Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2013

Trends

MPG
CO_2
Report

EPA United States Environmental Protection Agency

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NOTICE:

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

TABLE OF CONTENTS

LIST OF FIGURES

List Of Tables

1 Introduction

This annual report (often referred to as the "Trends" report) is the authoritative reference on ***new*** light-duty (or personal) vehicle carbon dioxide (CO_2) emissions, fuel economy, and powertrain technology trends in the United States. These vehicles include passenger cars, sport utility vehicles, minivans, and all but the largest pickup trucks and vans. This report uses the most comprehensive database of its kind, both because it is comprised of detailed new vehicle test data provided, under statute, to EPA by automobile manufacturers, and because the database has been rigorously maintained since 1975. Since major methodological changes are propagated backwards through the historical database in order to maintain the integrity of long-term trends, this report supersedes all previous versions in the series and should ***not*** be compared to past reports.

Trends uses the term "fleetwide" to represent gasoline and diesel fueled vehicles, which represent 99+% of all vehicles produced since 1975.

Except where noted, all data in this report reflect the 99+ percent of all new personal vehicles that are dedicated to or are expected to operate primarily on gasoline or diesel fuel (including flexible fuel and conventional hybrid vehicles). Section 7 provides relevant data from the increasing number of electric, plug-in hybrid electric, and compressed natural gas vehicles produced for the U.S. market in 2013.

Trends uses harmonic averaging for fuel economy, which is essential to maintain mathematical integrity.

The CO_2 emissions and fuel economy data in this report are generated from the longstanding EPA test procedures that were first developed in the 1970s and refined in the subsequent decades. The CO_2 emissions data in this report reflect the sum of the vehicle tailpipe emissions of CO_2, carbon monoxide, and hydrocarbons, with the latter two converted to equivalent CO_2 levels on a mass basis. While carbon monoxide and hydrocarbon emissions add, on average, less than one percent to overall CO_2 emissions values, these compounds are included here because they are converted to CO_2 relatively quickly in the atmosphere, and to maintain consistency with the methods used for greenhouse gas (GHG) emissions standards compliance. The CO_2 emissions data do ***not*** reflect other vehicle greenhouse gases (such as methane, nitrous oxide, or air conditioner refrigerants) or CO_2 emissions associated with vehicle production and disposal, or fuel production and distribution.

The data presented in this report are tabulated on a model year (MY), not calendar year, basis and reflect MY 1975-2013. Data through MY 2012 are ***final*** (at the time of publication, EPA is in the process of submitting final manufacturer-specific CAFE values to NHTSA and the manufacturers), while data for MY 2013 are ***preliminary*** and will be finalized in next year's report. Vehicle population data represent production volumes delivered for sale in the U.S. market, rather than actual sales data.

Most of the data in this report reflect arithmetic production-weighted averages of individual CO_2 emissions values and harmonic production-weighted averages of individual fuel economy values (see Section 10 for details on harmonic averaging). The data in Sections 7 and 8 reflect individual models independent of production volumes.

Trends uses vehicle production data, not vehicle sales data, and aggregates production data for model years, not calendar years.

Unless noted, the CO_2 emissions and fuel economy values in this report are expressed as ***adjusted*** values based on EPA's 5-cycle test methodology (reflecting urban commuting, rural highway, high speed/acceleration, high temperature/air conditioning, and cold temperature operation). These adjusted values use a 43 percent city/57 percent highway weighting in order to be consistent with the national driving activity analysis underlying the development of the 5-cycle test methodology, and therefore yield EPA's best estimate of **real world** CO_2 emissions and fuel consumption. See Section 10 for a more detailed explanation of the methodology for how these adjusted values are calculated.

Type of CO_2 and Fuel Economy Data	*Purpose*	*City/Highway Weighting*	*Test Basis*
Adjusted	*Best estimate of real world performance*	*43%/57%*	*5-cycle (see text)*
Unadjusted, Laboratory	*Basis for automaker compliance with standards*	*55%/45%*	*2-cycle (see text)*

This report occasionally provides ***unadjusted, laboratory*** CO_2 emissions and fuel economy values based on EPA's 2-cycle test methodology (reflecting urban commuting and rural highway operation only). These unadjusted values are weighted 55 percent city/45 percent highway when used as the basis for ***automaker compliance*** with GHG emissions and corporate average fuel economy (CAFE) standards. Adjusted CO_2 emissions values are, on average, about 25% higher than unadjusted CO_2 values, and adjusted fuel economy values are about 20% lower than unadjusted fuel economy values. While the unadjusted values form the starting point for GHG emissions and CAFE standards compliance, they do not reflect various credits, incentives, and adjustments available to automakers.

In early 2014, EPA intends to publish a separate, annual GHG Report at epa.gov/otaq/regs/ld-hwy/greenhouse/ld-ghg.htm that will summarize individual manufacturer performance relative to the MY 2012 GHG emissions standards. The Department of Transportation's National Highway Traffic Safety Administration (NHTSA, at nhtsa.dot.gov/fuel-economy) also publishes a separate document entitled "Summary of Fuel Economy Performance" and will update this document after receiving final CAFE compliance data from EPA for all manufacturers.

This report has been extensively rewritten this year to focus on those trends and themes that we believe are the most important to a wide range of readers and users.

Important changes to this year's report:

- *It includes several new sections and many new tables and figures*
- *The vehicle classification schema has been simplified*
- *There is no longer a separate CO_2 emissions section*
- *The Executive Summary is now a separate document*
- *A few Appendices have been deleted*

2 Fleetwide Trends Overview

This section provides an overview of important fleetwide data for MY 1975-2013, including a reference table for CO_2 emissions, fuel economy, and several other key parameters. As discussed above, fleetwide refers to the production-weighted analysis of the 99+% of ***new*** vehicles that are dedicated to or are expected to operate primarily on gasoline or diesel fuel. Unless otherwise noted, all CO_2 emissions and fuel economy data are adjusted values that reflect real world performance, and are not comparable to unadjusted, laboratory values used for EPA emissions and NHTSA fuel economy standards compliance. Subsequent sections of the report analyze the Trends data in more detail.

A. Overview of Final MY 2012 Data

Table 2.1 shows that the fleetwide average real world CO_2 emissions rate for new vehicles produced in MY 2012 is 376 grams per mile (g/mi), a 22 g/mi decrease from MY 2011. The MY 2012 fuel economy value is 23.6 miles per gallon (mpg), a 1.2 mpg increase from MY 2011. These MY 2012 values, which represent an all-time record low for CO_2 emissions and record high for fuel economy, are based on final data. Both CO_2 emissions and fuel economy have improved in seven of the last eight years. The 1.2 mpg annual fuel economy increase is the fourth highest ever, exceeded only by the increases from MY 1979-1980, MY 1980-1981, and MY 2008-2009. It is likely that the CO_2 emissions and fuel economy improvements in MY 2012 are slightly larger than they otherwise would have been due to the impacts of the earthquake, tsunami, and nuclear tragedy in Japan in March 2011, which lowered MY 2011 car and car parts production in Japan.

Car production share of the overall personal vehicle market increased by 6 percentage points in MY 2012. Car-truck production share has been very volatile in recent years, and the increased car share in MY 2012 had significant impacts on other parameters. Average personal vehicle weight fell by 150 pounds (4%) in MY 2012, to its second lowest level in the last decade. Power decreased by 8 horsepower (3%), though it remains at its second highest level ever. Average vehicle footprint fell by 0.7 square foot (1%), remaining within a fairly narrow band over the last few years.

Tables 3.3.1 and 3.3.2, shown later in this report, disaggregate the data in Table 2.1 for the individual car and truck fleets, respectively, for MY 1975-2013.

B. Overview of Preliminary MY 2013 Data

Preliminary values for MY 2013 are 370 g/mi CO_2 emissions and 24.0 mpg and are based on projected vehicle production values provided to EPA by manufacturers prior to the beginning of the model year. Final values for MY 2013 will be published in next year's report. The preliminary data suggest that truck production share will remain unchanged and that vehicle weight, horsepower, and footprint will all increase somewhat in MY 2013, with power levels tying an all-time high.

Table 2.1

Adjusted CO_2 Emissions, Adjusted Fuel Economy, and Key Parameters for MY 1975-2013

	New Gasoline and Diesel Vehicles									Gasoline and Diesel Share of All Vehicle Production
Model Year	Production (000)	Adj CO_2 (g/mi)	Adj Fuel Economy (MPG)	Weight (lb)	HP	Footprint (sq ft)	0-to-60 Time (sec)	Car Production	Truck Production	
1975	10,224	681	13.1	4060	137	-	14.1	80.7%	19.3%	100.0%
1976	12,334	625	14.2	4079	135	-	14.3	78.9%	21.1%	100.0%
1977	14,123	590	15.1	3982	136	-	13.8	80.1%	19.9%	100.0%
1978	14,448	562	15.8	3715	129	-	13.6	77.5%	22.5%	100.0%
1979	13,882	560	15.9	3655	124	-	13.9	77.9%	22.1%	100.0%
1980	11,306	466	19.2	3228	104	-	14.3	83.5%	16.5%	100.0%
1981	10,554	436	20.5	3202	102	-	14.4	82.8%	17.2%	100.0%
1982	9,732	425	21.1	3202	103	-	14.4	80.5%	19.5%	100.0%
1983	10,302	426	21.0	3257	107	-	14.1	78.0%	22.0%	100.0%
1984	14,020	424	21.0	3262	109	-	14.0	76.5%	23.5%	100.0%
1985	14,460	417	21.3	3271	114	-	13.5	75.2%	24.8%	100.0%
1986	15,365	407	21.8	3238	114	-	13.4	72.1%	27.9%	100.0%
1987	14,865	405	22.0	3221	118	-	13.1	72.8%	27.2%	100.0%
1988	15,295	407	21.9	3283	123	-	12.8	70.9%	29.1%	100.0%
1989	14,453	415	21.4	3351	129	-	12.5	70.1%	29.9%	100.0%
1990	12,615	420	21.2	3426	135	-	12.2	70.4%	29.6%	100.0%
1991	12,573	418	21.3	3410	138	-	12.1	69.6%	30.4%	100.0%
1992	12,172	427	20.8	3512	145	-	11.8	68.6%	31.4%	100.0%
1993	13,211	426	20.9	3519	147	-	11.8	67.6%	32.4%	100.0%
1994	14,125	436	20.4	3603	152	-	11.7	61.9%	38.1%	100.0%
1995	15,145	434	20.5	3613	158	-	11.3	63.5%	36.5%	100.0%
1996	13,144	435	20.4	3659	164	-	11.1	62.2%	37.8%	100.0%
1997	14,458	441	20.2	3727	169	-	11.0	60.1%	39.9%	100.0%
1998	14,456	442	20.1	3744	171	-	10.9	58.3%	41.7%	100.0%
1999	15,215	451	19.7	3835	179	-	10.7	58.3%	41.7%	100.0%
2000	16,571	450	19.8	3821	181	-	10.6	58.8%	41.2%	100.0%
2001	15,605	453	19.6	3879	187	-	10.5	58.6%	41.4%	100.0%
2002	16,115	457	19.5	3951	195	-	10.2	55.3%	44.7%	100.0%
2003	15,773	454	19.6	3999	199	-	10.2	53.9%	46.1%	100.0%
2004	15,709	461	19.3	4111	211	-	9.9	52.0%	48.0%	100.0%
2005	15,892	447	19.9	4059	209	-	9.9	55.6%	44.4%	100.0%
2006	15,104	442	20.1	4067	213	-	9.8	57.9%	42.1%	100.0%
2007	15,276	431	20.6	4093	217	-	9.7	58.9%	41.1%	100.0%
2008	13,898	424	21.0	4085	219	48.9	9.7	59.3%	40.7%	100.0%
2009	9,315	397	22.4	3914	208	48.1	9.7	67.0%	33.0%	100.0%
2010	11,110	394	22.6	4002	214	48.6	9.6	62.7%	37.3%	100.0%
2011	12,003	398	22.4	4127	230	49.5	9.4	57.8%	42.2%	99.9%
2012	13,438	376	23.6	3977	222	48.8	9.4	64.4%	35.6%	99.6%
2013	-	*370*	*24.0*	*4041*	*230*	*49.1*	*9.3*	*64.4%*	*35.6%*	-

C. Overview of Long-Term Trends

While the most recent annual changes often receive the most public attention, the greatest value of the Trends database is to document long-term trends. This is because: 1) year-to-year variability can reflect short-term trends (recent examples include the economic recession and Cash for Clunkers rebates in 2009, the impact of the tsunami aftermath on Japan-based manufacturers in 2011, and changes in gasoline prices) that may not be meaningful from a long-term perspective, and 2) the magnitude of year-to-year changes in annual CO_2 emissions and fuel economy tend to be small relative to longer, multi-year trends.

Figures 2.1 and 2.2 show fleetwide adjusted CO_2 emissions and fuel economy from Table 2.1 for MY 1975-2013. For both figures, the individual data points represent annual values, and the curves represent 3-year moving averages (where each year represents the average of that model year, the model year prior, and the model year following, e.g., the value for MY 2012 represents the average of MY 2011-2013) which "smooth out" the year-to-year volatility. The two curves are essentially "inversely proportional" to each other, i.e., vehicle tailpipe CO_2 emissions (grams per mile) are proportional to fuel consumption (gallons per mile), which is the reciprocal of fuel economy (miles per gallon).

Figure 2.1

Adjusted CO_2 Emissions for MY 1975-MY 2013

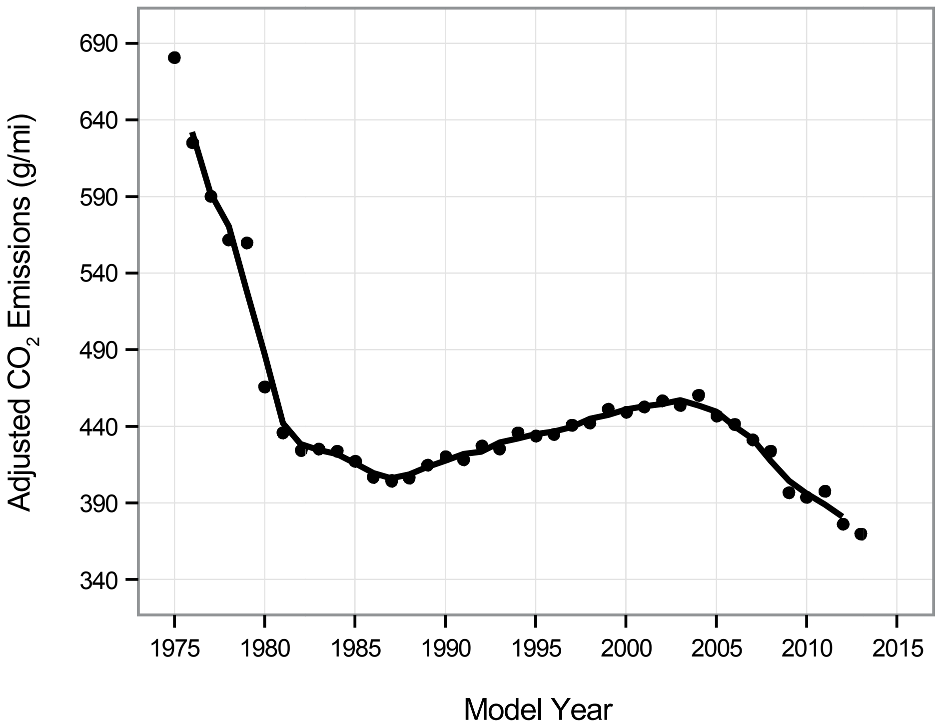
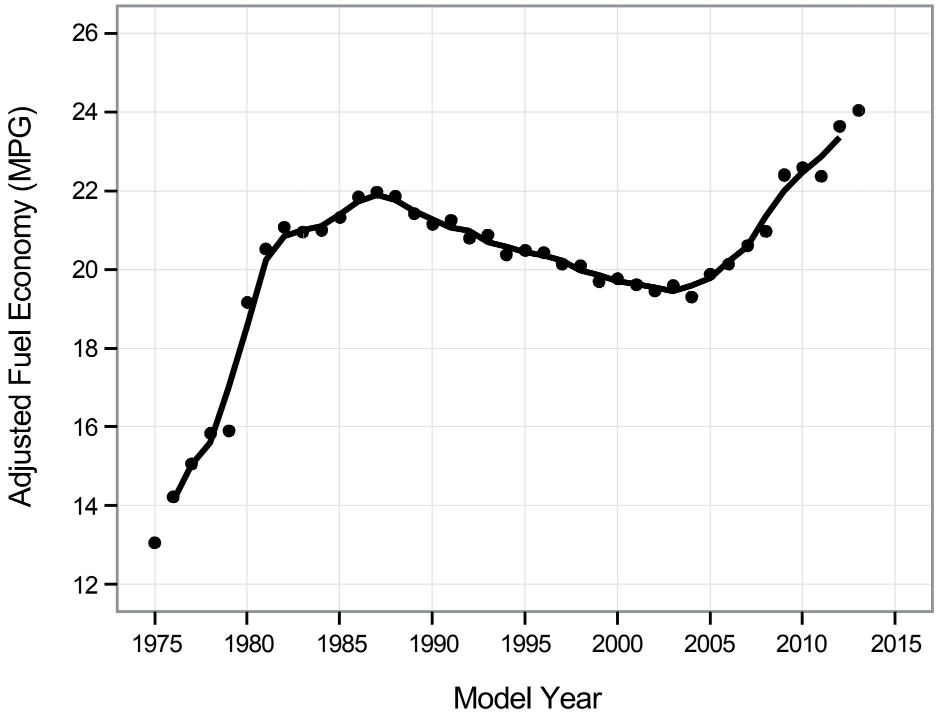


Figure 2.2

Adjusted Fuel Economy for MY 1975-MY 2013



These two figures show that fleetwide adjusted CO_2 emissions and fuel economy have undergone four clearly defined phases since 1975. Figure 2.3 shows fleetwide adjusted fuel economy, weight, and horsepower data for MY 1975-2013 from Table 2.1. All of the data in Figure 2.3 are presented as percentage changes since 1975. Vehicle weight and horsepower are critical vehicle attributes in that higher values, other things being equal, will increase CO_2 emissions and decrease fuel economy.

Long-Term CO_2 Emissions and Fuel Economy Phases:

- ***Rapid improvements from MY 1975 through MY 1981, with fleet-wide adjusted CO_2 emissions decreasing by 36% and fuel economy increasing by 56% over those six years***
- ***Slower improvements from MY 1982 through MY 1987***
- ***A slow, but steady reversal of improvements from MY 1988 through MY 2004, with CO_2 emissions increasing by 14% and fuel economy decreasing by 12%, even as technology innovation continued to evolve***
- ***A very favorable trend beginning in 2005, with annual CO_2 emissions and fuel economy improvements in seven of the eight individual years, and with CO_2 emissions decreasing by 18% and fuel economy increasing by 22% since MY 2004***

Figure 2.3

Adjusted Fuel Economy, Weight, and Horsepower for MY 1975-2013

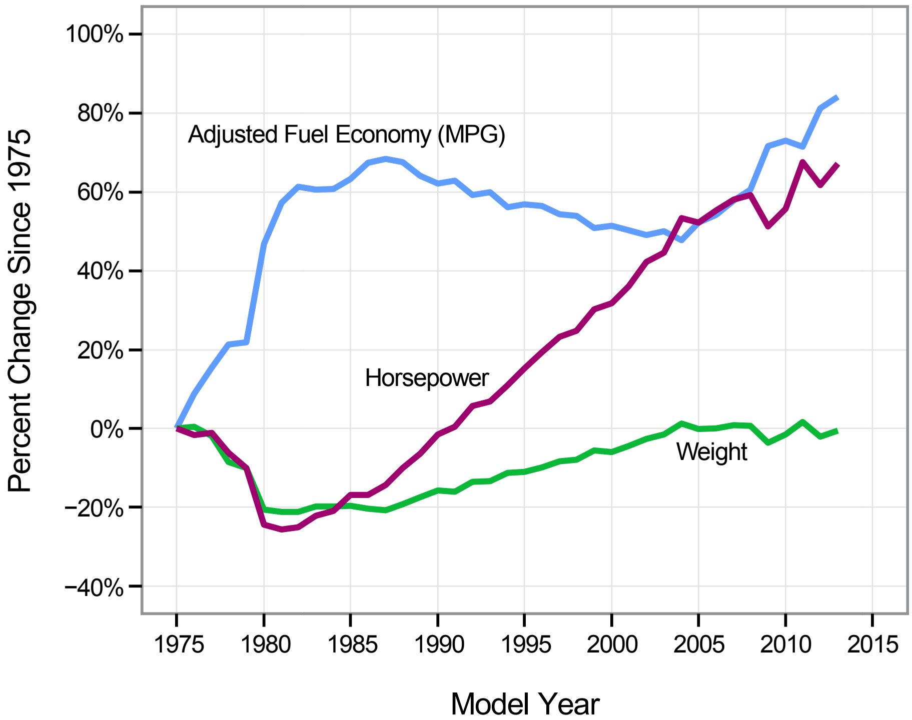


Figure 2.3 shows some very significant long-term trends. Both average vehicle weight and horsepower decreased in the late 1970s as fuel economy increased. During the two decades from the mid-1980s to the mid-2000s, vehicle weight and horsepower rose consistently and significantly, while fuel economy steadily decreased. It is clear from Figure 2.3 that the considerable technology innovation during these two decades, on a fleet-wide basis, supported attributes such as vehicle weight and power (and associated utility functions such as vehicle size, acceleration performance, safety features and content), but did not improve fuel economy. Since MY 2005, new automotive technology has improved both fuel economy and power, while keeping vehicle weight relatively constant. As a result, recent vehicles have greater acceleration performance, higher fuel economy, and lower CO_2 emissions.

Table 2.1 shows data for vehicle footprint and estimated 0-60 miles per hour acceleration time. Footprint is a critical vehicle attribute since it is the basis for current and future GHG emissions and fuel economy standards. The Trends database includes footprint data from external sources beginning in MY 2008, but because footprint data has only been provided by automakers since MY 2011, it is impossible to discern any long-term footprint trends at this time. Estimated 0-60 acceleration times are calculated based on a relationship between acceleration, horsepower, and weight (see Section 10). For more detail on weight, horsepower, footprint, and 0-60 acceleration times, see Section 3.

Table 2.1 also shows that truck share increased consistently from 1980 through 2004. The truck share increases from 1988 through 2004 were a critical underlying factor in the increase in fleet-wide weight and power discussed above, as well as in the higher fleet-wide CO_2 emissions and lower fleet-wide fuel economy over that same period. Since 2004, truck share has been volatile, affected by factors such as the economic recession of 2009, the Car Allowance Rebate System (also known as Cash for Clunkers) in 2009, and the aftermath of the earthquake and tsunami in Japan in 2011. For more data and discussion of relative car/truck production share, as well as data for the separate car and truck fleets, see Section 3.

Table 2.2 shows a comparison, for fuel economy and several other key attributes, of final MY 2012 data with MY 2008 and MY 2004 data, all taken from Table 2.1.

MY 2008 is selected for comparison for three reasons: 1) four years provide a sufficient time to see meaningful multi-year trends, 2) it preceded a multi-year period of variability beginning in MY 2009, and 3) there have only been relatively minor changes in key vehicle attributes that influence fuel economy in the four years that followed. From MY 2008 to MY 2012, weight decreased by 2.6% (which would be expected to result in a slight increase in fuel economy, other things being equal), while horsepower increased by 1.4% (which would be expected to result in a slight decrease in fuel economy), so these two impacts counter balance to some degree. Footprint remained essentially unchanged. Fuel economy, on the other hand, increased by 2.6 mpg, or 12%, from MY 2008 to MY 2012.

MY 2004 is shown in Table 2.2 primarily because it is the "valley year," i.e., it is the year with the lowest adjusted fuel economy since MY 1980 and therefore now represents a 32-year low. As with the comparison of MY 2008 and MY 2012 above, the changes in weight and horsepower from MY 2004 to MY 2012 have gone in opposite directions—weight has decreased by 3.3% and horsepower has increased by 5.2%. We do not have footprint data for MY 2004. From MY 2004 to MY 2012, fuel economy has increased by 4.3 mpg, or 22%.

These fuel economy increases of 12% since MY 2008 and 22% since MY 2004 are unprecedented over the last 30 years. As shown in Table 2.1, the only other period with a greater and more rapid fuel economy increase was from MY 1975 through MY 1981.

Table 2.2

Comparison of MY 2012 with MY 2008 and MY 2004

MY 2012 Relative to MY 2008

Fuel Economy		Weight	Horsepower	Footprint
MPG	%	%	%	%
+2.6	+12	-2.6	+1.4	-0.2

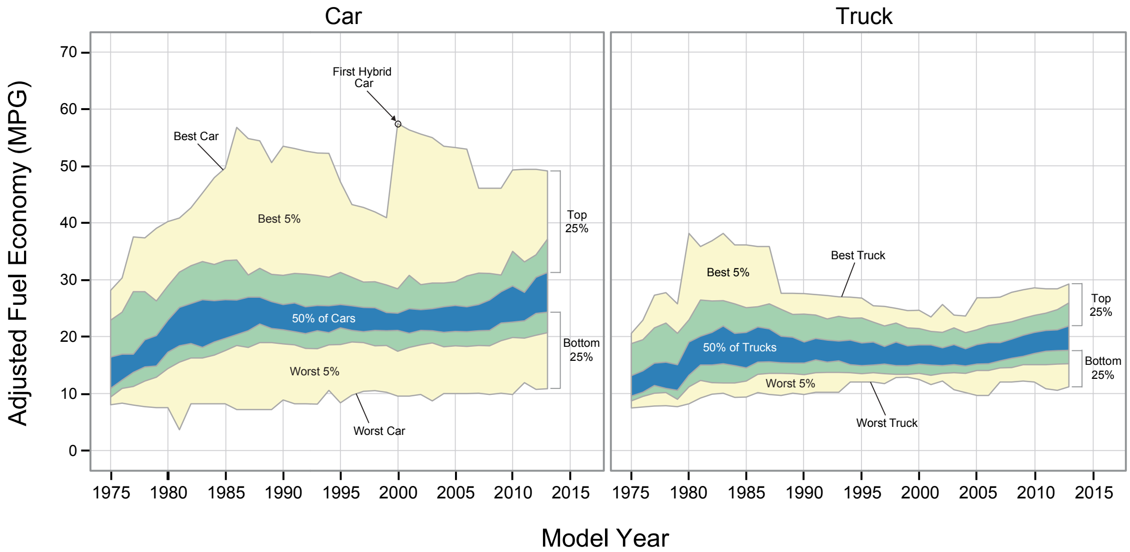
MY 2012 Relative to MY 2004

Fuel Economy		Weight	Horsepower	Footprint
MPG	%	%	%	%
+4.3	+22	-3.3	+5.2	-

Figure 2.4 shows the production-weighted distribution of adjusted fuel economy by model year, for gasoline (including conventional hybrids) and diesel vehicles (no electric or natural gas fuel vehicles are included in Figure 2.4). It is important to note that the methodology used in this report for calculating adjusted fuel economy values has changed over time (see Section 10 for a detailed explanation). For example, the adjusted fuel economy for a 1980s vehicle in the Trends database is somewhat higher than it would be if the same vehicle were being produced today. These changes are small for most vehicles, but larger for very-high fuel economy vehicles. For example, the "Best Car" line in Figure 2.4 for MY 2000 through MY 2006 represents the original Honda Insight hybrid, and the several miles per gallon decrease over that period is primarily due to the change in methodology for adjusted fuel economy values, with just a 1 mpg decrease due to minor vehicle design changes during that time.

Figure 2.4

Production-Weighted Adjusted Fuel Economy Distribution for MY 1975-MY 2013



Since 1975, half of car production has consistently been within several mpg of each other. The fuel economy difference between the least efficient and most efficient car increased from about 20 mpg in MY 1975 to nearly 50 mpg in MY 1986 (when the most efficient car was the General Motors Sprint ER) and in MY 2000 (when the most efficient car was the original Honda Insight hybrid), and is now about 40 mpg. Hybrids have defined the "Best Car" line since MY 2000. The ratio of the highest-to-lowest fuel economy has increased from about three-to-one in MY 1975 to nearly five-to-one today, as the fuel economy of the least fuel efficient cars has remained roughly constant in comparison to the most fuel efficient cars whose fuel economy has nearly doubled since MY 1975.

The overall fuel economy distribution for trucks is narrower than that for cars, with a peak in the fuel economy of the most efficient truck in the early 1980s when small pickup trucks equipped with diesel engines were sold by Volkswagen and General Motors. As a result, the fuel economy range between the most efficient and least efficient truck peaked at about 25 mpg in the early 1980s. The fuel economy range for trucks then narrowed, and is now less than 20 mpg. Like cars, half of the trucks built each year have always been within a few mpg of each year's average fuel economy value.

All of the above data are adjusted, combined city/highway CO_2 emissions and fuel economy values for the combined car and truck fleet. Table 10.1 provides, for the overall car and truck fleets, adjusted and unadjusted, laboratory values for city, highway, and combined city/highway. Appendices B and C provide more detailed data on the distribution of adjusted fuel economy values by model year.

Finally, Table 2.3 shows the highest fuel economy gasoline and diesel vehicles for the MY 1975-2013 time frame (while the Trends report database began in MY 1975, we are confident that these are also the highest fuel economy values of all time for mainstream vehicles in the U.S. market). Note that alternative fuel vehicles, such as electric and plug-in hybrid electric vehicles, are excluded from this table. See Appendix A for a listing of the highest and lowest fuel economy vehicles, based on unadjusted fuel economy values, for each year since 1975.

<u>Unadjusted, laboratory</u> fuel economy (weighted 55% city/45% highway) values are used to rank vehicles in Table 2.3, since the test procedures and methodology for determining unadjusted, laboratory fuel economy values have been unchanged since 1975. Accordingly, unadjusted, laboratory values provide a more equitable fuel economy metric, from a vehicle design perspective, over the historical time frame, than the adjusted fuel economy values used throughout most of this report, as the latter also reflect changes in real world driving behavior such as speed, acceleration, and use of air conditioning.

For Table 2.3, vehicle models with the same powertrain and essentially marketed as the same vehicle to consumers are shown only once. Models are typically sold for several years before being redesigned, so the convention for models with the same fuel economy for several years is to show MY 2013, if applicable, and otherwise to show the first year when the model achieved its maximum fuel economy. Data are also shown for number of seats, inertia weight class, and projected 0-60 acceleration time.

Table 2.3

Top Ten Highest Unadjusted, Laboratory Fuel Economy Gasoline/Diesel Vehicles for MY 1975-MY 2013

Model Year	Manufacturer	Model	Powertrain	Unadjusted, Laboratory Combined Fuel Economy (MPG)	Number of Seats	Inertia Weight Class (lbs)	0-to-60 Accel (sec)
2000	Honda	Insight	Gasoline Hybrid	76	2	2000	11
2013	Toyota	Prius	Gasoline Hybrid	71	5	3500	10
2013	Toyota	Prius c	Gasoline Hybrid	71	5	2750	11
1986	GM	Sprint ER	Conv. Gasoline	67	4	1750	16
1989	GM	Metro XFi	Conv. Gasoline	66	4	1750	14
2013	Ford	Fusion	Gasoline Hybrid	66	5	4000	8
1986	Honda	Civic CRX HF	Conv. Gasoline	64	2	2000	15
2013	Honda	Civic	Gasoline Hybrid	63	5	3000	10
2013	VW	Jetta	Gasoline Hybrid	61	5	3500	9
1994	Honda	Civic HB VX	Conv. Gasoline	60	5	2250	12

As expected, all of the vehicles listed in Table 2.3 are cars. The top fuel economy vehicle is the MY 2000 Honda Insight, a two-seater that was the first hybrid vehicle sold in the U.S. market. The MY 2000 Insight had an unadjusted, laboratory value of 76 mpg, 5 mpg higher than the MY 2013 Prius and Prius c vehicles, which are the second and third highest fuel economy vehicles, both of which have unadjusted, laboratory fuel economy values of 71 mpg.

Five of the highest ten fuel economy gasoline and diesel vehicles of all time are on the market in MY 2013, and all of these are conventional hybrids. In addition to the MY 2000 Insight, the remaining four vehicles in Table 2.3 are non-hybrid gasoline vehicles from the late 1980s and early 1990s.

One of the most important lessons from Table 2.3 is that there are important differences between the highest fuel economy vehicles of the past and those of today. All but one of the pre-MY 2013 vehicles in Table 2.3 had 2 or 4 seats, while the MY 2013 vehicles all seat 5 passengers. The pre-MY 2013 vehicles had inertia weight class values of 1750-2250 pounds, while the MY 2013 vehicles are in inertia weight classes of 2750-4000 pounds, or 1000-2000 pounds heavier. While the MY 2013 vehicles have 0-60 acceleration times of 8-11 seconds, three of the pre-MY 2013 vehicles have 0-60 acceleration times of 14 seconds or greater. Though not shown in Table 2.3, MY 2013 vehicles were also required to meet more stringent DOT safety standards than vehicles produced in the earlier model years. One clear conclusion from Table 2.3 is that conventional hybrid technology has enabled manufacturers to offer high fuel economy vehicles with much greater utility than the high fuel economy vehicles of the past.

3 Vehicle Class, Type, and Attributes

A. Vehicle Class

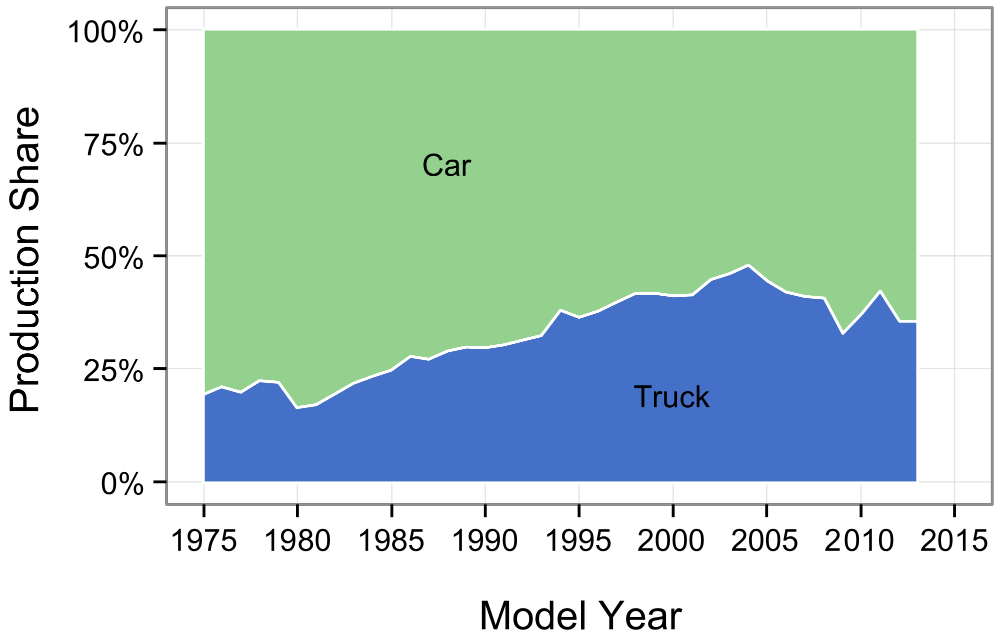
We use "class" to refer to the overall division of light-duty (or personal) vehicles into the two classes of "cars" and "trucks." This car-truck distinction has been recognized since the database was originated in the 1970s, though the precise definitions associated with these two classes have changed somewhat over time. Car-truck classification is important both because of functional differences between the design of many cars and trucks, and because there are now separate footprint-based CO_2 emissions and fuel economy standards curves for cars and trucks. The regulatory challenge has been where to draw the line between the highest-utility cars and the lowest-utility trucks, and this has been why car-truck definitions have evolved over time.

Car and truck classifications in this report are based on the current regulatory definitions used by both EPA and NHTSA for CO_2 emissions and fuel economy standards. These current definitions are somewhat different than those used in older versions of this report. The most important recent change was re-classification of many small and mid-sized, 2-wheel drive sport utility vehicles (SUVs) from the truck category to the car category. As with other such changes in this report, this change has been propagated back throughout the entire historical database. This re-classification reduced the absolute truck share by approximately 10% for recent years. A second recent change was the inclusion of medium-duty passenger vehicles (MDPVs), those SUVs and passenger vans with gross vehicle weight ratings between 8500 and 10,000 pounds and which previously had been treated as heavy-duty vehicles, into the light-duty truck category. But, this is a far less important change, since the number of MDPVs is much smaller than it once was (e.g., only 6500 MDPVs were sold in MY 2012). In this report, "cars" include passenger cars and most small and mid-sized, 2 wheel-drive SUVs, while "trucks" include all other SUVs, minivans and vans, and pickup trucks below 8500 pounds gross vehicle weight rating.

Figure 3.1 shows the car and truck production volume shares for MY 1975-2013 using the current car-truck definitions throughout the database.

Figure 3.1

Car and Truck Production Share for MY 1975-2013



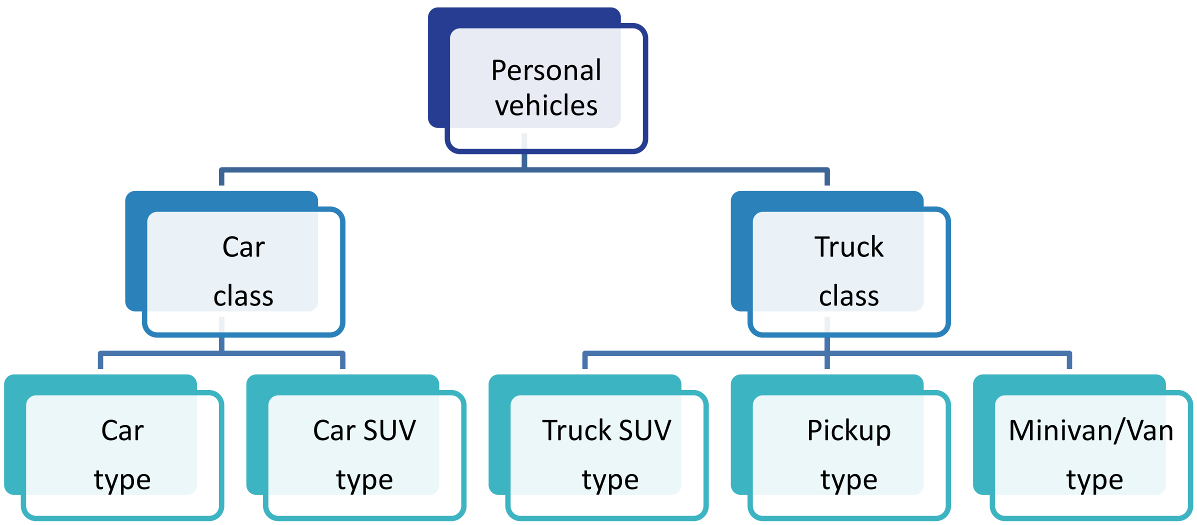
Truck share was around 20% from MY 1975-1982, and then started to increase steadily through MY 2004, when it peaked at 48%. The truck share increases from MY 1988-2004, a period during which inflation-adjusted gasoline prices remained at or near historical lows, were a critical factor in the increased fleetwide CO_2 emissions and decrease in fleetwide fuel economy over that same period. Since 2004, truck share has been volatile, affected by factors such as the economic recession of 2009, the Car Allowance Rebate System (also known as Cash for Clunkers) in 2009, and the earthquake and tsunami aftermath in Japan in 2011.

The final truck share value for MY 2012 is 36%, a 6 percentage point decrease relative to MY 2011 and 12 percentage points lower than the peak truck share of 48% in MY 2004. The MY 2013 truck market share is projected to remain at 36%.

