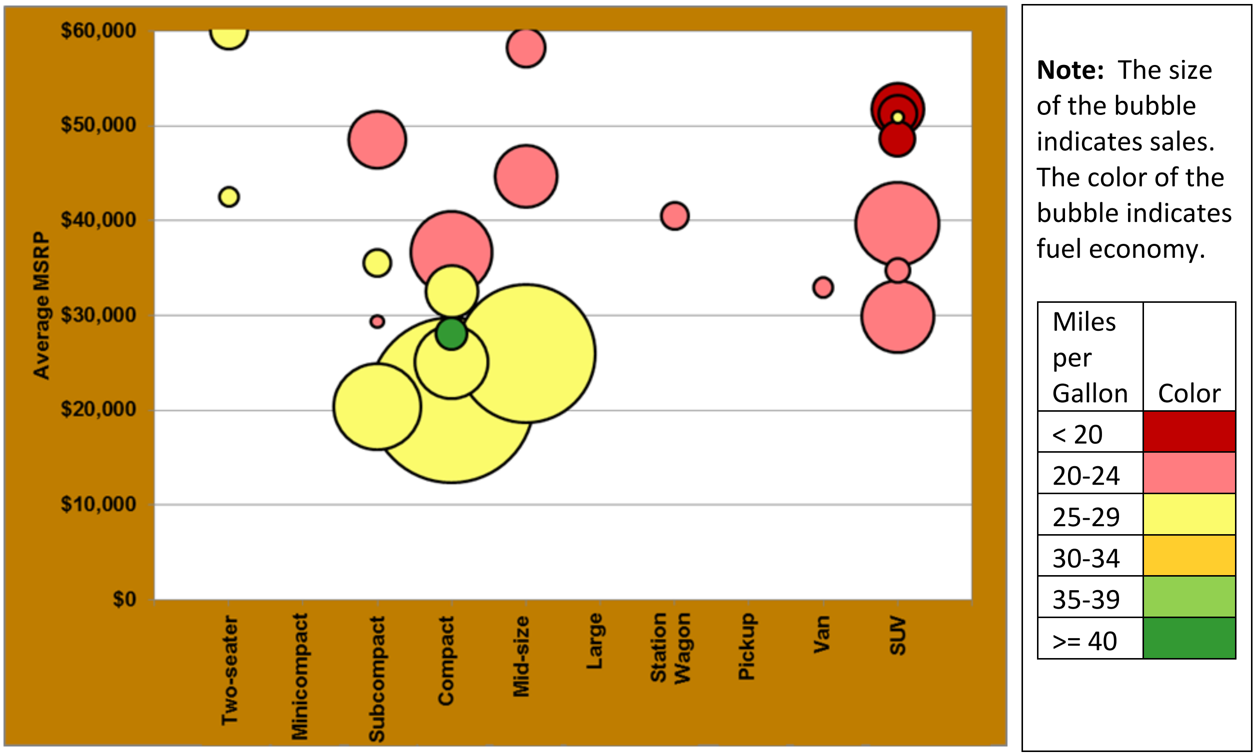


FIGURE 49. VW Sales by Model, MSRP, EPA Size Class, and Fuel Economy, 2013

TABLE 21. VW Models by EPA Size Class, 2013

Two-Seater	Mini-compact	Sub-compact	Compact	Mid-Size	Large	Station Wagon	Pickup	Van	SUV
R8 *Lamborghini* Boxster/ Cayman TT	*911 Series*	A5/S5 Eos A3 Beetle	A4/S4 CC Jetta-Hybrid Golf Jetta	*A8/S8* A7 A6/S6 Passat	*Bentley* *Panamera* *Panamera S-Hybrid*	allroad quattro		Routan	*Range Rover Evoque* *Cayenne* *Cayenne S-Hybrid* *Touareg-Hybrid* Q7 Touareg Q5-Hybrid LR4 Q5 LR2 Tiguan

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

VW Offers a Wide Range of Hybrid and Plug-In Vehicles

One all-electric vehicle, two plug-in hybrids (PHEV), and five hybrid models were sold by VW in 2014. Despite this array of models, none of the vehicles have sales of more than 2,000 units. Jetta HEV sales plunged by 66% from 2013 to 2014. However, the new e-Golf EV and Porsche Panamera PHEV added to VW sales for 2014. Their share of the hybrid-electric (HEV) and plug-in vehicle (PEV) market is just under 1%.

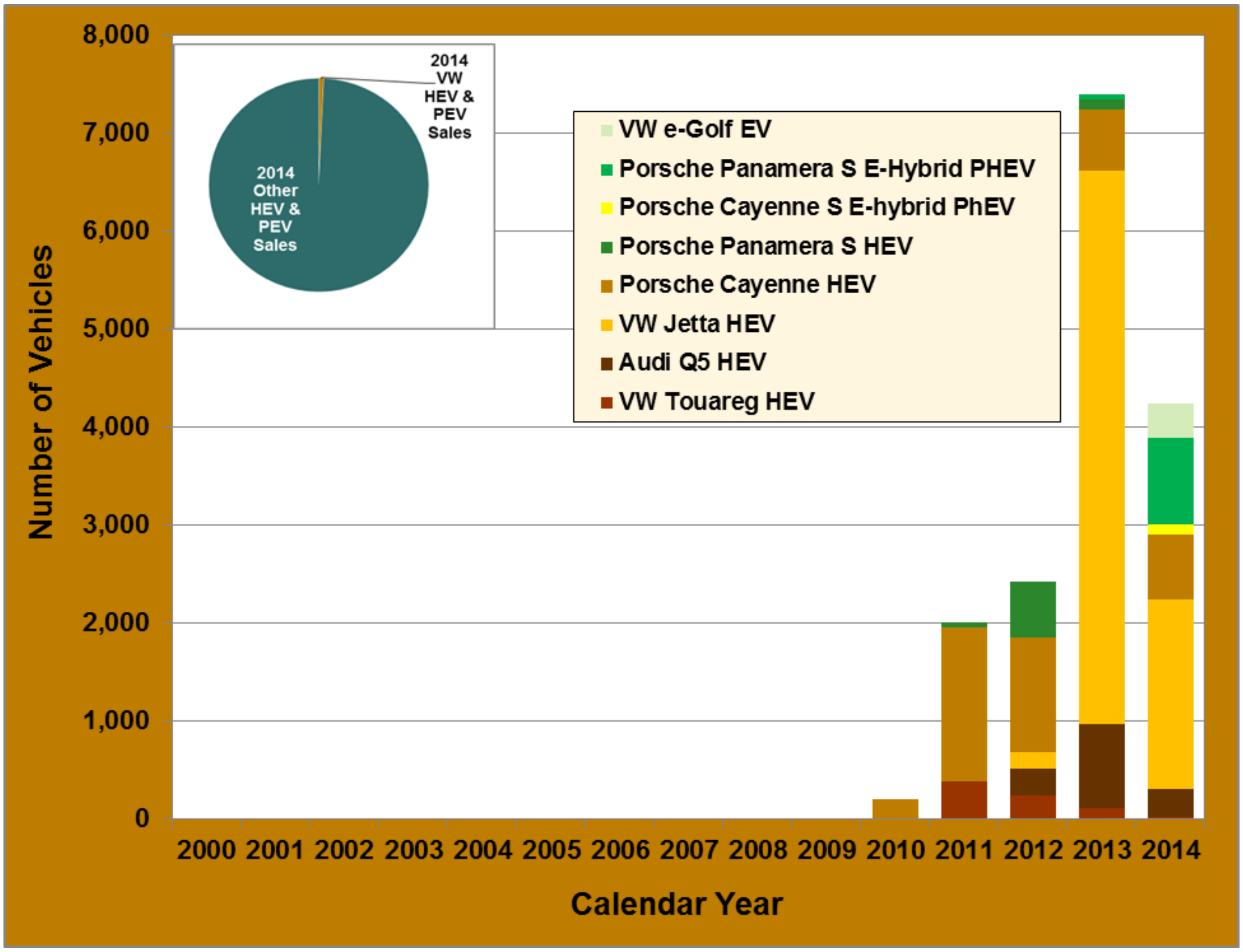


FIGURE 50. VW Hybrid and Plug-In Electric Vehicle Sales, 2000-2014

Note: Due to the wide variation of hybrid sales among manufacturers, other manufacturers' hybrid sales charts (pp. 36, 40, 44, 48, 52, 56, 60, 64) will have different vertical axis scales.

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

As One of the Largest Manufacturers in the World, VW has Few Interrelationships

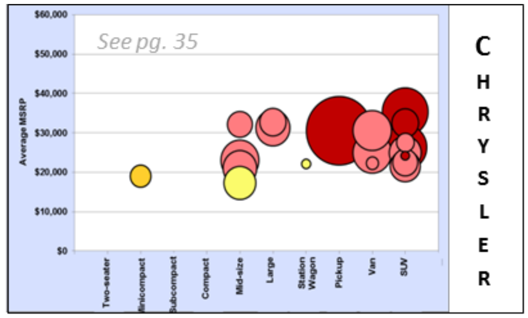
TABLE 22. VW Interrelationships with Other Automotive Manufacturers

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
Suzuki	✓						VW holds a stake in Suzuki

Source:
Wards AutoInfoBank, *Interrelationships among the World's Major Auto Makers*, December 2014.

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 Chrysler's market is mainly light trucks.



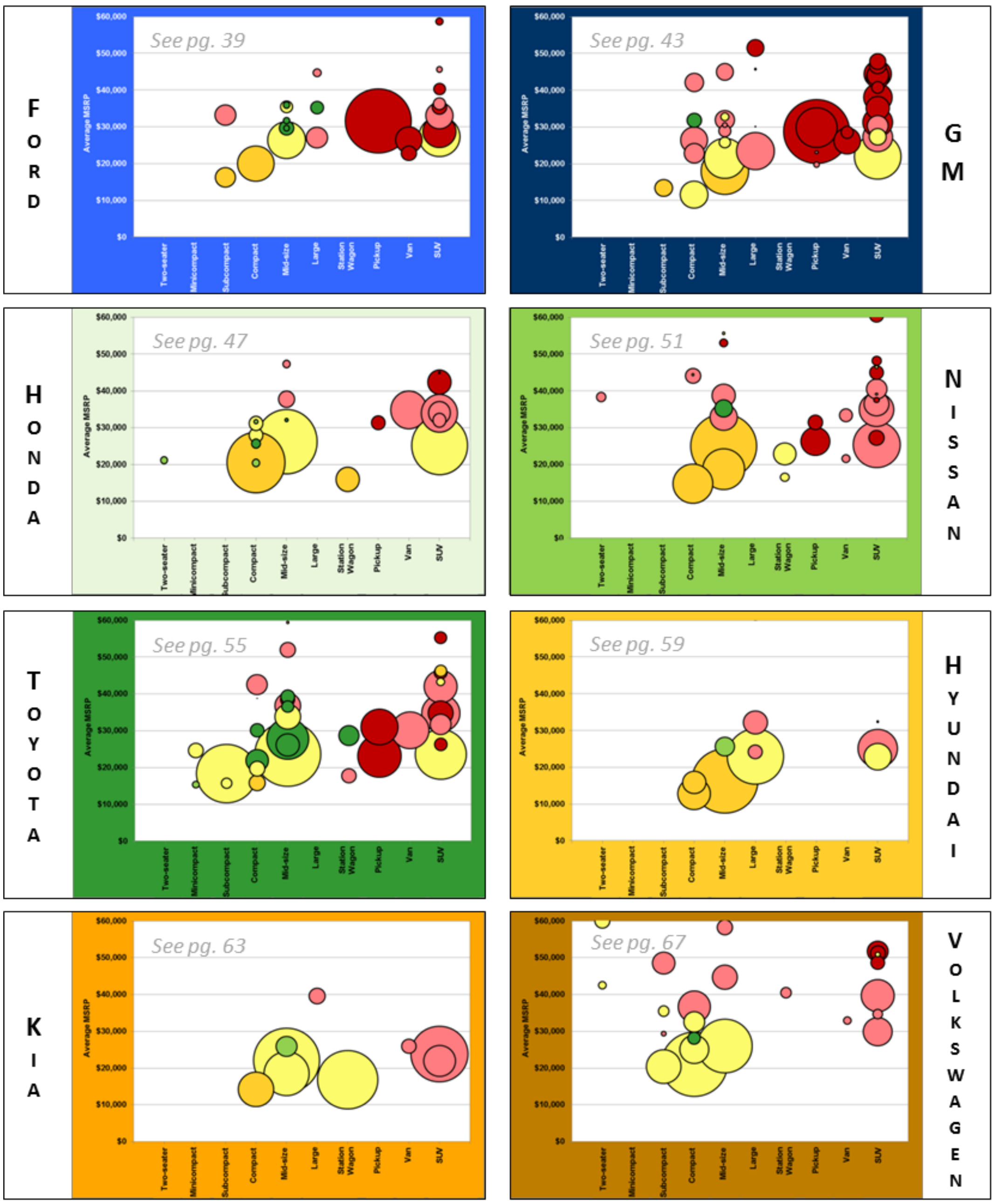


FIGURE 51. Summary Comparison of Manufacturers' Markets, 2013

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

The companies that made 92% of all vehicles produced in the United States in 2013 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 2013. 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 48% of world production. The U.S. produces about 12% of the world's vehicles.

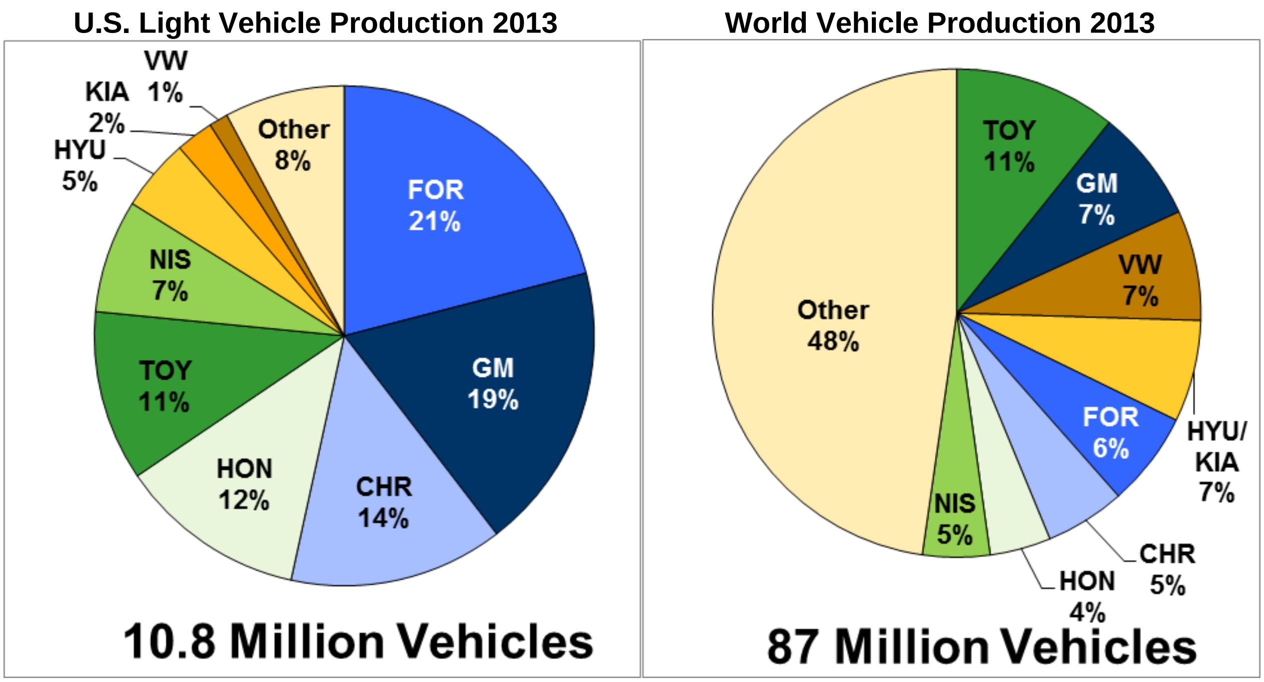


FIGURE 52. Production of United States and World Vehicles in 2013 by Manufacturer

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 5.5% share in 2013.

Source:
Wards AutoInfoBank.

U.S. Sales Volumes Continued to Rise in 2013

Sales volumes rose from 2009 to 2013. In fact, 2009 was the lowest point for sales during the recent recession. By 2013, sales reached between 7 and 8 million for both cars and light trucks.

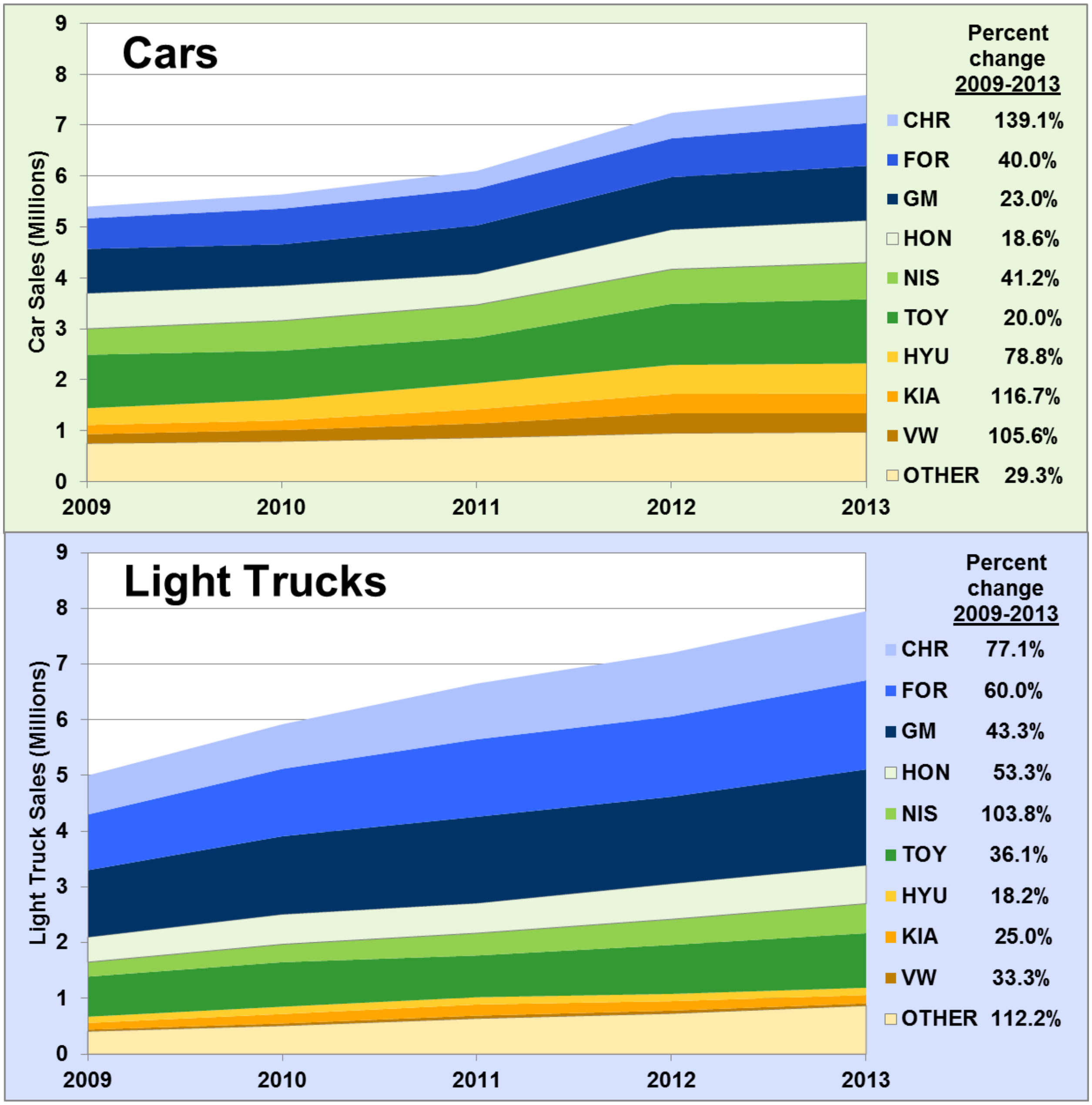


FIGURE 53. New Light Vehicle Sales by Manufacturer, 2009-2013

Source:
Wards AutoInfoBank.

Market Share Shifted among Manufacturers

Chrysler, Hyundai, Kia and Volkswagen experienced the largest gains in car market share from 2009-2013. Nissan experienced a slight gain in car market share in the five-year period while the market share declined for General Motors, Honda and Toyota. The three domestic manufacturers accounted for about 58% of the light truck market share in 2009 and 2013.

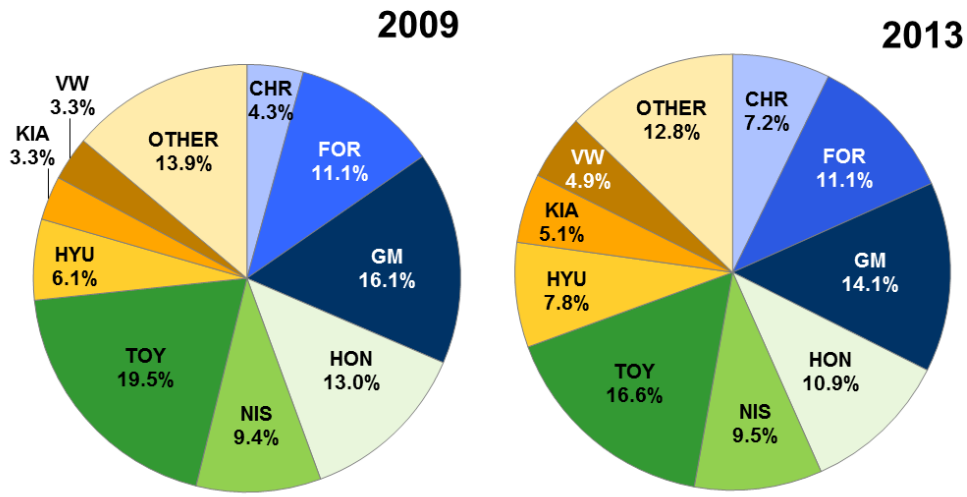


FIGURE 54. New Car Market Share by Manufacturer, 2009 and 2013

Source:
Ward's AutoInfoBank

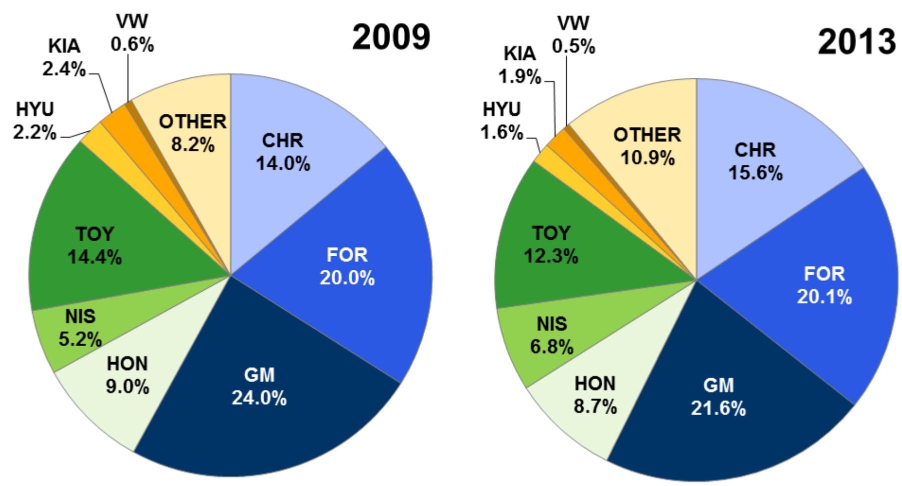


FIGURE 55. New Light Truck Market Share by Manufacturer, 2009 and 2013

Source:
Ward's AutoInfoBank.

Share of Import Cars Declines to Less than 30% of Car Sales in 2013

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 27% but accounted for just 16% in 2013.

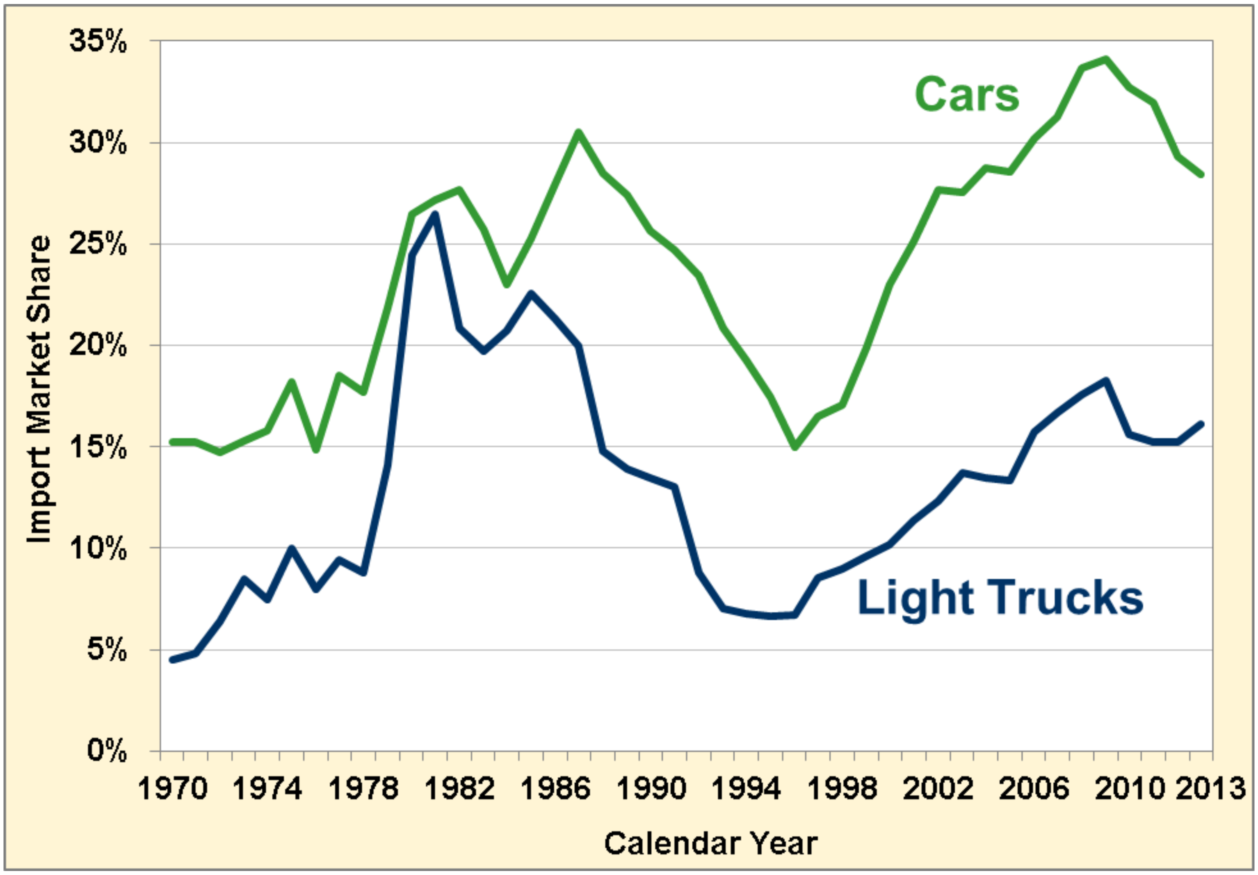


FIGURE 56. Import Market Share of Cars and Light Trucks, 1970-2013

Source:
Ward's AutoInfoBank.

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 30% of their sales. Kia, however, has the highest import share – imports accounted for 54% of Kia light vehicle sales in 2013.

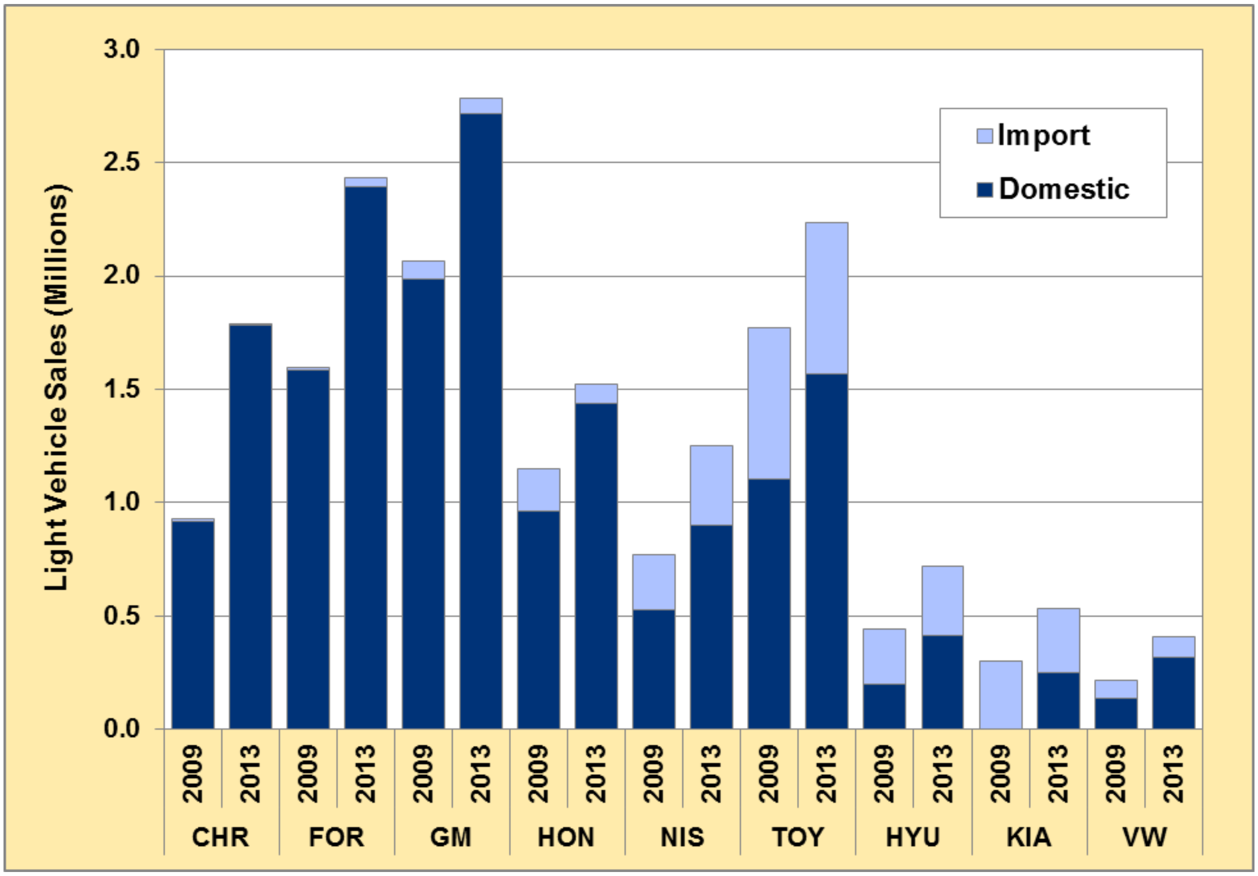


FIGURE 57. Light Vehicle Sales by Source and Manufacturer, 2009 and 2013

Source:
Ward's AutoInfoBank.

Engine Displacement for Cars is Down 5%

Average sales-weighted engine displacement for all new cars declined 5% from 2010 to 2014. In the same time period, average displacement for light trucks declined by 2%. In general, Ford, General Motors, and Chrysler have larger engines than the other major manufacturers. Yearly fluctuations are typically a result of the introduction or elimination of a model.

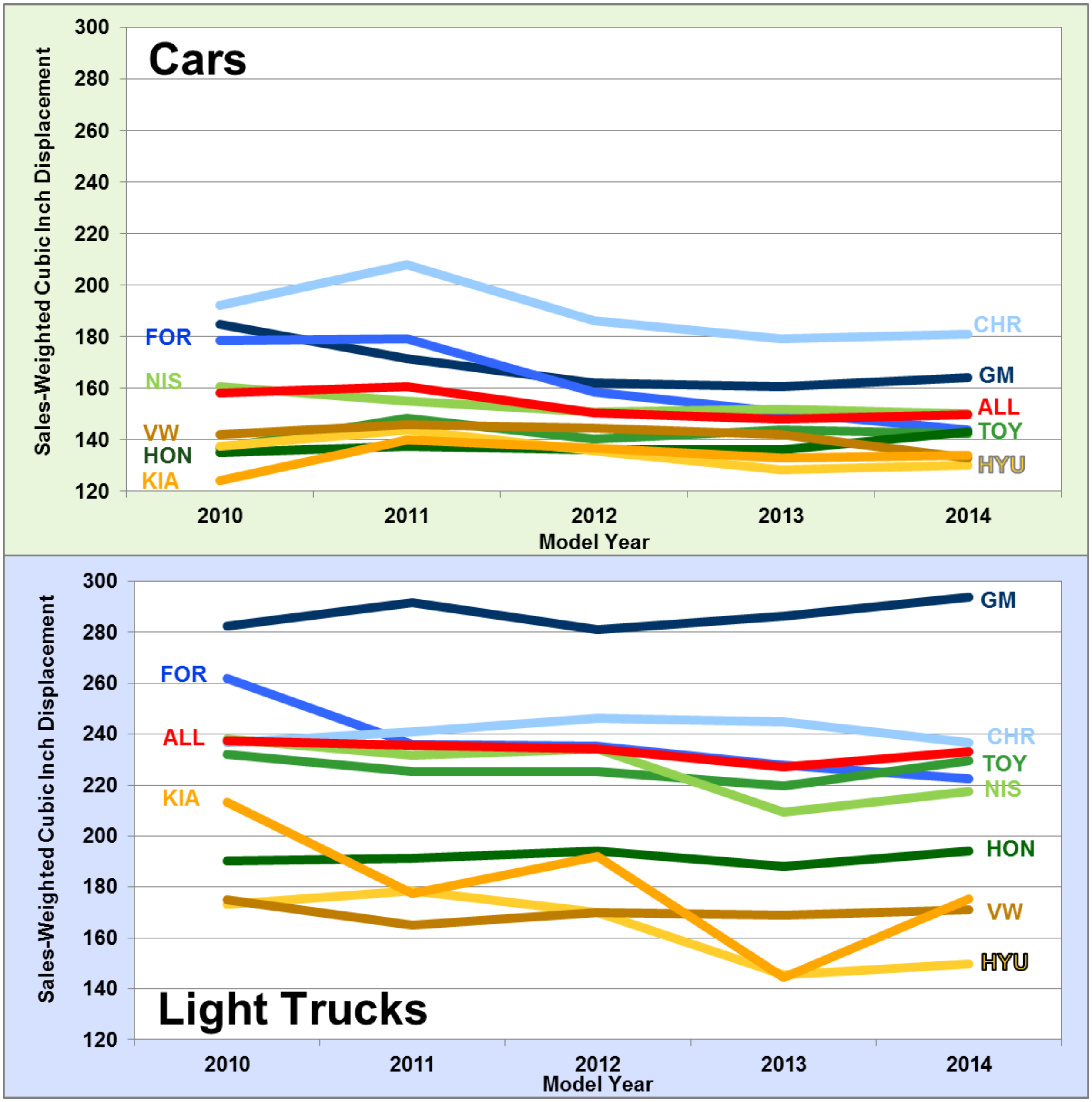


FIGURE 58. Car and Light Truck Engine Size by Manufacturer, 2010-2014

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Light Truck Horsepower Increased by 12% from 2010 to 2014

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 2010. 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 risen 6% over the five-year time period.

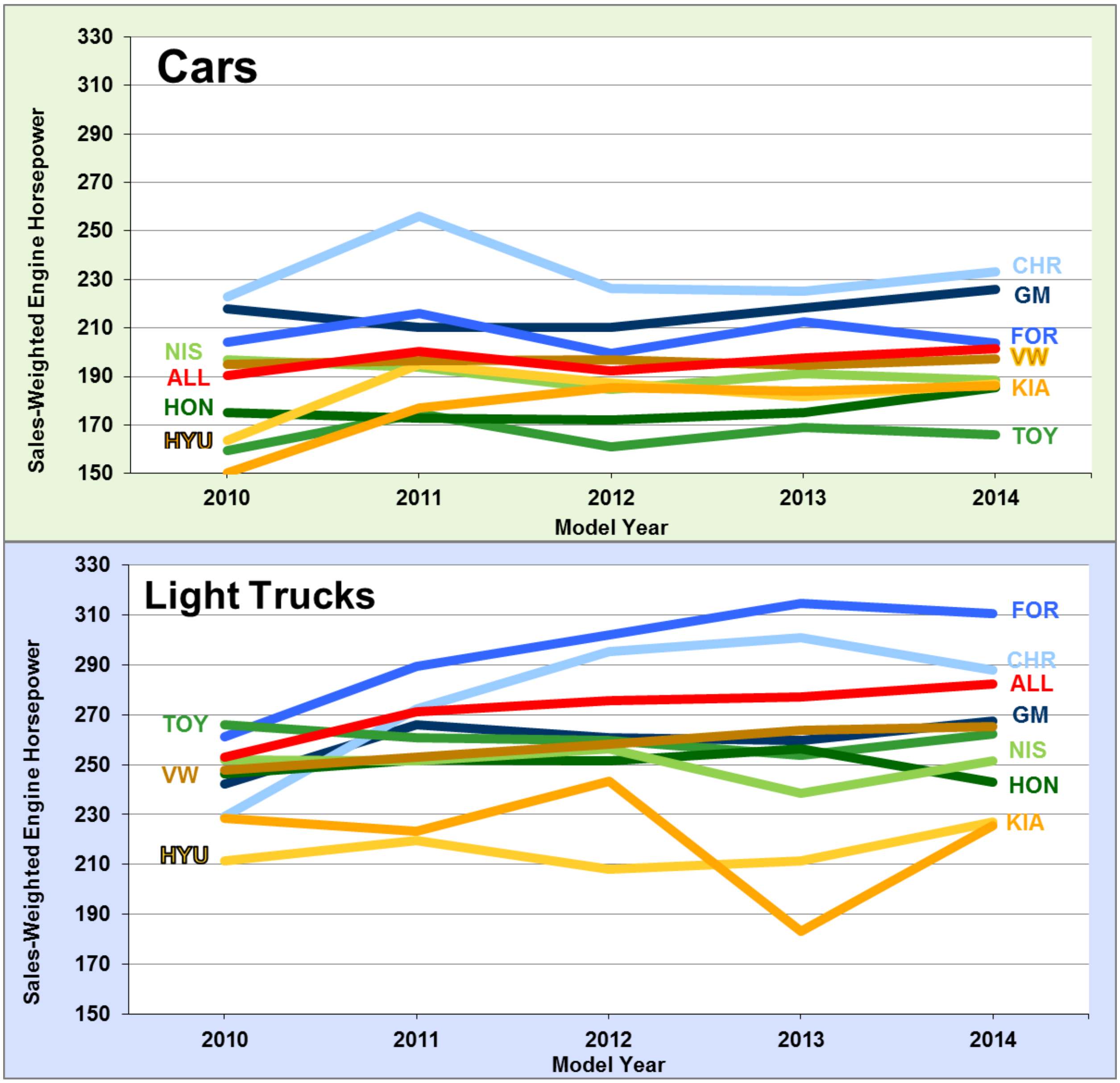


FIGURE 59. Car and Light Truck Horsepower by Manufacturer, 2010-2014

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Technology Has Improved Performance More than Fuel Economy

Despite a 124% increase in horsepower and 47% decrease in 0-60 time from 1980 to 2014, the fuel economy of vehicles improved 27%. All of these data series are sales-weighted averages. The weight of the vehicle appears to have an inverse relationship with fuel economy.

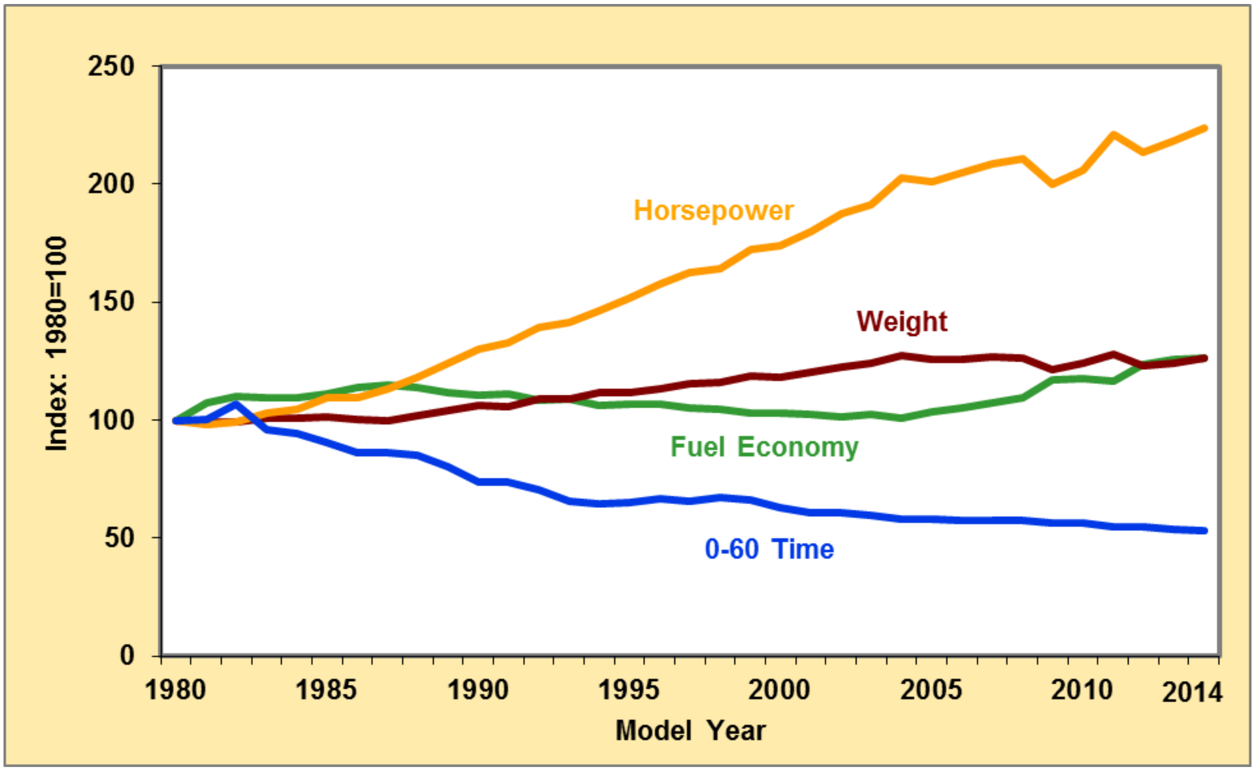


FIGURE 60. Characteristics of Light Vehicles Sold, 1980-2014

Note: Data are sales-weighted.

Source:
U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

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

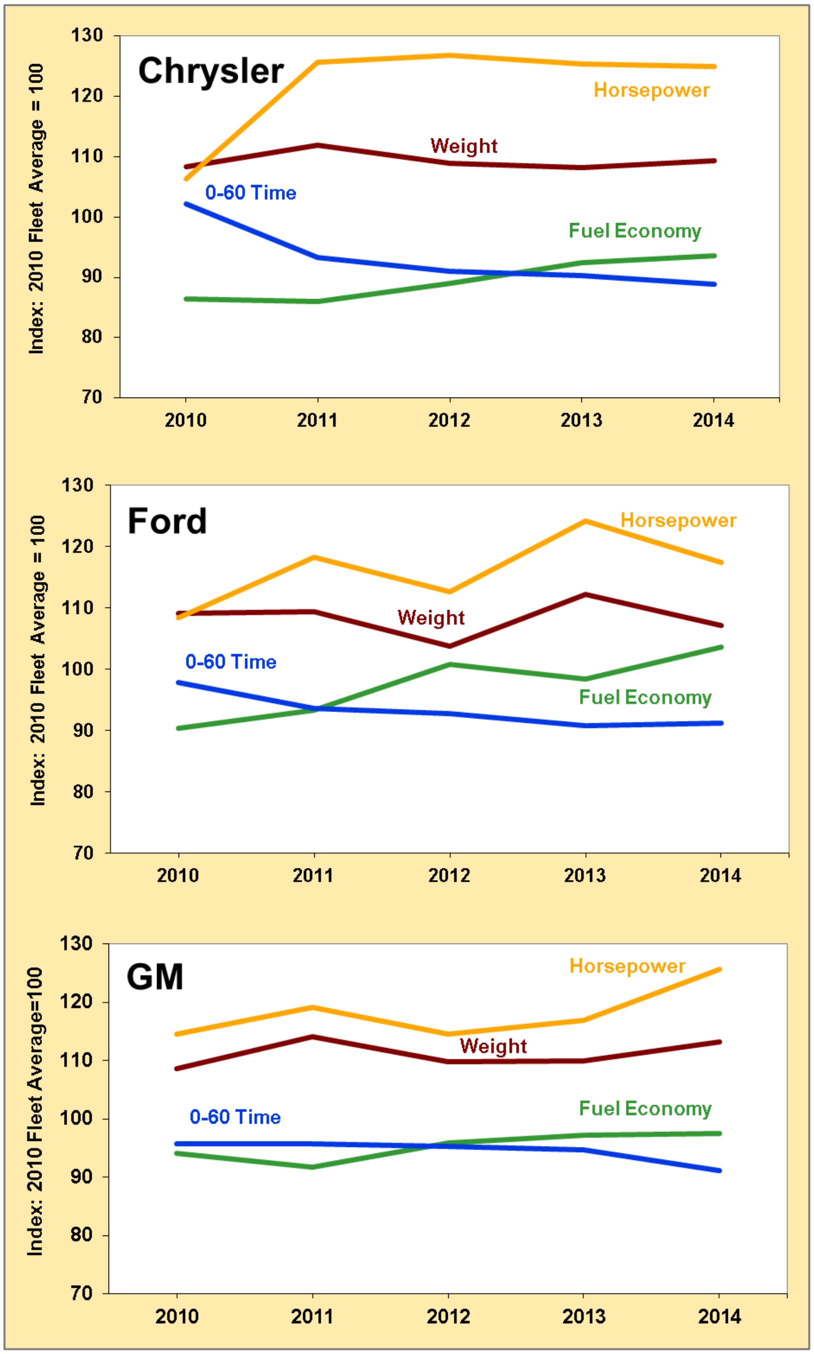


FIGURE 61. Characteristics of Detroit 3 Light Vehicles Sold, 2010-2014

These sales-weighted averages show that all of the Detroit 3 manufacturers have increased the horsepower and decreased the 0-60 times of the light vehicles they sell. 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. Ford made the biggest improvement in fuel economy over the five year period – a 15% improvement from 2010 to 2014. In the same time frame, Chrysler had an 8% and General Motors (GM) a 4% improvement. Fuel economy in 2014 was below the fleet average (below 100 on the graph) for Chrysler and GM.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. 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

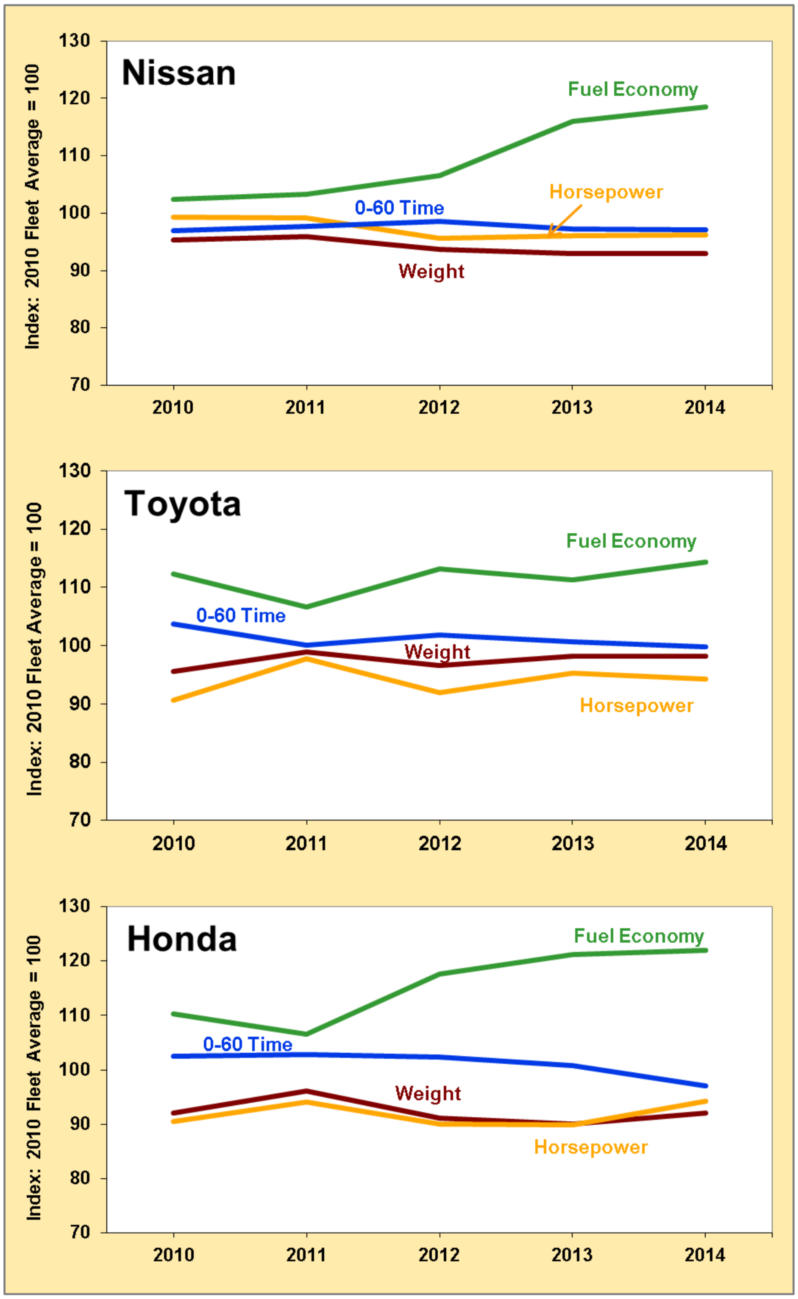


FIGURE 62. Characteristics of Japanese Light Vehicles Sold, 2010-2014

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 – 16% over the five year period – followed by Honda with 11% improvement. While Nissan's fuel economy improved, horsepower and weight remained steady. Weight for all three manufacturers was equal to or below fleet average.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

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

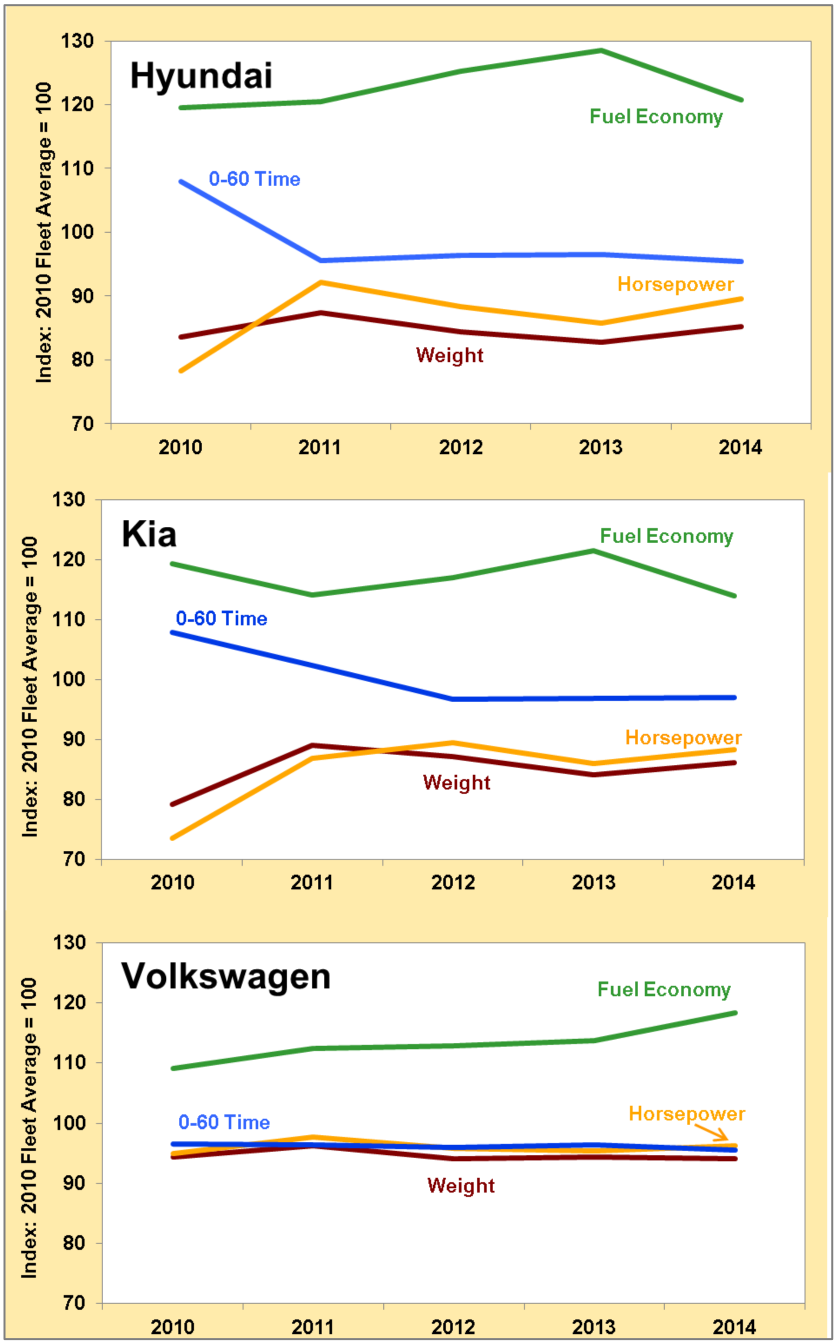


FIGURE 63. Characteristics of Light Vehicles Sold by Other Large Manufacturers, 2010-2014

These sales-weighted averages show that Volkswagen has improved fuel economy since 2010 while weight, horsepower and 0-60 time remained steady. The fuel economy for all three companies' light vehicles in 2010 was higher than the fleet average (higher than 100 on the graph). Hyundai decreased 0-60 time by 12% from 2010 to 2014, while horsepower increased by 14%. Kia decreased 0-60 time over the period while also decreasing horsepower. Horsepower and weight were below the fleet averages for all three manufacturers.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

More than 18% of 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 18.2% of car and 8.7% of light truck market share with a total share of 14.7% for all light vehicles. Nissan sold more than half of the cars and the light trucks in 2013 that were equipped with CVT.

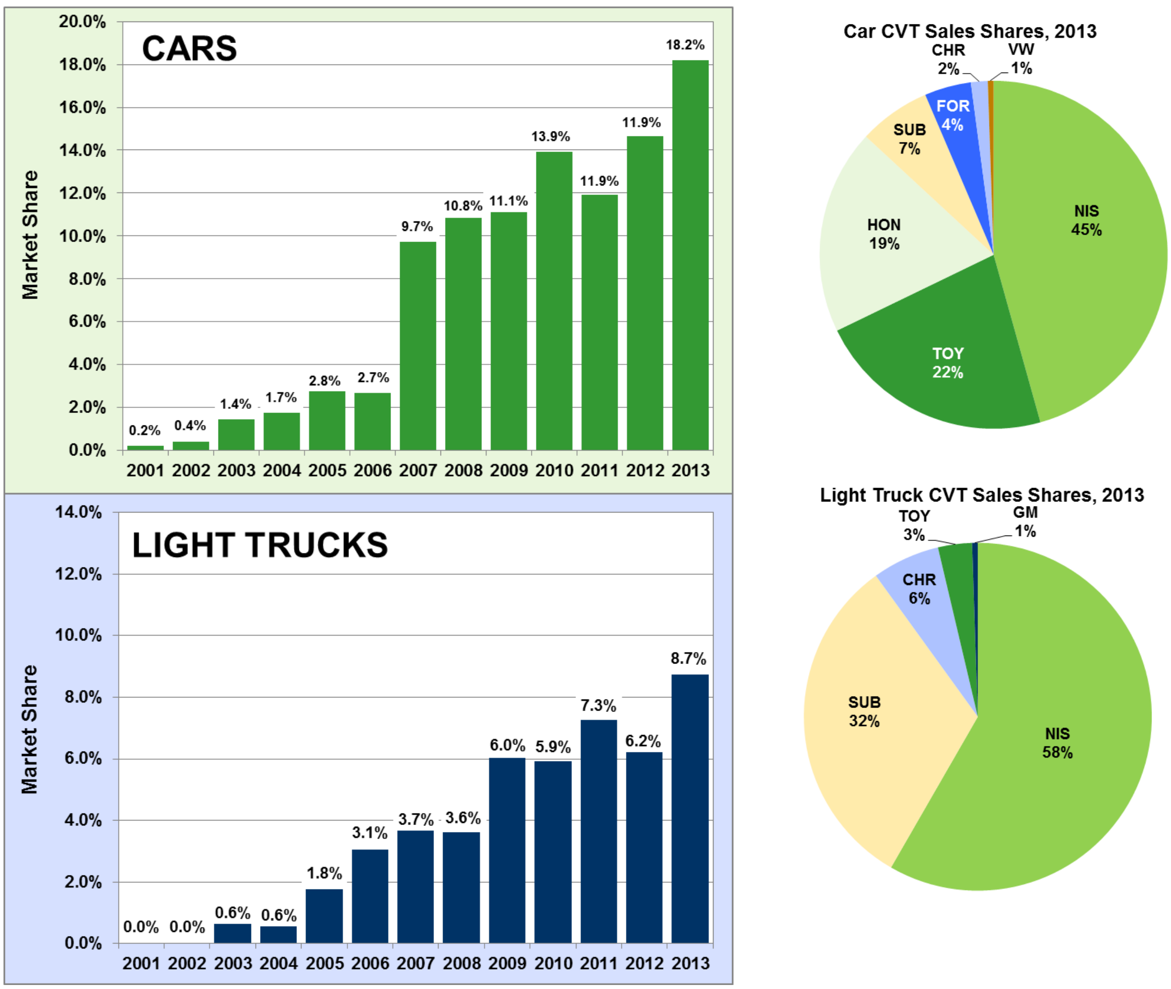


FIGURE 64. CVT Market Share, 2001-2013 and CVT Manufacturers' Share, 2013

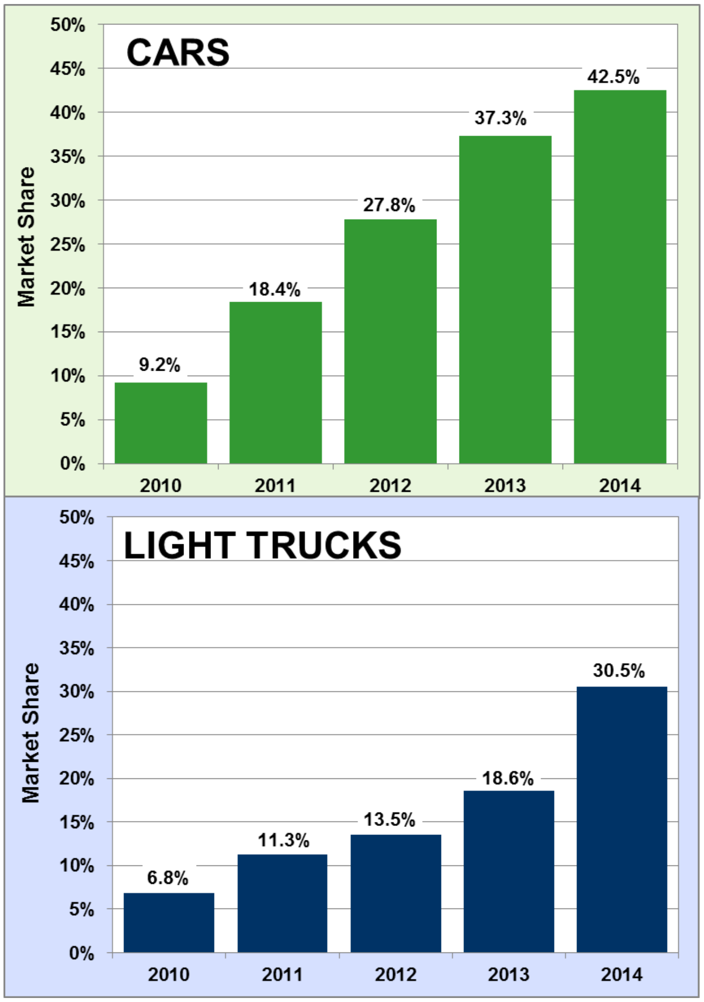
Note: SUB = Subaru

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Nearly 38% 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 2014, the market share for GDI was 42.5% for cars and 30.5% for light trucks.



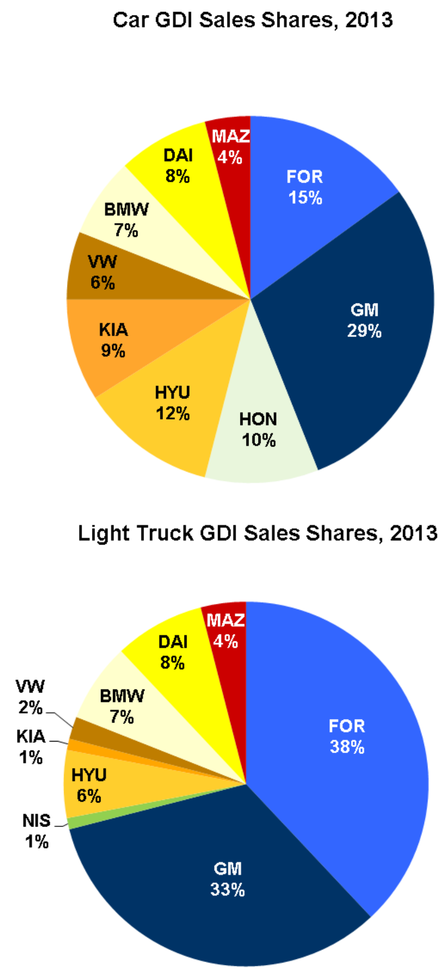


FIGURE 65. GDI Market Share, 2010-2014 and GDI Manufacturer's Share, 2013

Note: Light trucks include pickups, sport utility vehicles, and vans. MAZ = Mazda, DAI = Daimler.

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Manufacturers Are Using Cylinder Deactivation and Stop-Start Technology to Boost Fuel Economy

GM, Honda, and Chrysler are using cylinder deactivation (CD) as a fuel saving technology in cars and light trucks. VW and Daimler have also produced vehicles with CD, but not in quantities that would show in these data. Overall, 11.7% of the light vehicle market in 2014 was equipped with CD. BMW and Daimler (DAI) are the top manufacturers using stop-start technology, along with Jaguar-Land Rover (JLR), VW, and Kia. Stop-start technology penetrated 4.6% of the light vehicle market in 2014.

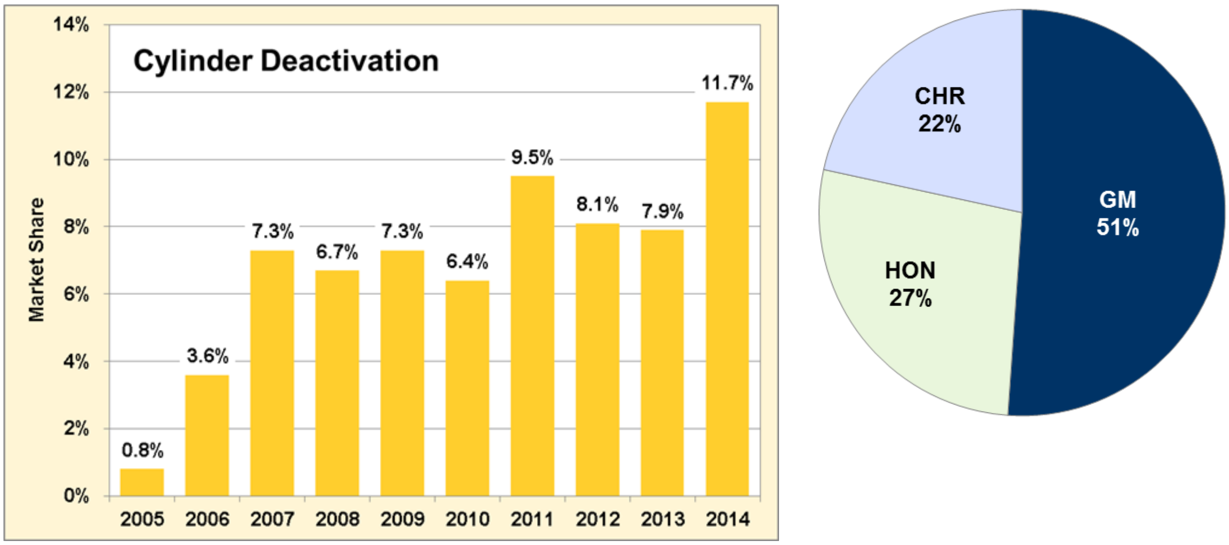


FIGURE 66. Cylinder Deactivation Market Share, 2005-2014 and Manufacturer's Share, 2013

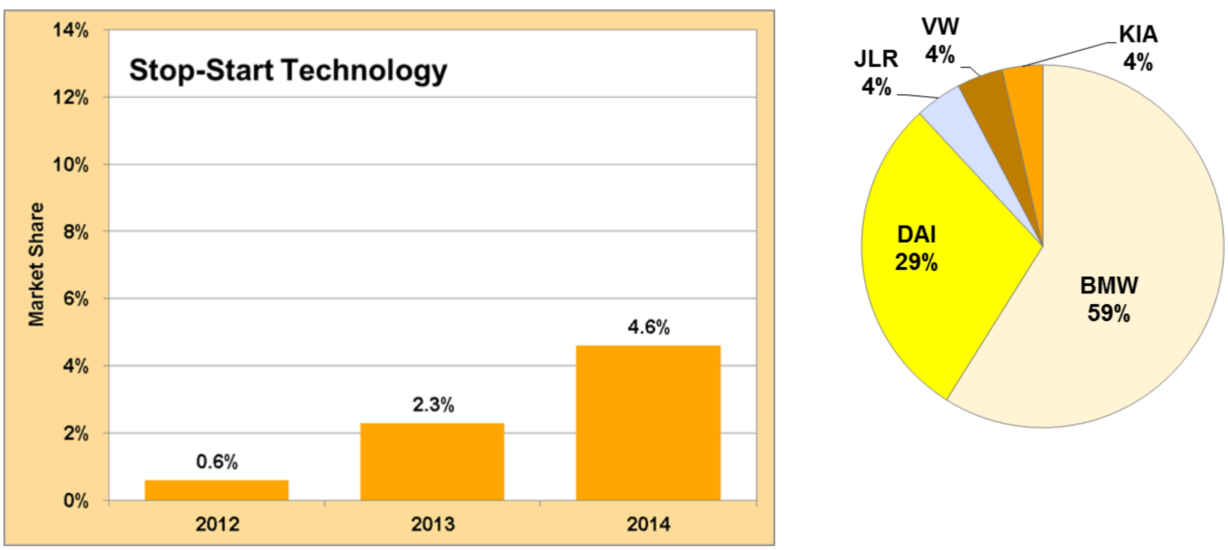


FIGURE 67. Stop-Start Technology Market Share, 2012-2014 and Manufacturer's Share, 2013

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

The Number of Transmission Speeds Has Been Increasing

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. Four-speed transmissions were the norm for cars and light trucks until the mid-2000's when transmissions of five speeds or more began dominating the market. The market share grew for 6-, 7-, 8- and 9-speed cars and light trucks in 2014. Continuously variable transmissions (CVT) are also making their way into the market.

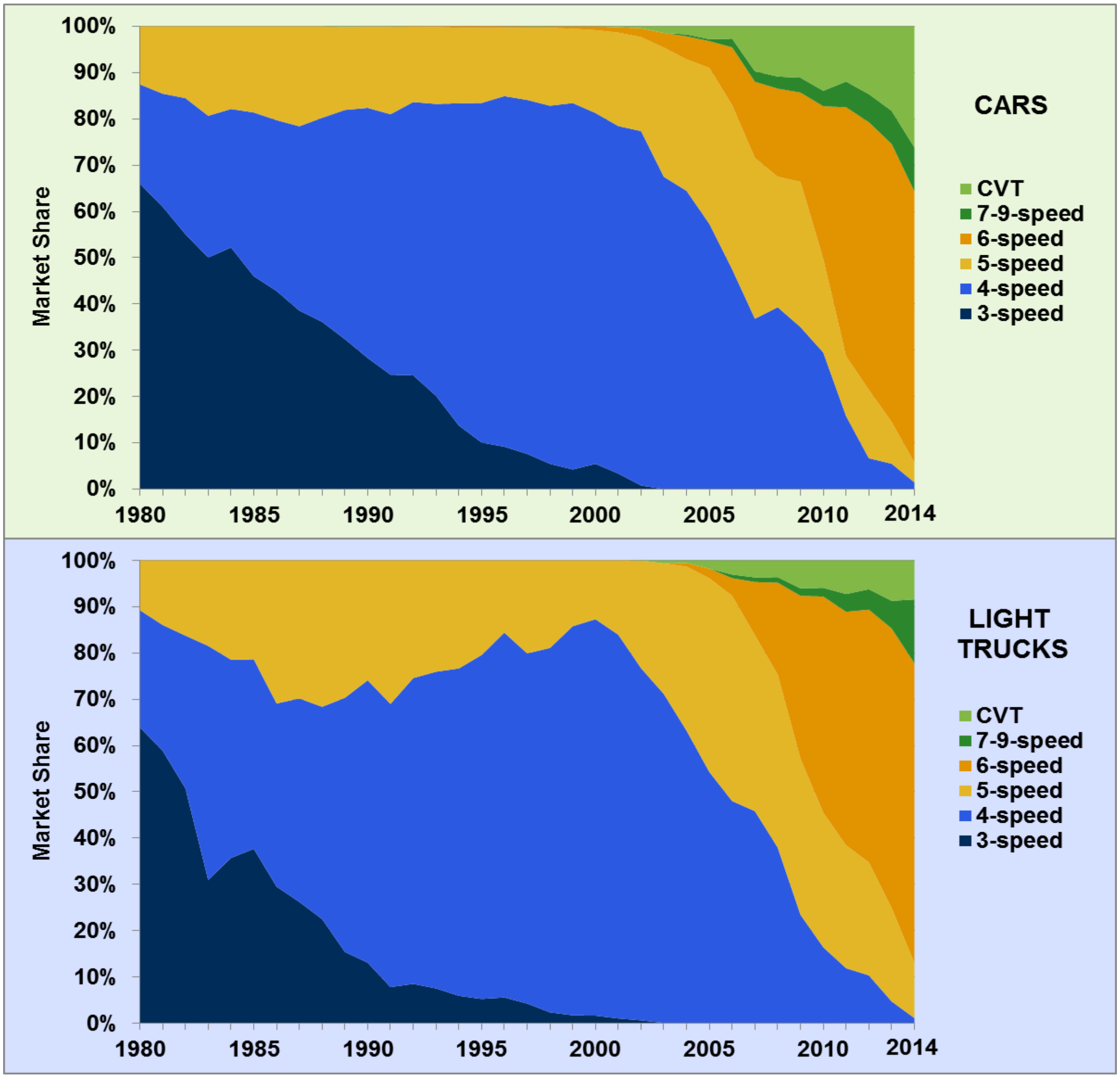


FIGURE 68. Market Share of Transmission Speeds, 1980-2014

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

More than 20 Models of Light Vehicles Are Diesel in Model Year 2014

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 2014, 7 different manufacturers have 24 light vehicle models for sale with clean diesel engines that meet current emission standards.

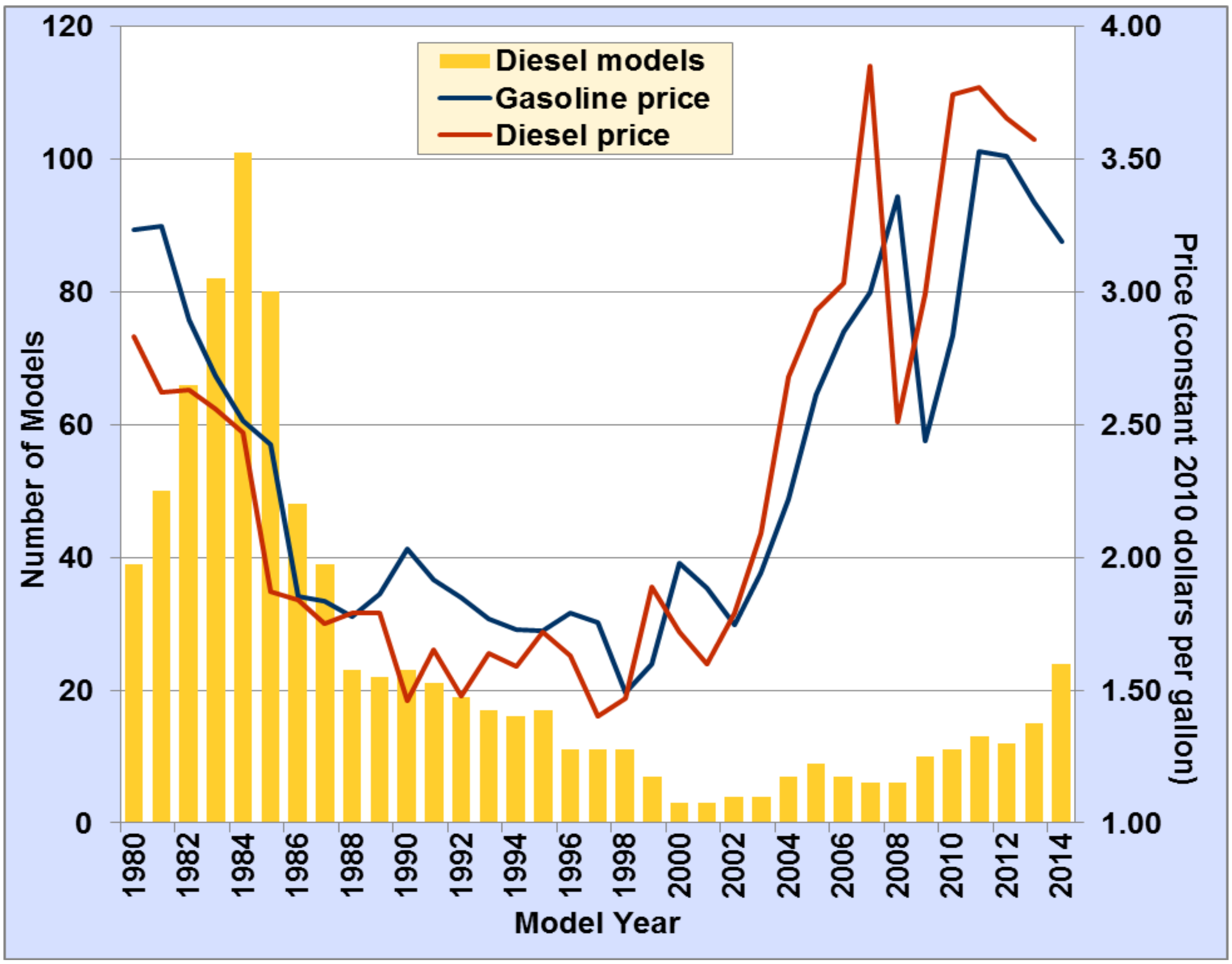


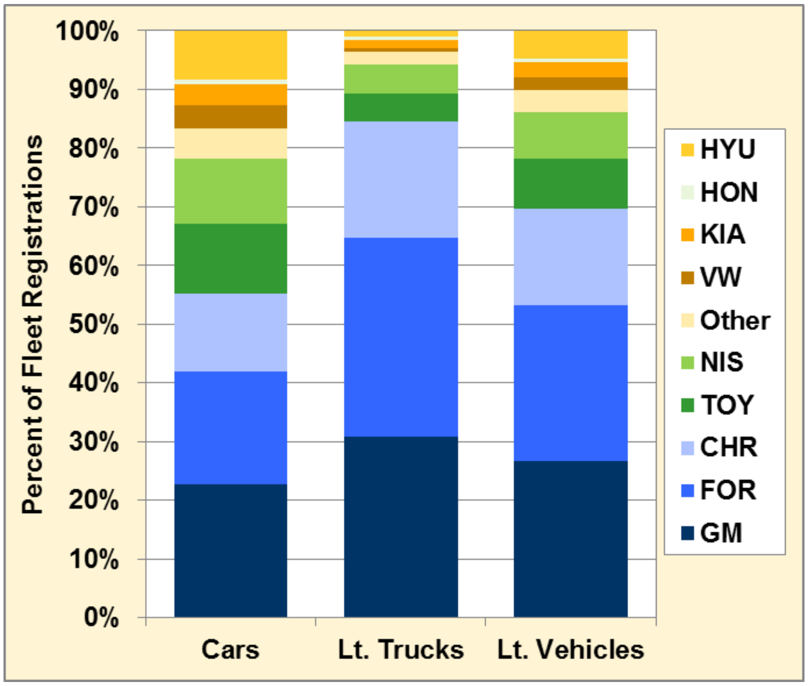
FIGURE 69. Number of Diesel Models and the Price of a Gallon of Gasoline and Diesel, 1980-2014

Sources:

Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov – Data accessed January 2015.

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

Chrysler, Ford, and GM Dominate New Fleet Registrations in 2013



Ford, General Motors, and Chrysler together accounted for 55% of new fleet car registrations and 84% of the new fleet light truck registrations in 2013. New registrations are often used as a proxy for sales. Of the top nine manufacturers, Honda had the smallest share of new fleet registrations and GM had the largest share.

Ford, General Motors, and Chrysler all had between 20% and 30% of the total fleet registrations in 2013. Almost 30% of the new Chrysler cars registered in 2013 were registered to fleets. Honda had only 1.1% of total new vehicles registered to fleets.

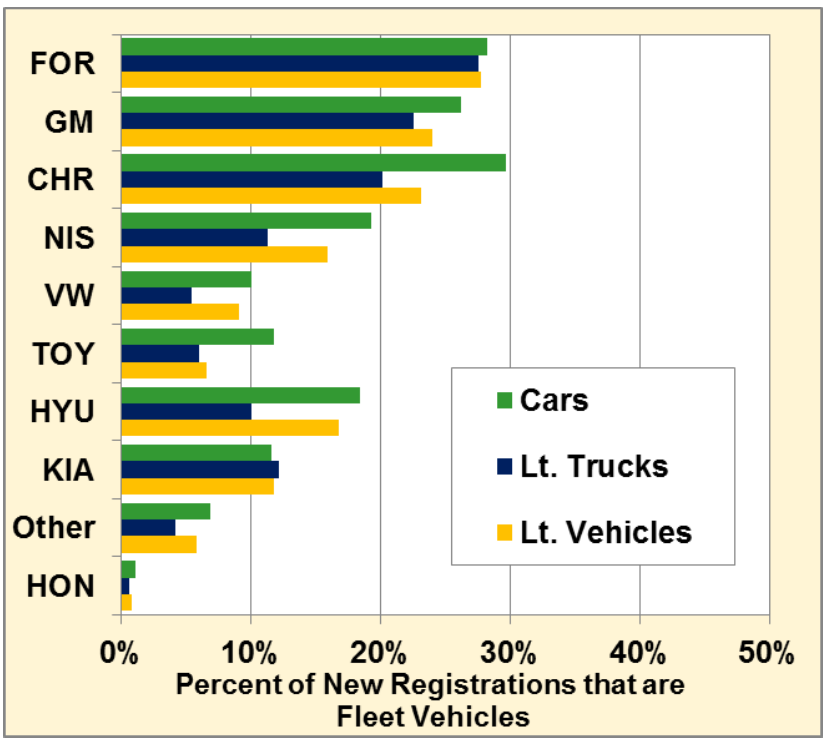


FIGURE 70. New Fleet Registration Data by Manufacturer, 2013

Source:
Bobit Publishing Company, *Automotive Fleet Factbook 2014*. http://www.automotive-fleet.com/statistics

Chevrolet Impala Was the Top New Fleet Car in 2013

The Chevrolet Impala topped the list of new cars which were registered to fleets in 2013. New registrations are often used as a proxy for sales. Over 66% of the new Impalas registered in 2013 were fleet vehicles, most of them in rental fleets. The Dodge Charger was the top model for government fleets, likely due to law enforcement. The Ford Fusion was the model with the most new registrations in commercial fleets, possibly due to the high fuel economy of the Fusion.

TABLE 23. Top 25 New Registrations of Cars in Fleets in 2013

Make	Model	Commercial	Government	Rental	Total Fleet	Total Retail	Total	% Fleet vs Total
Chevrolet	Impala	5,233	9,047	86,569	100,849	51,542	152,391	66.2%
Ford	Fusion	39,426	5,762	43,387	88,575	204,633	293,208	30.2%
Nissan	Altima	7,681	176	69,864	77,721	239,640	317,361	24.5%
Ford	Focus	11,497	5,421	45,271	62,189	173,811	236,000	26.4%
Toyota	Camry	8,229	546	52,941	61,716	343,967	405,683	15.2%
Chevrolet	Malibu	7,381	831	50,902	59,114	139,795	198,909	29.7%
Chrysler	200	2,023	244	51,606	53,873	68,963	122,836	43.9%
Chevrolet	Cruze	4,809	500	47,820	53,129	193,884	247,013	21.5%
Toyota	Corolla	5,697	153	38,604	44,454	256,421	300,875	14.8%
Dodge	Charger	1,410	11,775	29,851	43,036	52,404	95,440	45.1%
Ford	Taurus	12,878	11,376	18,161	42,415	36,426	78,841	53.8%
Hyundai	Sonata	1,416	141	38,133	39,690	163,136	202,826	19.6%
Hyundai	Elantra Sedan	781	75	35,962	36,818	166,670	203,488	18.1%
Nissan	Versa	3,689	67	28,450	32,206	85,505	117,711	27.4%
Dodge	Avenger	490	2,121	29,485	32,096	61,769	93,865	34.2%
Chevrolet	Sonic	2,423	82	18,828	21,333	62,834	84,167	25.3%
Volkswagen	Jetta	2,311	26	18,200	20,537	143,468	164,005	12.5%
KIA	Optima	460	23	19,375	19,858	135,436	155,294	12.8%
Hyundai	Accent	1,087	5	18,613	19,705	36,941	56,646	34.8%
Ford	Mustang	907	36	17,055	17,998	59,315	77,313	23.3%
Chrysler	300	1,167	98	13,638	14,903	43,318	58,221	25.6%
Volkswagen	Passat	4,126	48	9,823	13,997	96,419	110,416	12.7%
Toyota	Prius	3,617	879	8,426	12,922	132,097	145,019	8.9%
Nissan	Maxima	520	15	12,199	12,734	40,126	52,860	24.1%
Toyota	Yaris	451	4	11,671	12,126	8,337	20,463	59.3%

Source:
Bobit Publishing Company, *Automotive Fleet Factbook 2014*. http://www.automotive-fleet.com/statistics

Ford F-Series Was the Top New Fleet Truck in 2013

The Ford F-series topped the list of new light trucks which were registered to fleets in 2013. New registrations are often used as a proxy for sales. Over 24% percent of the new F-Series trucks registered in 2013 were fleet vehicles, the majority of them in commercial fleets. The F-Series was also the top vehicle model for government fleets. The Chrysler Town & Country and the Chevrolet Captiva were the models with the most new registrations in rental fleets.

TABLE 24. Top 25 New Registrations of Trucks in Fleets in 2013

Make	Model	Commercial	Government	Rental	Total Fleet	Total Retail	Total	% Fleet vs Total
Ford	F-Series	95,998	26,343	31,426	153,767	483,623	637,390	24.1%
Chevrolet	Silverado	52,090	9,500	16,733	78,323	365,083	443,406	17.7%
Ford	Econoline	30,605	5,943	31,601	68,149	18,276	86,425	78.9%
Ford	Escape	31,434	3,616	30,868	65,918	229,348	295,266	22.3%
Dodge	Caravan/ Grand Caravan	17,118	8,023	38,971	64,112	60,135	124,247	51.6%
Ford	Explorer	12,414	18,028	20,872	51,314	140,758	192,072	26.7%
Ram		21,336	4,589	21,594	47,519	254,605	302,124	15.7%
Chrysler	Town & Country	1,041	40	45,986	47,067	74,955	122,022	38.6%
Chevrolet	Captiva	964	73	45,112	46,149	782	46,931	98.3%
Chevrolet	Express	28,926	5,445	11,406	45,777	18,717	64,494	71.0%
Chevrolet	Tahoe	2,666	14,215	21,028	37,909	45,128	83,037	45.7%
Chevrolet	Equinox	15,006	1,702	20,317	37,025	200,059	237,084	15.6%
Chevrolet	Suburban	1,499	1,529	20,686	23,714	27,218	50,932	46.6%
Ford	Edge	6,259	224	16,792	23,275	105,302	128,577	18.1%
Ford	Transit Connect Van	19,876	1,482	889	22,247	16,869	39,116	56.9%
Dodge	Journey	3,605	382	15,714	19,701	62,823	82,524	23.9%
Chevrolet	Traverse	3,702	393	14,806	18,901	76,198	95,099	19.9%
Jeep	Patriot	3,843	668	11,361	15,872	59,183	75,055	21.1%
Toyota	Sienna	6,672	310	8,798	15,780	102,685	118,465	13.3%
Nissan	Rogue	2,913	62	12,494	15,469	146,554	162,023	9.5%
GMC	Yukon XL	245	77	14,348	14,670	4,911	19,581	74.9%
GMC	Sierra	12,357	1,461	398	14,216	157,352	171,568	8.3%
Toyota	Tacoma	10,074	948	2,130	13,152	146,320	159,472	8.2%
Jeep	Grand Cherokee	4,191	297	7,834	12,322	160,994	173,316	7.1%
Jeep	Compass	1,246	140	10,169	11,555	41,143	52,698	21.9%

Source:
Bobit Publishing Company, *Automotive Fleet Factbook 2014*. http://www.automotive-fleet.com/statistics

Fleet Management Companies Remarket Vehicles On-Line

The top ten fleet management companies owned or managed over 3.6 million vehicles in 2013. 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-six percent of the vehicles remarketed in 2013 by the top ten fleet management companies were remarketed on-line. Emkay and Penske remarketed over 80% of their vehicles on-line.