B. Vehicle Type

We use vehicle "type" to refer to secondary divisions within the car and truck classes. Vehicle type is not relevant to standards compliance, as all cars (and, separately, all trucks) use the same footprint-CO_2 emissions and footprint-fuel economy target curves, but we believe that certain vehicle type distinctions are illustrative and meaningful from both vehicle design and marketing perspectives.

This report breaks the car class into two types—cars and car SUVs. The truck class is split into three types—truck SUVs, pickups, and minivans/vans. This is a simpler approach than that used in previous versions of this report.

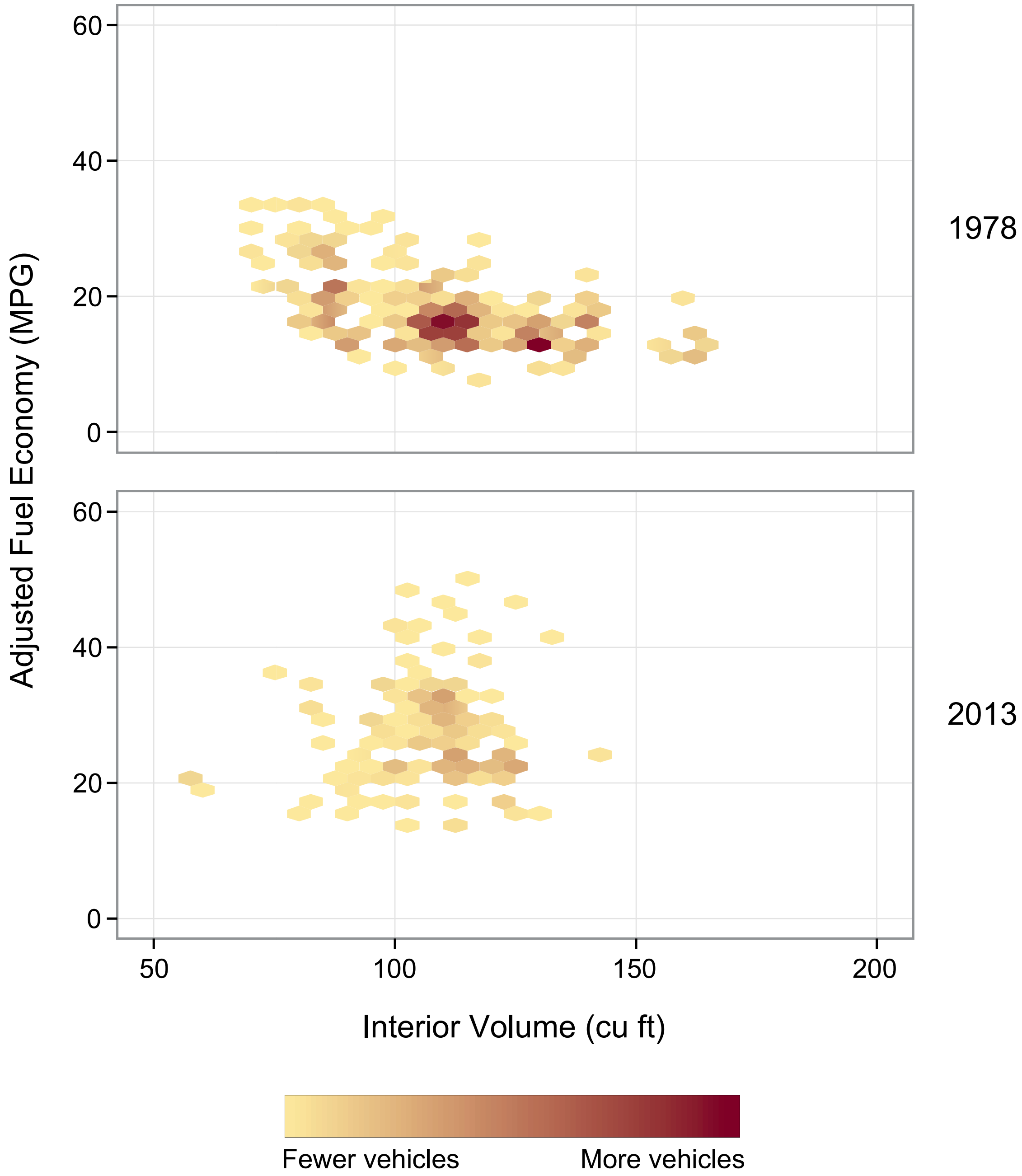


For cars, previous versions of this report generally divided the car class into 9 types/sizes (cars, Wagons, and car SUVs, each further subdivided into small, medium, and large sizes based on interior volume). We no longer use wagons as a car type in this report. Wagons only represent 3% of fleet-wide production in MY 2012.

More importantly, we believe that interior volume (the sum of passenger volume and cargo volume, typically measured in cubic feet), the metric that has historically been used to differentiate various car types and sizes, is not as informative as it once was. For example, Figure 3.2 shows fuel economy versus interior volume for the car type for two years, MY 1978 and MY 2013, for high-volume manufacturers.

Figure 3.2

Adjusted Fuel Economy vs. Interior Volume for High Volume Manufacturers: MY 1978 and MY 2013: Car Type Only



The data in Figure 3.2 illustrate the "compression" in the range of interior volumes for car type vehicles since 1978. In MY 1978, there were mainstream car type vehicles on the market with interior volumes ranging from about 70 cubic feet to about 160 cubic feet, with a large number of offerings at both ends of the spectrum. Today, mainstream offerings range from about 80 cubic feet to about 130 cubic feet, with just a few outliers at about 55 and 140 cubic feet. The compression is even greater when considering production volumes. We reviewed the data for one high-volume make that offered seven car type models in MY 2012. The interior volume of these seven models ranged from 97-124 cubic feet, with 75% of sales within a very narrow interior volume range of 104-111 cubic feet, and about 50% of production (representing 3 models) with essentially the same interior volume (110-111 cubic feet).

Based on the above figures and data, we believe that interior volume is no longer useful as a differentiator for the car types in the Trends database, and we will no longer use the small/medium/large vehicle size metric based on interior volume. We believe that vehicle footprint is a more appropriate indicator of car size because it is the basis for both CO_2 emissions and fuel economy standards (and it is relevant to both cars and trucks). Interior volume data for car type vehicles will still be included in the Trends database.

As a result, this report now divides the car class into two types: 1) a car SUV type for those SUVs that must meet the car GHG emissions and fuel economy standards, and 2) a car type for all other vehicles in the car class, including the fueleconomy.gov designations of minicompact, subcompact, compact, midsize, large, two-seater cars, and station wagons. For propagating back in the historical database, station wagons are generally allocated to the car type.

For trucks, previous versions of this report divided the truck class into 9 types/sizes (SUVs, Pickups, and Vans (including minivans), each further subdivided into small, medium, and large sizes based on vehicle wheelbase). This report retains the three truck types because we believe that there continue to be meaningful functional and marketing differences between truck SUVs (those SUVs that must meet the truck GHG emissions and fuel economy standards), pickups, and minivans/vans. See Section 10 for the definitions for SUVs, pickups, minivans, and vans and for more information about car-truck classifications. We use engineering judgment to allocate the very small number of special purpose vehicles (as designated on fuel economy.gov) to the three truck types.

It is important to note that this report no longer uses wheelbase to differentiate between truck type sizes. The rationale for this change, similar to that for car interior volume above, is that the wheelbase metric is not as informative as it once was. For example, under the wheelbase thresholds that were used in the 2012 report, 99% of MY 2011 pickups are "large" and 99% of MY 2011 minivans/vans are "medium." In addition, since wheelbase is one of the two factors associated with vehicle footprint (wheelbase times average track width), we believe that vehicle footprint is a more appropriate indicator of truck size.

Figure 3.3 shows the car and truck production volume shares for MY 1975-2013, subdivided into the two car types and three truck types. Table 3.1 shows the same data in tabular form.

Figure 3.3

Vehicle Type Production Share by Model Year

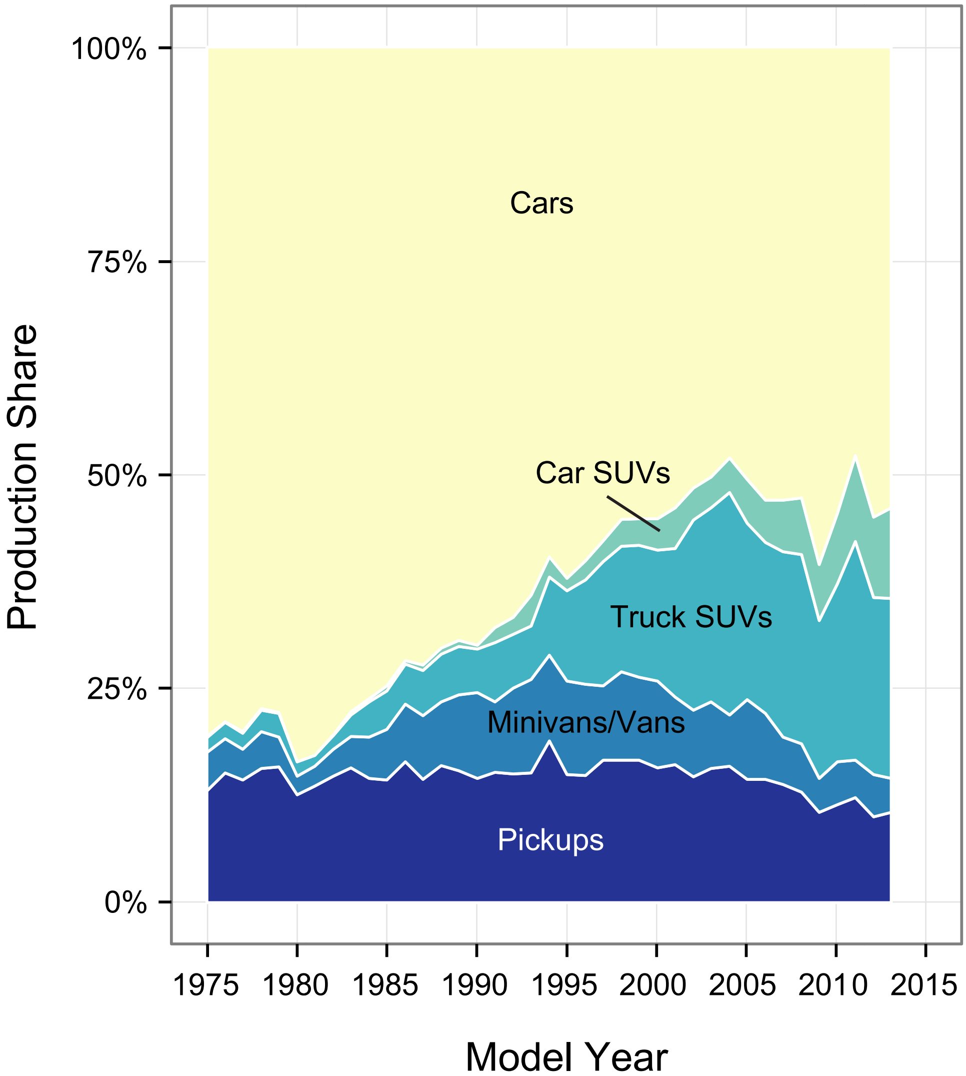


Table 3.1

Vehicle Type Production Share by Model Year

Model Year	Cars	Car SUVs	All Cars	Truck SUVs	Pickups	Minivans/ Vans	All Trucks
1975	80.6%	0.1%	80.7%	1.7%	13.1%	4.5%	19.3%
1976	78.8%	0.1%	78.9%	1.9%	15.1%	4.1%	21.1%
1977	80.0%	0.1%	80.1%	1.9%	14.3%	3.6%	19.9%
1978	77.3%	0.1%	77.5%	2.5%	15.7%	4.3%	22.5%
1979	77.8%	0.1%	77.9%	2.8%	15.9%	3.5%	22.1%
1980	83.5%	0.0%	83.5%	1.6%	12.7%	2.1%	16.5%
1981	82.7%	0.0%	82.8%	1.3%	13.6%	2.3%	17.2%
1982	80.3%	0.1%	80.5%	1.5%	14.8%	3.2%	19.5%
1983	77.7%	0.3%	78.0%	2.5%	15.8%	3.7%	22.0%
1984	76.1%	0.4%	76.5%	4.1%	14.6%	4.8%	23.5%
1985	74.6%	0.6%	75.2%	4.5%	14.4%	5.9%	24.8%
1986	71.7%	0.4%	72.1%	4.6%	16.5%	6.8%	27.9%
1987	72.2%	0.6%	72.8%	5.2%	14.4%	7.5%	27.2%
1988	70.2%	0.7%	70.9%	5.6%	16.1%	7.4%	29.1%
1989	69.3%	0.7%	70.1%	5.7%	15.4%	8.8%	29.9%
1990	69.8%	0.5%	70.4%	5.1%	14.5%	10.0%	29.6%
1991	67.8%	1.8%	69.6%	6.9%	15.3%	8.2%	30.4%
1992	66.6%	2.0%	68.6%	6.2%	15.1%	10.0%	31.4%
1993	64.0%	3.6%	67.6%	6.3%	15.2%	10.9%	32.4%
1994	59.6%	2.3%	61.9%	9.1%	18.9%	10.0%	38.1%
1995	62.0%	1.5%	63.5%	10.5%	15.0%	11.0%	36.5%
1996	60.0%	2.2%	62.2%	12.2%	14.9%	10.7%	37.8%
1997	57.6%	2.5%	60.1%	14.5%	16.7%	8.8%	39.9%
1998	55.1%	3.1%	58.3%	14.7%	16.7%	10.3%	41.7%
1999	55.1%	3.2%	58.3%	15.4%	16.7%	9.6%	41.7%
2000	55.1%	3.7%	58.8%	15.2%	15.8%	10.2%	41.2%
2001	53.9%	4.8%	58.6%	17.3%	16.1%	7.9%	41.4%
2002	51.5%	3.7%	55.3%	22.3%	14.8%	7.7%	44.7%
2003	50.2%	3.6%	53.9%	22.6%	15.7%	7.8%	46.1%
2004	48.0%	4.1%	52.0%	25.9%	15.9%	6.1%	48.0%
2005	50.5%	5.1%	55.6%	20.6%	14.5%	9.3%	44.4%
2006	52.9%	5.0%	57.9%	19.9%	14.5%	7.7%	42.1%
2007	52.9%	6.0%	58.9%	21.7%	13.8%	5.5%	41.1%
2008	52.7%	6.6%	59.3%	22.1%	12.9%	5.7%	40.7%
2009	60.5%	6.5%	67.0%	18.4%	10.6%	4.0%	33.0%
2010	54.5%	8.2%	62.7%	20.8%	11.5%	5.0%	37.3%
2011	47.7%	10.1%	57.8%	25.6%	12.3%	4.3%	42.2%
2012	54.9%	9.4%	64.4%	20.6%	10.1%	4.9%	35.6%
2013	*53.8%*	*10.6%*	*64.4%*	*21.0%*	*10.6%*	*4.0%*	*35.6%*

The data from Table 3.1 show that car type market share has dropped from around 80% in the MY 1975-1985 timeframe to about 50% today. Pickups accounted for most of the remaining market share in MY 1975-1985. In the late 1980s, both minivans/vans and truck SUVs began to erode car type market share, with truck SUV market share reaching as high as 26%, before declining to about 20% today. More recently, car SUVs have increased market share to about 10%. Total SUVs, including both car SUVs and truck SUVs, have achieved market share in the 30% range over the last few years. Pickup market share was approximately 15% from MY 1975 through MY 2005, but has declined to about 10% today.

One particular comparison of interest is the trend associated with small SUVs that are classified as cars if they have 2-wheel drive and as trucks if they have 4-wheel drive. For this analysis summarized in Table 3.2, we reviewed MY 2000-2013 SUVs with inertia weights (see below for more detail about inertia weight) of 4000 pounds or less (SUVs with inertia weights in excess of 4000 pounds are typically categorized as trucks regardless of whether they are 2-wheel or 4-wheel drive). Note that we have propagated the current car-truck definitions back to previous years in the Trends database in order to maintain the integrity of historical trends (i.e., some vehicles that were defined as trucks in past years are now defined as cars in the Trends database).

Table 3.2

Car-Truck Classification of SUVs with Inertia Weights of 4000 Pounds or Less

Model Year	Car SUV Production	Truck SUV Production	Total SUV Production	Percent Car SUV	Percent Truck SUV
2000	617	796	1,413	43.7%	56.3%
2001	743	920,	1,663	44.7%	55.3%
2002	603	928	1,531	39.4%	60.6%
2003	575	994	1,569	36.6%	63.4%
2004	599	1,116	1,715	34.9%	65.1%
2005	753	867	1,620	46.5%	53.5%
2006	691	758	1,449	47.7%	52.3%
2007	761	843	1,604	47.4%	52.6%
2008	748	799	1,547	48.4%	51.6%
2009	539	575	1,115	48.4%	51.6%
2010	659	854	1,512	43.5%	56.5%
2011	985	1,044	2,029	48.5%	51.5%
2012	1,043	869	1,912	54.6%	45.4%
2013	-	-	-	*55.5%*	*44.5%*

Table 3.2 shows that the fraction of SUVs with curb weights less than 4000 pounds that are classified as trucks, using the current car-truck definitions propagated back in time, has been declining somewhat over the last decade, from around 60% in the early 2000s to less than 50% in recent years and to about 45% in MY 2012-2013.

Appendix D gives additional data stratified by vehicle type.

C. Vehicle Attributes

This section focuses on four key attributes that impact CO_2 emissions and fuel economy (footprint, weight, horsepower, and 0-60 acceleration time) that are relevant to all light-duty vehicles and that were included in the Table 2.1 fleetwide data presented in Section 2.

Vehicle footprint is a very important attribute since it is the basis for the current CO_2 emissions and fuel economy standards. Footprint is the product of wheelbase times average track width (or the area defined by where the centers of the tires touch the ground). We provide footprint data beginning with MY 2008, though it is important to highlight that we have higher confidence in the data beginning in MY 2011. Footprint data from MY 2008-2010 were aggregated from various sources, some independent of formal automaker data, and EPA has less confidence in the consistency and precision of this data. Beginning in MY 2011, automakers began to formally submit reports to EPA with footprint data. With these caveats, Table 2.1 above shows that average fleetwide footprint has hovered around 49 square feet since MY 2008, with MY 2012 footprint of 48.8 square feet representing a 0.7 square feet decrease relative to MY 2011. The preliminary MY 2013 footprint value is 49.1 square feet, which if realized would be a slight increase relative to MY 2012. Future footprint trends will be a major topic of interest in future Trends reports as we continue to add to the more consistent and precise data that we began to collect in MY 2011.

Vehicle weight is a fundamental vehicle attribute, both because it can be related to utility functions such as vehicle size and features, and because higher weight, other things being equal, will increase CO_2 emissions and decrease fuel economy. All Trends vehicle weight data are based on inertia weight class. Each inertia weight class represents a range of loaded vehicle weights, or vehicle curb weights plus 300 pounds. Vehicle inertia weight classes are in 250-pound increments for inertia weight classes that are less than 3000 pounds, while inertia weight classes over 3000 pounds are divided into 500-pound increments. Table 1 above shows that average fleetwide vehicle weight decreased from nearly 4100 pounds in MY 1976 to 3200 pounds in MY 1981, likely driven by both increasing fuel economy standards (which, at that time, were universal standards, and not based on any type of vehicle attribute) and higher gasoline prices. Average vehicle weight then grew slowly but steadily over the next 23 years (in part because of the increasing truck share), essentially returning to its mid-1970s levels in MY 2004. Since 2004, average vehicle weight has stayed fairly constant in the range of 4000 to 4100 pounds. Average MY 2012 weight was 3977 pounds, a 150 pound decrease relative to MY 2011. The preliminary MY 2013 value for weight is 4041 pounds, which if realized would represent a 64 pound increase compared to MY 2012.

Horsepower (hp) is of interest as a direct measure of vehicle power. All else equal, higher power generally increases CO_2 emissions and decreases fuel economy. Trends horsepower data for all gasoline (including conventional hybrids) and diesel vehicles in the Trends database reflect engine rated horsepower. Average fleetwide horsepower dropped from 137 hp in MY 1975 to 102 hp in MY 1981. Since MY 1981, horsepower values have increased just about every year (again, in part due to the increasing truck share through 2004), and current levels are over twice those of the early 1980s. Average MY 2012 horsepower was 222 hp, an 8 hp decrease relative to MY 2011. The preliminary value for MY 2013 is 230 hp, which, if achieved, would tie the all-time high set in MY 2011.

The most commonly reported measure of vehicle acceleration performance in the automotive press is 0-to-60 miles per hour acceleration time (in seconds). Generally, for a given vehicle, lower 0-60 acceleration times will increase CO_2 emissions and decrease fuel economy. EPA does not receive 0-60 acceleration time data directly from automakers, so Trends 0-60 acceleration times for non-hybrid gasoline vehicles are calculated based on a relationship between 0-60 acceleration time, horsepower, and vehicle weight (see Section 10 for more detail). For diesel and conventional hybrid vehicles, EPA uses published values from trade press sources. Table 2.1 above shows that the average 0-60 acceleration times were fairly stable at about 14 seconds from MY 1975 through MY 1984, but have steadily declined since. Average 0-60 acceleration times have been around 9.5 seconds for the last few years, and the MY 2012 value is 9.4 seconds. The preliminary MY 2013 value is 9.3 seconds, which if realized, would be an all-time low.

The following two tables provide the key attribute data for the car and truck classes separately (these data are shown for the entire fleet in Table 2.1 above).

Table 3.3.1 shows that car adjusted fuel economy reached an all-time record of 27.0 mpg in MY 2012, which is exactly twice the MY 1975 level of 13.5 mpg. The 1.4 mpg increase from MY 2011 to MY 2012 is the largest for car fuel economy since MY 1981. Car weight, horsepower and footprint all decreased in MY 2012, but are projected to increase in MY 2013, as is car fuel economy. The interior volume data shown in Table 3.3.1 is only for car type vehicles, as EPA does not collect interior volume data for car SUVs.

Table 3.3.2 shows, for trucks only, the same data provided for cars in Table 3.3.1 above and for the overall light vehicle fleet in Table 2.1. Truck adjusted fuel economy was also a record high in MY 2012 at 19.3 mpg, which was a 0.2 mpg increase over MY 2011. Truck weight was slightly lower in MY 2012, while truck horsepower and footprint were slightly higher. Truck fuel economy, weight, horsepower, and footprint are all projected to increase in MY 2013.

Table 3.3.1

Car Adjusted CO_2 Emissions, Adjusted Fuel Economy, and Key Parameters for MY 1975-2013

Model Year	Gasoline and Diesel Production (000)	Car Production Share	Adj CO_2 (g/mi)	Adj Fuel Economy (MPG)	Weight (lb)	HP	Footprint (sq ft)	0-to-60 Time (sec)	Interior Volume (cu ft)*
1975	8,247	80.7%	661	13.5	4057	136	-	14.2	-
1976	9,734	78.9%	598	14.9	4059	134	-	14.4	-
1977	11,318	80.1%	570	15.6	3944	133	-	14.0	110
1978	11,191	77.5%	525	16.9	3588	124	-	13.7	109
1979	10,810	77.9%	517	17.2	3485	119	-	13.8	109
1980	9,444	83.5%	446	20.0	3101	100	-	14.3	104
1981	8,734	82.8%	418	21.4	3076	99	-	14.4	106
1982	7,832	80.5%	402	22.2	3053	99	-	14.4	106
1983	8,035	78.0%	403	22.1	3112	104	-	14.0	109
1984	10,730	76.5%	397	22.4	3101	106	-	13.8	108
1985	10,879	75.2%	387	23.0	3096	111	-	13.3	108
1986	11,074	72.1%	375	23.7	3043	111	-	13.2	107
1987	10,826	72.8%	374	23.8	3035	113	-	13.0	107
1988	10,845	70.9%	369	24.1	3051	116	-	12.8	107
1989	10,126	70.1%	376	23.6	3104	121	-	12.4	108
1990	8,875	70.4%	382	23.3	3178	129	-	12.1	107
1991	8,748	69.6%	382	23.3	3168	133	-	11.9	107
1992	8,350	68.6%	389	22.9	3254	141	-	11.5	108
1993	8,929	67.6%	386	23.0	3241	140	-	11.5	108
1994	8,747	61.9%	386	23.0	3268	144	-	11.4	108
1995	9,616	63.5%	382	23.3	3274	153	-	10.9	109
1996	8,177	62.2%	384	23.1	3297	155	-	10.8	109
1997	8,695	60.1%	384	23.2	3285	156	-	10.7	109
1998	8,425	58.3%	386	23.0	3334	160	-	10.6	109
1999	8,865	58.3%	392	22.7	3390	164	-	10.5	109
2000	9,742	58.8%	395	22.5	3401	168	-	10.4	110
2001	9,148	58.6%	393	22.6	3411	169	-	10.3	109
2002	8,904	55.3%	390	22.8	3415	173	-	10.2	110
2003	8,496	53.9%	386	23.0	3437	176	-	10.0	110
2004	8,176	52.0%	389	22.9	3492	184	-	9.8	110
2005	8,839	55.6%	384	23.1	3498	183	-	9.9	111
2006	8,744	57.9%	386	23.0	3563	194	-	9.6	112
2007	9,001	58.9%	375	23.7	3551	191	-	9.6	110
2008	8,243	59.3%	372	23.9	3569	194	45.3	9.6	110
2009	6,244	67.0%	356	25.0	3502	186	45.1	9.8	110
2010	6,969	62.7%	346	25.7	3536	190	45.4	9.6	110
2011	6,934	57.8%	348	25.6	3617	200	46.0	9.5	111
2012	8,648	64.4%	329	27.0	3516	192	45.7	9.6	111
2013	*9,257*	*64.4%*	*325*	*27.4*	*3578*	*201*	*45.9*	*9.4*	*110*

*Interior volume calculated using Car type only.

Table 3.3.2

Truck Adjusted CO_2 Emissions, Adjusted Fuel Economy, and Key Parameters for MY 1975-2013

Model Year	Gasoline and Diesel Production (000)	Truck Production Share	Adj CO_2 (g/mi)	Adj Fuel Economy (MPG)	Weight (lb)	HP	Footprint (sq ft)	0-to-60 Time (sec)
1975	1,977	19.3%	764	11.6	4073	142	-	13.6
1976	2,600	21.1%	726	12.2	4155	141	-	13.8
1977	2,805	19.9%	669	13.3	4136	147	-	13.3
1978	3,257	22.5%	687	12.9	4152	146	-	13.4
1979	3,072	22.1%	711	12.5	4257	138	-	14.3
1980	1,863	16.5%	565	15.8	3869	121	-	14.5
1981	1,821	17.2%	523	17.1	3806	119	-	14.6
1982	1,901	19.5%	516	17.4	3813	120	-	14.5
1983	2,267	22.0%	504	17.7	3773	118	-	14.6
1984	3,289	23.5%	512	17.4	3787	118	-	14.7
1985	3,581	24.8%	509	17.5	3803	124	-	14.1
1986	4,291	27.9%	489	18.2	3741	123	-	14.0
1987	4,039	27.2%	486	18.3	3718	131	-	13.4
1988	4,450	29.1%	498	17.8	3850	141	-	13.0
1989	4,327	29.9%	506	17.6	3932	146	-	12.8
1990	3,740	29.6%	512	17.4	4014	151	-	12.6
1991	3,825	30.4%	500	17.8	3961	150	-	12.5
1992	3,822	31.4%	512	17.3	4078	155	-	12.5
1993	4,281	32.4%	507	17.5	4098	160	-	12.2
1994	5,378	38.1%	518	17.2	4149	166	-	12.0
1995	5,529	36.5%	524	17.0	4201	168	-	12.0
1996	4,967	37.8%	518	17.2	4255	179	-	11.6
1997	5,762	39.9%	528	16.8	4394	189	-	11.4
1998	6,030	41.7%	521	17.1	4317	188	-	11.2
1999	6,350	41.7%	535	16.6	4457	199	-	11.0
2000	6,829	41.2%	528	16.8	4421	199	-	11.0
2001	6,458	41.4%	538	16.5	4543	212	-	10.6
2002	7,211	44.7%	539	16.5	4612	223	-	10.3
2003	7,277	46.1%	533	16.7	4655	224	-	10.4
2004	7,533	48.0%	538	16.5	4783	240	-	10.1
2005	7,053	44.4%	526	16.9	4763	242	-	10.0
2006	6,360	42.1%	518	17.2	4758	240	-	10.0
2007	6,275	41.1%	512	17.4	4871	254	-	9.8
2008	5,656	40.7%	499	17.8	4837	254	54.0	9.7
2009	3,071	33.0%	480	18.5	4753	252	54.0	9.7
2010	4,141	37.3%	474	18.8	4784	253	53.8	9.7
2011	5,069	42.2%	466	19.1	4824	271	54.4	9.2
2012	4,791	35.6%	461	19.3	4809	276	54.5	9.1
2013	*5,114*	*35.6%*	*452*	*19.7*	*4878*	*282*	*54.9*	*9.1*

Figure 3.4 includes summary charts showing long-term trends for adjusted CO_2 emissions, adjusted fuel economy, footprint, weight, horsepower, and 0-60 acceleration time for the five vehicle types discussed above. Most of the long-term trends are similar across the various vehicle types, with the major exception being pickups, for which CO_2 emissions and fuel economy have not reached all-time records in recent years (unlike the other vehicle types) due to considerably greater increases in weight and horsepower relative to the other vehicle types.

Figure 3.4

Adjusted CO_2 Emissions, Adjusted Fuel Economy and Other Key Parameters by Vehicle Type: MY 1975-2013

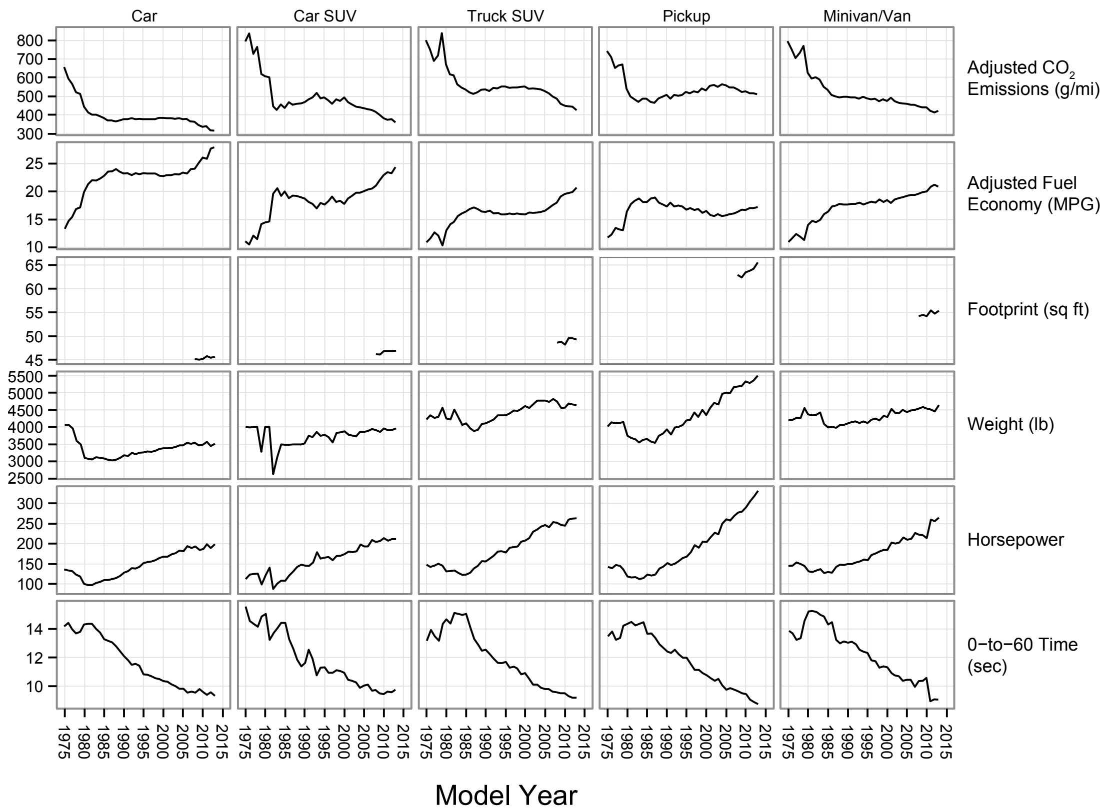
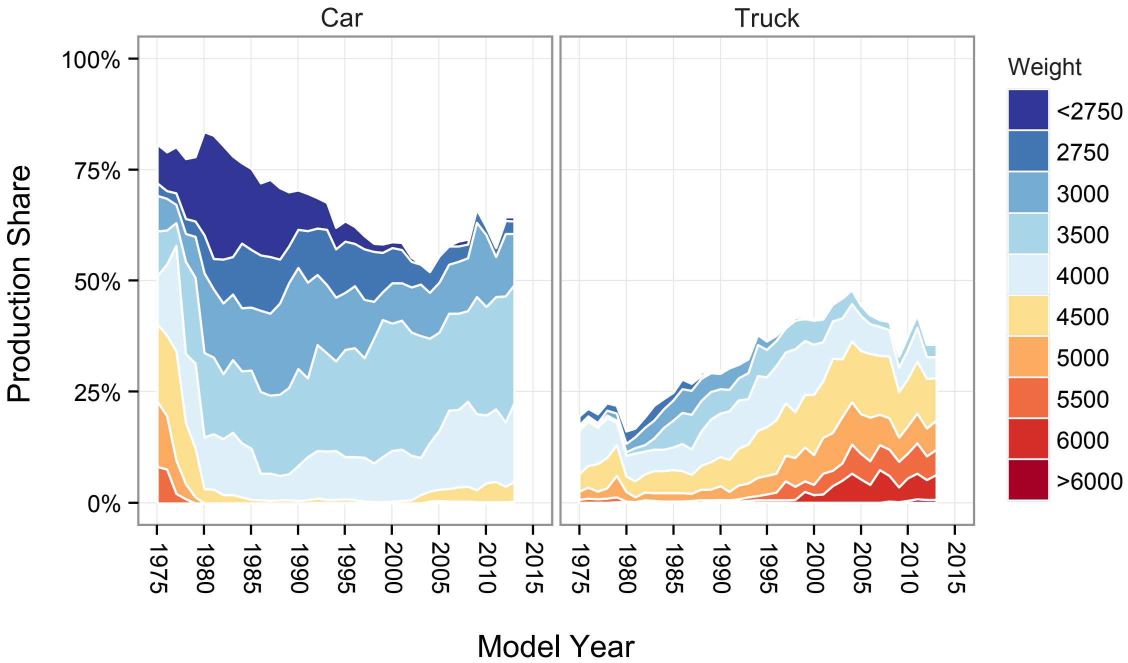


Figure 3.5 shows the annual production share of different inertia weight classes for cars and trucks. This figure again shows the “compression” on the car side that was also discussed with respect to interior volume—in the late 1970s there were significant car sales both in the <2750 pound class as well as in the 5500 pound class (interestingly, there were more 5500 pound cars sold in the late 1970s than there were 5500 pound trucks). Today, both the lightest and heaviest cars have largely disappeared from the market, and over 95% of all cars are in just three inertia weight classes (3000, 3500, and 4000 pounds). Conversely, the heavy end of the truck market has expanded markedly such that 4500 pounds and greater trucks now account for over 80% of the truck market.

Figure 3.5

Car and Truck Production Share by Vehicle Inertia Weight Class



The final four figures in this section, Figures 3.6 through 3.9, address the engineering relationships between efficiency and four key vehicle attributes: footprint, weight, 0-60 acceleration time, and interior volume (car type only). It is important to emphasize that, in order to best reflect the engineering relationships involved, these figures differ from most of the figures and tables presented so far in three important ways. One, they show fuel consumption (the inverse of fuel economy) rather than fuel economy, because fuel consumption represents a linear relationship while fuel economy is non-linear (i.e., a 1 mpg difference at a lower fuel economy represents a greater change in fuel consumption than a 1 mpg difference at a higher fuel economy). The metric used for fuel consumption is gallons per 100 miles, also shown on new vehicle Fuel Economy and Environment Labels. Fuel consumption is an excellent surrogate for CO_2 emissions, as well. Two, Figures 3.6 through 3.9 show unadjusted, laboratory values (for fuel consumption), rather than the adjusted values shown up to this point, in order to exclude the impact of non-technology factors associated with the adjusted fuel economy values (e.g., changes in driving speeds or use of air conditioning over time). Three, there is no sales weighting in either the calculations of the individual data points or the regression lines as the purpose of these figures is to illustrate the technical relationships between fuel consumption and key vehicle attributes, rather than market success of the attributes. The non-hybrid gasoline, diesel, and gasoline hybrid data points in these figures are averages for each integer footprint value, and are plotted separately to illustrate the differences between these technologies, and the regression lines are based on the non-hybrid gasoline data points only. As would be expected, the conventional hybrid and diesel data points almost always reflect lower fuel consumption that the regression line representing non-hybrid gasoline vehicles.

Figure 3.6 shows unadjusted, laboratory fuel consumption as a function of vehicle footprint for the MY 2012 car and truck fleets (a full set of historical footprint data is not available). On average, higher footprint values are correlated with greater fuel consumption. Car fuel consumption is more sensitive to footprint (i.e., greater slope for the regression line based on conventional gasoline vehicles) than truck fuel consumption, though this relationship may be exaggerated somewhat by the fact that the very high footprint cars are extremely low-volume luxury cars with very high fuel consumption. Most cars have footprint values below 50 square feet, and at these footprint levels, the average car has lower fuel consumption than the average truck. For the much smaller number of cars that have footprint values greater than 55 square feet (typically performance or luxury cars), these cars generally have higher fuel consumption than trucks of the same footprint.

Figure 3.6

Unadjusted, Laboratory Fuel Consumption vs. Footprint: Cars and Trucks, MY 2012

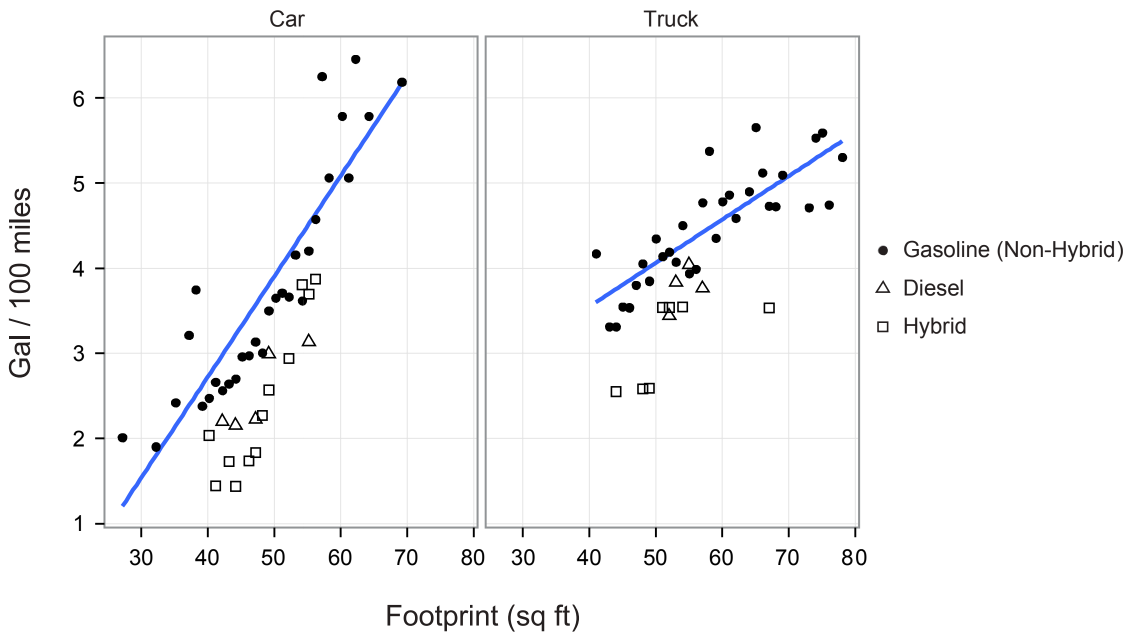


Figure 3.7 shows unadjusted, laboratory fuel consumption as a function of vehicle inertia weight for the MY 1975 and MY 2012 car and truck fleets. On average, fuel consumption increases linearly with vehicle weight, and the regressions are particularly tight for the data points representing non-hybrid gasoline vehicles. In 1975, trucks consistently had higher fuel consumption than cars for a given weight, but in 2012, the differences were much smaller, and at 5000 pounds and above, the average car had higher fuel consumption than the average truck, again likely due to the fact that very heavy cars are typically luxury and/or performance vehicles with high fuel consumption. At a given weight, most cars and trucks have reduced their fuel consumption by about 50% since 1975, with the major exception being the heaviest cars which have achieved more modest reductions in fuel consumption.