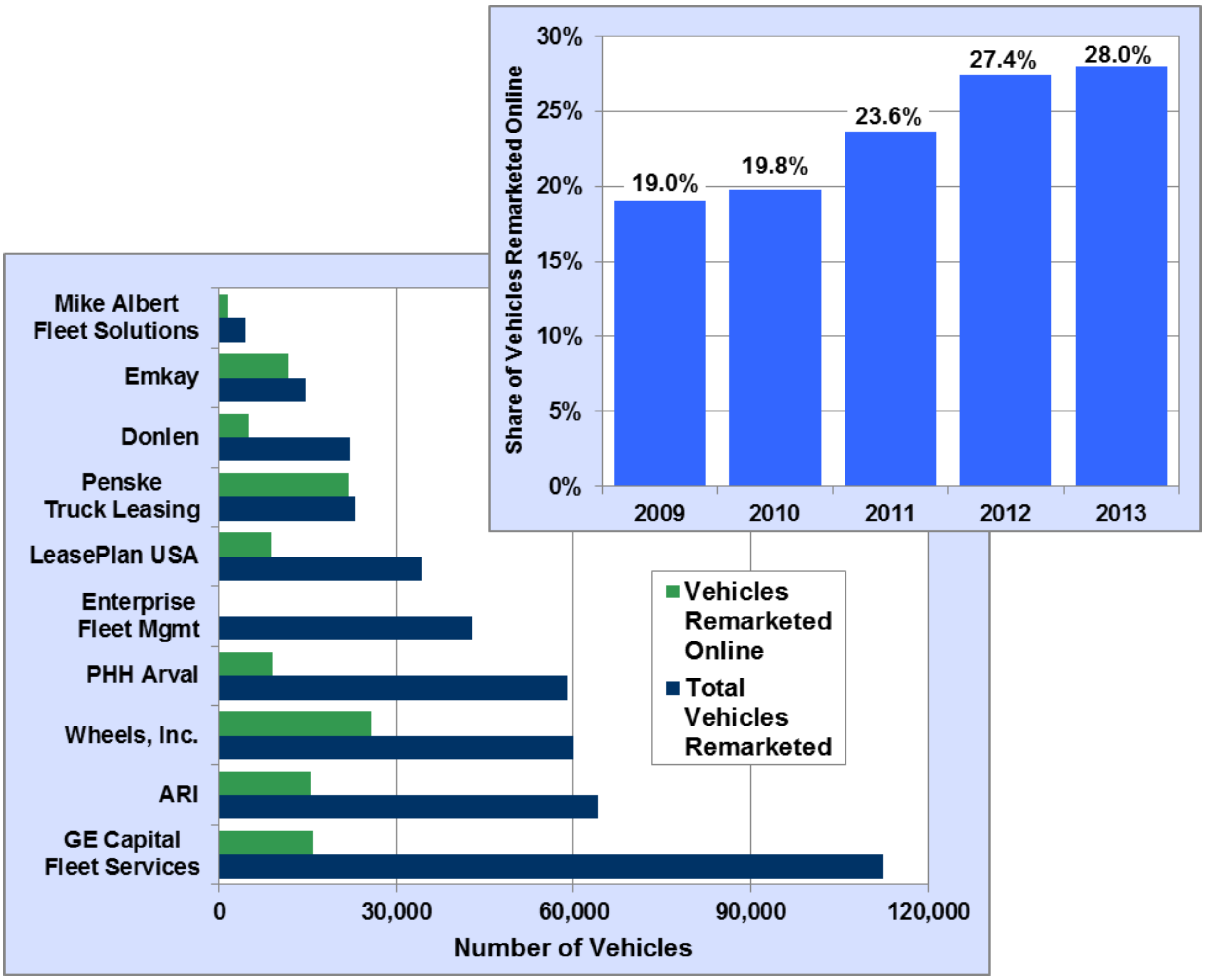
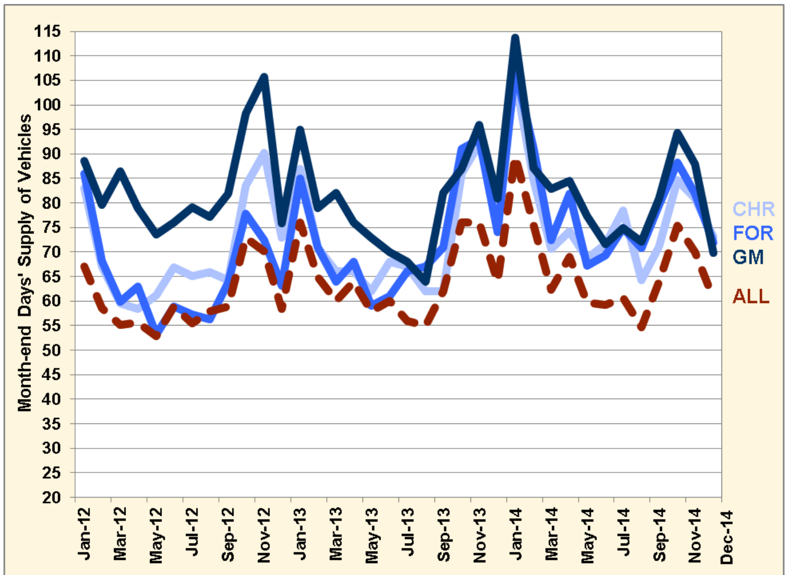


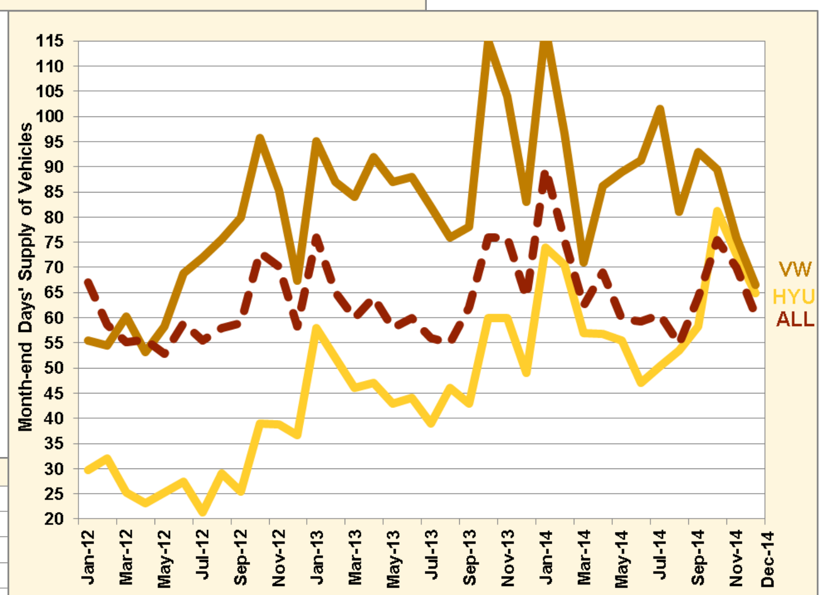
FIGURE 71. Vehicles Remarketed by the Top Ten Fleet Management Companies, 2013, and Share of Vehicles Remarketed On-Line, 2009-2013

Source:
Bobit Publishing Company, *Automotive Fleet Factbook 2014*. 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.



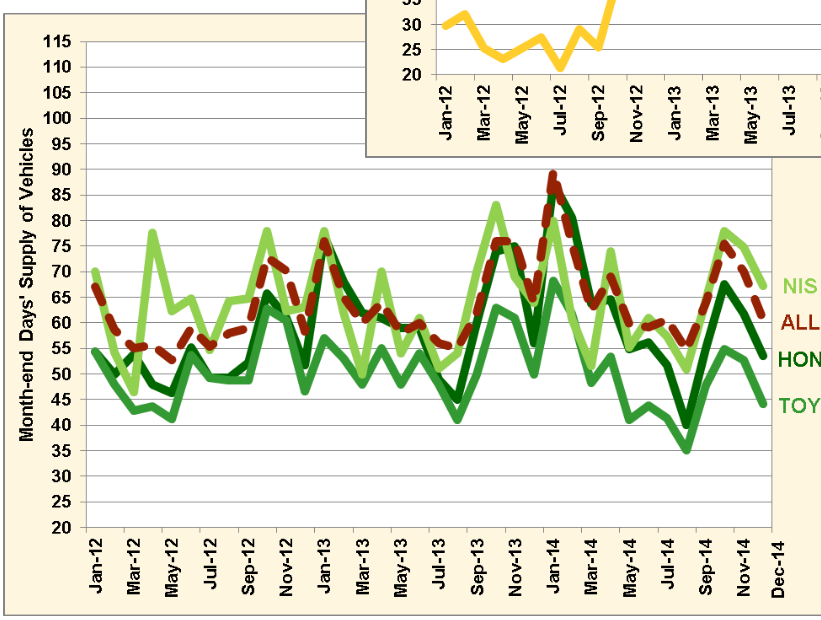


FIGURE 72. Monthly Dealer Supplies by Manufacturer, 2012-2014

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

Source:
Ward's Autoinfobank.
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. The figure below shows that the days to turn by vehicle class were closer together in November 2010 when light vehicle sales were depressed across all classes and fuel prices were under $3 per gallon. As light vehicle sales recovered, there was greater variability in the pace of sales among the different vehicle classes. The sharp decline for compact and subcompact cars in 2011 probably reflects the earthquake and tsunami that struck Japan which constrained supplies, limited dealer inventories and shortened days to turn, particularly among the smaller cars produced in Japan. In mid-2014 the price of gasoline began to decline and the turnover time for most vehicle classes declined as well.

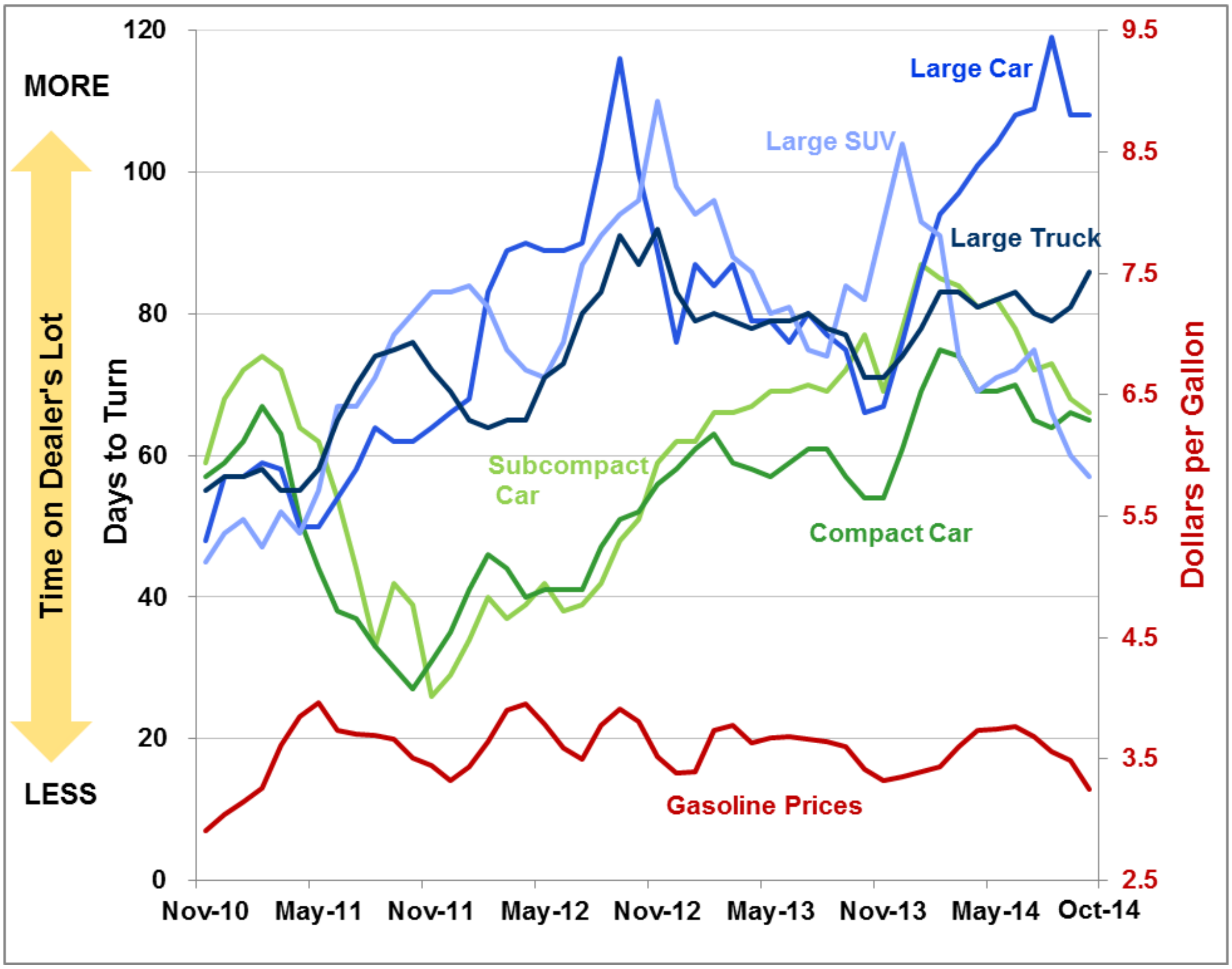


FIGURE 73. Days to Turn Trend by Vehicle Class, 2010-2014

Sources:

Edmunds website data, www.Edmunds.com; U.S. Department of Energy, Energy Information Administration, International Statistics website, December 2014.

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 $40 billion in parts sales to OEMs in 2013. Within the top ten suppliers, only one – Magna International, Inc. – has the majority (51%) 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 25. List of Top Ten Tier 1 Global Suppliers, 2013

			Market Share				
Rank	**Company**	**Company Headquarters**	**North America**	**Europe**	**Asia**	**Rest of World**	**Total**
1	Robert Bosch GMbH	Germany	18%	53%	25%	4%	100%
2	Denso Corp.	Japan	20%	12%	66%	2%	100%
3	Magna International, Inc.	Canada	51%	41%	5%	3%	100%
4	Continental AG	Germany	23%	49%	25%	3%	100%
5	Aisin Seiki Co., Ltd.	Japan	16%	8%	75%	1%	100%
6	Hyundai Motors	Korea	21%	11%	67%	1%	100%
7	Faurecia	France	27%	54%	13%	6%	100%
8	Johnson Controls, Inc.	United States	47%	42%	11%	0%	100%
9	ZF Friedrichshafen AG	Germany	18%	58%	18%	6%	100%
10	Lear Corp.	United States	38%	38%	18%	6%	100%

Note: Rank based on total global OEM automotive parts sales in 2013.

Source:
Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2014. http://www.autonews.com/

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

There are 10 U.S.-based companies in the top 50 automotive global suppliers. Of these companies, only two have more than half of their sales in North America.

TABLE 26. U.S.-Based Tier 1 Suppliers in the Top 50, 2013

Rank	Company	Percent North America Sales	Products
8	Johnson Controls, Inc.	47%	Seating, overhead systems, door & instrument panels, center & overhead consoles, interior electronics, lead-acid & hybrid vehicle batteries
10	Lear Corp.	38%	Seating & electrical distribution systems
11	TRW Automotive Holdings Corp.	36%	Steering, suspension, braking & engine components; fasteners, occupant-restraint systems, electronic safety & security systems
13	Delphi Automotive	34%	Mobile electronics; powertrain, safety, thermal, controls & security systems; electrical/electronic architecture; in-car entertainment technologies
25	Cummins, Inc.	52%	Diesel & natural gas engines
31	Visteon Corp.	19%	Climate-control systems, electronics, interiors
32	BorgWarner, Inc.	30%	Turbochargers, engine valve-timing systems, ignition systems, emissions systems, thermal systems, transmission-clutch systems, transmission-control systems & torque management systems
34	Dana Holding Corp.	44%	Axles, driveshafts, sealing & thermal management products
46	Flex-N-Gate Corp.	91%	Plastic & steel bumpers, fascias, stampings, mechanical assemblies, running boards, prototype sheet metal, interior & exterior plastic, towing hitches, body-in-white stampings, roll forming, lighting
50	Federal-Mogul Corp.	34%	Pistons, rings, cylinder liners, piston pins, ignition & spark plugs, bearings, valve seats & guides, gaskets, seals, heat shields, brake friction materials & products, systems protection products, lighting products, wipers, fuel pumps

Note: Rank based on total global OEM automotive parts sales in 2013.

Source:
Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2014.
http://www.autonews.com/

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

There are eight U.S. automotive parts suppliers that sold more than $5 billion in parts to original equipment manufacturers in 2013. Most of these companies have been diversifying their customer base over the last five years. Four of the companies increased their share of sales in Asia and North America while decreasing their sales share in Europe and the rest of the world. Visteon and Dana are the only two companies that decreased their sales share to North America between 2009 and 2013.

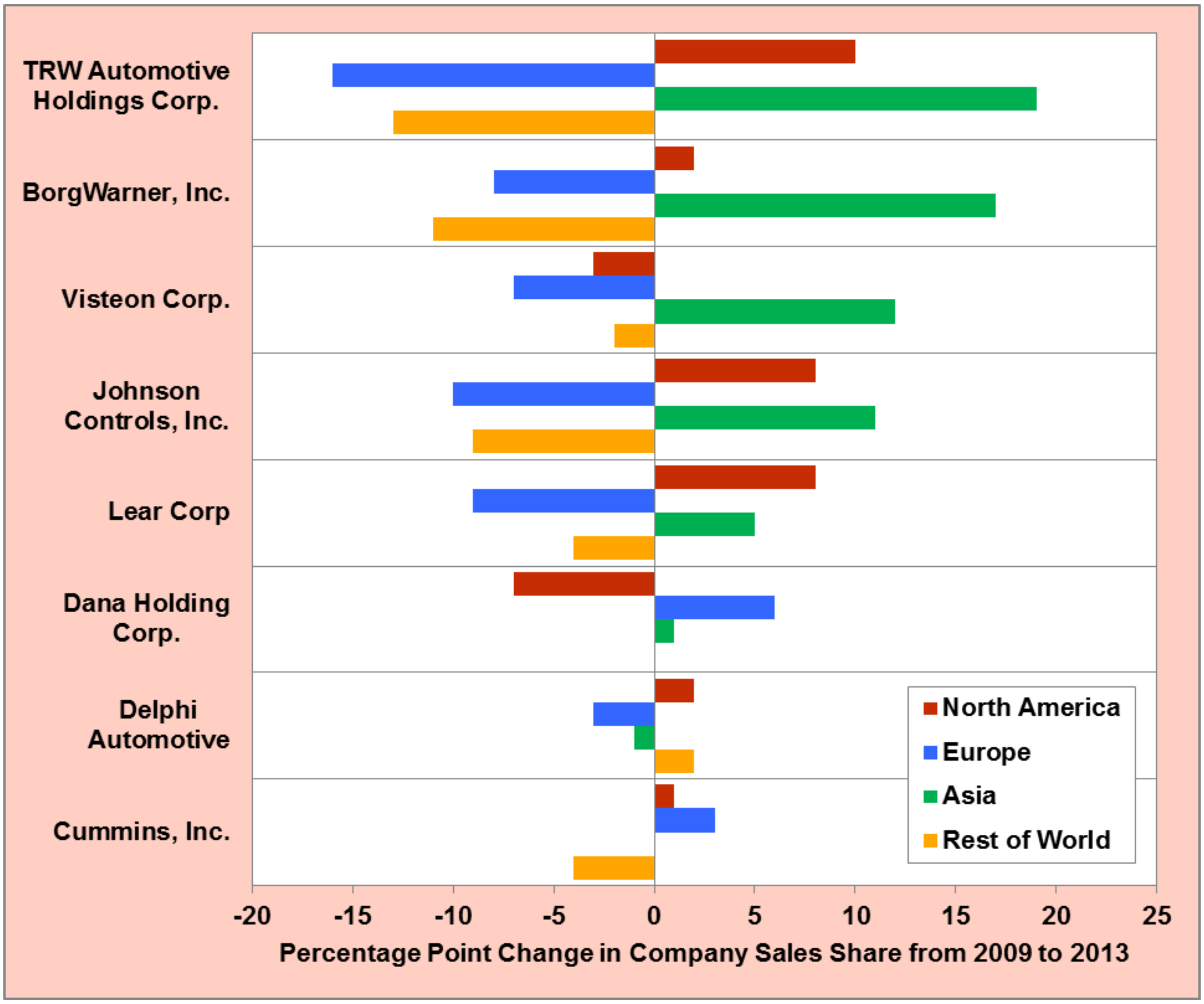


FIGURE 74. Change in Company Sales Share of Top U.S.-Based Tier 1 Suppliers, 2009-2013

Source:

Crain Communications, *Automotive News Supplement,* "Top 100 Global Suppliers," June 2014 and June 2010. http://www.autonews.com/

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Chapter 3

HEAVY TRUCKS

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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.

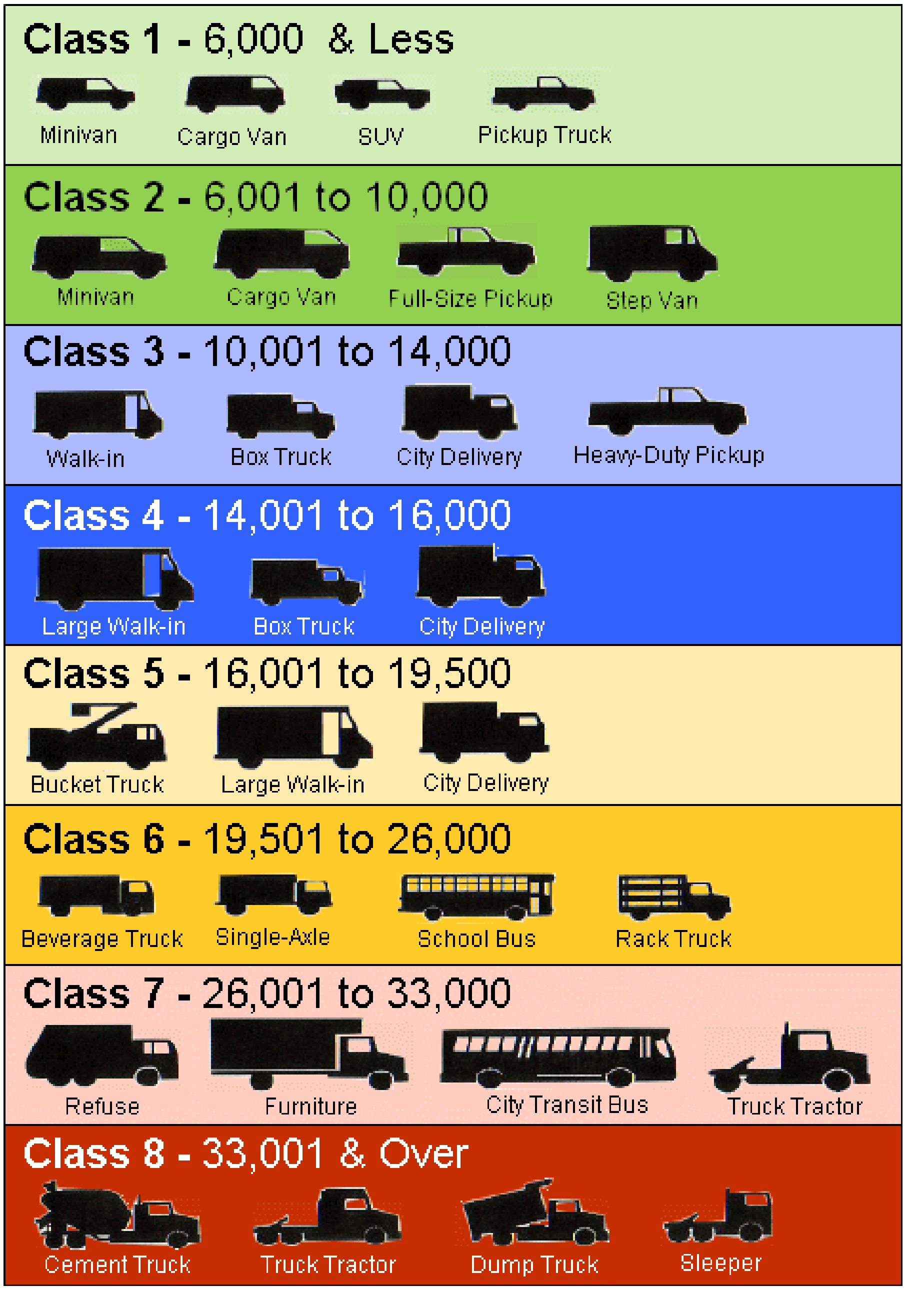

FIGURE 75. Examples of Trucks in Each Truck Class

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 27. 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

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, Mac, Peterbilt and Volvo. Two of those, Freightliner and International, also manufacture medium trucks (classes 3-6), along with Isuzu.

TABLE 28. Production of Medium and Heavy Trucks by Manufacturer, 2013

Freightliner & Western Star	Hino	International	Kenworth	Mack	Peterbilt	Volvo	Isuzu
57.2	5.7	21.3	30.9	21.2	26.3	26.1	2.5

Note: Production not available by plant site. Production not available for NEOPLAN, Sprinter, and Thomas. Medium trucks produced by Chrysler, Ford, and GM are not included.

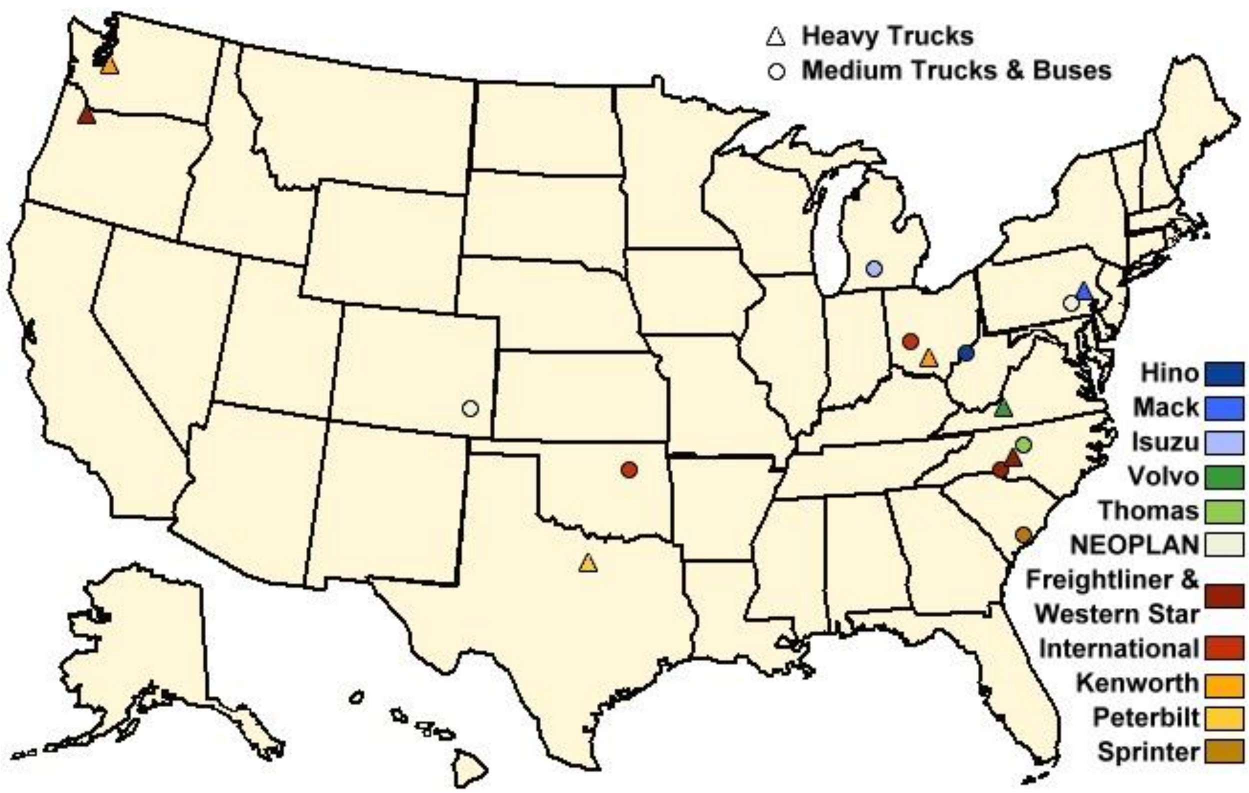

FIGURE 76. Medium and Heavy Truck Manufacturing Plants by Location, 2014

Source:
Ward's Autodata. 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). Truck classes 4 and 5 made up the majority of imports, but some were in Classes 6 and 7 as well. In 2013 there were no imported Class 8 trucks sold. Historically the import truck market share peaked in 1987 at 7.1% and after much volatility the overall import share was 3.1% in 2013.

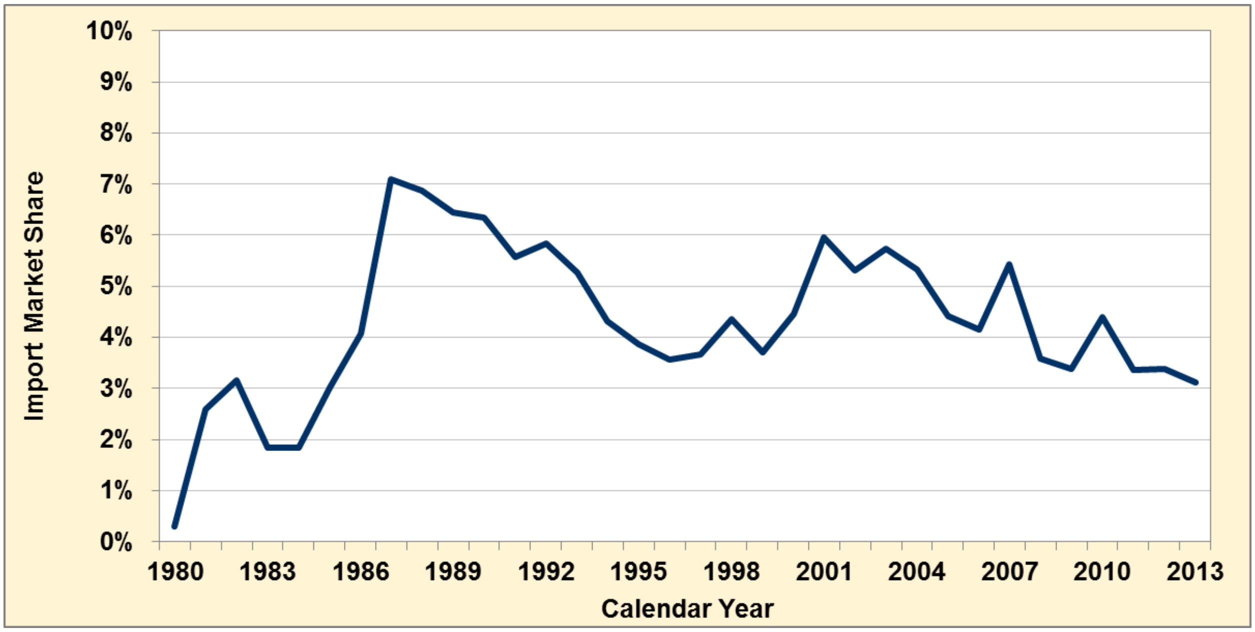

FIGURE 77 . Import Share of Medium and Heavy Trucks, 1980-2013

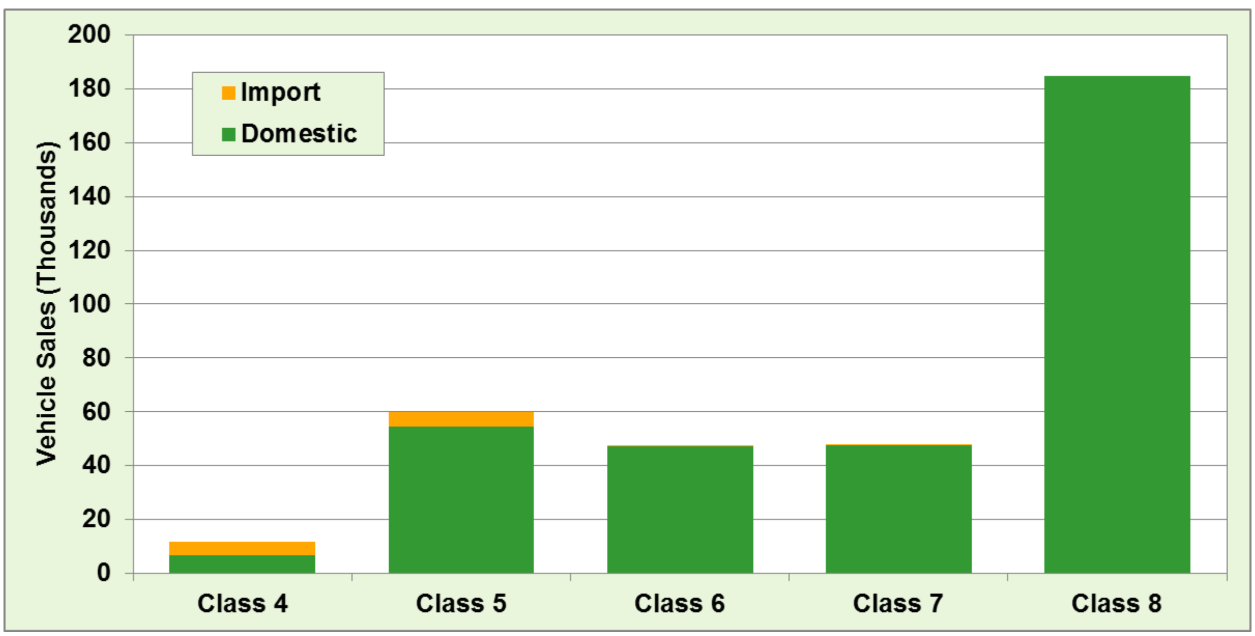

FIGURE 78 . Medium and Heavy Trucks Sold by Source and Weight Class, 2013

Source:
Ward's AutoInfoBank.

Class 3 Truck Sales in 2013 Are 127% Higher than 2009

Class 3 truck sales began to recover in 2010 from the economic downturn and have continued to increase through 2013. In fact, 2013 sales were 127% above 2009 sales. Chrysler, Ford, and General Motors dominate the class 3 market.

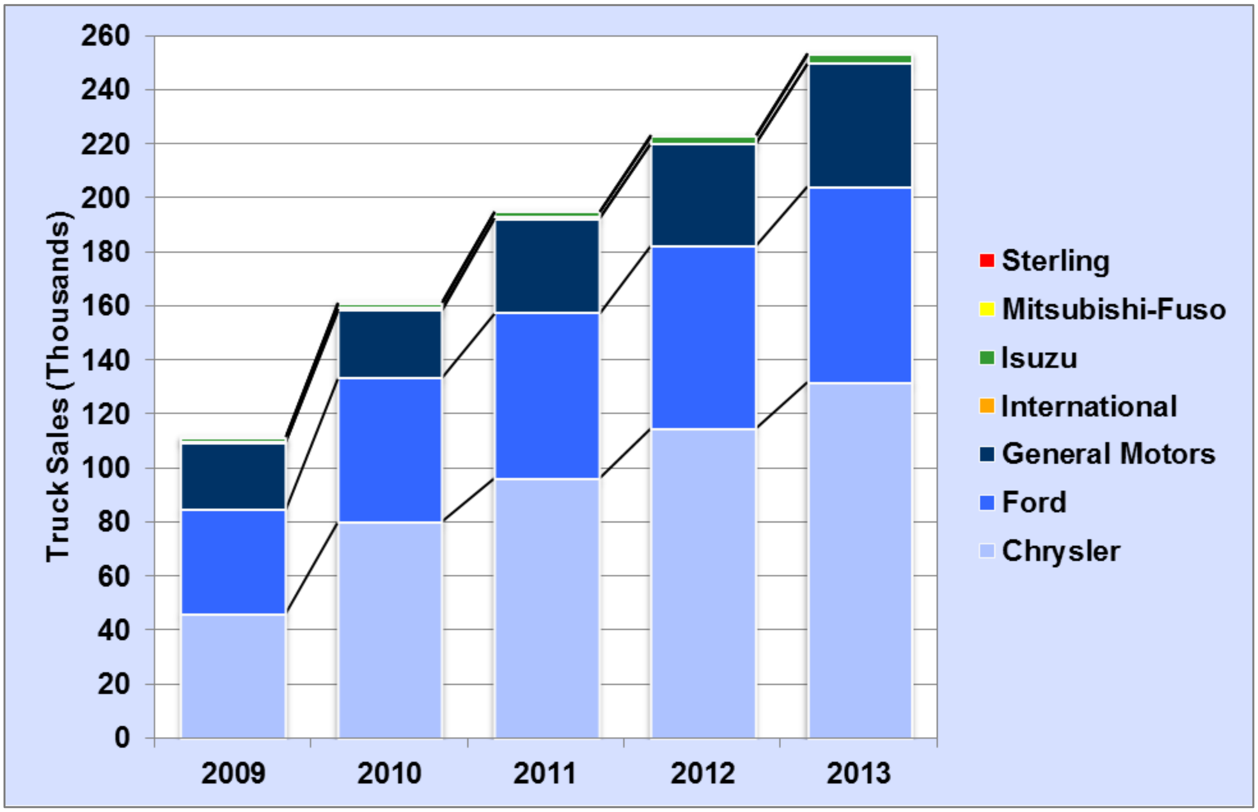

FIGURE 79. Class 3 Truck Sales by Manufacturer, 2009-2013

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2014*, Southfield, MI, 2014.
http://wardsauto.com

Class 4-7 Truck Sales in 2013 Are 66% Higher than 2009

The sales of class 4-7 trucks have continued to increase since 2009 and were 66% above the 2009 level. However, most companies kept their market share of the significantly lower market, with General Motors (GM) and International being the notable exceptions. In 2009 GM sold over 12,000 class 4-7 trucks, while in 2013 they sold none. Hino and Isuzu gained one to three percent of the market share after GM's decline. Chrysler, Ford, and Freightliner all gained between six to nine percent from 2009 to 2013.

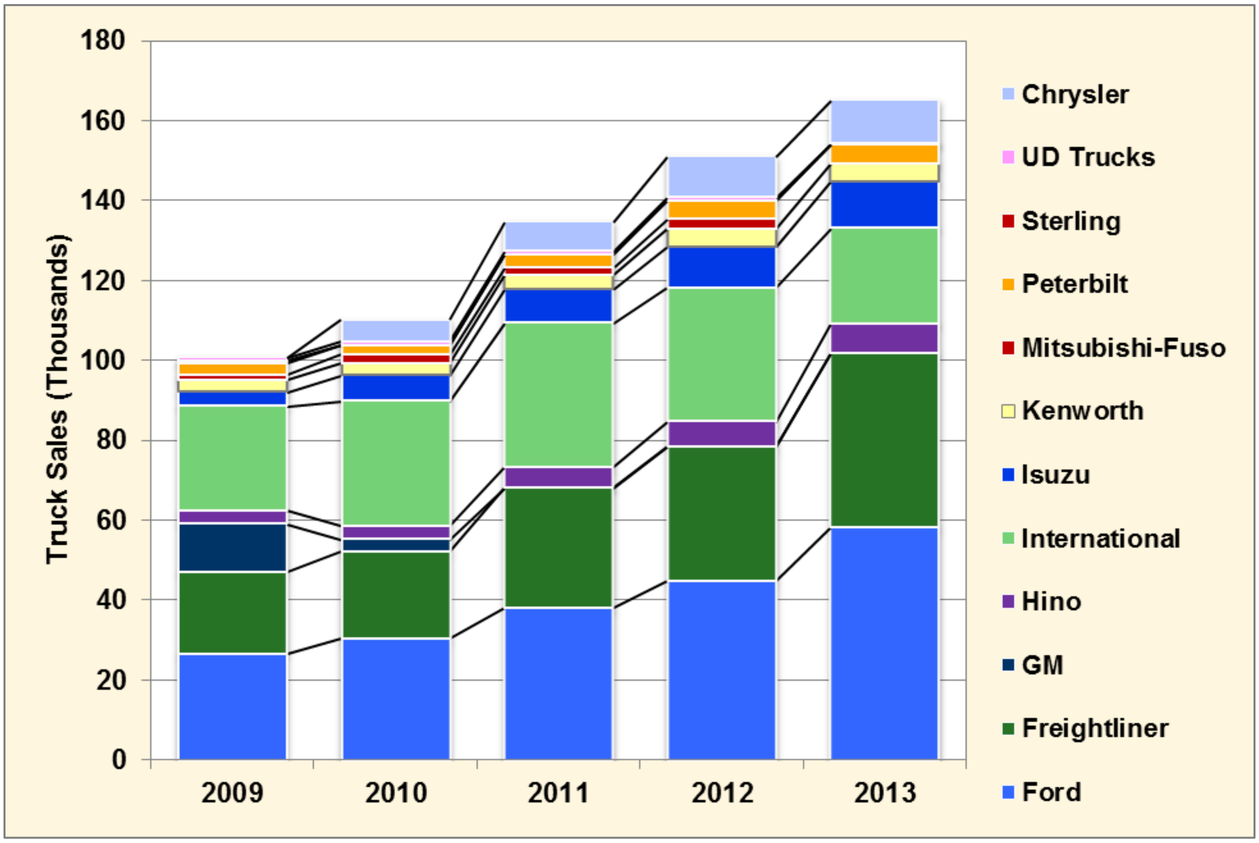

FIGURE 80. Class 4-7 Truck Sales by Manufacturer, 2009-2013

Note: Nissan Diesel was renamed UD Trucks at the end of 2009.

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2014*, Southfield, MI, 2014.
http://wardsauto.com

Class 8 Truck Sales in 2013 Are 95% Higher than 2009 but 5% Lower than 2012 Sales

Class 8 truck sales were down to 185,000 in 2013 after peaking at 195,000 in 2012. These sales totals are still much higher than in 2009, when sales did not reach 100,000 trucks. Over the five-year period, International lost market share, Freightliner and Volvo gained market share, and the others held steady.