Figure 3.7

Unadjusted, Laboratory Fuel Consumption vs. Inertia Weight: Cars and Trucks: MY 1975 and 2012

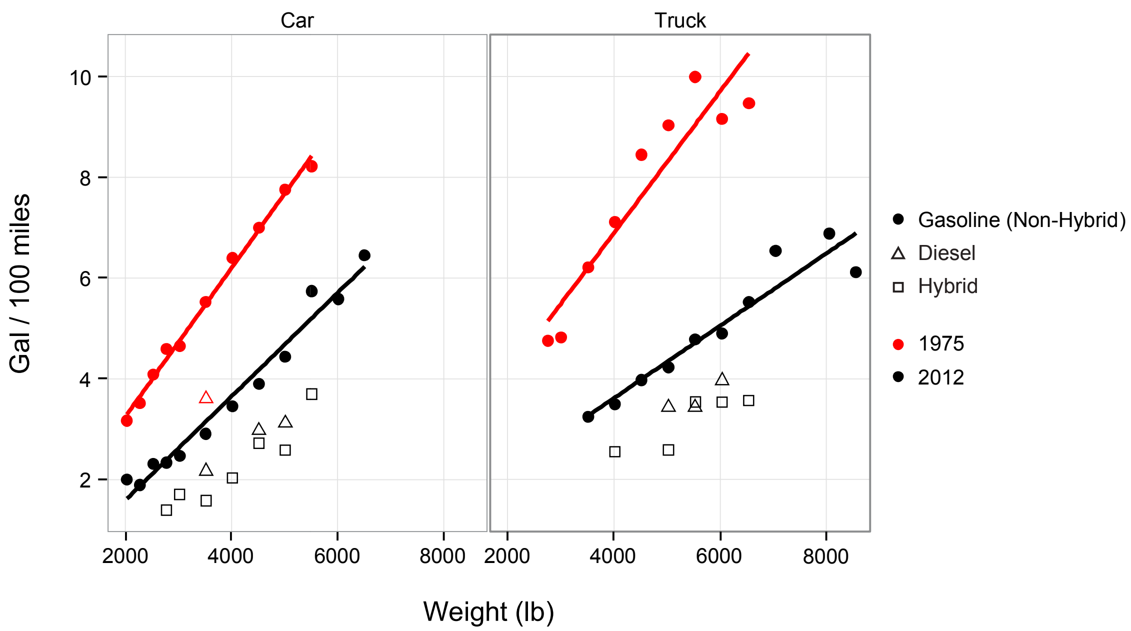
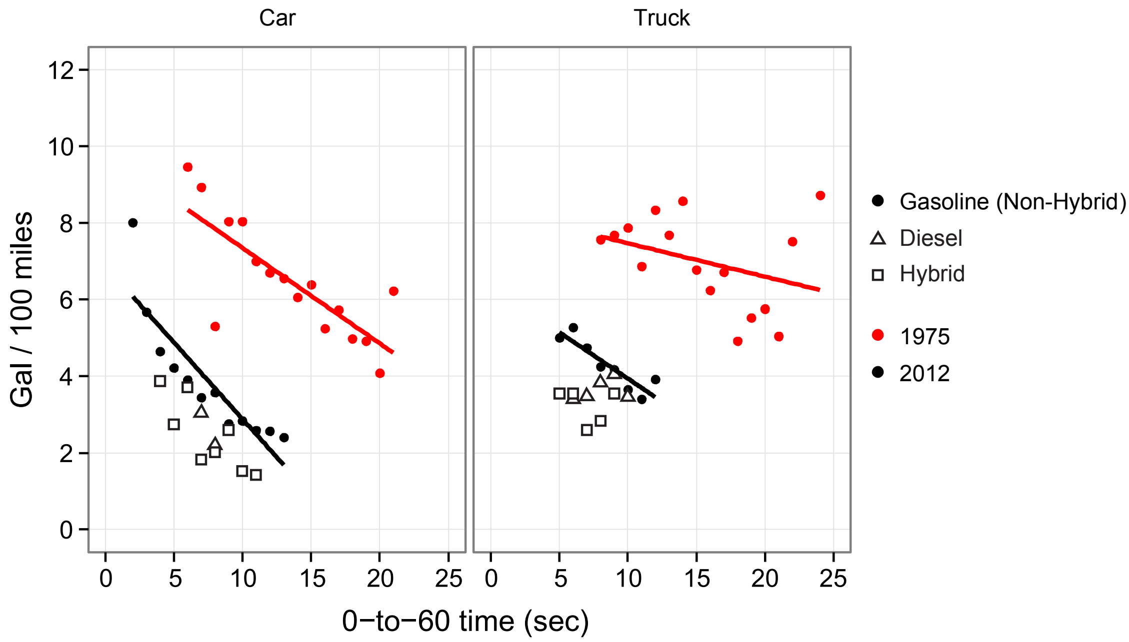


Figure 3.8 shows unadjusted, laboratory fuel consumption as a function of 0-60 mph acceleration time for the MY 1975 and 2012 car and truck fleets. Lower acceleration times are correlated with greater fuel consumption, and this relationship has strengthened over time. The regressions are much tighter for the 2012 data than for the 1975 data. While the slopes of the car and truck regression lines were considerably different in MY 1975, they are much more similar today. The range of acceleration times has also diminished: there were cars and trucks in MY 1975 with 0-60 acceleration times in the 15-25 second range, while today there are no vehicles with 0-60 times greater than 12-13 seconds.

Figure 3.8

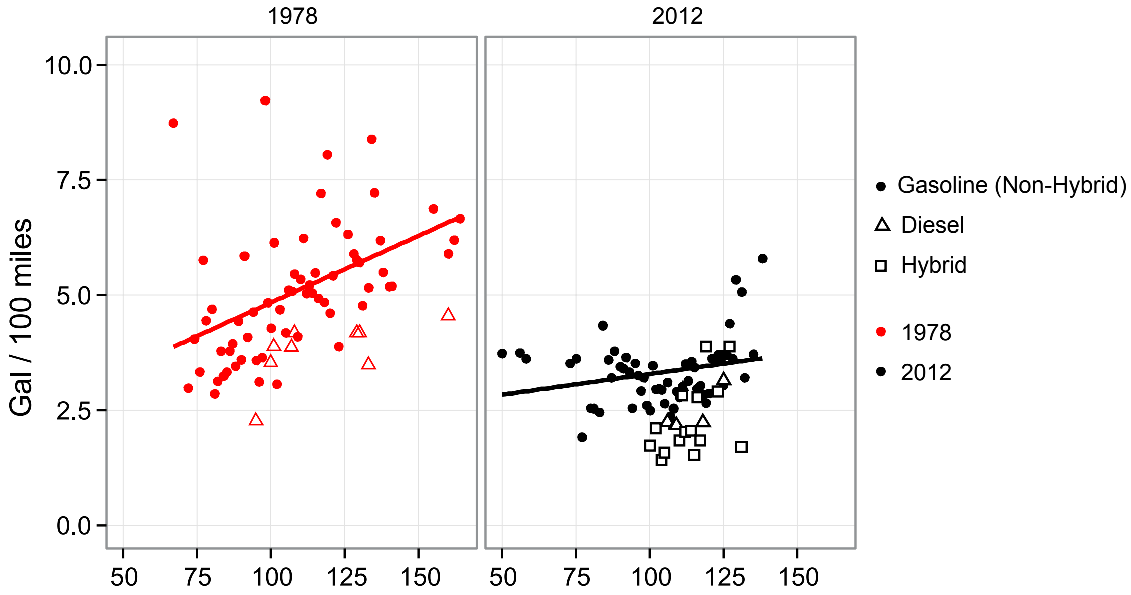
Unadjusted, Laboratory Fuel Consumption vs. 0-60 Acceleration Time: Cars and Trucks, MY 1975 and 2012



Finally, Figure 3.9 shows unadjusted, laboratory fuel consumption as a function of interior volume for MY 1978 and 2012 for the car type only. This figure excludes two-seater cars, as interior volume data is not reported for two-seaters. The data for MY 1978 is much more scattered than that for MY 2012. The slope of the regression line for non-hybrid gasoline vehicles in 2012 is nearly flat, suggesting that there is no longer much of a relationship between interior volume and fuel consumption within the car type. This MY 2012 data further confirm the point made in Section 3.B that interior volume is no longer a good attribute for differentiating within the car type.

Figure 3.9

Unadjusted, Laboratory Fuel Consumption vs. Car Interior Volume: Cars, MY 1978 and 2012



4 Manufacturers and Makes

This section groups vehicles by "manufacturer" and "make." Manufacturer definitions are those used by both EPA and the National Highway Traffic Safety Administration (NHTSA) for purposes of implementation of GHG emissions standards and the corporate average fuel economy (CAFE) program, respectively. Each year, the authors ensure that the manufacturer definitions in the Trends database are consistent with those used for regulatory compliance.

Most of the tables in this section, consistent with the rest of the report, show adjusted CO_2 emissions and fuel economy data which are the best estimates for real world CO_2 emissions and fuel economy performance, but are not comparable to regulatory compliance values. Two tables in this section show unadjusted, laboratory fuel economy and CO_2 emissions values, which form the basis for regulatory compliance values, though they do not reflect various compliance credits, incentives, and flexibilities available to automakers. Adjusted CO_2 values are, on average, about 25% higher than the unadjusted CO_2 values that form the starting point for GHG standards compliance, and adjusted fuel economy values are about 20% lower, on average, than unadjusted fuel economy values (note that these values differ because CO_2 emissions are proportional to fuel consumption, both expressed in units of "per mile," while fuel economy is the mathematical inverse of fuel consumption).

In early 2014, EPA intends to publish a separate, annual GHG Report at epa.gov/otaq/regs/ld-hwy/greenhouse/ld-ghg.htm that will summarize individual manufacturer compliance with the MY 2012 GHG emissions standards. The Department of Transportation's National Highway Traffic Safety Administration (NHTSA, at nhtsa.dot.gov/fuel-economy) also publishes a separate document entitled "Summary of Fuel Economy Performance" and will update this document after receiving final CAFE compliance data from EPA for all manufacturers.

A. Manufacturer and Make Definitions

Table 4.1 lists the 13 manufacturers which had production of 100,000 or more gasoline and/or diesel vehicles in MY 2011 and/or MY 2012, which together accounted for approximately 98% of total industry-wide production. There are no changes in the list of manufacturers in Table 4.1 included in this year's report. Make is typically included in the model name and is generally equivalent to the "brand" of the vehicle. Table 4.1 also lists the 29 makes for which data are shown in subsequent tables. The production threshold for makes to be included in Tables 4.2 through 4.5 is 40,000 vehicles in MY 2012, though the Smart was included as well because of the high interest in this make. The Mercury make no longer exists, but is included since these tables also provide data for MY 2011.

Table 4.1
Manufacturers and Makes for MY 2011-2013

Manufacturer	Makes Above Threshold	Makes Below Threshold
General Motors	Chevrolet, Cadillac, Buick, GMC	
Toyota	Toyota, Lexus, Scion	
Ford	Ford, Lincoln, Mercury	Roush, Shelby
Honda	Honda, Acura	
Chrysler-Fiat	Chrysler, Dodge, Jeep, Ram, Fiat	Ferrari, Maserati
Nissan	Nissan, Infiniti	
Hyundai	Hyundai	
Kia	Kia	
BMW	BMW, Mini	Rolls Royce
Volkswagen	Volkswagen, Audi	Lamborghini, Bentley, Bugatti
Subaru	Subaru	
Daimler	Mercedes-Benz, Smart	Maybach
Mazda	Mazda	
Others*		

*Note: Other manufacturers below the manufacturer threshold are Mitsubishi, Volvo, Rover, Porsche, Suzuki, Jaguar, Spyker (Saab), Aston Martin, Lotus, VPG, and Tesla (which only produces EVs).

It is important to note that when a manufacturer or make grouping is modified to reflect a change in the industry's current financial structure, EPA makes the same adjustment to the entire historical database. This maintains consistent manufacturer and make definitions over time, which allows a better identification of long-term trends. On the other hand, this means that the current database does not necessarily reflect the actual corporate arrangements of the past. For example, the 2013 database no longer accounts for the fact that Chrysler was combined with Daimler for several years, and includes Fiat, Ferrari, and Maserati in the Chrysler-Fiat manufacturer grouping for the entire database even though these other companies have been financially connected to Chrysler only recently.

Automakers submit vehicle production data, rather than vehicle sales data, in formal end-of-year CAFE and GHG emissions compliance reports to EPA. These vehicle production data are tabulated on a model year basis. Accordingly, the vehicle production data presented in this report often differ from similar data reported by press sources, which typically are based on vehicle sales data reported on a calendar basis. In years past, manufacturers typically used a more consistent approach for model year designations, i.e., from fall of one year to the fall of the following year. More recently, however, many manufacturers have used a more flexible approach, and it is not uncommon to see a new or redesigned model introduced with a new model year designation in the spring or summer, rather than the fall. This means that a model year for an individual vehicle can be either shortened or lengthened. Accordingly, year-to-year comparisons can be affected by these model year anomalies, though the overall trends even out over a multi-year period.

B. Manufacturer and Make Trends

Tables 4.2 through 4.5 provide comparative manufacturer- and make-specific data for fuel economy and CO_2 emissions for the three years from MY 2011-2013. Data are shown for cars only, trucks only, and cars and trucks combined. By including data from both MY 2011 and 2012, with formal end-of-year data for both years, it is possible to identify meaningful changes from year-to-year. Because of the uncertainty associated with the preliminary MY 2013 projections, changes from MY 2012 to MY 2013 are less meaningful.

For the first time in this report, tables are presented with both adjusted (Tables 4.2 and 4.3) and unadjusted, laboratory (Tables 4.4 and 4.5) data. Tables 4.2 and 4.3 provide adjusted data for fuel economy and CO_2 emissions, and therefore are consistent with tables presented earlier in the report. The data in these tables are very similar to the data used to generate the EPA/DOT Fuel Economy and Environment Labels and represent EPA's best estimate of nationwide real world fuel consumption and CO_2 emissions.

It is important to note that Tables 4.2 and 4.3 show rows with adjusted fuel economy and CO_2 emissions data for 11 manufacturers and 27 makes, while the table footnotes provide similar data for two additional manufacturers, Hyundai and Kia. On November 2, 2012, EPA announced that Hyundai and Kia would lower their Fuel Economy and Environment Label estimates for many vehicle models as the result of an EPA investigation of test data. Hyundai and Kia submitted corrected MY 2011-2013 fuel economy and CO_2 emissions data to EPA and re-labeled many of their model year 2012 and 2013 vehicles on the market. This report uses the corrected fuel economy values submitted by Hyundai and Kia for four MY 2011 vehicles and for many of Hyundai and Kia vehicles for MY 2012 and 2013. The magnitude of the changes between the original label values and the corrected label values ranges from 1 mpg to 6 mpg. For the changes in the label values for individual vehicles, see epa.gov/fueleconomy/labelchange.htm. Since EPA's investigation into Hyundai and Kia data submissions is continuing, Hyundai and Kia-specific values are not shown in rows in the following tables that list the fuel economy and CO_2 emissions performance for various manufacturers, but are provided in footnotes to the tables with adjusted fuel economy and CO_2 emissions. Hyundai and Kia data are included in industry-wide values, including the "All" rows in the following tables, throughout this report.

Of the 11 manufacturers shown in the body of Table 4.2, 10 manufacturers increased adjusted fuel economy from MY 2011 to MY 2012, and Mazda had the highest adjusted fuel economy in MY 2012 of 27.1 mpg. Honda had the second highest adjusted fuel economy of 26.6 mpg, followed by Volkswagen at 25.8 mpg. Chrysler-Fiat had the lowest adjusted fuel economy of 20.1 mpg, followed by Daimler and General Motors. Honda achieved the largest increase in adjusted fuel economy from MY 2011-2012 of 2.5 mpg, followed by Mazda at 2.1 mpg and Daimler at 2.0 mpg.

Table 4.2

Adjusted Fuel Economy (MPG) by Manufacturer and Make for MY 2011-2013

		MY 2011			MY 2012			MY 2013		
Manufacturer	Make	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks
Mazda	**All**	**26.3**	**19.6**	**25.0**	**29.3**	**21.9**	**27.1**	**29.2**	**23.6**	**27.5**
Honda	Honda	28.3	21.4	24.5	29.9	22.8	27.2	30.5	23.0	27.5
Honda	Acura	23.8	18.6	20.5	24.5	18.4	21.8	26.3	19.6	23.8
Honda	**All**	**27.9**	**21.1**	**24.1**	**29.3**	**22.2**	**26.6**	**29.9**	**22.6**	**27.0**
VW	VW	28.9	22.1	27.7	27.2	22.8	26.9	27.9	23.1	27.5
VW	Audi	24.1	21.4	23.2	24.0	21.5	23.1	23.7	22.7	23.4
VW	**All**	**27.3**	**21.7**	**26.0**	**26.4**	**21.9**	**25.8**	**26.8**	**22.9**	**26.2**
Toyota	Toyota	28.9	19.8	24.2	31.8	19.7	25.7	32.7	19.3	25.5
Toyota	Lexus	23.6	20.3	22.4	24.8	20.7	23.5	24.8	21.0	23.5
Toyota	Scion	26.1	-	26.1	27.2	-	27.2	27.3	-	27.3
Toyota	**All**	**28.1**	**19.8**	**24.1**	**30.7**	**19.7**	**25.6**	**30.3**	**19.6**	**25.2**
Subaru	**All**	**23.9**	**23.9**	**23.9**	**27.5**	**24.0**	**25.2**	**28.4**	**25.0**	**26.2**
Nissan	Nissan	26.8	19.1	23.7	27.5	18.9	24.5	29.6	20.9	25.9
Nissan	Infiniti	21.7	17.0	20.4	21.9	17.0	20.5	21.7	18.9	20.7
Nissan	**All**	**26.1**	**19.0**	**23.3**	**26.9**	**18.8**	**24.1**	**28.5**	**20.7**	**25.3**
BMW	BMW	22.4	20.3	21.9	23.3	20.1	22.0	24.8	20.2	23.2
BMW	Mini	30.3	-	30.3	29.9	-	29.9	29.6	-	29.6
BMW	**All**	**23.3**	**20.3**	**22.7**	**25.3**	**20.1**	**23.7**	**26.0**	**20.2**	**24.4**
Ford	Ford	25.2	18.4	21.1	27.2	18.5	22.9	27.6	19.2	22.6
Ford	Lincoln	22.0	17.7	18.9	22.6	17.6	20.9	24.4	19.6	21.9
Ford	Mercury	21.5	21.1	21.4	-	-	-	-	-	-
Ford	**All**	**24.8**	**18.4**	**21.1**	**26.9**	**18.5**	**22.8**	**27.4**	**19.2**	**22.6**
GM	Chevrolet	24.9	17.8	21.3	25.7	18.0	22.4	26.5	17.7	22.6
GM	GMC	23.6	17.7	18.7	23.7	18.0	19.3	24.2	17.8	19.3
GM	Buick	22.4	19.2	21.2	24.0	19.6	22.1	24.8	20.4	23.8
GM	Cadillac	20.5	15.6	19.5	20.5	15.5	19.6	21.8	17.6	21.0
GM	**All**	**24.0**	**17.8**	**20.7**	**24.8**	**18.1**	**21.7**	**25.6**	**17.9**	**22.0**
Daimler	Mercedes-Benz	20.1	16.9	19.0	22.4	18.4	20.9	23.4	19.3	22.1
Daimler	Smart	36.5	-	36.5	35.7	-	35.7	36.5	-	36.5
Daimler	**All**	**20.2**	**16.9**	**19.1**	**22.6**	**18.4**	**21.1**	**23.6**	**19.3**	**22.2**
Chrysler-Fiat	Jeep	-	19.1	19.1	22.2	18.7	19.2	24.7	19.1	19.5
Chrysler-Fiat	Dodge	22.8	19.3	20.6	22.7	20.2	21.4	24.9	20.0	23.0
Chrysler-Fiat	Chrysler	23.0	20.8	21.9	23.8	20.9	22.6	23.4	20.6	22.2
Chrysler-Fiat	Ram	-	16.0	16.0	-	16.1	16.1	-	17.4	17.4
Chrysler-Fiat	Fiat	-	-	-	31.5	-	31.5	31.6	-	31.6
Chrysler-Fiat	**All**	**22.7**	**18.6**	**19.4**	**23.7**	**18.6**	**20.1**	**24.7**	**19.2**	**21.6**
Other	**All**	**23.8**	**18.0**	**21.0**	**23.9**	**18.5**	**21.6**	**22.9**	**19.1**	**21.2**
All	**All**	**25.6**	**19.1**	**22.4**	**27.0**	**19.3**	**23.6**	**27.4**	**19.7**	**24.0**

*Note: Two manufacturers, Hyundai and Kia, are not included in rows in the table above due to a continuing investigation. On November 2, 2012, EPA announced that Hyundai and Kia would lower their fuel economy estimates for many vehicle models as the result of an EPA investigation of test data. This report uses the corrected fuel economy values submitted by Hyundai and Kia for four MY 2011 vehicles and for a majority of Hyundai and Kia vehicles for MY 2012 and MY 2013. Based on these corrected data, Hyundai's 2011 Cars and Trucks value is 27.2 mpg, Hyundai's 2012 Cars and Trucks value is 28.3 mpg, and Hyundai's preliminary 2013 Cars and Trucks value is 28.3 mpg, Kia's 2011 Cars and Trucks value is 25.8 mpg, Kia's 2012 Cars and Truck values is 26.5 mpg, and Kia's preliminary 2013 Car and truck value is 27.3 mpg. These corrected data are included in industry-wide or "All" values.

For MY 2012 cars only, of the 11 manufacturers shown in Table 4.2, Toyota achieved the highest adjusted fuel economy of 30.7 mpg, while Daimler reported the lowest adjusted car fuel economy of 22.6 mpg. For MY 2012 trucks only, Subaru had the highest adjusted fuel economy of 24.0 mpg, while General Motors had the lowest at 18.1 mpg.

In terms of the makes shown in Table 4.2 for MY 2012, the Smart make had the highest adjusted fuel economy at 35.7 mpg. The Smart Fourtwo is the smallest and lightest car in the U.S. market and has relatively low production. The make with the second-highest adjusted fuel economy in MY 2012 was Fiat, which also produces a relatively low number of small cars, at 31.5 mpg. Of the makes with higher production, for the 11 manufacturers shown, Honda had the highest adjusted fuel economy at 27.2 mpg.

Preliminary projections suggest that 9 of the 11 manufacturers shown will improve adjusted fuel economy further in MY 2013, though EPA will not have final data for MY 2013 until next year's report.

Table 4.3 shows manufacturer-specific values for adjusted CO_2 emissions for the same manufacturers, makes and model years as shown in Table 4.2 for adjusted fuel economy. Of the 11 manufacturers shown, 10 manufacturers decreased adjusted fuel CO_2 emissions from MY 2011 to MY 2012. Manufacturer rankings for CO_2 emissions are generally similar to those for fuel economy, though there can be some differences due to diesel vehicle production share (since diesel has a higher carbon content per gallon than gasoline). Table 4.3 shows that Mazda had the lowest adjusted CO_2 emissions in MY 2012 of 328 g/mi, followed by Honda at 334 g/mi and Toyota at 347 g/mi. Chrysler-Fiat had the highest adjusted CO_2 emissions of 442 g/mi, followed by Daimler and General Motors. Daimler achieved the largest decrease in adjusted CO_2 emissions from MY 2011-2012 of 43 g/mi, followed by Honda at 35 g/mi and Ford at 32 g/mi. Preliminary values suggest that 9 manufacturers will likely improve in MY 2013. The make rankings for adjusted CO_2 emissions in Table 4.3 are also similar to those for adjusted fuel economy in Table 4.2.

Table 4.3

Adjusted CO_2 Emissions (g/mi) by Manufacturer and Make for MY 2011-2013

		Final MY 2011			Final MY 2012			Preliminary MY 2013		
Manufacturer	Make	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks
Mazda	**All**	**338**	**453**	**356**	**304**	**406**	**328**	**305**	**376**	**324**
Honda	Honda	315	415	363	298	390	327	291	386	323
Honda	Acura	373	478	434	362	482	407	337	452	373
Honda	**All**	**319**	**422**	**369**	**303**	**400**	**334**	**297**	**394**	**329**
Toyota	Toyota	308	450	366	280	452	345	272	459	349
Toyota	Lexus	377	437	397	358	429	378	359	423	378
Toyota	Scion	340	-	340	326	-	326	326	-	326
Toyota	**All**	**317**	**449**	**369**	**290**	**450**	**347**	**293**	**454**	**352**
VW	VW	318	407	330	334	405	338	327	400	332
VW	Audi	371	423	387	372	419	388	376	392	381
VW	**All**	**333**	**415**	**349**	**343**	**414**	**351**	**339**	**394**	**346**
Subaru	**All**	**372**	**371**	**372**	**323**	**371**	**352**	**313**	**356**	**339**
Nissan	Nissan	331	464	374	323	470	363	300	424	343
Nissan	Infiniti	409	522	436	406	524	434	409	469	429
Nissan	**All**	**340**	**469**	**381**	**330**	**474**	**369**	**312**	**429**	**351**
BMW	BMW	398	447	408	382	452	407	358	440	383
BMW	Mini	293	-	293	297	-	297	300	-	300
BMW	**All**	**383**	**447**	**393**	**352**	**452**	**377**	**342**	**440**	**364**
Ford	Ford	352	484	421	327	479	389	322	463	393
Ford	Lincoln	404	503	471	393	505	425	365	454	406
Ford	Mercury	414	422	414	-	-	-	-	-	-
Ford	**All**	**359**	**484**	**422**	**330**	**480**	**390**	**324**	**463**	**394**
GM	Chevrolet	357	501	417	346	494	396	335	501	394
GM	GMC	377	503	475	375	493	461	367	498	460
GM	Buick	397	463	419	371	454	401	358	436	373
GM	Cadillac	433	570	456	434	574	453	407	505	423
GM	**All**	**371**	**501**	**429**	**358**	**492**	**410**	**348**	**498**	**404**
Daimler	Mercedes-Benz	444	533	472	398	495	430	380	467	405
Daimler	Smart	243	-	243	249	-	249	244	-	244
Daimler	**All**	**440**	**533**	**469**	**394**	**495**	**426**	**377**	**467**	**402**
Chrysler-Fiat	Jeep	-	465	465	401	474	463	359	466	456
Chrysler-Fiat	Dodge	391	460	431	392	439	416	357	444	386
Chrysler-Fiat	Chrysler	386	428	405	373	425	393	379	432	400
Chrysler-Fiat	Ram	-	554	554	-	553	553	-	510	510
Chrysler-Fiat	Fiat	-	-	-	282	-	282	282	-	282
Chrysler-Fiat	**All**	**392**	**477**	**458**	**376**	**478**	**442**	**359**	**462**	**411**
Other	**All**	**373**	**493**	**423**	**372**	**480**	**412**	**389**	**468**	**419**
All	**All**	**348**	**466**	**398**	**329**	**461**	**376**	**325**	**452**	**370**

*Note: Two manufacturers, Hyundai and Kia, are not included in rows in the table above due to a continuing investigation. On November 2, 2012, EPA announced that Hyundai and Kia would lower their fuel economy estimates for many vehicle models as the result of an EPA investigation of test data. This report uses the corrected fuel economy values submitted by Hyundai and Kia for four MY 2011 vehicles and for a majority of Hyundai and Kia vehicles for MY 2012 and MY 2013. Based on these corrected data, Hyundai's 2011 Cars and Trucks value is 327 g/mi CO_2, Hyundai's 2012 Cars and Trucks value is 314 g/mi CO_2, and Hyundai's preliminary 2013 Cars and Trucks value is 315 g/mi CO_2, Kia's 2011 Cars and Trucks value is 345 g/mi CO_2, Kia's 2012 Cars and Truck values is 336 g/mi CO_2, and Kia's preliminary 2013 Car and truck value is 326 g/mi CO_2. These corrected data are included in industry-wide or "All" values.

Tables 4.4 and 4.5 provide unadjusted, laboratory data for both fuel economy and CO_2 emissions on a manufacturer-specific basis. Unadjusted, laboratory data is relevant in a manufacturer-specific context because it is the foundation for EPA CO_2 emissions and NHTSA CAFE regulatory compliance, and because it provides a basis for comparing long-term trends from the perspective of vehicle design only, apart from the factors that affect real world performance that can change over time (i.e., driving behavior such as acceleration rates or the use of air conditioning). Note that EPA has not released corrected unadjusted, laboratory values for some Hyundai and Kia models for MY 2011-2013.

In general, manufacturer rankings based on the unadjusted, laboratory values in Tables 4.4 and 4.5 are very similar to those for the adjusted values in Tables 4.2 and 4.3. On average, in recent years, unadjusted, laboratory fuel economy values are about 25% greater than adjusted fuel economy values (slightly greater at higher absolute mpg levels), and average unadjusted, laboratory CO_2 emissions values are about 20% less than adjusted CO_2 emissions (slightly greater at lower CO_2 emissions levels).

Table 4.4

Unadjusted, Laboratory Fuel Economy (MPG) by Manufacturer and Make for MY 2011—2013

		Final MY 2011			Final MY 2012			Preliminary MY 2013		
Manufacturer	Make	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks
Mazda	**All**	**33.4**	**24.6**	**31.7**	**37.4**	**27.8**	**34.6**	**37.4**	**30.2**	**35.2**
Honda	Honda	35.9	26.9	30.9	38.1	28.6	34.5	39.3	28.9	35.1
Honda	Acura	29.9	23.4	25.7	30.9	23.3	27.5	33.3	24.7	30.1
Honda	**All**	**35.4**	**26.4**	**30.4**	**37.3**	**27.8**	**33.6**	**38.4**	**28.3**	**34.3**
Toyota	Toyota	37.0	24.9	30.8	41.4	24.8	33.0	43.0	24.4	32.8
Toyota	Lexus	29.7	25.6	28.3	31.5	26.1	29.8	31.5	26.6	29.8
Toyota	Scion	33.5	-	33.5	35.2	-	35.2	35.1	-	35.1
Toyota	**All**	**35.9**	**24.9**	**30.6**	**39.8**	**24.9**	**32.8**	**39.4**	**24.7**	**32.3**
VW	VW	35.4	27.7	34.1	34.2	28.9	33.9	34.4	27.1	33.9
VW	Audi	29.7	26.6	28.7	29.5	26.7	28.5	29.2	28.4	28.9
VW	**All**	**33.5**	**27.1**	**32.1**	**33.0**	**27.4**	**32.3**	**33.0**	**28.0**	**32.3**
Subaru	**All**	**30.2**	**30.4**	**30.4**	**35.2**	**30.5**	**32.2**	**36.4**	**31.9**	**33.6**
Nissan	Nissan	34.4	24.0	30.1	35.3	23.7	31.1	38.9	26.5	33.5
Nissan	Infiniti	27.1	21.0	25.4	27.4	20.9	25.5	27.2	23.7	25.9
Nissan	**All**	**33.3**	**23.8**	**29.6**	**34.4**	**23.5**	**30.5**	**37.2**	**26.2**	**32.6**
BMW	BMW	27.8	25.3	27.3	29.4	25.0	27.7	31.2	25.1	29.1
BMW	Mini	39.3	-	39.3	38.7	-	38.7	38.3	-	38.3
BMW	**All**	**29.1**	**25.3**	**28.4**	**32.2**	**25.0**	**30.0**	**32.9**	**25.1**	**30.8**
Ford	Ford	31.8	23.0	26.5	34.5	23.2	28.8	34.9	24.0	28.4
Ford	Lincoln	27.6	22.0	23.6	28.4	21.9	26.1	30.6	24.4	27.4
Ford	Mercury	26.7	26.8	26.7	-	-	-	-	-	-
Ford	**All**	**31.2**	**23.0**	**26.5**	**34.1**	**23.1**	**28.7**	**34.7**	**24.0**	**28.3**
GM	Chevrolet	31.0	22.0	26.5	32.2	22.3	28.0	33.4	21.7	28.1
GM	GMC	29.6	22.0	23.3	29.8	22.4	24.1	30.9	21.4	23.6
GM	Buick	27.6	23.8	26.2	29.7	24.5	27.5	31.1	25.6	29.9
GM	Cadillac	25.5	19.9	24.3	25.4	20.1	24.6	27.1	20.2	25.7
GM	**All**	**29.8**	**22.0**	**25.7**	**31.1**	**22.4**	**27.0**	**32.1**	**21.7**	**27.3**
Daimler	Mercedes-Benz	24.9	21.1	23.6	27.8	23.1	26.1	29.2	24.3	27.7
Daimler	Smart	48.7	-	48.7	49.5	-	49.5	50.3	-	50.3
Daimler	**All**	**25.1**	**21.1**	**23.7**	**28.2**	**23.1**	**26.3**	**29.6**	**24.3**	**27.9**
Chrysler-Fiat	Jeep	-	23.9	23.9	28.2	23.5	24.1	31.7	24.0	24.5
Chrysler-Fiat	Dodge	28.4	24.0	25.7	28.1	25.1	26.5	31.2	24.8	28.7
Chrysler-Fiat	Chrysler	28.4	25.7	27.1	29.5	25.9	28.0	29.0	25.4	27.5
Chrysler-Fiat	Ram	-	19.8	19.8	-	19.8	19.8	-	21.6	21.6
Chrysler-Fiat	Fiat	-	-	-	41.1	-	41.1	41.2	-	41.2
Chrysler-Fiat	**All**	**28.2**	**23.2**	**24.2**	**29.6**	**23.1**	**25.0**	**31.0**	**23.9**	**27.0**
Other	**All**	**29.9**	**22.4**	**26.3**	**30.1**	**23.1**	**27.0**	**28.8**	**23.9**	**26.7**
All	**All**	**32.3**	**23.9**	**28.1**	**34.3**	**24.1**	**29.8**	**34.8**	**24.5**	**30.3**

*Note: Two manufacturers, Hyundai and Kia, are not included in rows in the table above due to a continuing investigation. On November 2, 2012, EPA announced that Hyundai and Kia would lower their fuel economy estimates for many vehicle models as the result of an EPA investigation of test data. EPA has not yet released formal, corrected unadjusted, laboratory values for Hyundai and Kia.

Table 4.5

Unadjusted, Laboratory CO_2 Emissions (g/mi) by Manufacturer and Make for MY 2011-2013

		Final MY 2011			Final MY 2012			Preliminary MY 2013		
Manufacturer	Make	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks
Mazda	**All**	**266**	**361**	**281**	**238**	**319**	**257**	**238**	**294**	**253**
Honda	Honda	247	331	287	233	311	258	226	308	254
Honda	Acura	297	380	345	288	382	323	266	360	296
Honda	**All**	**251**	**336**	**293**	**238**	**319**	**264**	**231**	**314**	**259**
Toyota	Toyota	240	357	289	215	358	269	207	364	271
Toyota	Lexus	299	347	314	282	340	299	282	335	298
Toyota	Scion	266	-	266	252	-	252	253	-	253
Toyota	**All**	**248**	**357**	**291**	**223**	**357**	**271**	**226**	**360**	**275**
Subaru	**All**	**294**	**292**	**293**	**252**	**292**	**276**	**244**	**278**	**265**
VW	VW	258	324	268	266	319	268	265	343	270
VW	Audi	300	340	313	303	337	314	305	313	308
VW	**All**	**271**	**332**	**283**	**274**	**331**	**280**	**275**	**324**	**281**
Nissan	Nissan	258	370	295	252	375	286	232	335	267
Nissan	Infiniti	327	423	350	325	425	348	327	376	343
Nissan	**All**	**267**	**374**	**301**	**258**	**378**	**291**	**242**	**339**	**275**
BMW	BMW	320	358	328	303	363	324	285	353	305
BMW	Mini	226	-	226	230	-	230	232	-	232
BMW	**All**	**306**	**358**	**315**	**276**	**363**	**299**	**270**	**353**	**289**
Ford	Ford	279	387	335	258	384	309	254	371	313
Ford	Lincoln	321	403	377	313	406	340	290	364	324
Ford	Mercury	332	332	332	-	-	-	-	-	-
Ford	**All**	**285**	**387**	**336**	**261**	**384**	**310**	**256**	**370**	**314**
GM	Chevrolet	287	404	336	276	399	318	266	409	317
GM	GMC	301	405	382	298	396	369	287	415	377
GM	Buick	322	373	339	299	363	323	286	347	297
GM	Cadillac	348	447	365	350	443	362	328	439	346
GM	**All**	**298**	**404**	**345**	**286**	**396**	**329**	**277**	**409**	**326**
Daimler	Mercedes-Benz	358	427	379	320	394	344	304	369	323
Daimler	Smart	182	-	182	180	-	180	177	-	177
Daimler	**All**	**354**	**427**	**377**	**316**	**394**	**341**	**301**	**369**	**320**
Chrysler-Fiat	Jeep	-	372	372	315	379	369	280	371	362
Chrysler-Fiat	Dodge	313	371	346	316	354	335	285	359	310
Chrysler-Fiat	Chrysler	313	345	327	301	343	318	306	349	323
Chrysler-Fiat	Ram	-	449	449	-	448	448	-	412	412
Chrysler-Fiat	Fiat	-	-	-	216	-	216	216	-	216
Chrysler-Fiat	**All**	**315**	**383**	**368**	**301**	**384**	**355**	**287**	**371**	**329**
Other	**All**	**298**	**396**	**338**	**296**	**385**	**329**	**308**	**374**	**334**
All	**All**	**276**	**373**	**317**	**259**	**369**	**298**	**256**	**363**	**294**

*Note: Two manufacturers, Hyundai and Kia, are not included in rows in the table above due to a continuing investigation. On November 2, 2012, EPA announced that Hyundai and Kia would lower their fuel economy estimates for many vehicle models as the result of an EPA investigation of test data. EPA has not yet released formal, corrected unadjusted, laboratory values for Hyundai and Kia.

Table 4.6 shows footprint by manufacturer for MY 2011-2013. In recent years, industry-wide footprint has been fluctuating around 49 square feet. GM, Ford, and Chrysler-Fiat had the largest footprint values in MY 2011 in the 51-52 square feet range, and Subaru and Mazda had the lowest footprint values of 45 square feet. The remaining manufacturers had average footprint values in the 46-48 square feet range.

Table 4.6

Footprint (square feet) by Manufacturer for MY 2011—2013

	Final MY 2011			Final MY 2012			Preliminary MY 2013		
Manufacturer	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks	Cars	Trucks	Cars and Trucks
GM	47.2	61.0	53.4	47.0	60.1	52.1	46.4	61.9	52.2
Toyota	45.5	53.4	48.6	45.1	53.4	48.1	44.8	53.9	48.2
Ford	46.1	58.2	52.1	45.3	59.4	50.9	46.9	58.9	52.9
Honda	45.1	49.7	47.4	45.1	50.5	46.8	45.1	49.7	46.6
Chrysler-Fiat	49.0	52.6	51.8	47.2	53.7	51.4	47.3	52.2	49.8
Nissan	45.0	51.2	47.0	45.0	51.6	46.8	45.9	51.1	47.7
Hyundai	47.0	46.7	47.0	46.4	46.4	46.4	46.3	46.2	46.3
VW	44.4	47.8	45.1	45.0	49.0	45.5	45.5	48.8	45.9
Kia	45.4	48.3	45.9	45.6	52.0	46.2	45.8	46.0	45.8
Mazda	44.3	50.5	45.3	43.9	48.1	44.9	43.5	47.7	44.6
Subaru	44.2	44.8	44.6	44.3	44.7	44.5	44.2	44.6	44.5
BMW	45.9	51.1	46.8	45.9	51.4	47.3	46.2	51.2	47.4
Daimler	46.4	51.9	48.1	46.5	51.8	48.2	47.2	51.2	48.3
Other	45.2	48.2	46.4	45.5	48.5	46.6	45.0	48.3	46.3
All	**46.0**	**54.4**	**49.5**	**45.7**	**54.5**	**48.8**	**45.9**	**54.9**	**49.1**

Manufacturer-specific MY 2012 car footprint values varied little, within 44-47 square feet. MY 2012 truck footprint values were much more variable, ranging from 45 (Subaru) to 60 (General Motors) square feet.

In terms of change in footprint values from MY 2011 to MY 2012, four manufacturers (BMW, VW, Kia, and Daimler) slightly increased footprint, all equal to or less than 0.5 square feet. The remaining nine manufacturers decreased footprint, with the biggest decreases reported by General Motors (1.3 square feet) and Ford (1.2 square feet). In Ford's case, truck footprint increased in MY 2012, but its overall fleet decreased in footprint because of a major decrease in truck production share.

Industry-wide footprint is projected to increase slightly in MY 2013.

Table 4.7 shows manufacturer-specific values for adjusted fuel economy and production share for the two classes (cars and trucks) and the five vehicle types (cars, car SUVs, truck SUVs, pickups, and minivans/vans) for MY 2012. Toyota had the highest adjusted fuel economy for the car type, while Honda led for car SUVs. For the truck types, Subaru reported the highest adjusted fuel economy for truck SUVs, General Motors and Toyota had the highest pickup furl economy among manufacturers that make a significant number of pickups, and Mazda had the highest adjusted fuel economy for minivans/vans. VW had the highest car share, at 89%, with Mazda, BMW, and Nissan having car shares in the 73-77% range. Chrysler-Fiat had the highest truck share of 65%, followed by Subaru at 61% and Ford, General Motors, and Toyota in the 36-40% range.

Industry-wide, car type vehicles averaged 4.4 mpg higher than car SUVs in MY 2012. Among truck types, minivans/vans had the highest adjusted fuel economy of 21.4 mpg, followed by truck SUVs at 20.0 mpg, and pickups at 17.2 mpg. Notably, the car type, at 27.8 mpg, was the only one of the five vehicle types to exceed the fleetwide average of 23.6 mpg in MY 2012.

Table 4.7

Adjusted Fuel Economy and Production Share by Vehicle Classification and Type for MY 2012

	Cars		Car SUVs		All Cars		Truck SUVs		Pickups		Minivans/Vans		All Trucks		All	
Manufacturer	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share	Adj FE (MPG)	Prod Share
GM	25.7	43.1%	23.0	17.9%	24.8	61.0%	18.6	19.8%	17.6	18.3%	16.2	0.9%	18.1	39.0%	21.7	100.0%
Toyota	31.4	59.3%	23.6	4.7%	30.7	64.0%	20.9	18.8%	17.6	11.5%	21.2	5.6%	19.7	36.0%	25.6	100.0%
Ford	27.8	48.9%	23.4	11.1%	26.9	60.0%	19.8	17.0%	17.3	20.7%	22.6	2.3%	18.5	40.0%	22.8	100.0%
Honda	29.8	60.6%	25.5	7.3%	29.3	67.9%	22.3	21.7%	18.1	0.9%	22.4	9.5%	22.2	32.1%	26.6	100.0%
Chrysler-Fiat	24.0	29.5%	22.0	5.7%	23.7	35.2%	18.9	34.1%	16.0	14.3%	20.9	16.4%	18.6	64.8%	20.1	100.0%
Nissan	27.4	65.2%	23.6	7.5%	26.9	72.7%	19.7	17.4%	16.6	8.1%	21.7	1.8%	18.8	27.3%	24.1	100.0%
VW	26.5	85.3%	24.0	3.2%	26.4	88.5%	21.9	11.5%	-	-	-	-	21.9	11.5%	25.8	100.0%
Mazda	29.5	73.7%	23.2	2.8%	29.3	76.5%	19.6	11.9%	-	-	24.7	11.7%	21.9	23.5%	27.1	100.0%
Subaru	27.5	39.3%	-	-	27.5	39.3%	24.0	60.7%	-	-	-	-	24.0	60.7%	25.2	100.0%
BMW	25.3	74.4%	-	-	25.3	74.4%	20.1	25.6%	-	-	-	-	20.1	25.6%	23.7	100.0%
Daimler	22.9	63.5%	18.9	4.6%	22.6	68.1%	18.4	31.9%	-	-	-	-	18.4	31.9%	21.1	100.0%
Other	23.9	55.5%	24.2	7.4%	23.9	62.9%	18.6	35.7%	17.5	0.9%	14.9	0.5%	18.5	37.1%	21.6	100.0%
All	**27.8**	**54.9%**	**23.4**	**9.4%**	**27.0**	**64.4%**	**20.0**	**20.6%**	**17.2**	**10.1%**	**21.4**	**4.9%**	**19.3**	**35.6%**	**23.6**	**100.0%**

Table 4.8 shows average MY 2012 manufacturer-specific values, for all cars and trucks, for three important vehicle attributes: footprint, weight, and horsepower. The footprint data in Table 4.8 were also shown in Table 4.6 and discussed above. Daimler had the highest average weight of 4450 pounds, followed by General Motors and Chrysler-Fiat. Mazda reported the lowest average weight of 3330 pounds, followed by Hyundai and Kia. Daimler also had the highest average horsepower level of 282 hp, followed by Chrysler-Fiat and BMW. Mazda also reported the lowest horsepower level of 171 hp, followed by Subaru and Hyundai.

Table 4.8

Vehicle Footprint, Weight, and Horsepower by Manufacturer for MY 2012

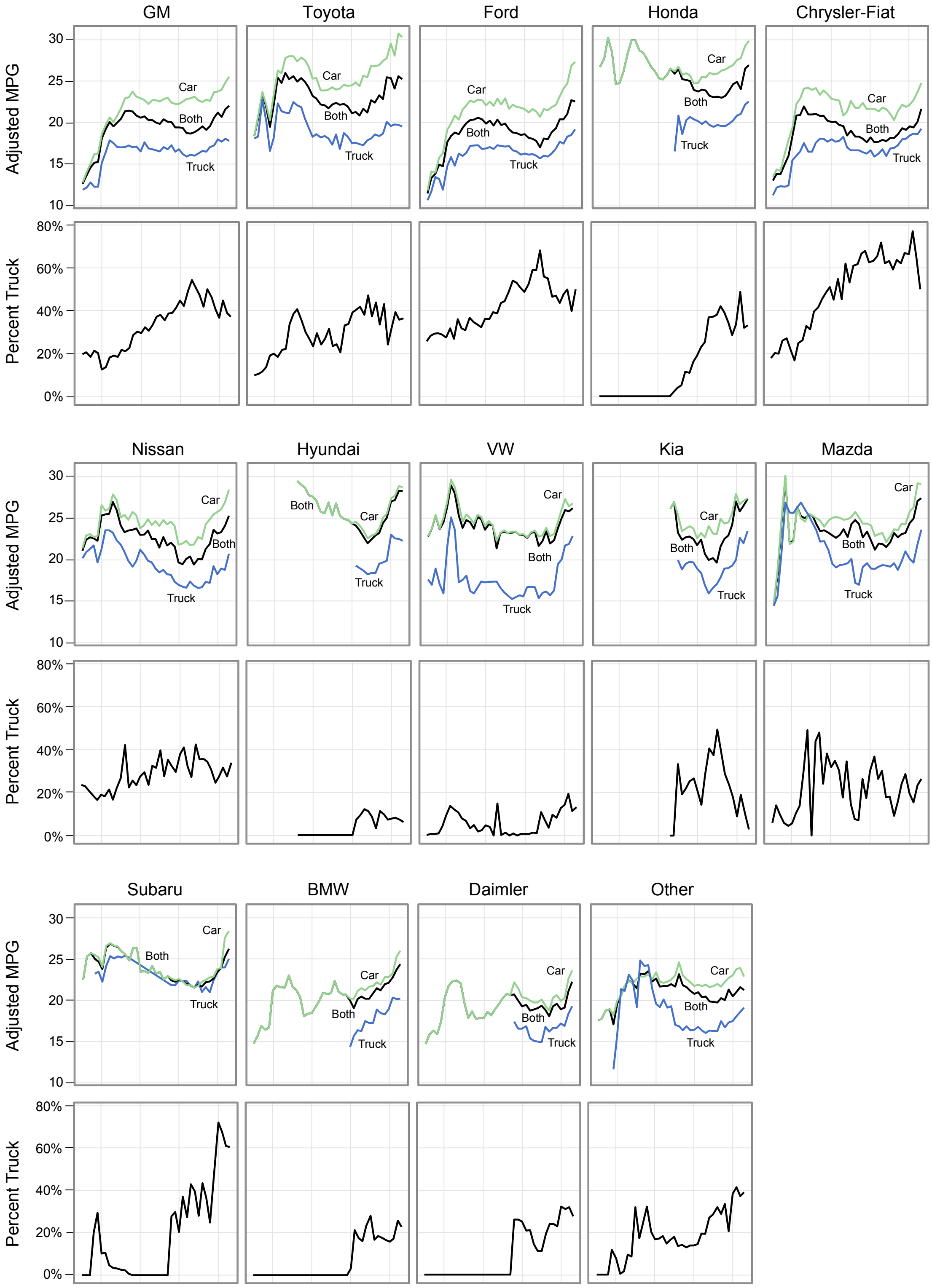
Manufacturer	Footprint (sq ft)	Weight (lb)	HP
GM	52.1	4395	245
Toyota	48.1	3863	196
Ford	50.9	4152	241
Honda	46.8	3646	192
Chrysler-Fiat	51.4	4361	271
Nissan	46.8	3748	204
Hyundai	46.4	3375	189
VW	45.5	3734	196
Kia	46.2	3485	191
Mazda	44.9	3330	171
Subaru	44.5	3663	176
BMW	47.3	4071	264
Daimler	48.2	4450	282
All	**48.8**	**3977**	**222**

Finally, Figure 4.1 provides a historical perspective, for both adjusted fuel economy and truck share, for each of the top 13 manufacturers. Adjusted fuel economy is presented for cars only, trucks only, and cars and trucks combined. One noteworthy result in Figure 4.1 is that there is very little difference between the adjusted fuel economy values for Subaru cars and trucks, the only manufacturer for which this is the case.

More information for the historic Trends database stratified by manufacturer can be found in Appendices J and K.

Figure 4.1

Adjusted Fuel Economy and Percent Truck by Manufacturer for MY 1975-2013



5 Powertrain Technologies

Technological innovation is a major driver of vehicle design in general, and vehicle fuel economy and CO_2 emissions in particular. Since its inception, this report has tracked the usage of key technologies as well as many major engine and transmission parameters. This section of the report will focus on the larger technology trends in engine and transmission production and the impact of those trends on vehicle fuel economy and CO_2 emissions.

Over the last 35 years, one trend is strikingly clear; automakers have consistently developed and commercialized new technologies that have provided more benefits to consumers. As discussed previously in Sections 2 and 3, the benefits provided by new technologies have varied over time. New technologies have been introduced for many reasons, including to increase fuel economy, reduce CO_2 emissions, increase vehicle power and performance, increase in vehicle content and weight, or some combination of all the above.

A. Trends in Engine Power and Size (cylinders and displacement)

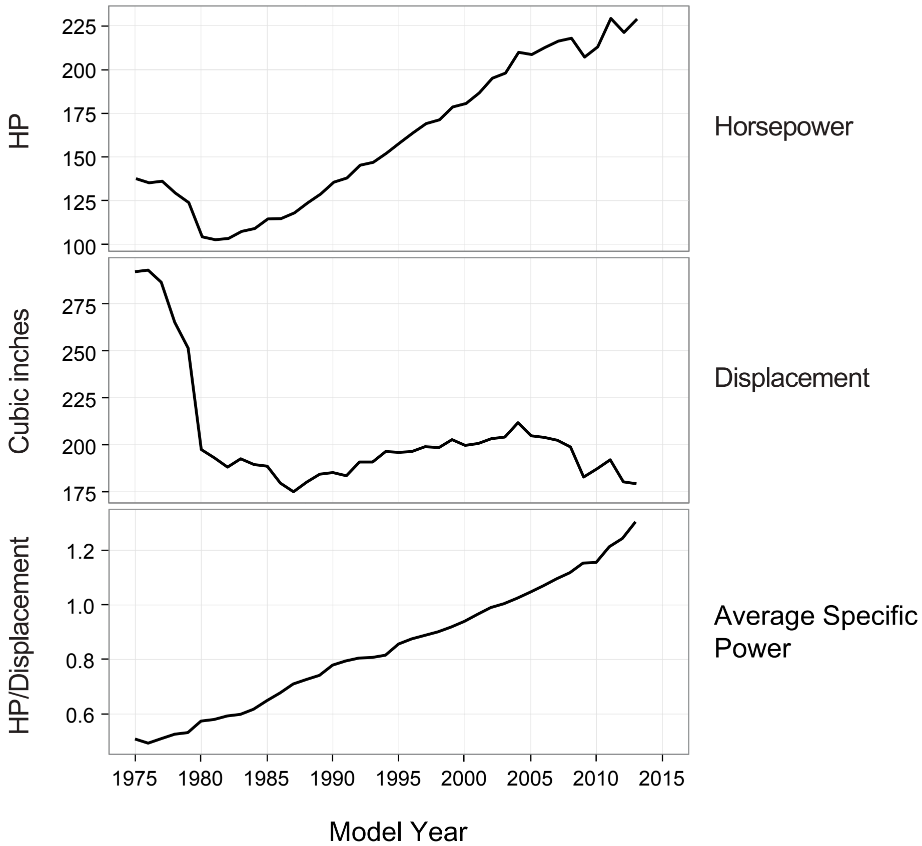
One of the most remarkable trends over the course of this report is the increase in vehicle power since the early 1980s. From 1975 through the early 1980s, average horsepower decreased, in combination with lower vehicle weight (see Table 2.1 and Figure 2.3) and smaller engine displacement (see below). Since the early 1980s, the average new vehicle horsepower has more than doubled, from just over 100 hp to over 230 hp in MY 2011. Average horsepower climbed consistently from MY1982 to MY 2008, and, after falling slightly in MY 2009, set a new all-time high of 230 hp in MY 2011. The trend in horsepower is mainly attributable to improvements in engine technology, but increasing sales of larger vehicles and an increasing percentage of truck sales have also influenced the increase of average new vehicle horsepower. The trend in average new vehicle horsepower is shown in Figure 5.1.

Engine size, as measured by total displacement, is also shown in Figure 5.1. Three general phases in engine displacement are discernible. From MY 1975 to 1987, the average engine displacement of new vehicles dropped dramatically by nearly 40%. From MY 1988 to 2004, displacement generally grew slowly, but the trend reversed in 2005 and engine displacement has been slowly decreasing since. In MY 2012, engine displacement is projected to be just slightly higher than the lowest average displacement in MY 1987.

The contrasting trends in horsepower (near an all-time high) and engine displacement (near an all-time low) highlight the continuing improvement in engines due to introduction of new technologies (e.g. port fuel injection) and smaller engineering improvements that are not tracked by this report (e.g. reduced internal friction). One additional way to examine the relationship between engine horsepower and displacement is to look at the trend in *specific* power, which is a metric to compare the power output of an engine relative to its size. Here, engine specific power is defined as horsepower divided by displacement.

Figure 5.1

Engine Displacement and Power

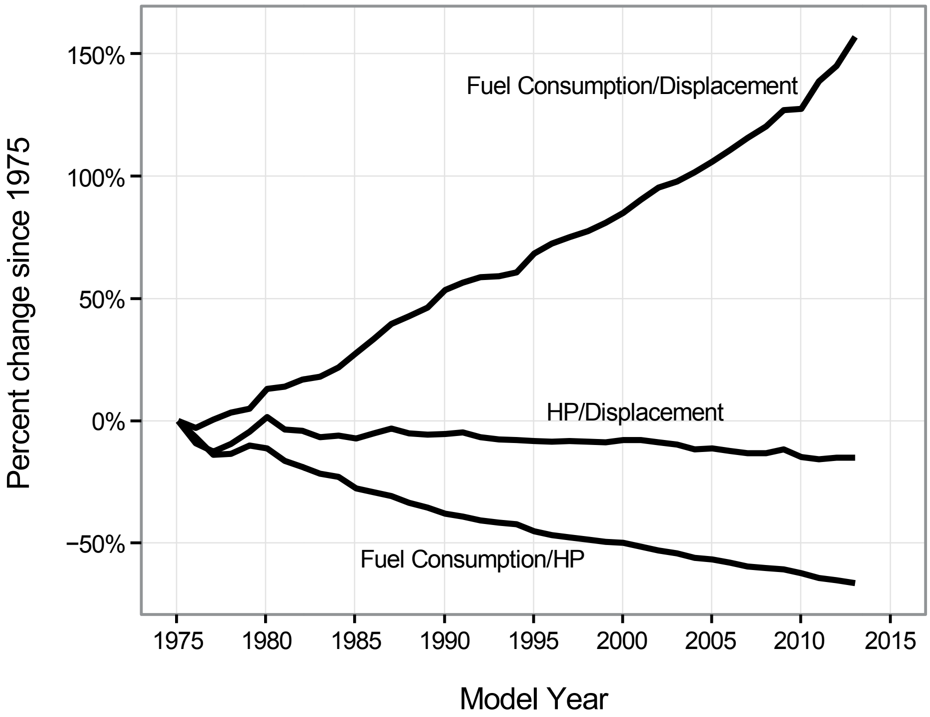


Since the beginning of this report, the average specific power of engines across the new vehicle fleet has increased at a remarkably steady rate, as shown in Figure 5.1. Over the 37 years covered by this report, the specific power of new vehicle engines has increased, on average, by 0.02 horsepower per cubic inch every year. Considering the numerous and significant changes to engines over this time span, changes in consumer preferences, and the external pressures on vehicle purchases, the long standing linearity of this trend is noteworthy. The roughly linear increase in specific power does not appear to be slowing (if anything the last few years of data suggest a slight increase above the historical norm.

Figure 5.2 summarizes three important engine metrics, each of which has shown a remarkably linear change over time. Specific power, as discussed above, has increased more than 150% over the 37 years of this report at a very steady rate. The amount of fuel consumed by an engine, relative to the total displacement, has fallen about 15% since MY 1975, and fuel consumption relative to engine horsepower has fallen nearly 65% since MY 1975. Taken as a whole, the trend lines in Figure 5.2 very clearly show that engine improvements over time have been steady, continual, and have resulted in impressive improvements to internal combustion engines.

Figure 5.2

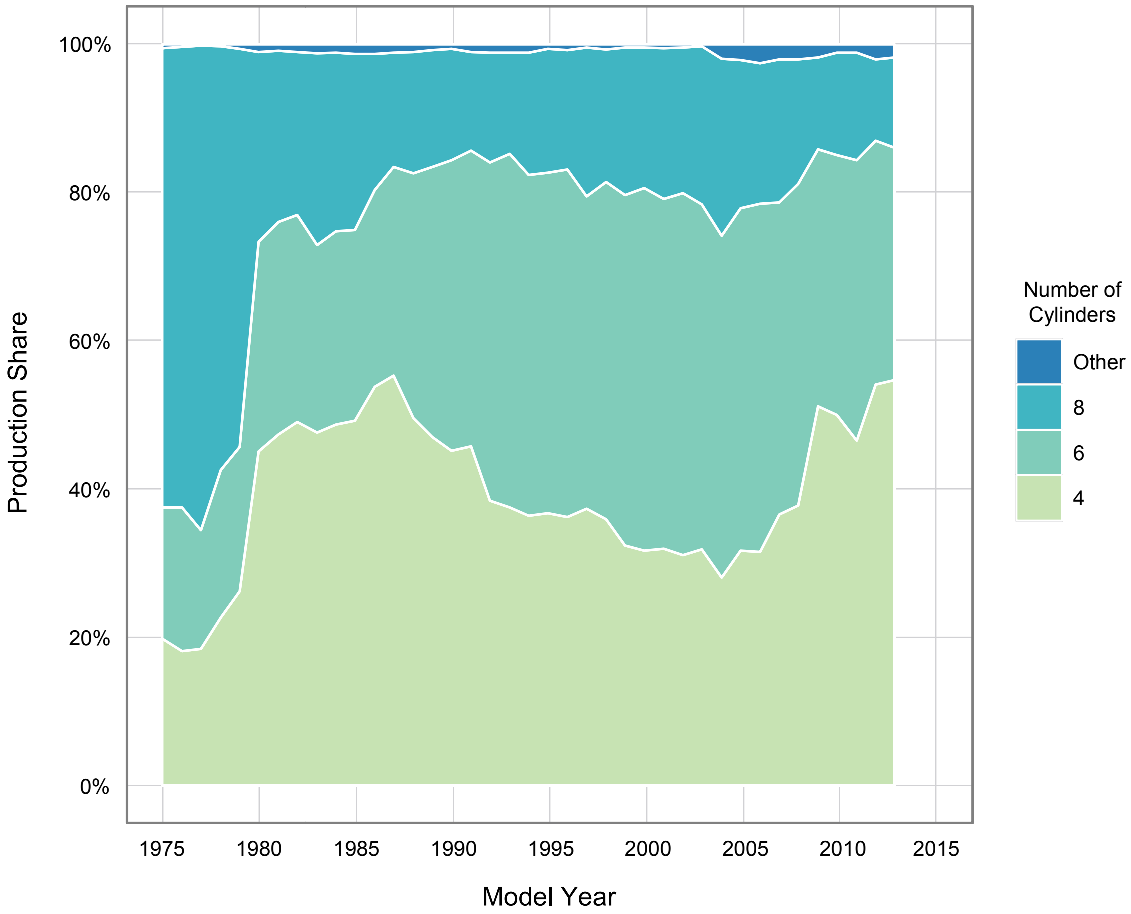
Percent Change for Specific Engine Metrics



Another basic engine design parameter that is useful to explore is the number of engine cylinders. Since 1975, there have been significant changes to the number of cylinders in new vehicles, as shown in Figure 5.3. In the mid and late 1970s, the 8-cylinder engine was dominant, accounting for over half of new vehicle production. In MY 1980 there was a significant change in the market, as 8-cylinder engine production share dropped from 54% to 26% and 4-cylinder production share increased from 26% to 45%. The 4-cylinder engine then continued to lead the market until they were overtaken by 6-cylinder engines in MY 1992. Model year 2009 marked a second major shift in engine production, as 4-cylinder engines once again became the production leader with 51% of the market (an increase of 13% in a single year), followed by 6-cylinder engines with 35%, and 8-cyinder engines at an all-time low of 12%. Production of four cylinder engines decreased slightly in MY 2010 and MY 2011, but increased back above 50% in MY 2012 and is projected to keep climbing in MY 2013. Engine displacement per cylinder has been relatively stable over the time of this report (around 35 cubic inches per cylinder since 1980), so the reduction in overall new vehicle engine displacement shown in Figure 5.1 is almost entirely due to the shift towards engines with fewer cylinders.

Figure 5.3

Production Share by Number of Cylinders



B. Trends in Fuel Delivery Methods and Valvetrains

One aspect of engine design that has changed significantly over time is how fuel is delivered into the engine. In the 1970s and early 1980s, nearly all engines used carburetors to meter fuel delivered to the engine. Carburetors were replaced over time with throttle body injection systems (TBI) and port fuel injection systems. More recently, engines with gasoline direct injection (GDI) have begun to replace engines with port fuel injection. Engines using GDI were first introduced into the market in very limited amounts in MY 2007, and only 6 years later GDI engines are projected to be installed on nearly 31% of new vehicles in MY 2013.

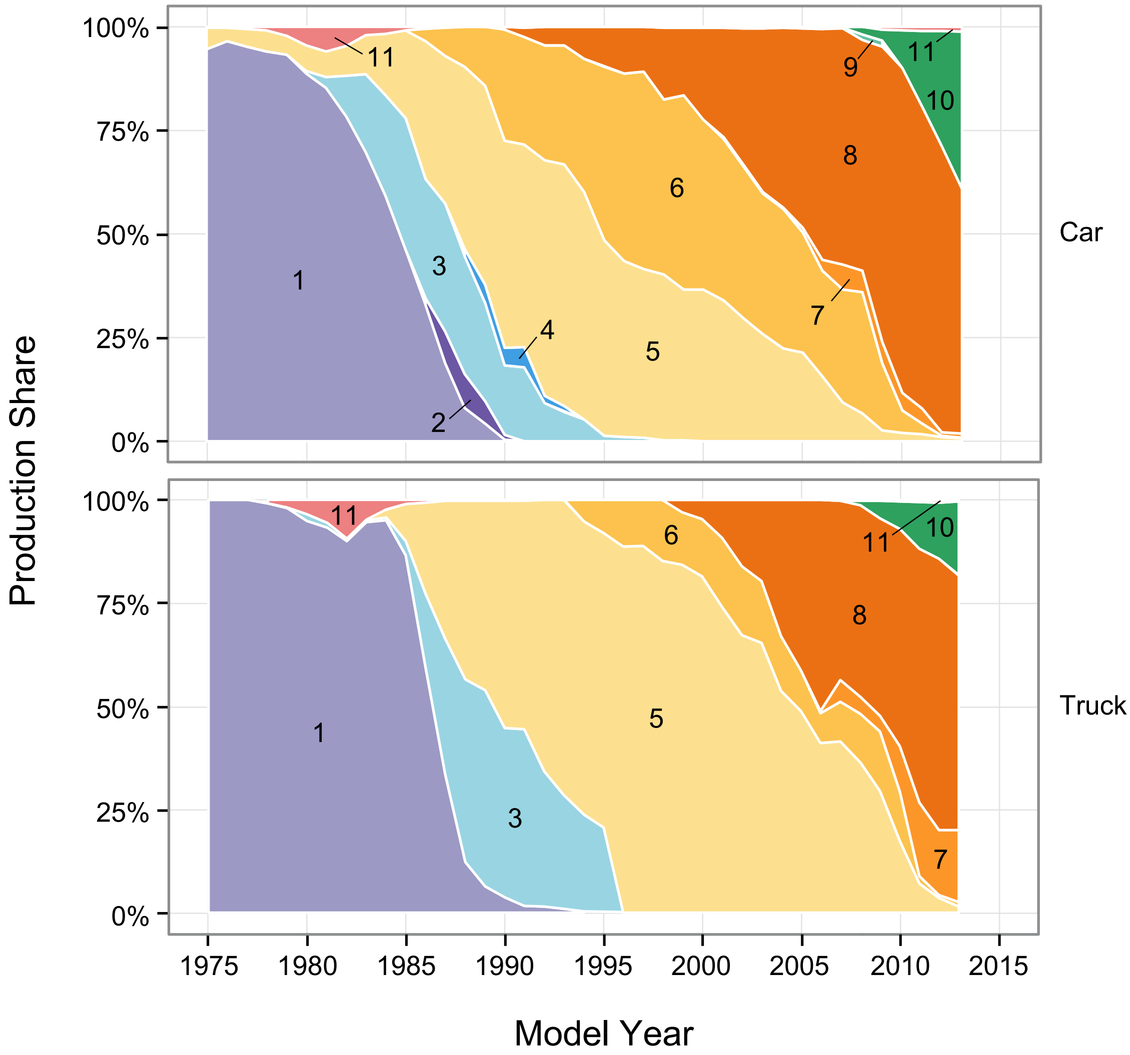
Another key aspect of engine design is the valvetrain. The number of valves per cylinder and the ability to alter valve timing during the combustion cycle can result in significant power and efficiency improvements. This report began tracking multi-valve engines (i.e., engines with more than 2 valves per cylinder) for cars in MY 1986, and since that time nearly the entire fleet has converted to multi-valve design. While some three and five valve engines have been produced, the vast majority of multi-valve engines are based on 4 valves per cylinder. In addition to the number of valves per cylinder, engine designs have evolved that allow engine valves to vary the timing when they are opened or closed with respect to the combustion cycle, creating more flexibility to control engine efficiency, power, and emissions. This report began tracking variable valve timing (VVT) for cars in MY 1990, and since then nearly the entire fleet has adopted this technology. Figure 5.4 shows the evolution of engine technology, including fuel delivery method and the introduction of VVT and multi-valve engines.

As clearly shown in Figure 5.4, fuel delivery and valve-train technologies have often developed over the same time frames. Nearly all carbureted engines relied on fixed valve timing and had two valves per cylinder, as did early port injected engines. Port injected engines largely developed into engines with both multi-valve and VVT technology. Engines with GDI are almost exclusively using multi-valve and VVT technology. These four engine groupings, or packages, represent a large share of the engines produced over the last 37 years of this report.

Figure 5.5 shows the changes in specific power and fuel consumption between each of these engine packages over time. There is a very clear increase in specific power of each engine package, as engines moved from carbureted engines, to two valve port fixed engines, to multi valve port VVT engines, and finally to GDI engines. Some of the increase for GDI engines may also be due to the fact that GDI engines are often paired with turbochargers to further increase power. Figure 5.5 additionally shows the reduction in fuel consumption, per horsepower, for each of the four engine packages.

Figure 5.4

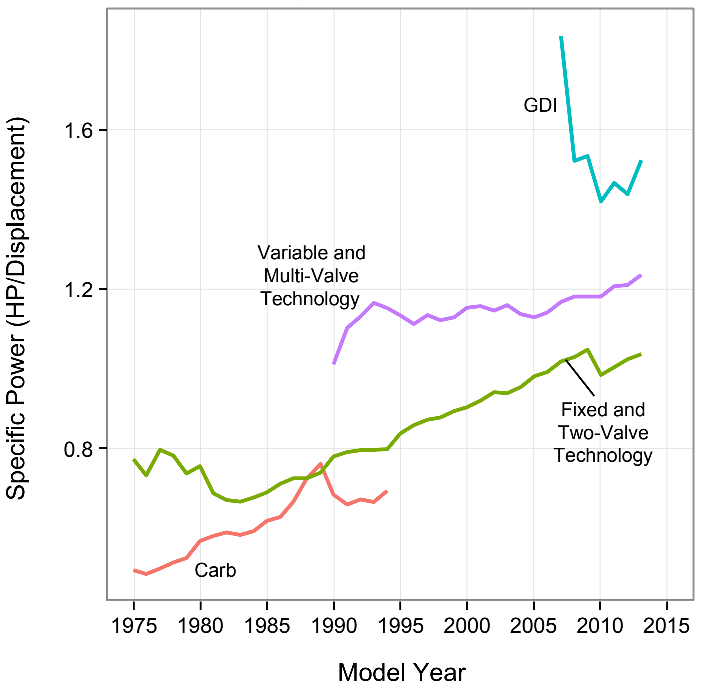
Production Share by Engine Technology

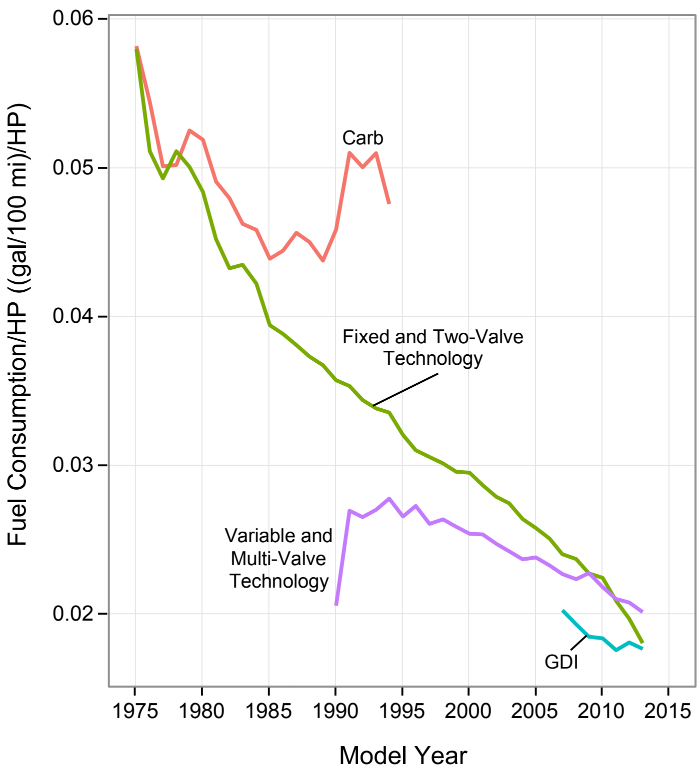


Fuel Delivery	Valve Timing	Number of Valves	Key
Carbureted	Fixed	Two-Valve	1
	Variable	Multi-Valve	2
Throttle Body Injection	Fixed	Two-Valve	3
	Fixed	Multi-Valve	4
Port Fuel Injection	Fixed	Two-Valve	5
		Multi-Valve	6
	Variable	Two-Valve	7
		Multi-Valve	8
Gasoline Direct Injection (GDI)	Fixed	Multi-Valve	9
	Variable	Multi-Valve	10
Diesel	—	—	11

Figure 5.5

Engine Metrics for Different Engine Technology Packages





C. New Powertrain Strategies: Turbo Downsizing, Hybrids, and Diesels

Two powertrain strategies that are relatively new to this report are turbo-downsizing and hybridization. Vehicles that employ turbo downsizing use a smaller displacement engine with a turbocharger in place of a larger naturally aspirated engine. Hybrid vehicles feature larger batteries that provide a second source of on-board power. Diesel engines, while certainly not new to the market or to this report, are also included in this section of the report due to the increased interest in diesel vehicles.

Turbo-downsizing

Nearly all manufacturers have introduced (or have plans to introduce) engines that are considered "turbo downsized" engines. This group of engines generally has three common features: a smaller displacement than the engines they are replacing, turbochargers, and (often, but not always) GDI. Turbo downsized engines are an approach to engine design that provides increased fuel economy by using a smaller engine for most vehicle operation, while retaining the ability to garner more power via the turbocharger, when needed.

Turbocharged engines are projected to capture approximately 15% of new vehicle production in MY 2013. This is a significant increase in market penetration over the last decade, and it is a trend that appears to be accelerating rapidly, as shown in Figure 5.6. Prior to the last few years, turbochargers (and superchargers) were available, but generally only on high performance, low volume vehicles. It is only in the last few years that turbochargers have been available as part of a downsized turbo vehicle package, many of which are now available in more mainstream vehicles. The sales of these vehicles are driving the increase in turbochargers across new vehicles. Both cars and trucks are rapidly adding turbocharged engine packages, as shown in Figure 5.6.

Turbochargers are most frequently combined with 4-cylinder engines. Excluding diesel engines, over 75% of all turbocharged engines are combined with 4-cylinder engines and about 18% are combined with 6-cylinder engines. Nearly 60% of all turbocharged engines are projected to be installed in 4-cylinder cars in MY 2013. The overall breakdown of turbocharger distribution in the new vehicle fleet is shown in Table 5.1.

In current engines, turbochargers are often being used in combination with GDI to allow for more efficient engine operation and to increase the resistance to engine knock (the use of variable valve timing also helps to reduce turbo lag). In MY 2013, over 70% of cars with gasoline turbocharged engines also use GDI, and nearly 98% of gasoline turbocharged trucks also use GDI.