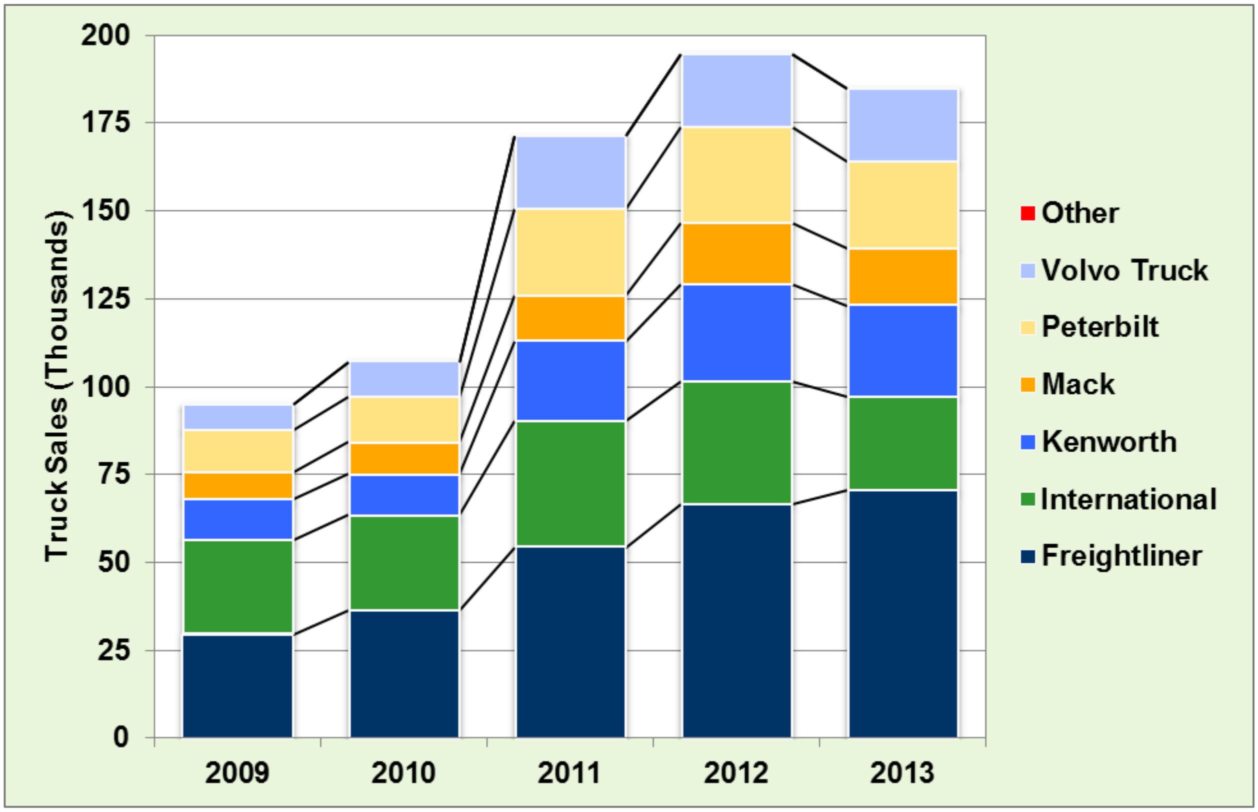

FIGURE 81. Class 8 Truck Sales by Manufacturer, 2009-2013

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2014*, Southfield, MI, 2014. http://wardsauto.com

Diesel Engine Use Declines 56% for Class 4 Trucks and Increases 73% for Class 6 Trucks

In 2009, over half of class 6 trucks sold were diesel; in 2013, nearly all of class 6 trucks sold were diesel. Class 4 trucks were predominately diesel in 2009, but in 2013 were predominately gasoline. Classes 3 and 5 trucks also showed a decline in diesel share. However, class 6 and class 7 trucks reversed the trend. Class 8 trucks have always been near 100% diesel and that has not changed. Overall, diesel comprised 72% of the class 3-8 trucks sold in 2013, up from 69% in 2009.

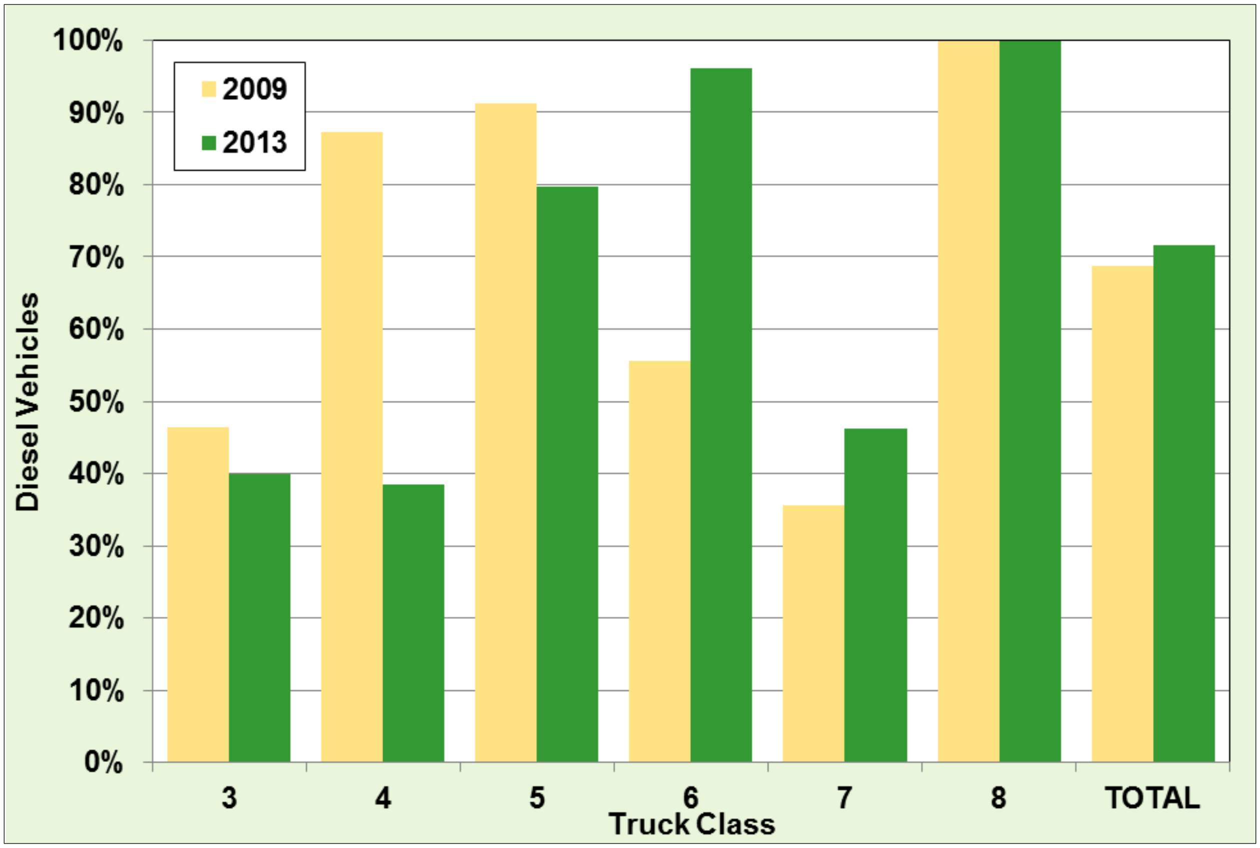

FIGURE 82. Share of Diesel Truck Sales by Class, 2009 and 2013

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

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2014*, Southfield, MI, 2014.
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 29. Diesel Engine Suppliers by Manufacturer, 2013

Make	Engine Manufacturer	Share
Freightliner	Cummins	62.3%
	Detroit Diesel	37.0%
	Mercedes Benz	0.7%
	Total	**100.0%**
Hino	Hino	100.0%
International	Cummins	7.2%
	Navistar	92.8%
	Total	**100.0%**
Kenworth	Cummins	66.0%
	PACCAR	34.0%
	Total	**100.0%**
Mack	Cummins	6.0%
	Mack	94.0%
	Total	**100.0%**
Peterbilt	Cummins	65.2%
	PACCAR	34.8%
	Total	**100.0%**
Volvo	Cummins	13.6%
	Volvo	86.4%
	Total	**100.0%**
Western Star	Cummins	21.2%
	Detroit Diesel	78.8%
	Total	**100.0%**
Other	Cummins	100%

Note: International's parent company is Navistar.

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

Cummins Leads Heavy Truck Diesel Engine Market

In 2009, Navistar held a 77% share of the heavy truck diesel engine market. By 2013, Navistar's share had declined to 9% and Cummins held the largest share of the market (47%).

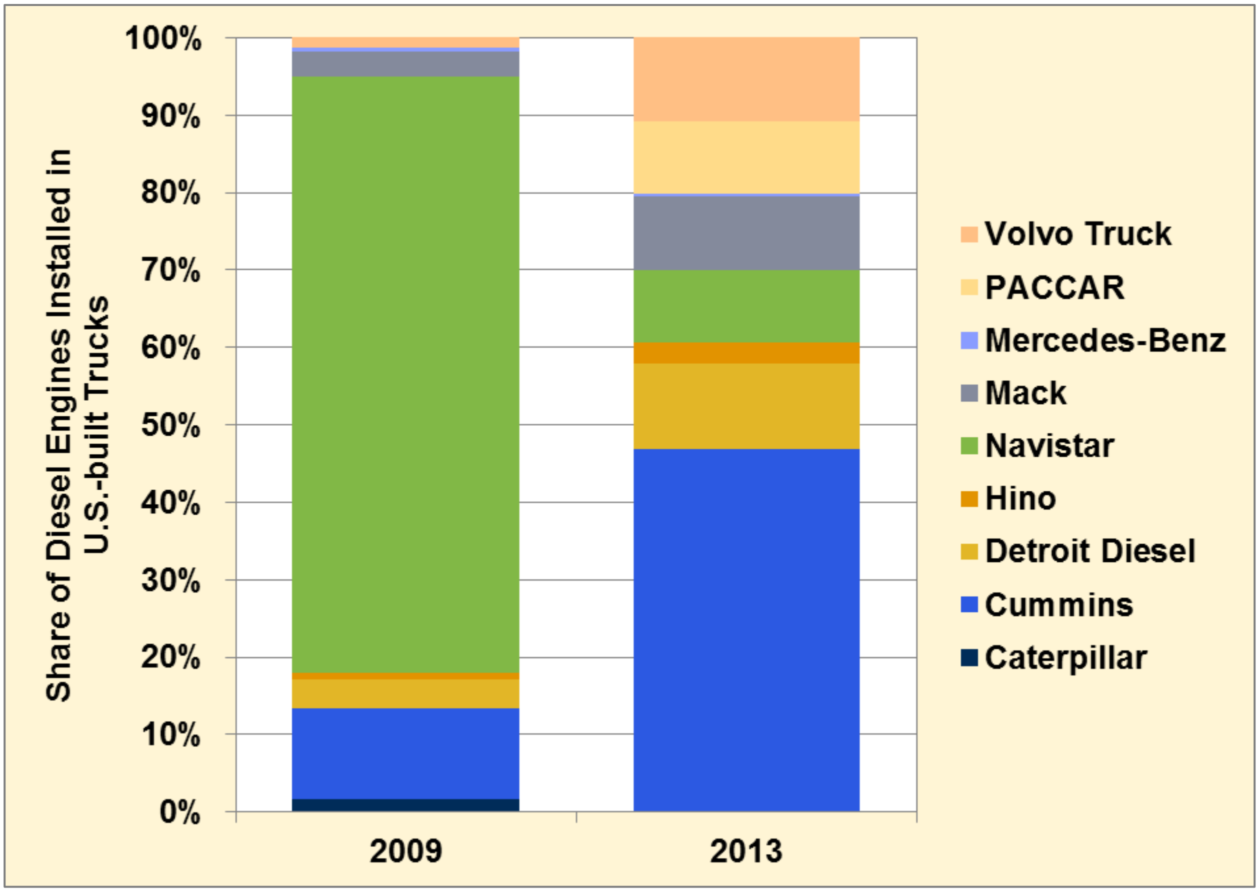

FIGURE 83. Diesel Engine Manufacturers Market Share, 2009 and 2013

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

Combination Trucks Average over 66,000 Miles per Year

According to the latest Federal Highway Administration estimates, the average miles traveled per truck was over 66,000 miles for a combination truck in 2012, down from over 68,000 miles in 2010. Because heavy truck duty-cycles vary, these averages have large standard deviations. Heavy single-unit trucks (above 10,000 lbs. 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 2012 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.

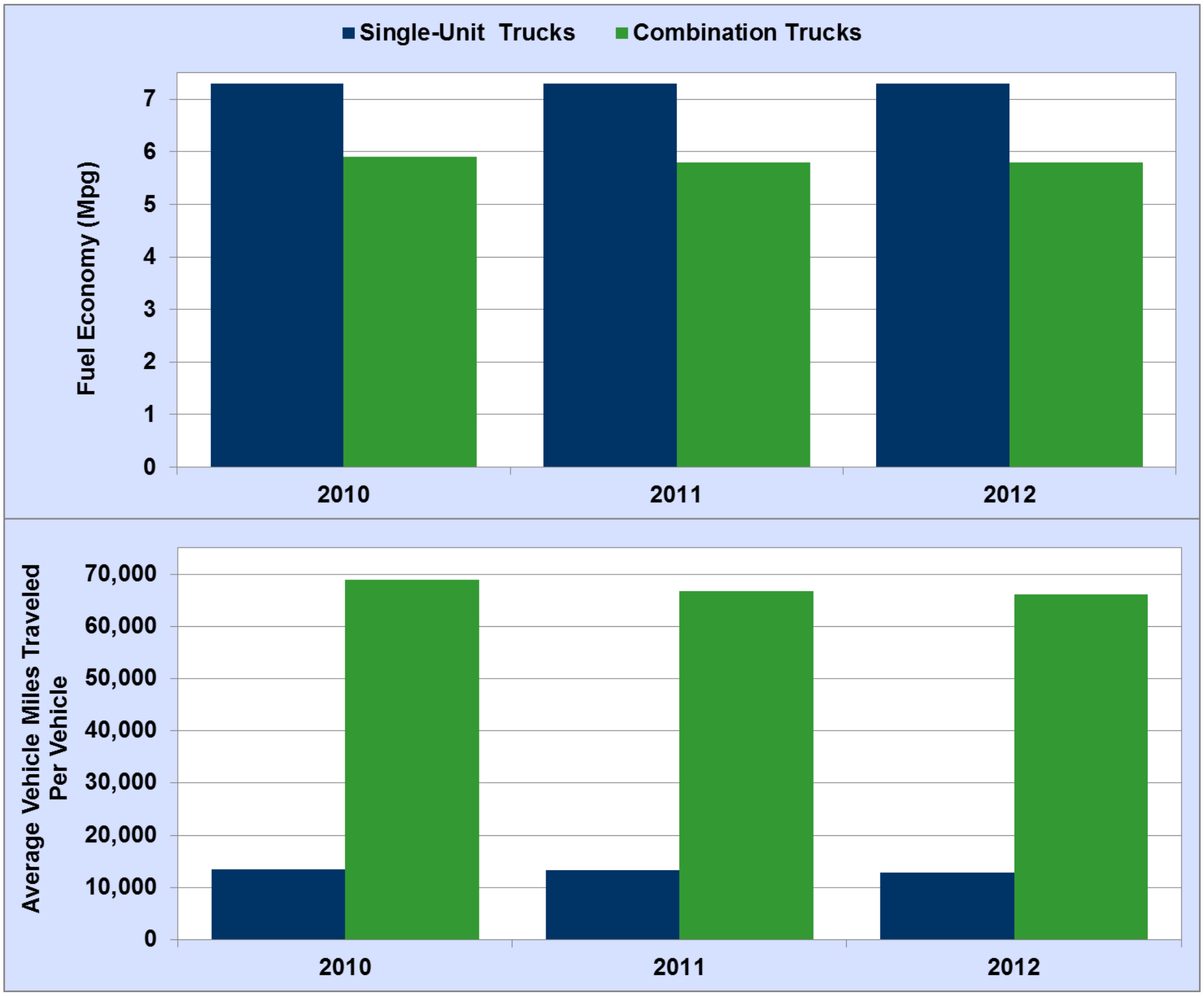

FIGURE 84. Vehicle-Miles of Travel and Fuel Economy for Heavy Trucks, 2010-2012

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 2012*, Table VM-1, 2014. http://www.fhwa.dot.gov/policyinformation/statistics/2012/vm1.cfm

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 30. 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.

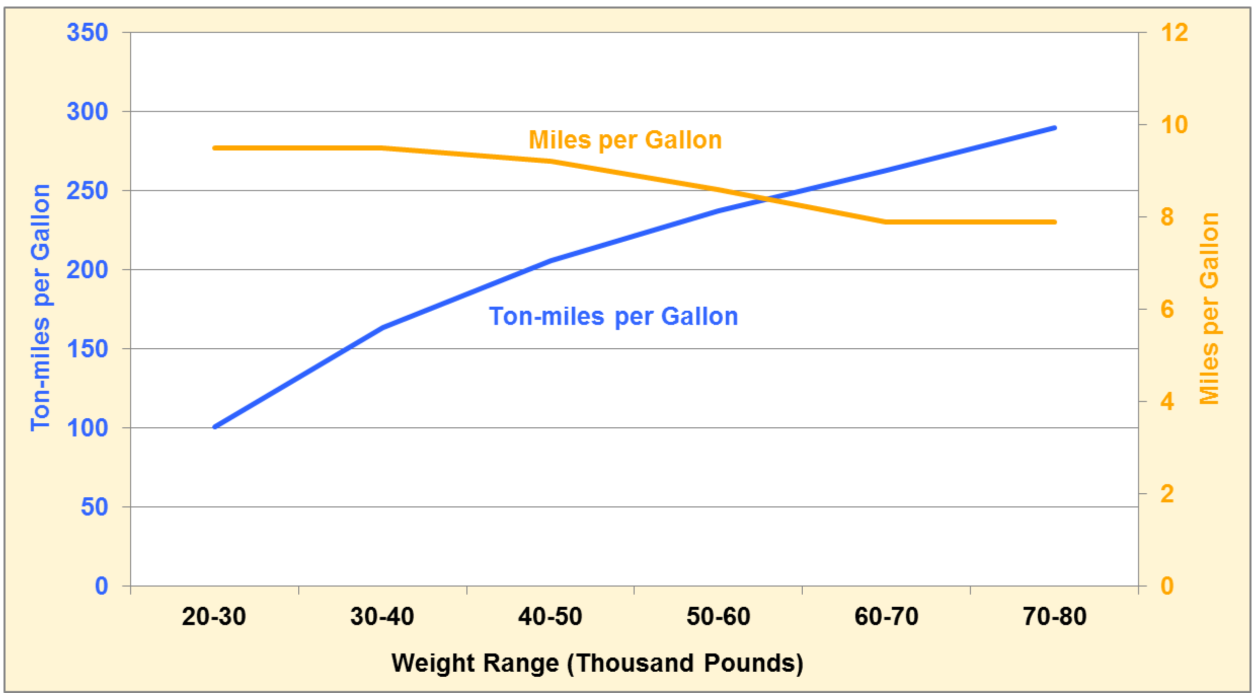

FIGURE 85. Fuel Efficiency of Class 8 Trucks by Vehicle Weight Range on Flat Terrain at 65 mph

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.

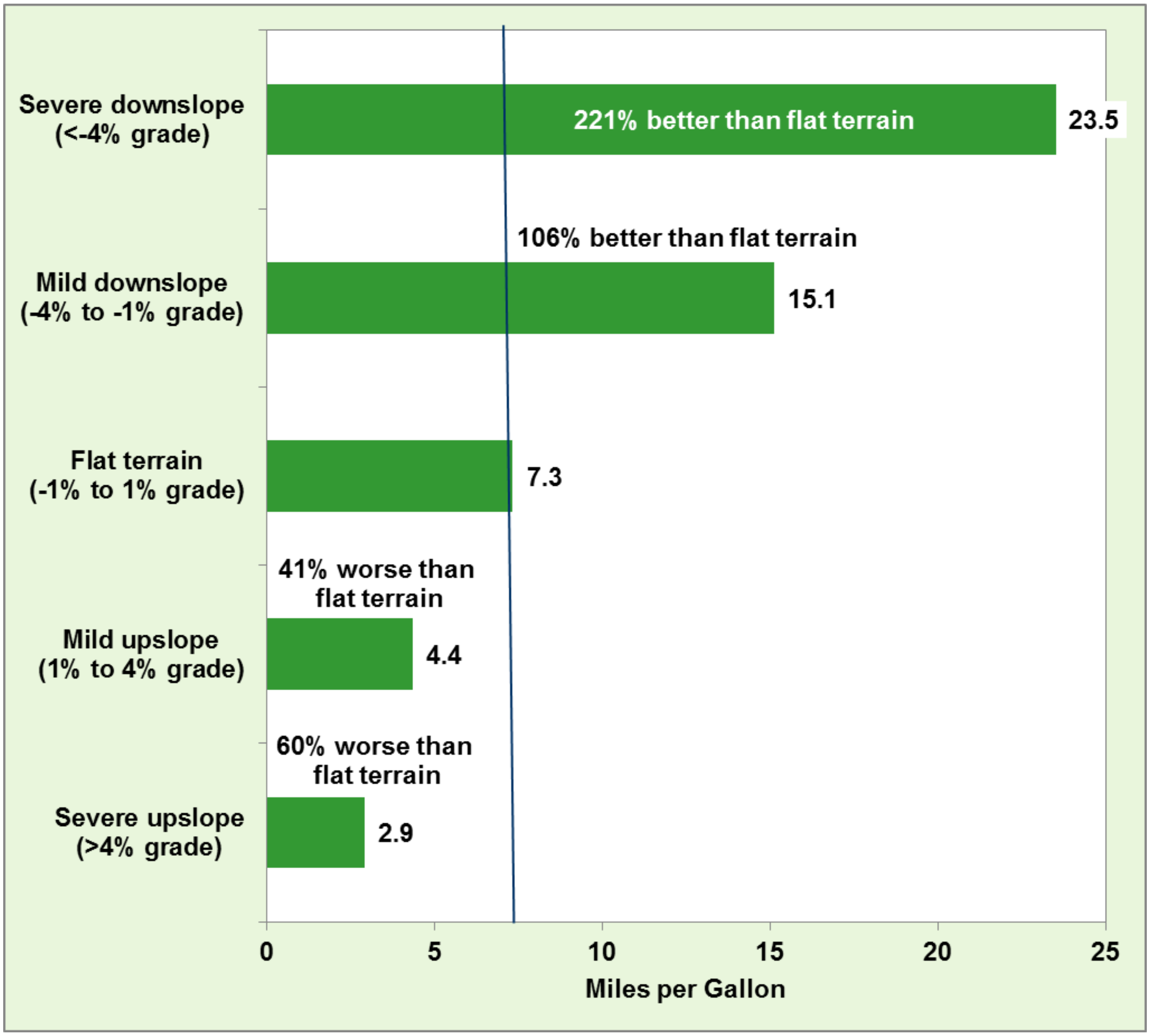

FIGURE 86. Fuel Efficiency of Class 8 Trucks by Roadway Grade

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 lbs. consumed more fuel at idle than the diesel medium heavy truck category at 23,000-33,000 lbs. GVW. By comparison, a compact sedan using diesel or gasoline uses less than 0.2 gal/hr when idling.

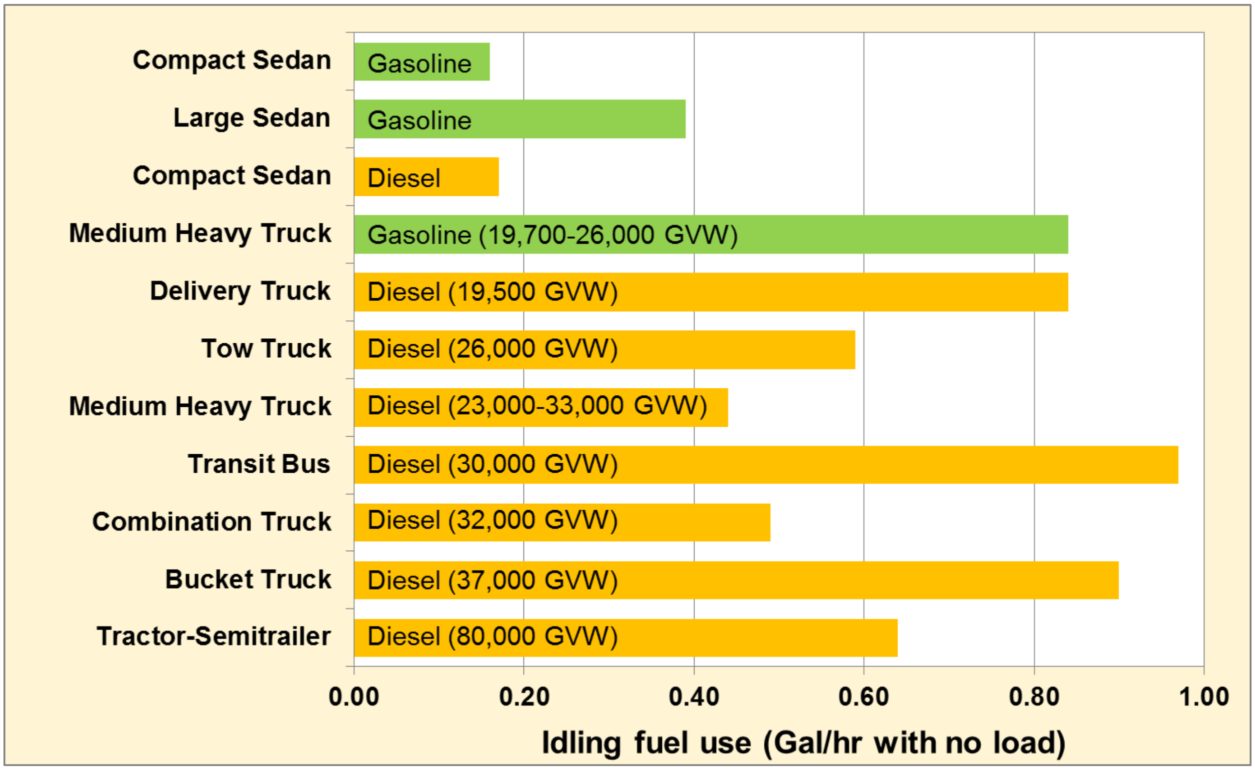

FIGURE 87. Fuel Consumption at Idle for Selected Gasoline and Diesel Vehicles

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.transportation.anl.gov/pdfs/idling_worksheet.pdf, accessed December 2014.

Truck Stop Electrification Reduces Idle Fuel Consumption

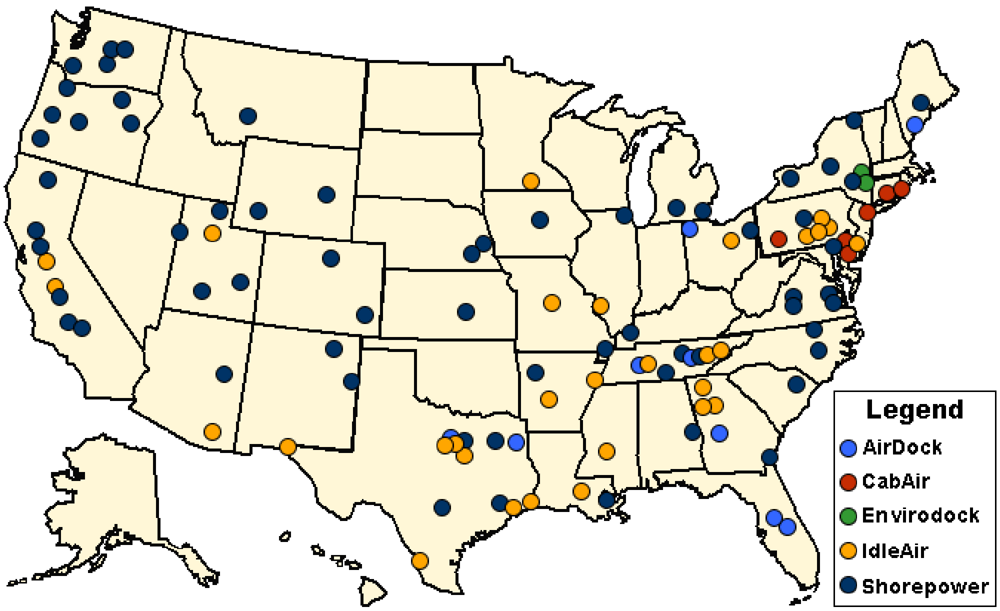

FIGURE 88. Map of Truck Stop Electrification Sites, 2014

TABLE 31. Number of Truck Stop Electrification Sites by State, 2014

State	Number of Sites	State	Number of Sites
Alabama	1	Mississippi	1
Arizona	2	Missouri	2
Arkansas	3	Montana	1
California	8	Nebraska	2
Colorado	2	New Jersey	2
Connecticut	1	New Mexico	2
Delaware	1	New York	6
Florida	2	North Carolina	2
Georgia	5	Ohio	3
Illinois	2	Oregon	6
Iowa	1	Pennsylvania	6
Kansas	1	South Carolina	1
Kentucky	1	Tennessee	8
Louisiana	2	Texas	18
Maryland	1	Utah	5
Maine	2	Virginia	4
Michigan	2	Washington	4
Minnesota	1	Wyoming	2
Total	**113**		

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 113 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, five companies equip electrification sites: Shorepower, CabAire, EnviroDock, AireDock, and IdleAir.

Source:

Alternative Fuels and Advanced Vehicles Data Center. (Data through 12/15/14).
http://www.afdc.energy.gov/afdc/tse_locator

SuperTruck Project Achieves 10.7 Miles per Gallon

The U.S. Department of Energy partnered with industry to explore fuel economy improvements for class 8 trucks. In February 2014, the Cummins/Peterbilt team announced that their fully-loaded class 8 truck achieved a fuel economy of 10.7 miles per gallon, which was a 75% increase in fuel economy, a 43% reduction in greenhouse gas (GHG) emissions and an 86% gain in freight efficiency in testing against a 2009 baseline truck.

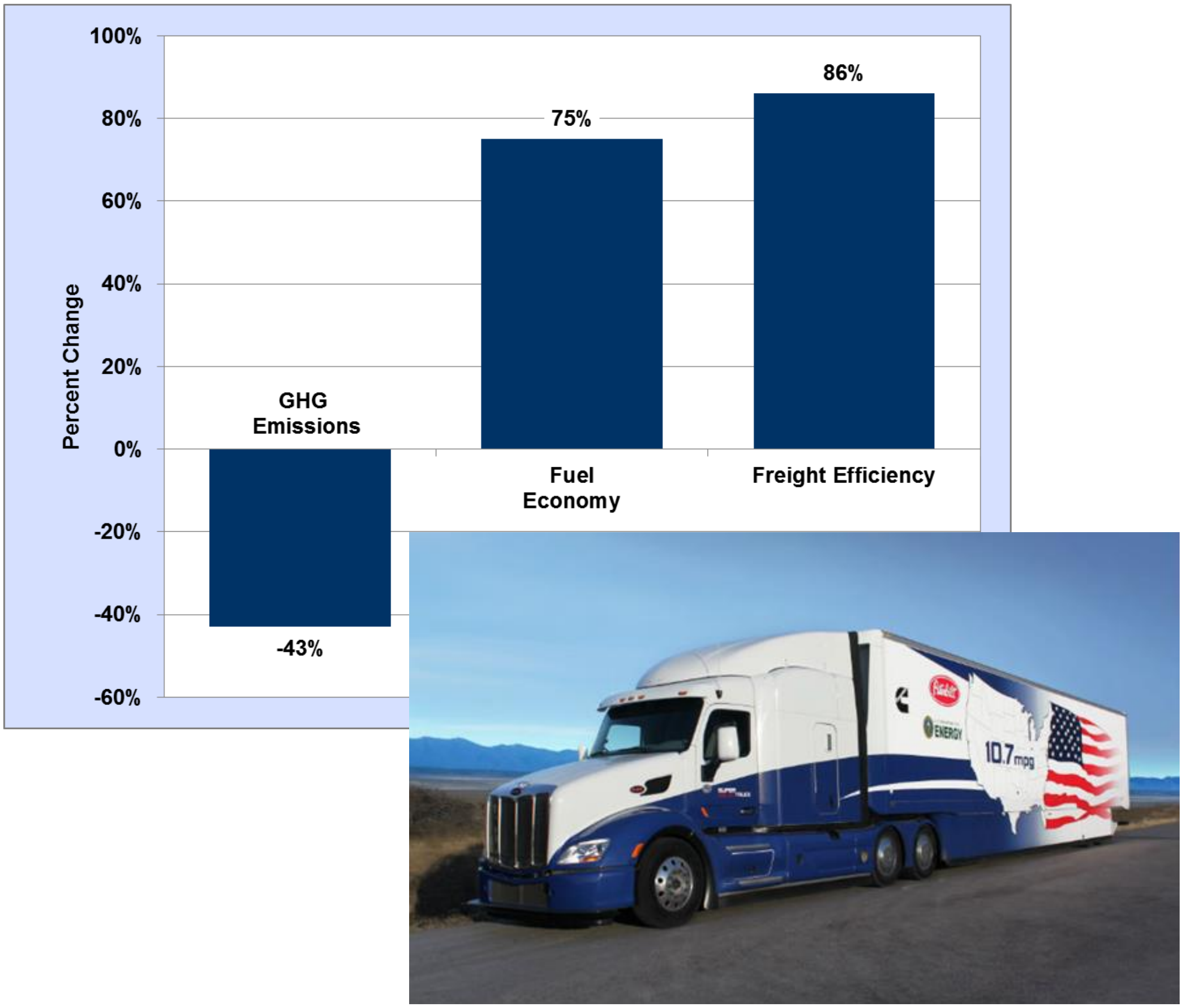

FIGURE 89. Changes in GHG Emissions, Fuel Economy, and Freight Efficiency for the SuperTruck Project, February 2014

Source:
Cummins Social Media News Hub, accessed February 24, 2014.
http://social.cummins.com/cummins-peterbilt-supertruck-passes-important-milestone/

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 91.8% of the market, but has declined due to the use of other new technologies, such as continuously variable transmissions. Variable valve timing and multi-valve use recently grew to over 90% 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.

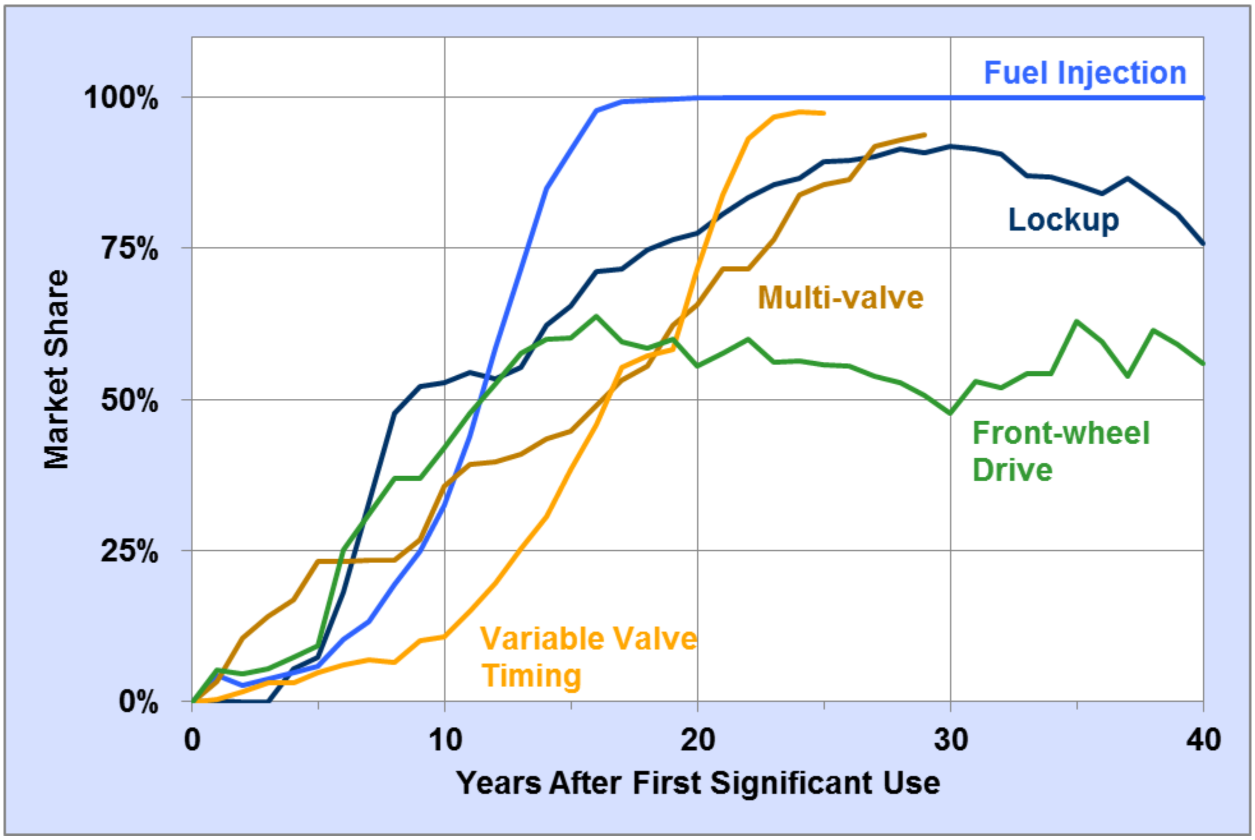


FIGURE 90. Light Vehicle Technology Penetration after First Significant Use

Source:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Gasoline Direct Injection Captures 38% Market Share in Just Seven 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 turbo charging for increasing power output from downsized engines. This is evident in the rapid rise of turbo- charged engines in the last four 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 12% market share. Stop-start technology in non-hybrid vehicles is relatively new in the U.S. market and has only been around for three years since its first significant use. However, in just three years, stop-start has reached 5% market share while gasoline hybrids have only grown to 4% market share in the past 15 years.

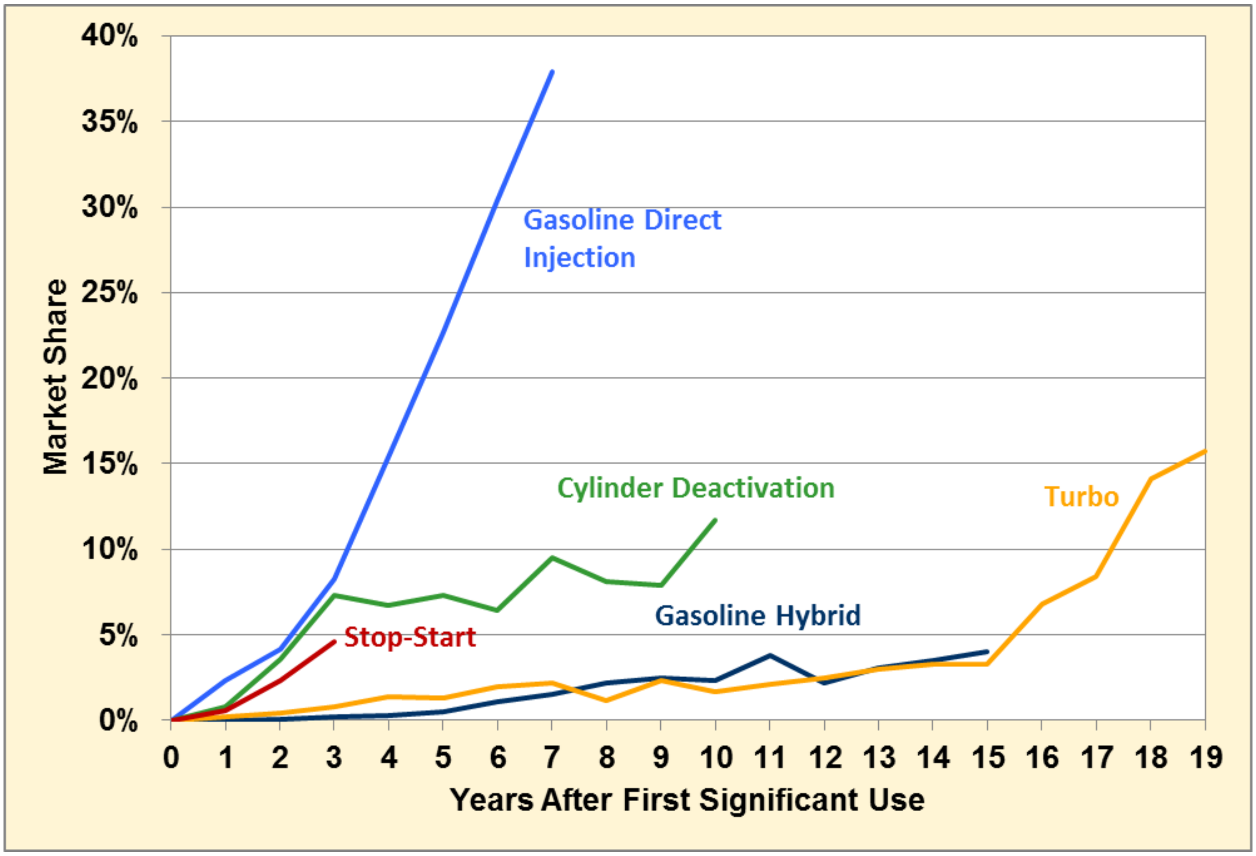


FIGURE 91. New Technology Penetration in Light Vehicles

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 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

Hybrid Sales Decline by 9% from 2013 to 2014

In 1999, the Honda Insight debuted as the first hybrid-electric vehicle (HEV) on the 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. In 2014 sales dropped to about 450,000 vehicles.

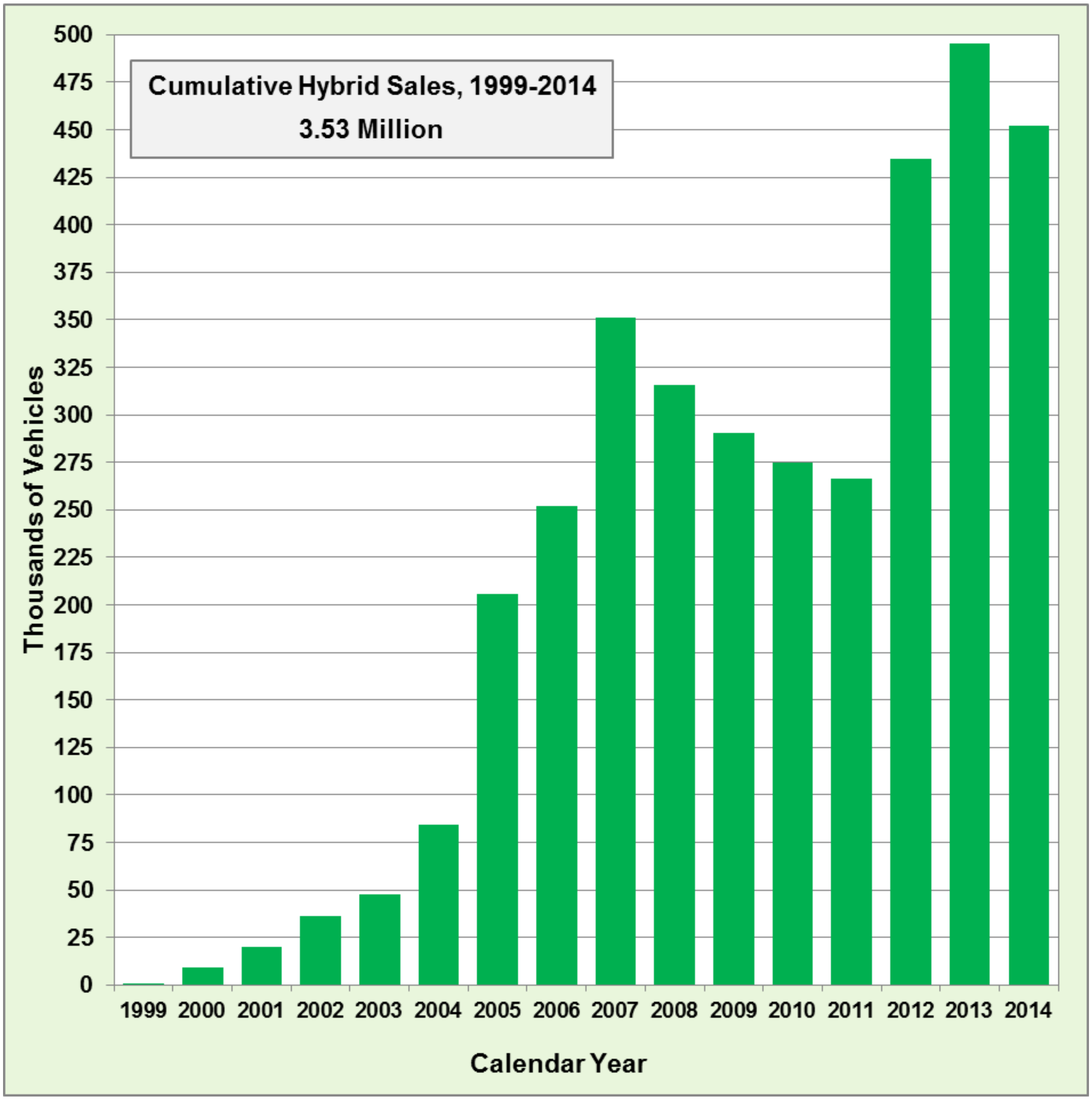


FIGURE 92. Hybrid-Electric Vehicle Sales, 1999-2014

Source:
Provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

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

Though Honda was the first manufacturer of hybrid-electric vehicles (HEV), 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.