Figure 5.6

Market Share of Gasoline Turbo Vehicles

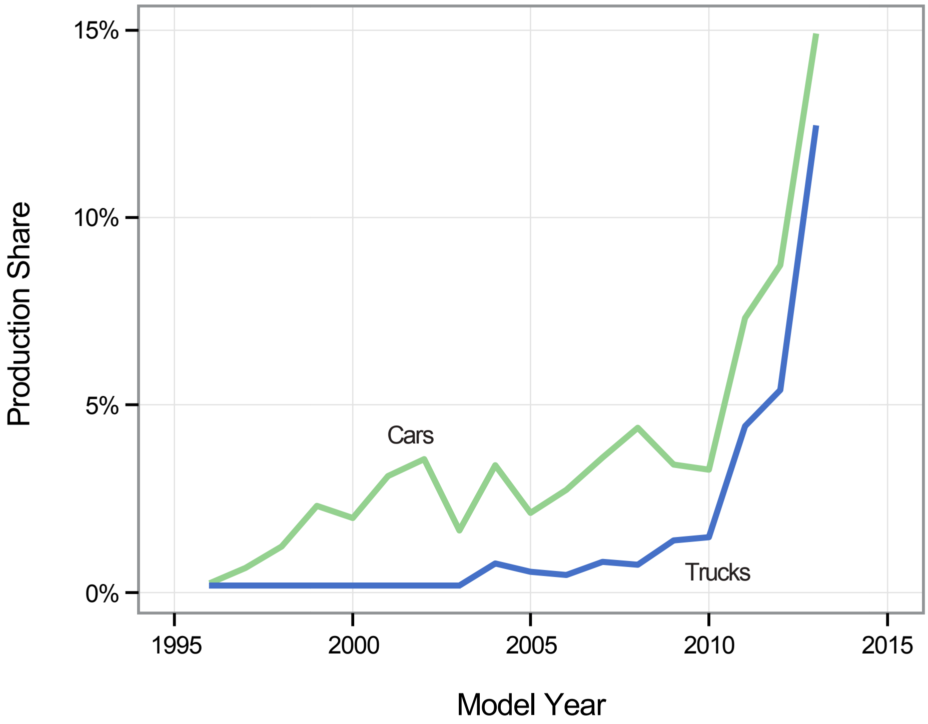


Table 5.1

Distribution of MY 2013 Turbocharged Engines (Excludes Diesel)

Category	Turbo Share
Car	
4 cylinder Car	60.1%
6 cylinder Car	3.4%
8 cylinder Car	3.4%
Other Car	1.4%
Truck	
4 cylinder Truck	15.2%
6 cylinder Truck	14.7%
8 cylinder Truck	1.8%

Figure 5.7

Distribution of Gasoline Turbo Vehicles by Displacement and Horsepower, MY 2010 – MY 2013

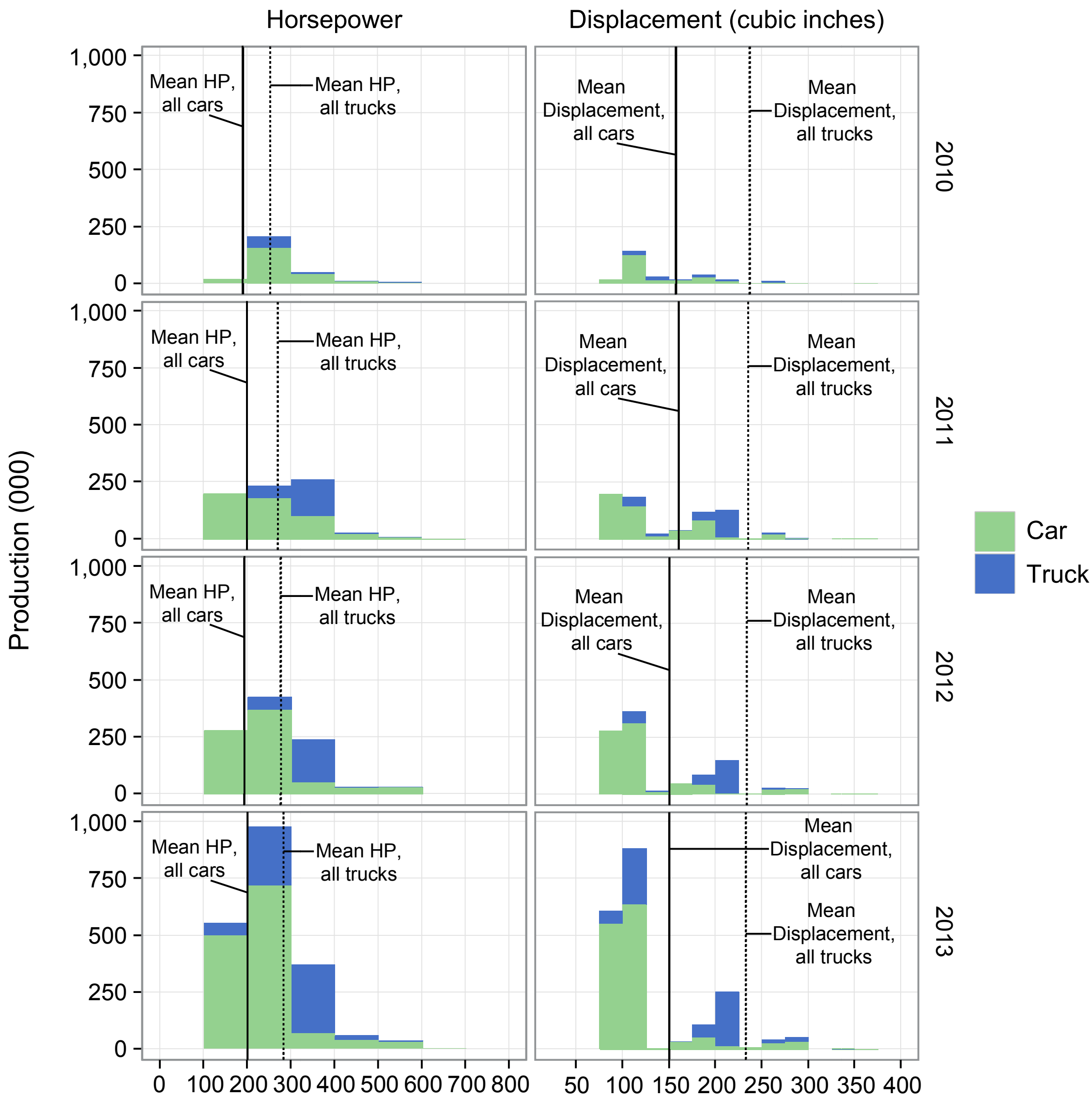


Figure 5.7 examines the distribution of engine displacement and power of turbocharged engines for MY 2010 to MY 2013. Note that the production values for cars and trucks in each bar are additive, e.g., there are projected to be nearly 750,000 gasoline cars with turbochargers in the 200-300 horsepower range in MY 2013, with another 250,000 gasoline trucks with turbochargers in the same horsepower range. In MY 2010, turbochargers were used mostly on cars, and were available on engines both above and below the average engine displacement. The biggest increase in turbocharger use over the last few years has been in cars with engine displacement well below average displacement. In addition, many more engines with turbochargers are at or below the new vehicle average horsepower, for both cars and trucks. This trend towards adding turbochargers to smaller, less powerful engines

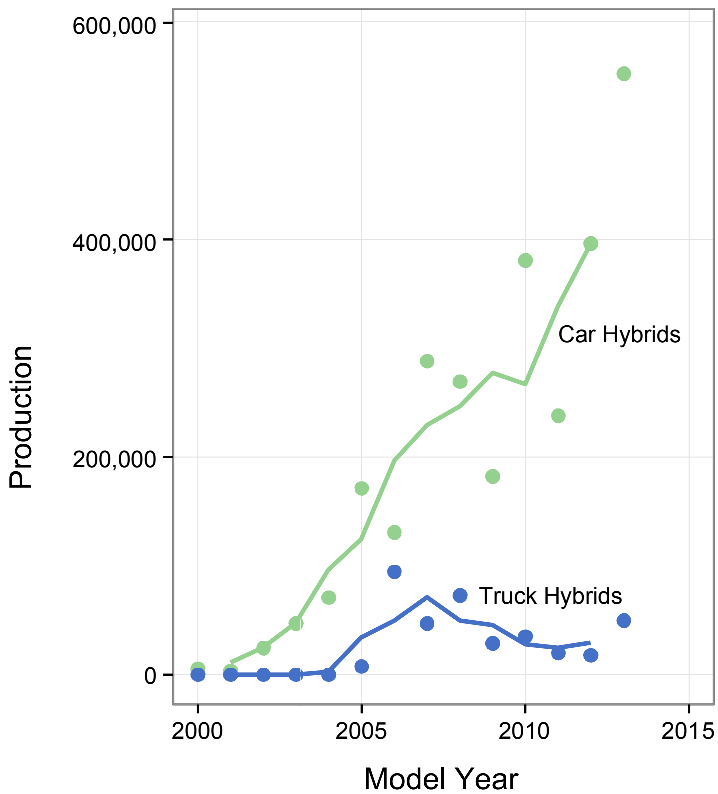
reinforces the conclusion that most turbochargers are currently being used for turbo downsizing, and not simply just to add power for performance vehicles.

Hybrids

Hybrid vehicles utilize larger battery packs, electric motor(s), and other hardware that increase vehicle fuel economy for several reasons including: 1) regenerative braking can capture energy that is otherwise lost in conventional friction braking to charge the battery, 2) two sources of on-board power can allow the engine to be operated at or near its peak efficiency more often, and 3) the engine can be shut off at idle. The introduction of the first hybrid into the U.S. marketplace occurred in MY 2000. Since then, hybrids have slowly increased market share and are projected to reach 4.2% of all new vehicles produced in MY 2013. The market share of hybrids has fluctuated from year to year, but the general trend has been a clear increase in overall market penetration as shown in Figure 5.8. A large factor in the fluctuating hybrid sales is the fact that hybrid sales are still largely dominated by one vehicle, the Toyota Prius. Production of the Toyota Prius, like many other vehicles produced in Japan, was impacted by the earthquake and tsunami that hit Japan in 2011, and a shortened model year in MY 2009 due to the introduction of a redesigned vehicle.

Figure 5.8

Hybrid Production MY 2000 – MY 2013 (With 3-Year Moving Average)

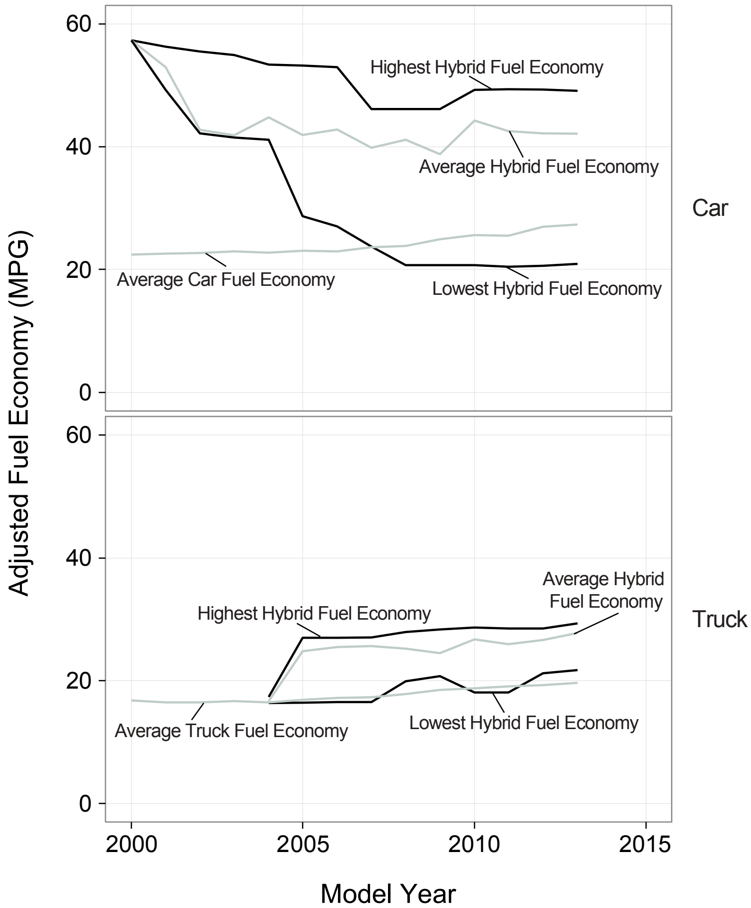


Hybrid vehicles were introduced into the market in MY 2000 as low production, specialty vehicles with very high fuel economy. Over time, more hybrids models were introduced into the market, and hybrids were introduced over a broader range of vehicle types, including larger vehicles and even some vehicles that were more performance oriented. Hybrid powertrains are now frequently offered as options on many popular models and are nearly indistinguishable from their non-hybrid relatives. Most hybrids provide higher fuel economy than comparable vehicles, although some hybrids have been offered as more performance-oriented vehicles with more minor fuel economy improvements.

Figure 5.9 shows the production-weighted distribution of fuel economy for all hybrid vehicles by year. The average hybrid fuel economy is well above the new vehicle average in all model years, even as hybrid systems have been introduced into a wide range of larger and more powerful vehicles. The production-weighted average hybrid car fuel economy shown in Figure 5.9 does actually fall from MY 2000 until MY 2003, but this is a reflection of the widening availability of hybrid models, not of the technology. Hybrid truck fuel economy has been less variable; however there have been fewer hybrid truck models introduced and less production, compared to hybrid cars.

Figure 5.9

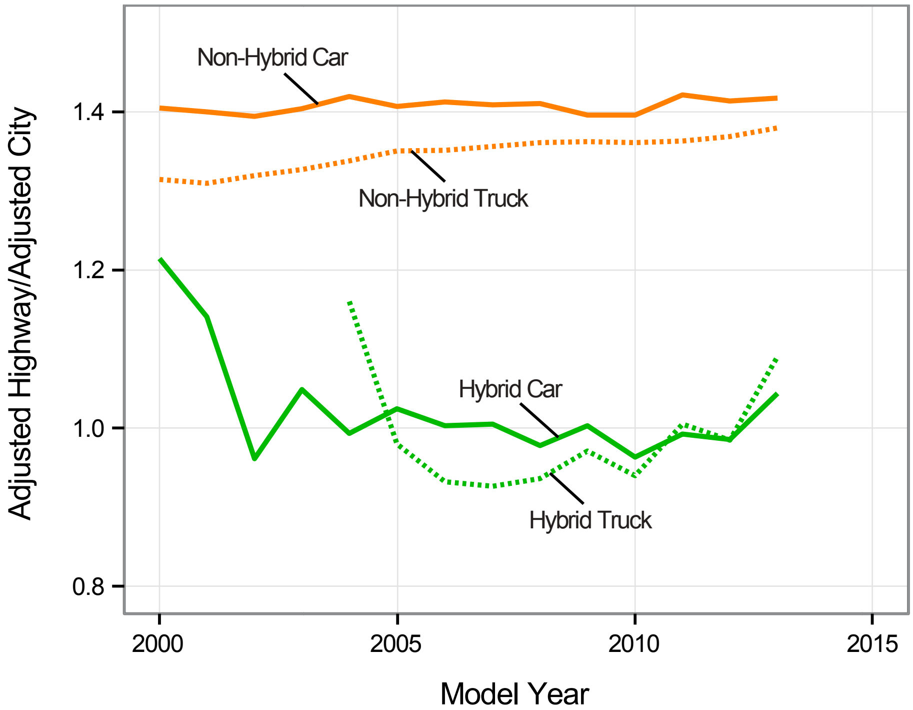
Hybrid Adjusted Fuel Economy Distribution by Year



One significant design aspect of hybrids is the ability to use regenerative braking to capture some of the energy lost by a vehicle during braking. The recaptured energy is stored in a battery and is then used to help propel the vehicle, generally during vehicle acceleration. This process results in significantly higher city fuel economy ratings for hybrid vehicles compared to non-hybrid vehicles, and in fact the city fuel economy of many hybrids is about equal to their highway fuel economy. Figure 5.10 below shows the ratio of highway to city fuel economy for hybrid cars and trucks. Hybrid models have a ratio of highway to city fuel economy of near 1.0 (meaning the city and highway fuel economy are nearly equivalent) which is much lower than the 1.4 ratio of highway to city fuel economy for non-hybrid models. This is one aspect of operating a hybrid that is fundamentally different from a conventional vehicle and appears to be relatively steady over time.

Figure 5.10

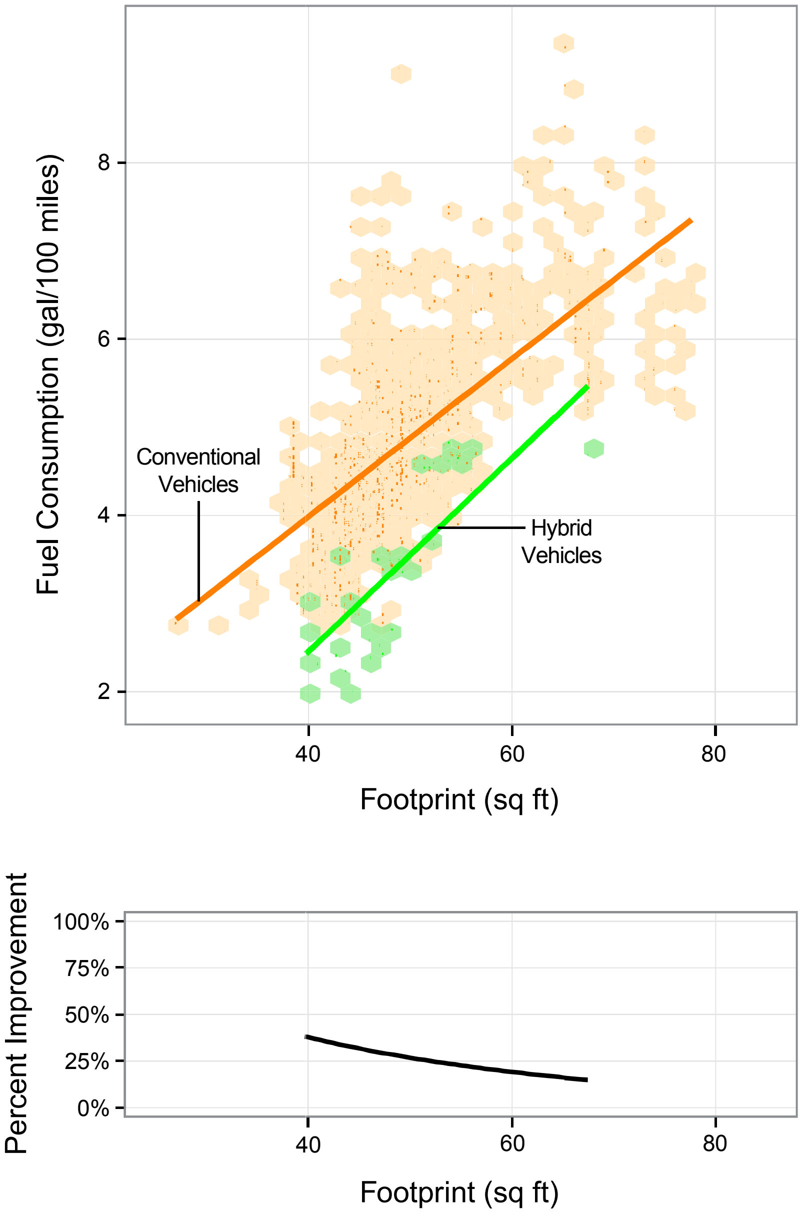
Highway/City Fuel Economy Ratio for Hybrids and Non hybrids



Hybrid cars, on average, have fuel economy nearly 60% higher than all other non-hybrid vehicles. As a production weighted average, hybrid cars achieved 42 mpg for MY 2012, while non-hybrid cars averaged about 27 mpg. However, hybrids are often smaller and less powerful than the average non-hybrid. The relationship between hybrids and non-hybrids is clearer if vehicles of the same footprint are compared directly. As shown in Figure 5.11, the fuel consumption of vehicles increases as the footprint increases at about the same rate for both hybrid and non-hybrid vehicles. Hybrids do however achieve a higher percentage improvement in smaller vehicles, and achieve 32% lower fuel consumption, on average, for vehicles with a footprint of 45 square feet, which is about the size of a standard midsize sedan. The percent improvement figure at the bottom of Figure 5.11 describes the fuel consumption improvement for hybrid vehicles as compared to conventional vehicles over the range of footprints for which both hybrid and conventional vehicles are available. It depicts the percentage difference between the 'best fit' lines for hybrid vehicles and conventional vehicles shown in the upper part of Figure 5.11.

Figure 5.11

Percent Improvement in Adjusted Fuel Consumption for Hybrid Vehicles, MY 2012



Diesels

While diesel engines are not a new technology, interest in diesel engines for light duty passenger applications has grown in recent years. Light duty diesel vehicles increased to about 1% of new vehicle production for MY 2012 and MY 2013. As with hybrid vehicles, diesels generally achieve higher fuel economy than other non-diesel vehicles. However, for diesel vehicles available in MY 2012, the percent improvement is more pronounced in vehicles with a smaller footprint than in vehicles with a larger footprint. This is partly explained due to the fact that MY 2012 larger footprint diesel offerings are limited to higher power offerings from luxury manufacturers. The relationship between diesel vehicles and all new vehicles is shown in Figure 5.12.

While diesel engines generally achieve higher fuel economy than comparable gasoline vehicles, there is less of an advantage in terms of CO_2 emissions. Some of the fuel economy benefit of diesel engines is negated by the fact that diesel fuel contains about 15% more carbon per gallon, and thus emits more CO_2 per gallon burned than gasoline. Figure 5.13 shows the impact of diesel vehicles on CO_2 emissions by comparing the fuel consumption of MY 2012 diesel gasoline vehicles by footprint.

Other Technologies

Table 5.2.1 presents comprehensive annual data for the historic MY 1975-2013 database for all of the engine technologies and parameters discussed above and several additional technologies. This is the first year that this report has included engine stop-start technology (for non-hybrid vehicles), and already stop-start technology is projected to be included on over 2% of new non-hybrid vehicle production in MY 2013 (note that total use of stop-start is over 6% of the market since hybrids typically utilize stop-start as well). Cylinder deactivation, another technology not discussed above, has also grown to capture a projected 8.3% of production in MY 2013. Tables 5.2.2 and 5.2.3 provide the same data for cars only and trucks only, respectively. This data, and additional data, is further broken down in Appendices E through I.

Figure 5.12

Percent Improvement in Adjusted Fuel Consumption for Diesel Vehicles, MY 2012

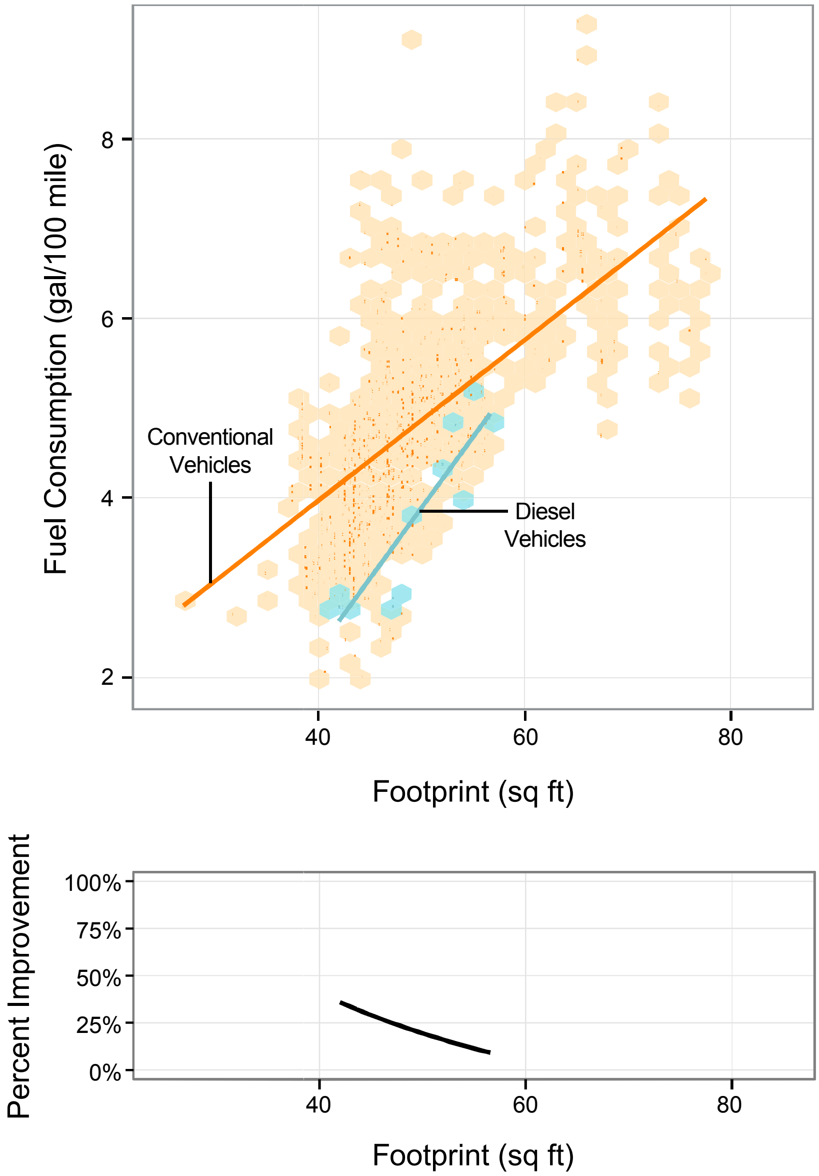


Figure 5.13

Percent Improvement in CO_2 Emissions for Diesel Vehicles, MY 2012

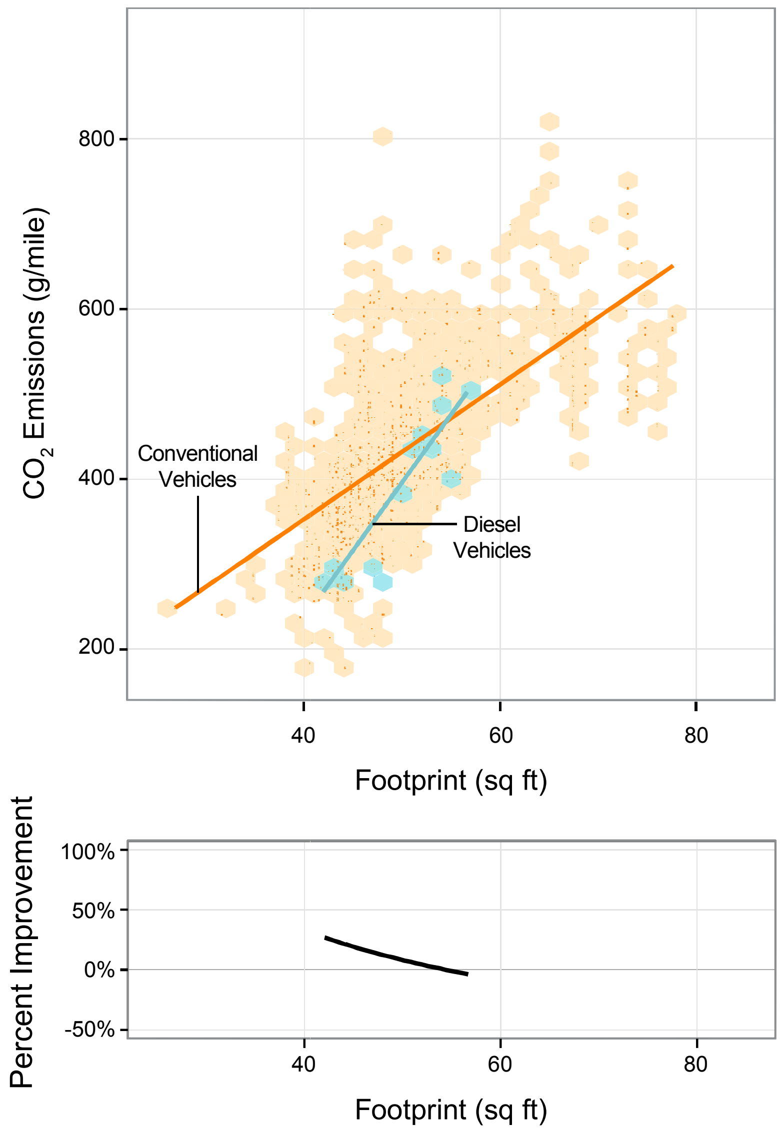


Table 5.2.1

Engine Characteristics of MY 1975 to MY 2013: Both Cars and Trucks

Model Year	Powertrain: Gasoline	Powertrain: Gasoline Hybrid	Powertrain: Diesel	Fuel Delivery Method: Carbureted	Fuel Delivery Method: GDI	Fuel Delivery Method: Port	Fuel Delivery Method: TBI	Fuel Delivery Method: Diesel	Avg. No. of Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Non-Hybrid Stop/ Start
1975	99.8%	-	0.2%	95.7%	-	4.1%	0.0%	0.2%	6.82	293	137	-	-	-	-	-
1976	99.8%	-	0.2%	97.3%	-	2.5%	0.0%	0.2%	6.87	294	135	-	-	-	-	-
1977	99.6%	-	0.4%	96.2%	-	3.4%	0.0%	0.4%	6.94	287	136	-	-	-	-	-
1978	99.1%	-	0.9%	95.2%	-	3.9%	0.0%	0.9%	6.69	266	129	-	-	-	-	-
1979	98.0%	-	2.0%	94.2%	-	3.7%	0.1%	2.0%	6.53	252	124	-	-	-	-	-
1980	95.7%	-	4.3%	89.7%	-	5.2%	0.8%	4.3%	5.59	198	104	-	-	-	-	-
1981	94.1%	-	5.9%	86.7%	-	5.1%	2.4%	5.9%	5.50	193	102	-	-	-	-	-
1982	94.4%	-	5.6%	80.6%	-	5.8%	8.0%	5.6%	5.43	188	103	-	-	-	-	-
1983	97.3%	-	2.7%	75.2%	-	7.3%	14.8%	2.7%	5.54	193	107	-	-	-	-	-
1984	98.2%	-	1.8%	67.6%	-	11.9%	18.7%	1.8%	5.49	190	109	-	-	-	-	-
1985	99.1%	-	0.9%	56.1%	-	18.2%	24.8%	0.9%	5.46	189	114	-	-	-	-	-
1986	99.6%	-	0.4%	41.4%	-	32.5%	25.7%	0.4%	5.26	180	114	3.4%	-	-	-	-
1987	99.7%	-	0.3%	28.4%	-	39.9%	31.4%	0.3%	5.17	175	118	10.6%	-	-	-	-
1988	99.9%	-	0.1%	15.0%	-	50.6%	34.3%	0.1%	5.31	180	123	14.0%	-	-	-	-
1989	99.9%	-	0.1%	8.7%	-	57.3%	33.9%	0.1%	5.36	185	129	16.9%	-	-	-	-
1990	99.9%	-	0.1%	2.1%	-	70.8%	27.0%	0.1%	5.39	185	135	23.1%	-	-	-	-
1991	99.9%	-	0.1%	0.6%	-	70.6%	28.7%	0.1%	5.32	184	138	23.1%	-	-	-	-
1992	99.9%	-	0.1%	0.5%	-	81.6%	17.8%	0.1%	5.50	191	145	23.3%	-	-	-	-
1993	100.0%	-	-	0.3%	-	85.0%	14.6%	-	5.50	191	147	23.5%	-	-	-	-
1994	100.0%	-	0.0%	0.1%	-	87.7%	12.1%	0.0%	5.58	197	152	26.7%	-	-	-	-
1995	100.0%	-	0.0%	-	-	91.6%	8.4%	0.0%	5.59	196	158	35.6%	-	-	-	-
1996	99.9%	-	0.1%	-	-	99.3%	0.7%	0.1%	5.59	197	164	39.3%	-	-	0.2%	-
1997	99.9%	-	0.1%	-	-	99.5%	0.5%	0.1%	5.65	199	169	39.6%	-	-	0.4%	-
1998	99.9%	-	0.1%	-	-	99.8%	0.1%	0.1%	5.63	199	171	40.9%	-	-	0.8%	-
1999	99.9%	-	0.1%	-	-	99.9%	0.1%	0.1%	5.75	203	179	43.4%	-	-	1.4%	-
2000	99.8%	0.0%	0.1%	-	-	99.8%	0.0%	0.1%	5.74	200	181	44.8%	15.0%	-	1.3%	-
2001	99.8%	0.0%	0.1%	-	-	99.9%	-	0.1%	5.76	201	187	49.0%	19.6%	-	2.0%	-
2002	99.6%	0.2%	0.2%	-	-	99.8%	-	0.2%	5.77	203	195	53.3%	25.3%	-	2.2%	-
2003	99.5%	0.3%	0.2%	-	-	99.8%	-	0.2%	5.79	204	199	55.5%	30.6%	-	1.2%	-
2004	99.4%	0.5%	0.1%	-	-	99.9%	-	0.1%	5.90	212	211	62.3%	38.5%	-	2.3%	-
2005	98.6%	1.1%	0.3%	-	-	99.7%	-	0.3%	5.75	205	209	65.6%	45.8%	0.8%	1.7%	-
2006	98.1%	1.5%	0.4%	-	-	99.6%	-	0.4%	5.73	204	213	71.7%	55.4%	3.6%	2.1%	-
2007	97.7%	2.2%	0.1%	-	-	99.8%	-	0.1%	5.64	203	217	71.7%	57.3%	7.3%	2.5%	-
2008	97.4%	2.5%	0.1%	-	2.3%	97.6%	-	0.1%	5.56	199	219	76.4%	58.2%	6.7%	3.0%	-
2009	97.2%	2.3%	0.5%	-	4.2%	95.3%	-	0.5%	5.21	183	208	83.8%	71.5%	7.3%	3.3%	-
2010	95.6%	3.8%	0.7%	-	8.3%	91.0%	-	0.7%	5.27	188	214	85.5%	83.8%	6.4%	3.3%	-
2011	97.1%	2.2%	0.8%	-	15.4%	83.8%	-	0.8%	5.35	192	230	86.4%	93.1%	9.5%	6.8%	-
2012	96.0%	3.1%	0.9%	-	22.7%	76.4%	-	0.9%	5.12	180	222	91.9%	96.7%	8.1%	8.4%	0.6%
2013	*94.9%*	*4.2%*	*0.9%*	-	*30.8%*	*68.3%*	-	*0.9%*	*5.13*	*179*	*230*	*92.2%*	*97.6%*	*8.2%*	*14.8%*	*2.1%*

Table 5.2.2

Engine Characteristics of MY 1975 to MY 2013: Cars Only

Model Year	Powertrain			Fuel Delivery Method					Avg. No. of Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Non-Hybrid Stop/ Start
	Gasoline	Gasoline Hybrid	Diesel	Carbureted	GDI	Port	TBI	Diesel								
1975	99.8%	-	0.2%	94.6%	-	5.1%	-	0.2%	6.71	288	136	-	-	-	-	-
1976	99.7%	-	0.3%	96.6%	-	3.2%	-	0.3%	6.75	287	134	-	-	-	-	-
1977	99.5%	-	0.5%	95.3%	-	4.2%	-	0.5%	6.85	279	133	-	-	-	-	-
1978	99.1%	-	0.9%	94.0%	-	5.1%	-	0.9%	6.52	251	124	-	-	-	-	-
1979	97.9%	-	2.1%	93.2%	-	4.7%	-	2.1%	6.38	238	119	-	-	-	-	-
1980	95.6%	-	4.4%	88.7%	-	6.2%	0.7%	4.4%	5.48	188	100	-	-	-	-	-
1981	94.1%	-	5.9%	85.3%	-	6.1%	2.6%	5.9%	5.36	182	99	-	-	-	-	-
1982	95.3%	-	4.7%	78.4%	-	7.2%	9.8%	4.7%	5.23	175	99	-	-	-	-	-
1983	97.9%	-	2.1%	69.7%	-	9.4%	18.8%	2.1%	5.39	182	104	-	-	-	-	-
1984	98.3%	-	1.7%	59.1%	-	14.9%	24.3%	1.7%	5.34	179	106	-	-	-	-	-
1985	99.1%	-	0.9%	46.0%	-	21.3%	31.8%	0.9%	5.29	177	111	-	-	-	-	-
1986	99.7%	-	0.3%	34.4%	-	36.5%	28.7%	0.3%	5.09	167	111	4.7%	-	-	-	-
1987	99.8%	-	0.2%	26.5%	-	42.4%	30.8%	0.2%	4.98	162	113	14.6%	-	-	-	-
1988	100.0%	-	0.0%	16.1%	-	53.7%	30.2%	0.0%	5.02	161	116	19.7%	-	-	-	-
1989	100.0%	-	0.0%	9.6%	-	62.2%	28.1%	0.0%	5.07	163	121	24.1%	-	-	-	-
1990	100.0%	-	0.0%	1.4%	-	77.4%	21.2%	0.0%	5.05	163	129	32.8%	0.6%	-	-	-
1991	99.9%	-	0.1%	0.1%	-	77.2%	22.6%	0.1%	5.05	164	133	33.2%	2.4%	-	-	-
1992	99.9%	-	0.1%	0.0%	-	88.9%	11.0%	0.1%	5.23	171	141	34.0%	4.4%	-	-	-
1993	100.0%	-	-	0.0%	-	91.5%	8.5%	-	5.19	170	140	34.8%	4.5%	-	-	-
1994	100.0%	-	0.0%	-	-	94.8%	5.2%	0.0%	5.20	169	144	39.9%	7.7%	-	-	-
1995	99.9%	-	0.1%	-	-	98.6%	1.3%	0.1%	5.23	168	153	51.4%	9.6%	-	-	-
1996	99.9%	-	0.1%	-	-	98.8%	1.1%	0.1%	5.18	167	155	56.4%	11.3%	-	0.3%	-
1997	99.9%	-	0.1%	-	-	99.2%	0.8%	0.1%	5.10	165	156	58.4%	10.8%	-	0.7%	-
1998	99.8%	-	0.2%	-	-	99.7%	0.1%	0.2%	5.15	167	160	59.6%	17.4%	-	1.4%	-
1999	99.8%	-	0.2%	-	-	99.8%	0.1%	0.2%	5.21	168	164	63.2%	16.4%	-	2.5%	-
2000	99.7%	0.1%	0.2%	-	-	99.7%	0.1%	0.2%	5.22	168	168	63.2%	22.2%	-	2.2%	-
2001	99.7%	0.0%	0.2%	-	-	99.8%	-	0.2%	5.19	167	169	65.3%	26.9%	-	3.3%	-
2002	99.3%	0.3%	0.4%	-	-	99.6%	-	0.4%	5.12	167	173	69.9%	32.8%	-	3.9%	-
2003	99.1%	0.6%	0.3%	-	-	99.7%	-	0.3%	5.13	166	176	73.4%	39.8%	-	2.0%	-
2004	98.9%	0.9%	0.3%	-	-	99.7%	-	0.3%	5.16	170	184	77.1%	43.7%	-	3.6%	-
2005	97.6%	1.9%	0.4%	-	-	99.6%	-	0.4%	5.08	168	183	77.2%	49.4%	1.0%	2.4%	-
2006	97.9%	1.5%	0.6%	-	-	99.4%	-	0.6%	5.17	173	194	81.3%	58.2%	2.0%	3.2%	-
2007	96.7%	3.2%	0.0%	-	-	99.7%	-	0.0%	5.00	167	191	84.6%	63.3%	0.9%	3.6%	-
2008	96.7%	3.3%	0.1%	-	3.1%	96.9%	-	0.1%	4.97	166	194	88.0%	62.7%	2.0%	4.5%	-
2009	96.4%	2.9%	0.6%	-	4.2%	95.2%	-	0.6%	4.70	157	186	92.2%	79.1%	1.8%	4.0%	-
2010	93.6%	5.5%	0.9%	-	9.2%	89.9%	-	0.9%	4.70	158	190	93.8%	91.8%	2.1%	4.1%	-
2011	95.6%	3.4%	0.9%	-	18.4%	80.7%	-	0.9%	4.74	161	200	94.6%	94.9%	1.3%	8.2%	-
2012	94.4%	4.6%	1.0%	-	27.8%	71.2%	-	1.0%	4.54	151	192	98.2%	97.7%	1.7%	9.7%	0.9%
2013	*92.8%*	*6.0%*	*1.2%*	-	*37.8%*	*60.9%*	-	*1.2%*	*4.56*	*150*	*201*	*98.3%*	*98.0%*	*2.3%*	*16.0%*	*2.7%*

Table 5.2.3

Engine Characteristics of MY 1975 to MY 2013: Trucks Only

	Powertrain			Fuel Delivery Method												
Model Year	Gasoline	Gasoline Hybrid	Diesel	Carbureted	GDI	Port	TBI	Diesel	Avg. No. of Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Non-Hybrid Stop/ Start
1975	100.0%	-	-	99.9%	-	-	0.1%	-	7.28	311	142	-	-	-	-	-
1976	100.0%	-	-	99.9%	-	-	0.1%	-	7.31	320	141	-	-	-	-	-
1977	100.0%	-	-	99.9%	-	-	0.1%	-	7.28	318	147	-	-	-	-	-
1978	99.2%	-	0.8%	99.1%	-	-	0.1%	0.8%	7.25	315	146	-	-	-	-	-
1979	98.2%	-	1.8%	97.9%	-	-	0.3%	1.8%	7.05	299	138	-	-	-	-	-
1980	96.5%	-	3.5%	94.9%	-	-	1.7%	3.5%	6.15	248	121	-	-	-	-	-
1981	94.4%	-	5.6%	93.3%	-	-	1.1%	5.6%	6.15	247	119	-	-	-	-	-
1982	90.6%	-	9.4%	89.9%	-	-	0.7%	9.4%	6.26	244	120	-	-	-	-	-
1983	95.2%	-	4.8%	94.6%	-	-	0.6%	4.8%	6.07	232	118	-	-	-	-	-
1984	97.6%	-	2.4%	95.0%	-	2.0%	0.6%	2.4%	5.99	225	118	-	-	-	-	-
1985	98.9%	-	1.1%	86.5%	-	8.9%	3.5%	1.1%	5.97	225	124	-	-	-	-	-
1986	99.3%	-	0.7%	59.4%	-	22.1%	17.8%	0.7%	5.71	212	123	-	-	-	-	-
1987	99.7%	-	0.3%	33.6%	-	33.3%	32.8%	0.3%	5.69	211	131	-	-	-	-	-
1988	99.8%	-	0.2%	12.4%	-	43.2%	44.3%	0.2%	6.00	228	141	-	-	-	-	-
1989	99.8%	-	0.2%	6.5%	-	45.9%	47.5%	0.2%	6.04	234	146	-	-	-	-	-
1990	99.8%	-	0.2%	3.8%	-	55.0%	40.9%	0.2%	6.17	237	151	-	-	-	-	-
1991	99.9%	-	0.1%	1.7%	-	55.3%	42.8%	0.1%	5.95	229	150	-	-	-	-	-
1992	99.9%	-	0.1%	1.6%	-	65.7%	32.6%	0.1%	6.09	236	155	-	-	-	-	-
1993	100.0%	-	-	1.0%	-	71.5%	27.5%	-	6.13	235	160	-	-	-	-	-
1994	100.0%	-	-	0.4%	-	76.2%	23.4%	-	6.19	241	166	5.2%	-	-	-	-
1995	100.0%	-	-	-	-	79.4%	20.6%	-	6.22	245	168	8.0%	-	-	-	-
1996	99.9%	-	0.1%	-	-	99.9%	-	0.1%	6.25	245	179	11.2%	-	-	-	-
1997	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.47	251	189	11.1%	-	-	-	-
1998	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.30	244	188	14.8%	-	-	-	-
1999	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.50	252	199	15.7%	-	-	-	-
2000	100.0%	-	-	-	-	100.0%	-	-	6.48	245	199	18.6%	4.6%	-	-	-
2001	100.0%	-	-	-	-	100.0%	-	-	6.58	249	212	25.9%	9.3%	-	-	-
2002	100.0%	-	-	-	-	100.0%	-	-	6.57	249	223	32.8%	16.0%	-	-	-
2003	100.0%	-	-	-	-	100.0%	-	-	6.56	248	224	34.6%	19.7%	-	0.2%	-
2004	100.0%	0.0%	0.0%	-	-	100.0%	-	0.0%	6.70	258	240	46.2%	32.9%	-	0.8%	-
2005	99.8%	0.1%	0.1%	-	-	99.9%	-	0.1%	6.58	251	242	51.1%	41.2%	0.5%	0.7%	-
2006	98.4%	1.5%	0.1%	-	-	99.9%	-	0.1%	6.50	247	240	58.4%	51.5%	5.9%	0.6%	-
2007	99.1%	0.8%	0.1%	-	-	99.9%	-	0.1%	6.57	253	254	53.3%	48.7%	16.4%	1.0%	-
2008	98.5%	1.3%	0.2%	-	1.1%	98.7%	-	0.2%	6.42	246	254	59.5%	51.6%	13.5%	1.0%	-
2009	98.8%	0.9%	0.3%	-	4.2%	95.5%	-	0.3%	6.23	236	252	66.6%	56.0%	18.4%	1.7%	-
2010	98.8%	0.9%	0.4%	-	6.8%	92.9%	-	0.4%	6.22	237	253	71.5%	70.5%	13.8%	1.8%	-
2011	99.1%	0.4%	0.5%	-	11.3%	88.1%	-	0.5%	6.18	236	271	75.2%	90.7%	20.6%	4.9%	-
2012	98.9%	0.4%	0.7%	-	13.5%	85.8%	-	0.7%	6.16	234	276	80.6%	94.9%	19.6%	6.1%	0.2%
2013	*98.6%*	*1.0%*	*0.4%*	-	*18.0%*	*81.6%*	-	*0.4%*	*6.17*	*233*	*282*	*81.1%*	*96.8%*	*19.0%*	*12.8%*	*0.9%*

D. Trends in Transmission Types

Transmission technologies have been rapidly evolving in new light duty vehicles. New transmission technologies have been gaining market share, and nearly all transmission types have been increasing the number of gears. Dual clutch transmission (DCTs), continuously variable transmissions (CVTs), and automatic transmissions with greater numbers of gears are increasing production share across the fleet.

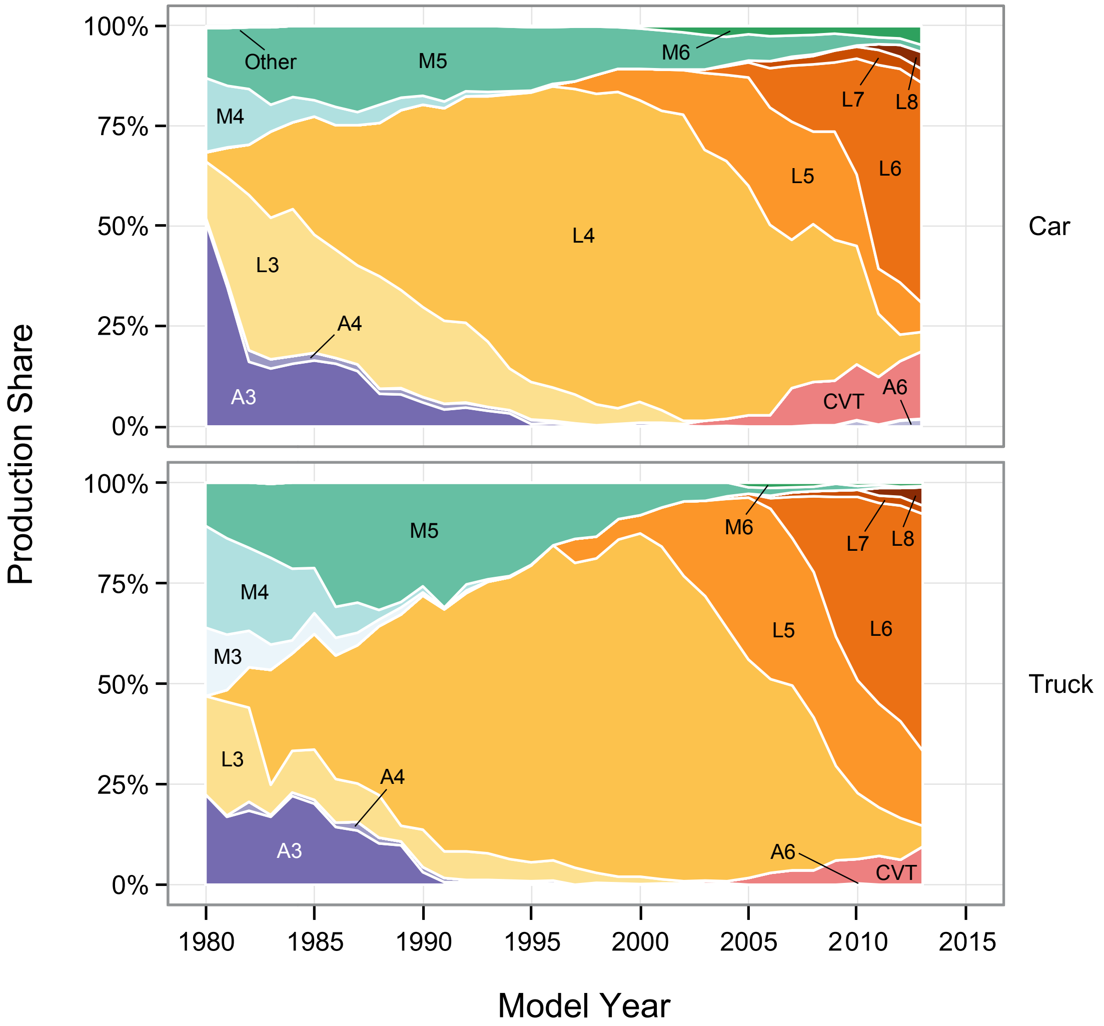
Figure 5.14 shows the evolution of transmission production share for cars and trucks since MY 1980. For this analysis, transmissions are separated into manual transmissions, CVTs, and automatic transmissions. Automatic transmissions are further seperated into those with and without lockup mechanisms, which can lock up the torque converter in an automatic transmission under certain driving conditions and improve efficiency.

Dual clutch transmissions are relatively new to the light duty vehicle market. DCTs are essentially automatic transmissions that operate internally much more like traditional manual transmissions. The two main advantages of DCTs are that they can shift very quickly and they can avoid some of the internal resistance of a traditional automatic transmission by eliminating the torque converter. Currently, automaker submissions to EPA do not explicitly identify DCTs as a separate transmission category. Thus, the introduction of DCTs shows up in Table 14 as a slight increase in automatic transmissions without torque converters (although some DCTs may still be reported as traditional automatic transmissions). EPA's long-term goal is to improve DCT data collection, and to be able to quantify DCTs in future Trends reports.

Figure 5.14 shows transmission production share for the individual car and truck fleets, and begins with MY 1980 because EPA has incomplete data on the number of transmission gears for MY 1975 through 1978. In the early 1980s, 3 speed automatic transmissions, both with and without lockup torque converters (shown as L3 and A3 in Figure 5.14) were the most popular transmissions, but by MY 1985, the 4 speed automatic transmission with lockup (L4) became the most popular transmission, a position it would hold for 25 years. Over 80% of all new vehicles produced in MY 1999 were equipped with an L4 transmission. After MY 1999, the production share of L4 transmissions slowly decreased as L5 and L6 transmissions were introduced into the market. Production of L5 and L6 transmissions combined passed the production of L4 transmissions in MY 2007). Interestingly, 5 speed transmissions were never the leading transmission technology in terms of production share. Currently, L6 transmissions are projected to be installed in nearly 60% of new vehicles produced in MY 2013, and the percentage of vehicle with L6 transmissions is still trending upwards.

Figure 5.14

Transmission Production Share by Model Year



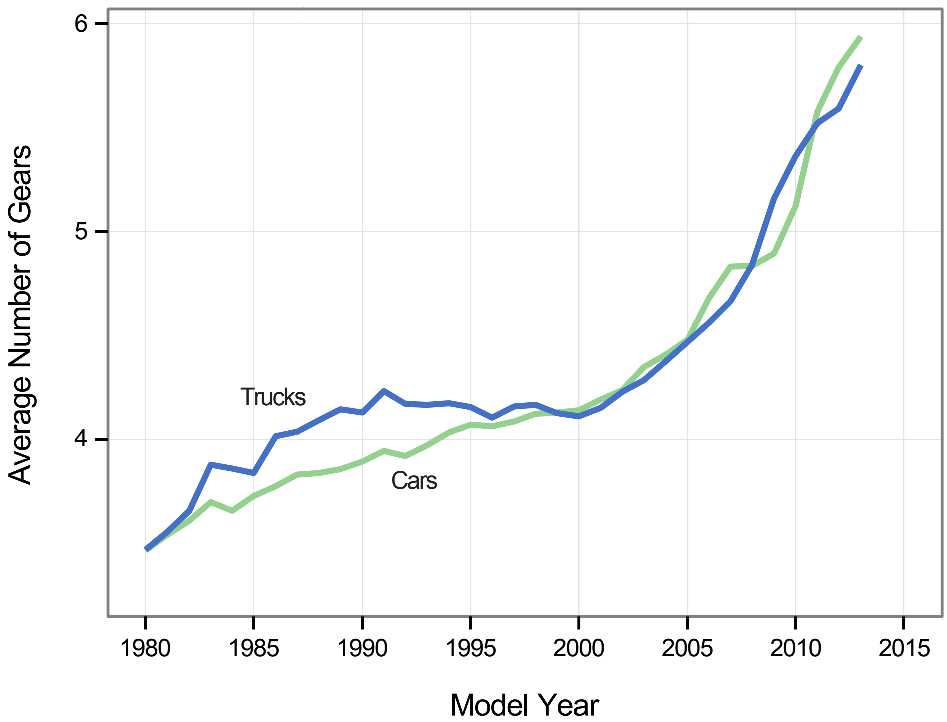
Transmission	Lockup?	Number of Gears	Key
Automatic Semi-Automatic Automated Manual	No	3	A3
		4	A4
		5	A5
		6	A6
	Yes	2	L2
		3	L3
		4	L4
		5	L5
		6	L6
		7	L7
		8	L8
Continuously Variable	–	–	CVT
Manual	–	3	M3
		4	M4
		5	M5
		6	M6
Other	–	–	Other

Continuously variable transmissions have shown a large increase in production. In MY 2012, 11.8% of new vehicles were produced with CVTs, and production is expected to reach 14.3% in MY 2013. This is a significant increase considering that as recently as MY 2006 CVTs were installed on less than 3% of vehicles produced. Automatic transmissions with 7 or more speeds have also been increasing, and are expected to be over 7% of production for MY 2013. Manufacturers are publicly discussing the development of transmissions with as many as 10 or more gears, so this is a trend that the authors also expect to continue.

Figure 5.15 shows the average number of gears in new vehicle transmissions since MY 1980, regardless of transmission type. In MY 1980, the average number of gears in a new vehicle transmission was 3.5. As 4 speed transmissions became more popular, the average number of gears increased to 4.0 by MY 1990, and then stayed relatively constant until MY 2000, largely due to the dominance of 4 speed transmissions. After MY 2000, the average number of gears began to increase much more rapidly until reaching its current level of 5.7 in MY 2012.

Figure 5.15

Average Number of Transmission Gears for New Vehicles (excluding CVTs)

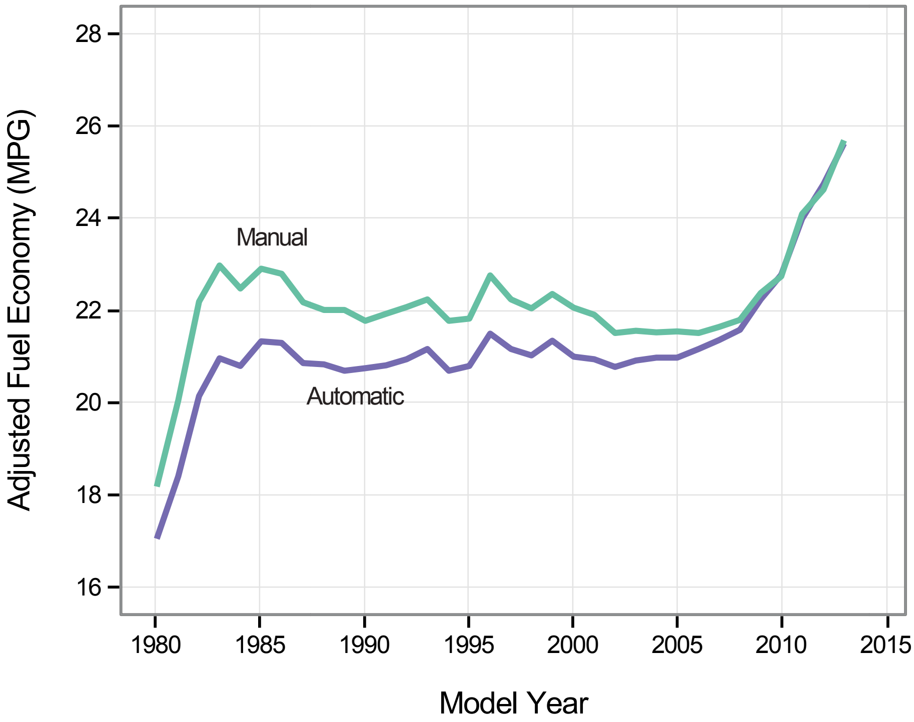


The production of manual transmissions has generally continued to decrease from the peak of nearly 35% of production in MY 1980. In MY 2012, manual transmissions accounted for only 3.6% of total production. Today, manual transmissions are used primarily in small vehicles, some sports cars, and a few pickups.

Generally, automatic transmissions have been less efficient than manual transmissions, largely due to inefficiencies in the automatic transmission torque converter. Figure 5.16 examines this trend over time by comparing the fuel economy of automatic and manual transmission options where both transmissions were available in one model with the same engine. The fuel economy of vehicles with automatic transmissions appears to have increased to a point where it is now approximately the same as the fuel economy of vehicles with manual transmissions. Two contributing factors to this trend are that automatic transmission design has become more efficient (using earlier lockup and other strategies), and the number of gears used in automatic transmissions has increased much quicker than in manual transmission.

Figure 5.16

Comparison of Manual and Automatic Transmission Adjusted Fuel Economy, MY 1980 – MY 2013



E. Trends in Drive Types

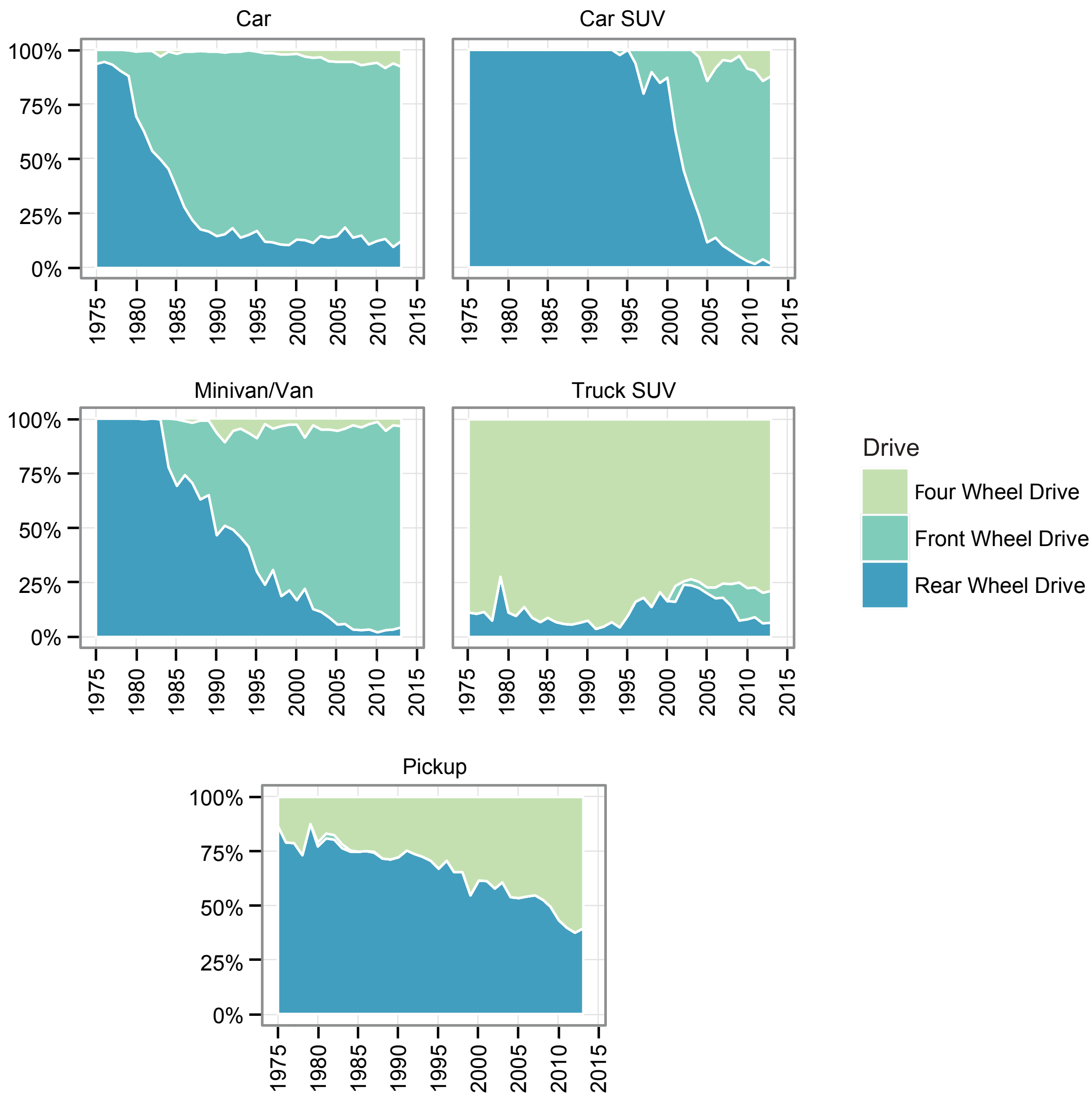
There has been a long and steady trend in new vehicle drive type away from rear wheel drive vehicles towards front wheel drive and four wheel drive vehicles, as shown in Figure 5.17. In MY 1975, over 91% of new vehicles were produced with rear wheel drive. During the 1980s, production of rear wheel drive vehicles fell rapidly, to 26% in MY 1990. Since then, production of rear wheel drive vehicles has continued to decline, albeit at a slower rate, to a projected 13% for MY 2013. Current production of rear wheel drive vehicles is mostly limited to pickup trucks and some performance vehicles.

As production of rear wheel drive vehicles declined, production of front wheel drive vehicles increased. Front wheel drive vehicle production was only 5.3% of new vehicle production in MY 1975, but it became the most popular drive technology across new vehicles in MY 1985, and has remained so for the last 28 years. Since MY 1986, production of front wheel drive vehicles has remained, on average, at approximately 55% of production.

Four wheel drive vehicles (including all wheel drive), have slowly but steadily grown across new vehicle production. From 3.3% in MY 1975 to a projected 26% in MY 2013, four wheel drive production has steadily grown at approximately 0.6% per year, on average. The majority of four wheel drive vehicles are pickup trucks and truck SUVs, but there is also a small but slowly growing number of cars featuring four wheel drive (or more likely) all wheel drive systems.

Figure 5.17

Front, Rear, and Four Wheel Drive Usage - Production Share by Vehicle Type



There are noticeable differences in fuel economy between vehicles with different drive types. Figure 5.18 shows the fuel consumption of MY 2012 vehicles separated by drive type and footprint. Rear wheel drive vehicles and four wheel drive vehicles have on average the same fuel consumption for equivalent footprint vehicles. Front wheel drive vehicles have much lower fuel consumption than rear wheel drive or four wheel drive vehicles of the same footprint. For 45 square foot vehicles, front wheel drive vehicles have fuel consumption about 22% lower. There are certainly other factors involved (the rear wheel drive vehicles are likely more performance oriented, for example), but this is a noticeable trend across new vehicle production. The points in Figure 5.18 are generated for each combination of adjusted fuel consumption and footprint; if there are multiple vehicles with the same combination, the points will overlay, and the color will be darker.

Tables 5.3.1, 5.3.2, and 5.3.3 summarize transmission and drive technology production data by year for the combined car and truck fleet, cars only, and trucks only, respectively.

Figure 5.18

Differences in Adjusted Fuel Consumption Trends for FWD, RWD, and 4WD/AWD Vehicles

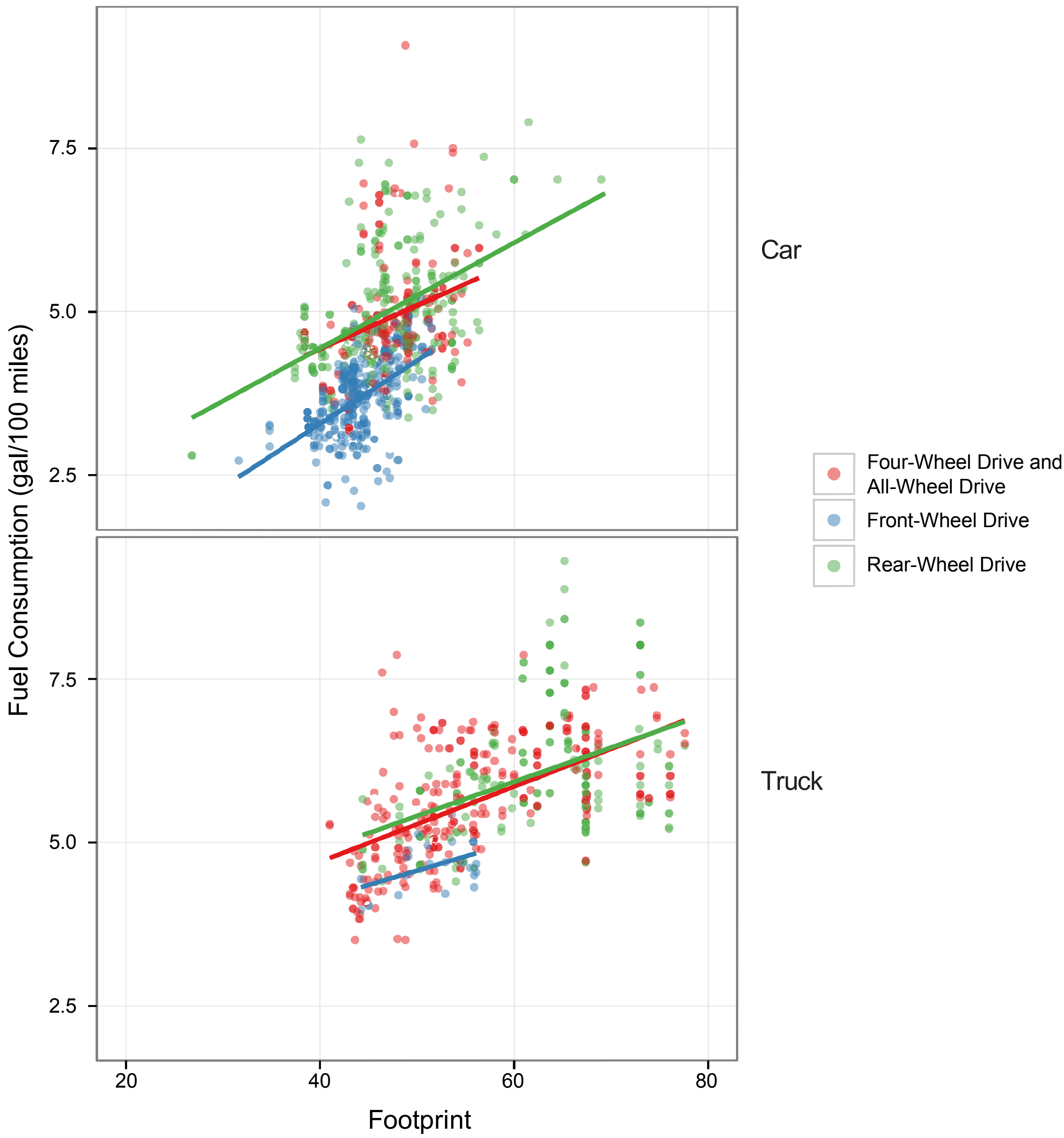


Table 5.3.1

Transmission and Drive Characteristics of MY 1975 to MY 2013: Both Cars and Trucks

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT	4 Gears of Fewer	5 Gears	6 Gears	7 Gears or More	CVT	Average Number of Gears	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive
1975	23.0%	0.2%	76.8%	-	-	-	-	-	-	-	5.3%	91.4%	3.3%
1976	20.9%	-	79.1%	-	-	-	-	-	-	-	4.6%	90.6%	4.8%
1977	19.8%	-	80.2%	-	-	-	-	-	-	-	5.5%	89.8%	4.7%
1978	22.7%	5.5%	71.9%	-	-	-	-	-	-	-	7.4%	86.0%	6.6%
1979	24.2%	7.3%	68.1%	-	93.8%	6.2%	-	-	-	3.3	9.2%	86.5%	4.3%
1980	34.6%	18.1%	46.8%	-	87.9%	12.1%	-	-	-	3.5	25.0%	70.1%	4.9%
1981	33.6%	33.0%	32.9%	-	85.6%	14.4%	-	-	-	3.5	31.0%	65.0%	4.0%
1982	32.4%	47.8%	19.4%	-	84.4%	15.6%	-	-	-	3.6	37.0%	58.4%	4.6%
1983	30.5%	52.1%	17.0%	-	80.9%	19.1%	-	-	-	3.7	37.0%	54.8%	8.1%
1984	28.4%	52.8%	18.8%	-	81.3%	18.7%	-	-	-	3.7	42.1%	49.8%	8.2%
1985	26.5%	54.5%	19.1%	-	80.7%	19.3%	-	-	-	3.8	47.8%	42.9%	9.3%
1986	29.8%	53.5%	16.7%	-	76.8%	23.2%	-	-	-	3.8	52.6%	38.0%	9.3%
1987	29.1%	55.4%	15.5%	-	76.2%	23.8%	-	-	-	3.9	57.7%	32.8%	9.6%
1988	27.6%	62.2%	10.2%	-	76.8%	23.2%	-	-	-	3.9	60.0%	29.5%	10.5%
1989	24.6%	65.5%	9.9%	0.1%	78.5%	21.4%	0.0%	-	0.1%	3.9	60.2%	29.3%	10.5%
1990	22.2%	71.2%	6.5%	0.0%	79.9%	20.0%	0.1%	-	0.0%	4.0	63.8%	26.1%	10.1%
1991	23.9%	71.6%	4.5%	0.0%	77.3%	22.6%	0.0%	-	0.0%	4.0	59.6%	28.1%	12.3%
1992	20.7%	74.8%	4.5%	0.0%	80.8%	19.2%	0.1%	-	0.0%	4.0	58.4%	30.4%	11.2%
1993	19.8%	76.5%	3.7%	0.0%	80.9%	19.0%	0.1%	-	0.0%	4.0	59.9%	28.8%	11.3%
1994	19.5%	77.6%	3.0%	-	80.8%	19.0%	0.2%	-	-	4.1	55.6%	29.2%	15.2%
1995	17.9%	80.7%	1.4%	-	82.0%	17.7%	0.2%	-	-	4.1	57.6%	26.3%	16.2%
1996	15.2%	83.5%	1.3%	0.0%	84.7%	15.1%	0.2%	-	0.0%	4.1	60.0%	24.3%	15.7%
1997	14.0%	85.5%	0.5%	0.0%	82.4%	17.3%	0.2%	-	0.0%	4.1	56.1%	24.9%	19.0%
1998	12.8%	86.7%	0.5%	0.0%	82.1%	17.7%	0.2%	-	0.0%	4.1	56.4%	23.5%	20.1%
1999	10.1%	89.4%	0.5%	0.0%	84.4%	15.3%	0.3%	-	0.0%	4.1	55.8%	22.9%	21.3%
2000	9.7%	89.5%	0.7%	0.0%	83.7%	15.8%	0.5%	-	0.0%	4.1	55.5%	24.3%	20.2%
2001	9.0%	90.3%	0.6%	0.1%	80.7%	18.5%	0.7%	-	0.1%	4.2	53.8%	24.2%	22.0%
2002	8.2%	91.4%	0.3%	0.2%	77.1%	21.6%	1.1%	-	0.2%	4.2	52.7%	22.3%	25.0%
2003	8.0%	90.8%	0.1%	1.1%	69.2%	28.1%	1.7%	-	1.1%	4.3	50.7%	24.3%	25.0%
2004	6.8%	91.8%	0.3%	1.2%	63.9%	31.8%	3.0%	0.2%	1.2%	4.4	47.7%	22.4%	29.8%
2005	6.2%	91.5%	0.1%	2.3%	56.0%	37.3%	4.1%	0.2%	2.3%	4.5	53.0%	20.2%	26.8%
2006	6.5%	90.6%	0.0%	2.8%	47.7%	39.2%	8.8%	1.4%	2.8%	4.6	51.9%	22.3%	25.8%
2007	5.6%	87.1%	0.0%	7.2%	40.5%	36.1%	14.4%	1.8%	7.2%	4.8	54.3%	19.6%	26.1%
2008	5.2%	86.8%	0.2%	7.9%	38.8%	31.9%	19.4%	2.0%	7.9%	4.8	54.2%	18.5%	27.3%
2009	4.8%	85.5%	0.2%	9.4%	31.3%	32.2%	24.5%	2.6%	9.4%	5.0	62.9%	13.6%	23.5%
2010	3.8%	84.1%	1.2%	10.9%	24.6%	23.5%	38.1%	2.8%	10.9%	5.2	59.5%	13.8%	26.7%
2011	3.2%	86.6%	0.3%	10.0%	14.2%	18.7%	52.4%	4.8%	10.0%	5.6	53.8%	13.8%	32.4%
2012	3.6%	83.7%	1.1%	11.6%	8.0%	18.2%	56.7%	5.5%	11.6%	5.7	61.4%	10.9%	27.7%
2013	*4.7%*	*79.9%*	*1.3%*	*14.2%*	*5.0%*	*12.6%*	*60.7%*	*7.5%*	*14.2%*	*5.9*	*58.7%*	*12.5%*	*28.8%*

Table 5.3.2

Transmission and Drive Characteristics of MY 1975 to MY 2013: Cars Only

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT	4 Gears or Fewer	5 Gears	6 Gears	7 Gears or More	CVT	Average Number of Gears	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive
1975	19.7%	0.3%	80.0%	-	-	-	-	-	-	-	6.5%	93.5%	-
1976	17.2%	-	82.8%	-	-	-	-	-	-	-	5.8%	94.2%	-
1977	16.9%	-	83.1%	-	-	-	-	-	-	-	6.8%	93.2%	-
1978	19.9%	7.1%	73.0%	-	-	-	-	-	-	-	9.6%	90.4%	-
1979	21.1%	8.8%	69.6%	-	93.1%	6.9%	-	-	-	3.3	11.9%	87.8%	0.3%
1980	30.9%	16.8%	51.6%	-	87.6%	12.4%	-	-	-	3.5	29.7%	69.4%	0.9%
1981	29.9%	33.3%	36.2%	-	85.5%	14.5%	-	-	-	3.5	37.0%	62.2%	0.7%
1982	29.2%	51.3%	19.1%	-	84.6%	15.4%	-	-	-	3.6	45.6%	53.6%	0.8%
1983	26.0%	56.7%	16.8%	-	80.8%	19.2%	-	-	-	3.7	47.1%	49.9%	3.1%
1984	24.1%	58.3%	17.5%	-	82.1%	17.9%	-	-	-	3.7	53.5%	45.5%	1.0%
1985	22.8%	58.9%	18.4%	-	81.4%	18.6%	-	-	-	3.7	61.1%	36.8%	2.1%
1986	24.7%	58.1%	17.1%	-	79.7%	20.3%	-	-	-	3.8	70.7%	28.2%	1.0%
1987	24.8%	59.7%	15.5%	-	78.4%	21.6%	-	-	-	3.8	76.4%	22.6%	1.1%
1988	24.3%	66.2%	9.5%	-	80.2%	19.8%	-	-	-	3.8	80.9%	18.3%	0.8%
1989	21.1%	69.3%	9.5%	0.1%	81.9%	17.9%	0.0%	-	0.1%	3.9	81.6%	17.4%	1.0%
1990	19.8%	72.8%	7.4%	0.0%	82.4%	17.5%	0.1%	-	0.0%	3.9	84.0%	15.0%	1.0%
1991	20.6%	73.7%	5.7%	0.0%	81.0%	18.9%	0.1%	-	0.0%	3.9	81.1%	17.5%	1.3%
1992	17.6%	76.4%	6.0%	0.0%	83.6%	16.3%	0.1%	-	0.0%	3.9	78.4%	20.5%	1.1%
1993	17.5%	77.6%	4.9%	0.0%	83.2%	16.6%	0.2%	-	0.0%	4.0	80.6%	18.3%	1.1%
1994	16.9%	78.9%	4.1%	-	83.4%	16.3%	0.3%	-	-	4.0	81.3%	18.3%	0.4%
1995	16.3%	81.9%	1.8%	-	83.4%	16.2%	0.4%	-	-	4.1	80.1%	18.8%	1.1%
1996	14.9%	83.6%	1.5%	0.0%	84.9%	14.7%	0.3%	-	0.0%	4.1	83.7%	14.8%	1.4%
1997	13.9%	85.2%	0.8%	0.1%	84.1%	15.5%	0.3%	-	0.1%	4.1	83.8%	14.5%	1.7%
1998	12.2%	87.4%	0.3%	0.1%	82.8%	16.8%	0.3%	-	0.1%	4.1	82.9%	15.0%	2.1%
1999	10.8%	88.6%	0.6%	0.0%	83.4%	16.1%	0.5%	-	0.0%	4.1	83.2%	14.7%	2.1%
2000	10.8%	88.1%	1.0%	0.0%	81.3%	17.9%	0.8%	-	0.0%	4.1	80.4%	17.7%	2.0%
2001	11.0%	88.0%	0.8%	0.2%	78.5%	20.2%	1.2%	-	0.2%	4.2	80.3%	16.7%	3.0%
2002	10.9%	88.4%	0.2%	0.4%	77.4%	20.3%	1.9%	-	0.4%	4.2	82.9%	13.5%	3.6%
2003	10.9%	87.7%	-	1.4%	67.5%	27.9%	3.1%	-	1.4%	4.3	80.9%	15.9%	3.2%
2004	9.8%	88.2%	0.2%	1.7%	64.5%	28.4%	5.0%	0.4%	1.7%	4.4	80.2%	14.5%	5.3%
2005	8.8%	88.4%	0.1%	2.8%	57.3%	33.7%	5.8%	0.4%	2.8%	4.5	79.2%	14.2%	6.6%
2006	8.8%	88.4%	0.1%	2.7%	47.5%	35.4%	12.5%	1.9%	2.7%	4.7	75.9%	18.0%	6.0%
2007	7.8%	82.5%	0.0%	9.7%	36.8%	34.7%	16.5%	2.3%	9.7%	4.8	81.0%	13.4%	5.6%
2008	7.2%	81.7%	0.3%	10.8%	39.3%	28.2%	19.0%	2.6%	10.8%	4.8	78.8%	14.1%	7.1%
2009	6.2%	82.4%	0.3%	11.1%	35.1%	31.4%	19.3%	3.1%	11.1%	4.9	83.5%	10.2%	6.3%
2010	5.0%	79.5%	1.6%	13.9%	29.5%	20.2%	33.0%	3.4%	13.9%	5.1	82.5%	11.2%	6.3%
2011	4.6%	83.0%	0.5%	11.9%	15.8%	12.9%	53.8%	5.5%	11.9%	5.6	80.1%	11.3%	8.6%
2012	4.9%	78.8%	1.7%	14.6%	6.7%	14.8%	57.8%	6.0%	14.6%	5.8	83.8%	8.8%	7.4%
2013	*6.5%*	*74.7%*	*2.0%*	*16.7%*	*5.0%*	*9.0%*	*61.3%*	*8.0%*	*16.7%*	*5.9*	*80.8%*	*10.6%*	*8.7%*

Table 5.3.3

Transmission and Drive Characteristics of MY 1975 to MY 2013: Trucks Only

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT	4 Gears or Fewer	5 Gears	6 Gears	7 Gears or More	CVT	Average Number of Gears	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive
1975	36.9%	-	63.1%	-	-	-	-	-	-	-	-	82.8%	17.2%
1976	34.7%	-	65.3%	-	-	-	-	-	-	-	-	77.0%	23.0%
1977	31.6%	-	68.4%	-	-	-	-	-	-	-	-	76.2%	23.8%
1978	32.1%	-	67.9%	-	-	-	-	-	-	-	-	70.9%	29.1%
1979	35.1%	2.1%	62.8%	-	96.0%	4.0%	-	-	-	3.3	-	81.9%	18.1%
1980	53.0%	24.5%	22.4%	-	89.2%	10.8%	-	-	-	3.5	1.4%	73.6%	25.0%
1981	51.6%	31.1%	17.3%	-	86.1%	13.9%	-	-	-	3.6	1.9%	78.0%	20.1%
1982	45.9%	33.4%	20.7%	-	83.8%	16.2%	-	-	-	3.7	1.7%	78.1%	20.2%
1983	46.3%	36.0%	17.4%	-	81.6%	18.4%	-	-	-	3.9	1.4%	72.5%	26.1%
1984	42.5%	34.6%	22.9%	-	78.6%	21.4%	-	-	-	3.9	5.0%	63.5%	31.5%
1985	37.6%	41.1%	21.2%	-	78.6%	21.4%	-	-	-	3.8	7.3%	61.4%	31.3%
1986	43.0%	41.5%	15.5%	-	69.1%	30.9%	-	-	-	4.0	5.9%	63.4%	30.7%
1987	40.5%	43.8%	15.7%	-	70.1%	29.9%	-	-	-	4.0	7.6%	60.2%	32.2%
1988	35.8%	52.5%	11.7%	-	68.4%	31.6%	-	-	-	4.1	9.2%	56.7%	34.1%
1989	32.8%	56.4%	10.8%	-	70.3%	29.7%	-	-	-	4.1	10.1%	57.1%	32.8%
1990	28.1%	67.5%	4.4%	-	74.1%	25.9%	-	-	-	4.1	15.8%	52.4%	31.8%
1991	31.5%	66.8%	1.7%	-	69.0%	31.0%	-	-	-	4.2	10.3%	52.3%	37.3%
1992	27.5%	71.3%	1.2%	-	74.6%	25.4%	-	-	-	4.2	14.5%	52.1%	33.4%
1993	24.7%	74.2%	1.1%	-	76.0%	24.0%	-	-	-	4.2	16.8%	50.6%	32.7%
1994	23.7%	75.3%	1.0%	-	76.7%	23.3%	-	-	-	4.2	13.8%	47.0%	39.2%
1995	20.7%	78.5%	0.9%	-	79.6%	20.4%	-	-	-	4.2	18.4%	39.3%	42.3%
1996	15.6%	83.4%	1.0%	-	84.4%	15.6%	-	-	-	4.1	20.9%	39.8%	39.2%
1997	14.1%	85.8%	0.1%	-	79.9%	20.1%	-	-	-	4.2	14.2%	40.6%	45.2%
1998	13.6%	85.8%	0.6%	-	81.1%	18.9%	-	-	-	4.2	19.3%	35.5%	45.1%
1999	9.2%	90.4%	0.4%	-	85.8%	14.2%	-	-	-	4.1	17.5%	34.4%	48.1%
2000	8.2%	91.5%	0.3%	-	87.3%	12.7%	-	-	-	4.1	20.0%	33.8%	46.3%
2001	6.3%	93.4%	0.3%	-	84.0%	16.0%	-	-	-	4.2	16.3%	34.8%	48.8%
2002	4.7%	94.9%	0.3%	0.0%	76.7%	23.3%	-	-	0.0%	4.2	15.4%	33.1%	51.6%
2003	4.6%	94.4%	0.3%	0.6%	71.1%	28.2%	-	-	0.6%	4.3	15.4%	34.1%	50.4%
2004	3.5%	95.6%	0.3%	0.6%	63.2%	35.5%	0.8%	-	0.6%	4.4	12.5%	31.0%	56.5%
2005	2.9%	95.3%	-	1.8%	54.3%	41.9%	2.1%	-	1.8%	4.5	20.1%	27.7%	52.2%
2006	3.3%	93.7%	-	3.1%	48.0%	44.3%	3.8%	0.8%	3.1%	4.6	18.9%	28.0%	53.1%
2007	2.6%	93.8%	-	3.7%	45.8%	38.0%	11.5%	1.0%	3.7%	4.7	16.1%	28.4%	55.5%
2008	2.2%	94.1%	-	3.6%	37.9%	37.4%	19.9%	1.2%	3.6%	4.8	18.4%	24.8%	56.8%
2009	2.0%	92.0%	-	6.0%	23.5%	33.7%	35.1%	1.6%	6.0%	5.2	21.0%	20.5%	58.4%
2010	1.8%	91.9%	0.4%	5.9%	16.4%	29.1%	46.7%	1.9%	5.9%	5.4	20.9%	18.0%	61.0%
2011	1.3%	91.4%	0.0%	7.3%	11.9%	26.5%	50.5%	3.9%	7.3%	5.5	17.7%	17.3%	65.0%
2012	1.4%	92.4%	-	6.2%	10.3%	24.4%	54.6%	4.4%	6.2%	5.6	20.9%	14.8%	64.4%
2013	*1.2%*	*89.2%*	-	*9.5%*	*5.2%*	*19.0%*	*59.7%*	*6.6%*	*9.5%*	*5.8*	*18.8%*	*16.1%*	*65.1%*

6 Technology Adoption Rates

Technology available in new vehicles is continually changing and evolving. Innovative new technologies are regularly being introduced, replacing older and less effective technologies. This continuous cycle of improvement and re-invention has been the driving force behind nearly all of the trends examined in this report. Section 5 detailed many specific technological changes that have taken place since 1975. This section provides a detailed look at the rate at which the automotive industry as a whole has adopted new technology, the rate at which individual manufacturers have adopted technology, and the differences between the overall industry and manufacturer adoption rates.