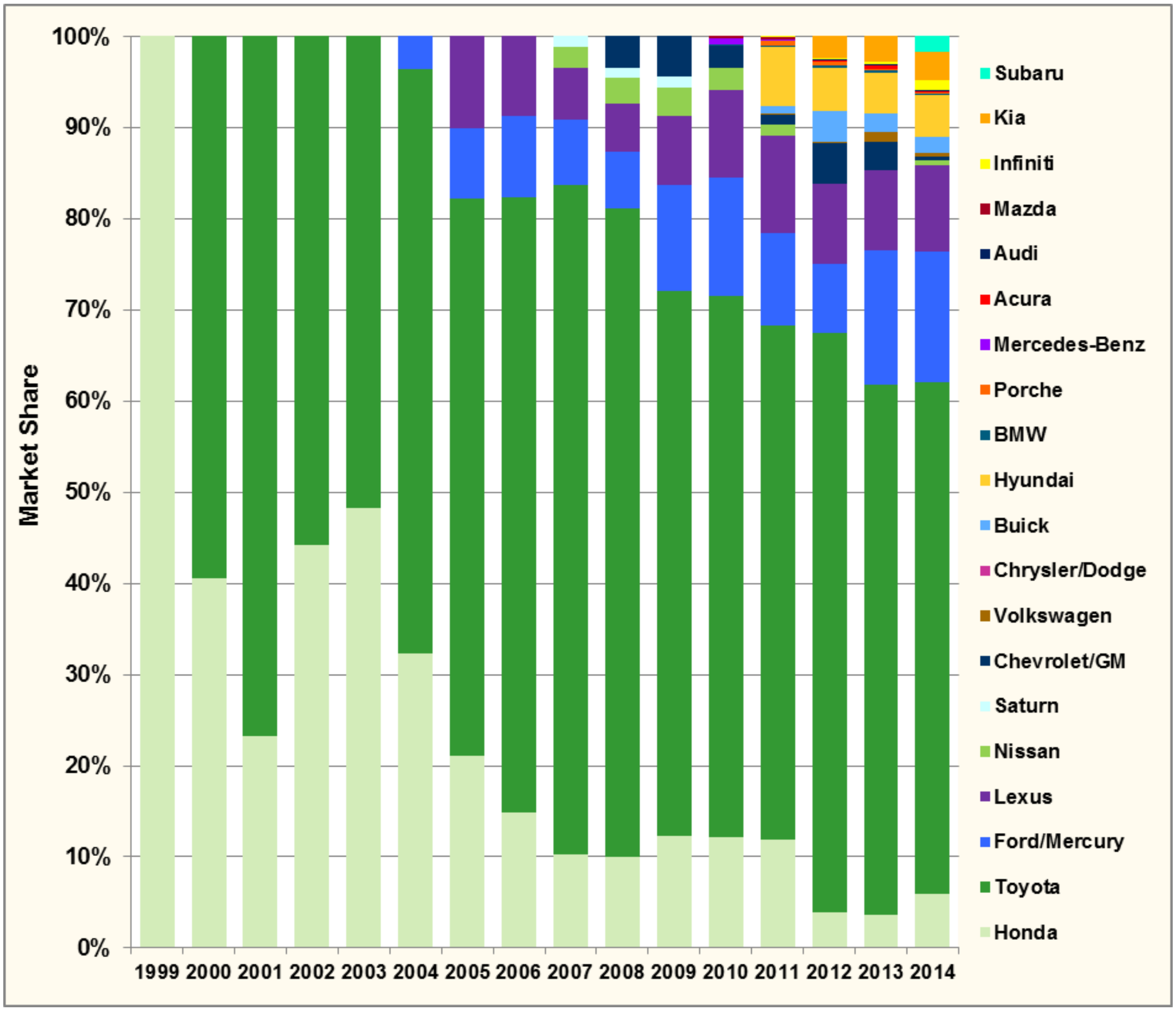


FIGURE 93. Hybrid-Electric Vehicle Market Share, 1999-2014

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

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.

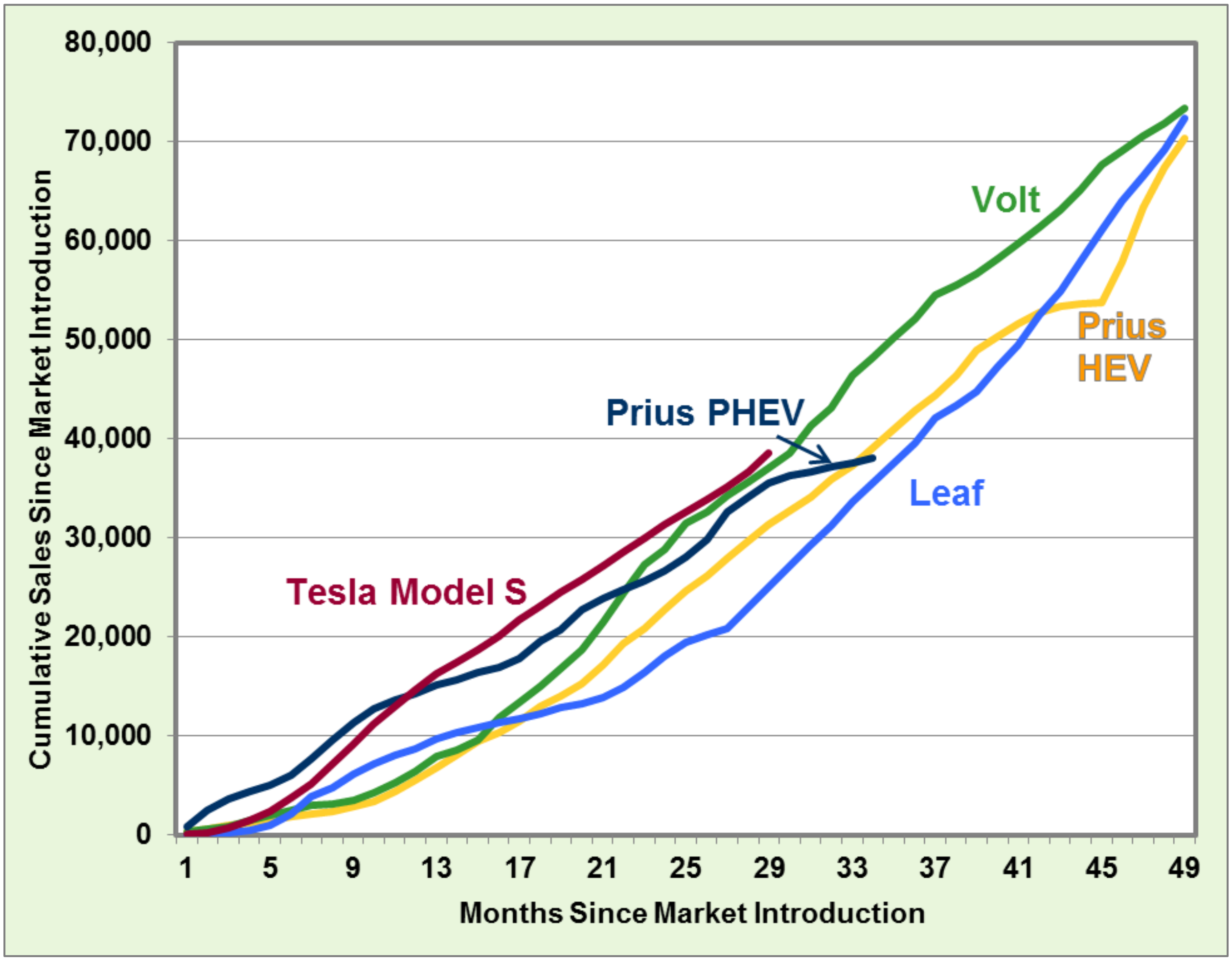


FIGURE 94. Monthly Sales since Market Introduction for Hybrid Vehicles and Plug-In Vehicles

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 Argonne National Laboratory, http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Plug-In Vehicle Sales Total Nearly 120,000 Units in 2014

The number of plug-in vehicles sold in the United States in 2014 grew to nearly 120,000, up from 97,000 the year before. 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 23 different plug-in models available in 2014, many selling less than 5,000 units. The biggest plug-in sellers in 2014 were the Nissan Leaf, Chevrolet Volt, Tesla Model S, Toyota Prius PHEV, and Ford Fusion Energi.

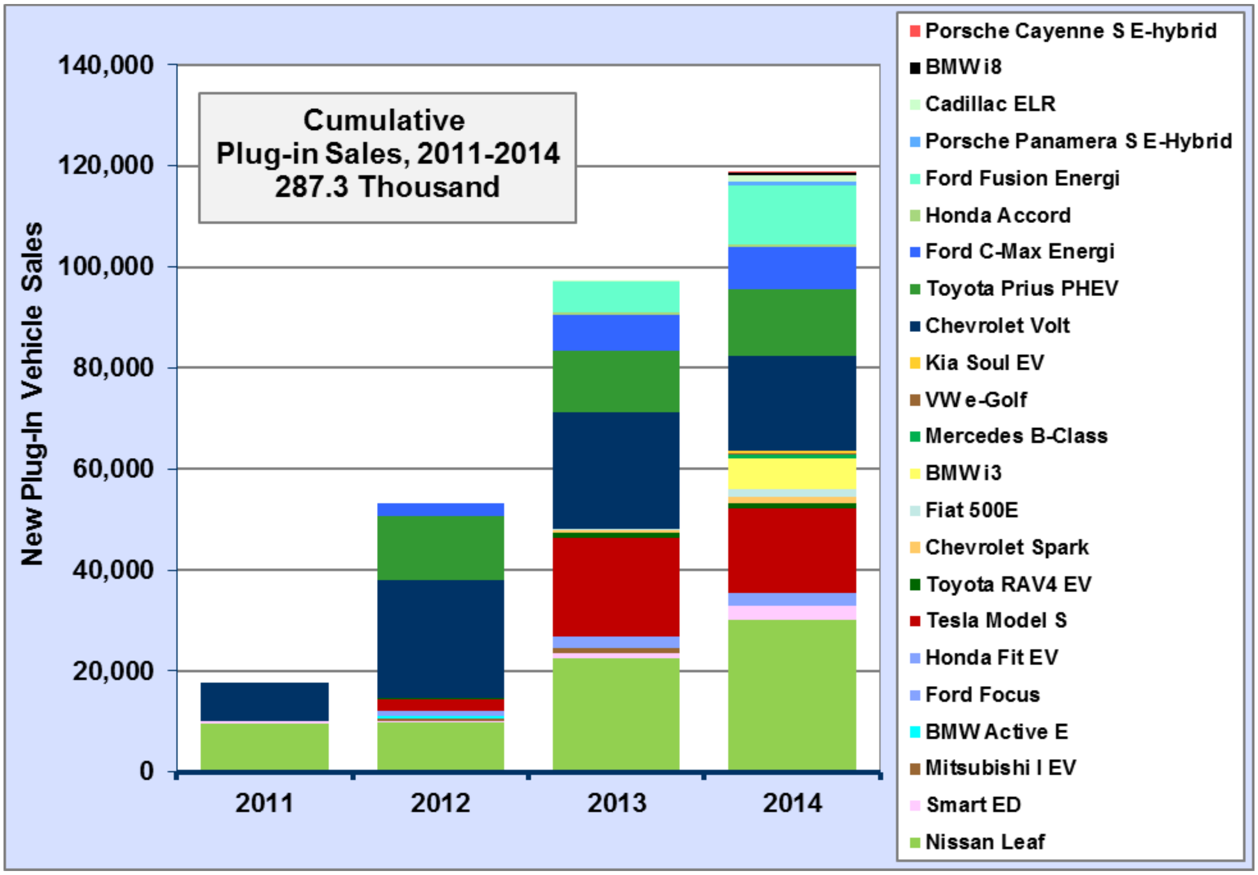


FIGURE 95. Plug-In Vehicle Sales, 2011-2014

Source:
Data provided by Yan (Joann) Zhou, Argonne National Laboratory.
http://www.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html

Plug-In Vehicles Available from Eleven Manufacturers

There are 16 different makes and 26 different models that plug into electrical outlets to get all or part of their fuel. The Tesla Model S has the longest all-electric range at 265 miles with the 85 kW-hr battery pack. Among plug-in hybrid-electric models, the BMW i3 REx has the longest all-electric range (72 miles), but the shortest total range (150 miles).

TABLE 32. Available Plug-In Vehicles

Make and Model	All-Electric Range (Miles)	Total Range (Miles)	Time to Charge Battery (Hours at 240V)	Specifications
All- Electric Plug-In Vehicles				
BMW i3	81	81	4.0	125 kW ACIPM
Chevrolet Spark EV	82	82	7.0	104 kW AC Induction
Fiat 500e	87	87	4.0	82 kW ACIPM
Ford Focus Electric	76	76	3.6	107 kW AC PMSM
Honda Fit-EV	82	82	4.0	92kW DCPM
Kia Soul EV	93	93	4.0	81 kW AC PMSM
Mercedes-Benz B-Class	87	87	3.5	132 kW AC Induction
Mitsubishi iMiEV	62	62	7.0	49 kW DCPM
Nissan Leaf	84	84	8 (3.6 kW Charger) 5 (6.6 kW charger)	80 kW DCPM
Smart For Two Electric Drive	68	68	6.0	55 kW DCPM
Tesla Model S, 60kW-hr	208	208	10 (std. charger) 3.75 (80 amp charger)	225 kW AC Induction
Tesla Model S, 85kW-hr AWD 85D AWD P85D	265 270 253	265 270 253	12 (std. charger) 4.75 (80 amp charger)	270 kW AC Induction 140 kW front, 140 kW rear 164 kW front, 130 kW rear
Toyota RAV 4 EV	103	103	6.0	115 kW AC Induction
Volkswagen e-Golf	83	83	4.0	85 kW AC PMSM
Hybrid-Electric Plug-In Vehicles				
BMW i3 REx (range extender)	72	150	4.0	125 kW electric motor, 0.6L, 2 cyl
BMW i8	15	330	2.0	96 kW electric motor, 1.5L, 3 cyl
Cadillac ELR	37	340	5.0	126 kW electric motor, 1.4L, 4 cyl
Chevrolet Volt	38	380	4.0	111 kW electric motor, 1.4L, 4 cyl
Ford C-Max Energi	20	550	2.5	68 kW electric motor, 2.0L, 4 cyl
Ford Fusion Energi	20	550	2.5	68 kW electric motor, 2.0L, 4 cyl
Honda Accord Plug-In	13	570	0.7	124 kW electric motor, 2.0L, 4 cyl
McLaren Automotive P1	19	300	3.0	132 kW electric motor, 3.8L, 8 cyl
Porsche 918 Spyder	12	420	3.0	95 & 116 kW electric motor, 4.6L, 8 cyl
Porsche Cayenne S e-Hybrid	14	480	3.0	70 kW electric motor, 3.0L, 6 cyl
Porsche Panamera S e-Hybrid	16	540	3.0	70 kW electric motor, 3.0L, 6 cyl
Toyota Prius Plug-In	11	540	1.5	18 kW electric motor, 1.8L, 4cyl

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

Source:
Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov

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

There are at least six new plug-in vehicles expected in model years 2015 and 2016: two all-electric and four hybrid-electric. Both of the all-electric vehicles are expected to have ranges in excess of 200 miles. The four new hybrid-electrics, which also use gasoline, have expected electric ranges of 20-32 miles. There are also at least three fuel cell vehicles planned for 2015 and 2016 model years.

TABLE 33. 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				
2015	Rimac Concept One	311	311	92 kWh battery
2016	Tesla Model X	230-300	230-300	60-85 kWh battery, dual motor, all-wheel drive
Hybrid-Electric Plug-In Vehicles				
2015	Audi A3 Sportback E-tron Hybrid	30	Unknown	8.8 kWh Li-ion battery, 150 hp 1.4 direct injection engine, 102 hp motor
2015	Mercedes-Benz C-Class Plug-in	32	Unknown	2.0-liter 4 cylinder engine, 67 hp electric motor
2015	Mercedes-Benz S500 Plug-in	20	Unknown	8.7 kWh Li-ion battery, 3.0-liter 6 cylinder engine, 114 bhp electric motor
2015	Mitsubishi Outlander Plug-in Hybrid	30	Unknown	12 kWh Li-ion battery, 2.0-liter 4 cylinder gasoline engine, 80 hp electric motor
Fuel Cell Vehicles				
2015	Hyundai Tucson Fuel Cell	N/A	265	134 hp, 221lb-ft torque
2015	Toyota Mirai	N/A	~300	153 hp. 247 lb-ft torque
2016	Honda FCV Concept	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:

Fuel Economy, *U.S. Department of Energy*, http://www.fueleconomy.gov; and Car and Driver website www.caranddriver.com

Primearth EV Energy Supplied the Most Batteries by Number but Panasonic Supplied the Most Battery Capacity for Model Year 2014

Primearth EV Energy supplied a majority of the batteries for hybrid vehicles in 2014. 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. For model year 2014, the battery capacity for a plug-in vehicle could be as high as 85 kW-hrs – a battery offering for the Tesla Model S. AESC and LG Chem also produced a substantial amount of battery capacity for plug-in vehicles in that year.

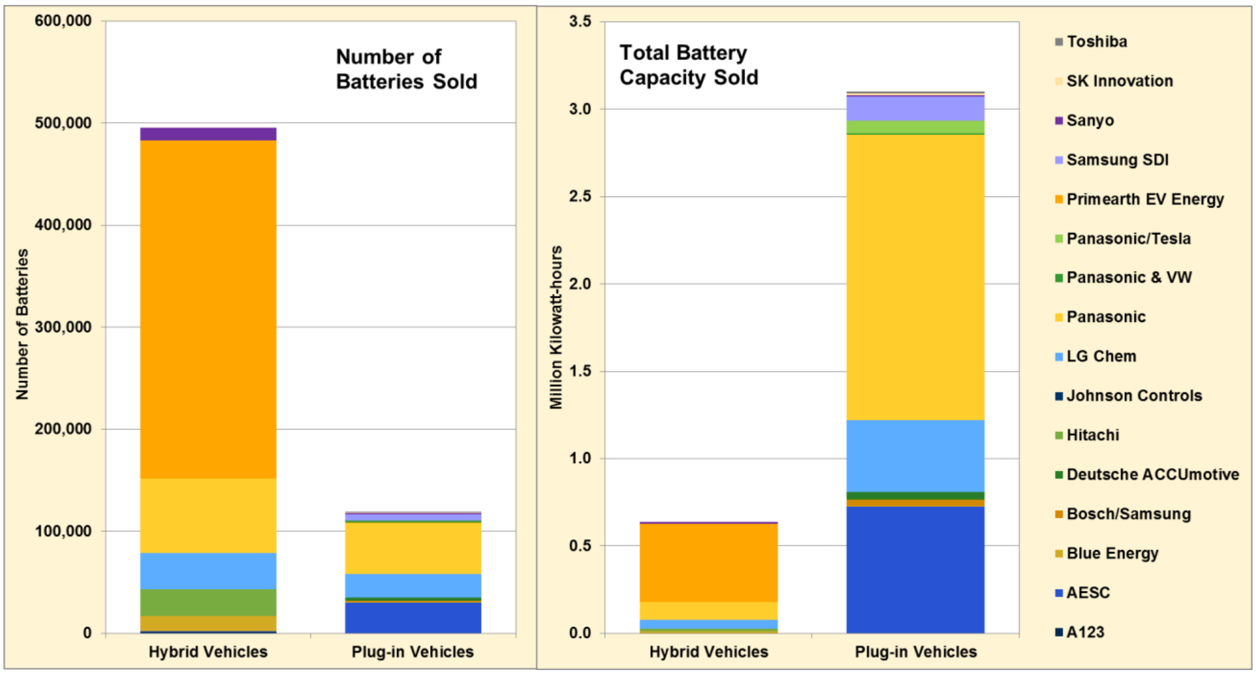


FIGURE 96. Battery Sales Estimates for Hybrid and Plug-In Vehicles, 2014

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.transportation.anl.gov/technology_analysis/edrive_vehicle_monthly_sales.html
Battery Suppliers – Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2015.

Battery Capacity Varies Widely for Plug-In Vehicles

The all-electric plug-in vehicles have capacities ranging from 12 kW-hrs in the Scion iQ EV to 85 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 34. Batteries for Selected Available and Upcoming Plug-in Vehicles, Model Years 2014-2016

Vehicle	Model Year	Battery Capacity (kW-hrs)	Battery Type	Supplier
All-Electric Vehicles				
BMW i3	2014	22.0	Li-ion	Samsung SDI
Chevrolet Spark EV	2015	18.4	Li-ion	LG Chem (replacing A123)
Fiat 500e	2015	24.0	Li-ion	Bosch/Samsung
Ford Focus Electric	2015	23.0	Li-ion	LG Chem
Honda Fit-EV	2014	20.0	Li-ion	Toshiba
Kia Soul EV	2015	27.0	Li-ion polymer	SK Innovation
Mercedes-Benz B-Class Electric Drive	2015	28.0	Li-ion	Tesla/Panasonic
Mitsubishi iMiEV	2014	16.0	Li-ion	Toshiba, Lithium Energy Japan
Nissan Leaf	2015	24.0	Li-ion	AESC
Scion iQ EV	2014	12.0	Li-ion	Panasonic
Smart For Two Electric Drive	2015	17.6	Li-ion	Deutsche ACCUmotive
Tesla Model S, 60kW-hr	2014	60.0	Li-ion	Panasonic
Tesla Model S, 85kW-hr	2014	85.0	Li-ion	Panasonic
Tesla Model X	2016	60 or 85	Li-ion	Panasonic
Toyota RAV 4 EV	2014	41.8	Li-ion	Tesla/Panasonic
Volkswagen e-Golf	2015	24.2	Li-ion	VW & Panasonic
Plug-In Hybrid-Electric Vehicles				
BMW i3 REX (range extender)	2014	22.0	Li-ion	Samsung SDI
BMW i8	2014	7.1	Li-ion	Samsung SDI
Cadillac ELR	2015	17.1	Li-ion	LG Chem
Chevrolet Volt	2015	17.1	Li-ion	LG Chem
Ford C-Max Energi	2014	7.6	Li-ion	Panasonic
Ford Fusion Energi	2014	7.6	Li-ion	Panasonic
Honda Accord Plug-In	2014	6.7	Li-ion	Blue Energy
McLaren Automotive P1	2015	4.4	Li-ion	Johnson Matthey Battery Systems
Mercedes-Benz S-Class Plug-In Hybrid	2015	8.7	Li-ion	A123
Mitsubishi Outlander	2014	12.0	Li-ion	Lithium Energy Japan
Porsche 918 Spyder	2015	6.8	Li-ion	Sanyo
Porsche Cayenne S e-Hybrid	2015	10.8	Li-ion	Sanyo
Porsche Panamera S e-Hybrid	2015	9.4	Li-ion	Sanyo
Toyota Prius Plug-In	2015	4.4	Li-ion	Panasonic

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. Tesla has supplied EV batteries built from Panasonic cells to Toyota and Mercedes Benz. Blue Energy is a joint venture between GS Yuasa and Honda. Lithium Energy Japan is a joint venture between GS Yuasa and Mitsubishi.

Source:
Compiled from public sources by John Thomas, Oak Ridge National Laboratory, January 2015.

Hybrid-Electric Vehicles Use Batteries with Capacities up to 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 35. Batteries for Selected Hybrid-Electric Vehicles, Model Years 2013-2015

Vehicle	Model Year	Battery Capacity (kW-hrs)	Battery Type	Supplier
Acura ILX	2014	0.7	Li-ion	Blue Energy
Acura RLL Hybrid	2014	1.3	Li-ion	Blue Energy
Audi Q5 Hybrid	2015	1.3	Li-ion	Sanyo
BMW ActiveHybrid 3	2015	1.4	Li-ion	A123
BMW ActiveHybrid 5	2015	1.4	Li-ion	A123
BMW ActiveHybrid 7L	2015	1.4	Li-ion	A123
Buick LaCrosse eAssist	2015	0.5	Li-ion	Hitachi
Buick Regal eAssist	2015	0.5	Li-ion	Hitachi
Chevrolet Impala eAssist	2014	0.5	Li-ion	Hitachi
Chevrolet Malibu eAssist	2014	0.5	Li-ion	Hitachi
Ford C-Max Hybrid	2015	1.4	Li-ion	Panasonic
Ford Fusion Hybrid	2015	1.4	Li-ion	Panasonic
Honda Accord Hybrid	2015	1.3	Li-ion	Blue Energy
Honda Civic Hybrid	2015	0.7	Li-ion	Blue Energy
Honda CR-Z Hybrid	2015	0.7	Li-ion	Blue Energy
Honda Insight Hybrid	2014	0.6	NiMH	Sanyo
Hyundai Sonata Hybrid	2015	1.4	Li polymer	LG Chem
Inifiniti Q50 Hybrid + AWD	2015	1.4	Li-ion	AESC
Inifiniti Q70 (was M Hybrid)	2015	1.4	Li-ion	AESC
Inifiniti QX60 + AWD	2015	0.7	Li-ion	Hitachi
Kia Optima	2015	1.4	Li polymer	LG Chem
Lexus CT 200h	2015	1.3	NiMH	Primearth EV Energy
Lexus ES 300h	2015	1.6	NiMH	Primearth EV Energy
Lexus GS 450h + AWD	2015	1.9	NiMH	Primearth EV Energy
Lexus LS 600h L	2015	1.9	NiMH	Primearth EV Energy
Lexus NX 300h + AWD	2015	1.6	NiMH	Primearth EV Energy
Lexus RX 450h	2015	1.9	NiMH	Primearth EV Energy
Lincoln MKZ Hybrid	2015	1.4	Li-ion	Panasonic
Mercedes Benz E400 Hybrid	2015	0.8	Li-ion	Johnson Controls
Nissan Pathfinder Hybrid	2015	0.7	Li-ion	Hitachi
Porsche Cayenne S Hybrid	2013	1.7	NiMH	Sanyo
Suburu XV Crosstrek Hybiid	2015	0.6	NiMH	Panasonic
Toyota Avalon Hybrid	2015	1.6	NiMH	Primearth EV Energy
Toyota Camry Hybrid	2015	1.6	NiMH	Primearth EV Energy
Toyota Highlander Hybrid	2015	1.9	NiMH	Primearth EV Energy
Toyota Prius	2015	1.3	NiMH	Primearth EV Energy
Toyota Prius c	2015	0.9	NiMH	Primearth EV Energy
Toyota Prius v	2015	1.3	NiMH	Primearth EV Energy
Volkswagen Jetta Hybrid	2015	1.1	Li-ion	Sanyo
Volkswagen Touareg Hybrid	2015	1.7	NiMH	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 2015.

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 36. 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, http://www.afdc.energy.gov/afdc.vehicles/search.

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

There are 17 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 37. 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
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, http://www.afdc.energy.gov/afdc.vehicles/search.

Flex-Fuel Vehicle Offerings Decline by 13% for Model Year 2014

In the last five years, GM, Ford and Chrysler 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 2014 there were 72 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 E-85 and/or gasoline.

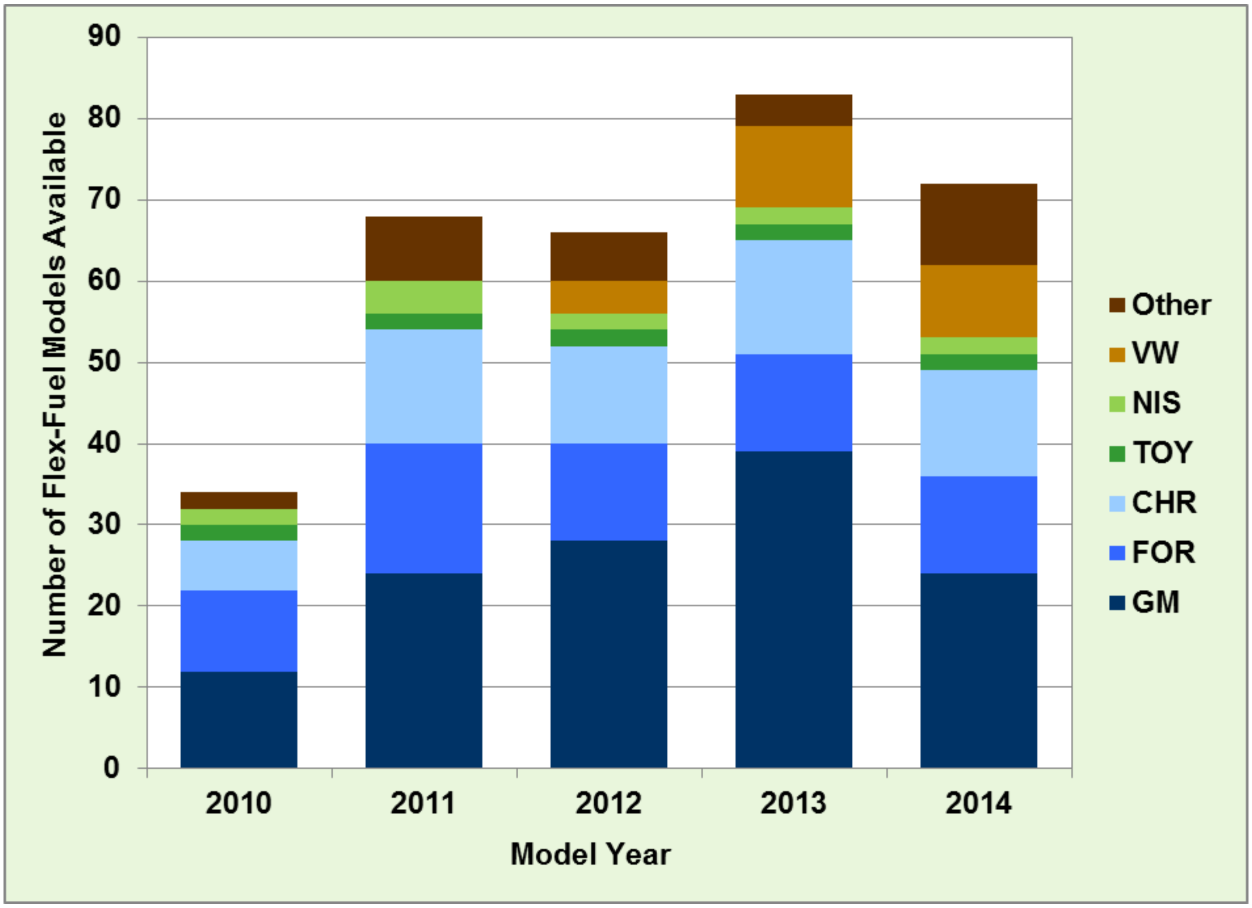
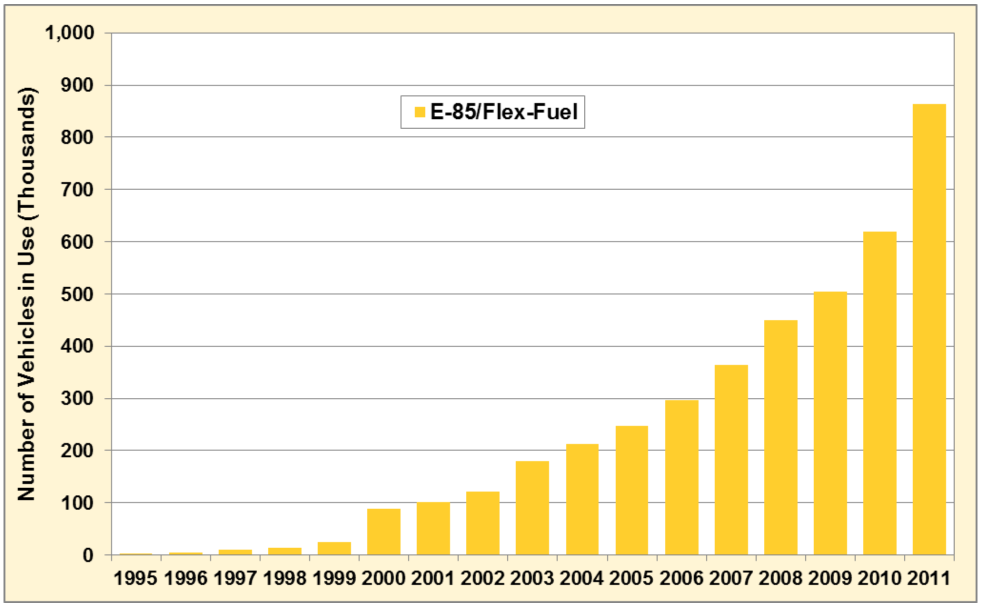


FIGURE 97. Number of Flex-Fuel Models Available, 2010-2014

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

Alternative Fuel Vehicles in Use Are Mostly Flex-Fuel Vehicles

According to the Energy Information Administration's (EIA's) latest data (2011) there are over 800 thousand vehicles in use that run on E-85, often called flex-fuel vehicles. This includes only those vehicles believed to be using E-85, which are primarily fleet-operated vehicles. The number of vehicles using liquefied petroleum gas (LPG) has declined each year since 2003, while plug-in electric vehicles (including low-speed electric vehicles) have increased.



Note: Latest available data. Includes only those vehicles believed to be using E-85; see source for methodology.

Note: Electricity includes only vehicles that plug into an outlet, including low-speed vehicles.
LPG = Liquefied petroleum gas.
CNG = Compressed natural gas.
LNG = Liquefied natural gas.

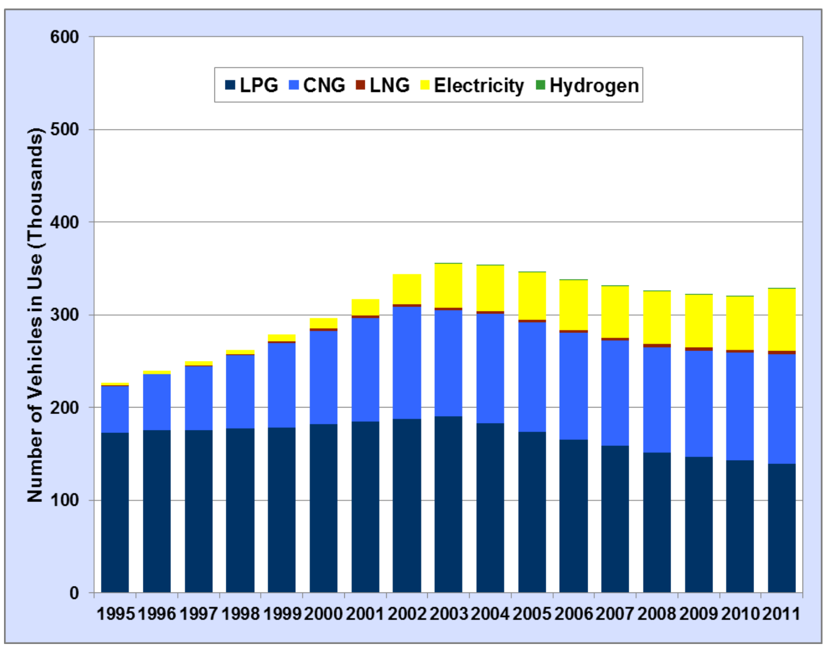


FIGURE 98. Number of Alternative Fuel Vehicles in Use, 1995-2011

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

Biofuel Stations Spread beyond the Midwest

E-85, which is nominally 85% ethanol and 15% gasoline, is sold at 2,839 stations nationwide. Many stations are located in the Midwest where the majority of ethanol feedstock is grown, but E-85 stations are found throughout the nation. Biodiesel is sold at 782 stations across the country, with the predominance of stations in the Southeast. Data are as of December 31, 2014.

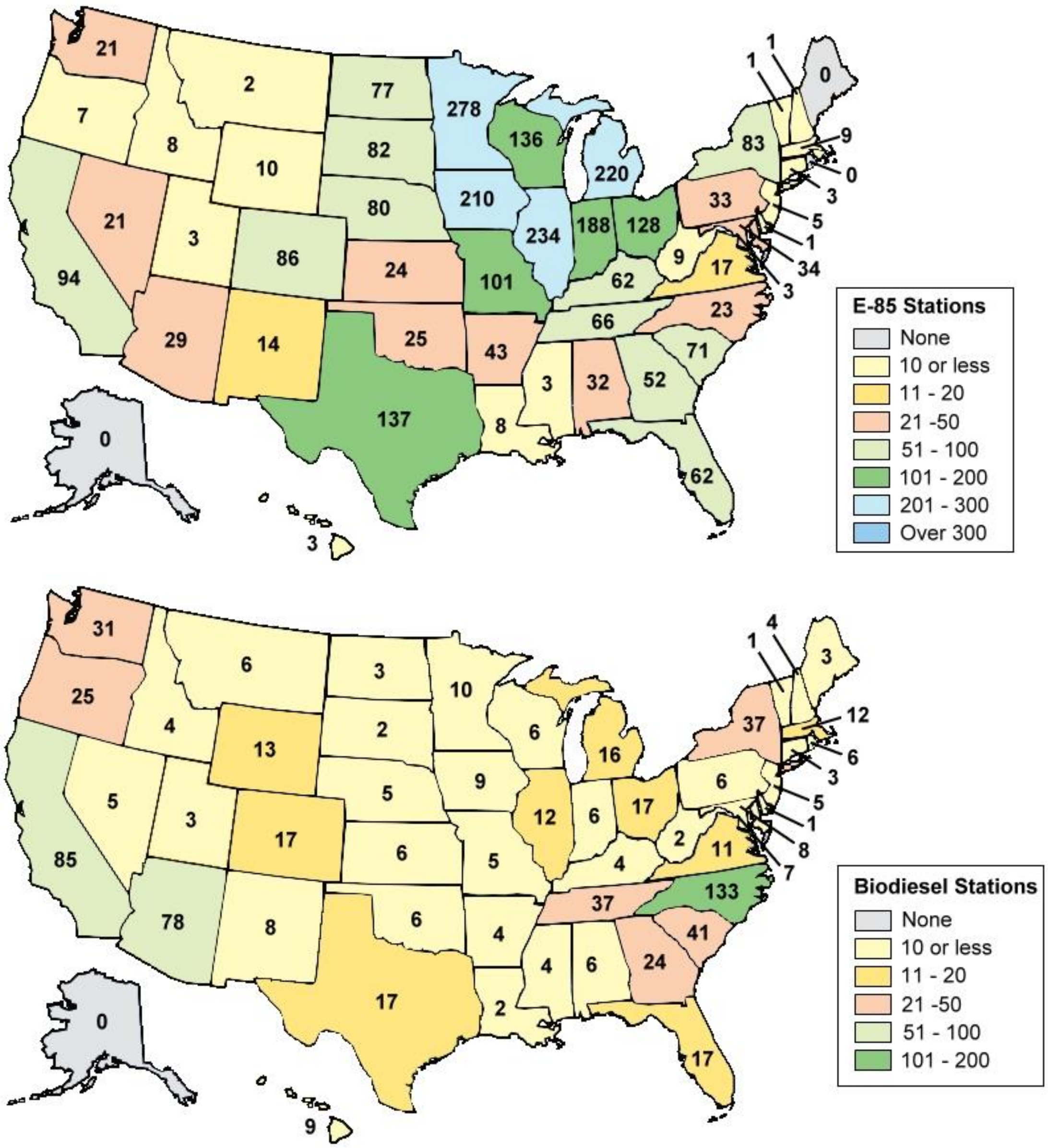


FIGURE 99. Number of E-85 (top) and Biodiesel Stations by State, 2014

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 2,929 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 1,599 stations nationwide. New York and California have the most natural gas stations. Data are as of December 31, 2014.

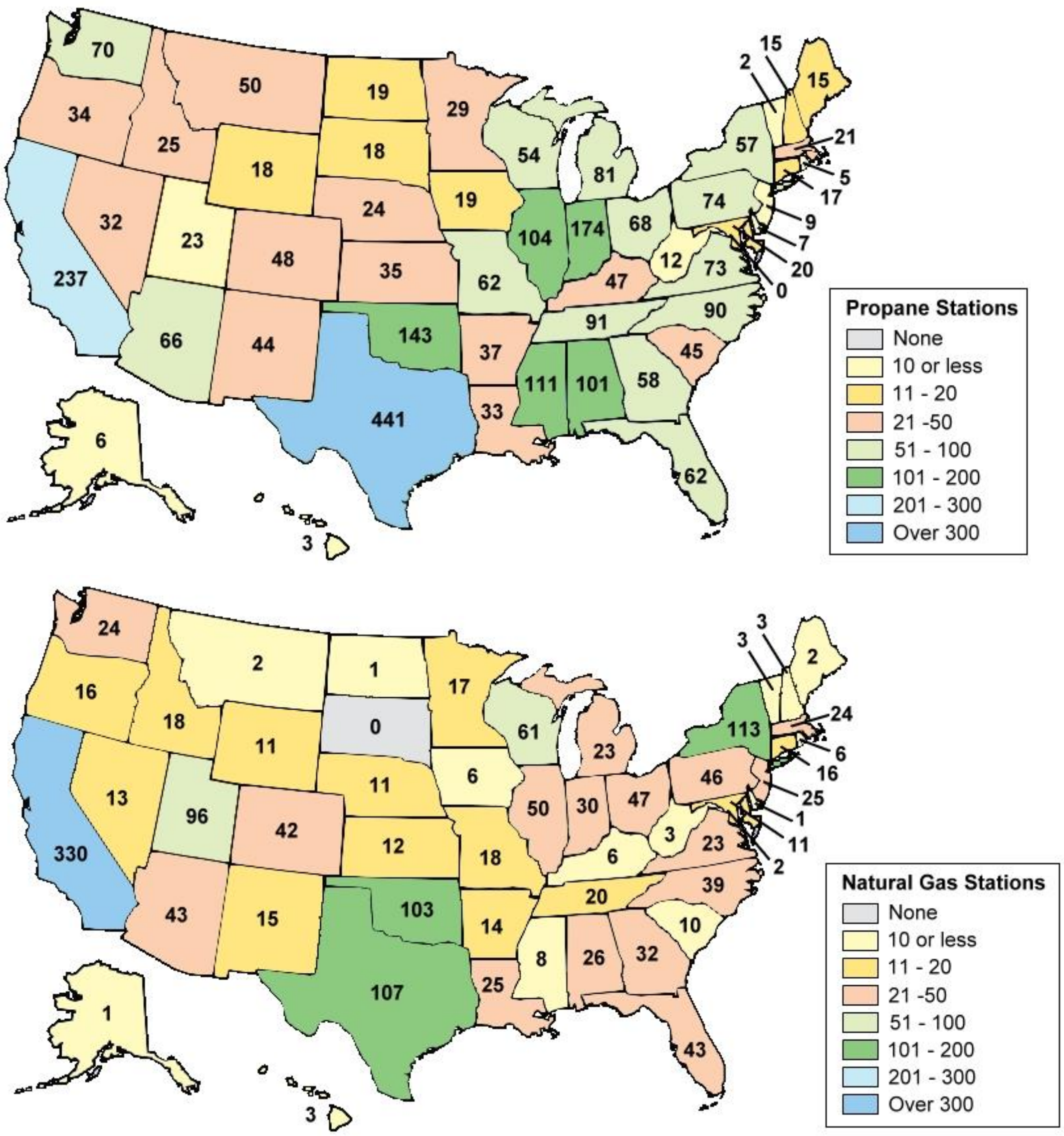


FIGURE 100. Number of Propane (top) and Natural Gas Stations by State, 2014

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 (10,710 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 December 31, 2014.

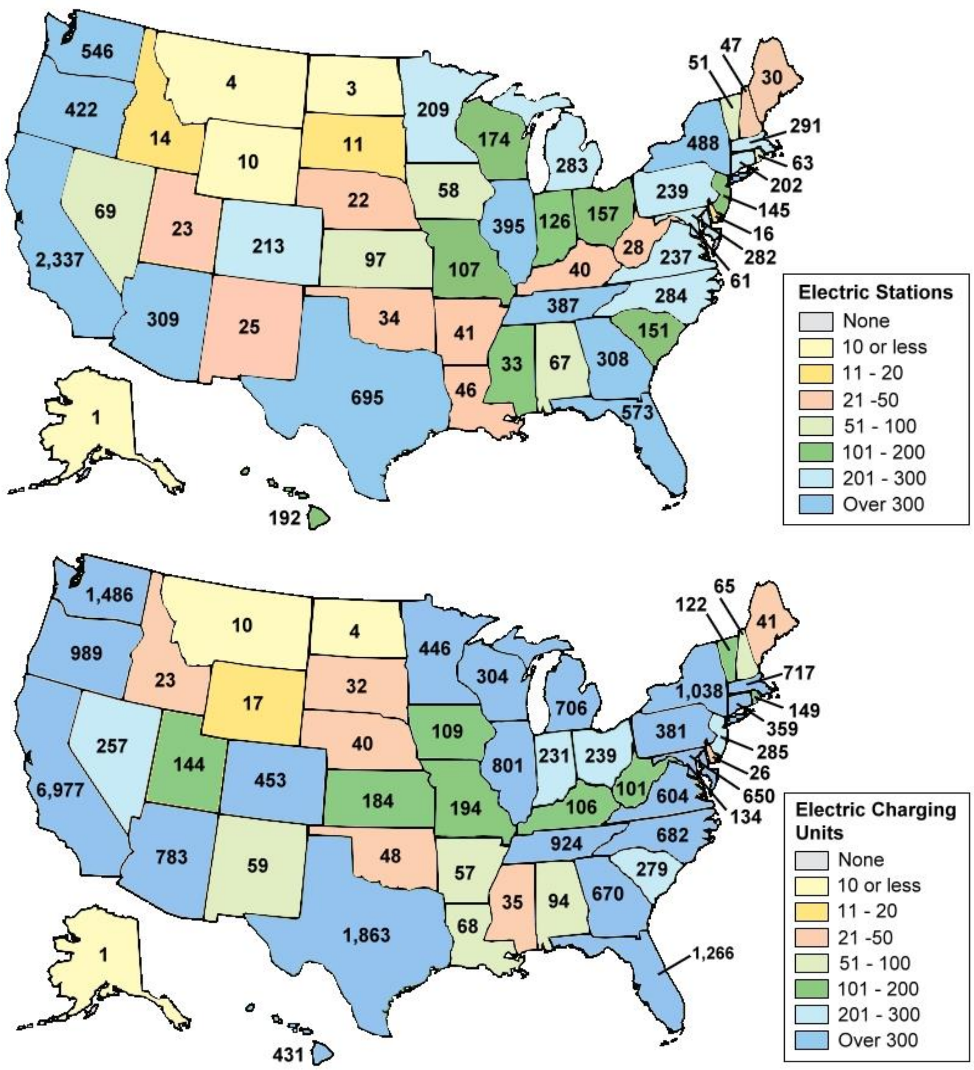


FIGURE 101. Number of Electric Stations (top) and Electric Charging Units by State, 2014

Note: Includes public and private stations and units. About 85% 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 and New York, where research and development is on-going for this fuel. There are 17 states with at least one hydrogen refueling station. Data are as of December 31, 2014.

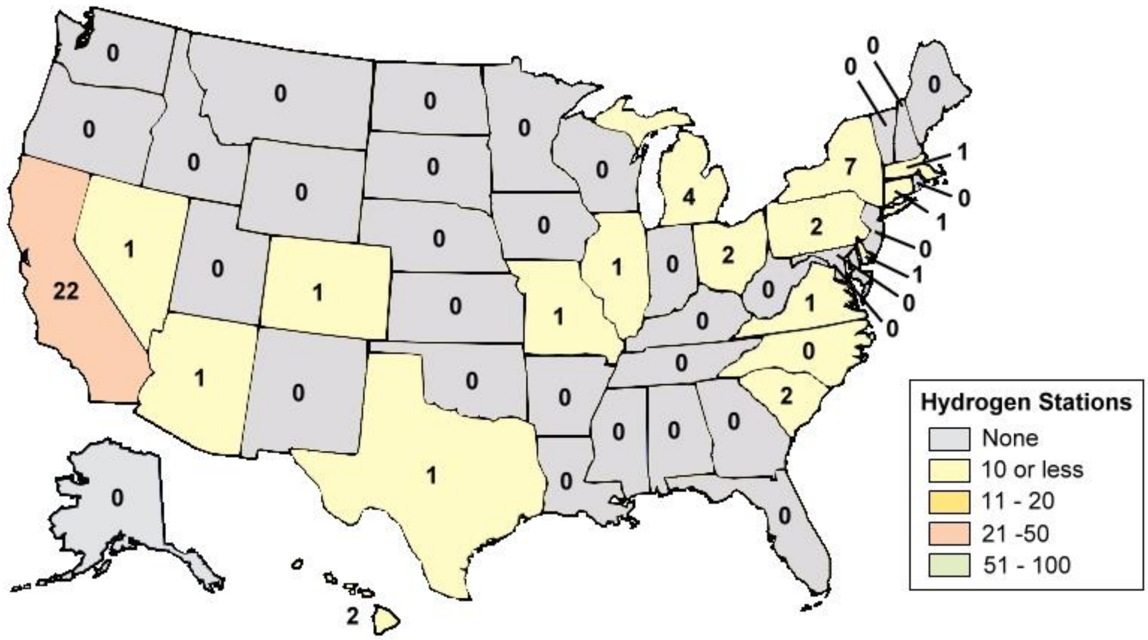


FIGURE 102. Number of Hydrogen Stations by State, 2014

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 20 million gasoline-equivalent gallons (GGEs) of biofuels (E-85 and biodiesel) were used in 2013. Federal use of other alternative fuels has been less than one million GGEs combined in 2009-2013. Note the large difference in the scales of the two graphs.

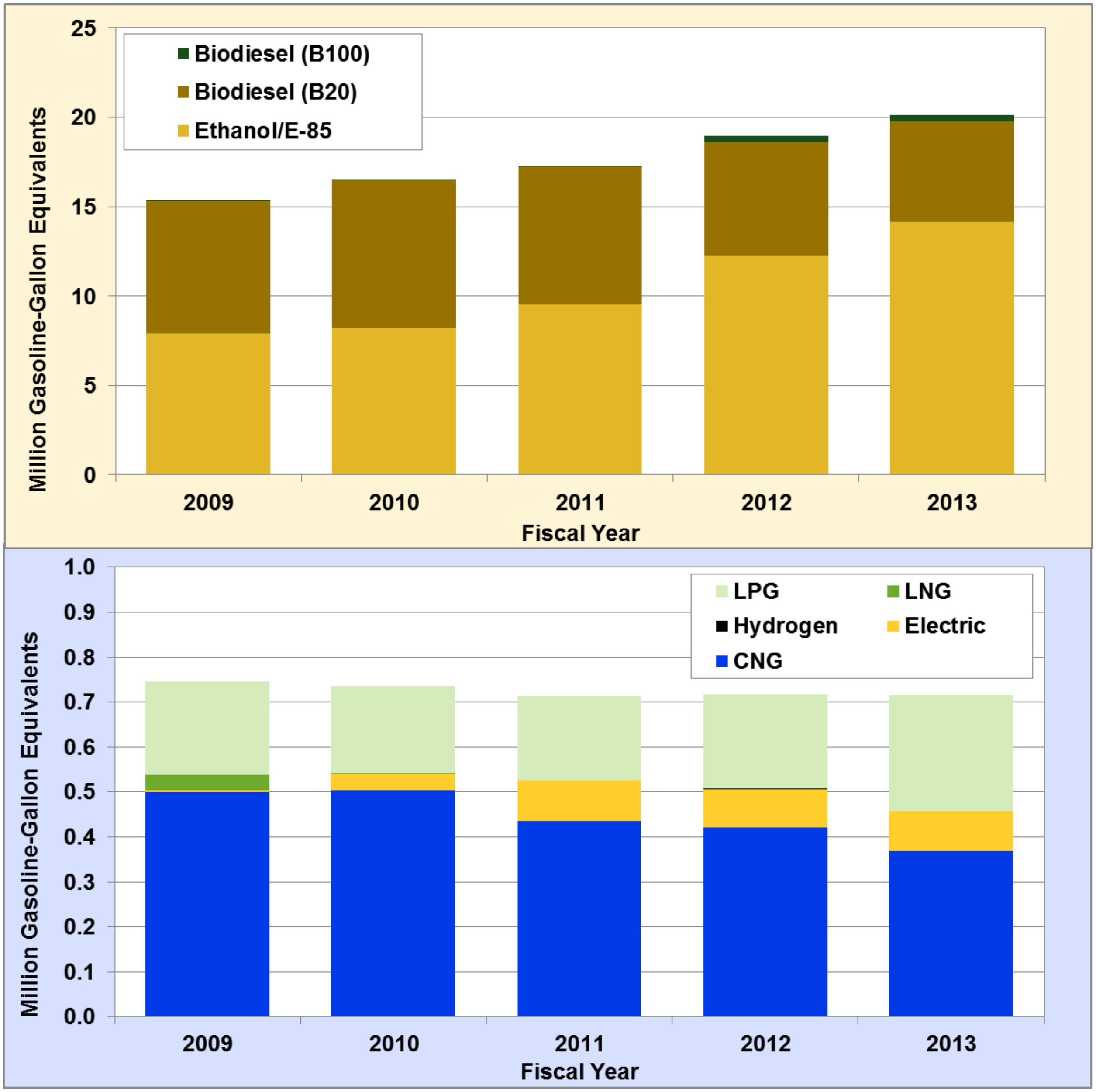


FIGURE 103. Alternative Fuel Use by the Federal Government, 2009-2013

Source:

U.S. General Services Administration, *FY 2013 Federal Fleet Report*, Washington, DC, 2014. http://www.gsa.gov/portal/content/102943

E-85 Vehicles Top Diesels in the Federal Government Fleet

Though gasoline vehicles are the most prevalent in the Federal Government fleet, there are more E-85 vehicles than diesels in the inventory. The number of gasoline hybrid vehicles and electric vehicles both rose substantially between 2009 and 2013.

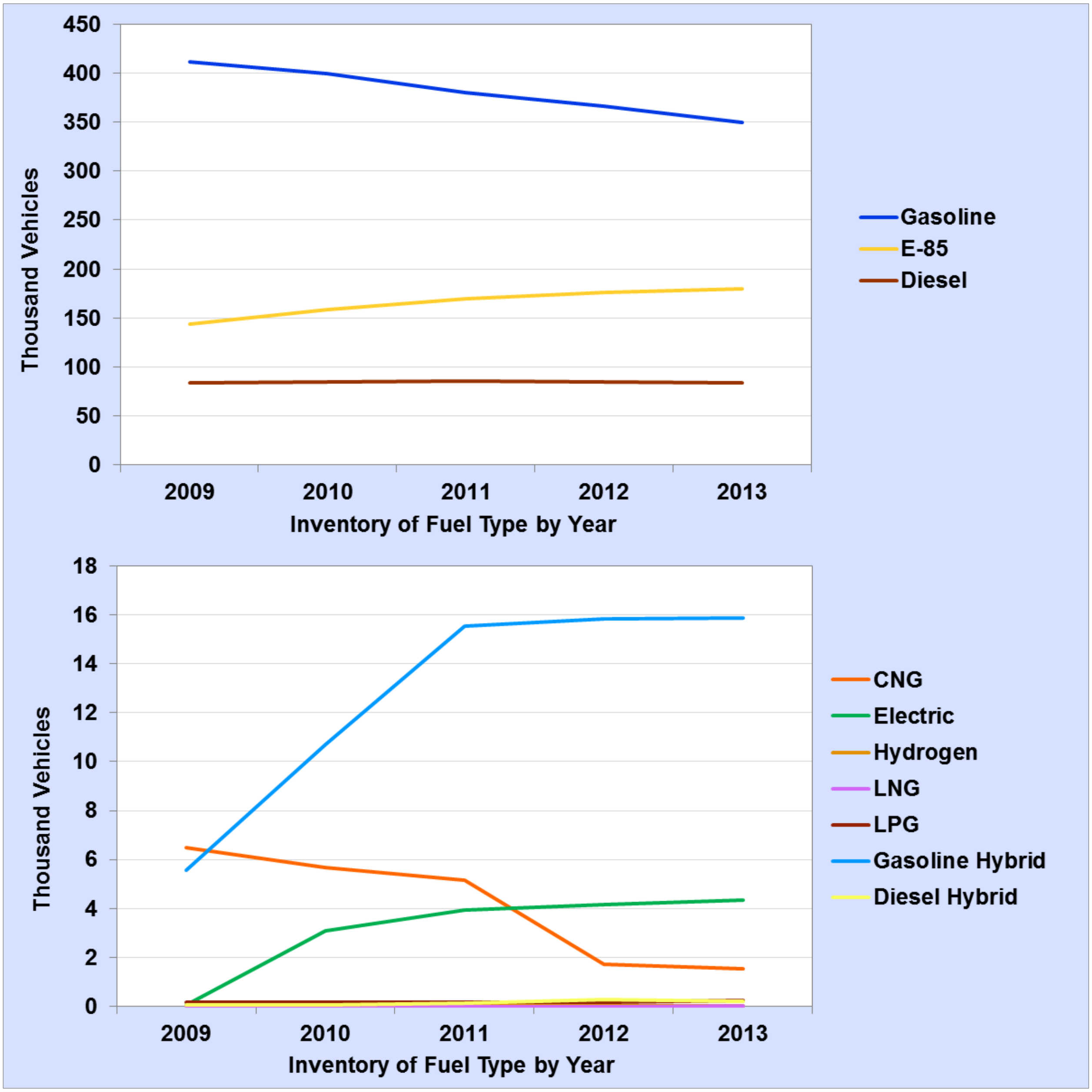


FIGURE 104. Federal Government Vehicles by Fuel Type, 2009-2013

Source:

U.S. General Services Administration, *FY 2013 Federal Fleet Report*, Washington, DC, 2014.
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 United Parcel Service uses more than 12,000 alternative fuel vehicles, most of them biodiesel. Eighty-four percent of Schwan's Home Service vehicles run on propane.

TABLE 38. Top 25 Commercial Fleets Using Alternative Fuel and Advanced Technology Vehicles, 2014

	Company	Total Alt Fuel	CNG*	Propane*	Flex-Fuel	Biodiesel	Hybrid/ Electric*	Total Vehicles	Percent Alt Fuel	Percent Hybrid/Electric
1	United Parcel Service (UPS)	12,331	933	10	0	11,000	388	92,614	13%	3%
2	Comcast Corp.	10,469	0	0	10,214	0	255	34,615	30%	2%
3	AT&T	8,219	6,051	0	0	0	2,168	73,330	11%	26%
4	Verizon	6,821	514	0	3,500	1,500	1,307	32,720	21%	19%
5	Waste Management	5,824	1,144	20	2,100	2,300	4	5,310	110%	0%
6	Merck Sharpe & Dohme Corp.	5,190	0	0	5,000	0	190	8,720	60%	4%
7	Schwan's Home Service	4,800	0	4,800	0	0	0	5,700	84%	0%
8	Chesapeake Energy	4,777	1,563	0	3,210	0	0	4,489	106%	0%
9	State Farm Mutual Auto Insurance Co.	4,657	0	0	3,932	0	725	10,645	44%	16%
10	Cox Enterprises	4,591	2	0	4,328	0	261	12,779	36%	6%
11	Johnson & Johnson	4,544	0	0	1,873	0	2,671	7,924	57%	59%
12	DIRECTV	4,303	0	77	4,225	0	1	5,770	75%	0%
13	Pacific Gas & Electric	3,473	712	0	294	1,201	1,266	7,442	47%	36%
14	Monsanto Co.	3,185	0	0	3,185	0	0	3,664	87%	0%
15	Johnson Controls, Inc.	3,182	5	0	2,489	0	688	6,559	49%	22%
16	Liberty Mutual Insurance	2,647	0	0	2,647	0	0	2,677	99%	0%
17	PepsiCo, Inc.	2,631	215	118	48	0	2,244	23,855	11%	85%
18	Public Service Enterprise Group (PSE&G)	2,331	60	0	0	1,741	530	4,060	57%	23%
19	Charter Communications	2,157	0	0	2,157	0	0	9,628	22%	0%
20	Florida Power & Light	2,142	0	0	0	1,638	504	1,598	134%	24%
21	Xerox Corp	2,030	0	0	2,000	0	30	4,501	45%	1%
22	Delta Airlines	2,013	30	151	0	0	1,832	1,827	110%	91%
23	Pioneer Natural Resources	2,010	310	0	1,700	0	0	1,800	112%	0%
24	Kelloggs	2,002	0	0	2,000	0	2	1,207	166%	0%
25	Consolidated Edison Company of New York	1,962	149	149	0	1,450	214	4,054	48%	11%

*Includes dedicated and bi-fuel vehicles.

Note: Total Alt Fuel and Percent Alt Fuel columns include hybrid/electric vehicles.

Source:
Bobit Publishing, *Automotive Fleet 500*, "Top 50 Green Fleets," 2014.
http://digital.automotive-fleet.com/fleet5002014

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 pounds per vehicle from 1995 to 2012 while the use of high and medium strength steels has increased by 282 lbs. 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 48% 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.

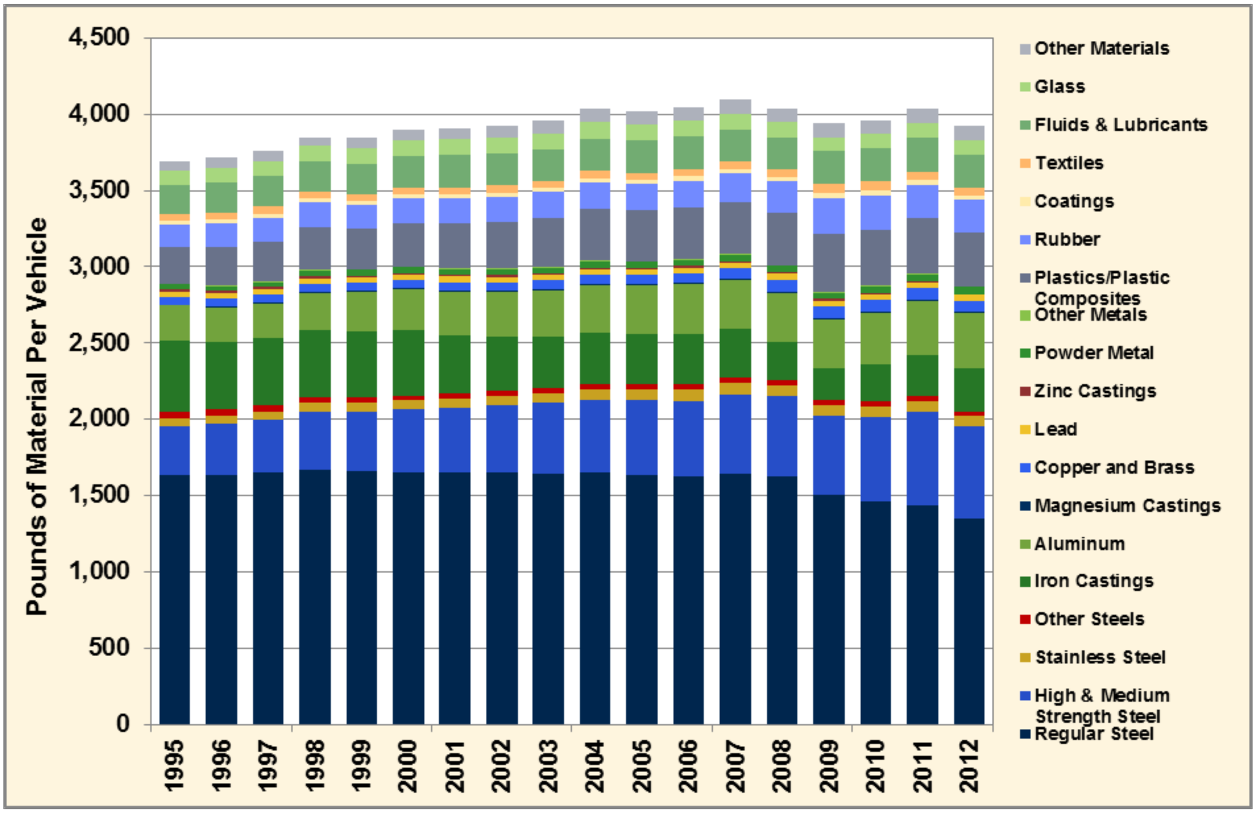


FIGURE 105. Average Materials Content of Light Vehicles, 1995-2012

Source:
Ward's AutoInfoBank. 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.

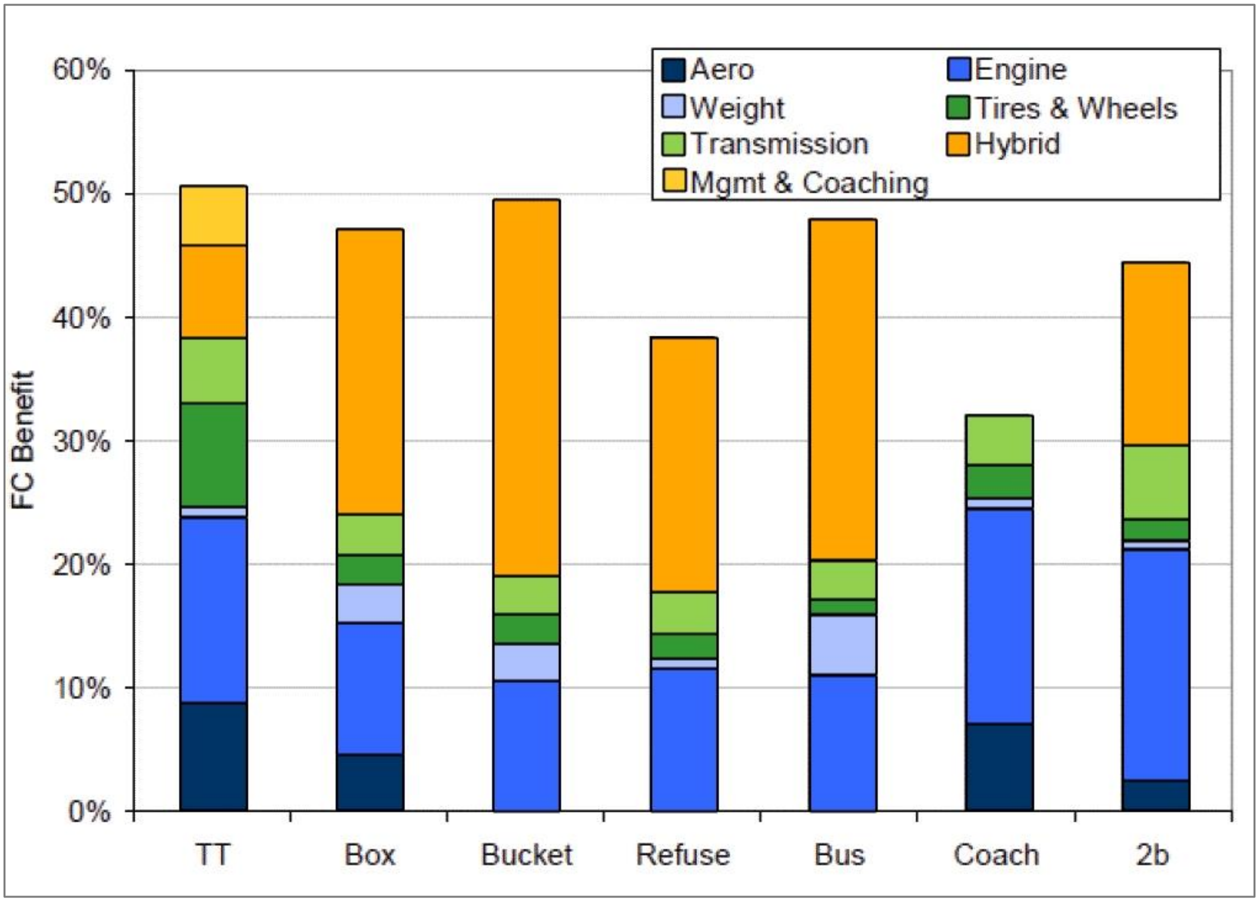


FIGURE 106. Comparison of 2015-2020 New Vehicle Potential Fuel Saving Technologies

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

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 39. 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 152 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

Some 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, as well as those still under development that show promise for further improvements to performance and efficiency.

TABLE 40. Fuel Saving Engine Technologies

Engine Technologies Currently Being Used	
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.
Cylinder Deactivation	Cylinder deactivation allows the engine to shut down some of its cylinders during light load operation for greater fuel efficiency.
Down-speeding	This is a strategy that is widely used in the light vehicle market where the transmission and differential are matched to the engine so that the engine turns at the lowest possible speed (RPM) for any given highway speed.
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.
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.
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.
Dual Port Injection	Rather than a single injector per port, a dual injector arrangement improves combustion and increases performance and fuel economy.
Variable Displacement Oil Pump	Rather than pump oil through the engine at a constant rate and pressure, the intensity and rate of pumping can be 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.
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.
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.

TABLE 40. Fuel Saving Engine Technologies (continued)

Engine Technologies Under Development	
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 and Transmission Technologies Can Improve Fuel Economy

There are many different implementations of hybrid technology but most fall within the basic classifications shown in the table below. Similarly, there are many different strategies for improving transmission efficiency and performance. Shown are the more prevalent technologies and strategies.

TABLE 41. Drivetrain Technologies

Hybrid Technologies	
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.
Transmission Technologies	
Continuously Variable Transmission (CVT)	Continuously variable 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.
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.
Automated Manual Transmission (AMT)	Automated manual transmissions operate like a manual transmission but without a clutch pedal. The shifting can be entirely computer controlled or allow driver input through shifter paddles or buttons mounted on the steering wheel. AMT transmissions are increasingly used on heavy trucks in urban settings and are also found in light duty vehicles as well.
Dual Clutch Transmission	A dual clutch transmission is an automated manual transmission that uses two clutches to select gears. One clutch selects the odd gears (1, 3, & 5) while the other selects the even gears (2, 4, & 6). The advantage of this arrangement is that gears are preselected by the alternate clutch allowing for instantaneous shifts that maintain torque to the wheels at all times. Eliminating the power interruption between shifts that occurs with a single clutch improves both performance and efficiency.
Increased Number of Gears	More gears allow the engine to remain closer to its optimal speed as the vehicle accelerates and decelerates. To maintain an optimal engine speed and improve fuel economy and performance, manufacturers have been increasing the number of gears in both manual and automatic transmissions. Manual transmissions now commonly have 6 speeds while conventional automatic transmissions have reached 9 speeds and manufacturers continue to develop transmissions with even more gear ratios.

Source:

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

Heavy Vehicles Use Hybrid Technologies in Different Ways

FIGURE 107. 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 109. Hybrid Bus

FIGURE 108. 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.)

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.

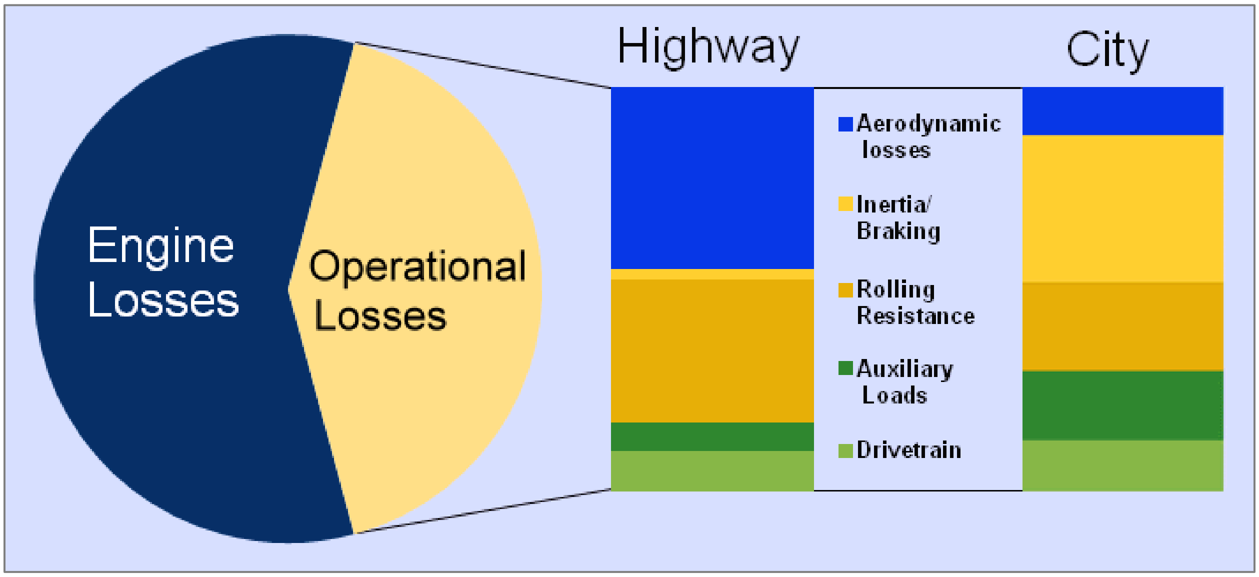


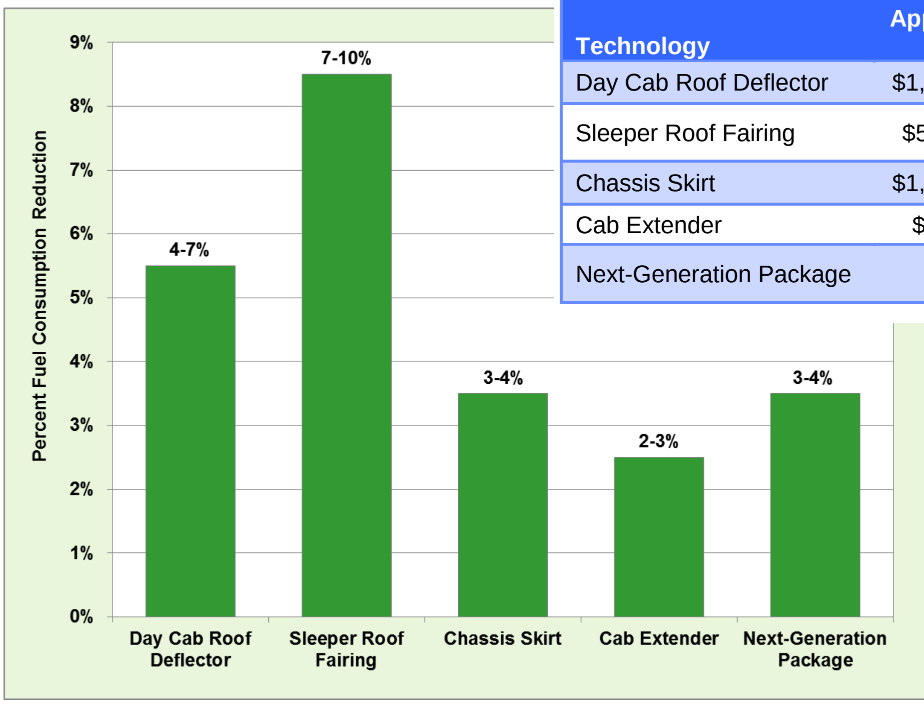
FIGURE 110. Class 8 Truck-Tractor Energy Losses

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 adopted as widely. 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 111. 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 lbs. of weight added, there is a 0.5% penalty in fuel consumption. Trailer skirts alone can add more than 200 lbs. 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.

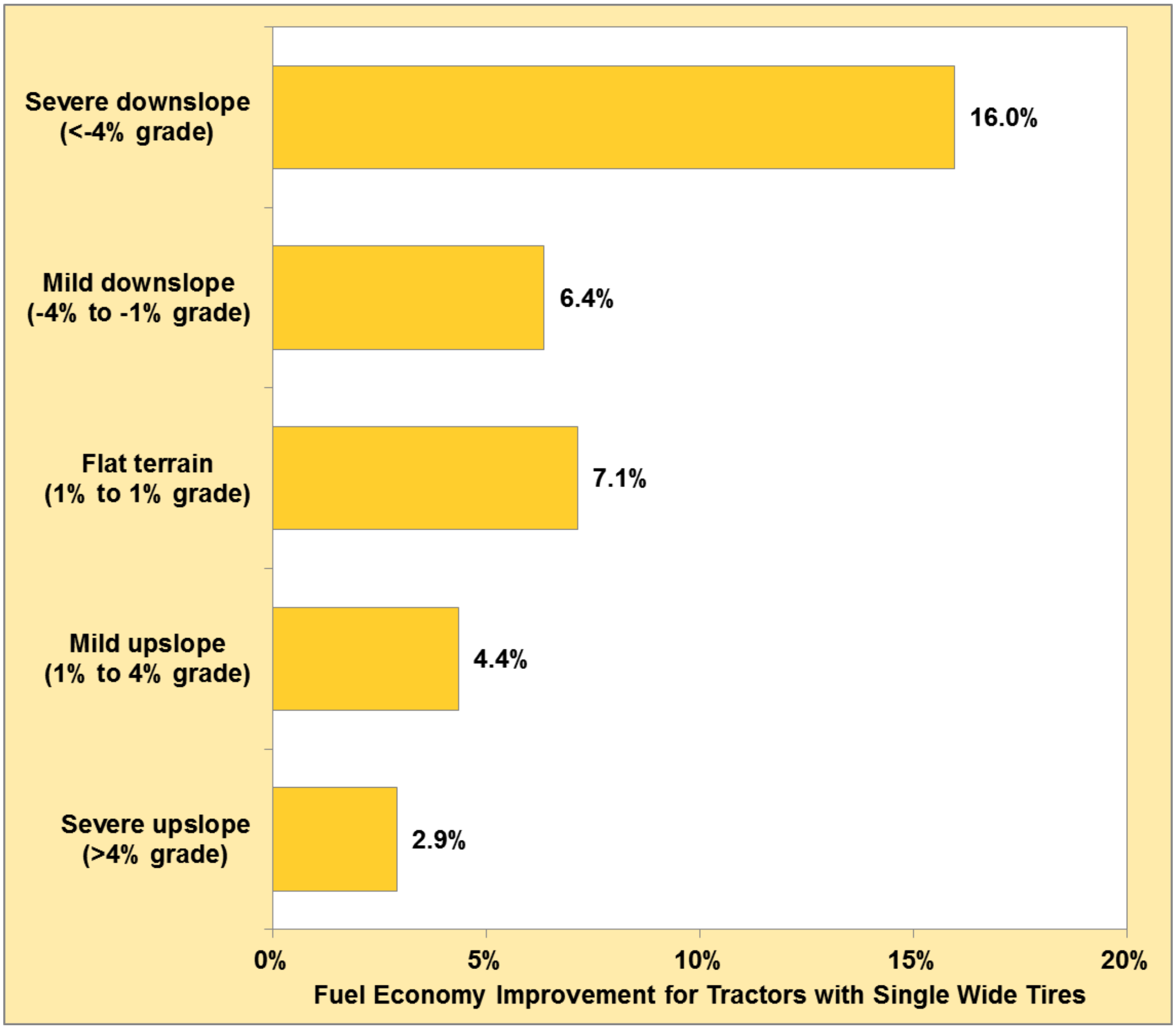


FIGURE 112. Fuel Economy Improvement for Class 8 Tractors with Single Wide Tires

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

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 16 plug-in hybrid-electric vehicle models that currently qualify for a credit, and 22 electric vehicle models that qualify. The maximum credit amount depends on the capacity of the battery, thus some vehicles have lower maximums than others.

TABLE 42. Federal Government Tax Incentives for Advanced Technology Vehicles

<table>
<tr><th>Vehicle Type</th><th>Calendar Year in which the Vehicle was Purchased</th><th>Maximum Credit Amount</th><th>Vehicles Currently Eligible for a Tax Credit</th></tr>
<tr><td rowspan="8">Plug-in Hybrid-Electric Vehicles</td><td rowspan="8">2010-on</td><td>$2,500</td><td>2012-2015 Toyota Prius Plug-In Hybrid</td></tr>
<tr><td>$3,626</td><td>2014 Honda Accord Plug-In Hybrid</td></tr>
<tr><td>$3,667</td><td>2015 Porsche 918 Spyder</td></tr>
<tr><td>$3,793</td><td>2014 BMW i8</td></tr>
<tr><td>$4,007</td><td>2013-2015 Ford C-Max Energi
2013-2015 Ford Fusion Energi</td></tr>
<tr><td>$4,751.80</td><td>2014-2015 Porsche Panamera S E Hybrid</td></tr>
<tr><td>$5,335.60</td><td>2015 Porsche Cayenne S E-Hybrid</td></tr>
<tr><td>$7,500</td><td>2011-2015 Chevrolet Volt
2012 Fisker Karma Sedan
2014 BMW i3 Sedan w/ Range Extender
2014 Cadillac ELR
2014 VIA 1500 Extended Range Electric Truck 4WD
2014 VIA 1500 Extended Range Electric Truck 2WD
2014 VIA 2500 Extended Range Electric Cargo Van
2014 VIA 2500 Extended Range Electric Passenger Van</td></tr>
<tr><td>Electric Vehicles</td><td>2010-on</td><td>$7,500</td><td>2012 AMP GCE Electric Vehicle
2012 AMP MLE Electric Vehicle
2014 BMW i3 Sedan
2012-2014 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
2013-2014 Fiat 500e
2012-2014 Ford Focus EV
2011-2012 Ford/Azure Dynamics Transit Connect EV
2014-2014 Chevrolet Spark EV
2014 Mercedes-Benz B-Class EV
2012, 2014 Mitsubishi i-MiEV
2011-2015 Nissan Leaf
2011 Smart USA fortwo EV
2013 Smart USA Coupe/Cabriolet EV
2012-2014 Tesla Model S
2008-2011 Tesla Roadster
2011 Think City EV
2012-2014 Toyota RAV4 EV
2011 Wheego LiFe</td></tr>
</table>

Source:

Fuel Economy, *U.S. Department of Energy*,
http://www.fueleconomy.gov/feg/taxcenter.shtml – Data accessed March 2015.

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.

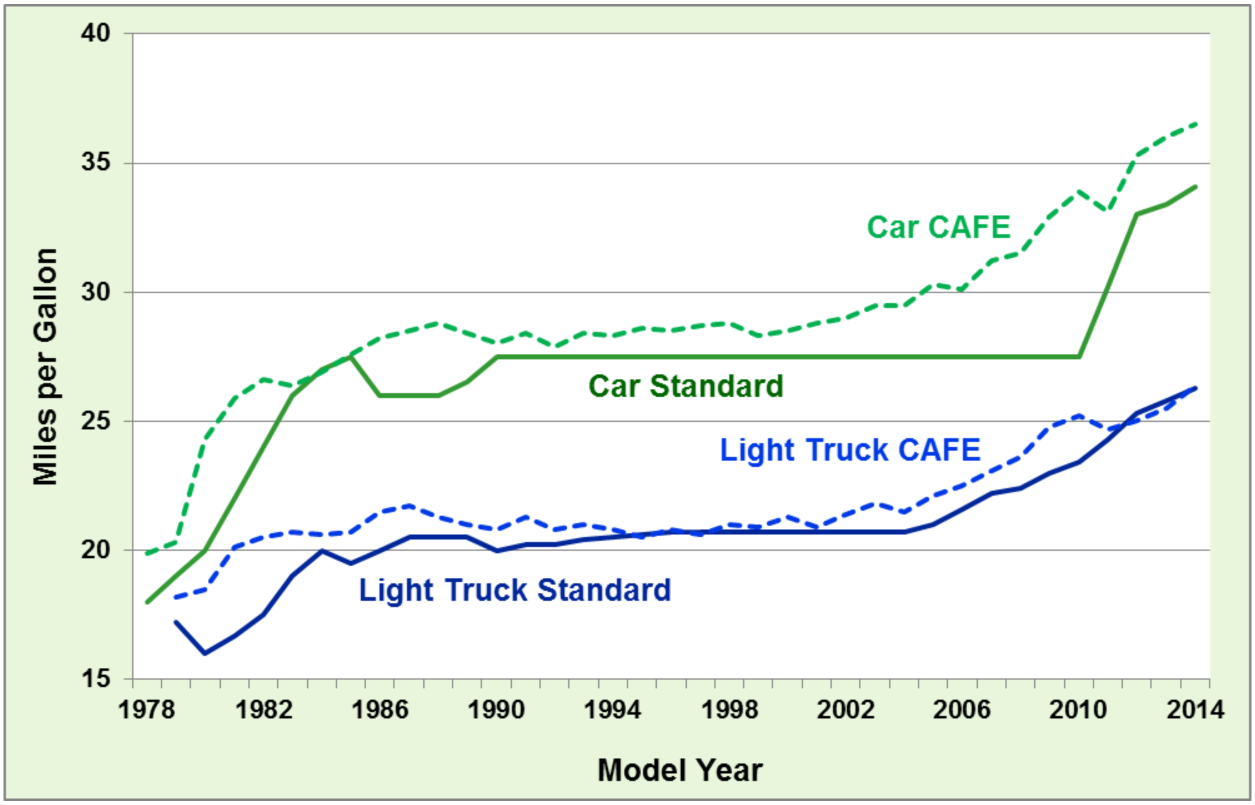


FIGURE 113. CAFE for Cars and Light Trucks, 1978-2014

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," June 2014.
http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/June_2014_Summary_Report.pdf

Corporate Average Fuel Economy Improves for All Manufacturers

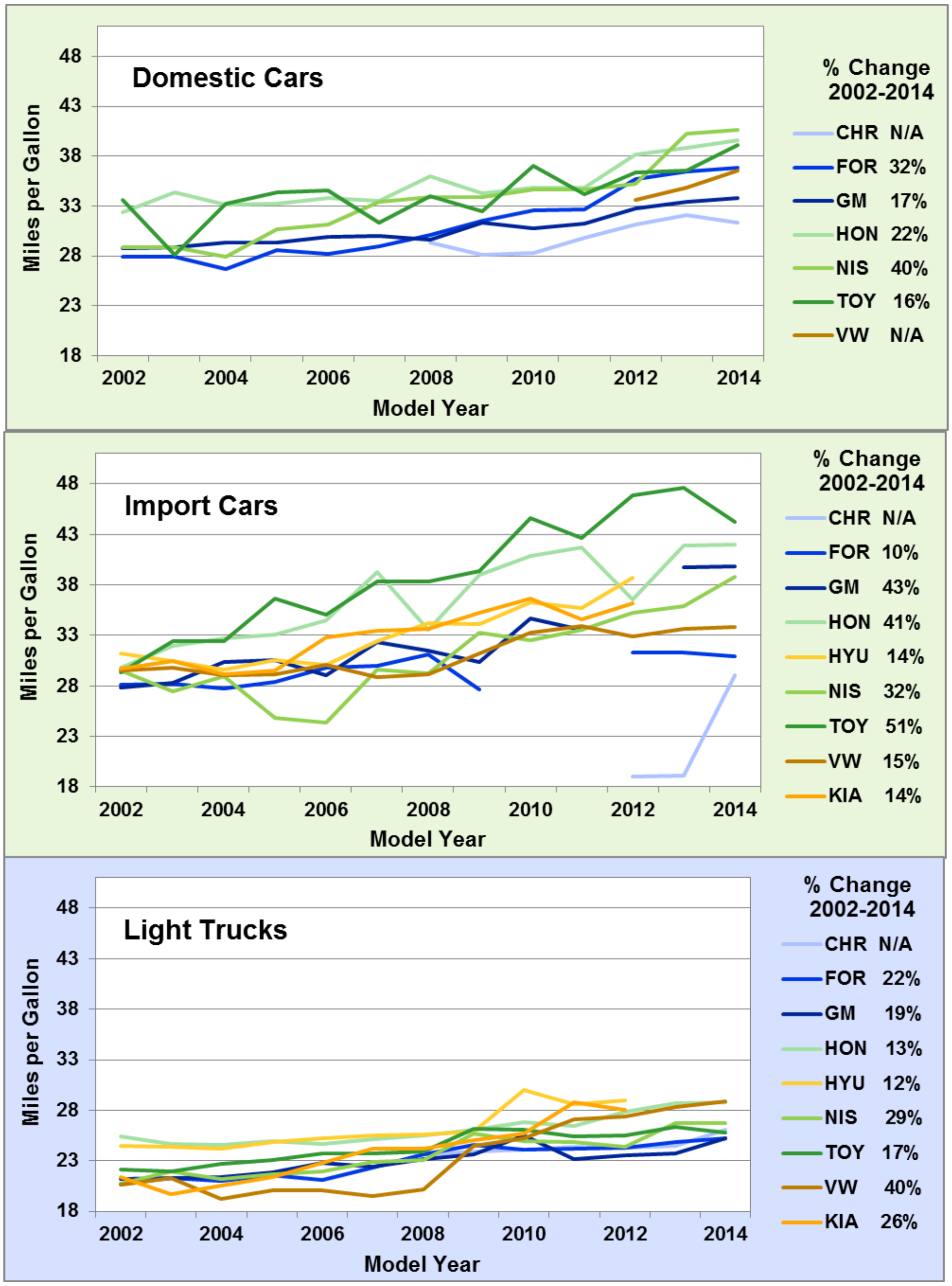


FIGURE 114. CAFE for Domestic and Import Cars and Light Trucks by Manufacturer, 2002-2014

Note: Data for Chrysler 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," June 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 lbs. gross vehicle weight rating (GVWR), and sport utility vehicles and passenger vans less than 10,000 lbs. GVWR.