It is important to note that this section focuses on "successful" technologies, those technologies that have achieved widespread use by multiple manufacturers and, in some cases, by all or nearly all manufacturers. This section does not look at "unsuccessful" technologies which never achieved widespread use. One consequence of a competitive and technology-driven enterprise like the automobile industry is that there will certainly be a number of unsuccessful technologies. A technology may prove to be unsuccessful for one or more of many reasons: cost, effectiveness, tradeoffs with other vehicle attributes, consumer acceptance, or, in some cases, the technology may be successful for a time but simply be displaced by a newer and better technology. The Trends database does not provide data on why technologies fail, but it does provide data on how quickly successful technologies can penetrate the marketplace, and the latter is the subject of this section.

One inherent limitation in using the Trends database to track the introduction of new technologies is that there is often a lag between the introduction of a new technology and the modifications to the formal EPA vehicle compliance information system that are necessary to ensure proper tracking of the new technology. Accordingly, for many of the technologies discussed in this section, the Trends database did not begin tracking production share data until after the technologies had achieved some limited market share. For example, as shown in Tables 5.2.2 and 5.2.3, Trends did not begin to track multi-valve engine data until MY 1986 for cars and MY 2004 for trucks, and in both cases multi-valve engines had captured about 5% market share by that time. Likewise, turbochargers were not tracked in Trends until MY 1996 for cars and MY 2003 for trucks, and while turbochargers had less than a 1% market share in both cases at that time, it is likely that turbochargers had exceeded 1% market share in the late 1980s. Cylinder deactivation was utilized by at least one major manufacturer in the 1980s, well before being tracked by Trends.

Accordingly, this section best addresses the question, "How quickly have successful technologies moved from limited use to widespread use," for both industry-wide and for individual manufacturers, and does not address other issues such as how long it takes for technologies to be developed or achieve limited market share, or why many technologies fail to ever achieve widespread use.

A. Industry-Wide Technology Adoption Since 1975

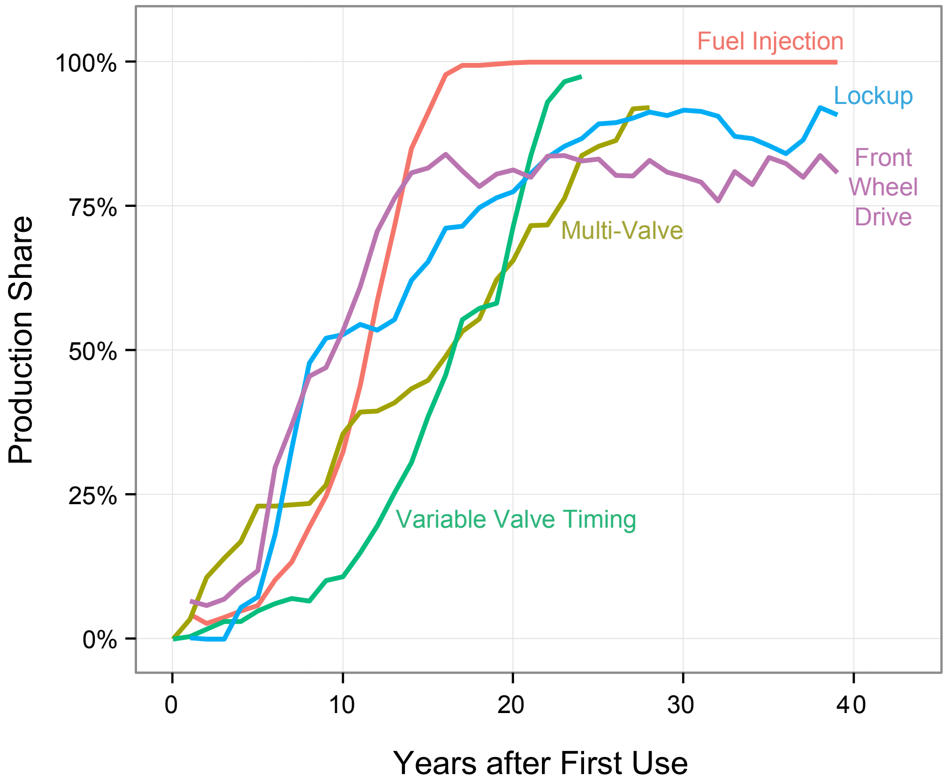
As explored in Section 5, automotive technology has continually evolved since 1975, resulting in vehicles that have better fuel economy, more power, and more content. One of the most notable examples of this continual improvement is the evolution of fuel delivery in gasoline engines. Carburetors, the dominant fuel delivery system in the late 1970s and early

1980s, were replaced by port fuel injection systems, which in turn are being replaced by direct injection systems. This trend, and the substantial impact on engine fuel economy and performance, is explored in Figures 5.4 and 5.5.

Figure 6.1 has been published in this report for many years, and has been widely cited in the literature. This figure shows industry-wide adoption rates for five mature technologies in passenger cars that have achieved wide adoption across the entire industry. To provide a common scale, the adoption rates are plotted in terms of the number of years after the technology was first introduced into the market (in some cases very limited use of the technology may have occurred before being tracked in this report). The five technologies included in Figure 6.1 are fuel injection (including throttle body, port, and direct injection), front wheel drive, multi-valve engines (i.e., engines with more than two valves per cylinder), engines with variable valve timing, and lockup transmissions. For each of these technologies, it took at least a decade to attain an industry wide production fraction of 60% after first use, and another five to ten years to reach maximum penetration. While some of these technologies may eventually be adopted in 100% of new vehicles, there may be design reasons that other technologies, like front-wheel drive, will likely never be adopted in all vehicles. Figure 6.1 shows that it has historically taken about 20 years for the industry to fully adopt a new technology after it was first introduced into the marketplace.

Figure 6.1

Industry-Wide Car Technology Penetration After First Significant Use



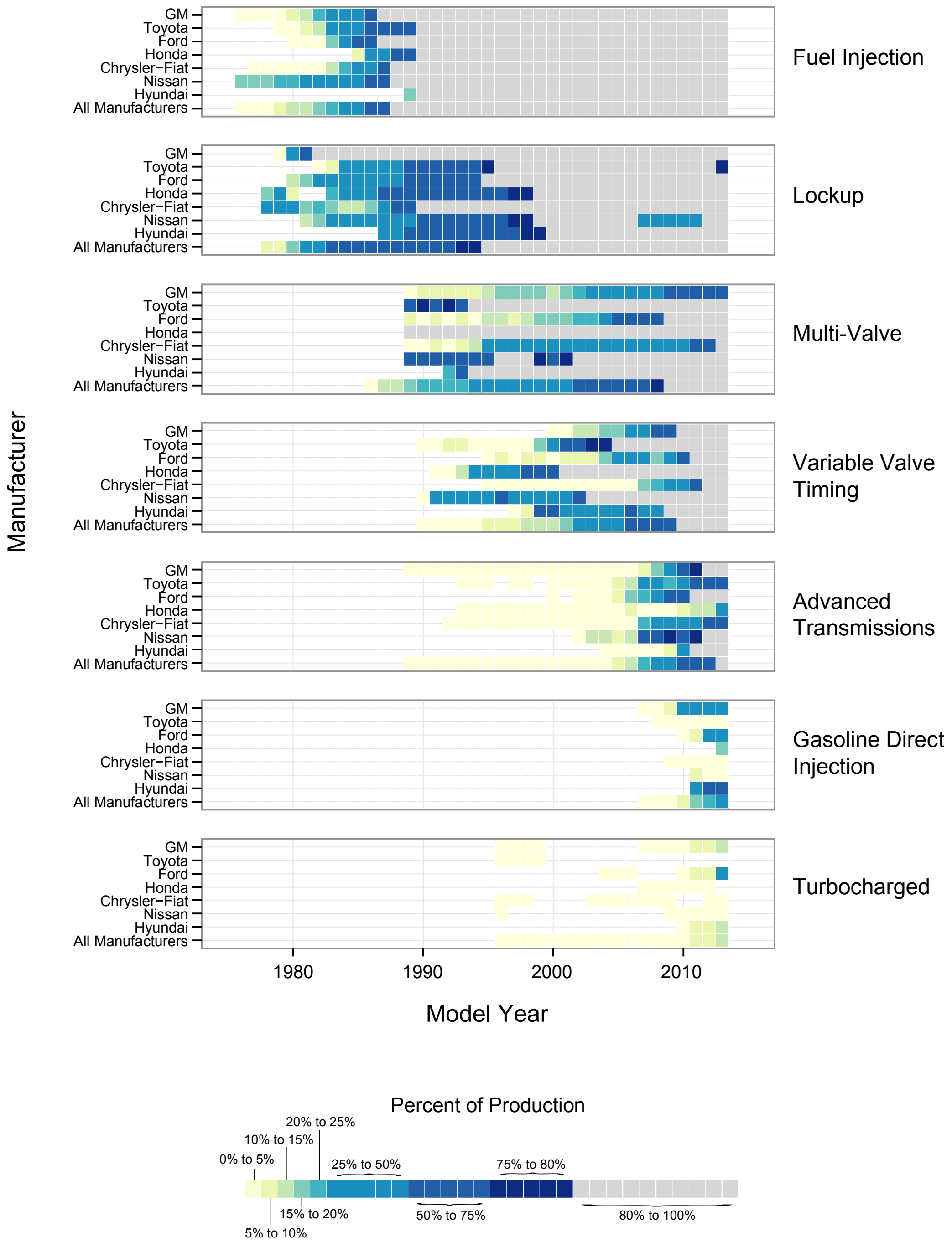
B. Technology Adoption By Manufacturers

The rate at which the overall industry adopts technology, as shown in Figure 6.1, is actually determined by how quickly, and at what point in time, individual manufacturers adopt the technology. While it is important to understand the industry wide adoption rates over time, the trends in Figure 6.1 mask the fact that not all manufacturers introduced these technologies at the same time, or at the same rate. The “sequencing” of manufacturers introducing new technologies is an important aspect of understanding the overall industry trend of technology adoption.

Figure 6.2 begins to disaggregate the industry-wide trends shown in Figure 6.1 to examine how individual manufacturers have adopted new technologies. The first four technologies shown in Figure 6.2, which are also shown in Figure 6.1, have reached (or are near) full market penetration for all manufacturers. Also included in Figure 6.2 are three additional technologies that are quickly increasing penetration in new vehicle production, and are projected to be installed on at least 15% of all MY 2013 vehicles. These technologies are advanced transmissions (defined here as transmissions with 6 or more speeds and CVTs), gasoline direct injection (GDI) systems, and turbocharged engines. Figure 6.2 shows the percent penetration of each technology over time for the industry as a whole, and individually for the top seven manufacturers by sales. Figure 6.2 focuses on the length of time each manufacturer required to move from initial introduction to 80% penetration for each technology. After 80% penetration, the technology is assumed to be largely incorporated into the manufacturer’s fleet changes between 80% and 100% are not highlighted.

Figure 6.2

Manufacturer Specific Technology Adoption over Time for Key Technologies



The technologies shown in Figure 6.2 vary widely in terms of complexity, application, and when they were introduced into the market. For each technology, there are clearly variations between manufacturers, both in terms of when they began to adopt a technology, and the rate with which they adopted the technology. The degree of variation between the manufacturers also varies by technology.

The data for variable valve timing, for example, shows that several manufactures were able to adopt the technology much faster than the overall industry rate might suggest. As shown in Figure 6.1, it took a little over 20 years for VVT to reach 80% penetration across the industry as a whole. However, Figure 6.2 shows that of the top 7 manufacturers, several were individually able to implement at least 80% VVT in significantly less time than the overall industry. Therefore, it was not the rate of technology adoption, but rather the staggered implementation timing between manufacturers that resulted in the longer industry average.

Fuel injection systems show the least amount of variation in initial adoption timing between manufacturers, which when combined with the rapid rates of adoption resulted in a faster adoption by the industry overall (see Figure 6.1) than technologies like VVT. One important driver for adoption of fuel injection was increasingly stringent emissions standards. Advanced transmissions, and turbocharged engines, have been available in small numbers for some time, but have very rapidly increased market penetration in recent years. Turbocharged engines and GDI systems are only recently beginning to reach significant parts of the market, and while both technologies are showing variation in adoption between manufacturers, it is too early to tell how, and if, they will ultimately be adopted by the industry.

A different way to look at technology adoption patterns is to look at the maximum rate of change that manufacturers have been able to achieve for each technology. Figure 6.3 uses this approach to look at technology adoption for the same manufacturers and technologies examined in Figure 6.2. For each technology and manufacturer, Figure 6.3 shows the maximum change in technology penetration that each manufacturer achieved over any 3 year and 5 year period.

There are many examples of manufacturers that were able to apply new technology to a large percentage of their new vehicles in only 3 to 5 years. For example, each of the 7 manufacturers was able to increase the percentage of their new vehicles with fuel injection systems by over 50% in 5 years, and 3 were able to increase the penetration of VVT by more than 85% in that time. For VVT, all 7 of the manufacturers achieved close to or above a 70% penetration change in a 5 year period, but the industry as a whole only achieved a 40% change over any 5 years. This data reinforces the conclusion that the staggered timing of VVT adoption by individual manufacturers resulted in an overall industry adoption period that is longer than actually required by many (if not most) manufacturers.

One important note for Figure 6.3 is that, in some cases, individual manufacturers were already at extremely high rates of adoption of some technologies before Trends started collecting data for that technology (for example, Honda was using multi-valve engines throughout its fleet when EPA starting monitoring multi-valve data in the mid-1980s). Data for "rates of increase" in these and similar cases are artificially low.

Figure 6.3

Maximum Three and Five Year Adoption for Key Technologies

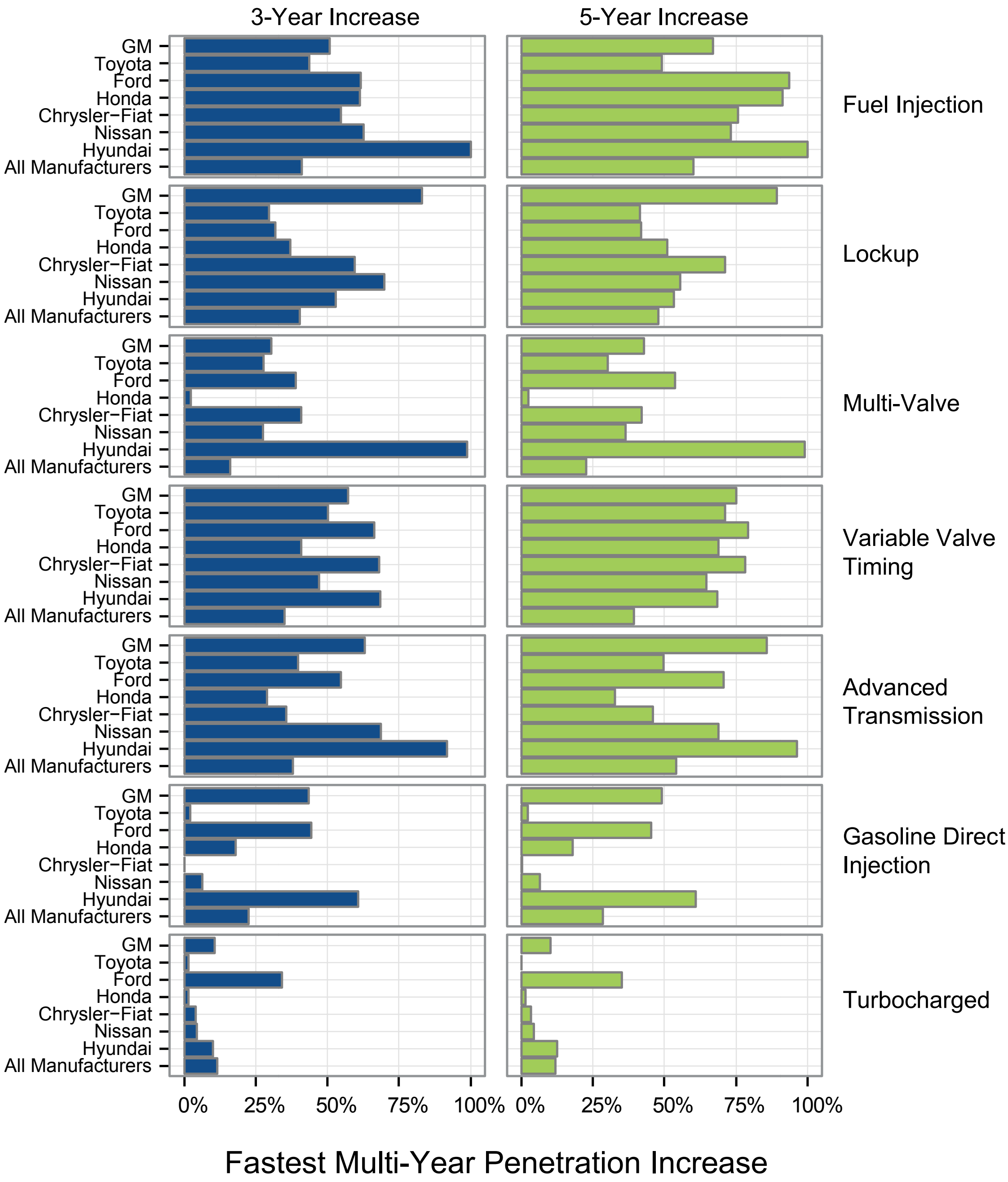
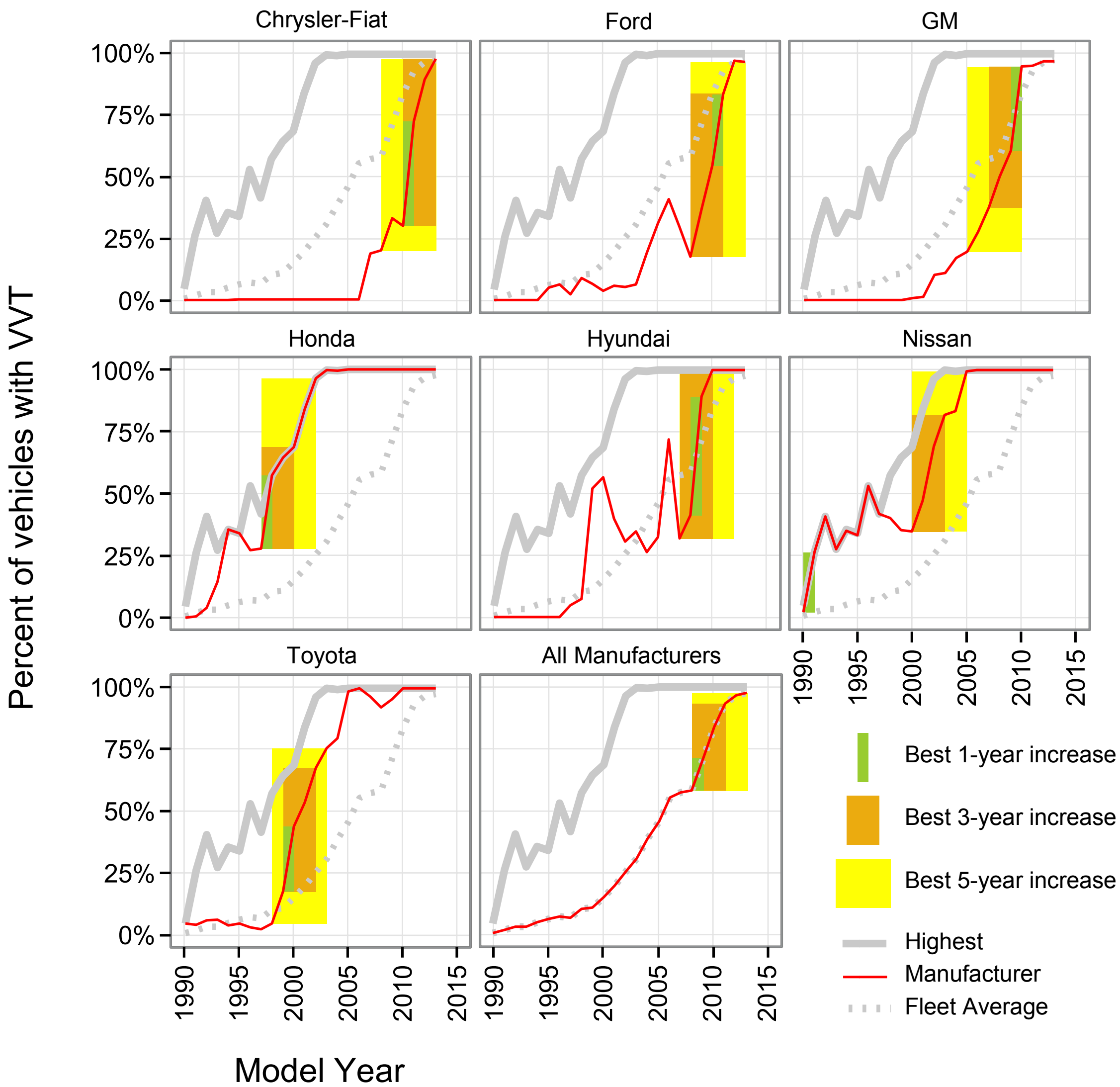


Figure 6.4 takes a more detailed look at the introduction of VVT by manufacturers by combining aspects of both Figure 6.2 and Figure 6.3. For each manufacturer, Figure 6.4 shows the actual percent penetration of VVT over time (solid red line) versus the average for all manufacturers (dotted grey line), and compared to the maximum penetration by any manufacturer (solid grey line) over time. Figure 6.4 also shows when the largest increase in VVT penetration over any 1, 3, and 5 year period occurred as green, orange, and yellow boxes.

Figure 6.4

VVT Adoption Details by Manufacturer



VVT was first tracked in this report for cars in MY 1990 and for trucks in MY 2000. Between MY 1990 and MY 2000, there may be a small number of trucks with VVT that are not accounted for in the data. However, the first trucks with VVT produced in larger volumes (greater than 50,000 vehicles) were produced in MY 1999 and MY 2000, so the discrepancy is not enough to noticeably alter the trends in the previous figures.

As shown in Figure 6.2, each manufacturer clearly followed a unique trajectory to adopt VVT. It took over 20 years for all new vehicles to adopt VVT; however it is also very clear that individual manufacturers were able to adopt VVT across their own vehicle offerings much faster. All of the manufacturers shown in Figure 6.4 were able to adopt VVT across the vast majority of their new vehicle offerings in under 15 years, and many accomplished that feat in under 10 years. As indicated by the yellow rectangles in Figure 6.4, several manufacturers increased their penetration rates of VVT by 75% or more over a 5-year period. It is also important to note that every manufacturer shown was able to adopt VVT into new vehicles at a rate faster than the overall industry data would imply. As noted earlier, the industry average represents both the rate that manufacturers adopted VVT and the effect of manufacturers adopting the technology at different times. Accordingly, the industry average shown in Figure 6.1 and Figure 6.4 does not represent the average pace at which individual manufacturers adopted VVT, which is considerably faster.

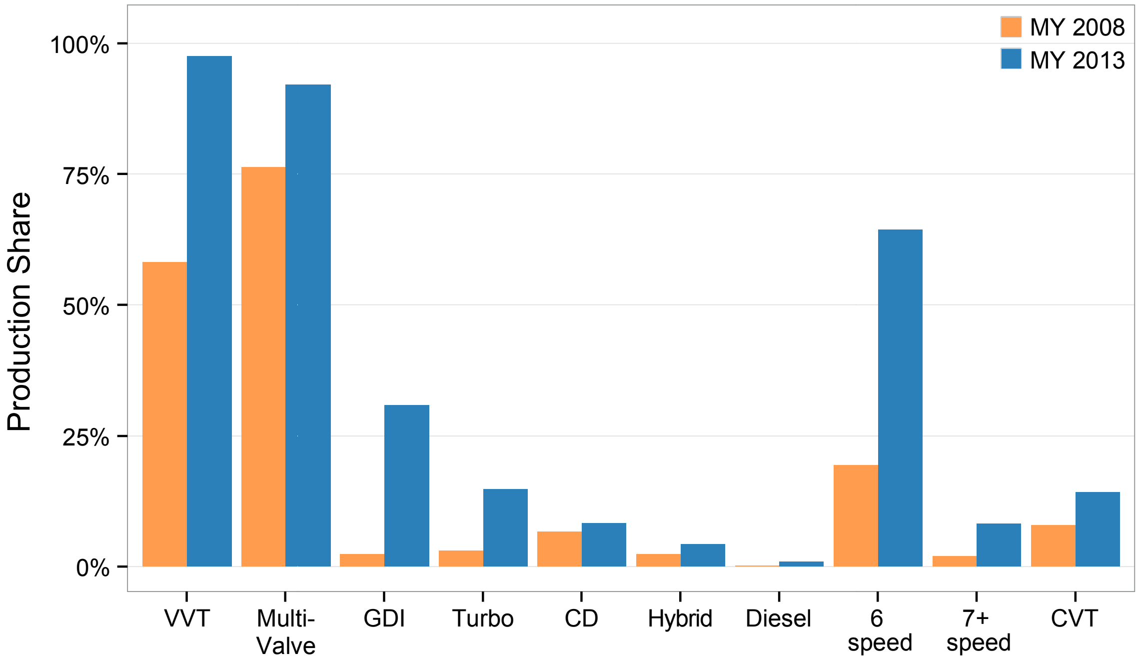
Figures 6.2 through 6.4 examine manufacturer specific technology adoption in different ways, but all three clearly support the conclusion that some manufacturers have been able to adopt technology much faster than industry wide data suggests, and that there is significant variation in how individual manufacturers have adopted technology.

C. Technology Adoption In the Last 5 Years

Over the last five years, engines and transmissions have continued to evolve and adopt new technologies. Figure 6.5 shows the penetration of several key technologies in MY 2008 and the projected penetration for each technology in MY 2013 vehicles. Over that five year span, VVT is projected to increase almost 40%, GDI by almost 30%, and 6 speed transmissions by over 40% across the entire industry. These are large changes taking place over a relatively short time. As discussed in the previous section, there are likely manufacturer specific changes in this timeframe that are even more impressive.

Figure 6.5

Five Year Change in Light Duty Vehicle Technology Penetration Share



There are many factors outside the scope of this report that influence the rate and timing of when technology is adopted by individual manufactures (e.g. price, manufacturing constraints, regulatory drivers, etc.) While no attempt is made here to identify the underlying causes, it is important to recognize that any variation between manufacturers for given technologies can be masked when only evaluating industry-wide trends. As the data in this section suggest, adoption by individual manufacturers is generally more rapid than has previously been reported for the overall industry, and it is clear that the penetration of important technologies has grown significantly over the last 5 years.

7 Alternative Fuel Vehicles

This section addresses original equipment manufacturer (OEM)[1] vehicles that are dedicated to, or are designed and expected to frequently operate on, alternative fuels. The main focus of this section will be preliminary data on MY 2013 vehicles that are designed and expected to operate on electricity and natural gas. OEM vehicles that operate predominantly on other alternative fuels, including ethanol, methanol, propane, hydrogen, etc., will be included in future reports if they become available to the public (the great majority of current ethanol flexible fuel vehicles are operated primarily on gasoline and therefore are not included in this section). Increasing interest in these alternative fuel vehicles is being driven by several factors: sustained high oil prices, concerns about future oil supplies and greenhouse gas emissions, and economic and national security issues associated with oil imports. This is an emerging area, with several new OEM alternative fuel vehicle models introduced in MY 2013 and more planned for subsequent model years. Often, alternative fuel vehicle models are initially introduced in selected areas of the country, but we expect that many alternative fuel vehicle models will be available on a nationwide basis in the next few years.

A. Methodology

The Trends analyses provided in Sections 2-6 includes vehicle data from 1975 to the present only for vehicles that are dedicated to or are expected to operate primarily on petroleum fuels, i.e., gasoline and diesel fuel. The primary reason for this is simply that the small number of OEM vehicles that predominantly use alternative fuels would have a very small impact on the analyses in Sections 2-6. In addition, complexities arise when analyzing trends of certain alternative fuel vehicles, particularly for those fuels that are not sold by the gallon.

Vehicles that can operate on both a petroleum-based fuel and an alternative fuel pose another analytical challenge. There are currently a large number of “flexible fuel vehicles” (FFVs) in the market that are capable of using either gasoline or E85 (a mixture of 85% ethanol and 15% gasoline, by volume), or any blend in between. Historically, these vehicles have operated predominantly on gasoline (and ethanol-gasoline blends with low levels of ethanol) only.[2] EPA believes that there are many reasons why most consumers use gasoline in their FFVs: limited E85 fuel availability, greater vehicle range on gasoline, and E85 fuel pricing such that the fuel cost per mile is typically cheaper on gasoline. Accordingly, this report continues to assume that ethanol FFVs operate primarily on gasoline, with the analysis in Sections 2-6 including data from FFV operation on gasoline and excluding data from FFV operation on E85. If, in the future, FFVs operate more often on E85 fuel, EPA will consider adding FFVs to this alternative fuel vehicle analysis.

Two other technologies that can use both a petroleum-based fuel and an alternative fuel are plug-in hybrid electric vehicles (PHEVs) and dual-fuel compressed natural gas (DF-CNG) vehicles. While it is almost certain that PHEVs and DF-CNG vehicles will use at least some

[1] This section, like the rest of the report, focuses only on OEM produced vehicles. There are aftermarket converters who modify OEM gasoline vehicles to operate on alternative fuels, but those vehicles are not accounted for in this section.

[2] Based on data from the Energy Information Administration, EPA projects that FFVs were fueled with E85 less than 1 percent of the time in 2008; see 75 Federal Register 14762 (March 26, 2010).

gasoline, there are two factors that strongly suggest that most owners of these vehicles will seek to use the alternative fuel as much as possible: 1) they have paid a substantial premium to buy a vehicle that can use the alternative fuel, and 2) the alternative fuel is considerably cheaper than gasoline, and provides an opportunity for the vehicle owner to recover the higher upfront cost of the vehicle through ongoing fuel savings. Because we expect PHEVs and DF-CNG vehicles to operate frequently on alternative fuels, they are included in this section and not in the primary Trends analysis in Sections 2-6.

With respect to other vehicles that may be introduced in the future that can operate on both petroleum and alternative fuels, EPA will determine on a case-by-case basis whether it is more appropriate to include them in the primary petroleum fuel analysis or in this separate alternative fuel vehicle section.

The number of alternative fuel vehicles produced is still too small (less than 0.5 percent of MY 2012 production) to have a large impact on the overall technology, CO_2 emissions, and fuel economy trends; however, many additional alternative fuel vehicle models are expected to enter the market over the next few years.[3] At some point in the future, as the sales of alternative fuel vehicles continue to increase, EPA will consider merging this alternative fuel vehicle data into the primary Trends analysis.

This section (and sections 8 and 9) reports combined fuel economy and CO_2 values based on the 55% city/45% highway weighting used on the Fuel Economy and Environment labels and for GHG emissions and fuel economy standards compliance, and not on the 43% city/57% highway weighting used for adjusted fuel economy values throughout sections 2-6 of this report.

B. Historical Trends

Gasoline and diesel vehicles have long dominated new light vehicle sales. OEM vehicles that operate frequently on alternative fuels have historically been available only in small numbers, though those limited production vehicles have in some cases created significant consumer and media interest.[4] From MY 1995 (which is as far back as reliable alternative fuel vehicle data was available for this report) to MY 2010, over 99.9% of all new OEM vehicles were petroleum fueled, with annual production of alternative fuel vehicles less than 4,000 per year. In MY 2011, several new alternative fueled vehicles were introduced into the market. The combined production of these vehicles led to an increase of alternative fuel vehicles from less than 1,200 in MY 2010 to well over 15,000 in MY 2011. While these vehicles still represented a very limited portion of overall new vehicle production (approximately 12 million in MY 2011), this change is notable. This upward trend continued in MY 2012. In MY 2012 there were even more alternative fuel vehicle models offered, and the combined production of these vehicles was about 55,000. Although this still only represents 0.4% of

[3] For example, see list of potential future EVs and PHEVs at fueleconomy.gov/feg/evnews.shtml

[4] Millions of ethanol FFVs have been sold in recent years, but these vehicles have operated primarily on gasoline.

total vehicle sales for MY 2012 (approximately 13.5 million), the continued increase in alternative fuel vehicle production is impressive.

In the mid-1990s, the state of California passed legislation creating the (Zero Emission Vehicle) ZEV mandate. In response to the ZEV mandate, OEMs began to produce limited numbers of electric vehicles. Most of these vehicles were leased, rather than sold, in the state of California. The majority of these electric vehicles were small passenger cars, SUVs, or pickup trucks, including the GM EV1, the Toyota RAV4 EV, and the Ford Ranger EV. Dedicated CNG vehicles have been available in limited numbers for the last twenty years, most commonly during and after periods of rising gasoline prices. CNG vehicles have spanned a wider range of vehicles, from work trucks and vans to the Honda Civic Natural Gas, which has been available in select markets since MY 1998.

In MY 2000, five electric vehicles (EVs), seven dedicated CNG vehicles, and one DF-CNG vehicle were available in the U.S. market. Chrysler-Fiat, Ford, GM, Honda, Nissan, and Toyota all produced at least one alternative fuel vehicle in MY 2000, with total production of about 3,500 vehicles. Most of these vehicles were produced in small volumes and only for a few model years. However, by MY 2006, only one alternative fuel vehicle was available, the Honda Civic Natural Gas. The Tesla Roadster, a dedicated electric vehicle, was introduced with limited production in MY 2008. From MY 2008 through MY 2010, the Civic Natural Gas and the Tesla Roadster were the only two alternative fuel vehicles produced by OEMs and available in some retail markets.

Two high profile OEM alternative fuel vehicles were introduced into the retail market in MY 2011, with much higher production volumes than previous alternative fuel vehicles: the Nissan Leaf EV and the Chevrolet Volt PHEV. The Volt and Leaf had combined production of nearly 13,000 vehicles in MY 2011, so production of these two vehicles alone tripled the total number of alternative fuel vehicles produced in MY 2011 relative to any model year since 1995. Production of the Volt and Leaf continued to climb in MY 2012, to nearly 30,000 combined vehicles.

In MY 2012[5], there were numerous additional entries into the electric vehicle and plug-in hybrid electric vehicle market. In addition to the Nissan Leaf, new electric vehicle models included the Ford Focus EV and Transit Connect EV, the Mitsubishi i-MiEV, the Tesla Model S, and the Toyota RAV4 EV. In addition to the Chevy Volt, new PHEVs introduced in MY 2012 included the Fisker Karma and the Toyota Prius Plug-in. Over 50,000 EVs and PHEVs were produced in MY 2012, compared to just 278 in MY 2010.

The Honda Civic Natural Gas model also set a production record in MY 2012, with production of over 3,300, or nearly triple the production of any other year. When it was initially introduced, the Honda Civic Natural Gas was available only to fleet customers, but it subsequently became available for retail in California, New York, Utah, and Oklahoma.

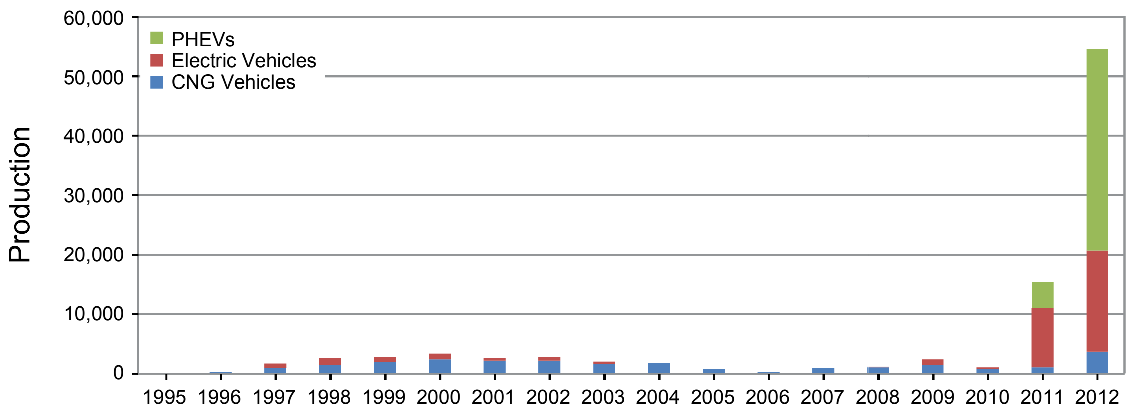
[5] Two fuel cell vehicles were also offered in MY 2012, the Honda FCX Clarity and Mercedes-Benz F-Cell. These vehicles were available in limited lease and/or demonstration programs.

Availability of the MY 2012 Civic Natural Gas was increased to 36 states, with more possible.[6] While the production trend of the Civic Natural Gas is positive, other OEMs have been reluctant to directly offer CNG vehicles, and the Civic Natural Gas is once again the only OEM natural gas vehicle on the market.

Figure 7.1 shows the historical sales of EVs, PHEVs, and CNG vehicles over the last 18 years (we do not have reliable data on alternative fuel vehicles back to 1975). This figure was compiled from several data sources, including manufacturer CAFE reports, Ward's, and publically available production data. Figure 7.1 includes dedicated CNG vehicles, but not dual fuel CNG vehicles as sales data were not available for dual fuel vehicles. The data only includes offerings from manufacturers, and does not include data on vehicles converted to alternative fuels in the aftermarket.

Figure 7.1

Historical Production of EVs, PHEVs, and Dedicated CNG Vehicles



[6] Ward's Automotive, http://wardsauto.com/sales-amp-marketing/honda-forecasts-steady-sales-pioneering-cng-civic, last accessed December 2013.