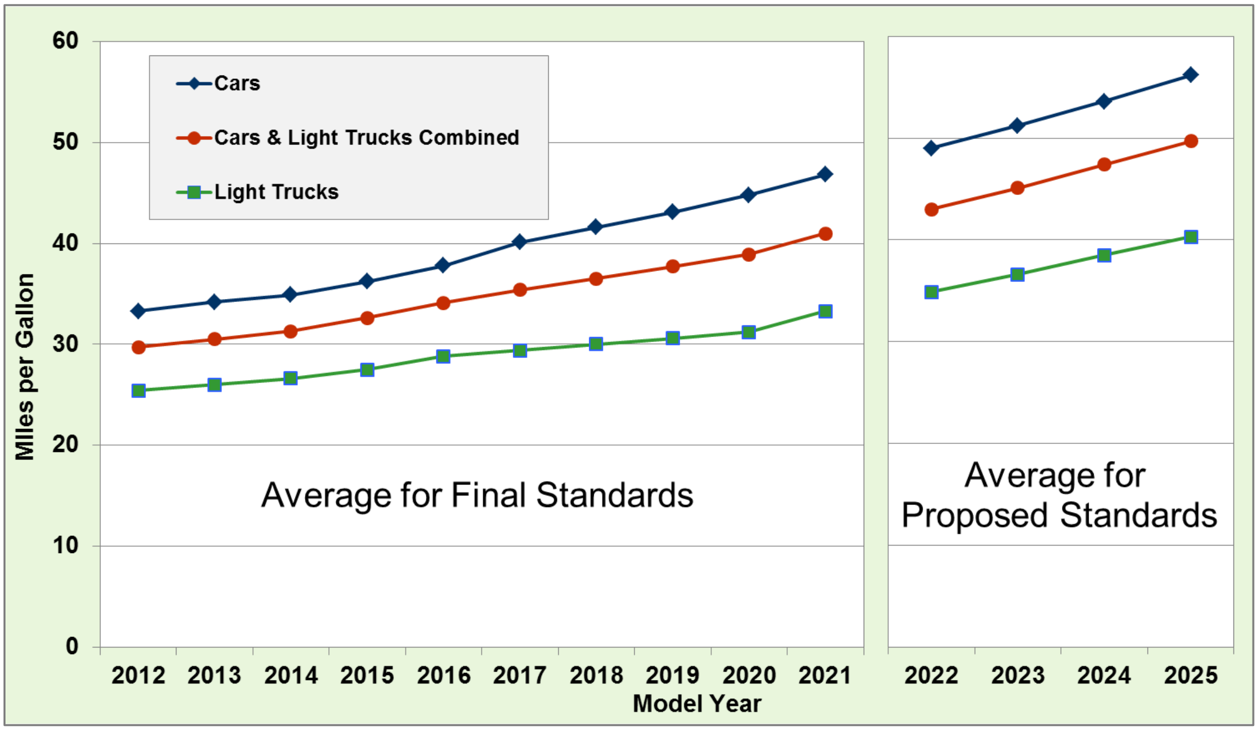


FIGURE 115. Average CAFE Standards for MY 2012-2025

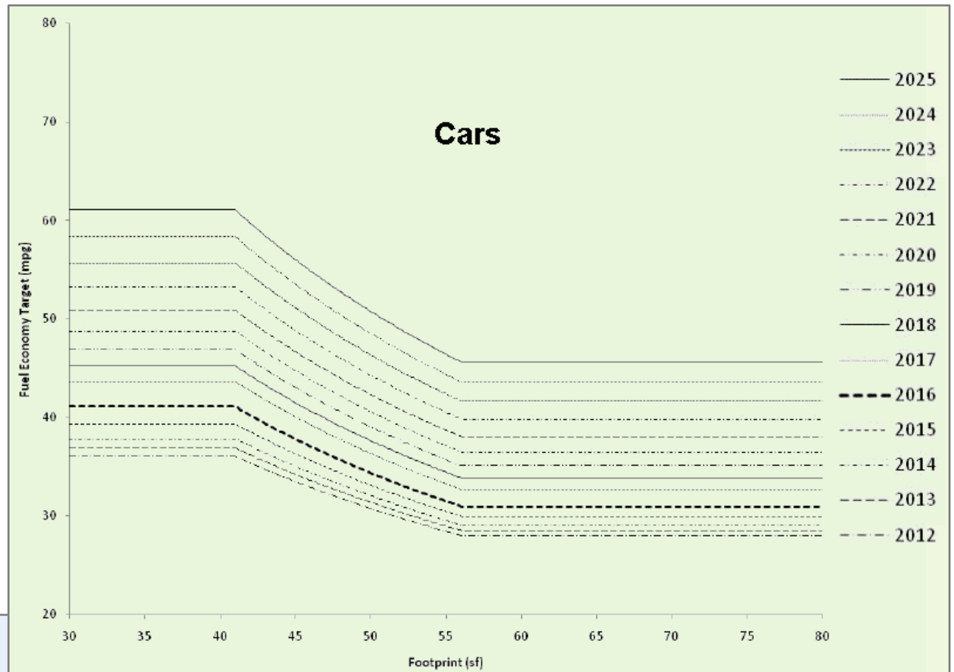
Notes: A MY 2008 baseline was used for MY 2017-2025.
The presented rates of increase in stringency for NHTSA CAFE standards are lower than the Environmental Protection Agency (EPA) rates of increase in stringency for greenhouse gas (GHG) standards. One major difference is that NHTSA's standards, unlike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



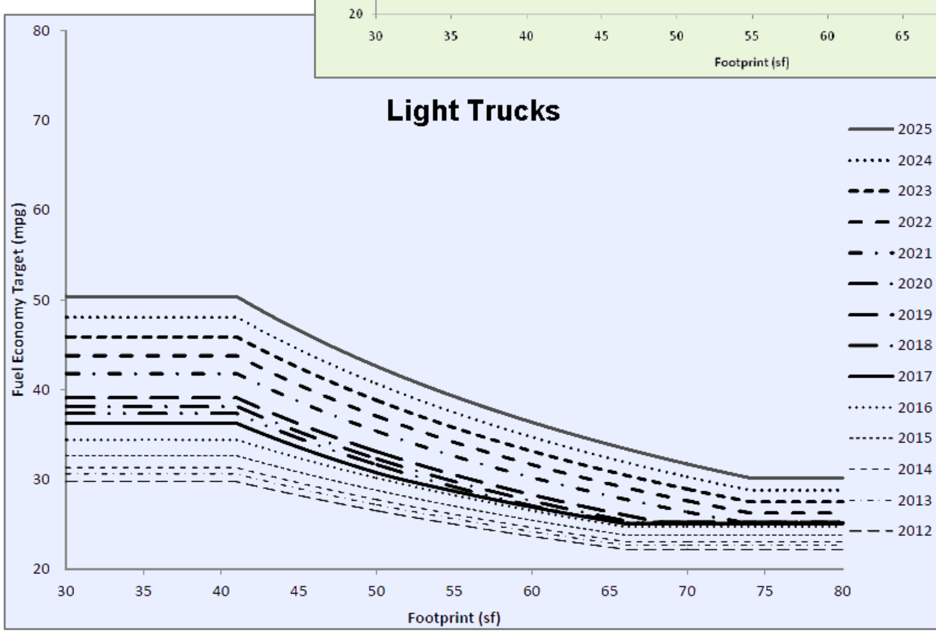


FIGURE 116. CAFE Standards for Cars and Light Trucks, MY 2012-2025

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 track width of the vehicle. The upcoming 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 in 2014. The table shows selected vehicles and their MY 2012 footprint.

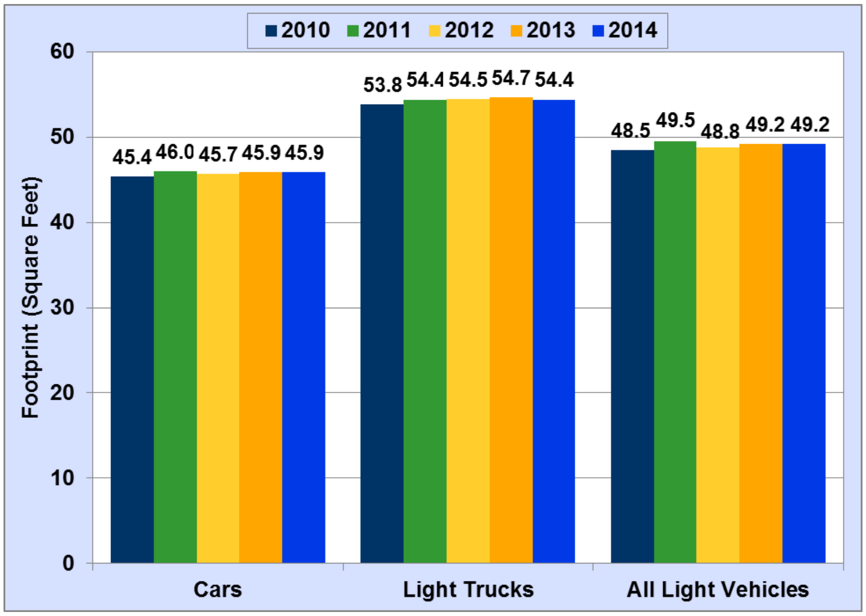


FIGURE 117. Average Vehicle Footprint, MY 2010-2014

TABLE 43. 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 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

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

Chrysler Has the Highest Car Footprint and General Motors Has the Highest Light Truck Footprint

The Corporate Average Fuel Economy (CAFE) standards are based on the vehicle's footprint beginning in model year (MY) 2012. In MY 2014, Chrysler had the highest sales-weighted average car footprint, thus would have the least stringent standards to meet according to the new CAFE methodology. General Motors has the highest sales-weighted average light truck footprint.

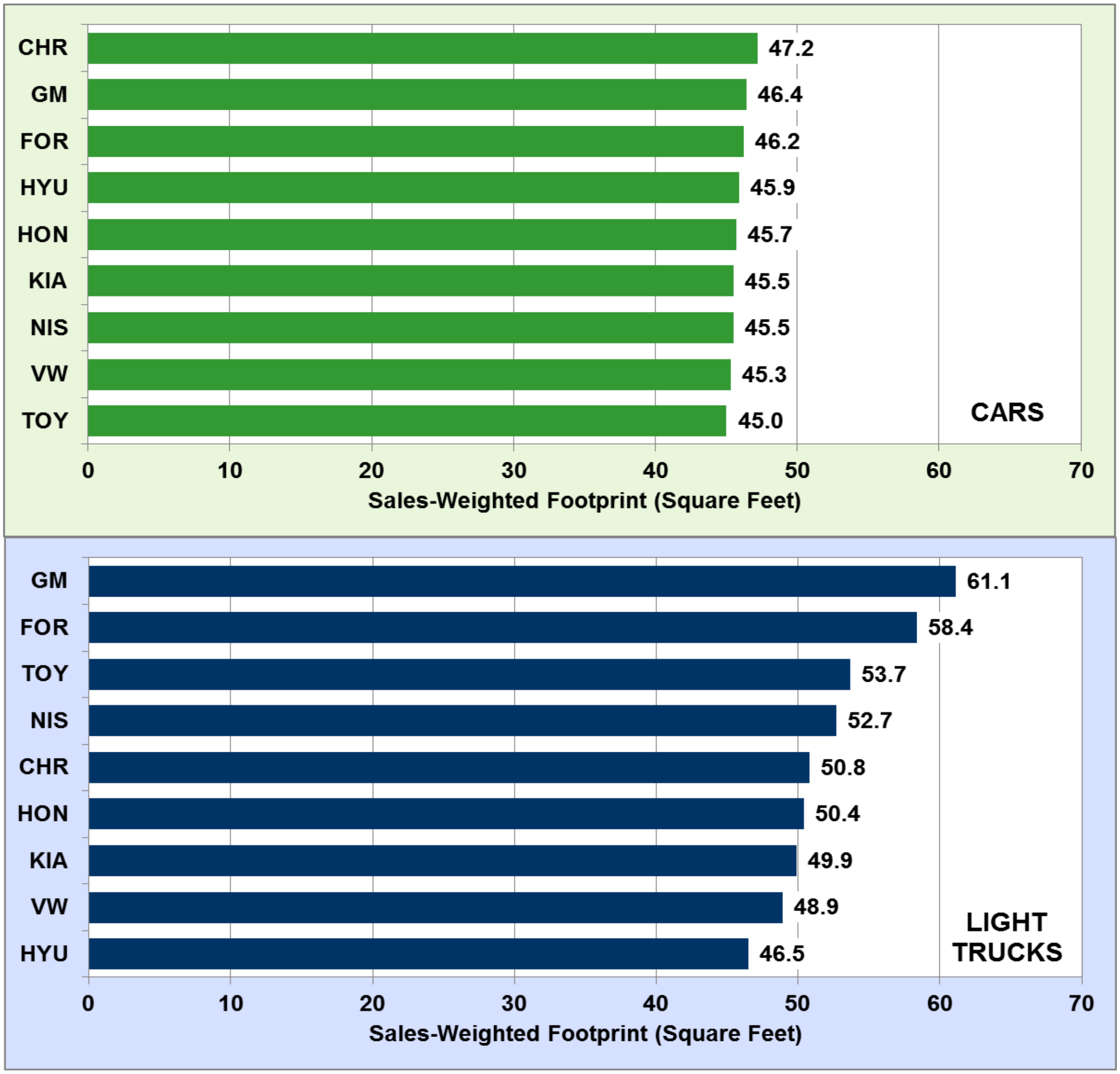


FIGURE 118. Car and Light Truck Footprint by Manufacturer, 2014

Sources:

U.S. Environmental Protection Agency, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2014*, EPA-420-R-14-023a, October 2014. http://www.epa.gov/otaq/fetrends.htm

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

Nissan, Tesla, and Honda 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 2012, Nissan had sold over 700,000 CAFE credits to other manufacturers. Tesla and Honda also sold credits, while Ferrari, Mercedes-Benz, and Chrysler purchased credits.

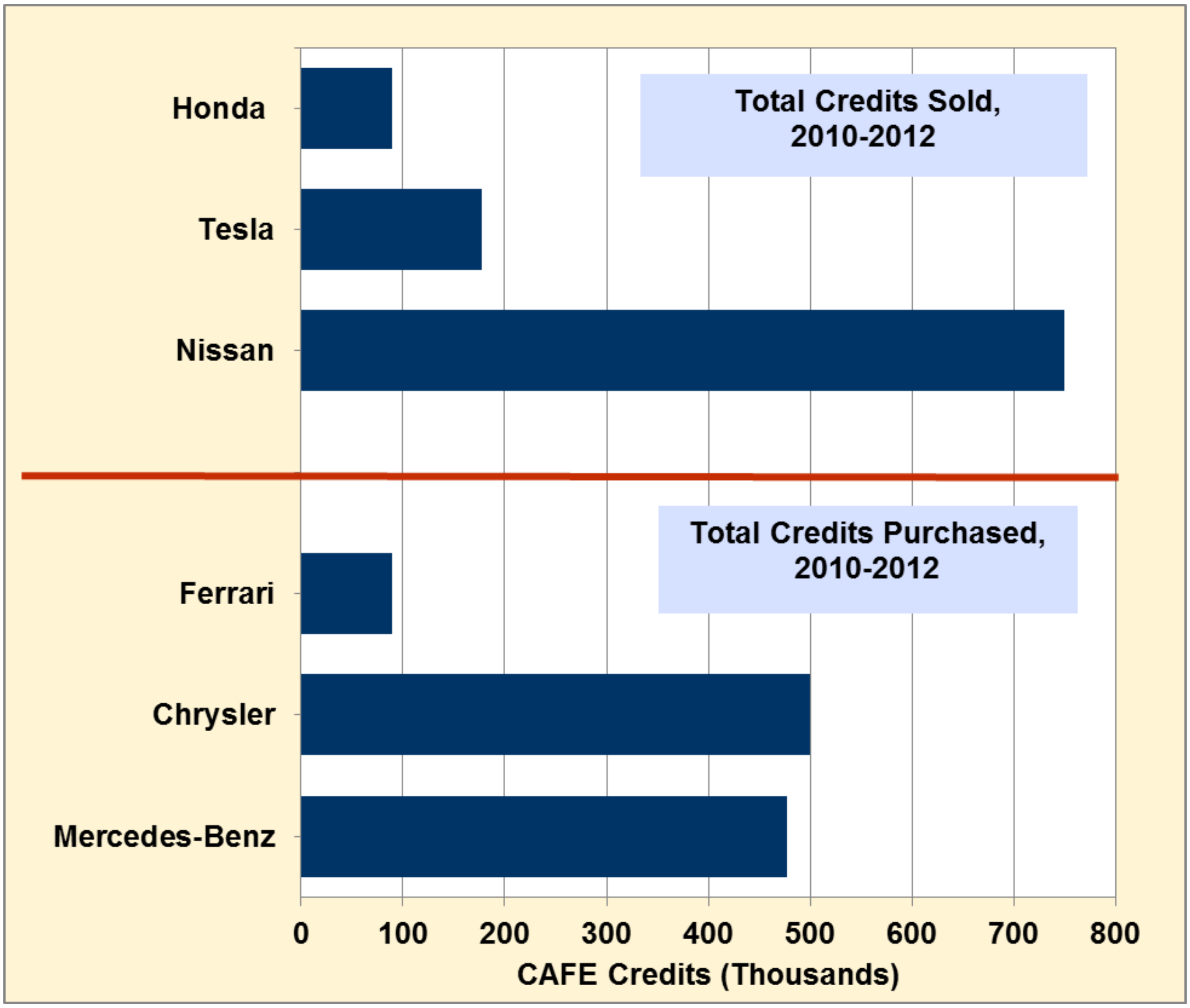


FIGURE 119. Cumulative CAFE Credits Sold and Purchased by Manufacturer at the End of MY 2012

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2012 Model Year*, EPA-420-R-14-011, April 2014. http://www.epa.gov/otaq/climate/documents/420r14011.pdf

Nearly All Manufacturers Have CAFE Credits at the End of 2012

Some of the early CAFE credits earned by manufacturers from 2009 to 2011 were used to offset deficits in model year (MY) 2012 and some credits were traded among manufacturers. After considering all these credit transactions, as of the end of MY 2012, all manufacturers but one (Jaguar Land Rover) carried a positive balance of credits into MY 2013. 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 MY.

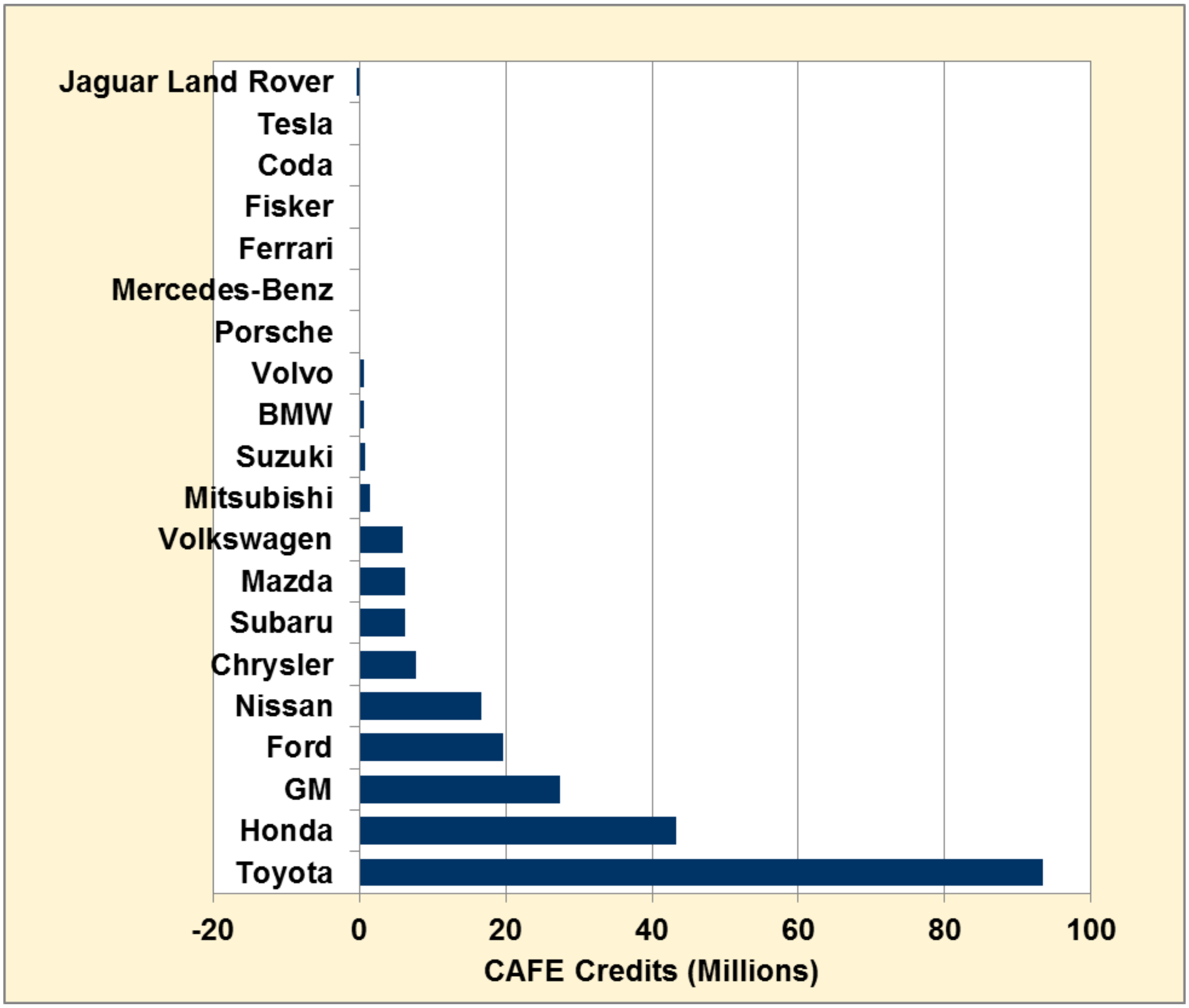


FIGURE 120. Cumulative CAFE Credits by Manufacturer as of the End of MY 2012

Source:

U.S. Environmental Protection Agency, *Greenhouse Gas Emission Standards for Light-Duty Vehicles: Manufacturer Performance Report for the 2012 Model Year*, EPA-420-R-14-011, April 2014. http://www.epa.gov/otaq/climate/documents/420r14011.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.

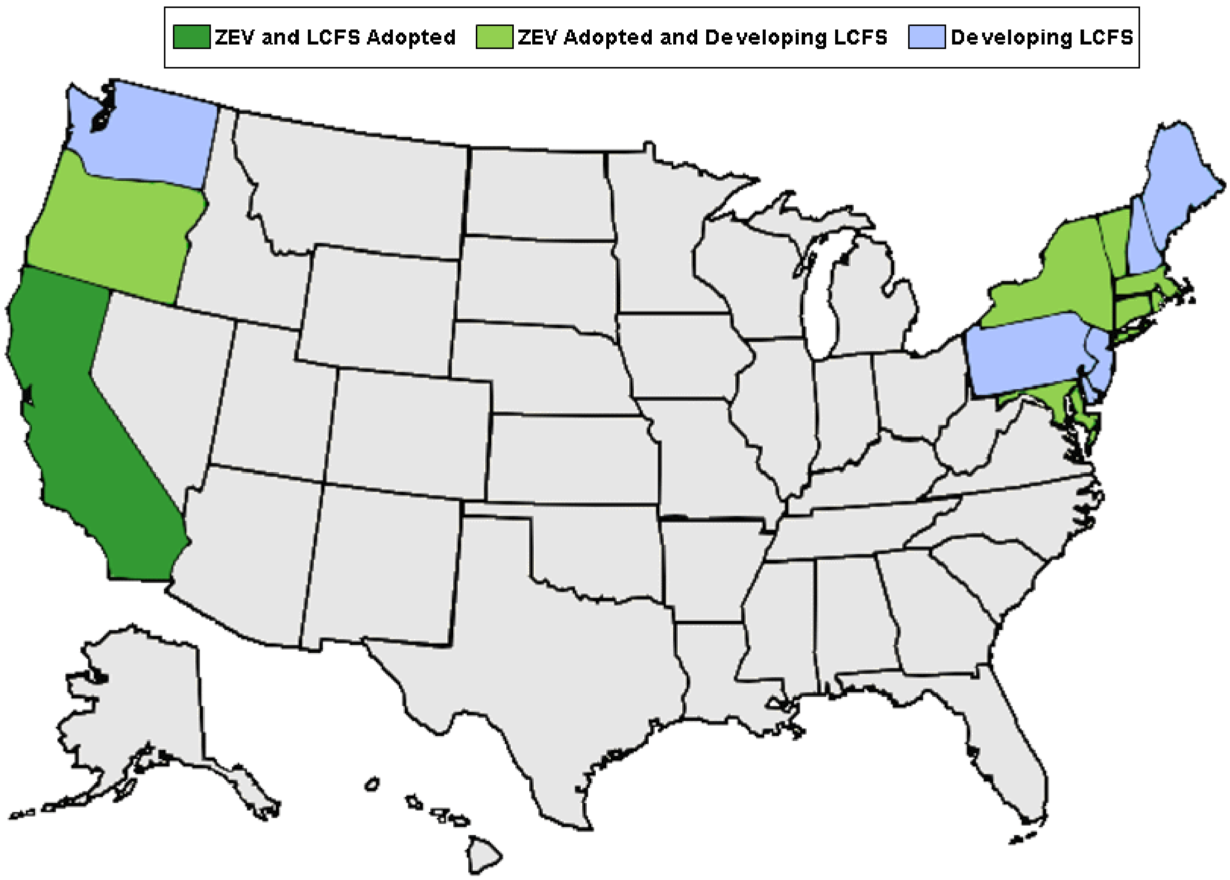


FIGURE 121. States with Zero Emission Vehicle and Low Carbon Fuel Standards

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

Nissan and Tesla Transferred Over 500 Zero Emission Vehicle Credits Out while Honda and Mercedes Benz Transferred Over 500 Credits In

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 lbs.) delivered for sale in California. The manufacturers can generate credits by exceeding minimum standards of ZEVs. Manufacturers are allowed to transfer credits earned; between October 1, 2013 and September 30, 2014, 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.

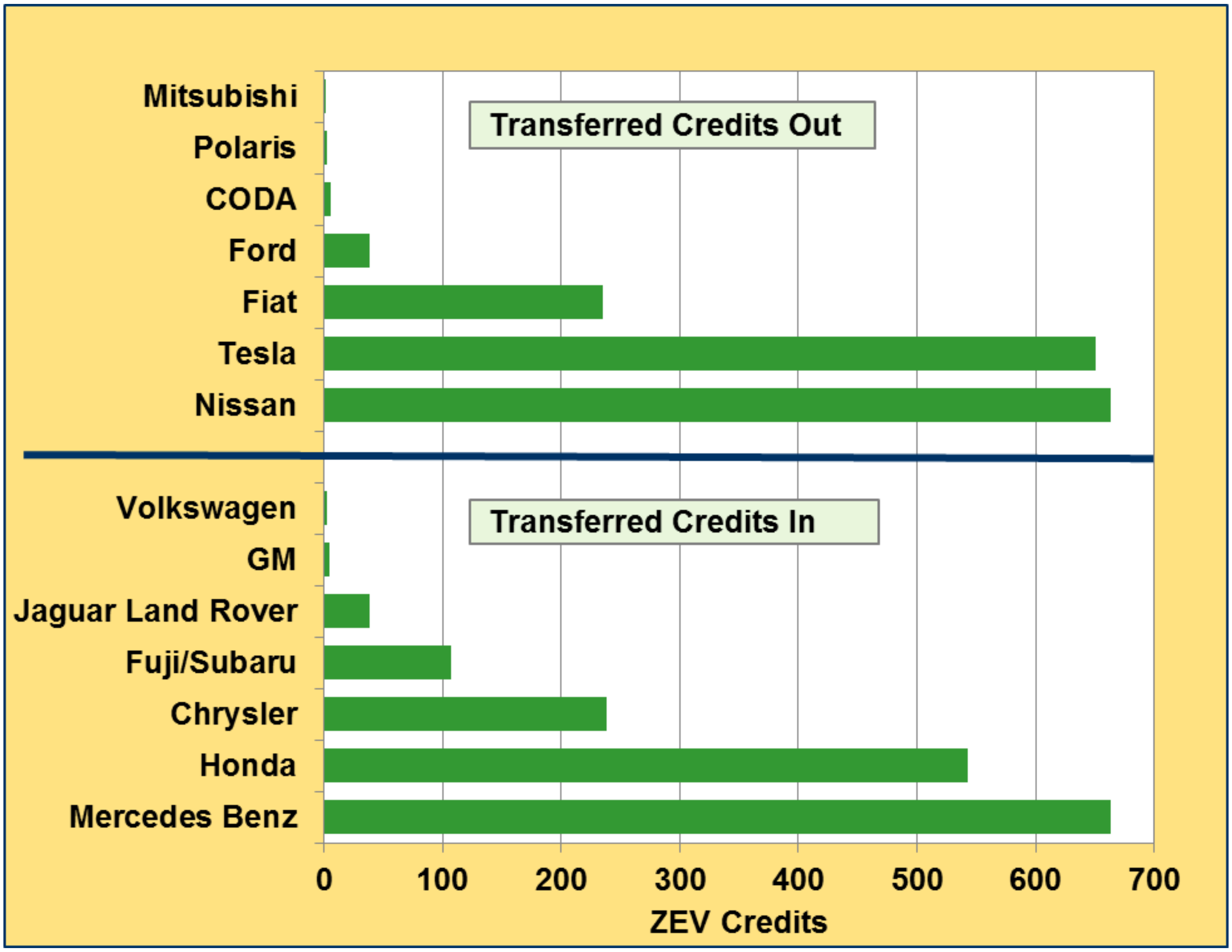


FIGURE 122. California Zero Emission Vehicle Credit Transfers

Note: Transfers between October 1, 2013 and September 30, 2014.

Source:
California Air Resources Board, "2013 Zero Emission Vehicle Credits," http://www.arb.ca.gov/msprog/zevprog/zevcredits/2013zevcredits.htm, accessed February 10, 2015.

Nissan Has Largest Zero Emission Vehicle Credit Balance

Taking into account all credit transfers, in and out, California's zero-emission vehicle (ZEV) balances show that Nissan has the largest amount of credit. These credit balances show ZEV regulation compliance through model year 2013. Tesla, the only manufacturer to produce exclusively ZEVs, has transferred many credits to other manufacturers. Honda has the second highest balance mainly due to credits that were transferred in from other manufacturers.

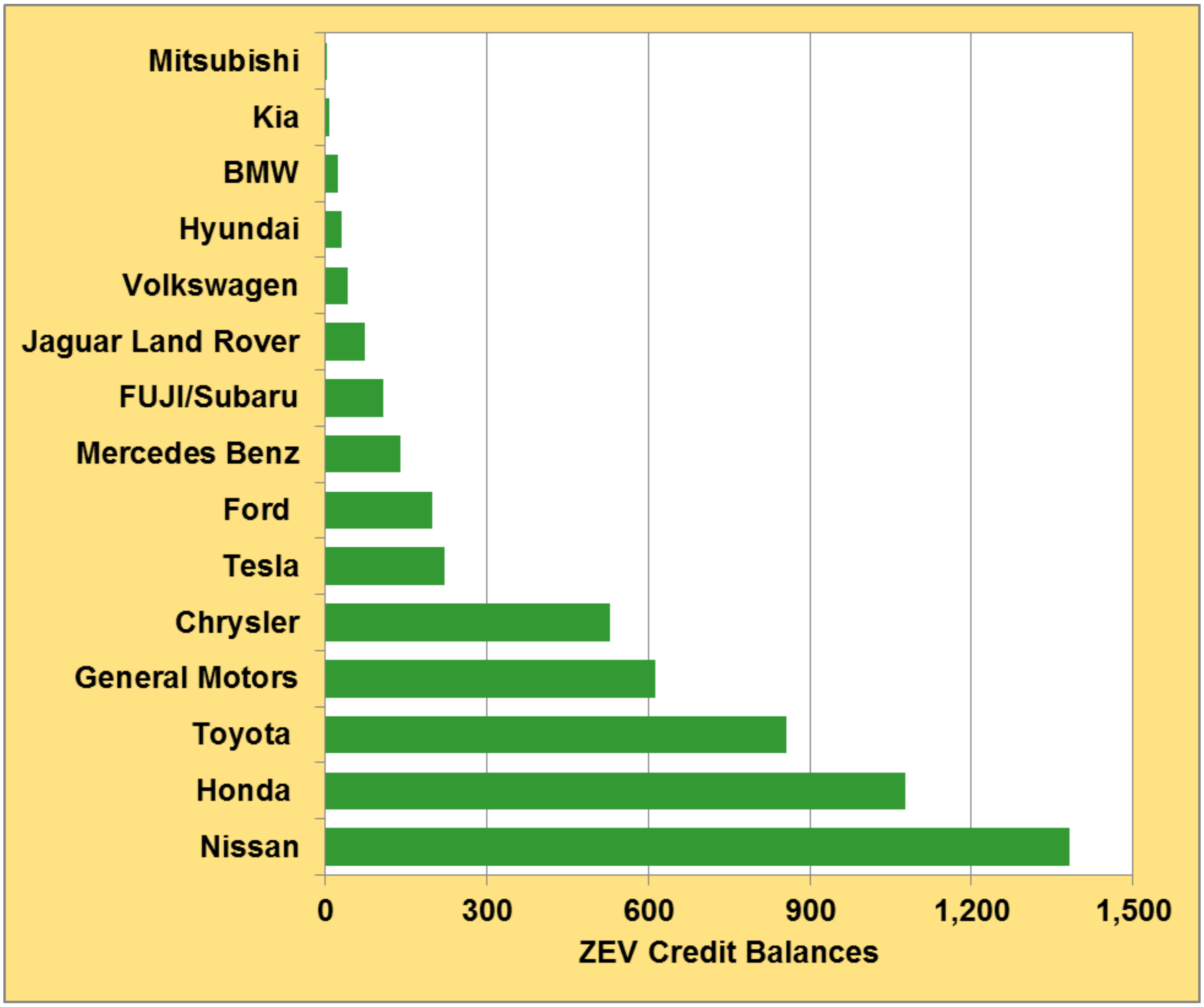


FIGURE 123. California Zero Emission Vehicle Credit Balances by Manufacturer, September 2014

Note: Does not include neighborhood electric vehicle credits, transitional ZEV credits, or partial ZEV credits.

Source:
California Air Resources Board, "2013 Zero Emission Vehicle Credits," http://www.arb.ca.gov/msprog/zevprog/zevcredits/2013zevcredits.htm, accessed February 10, 2015.

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.

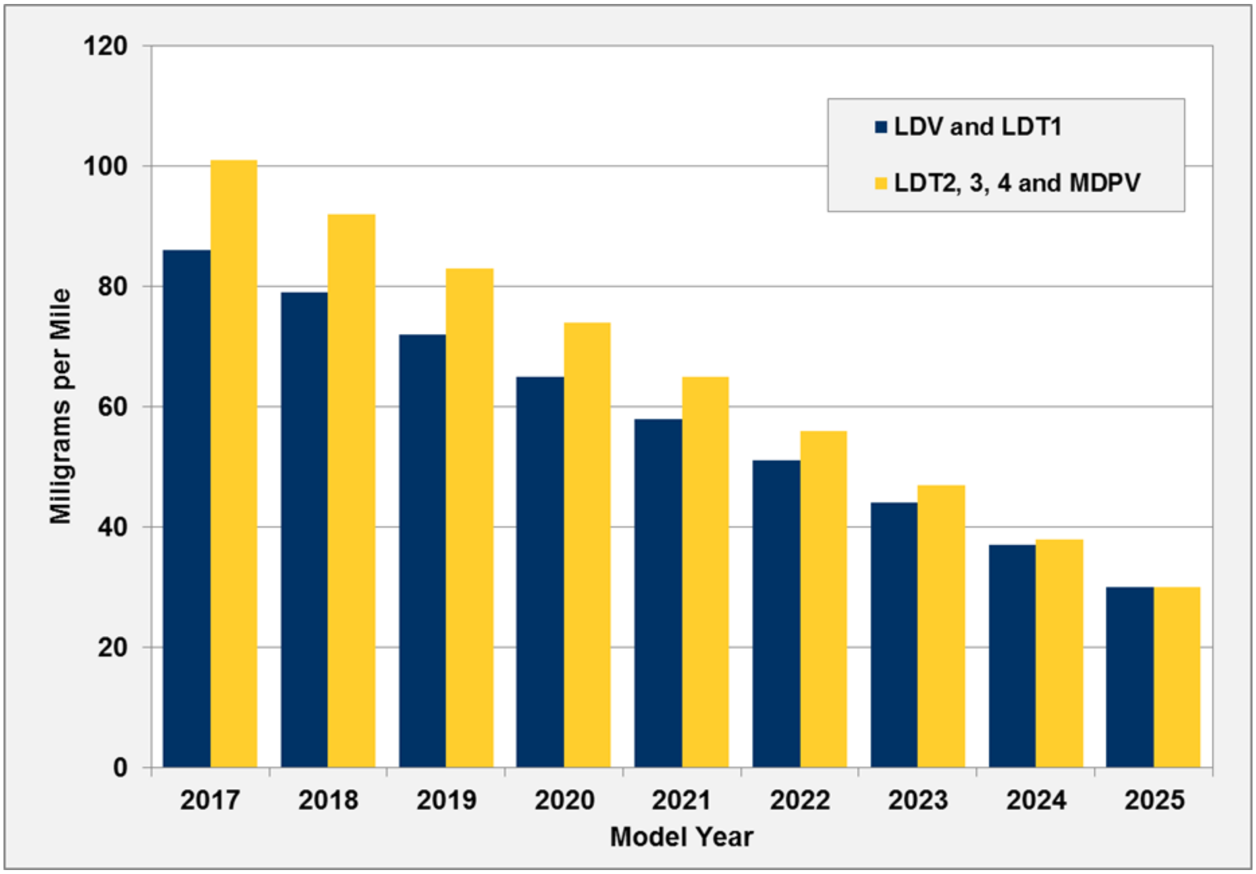


FIGURE 124. Tier 3 NMOG+NOx Emission Standards for Light Gasoline Vehicles, MY 2017-2025

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.

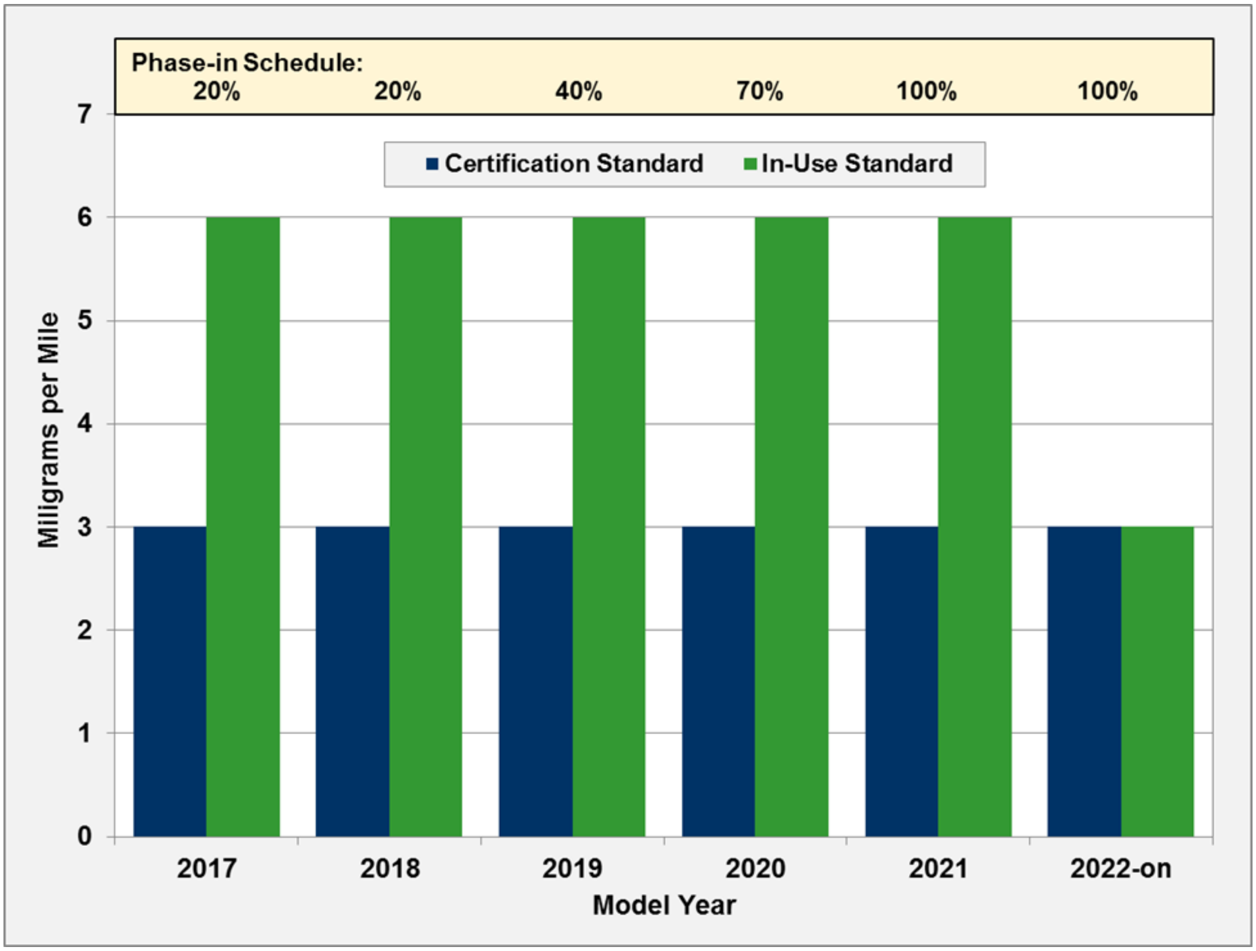


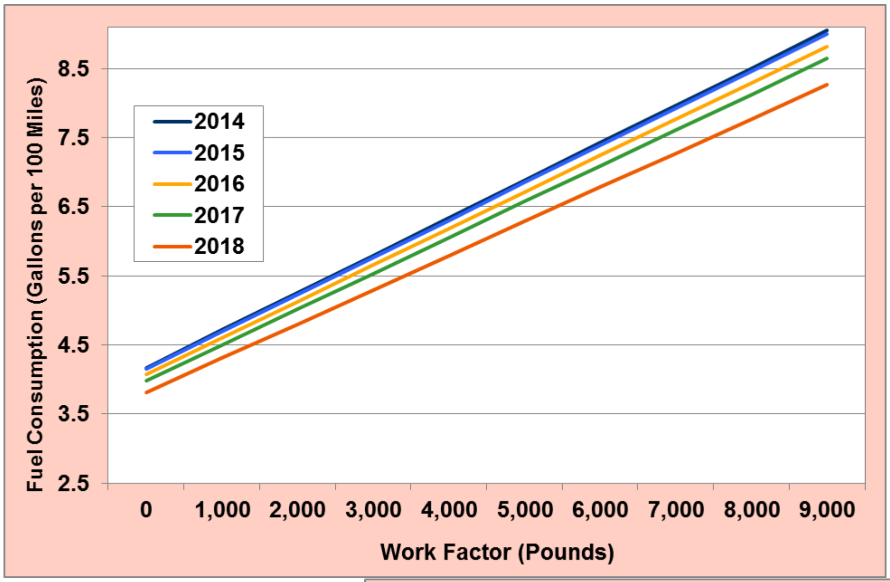
FIGURE 125. Tier 3 Particulate Matter Emission Standards for Light Gasoline Vehicles, MY 2017 and Beyond

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

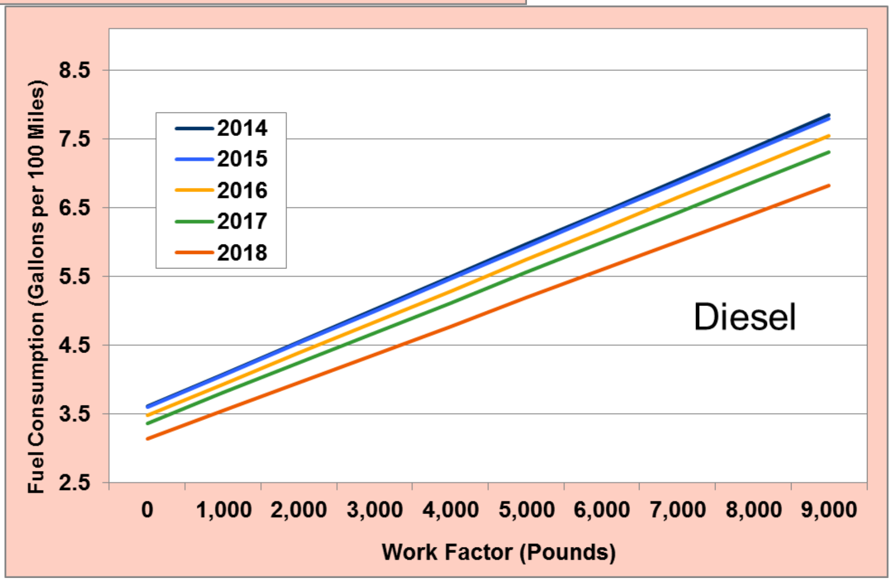
Fuel Consumption Standards Set for Heavy Pickups and Vans

In September 2011 the National Highway Traffic Safety Administration issued the final rule to set standards regulating the fuel use of new vehicles heavier than 8,500 lbs. gross vehicle weight. Included in the new standards are pickup trucks over 8,500 lbs., cargo trucks over 8,500 lbs., and passenger vans over 10,000 lbs. Standards were set separately for gasoline and diesel vehicles, on a scale that depends on a "work factor." The work factor, which is expressed in pounds, takes into account the vehicle's payload capacity, towing capacity, and whether or not the vehicle is four-wheel drive (see note below for work factor details). Standards for model years (MYs) 2014 and 2015 are voluntary, but standards are mandatory thereafter.



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

FIGURE 126. 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

The National Highway Traffic Safety Administration 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).

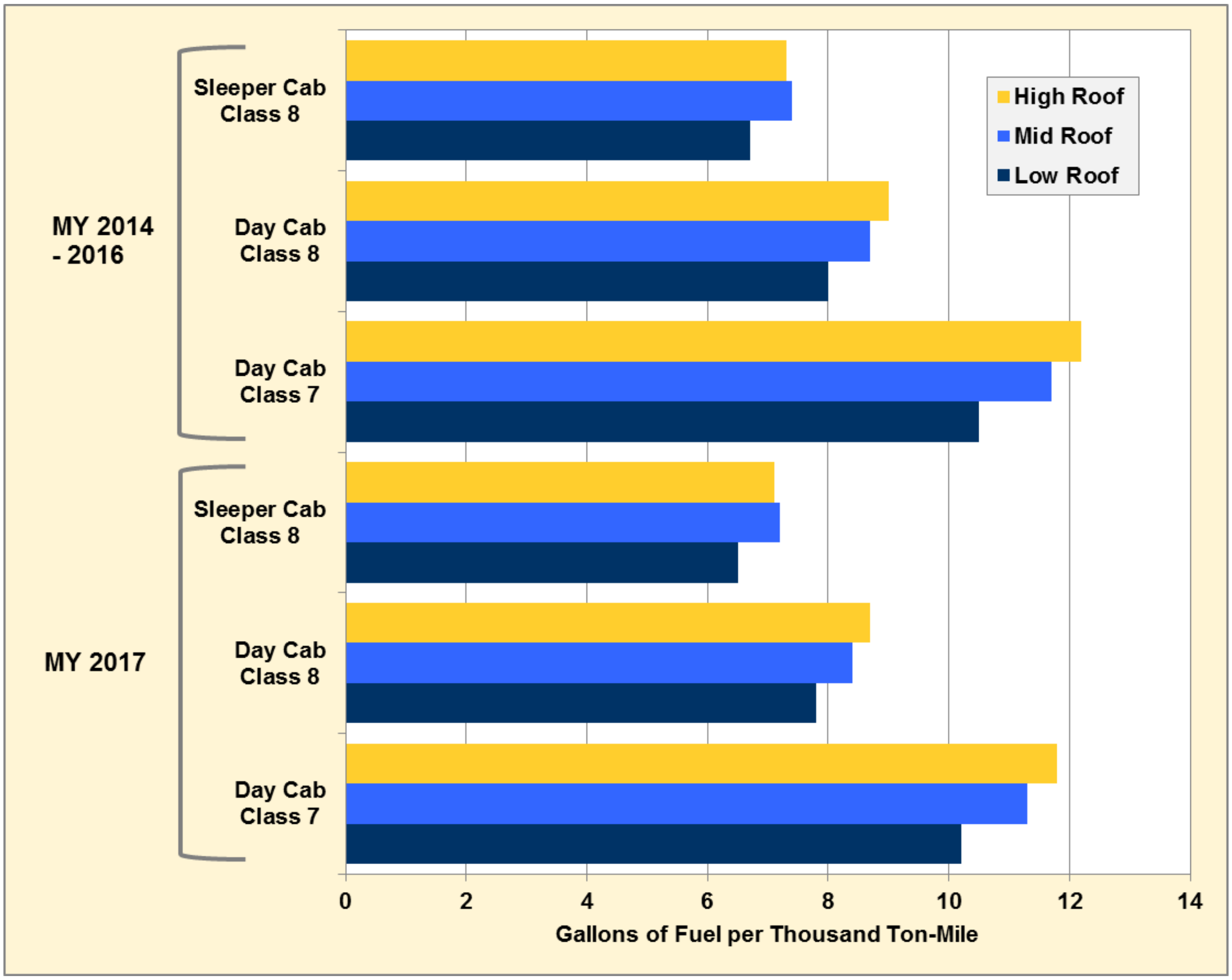


FIGURE 127. Fuel Consumption Standards for Combination Tractors, MY 2014-2017

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

The National Highway Traffic Safety Administration (NHTSA) recently published final fuel consumption standards for heavy vehicles called "vocational" vehicles. A vocational vehicle is generally a single-unit work vehicle over 8,500 lbs. gross vehicle weight rating (GVWR) or a passenger vehicle over 10,000 lbs. GVWR. These vehicles vary in size, and include smaller and larger 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 (but not the body builders).

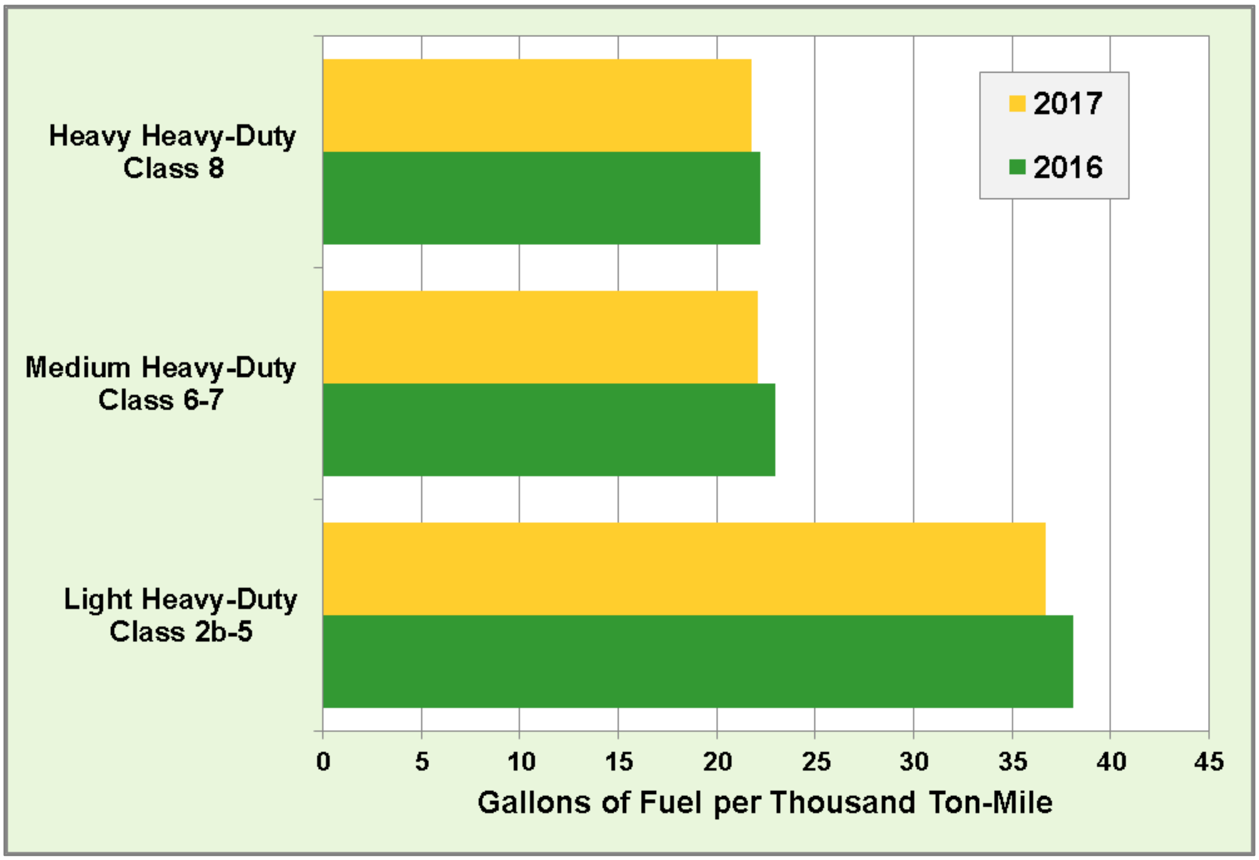


FIGURE 128. Vocational Vehicle Fuel Consumption Standards, MY 2016 and 2017

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

In addition to the combination truck and vocational truck fuel consumption standards, the National Highway Traffic Safety Administration set fuel consumption standards for diesel engines installed in truck-tractors and vocational vehicles. The standards are 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 are voluntary from 2014 through 2016 and mandatory thereafter.

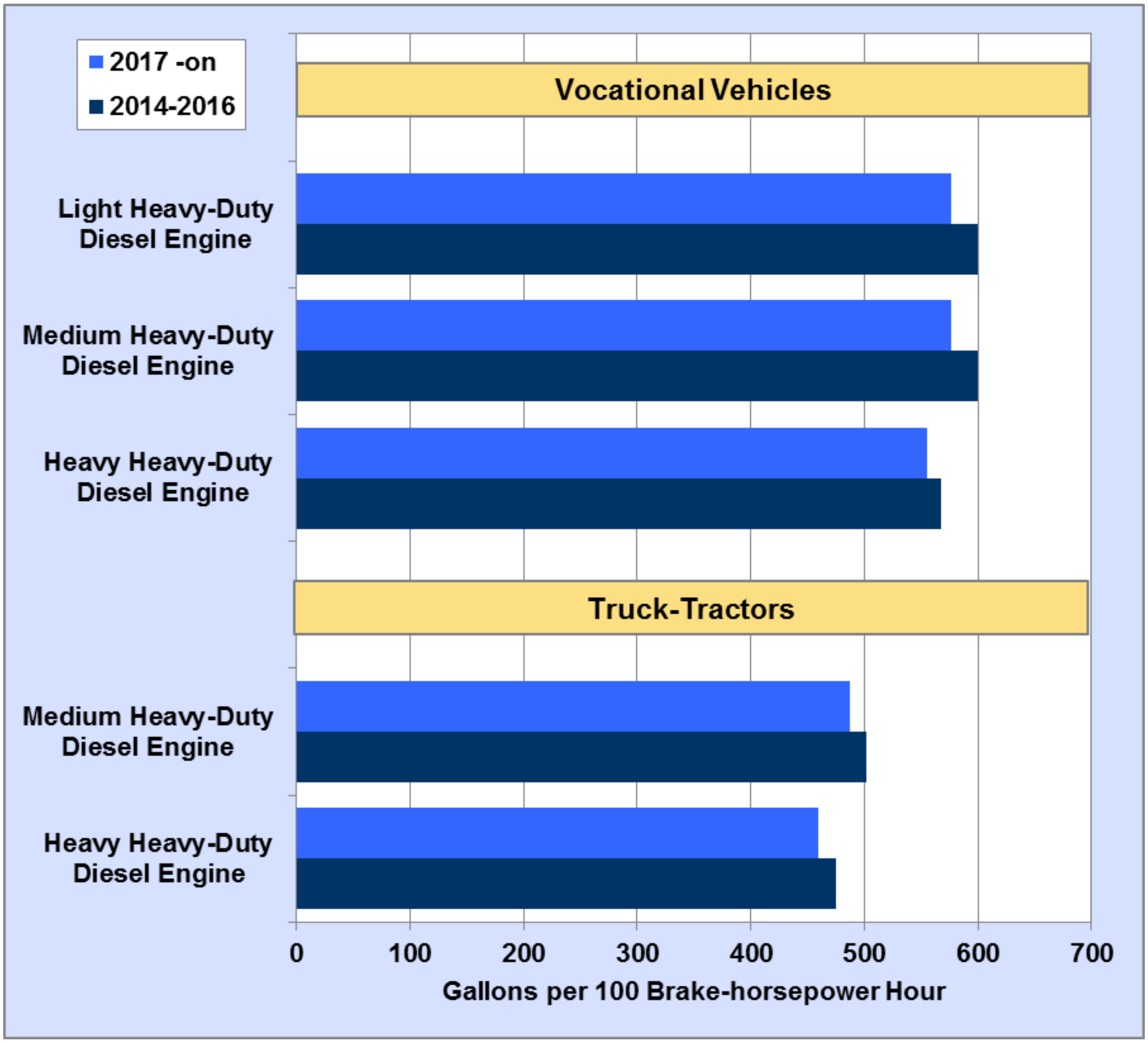


FIGURE 129. Fuel Standards for New Diesel Engines, MY 2014-on

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 idling reduction devices in large trucks, the Energy Policy Act of 2005 allowed for a weight exemption for the additional weight of idling 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 an additional 400 lbs. (green) or 550 lbs. (dark green). Other States have a 400-lb. weight allowance which is granted by enforcement personnel (light green). Five states plus the District of Columbia have not adopted the weight exemption (gold).

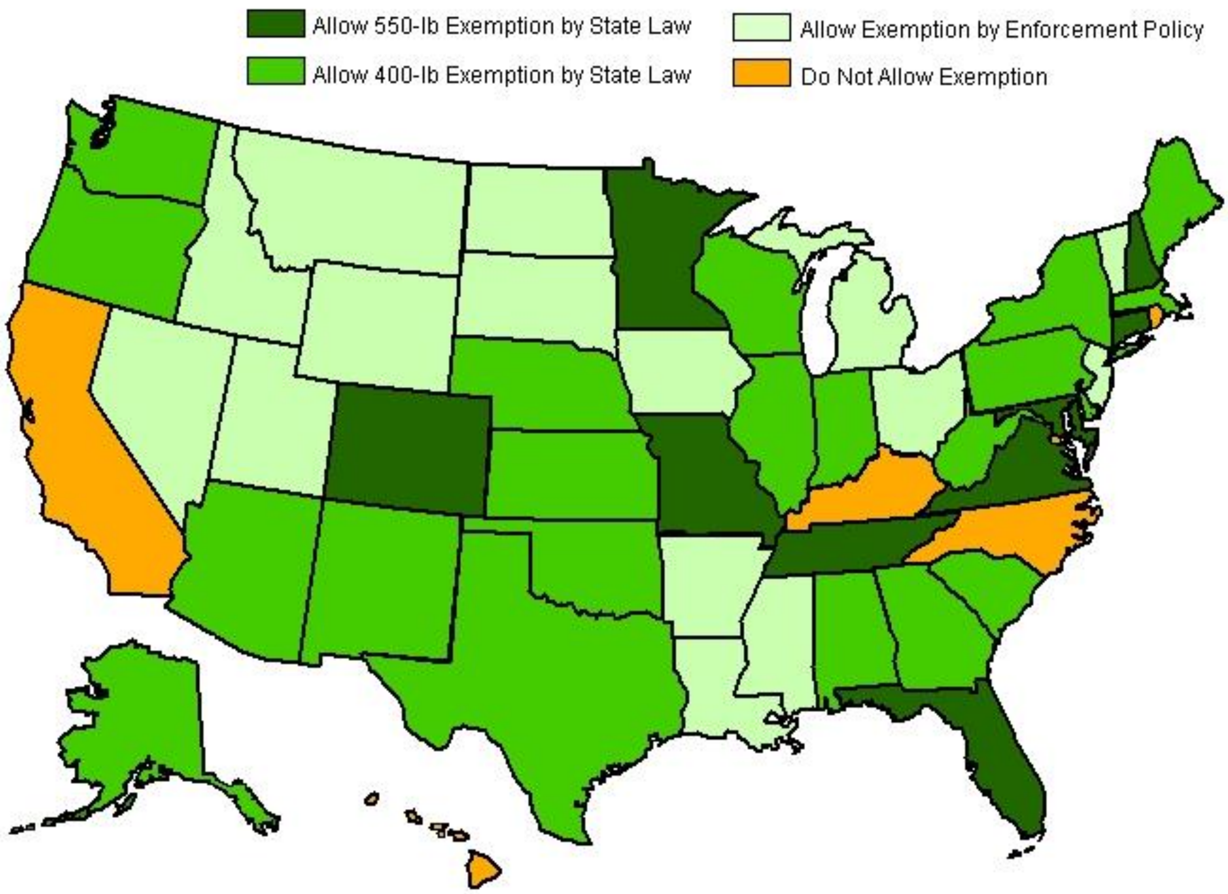


FIGURE 130. States Adopting Weight Exemptions for Idling Reduction Devices, 2014

Source:
U.S. Department of Energy, Energy Efficiency & Renewable Energy, *September 2014 National Idling Reduction News*. http://energy.gov/eere/vehicles/articles/september-2014-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 131. Idle Reduction Technologies which Are Granted Exemption from Federal Excise Taxes

Source:
U.S. Environmental Protection Agency, SmartWay Technology Program. January 2015.
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 are shown in the map below.

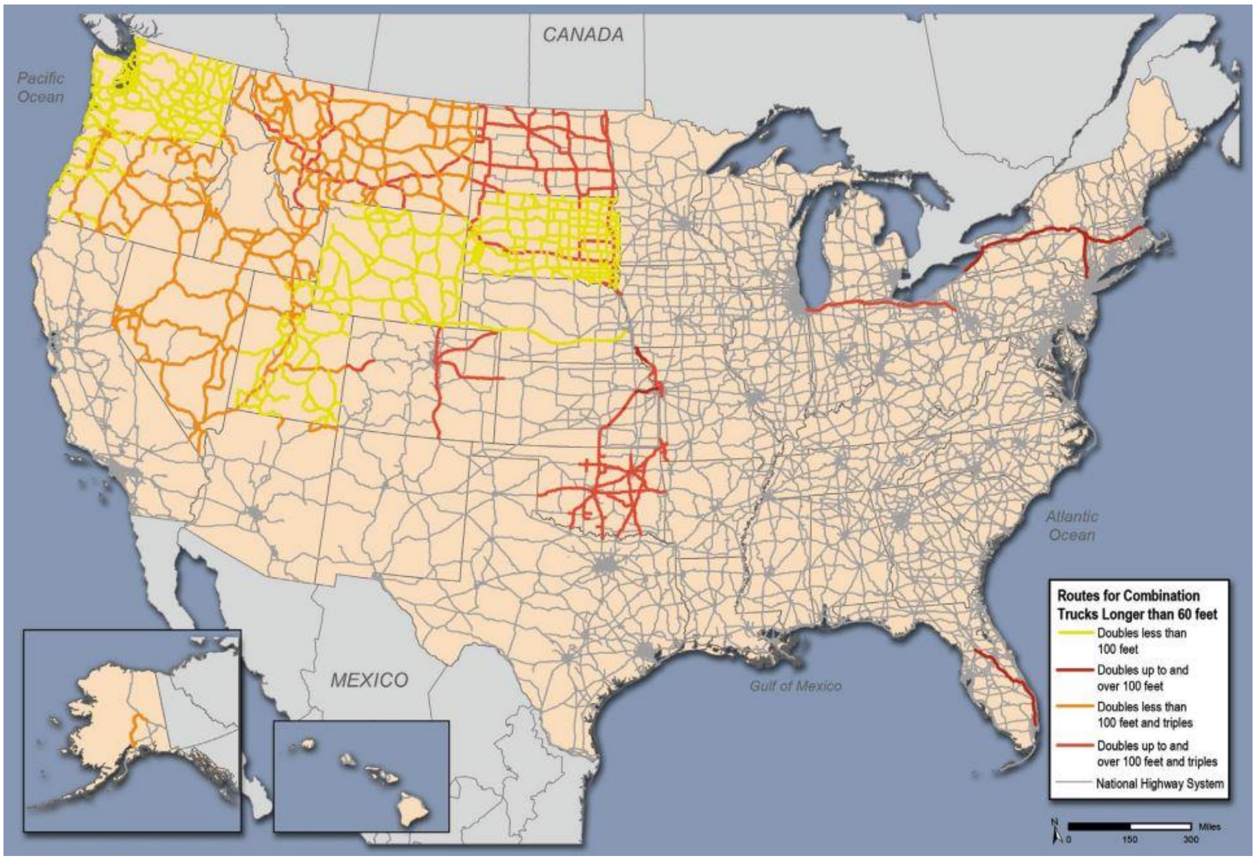


FIGURE 132. Routes Where Longer Combination Vehicles Are Permitted, 2011

Note: Empty triples are allowed on I-80 in Nebraska. National Highway System mileage as of 2011, prior to MAP-21 system expansion.

Source:

U.S. Department of Transportation, Federal Highway Administration, *Freight Facts and Figures 2013,* FHWA-HOP-13-001, May 2014. http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/13factsfigures

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 and Oregon have 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.

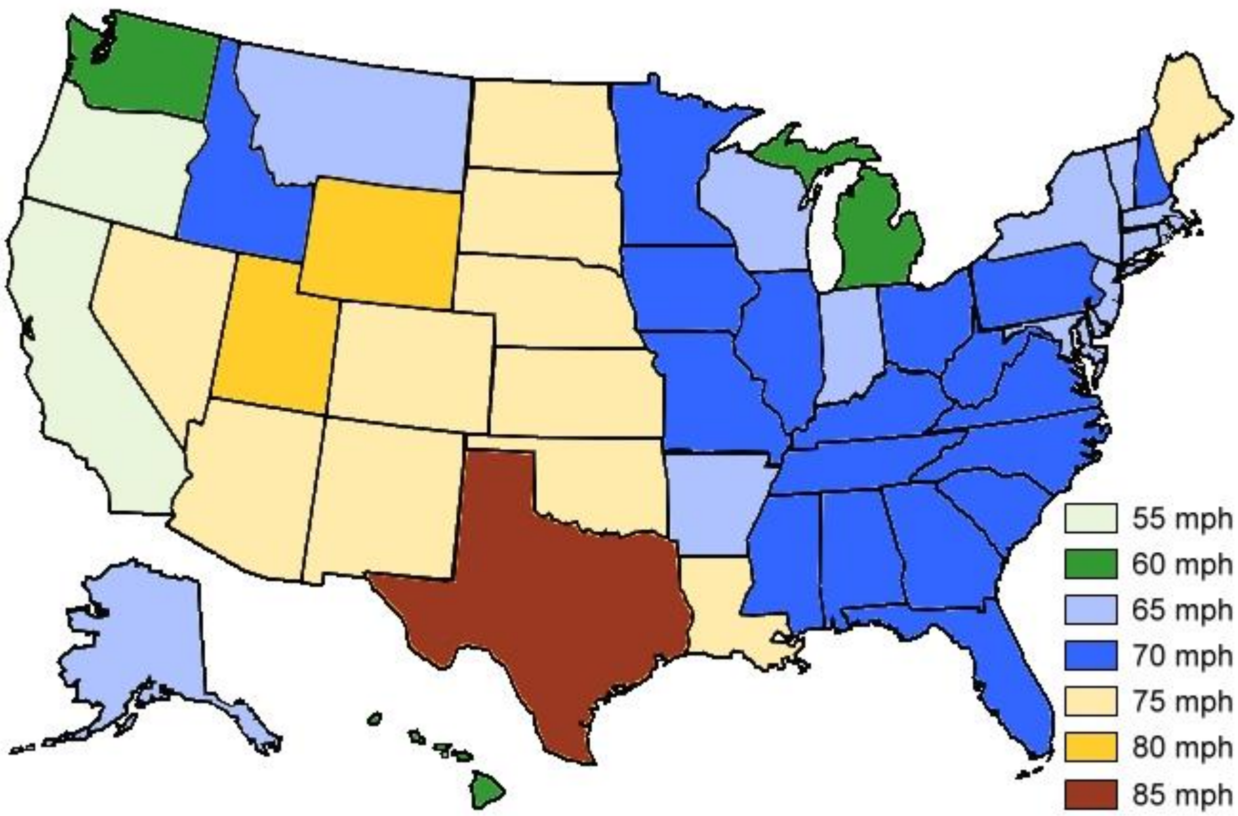


FIGURE 133. Maximum Daytime Truck Speed Limits by State, 2015

Source:
Insurance Institute for Highway Safety, Highway Loss Data Institute, January 2015.
http://www.iihs.org/laws/speedlimits.aspx

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.

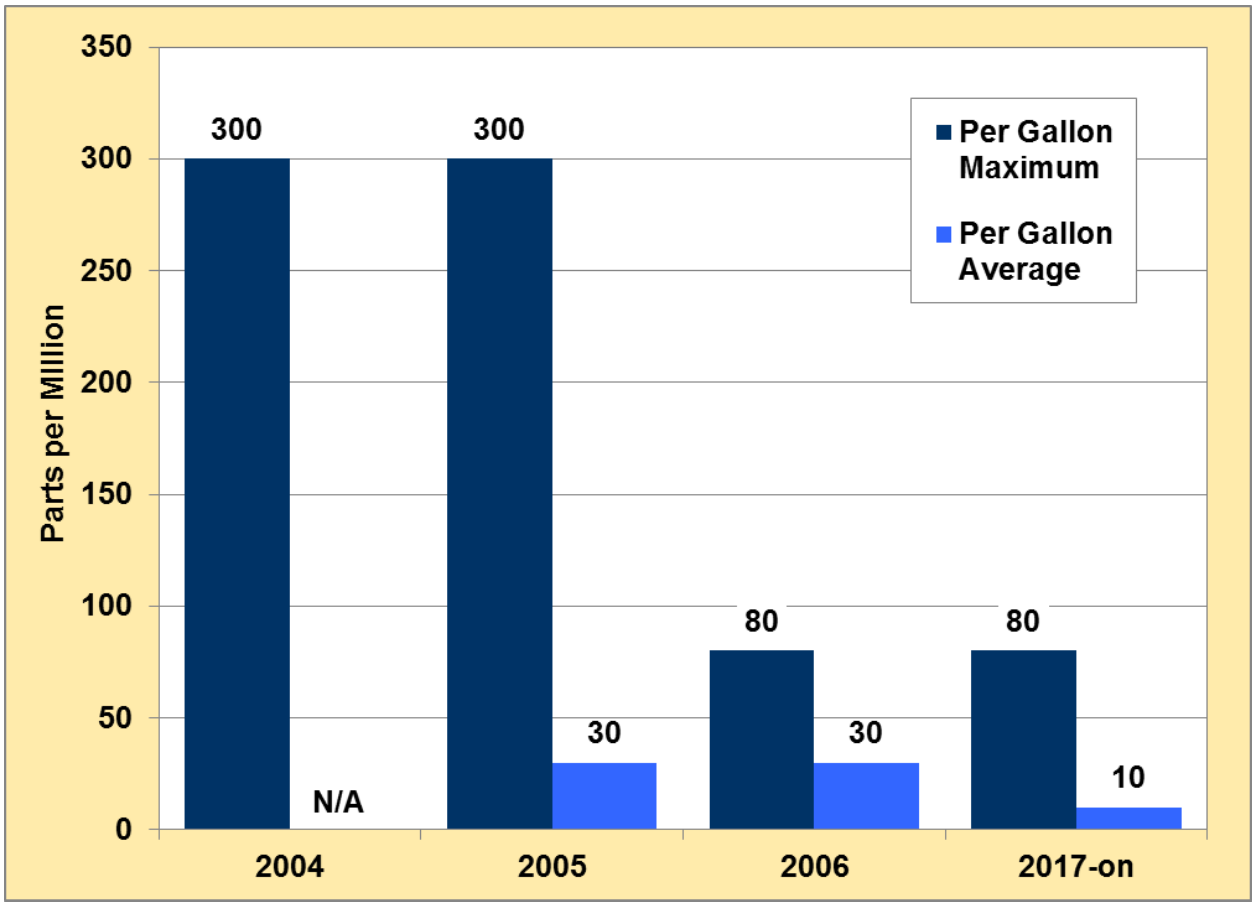


FIGURE 134. Gasoline Sulfur Standards, 2004-on

Note: N/A = not applicable.

Source:
U.S. Environmental Protection Agency, http://www.epa.gov/otaq/fuels/gasolinefuels/tier2/index.htm and http://www.epa.gov/otaq/tier3.htm.

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.

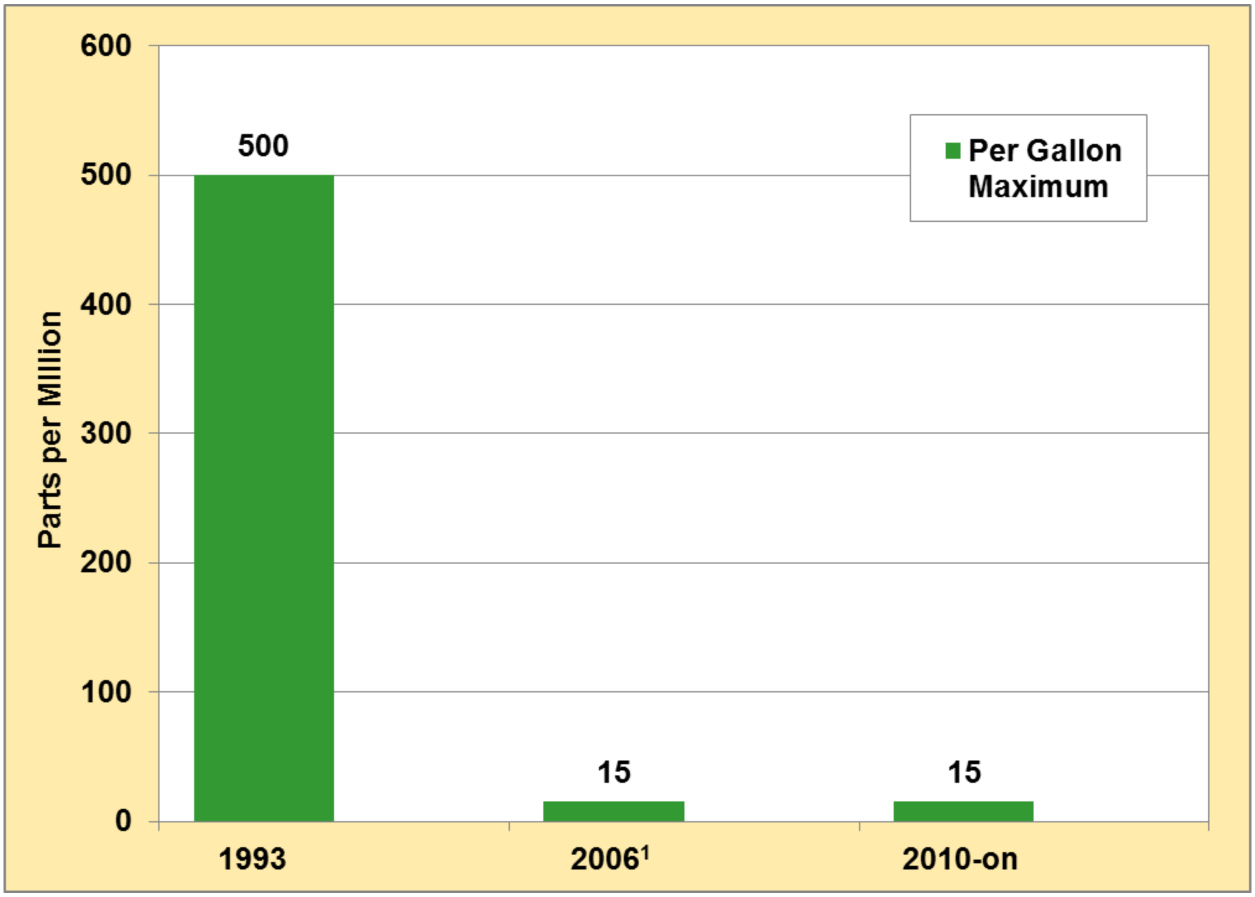


FIGURE 135. Diesel Sulfur Standards, 1993-on

[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, http://www.epa.gov/otaq/highway-diesel/regs/2007-heavy-duty-highway.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.

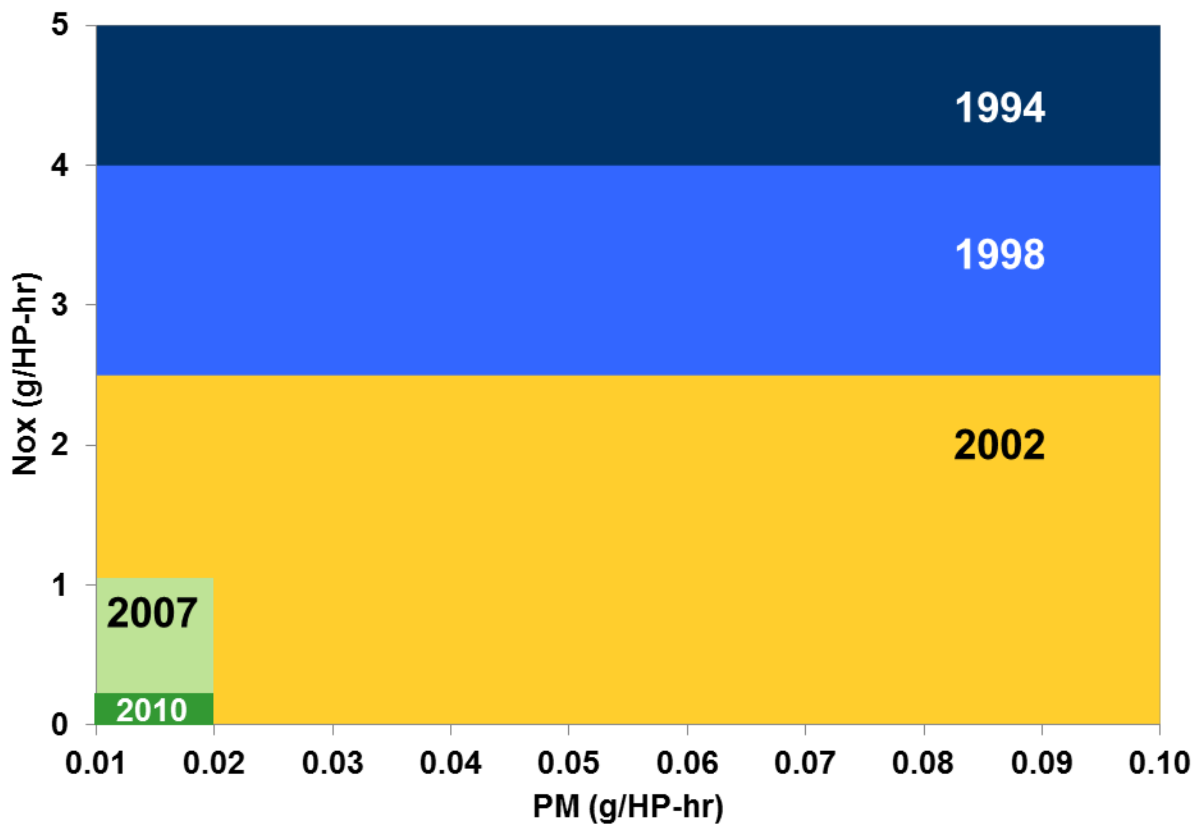


FIGURE 136. Diesel Emission Standards, 1994-2010

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.

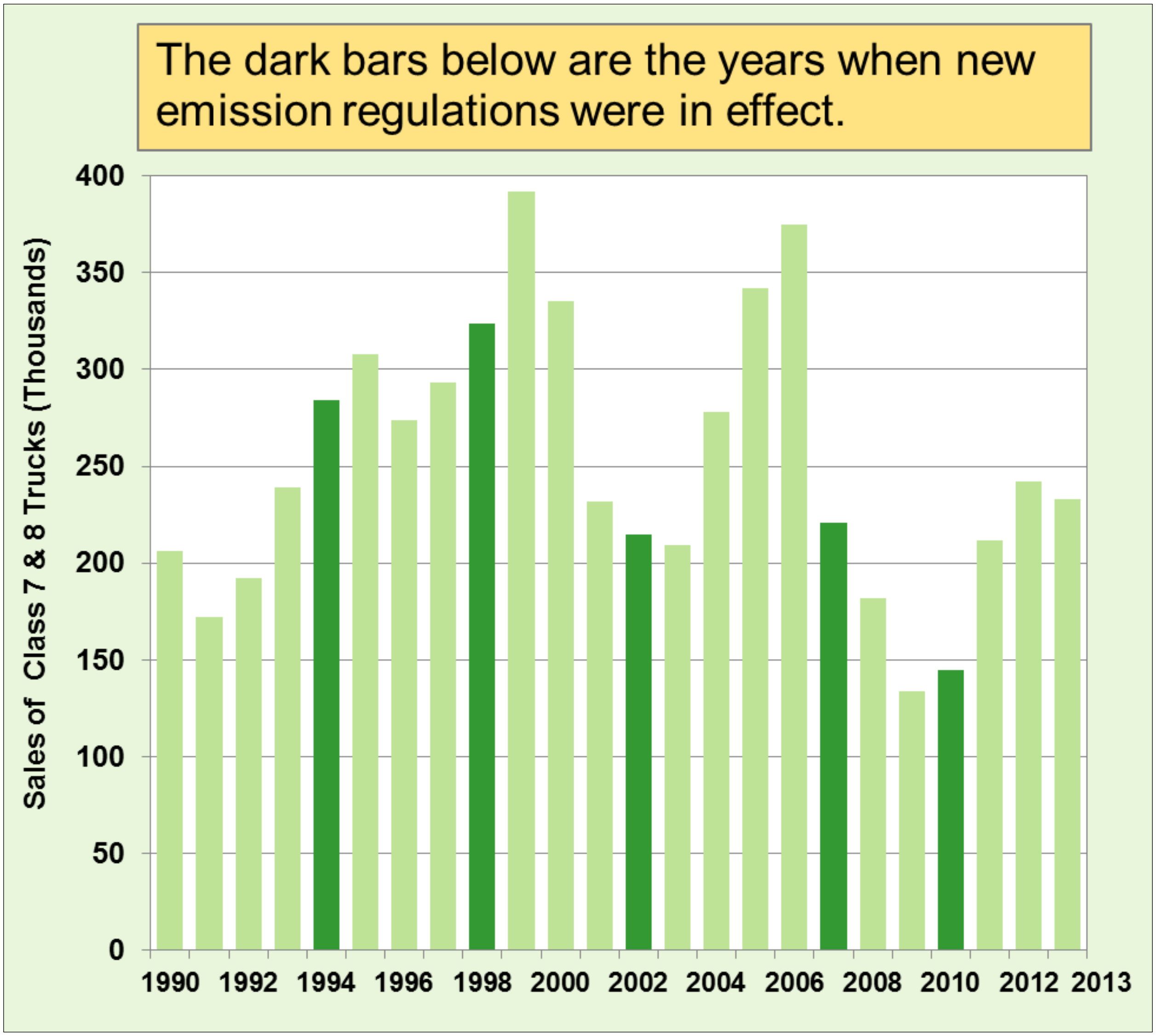


FIGURE 137. Class 7 and 8 Truck Sales, 1990-2013

Source:
Ward's Automotive Group, *Motor Vehicle Facts and Figures 2014*, Southfield, MI, 2014.
http://wardsauto.com