C. MY 2013 Vehicles

Since sales of alternative fuel vehicles have historically been limited, this section of the report will focus on currently available alternative fuel vehicles produced by OEMs and introduce several metrics that are important for alternative fuel vehicles, instead of analyzing aggregated data about new vehicles sales. Table 7.1 shows the alternative fuel vehicles available from OEMs in MY 2013, as well as the powertrain type of each vehicle, inertia weight class (IWT)[7], and footprint. These vehicles constitute a wide array of vehicle design, size, and function.

Table 7.1

MY 2013 Alternative Fuel Vehicle Classification and Size [8]

Make	Model	Fuel or Powertrain	Car or Truck	IWT (lbs)	Footprint (sq ft)
Fiat	500e	EV	Car	3000	34.9
Ford	Focus	EV	Car	4000	43.5
Honda	Fit	EV	Car	3500	39.6
Mitsubishi	i	EV	Car	2750	38.4
Nissan	Leaf	EV	Car	3500	44.7
Scion	iQ	EV	Car	2750	31.6
Smart	Fortwo	EV	Car	2250	26.8
Tesla	Model S (85kW-hr)	EV	Car	4500	53.5
Tesla	Model S (60kW-hr)	EV	Car	4500	53.5
Toyota	RAV4	EV	Car	4000	44.6
Chevrolet	Volt	PHEV	Car	4000	44.6
Ford	C-MAX	PHEV	Car	4000	43.8
Ford	Fusion	PHEV	Car	4000	45.9
Toyota	Prius	PHEV	Car	3500	44.2
Honda	Civic	CNG	Car	3000	43.5

As shown in Table 7.1, there are nine EVs available in MY 2013 (the two Tesla S variants are considered one model, as explained in Section 8), four PHEVs, and one dedicated CNG vehicle. The footprint of the largest vehicle, the Tesla S, is double that of the smallest vehicle, which is the Smart Fortwo. The weight of these vehicles also significantly varies, from an IWT of 2750 to 4500. For each of the vehicles listed in Table 7.1, Table 7.2 shows the label driving range, and introduces the concept of a utility factor for PHEVs (explained below).

[7] Each inertia weight class represents a range of loaded vehicle weights, or vehicle curb weights plus 300 pounds. Vehicle inertia weight classes are in 250-pound increments for inertia weight classes that are less than 3000 pounds, while inertia weight classes over 3000 pounds are divided into 500-pound increments.

[8] There are several other non-petroleum fueled vehicles that have been in limited lease and/or demonstration programs, including the Honda Clarity FCX fuel cell vehicle, Mercedes F-Cell vehicle, etc. But, these vehicles have not been available to the general public at large.

Table 7.2

MY 2013 Alternative Fuel Vehicle Powertrain and Range

Make	Model	Fuel or Powertrain	Alternative Fuel Range miles	Total Range miles	Utility Factor
Fiat	500e	EV	87	87	-
Ford	Focus	EV	76	76	-
Honda	Fit	EV	82	82	-
Mitsubishi	i	EV	62	62	-
Nissan	Leaf	EV	75	75	-
Scion	iQ	EV	38	38	-
Smart	Fortwo	EV	68	68	-
Tesla	Model S (85kW-hr)	EV	265	265	-
Tesla	Model S (60kW-hr)	EV	208	208	-
Toyota	RAV4	EV	103	103	-
Chevrolet	Volt	PHEV	38	380	0.66
Ford	C-Max	PHEV*	21	620	0.48
Ford	Fusion	PHEV*	21	620	0.48
Toyota	Prius	PHEV*	11**	540	0.29
Honda	Civic	CNG	-	-	-

* PHEVs that operate in blended mode.

** The Prius required a small amount of gasoline during the alternative fuel range.

PHEVs blend EV technology with more familiar powertrain technology from petroleum-fueled vehicles. Current PHEVs feature both an electric drive system designed to be charged from an electricity source external to the vehicle (like an EV), and a gasoline internal combustion engine. There are generally three ways that a PHEV can operate:

1. Electric only mode – In electric only mode the vehicle operates like an EV, using only energy stored in the battery to propel the vehicle.

2. Blended mode – In blended mode the vehicle uses both energy stored in the battery and energy from the gasoline tank to propel the vehicle.

3. Charge sustaining mode – In charge sustaining mode, the PHEV has exhausted the external energy from the electric grid that is stored in the battery and relies on the gasoline internal combustion engine. In charge sustaining mode, the vehicle will operate much like a traditional hybrid.

The presence of both an electric drive system and an internal combustion engine results in a complex system that can be used in many different combinations, and manufacturers are each choosing to operate PHEV systems in different ways. This complicates direct comparisons among PHEV models in this report. For each MY 2013 PHEV, Table 7.2 shows the estimated range on alternative fuel and estimated total range. For PHEVs like the

Chevrolet Volt, which cannot operate in blended mode, the alternative fuel range represents the estimated range operating in electric only mode. However, for PHEVs that operate in a blended mode, the alternative fuel range represents the estimated range of the vehicle operating in both electric only *and* blended mode, due to the design of the vehicle. For example, the Prius uses electricity stored in its battery and a small amount of gasoline to achieve an alternative fuel range of 11 miles. The C-Max and Fusion PHEVs did not use any gasoline to achieve an alternative fuel range of 21 miles on EPA test cycles; however driving conditions outside those represented on the EPA test cycles (e.g., more aggressive accelerations, higher speeds, and air conditioning or heater operation) would likely cause these vehicles to operate in a blended mode instead of an all electric mode. Table 7.2 also introduces the concept of a utility factor. The utility factor is directly related to the alternative fuel range for PHEVs, and is a projection, on average, of the percentage of miles that will be driven using the alternative fuel (in electric only and blended modes) by an average driver.

The one vehicle that operates on CNG has a traditional internal combustion engine. Many internal combustion engines designed to run on CNG are based on gasoline engines, with upgraded fuel systems and tanks designed specifically for natural gas. Therefore, specifications for CNG engines such as engine displacement and engine horsepower are essentially the same as those for traditional petroleum-based engines.

This report has not previously tracked or analyzed data on the range of vehicles using petroleum fuels because gasoline and diesel vehicles can generally travel at least 300 miles without refueling, and gasoline and diesel fuel stations are common and well distributed across the United States (although there are some rural areas where range may in fact be an important consideration). Most alternative fuel vehicles are expected to have lower vehicle range than gasoline and diesel vehicles, and all alternative fuel vehicles are likely to have more limited public refueling infrastructure. Range is of particular concern with electric vehicles, as today's battery technology limits the range of EVs to considerably less than that of comparable petroleum-fueled vehicles. The availability of dedicated EV charging stations is also currently limited, especially for stations powerful enough to be capable of "fast" charging.[9] Table 7.2 includes range data for the alternative fuel vehicles when operating on the alternative fuel, as well as total electricity plus gasoline range for PHEV vehicles.

Table 7.3 shows four energy-related metrics for the MY 2013 alternative fuel vehicles (no entry is shown if the metric is not applicable to that vehicle technology). These data are generally included on the EPA/NHTSA Fuel Economy and Environment labels beginning in MY 2013[10]. Comparing the energy or fuel efficiency performance from alternative fuel vehicles raises complex issues of how to compare different fuels. For example, consumers and OEMs are familiar and comfortable with evaluating gasoline and diesel vehicle fuel

[9] While dedicated EV charging stations are currently limited, electricity is available in nearly all but the most remote parts of the country. EVs can generally be recharged from a standard 110v outlet, though charging will be slower than at a dedicated 220v charging station.
[10] These values represent a 55% city/45% highway weighting, consistent with the methodology used for labeling vehicles.

economy in terms of miles per gallon, and it is the primary efficiency metric in this report. To enable this comparison for alternative fuel vehicles, the fuel efficiency of vehicles operating on CNG and electricity are evaluated in terms of miles per gallon of gasoline equivalent (an energy metric described in more detail below).

Table 7.3

MY 2013 Alternative Fuel Vehicle Fuel Economy Label Metrics

Make	Model	Fuel or Powertrain	Consumption (kW-hrs/ 100 miles)	Electric Only Fuel Economy (MPGe)	Gasoline Only Fuel Economy (MPG)	Overall Fuel Economy (MPGe)
Fiat	500e	EV	29	116	-	116
Ford	Focus	EV	32	105	-	105
Honda	Fit	EV	29	118	-	118
Mitsubishi	i	EV	30	112	-	112
Nissan	Leaf	EV	29	115	-	115
Scion	iQ	EV	28	121	-	121
Smart	Fortwo	EV	32	107	-	107
Tesla	Model S (85kW-hr)	EV	38	89	-	89
Tesla	Model S (60kW-hr)	EV	35	95	-	95
Toyota	RAV4	EV	44	76	-	76
Chevrolet	Volt	PHEV	35	98	37	62
Ford	C-Max	PHEV	34	100	43	58
Ford	Fusion	PHEV	34	100	43	58
Toyota	Prius	PHEV	29*	95**	50	58
Honda	Civic	CNG	-	-	-	31

* Note: Electric consumption only. Overall, the Prius PHEV consumes both electricity and gasoline over the alternative fuel range of 11 miles, at a rate of 29 kW-hrs/100 miles and 0.2 gal/100 miles.

** Prius PHEV mpge value reflects blended operation on both electricity and gasoline.

The fourth column in Table 7.3 gives consumption rates for vehicles operating on electricity, which includes EVs and PHEVs. The units for electricity consumption are kilowatt-hours per 100 miles (kW-hrs/100 miles). The values for all of the EVs and PHEVs, with the exception of the Toyota Prius PHEV, reflect electric-only operation. The Toyota Prius PHEV electric consumption value represents the tested electric consumption of the vehicle during both electric only and blended modes. The Prius PHEV also consumes 0.2 gallons of gasoline per 100 miles during this combination of electric-only and blended modes.

The fifth column simply converts the electricity consumption data in the fourth column to miles per gallon of gasoline-equivalent (mpge), i.e., the miles the vehicle can travel on an amount of electricity that has the same amount of energy as a gallon of gasoline. For a vehicle operating on electricity, mpge is simply calculated as 33.705 kW-hrs/gallon divided by the vehicle electricity consumption in kW-hrs/mile. For example, for the Leaf, 33.705 kW-hrs/gallon divided by 0.29 kW-hrs/mile (which is equivalent to 29 kW-hrs/100 miles) is 115 mpge. Because the Prius PHEV consumes both electricity and gasoline over the alternative fuel range of 11 miles, the electric consumption value of 95 mpge includes both the electricity and gasoline consumption, at a rate of 29 kW-hrs/100 miles of electricity and 0.2 gal/100 miles of gasoline.

The sixth column gives label fuel economy values for vehicles operating on gasoline only, which is relevant here only for the PHEVs operating in charge sustaining mode. For PHEVs, the EPA/NHTSA label shows both electricity consumption in kW-hrs/100 miles and mpge, when the vehicle operates exclusively on electricity, and gasoline fuel economy in mpg, when the vehicle operates exclusively on gasoline.

The final column gives the overall mpge values reflecting the overall energy efficiency of the vehicle on all of the fuels on which vehicle can operate. While mpge does not reflect how all alternative fuels are sold (natural gas is in fact sold in gallons of gasoline equivalent, but electricity is not), it does provide a common metric with which to compare fuels that are sold in different units, and mpge is generally included on the EPA/NHTSA labels for that reason. For PHEVs, the mpge metric can also be used to determine the overall equivalent fuel economy for a vehicle that operates on two unique fuels. In addition to the energy metrics in the previous columns, the one key additional parameter necessary to calculate a combined electricity/gasoline mpge value for a PHEV is the utility factor that was introduced in Table 7.2. The MY 2013 Volt, for example, has a utility factor of 0.66, i.e., it is expected that the Volt will operate 66% of the time on electricity and 34% of the time on gasoline. Utility factor calculations are based on an SAE methodology that EPA has adopted for regulatory compliance.[11] For EVs and natural gas vehicles, the last column simply reports the mpge values that are on the EPA/NHTSA label. CNG vehicle mpge values are based on the energy equivalency assumption that a gallon of gasoline contains the same energy as 121.5 standard cubic feet of natural gas.

Tables 7.4 and 7.5 show several key CO_2 emissions metrics for MY 2013 alternative fuel vehicles.

Table 7.4 gives vehicle tailpipe CO_2 emissions values. EPA and vehicle manufacturers have been measuring tailpipe emissions since the early 1970s using standardized laboratory tests. Table 7.4 gives tailpipe CO_2 emissions values that are included on the new EPA and NHTSA Fuel Economy and Environment labels (and reflected in the label's Greenhouse Gas Rating) that are currently used for advanced technology vehicles. These label values reflect EPA's best estimate of the CO_2 tailpipe emissions that these vehicles will produce, on average, in real world operation based on the EPA 5-cycle label methodology and using a 55% city/45% highway weighting. EVs, of course, have no tailpipe emissions. For the PHEVs, the label CO_2 emissions values utilize the same utility factors discussed above to weight the CO_2 emissions on electric and gasoline operation. For natural gas vehicles, these values are based on vehicle test data and our 5-cycle methodology. It is important to note that, to be consistent withCO_2 emissions data elsewhere in this report, the tailpipe CO_2

[11] See http://www.SAE.org, specifically SAE J2841 "Utility Factor Definitions for Plug-In Hybrid Electric Vehicles Using Travel Survey Data," September 2010.

emissions values given in Table 7.4 for CNG vehicles do not account for the higher global warming potency associated with methane emissions, which have the potential to be higher for some CNG vehicles.

Table 7.4

MY 2013 Alternative Fuel Vehicle Label Tailpipe CO_2 Emissions Metrics

Make	Model	Fuel or Powertrain	Tailpipe CO_2 (g/mile)
Fiat	500e	EV	0
Ford	Focus	EV	0
Honda	Fit	EV	0
Mitsubishi	i	EV	0
Nissan	Leaf	EV	0
Scion	iQ	EV	0
Smart	Fortwo	EV	0
Tesla	Model S (85kW-hr)	EV	0
Tesla	Model S (60kW-hr)	EV	0
Toyota	RAV4	EV	0
Chevrolet	Volt	PHEV	81
Ford	C-Max	PHEV	110
Ford	Fusion	PHEV	110
Toyota	Prius	PHEV	133
Honda	Civic	CNG	218

Table 7.5 accounts for the "upstream" CO_2 emissions associated with the production and distribution of electricity used in EVs and PHEVs. Gasoline and diesel fuels also have CO_2 emissions associated with their production and distribution, but these upstream emissions are not reflected in the tailpipe CO_2 emissions values discussed elsewhere in this report. Combining vehicle tailpipe and fuel production/distribution sources, gasoline vehicles emit about 80 percent of total CO_2 emissions at the vehicle tailpipe with 20 percent associated with upstream fuel production and distribution. Diesel fuel has a similar approximate relationship between tailpipe and upstream CO_2 emissions. CNG vehicle upstream CO_2 emissions data is not included in Table 7.5.[12] On the other hand, vehicles using electricity emit no CO_2 (or other emissions) at the vehicle tailpipe; therefore all CO_2 emissions associated with powering the vehicle are due to fuel production and distribution. Depending on how the electricity is produced, these fuels can have very high fuel production/distribution CO_2 emissions (for example, if coal is used with no CO_2 emissions control) or very low CO_2 emissions (for example, if renewable processes with minimal fossil energy inputs are used).

An additional complicating factor in Table 7.5 is that electricity production in the United States varies significantly from region to region. Hydroelectric plants provide a large

[12] There is considerable uncertainly and ongoing research on the topic of GHG emissions from natural gas production, particularly with respect to hydraulic fracturing ("fracking") processes.

percentage of electricity in the northwest, coal-fired power plants produce the majority of electricity in the Midwest, and natural gas has increased its electricity market share in many regions of the country. Nuclear power plants and renewable energy make up the balance of U.S. electricity production. In order to bracket the possible GHG emissions impact (there are additional complicating factors that are beyond the scope of this analysis and can only be addressed by sophisticated powerplant modeling), Table 7.5 provides ranges with the low end of the range corresponding to the California powerplant emissions factor, the middle of the range represented by the national average powerplant emissions factor, and the upper end of the range corresponding to the powerplant emissions factor for the Rockies.

Based on data from EPA's eGRID powerplant database, and accounting for additional greenhouse gas emissions impacts for feedstock processing upstream of the powerplant, EPA estimates that the electricity GHG emission factors for various regions of the country vary from 404 g CO_2/kW-hr in California to 976 g CO_2/kW-hr in the Rockies, with a national average of 651 g CO_2/kW-hr.[13] Emission rates for the region encompassing New York City are approximately equal to those in California, and small regions in upstate New York and Alaska have lower electricity upstream CO_2 emission rates than California. However, California is a good surrogate for the "low" end of the range because California is a leading market for current EVs and PHEVs. Initial sales of electric vehicles have been largely, though not exclusively, focused in regions of the country with powerplant CO_2 emissions factors lower than the national average, such as California, New York, and other coastal areas. In addition, sales of hybrid vehicles have also been disproportionately higher in these same areas. Accordingly, in terms of CO_2 emissions, EPA believes that the current "sales-weighted average" vehicle operating on electricity in the near term will likely fall somewhere between the low end of this range and the national average.[14]

The fourth through sixth columns in Table 7.5 provide the range of tailpipe plus *total* upstream CO_2 emissions for EVs and PHEVs based on regional electricity emission rates. For comparison, the average MY 2013 car is also included in Table 7.5. The methodology used to calculate the range of tailpipe plus total upstream CO_2 emissions for EVs, is shown in the following example for the MY 2013 Nissan Leaf:

- Start with the label (5-cycle values weighted 55% city/45% highway) vehicle electricity consumption in kW-hr/mile, which for the Leaf is 29 kW-hr/100 miles, or 0.29 kW-hr/mile
- Determine the regional powerplant emission rate, regional losses during electricity distribution, and the additional regional emissions due to fuel production upstream

[13] TranSystems|E.H. Pechan (2012).The emissions & generation resource integrated database for 2012 (eGRID2012) technical support document, prepared for the U.S. Environmental Protection Agency, Washington, DC, April 2012; Argonne National Laboratory, 2012, GREET web site, http://greet.es.anl.gov/ last accessed October 2012.
[14] For an individual who wants to know the upstream greenhouse gas emissions associated with operating an EV or PHEV in his or her geographical area, use the emissions calculator at fueleconomy.gov/feg/Find.do?action=bt2

of the powerplant (for California, these numbers are 299 g/kW-hr, 8.2%, and 24%).

- Determine the regional upstream emission factor (for California 299 g/kW-hr / (1-0.082) * (1+0.24) = 404 gCO_2/kW-hr)
- Multiply by the range of Low (California = 404 gCO_2/kW-hr), Average (National Average = 651 g CO_2/kW-hr), and High (Rockies = 976 g CO_2/kW-hr) electricity upstream GHG emission rates, which yields a range for the Leaf of 118-285 grams/mile.

The tailpipe plus total upstream CO_2 emissions values for PHEVs include the upstream CO_2 emissions associated with electricity operation and both the tailpipe and upstream CO_2 emissions associated with gasoline operation, using the utility factor discussed above to weight the values for electricity and gasoline operation. The tailpipe plus total upstream CO_2 emissions values for the average car are the average MY 2013 car tailpipe CO_2 emissions (from Table 4.3) multiplied by 1.25 to account for upstream emissions due to gasoline production.

The values in columns four through six are tailpipe plus *total* upstream CO_2 emissions. But, all of the gasoline and diesel vehicle CO_2 emissions data in the rest of this report refer to tailpipe only emissions and do not reflect the upstream emissions associated with gasoline or diesel production and distribution. Accordingly, in order to equitably compare the overall relative impact of EVs and PHEVs with tailpipe emissions of petroleum-fueled vehicles, EPA uses the metric "tailpipe plus *net* upstream emissions" for EVs and PHEVs (note that this same approach has been adopted for EV and PHEV regulatory compliance with the 2012-2025 light-duty vehicle GHG emissions standards for sales of EVs and PHEVs that exceed sales thresholds). The net upstream emissions for an EV is equal to the total upstream emissions for the EV minus the upstream emissions that would be expected from a comparable-sized (size is a good first-order measure for utility and footprint is the size-based metric used for standards compliance) gasoline vehicle. The net upstream emissions for PHEVs are equal to the net upstream emissions of the PHEV due to electricity consumption in electric or blended mode multiplied by the utility factor. The net upstream emissions for a gasoline vehicle are zero.

For each EV or PHEV, the upstream emissions for a comparable gasoline vehicle are determined by first using the footprint based compliance curves to determine the CO_2 compliance target for a vehicle with the same footprint. Since upstream emissions account for approximately 20% of total CO_2 emissions for gasoline vehicles, the upstream emissions for the comparable gasoline vehicle are equal to one fourth of the tailpipe-only compliance target.

The final three columns of Table 7.5 give the tailpipe plus net upstream CO_2 values for the EVs and PHEVs using the same Low, Average, and High electricity upstream CO_2 emissions rates discussed above. These values bracket the possible real world net CO_2 emissions that would be associated with consumer use of these vehicles. For the Leaf, these values are simply the values in columns three through five minus the upstream GHG emissions of a comparably sized gasoline vehicle. Based on the MY 2013 CO_2-footprint curve, the 5-cycle tailpipe GHG emissions for a Leaf sized vehicle meeting its compliance target would be approximately 318 grams/mile, with upstream emissions of one-fourth of this value, or 80 g/mile. The net upstream emissions are determined by subtracting this value, 80 g/mile, from the total upstream emissions for the Leaf. The result is a range for the tailpipe plus net upstream value of 38-205 g/mile as shown in Table 7.5, with a more likely typical value in the 38-111 g/mile range.

For PHEVs, the tailpipe plus net upstream emissions values use the utility factor values discussed above to weight the individual values for electric operation and gasoline operation.

Table 7.5

MY 2013 Alternative Fuel Vehicle Upstream CO_2 Emission Metrics

			Tailpipe + Total Upstream CO_2			Tailpipe + Net Upstream CO_2		
Make	**Model**	**Fuel or Powertrain**	**Low (g/mile)**	**Avg (g/mile)**	**High (g/mile)**	**Low (g/mile)**	**Avg (g/mile)**	**High (g/mile)**
Fiat	500e	EV	118	190	285	44	116	211
Ford	Focus	EV	130	209	313	52	131	235
Honda	Fit	EV	115	186	278	41	112	204
Mitsubishi	i	EV	121	196	293	47	121	219
Nissan	Leaf	EV	118	190	285	38	111	205
Scion	iQ	EV	113	181	272	39	107	198
Smart	Fortwo	EV	127	205	307	53	131	233
Tesla	Model S (85kW-hr)	EV	153	247	370	61	154	277
Tesla	Model S (60kW-hr)	EV	143	230	345	50	137	252
Toyota	RAV4	EV	179	288	432	99	209	353
Chevrolet	Volt	PHEV	194	250	324	121	177	252
Ford	C-Max	PHEV	203	243	295	138	178	230
Ford	Fusion	PHEV	203	243	295	136	176	229
Toyota	Prius	PHEV	200	221	248	144	165	192
	Average Car	*Gasoline*	*406*	*406*	*406*	*325*	*325*	*325*

While there are still relatively few OEM alternative fuel vehicles in MY 2013, this represents a significant increase in both the number of models available and the total production of alternative fuel vehicles. Based on manufacturer announcements and projected sales, this segment of the market will continue to grow in MY 2014 and beyond. This report will continue to track the metrics presented in this section and report on trends in alternative fuel vehicle CO_2 emissions and fuel economy as more models are introduced and more data becomes available in future years.

8 High Fuel Economy and Low CO_2 Choices

Consumers shopping for vehicles with comparatively high fuel economy and low tailpipe CO_2 emissions had more vehicles to choose among in MY 2013 than in MY 2008. These choices reflect both a more diverse range of technology packages on conventional gasoline vehicles as well as more advanced technology and alternative fuel vehicles. Section 5 analyzes important trends for a number of conventional gasoline and diesel vehicle technologies and for advanced technologies like hybrid vehicles. Section 7 provides data on individual alternative fuel vehicle models such as electric vehicles, plug-in hybrid electric vehicles, and compressed natural gas vehicles. This section focuses specifically on trends related to the new vehicle purchase choices available to consumers.

A. Methodology

There are some important methodological differences in the analysis in this section relative to Sections 1-6. First, the data in this section are not weighted by vehicle production levels, but instead reflect "model counts," which is more appropriate for evaluating vehicle choices for consumers. This is because, to an individual consumer in the market for a new vehicle, it makes little or no difference if a particular model has high or low production. Second, this section includes alternative fuel vehicles, whereas sections 1-6 generally analyze only gasoline and diesel vehicles. Third, the analysis in this section focuses on the changes between MY 2008 and MY 2013, rather than trends over multiple decades. These two model years are used because a 5-year period is long enough to identify meaningful multi-year trends.

This "model count" analysis requires assumptions about how to define a model. Our objective in this analysis is to count models that are generally marketed and perceived by consumers to be unique vehicle choices, but not to count multiple configurations that are generally marketed and perceived by consumers to be the same model. The application of this approach requires considerable judgment, and we have made every effort to be consistent for both MY 2008 and MY 2013. The most important guidelines used to classify vehicle configurations into unique "models" for this analysis are:

- Vehicles with the same name are generally counted as one model (e.g., all Honda Civics are counted as one model), with exceptions noted below. Vehicle options included as one model include:
    - Engine and transmission options (including hybrid, diesel, CNG, EV, PHEV, turbo, and ECO variants)
    - 2WD and 4WD versions
    - Trim levels
    - Convertible, hatchback, and wagon body styles
    - FFV and non-FFV models
    - BMW series. For example, all BMW 5 series variants are included as one model, including the ActiveHybrid 5

- Vehicles that are substantially similar, but are sold in multiple divisions, (often called "twins") are counted as separate models. For example:
    - Ford Escape and Mercury Mariner are counted as separate models
    - Chevrolet Equinox and GMC Terrain are counted as separate models

- Vehicles that are generally marketed as distinct models are counted as separate models. For example:
    - Prius, Prius v and Prius c are counted as distinct models

- Mini Cooper vehicles are grouped and counted as three models (Mini Cooper, Mini Cooper Clubman, and Mini Cooper Countryman), based on wheelbase, with multiple trim models within each wheelbase counted as the same model

- If at least one variant of an individual model meets a threshold defined in the analysis (e.g., cars with fuel economy greater than 30 mpg), the model is counted only once, regardless of the number of model variants that meet the threshold. For instance, if hybrid, CNG, and gasoline variant Honda Civics exceed 30 mpg, only one Civic is counted as exceeding 30 mpg

These "model count" guidelines resulted in approximately 300 models for both MY 2008 and MY 2013.

Finally, the last methodological difference in this section relative to most other sections is that two key parameters -vehicle classifications and combined city/highway fuel economy values- are aligned with the Fuel Economy and Environment label in order to be consistent with the information available to consumers when they are considering new vehicle purchases. The vehicle classifications in Figure 8.1 are based on Fuel Economy and Environment label classifications which differ slightly from the definitions of cars and light trucks used in Section 1-6 in this report (for example, in Figure 8.1, all SUVs are combined into a single category consistent with fuel economy labels and are not split into car SUVs and truck SUVs as is done for compliance with standards and elsewhere in this report). The label classes are simplified into four broader categories: cars, SUVs, pickups and minivans/vans. If variants of a model were in more than one of these four broader categories, then the variant was counted once in each relevant category. The combined fuel economy values used in Figure 8.1 and Figure 8.2 are based on the 55% city/45% highway weighting used on fuel economy labels, and not on the 43% city/57% highway weighting used for adjusted fuel economy values presented elsewhere in this report.

B. High Fuel Economy Vehicle Offerings

Figure 8.1 shows the change from MY 2008 to MY 2013 in the number of models where at least one model variant meets various fuel economy thresholds. The threshold values for EVs, PHEVs, and CNG vehicles that are represented in Figure 8.1 all use miles per gallon of gasoline-equivalent (mpge), i.e., the miles the vehicle can travel on an amount of electricity that has the same amount of energy as a gallon of gasoline. See Section 7 for a detailed discussion of EVs, PHEVs, CNG vehicles, and mpge.

Figure 8.1

Number of Models Meeting Fuel Economy Thresholds in MY 2008 and MY 2013

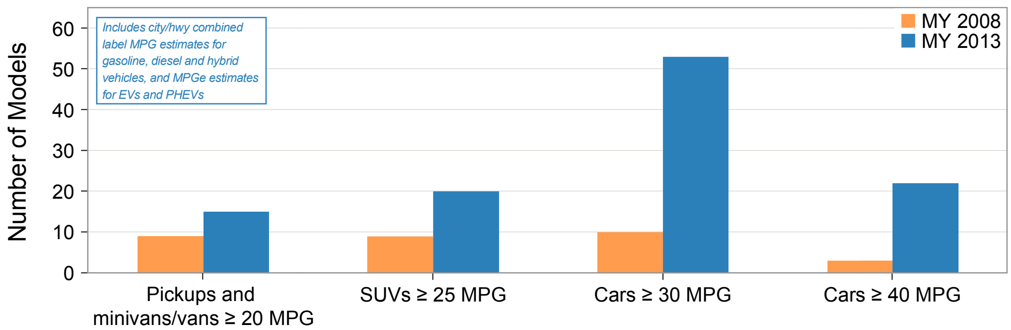


Figure 8.1 shows that there are 15 pickup and minivans/van models for which at least one variant of the model has a combined city/highway label fuel economy rating of 20 mpg or more, compared with nine models five years ago. Furthermore, the majority of the MY 2008 vehicles meeting the 20 mpg threshold were small pickups (pickups with a gross vehicle weight rating of less than 6000 pounds). Only two minivans and no standard-sized pick-up trucks met or exceeded a 20 mpg threshold in MY 2008, but in MY 2013 10 minivans/vans and three standard pickup trucks met the 20 mpg threshold. Twenty MY 2013 SUV models achieve 25 mpg or above, compared to nine models in 2008. It is interesting to note that, of the SUVs that achieved 25 mpg, there were five hybrids in MY 2008 and just three hybrids in MY 2013. Accordingly, the number of non-hybrid SUVs that achieved 25 mpg increased from four in MY 2008 to 17 in MY 2013, more than a four-fold increase. There are now 53 car models available where at least one variant has a combined city/highway label fuel economy of 30 mpg or more, compared to just ten in MY 2008, more than a five-fold increase. In addition, 22 of the MY 2013 cars achieve 40 mpg or higher, and 13 of the MY 2013 cars have at least one variant that achieves 50 mpg or higher. The cars achieving at least 40 mpg consist exclusively of hybrid electric vehicles, electric vehicles and plug-in hybrid electric vehicles, but of the car models that achieve at least 30 mpg, more than 60% reach this threshold with conventional gasoline or diesel variants.

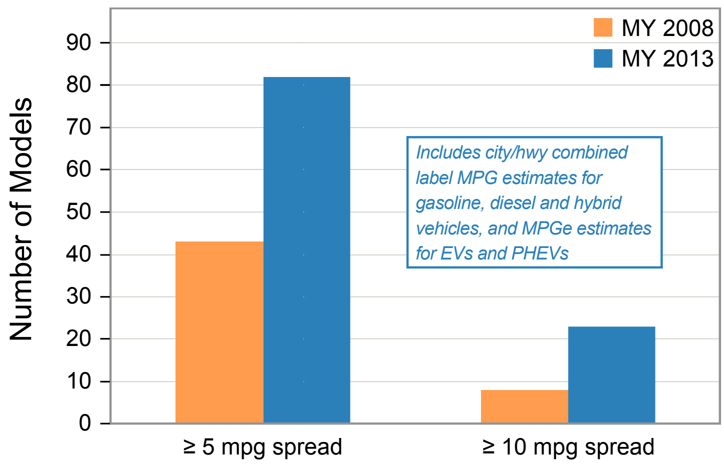
C. High Fuel Economy Ranges within Models

Within individual models, the number of models with a high mpg spread is also growing. Historically, models may have offered several engine and transmission choices with some variation in fuel economy, but some recent model year vehicles offer variants providing an even wider range of fuel economy choices. While high fuel economy variation is often due to hybrid and diesel variants, there is also increasing fuel economy variation for some conventional gasoline models due to the availability of optional packages that include low rolling resistance tires, aerodynamic improvements, turbochargers, and other technologies. These choices are allowing customers to choose among a wider range of fuel economy within an individual model.

The analysis for Figure 8.2 does not include alternative fuel vehicles, such as EVs, PHEVs, and CNG vehicles. The fuel economy variations within some models would be much higher if these vehicles and their mpge values were included. There are nearly twice as many MY 2013 models with at least a 5 mpg spread than there are MY 2008 models, and nearly three times as many MY 2013 models with at least a 10 mpg spread.

Figure 8.2

Number of Models Meeting Fuel Economy Spread Thresholds in MY 2008 and MY 2013



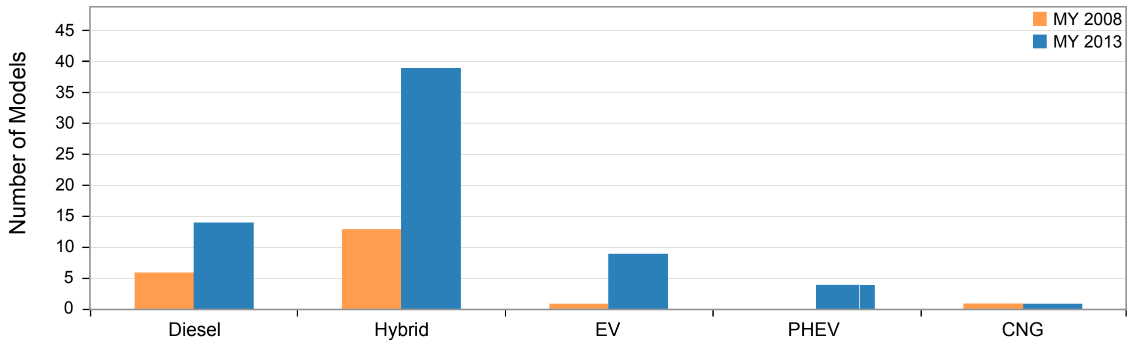
D. Advanced Technology Vehicle Offerings

Figure 8.3 shows that consumers also have many more alternatives to conventional gasoline vehicles. In MY 2008, the only advanced technology for which there were meaningful choices was hybrids, with a small number of diesels, one EV, and one dedicated compressed natural gas (CNG) vehicle. In MY 2013, there are three times as many hybrid offerings as there were in MY 2008 (from 13 in MY 2008 to 39 in MY 2013). In addition, the number of diesel offerings has more than doubled (from 6 in MY 2008 to 14 in MY 2013), and there are growing numbers of electric vehicles and plug-in hybrid electric vehicles as well. In MY 2013 there are nine EVs, four PHEVs, and one dedicated CNG vehicle.[15] Production share is also increasing for advanced technology vehicles though not as fast as the number of models is increasing. For a more detailed discussion of hybrids and diesel vehicles, see section 5, and see section 7 for more information about alternative fuel vehicles.

For Figure 8.3, the "model count" methodology is modified slightly to allow models that have more than one alternative fuel variant to be counted in each alternative fuel category (e.g., a Ford Fusion is available as both an HEV and PHEV, so the model was counted once in each category).

Figure 8.3

Advanced Technology and Alternative Fueled Vehicle Models in MY 2008 and MY 2013



[15] Some EV and CNG vehicles are generally available only in selected markets. Fuel cell vehicles may also be available to a very small number of consumers in a few California markets, but are not included in this analysis.

9 Regulatory Context

A. Personal Vehicle Fuel Economy and Greenhouse Gas Emissions Standards

National fuel economy standards have been in place in the United States for cars and light trucks since 1978. The Department of Transportation, through the National Highway Traffic Safety Administration (NHTSA), has the responsibility for setting and enforcing fuel economy standards through the Corporate Average Fuel Economy (CAFE) program. Since the inception of fuel economy standards, EPA has been responsible for establishing fuel economy test procedures and calculation methods, and for collecting data used to determine vehicle fuel economy and manufacturer CAFE levels.

For MY 2012 through 2025, EPA and NHTSA have jointly developed a historic and harmonized National Program, which established EPA greenhouse gas emissions standards and NHTSA CAFE standards that allow manufacturers to build a single national fleet to meet requirements of both programs while ensuring that consumers have a full range of vehicle choices. The standards have been supported by a wide range of stakeholders: most major automakers, the United Auto Workers, the State of California, and major consumer and environmental groups.

In 2010, the agencies finalized the first coordinated standards for MY 2012-2016 (75 Federal Register 25324, May 7, 2010). By MY 2016, the average industry-wide compliance levels for these footprint-based standards are projected to be 250 g/mi CO_2 and 34.1 mpg CAFE. The 250 g/mi CO_2 compliance level would be equivalent to 35.5 mpg if all CO_2 emissions reductions are achieved through fuel economy improvements. In 2012, the agencies finalized additional coordinated standards for MY 2017-2025 (77 Federal Register 62624, October 15, 2012). By MY 2025, the average industry-wide compliance levels are projected to be 163 g/mi CO_2 and 48.7-49.7 mpg CAFE.[16] [17] The 163 g/mi CO_2 compliance level would be equivalent to 54.5 mpg if all CO_2 emissions reductions are achieved solely through improvements in fuel economy.[18] For both MY 2012-2016 and MY 2017-2025, the agencies expect that a portion of the required CO_2 emissions improvements will be achieved by reductions in air conditioner refrigerant leakage, which would not contribute to higher fuel economy. These coordinated and harmonized standards are expected to yield "continuous improvement" reductions in CO_2 emissions and increases in fuel economy levels through MY 2025.

[16] The final rule establishing these standards requires EPA to conduct a midterm evaluation of the MY 2022-2025 standards.
[17] NHTSA CAFE standards for model years 2022-2025 are not final, and are augural. NHTSA is required by Congress to set CAFE standards for no more than five years at a time. NHTSA will conduct a new and full rulemaking in the future to establish standards for model years 2022-2025. NHTSA projects the augural standards would require a combined fleetwide fuel economy of 48.7-49.7 mpg.
[18] While many assumptions must be made to convert from projected standards compliance levels to projected adjusted (real world) levels, EPA has projected that MY 2025 standards compliance levels, with no over compliance, would result in adjusted levels of 223 g/mi CO_2 and 40 mpg (77 Federal Register 62773, October 15, 2012).

Automaker compliance with the above CO_2 and CAFE standards is based on unadjusted, laboratory CO_2 and fuel economy values, along with various regulatory incentives and credits, rather than on the adjusted CO_2 and fuel economy values that are used throughout most of this report. Neither unadjusted, laboratory nor adjusted CO_2 and fuel economy values reflect various incentives (e.g., for flexible fuel vehicles for both CO_2 and CAFE standards) and credits (air conditioner and other off-cycle technologies for CO_2 standards) that are available to manufacturers for regulatory compliance. Fleetwide CAFE standards compliance values are a minimum of 25% higher than adjusted fuel economy values and fleetwide CO_2 emissions standards compliance values are a minimum of 20% lower than adjusted CO_2 emissions values (these offsets can be greater due to alternative fuel vehicle, air conditioner, and/or other compliance credits). EPA (at epa.gov/otaq/regs/ld-hwy/greenhouse/ld-ghg.htm) and NHTSA (at nhtsa.dot.gov/fuel-economy) publish separate documents summarizing formal automaker compliance with GHG emissions and CAFE standards. NHTSA will prepare an updated report after EPA provides NHTSA with complete and final data through MY 2012.

B. Current Vehicles That Meet Future EPA CO_2 Emissions Compliance Targets

This section evaluates MY 2013 vehicles against future footprint-based CO_2 emission targets to determine which current vehicles could meet or exceed their targets in model years 2016-2025, based on current powertrain designs and only assuming credits for future improvements in air conditioner refrigerants and efficiency. EPA assumed the addition of air conditioning improvements since these are considered to be among the most straightforward and least expensive technologies available to reduce CO_2 and other greenhouse gas emissions.

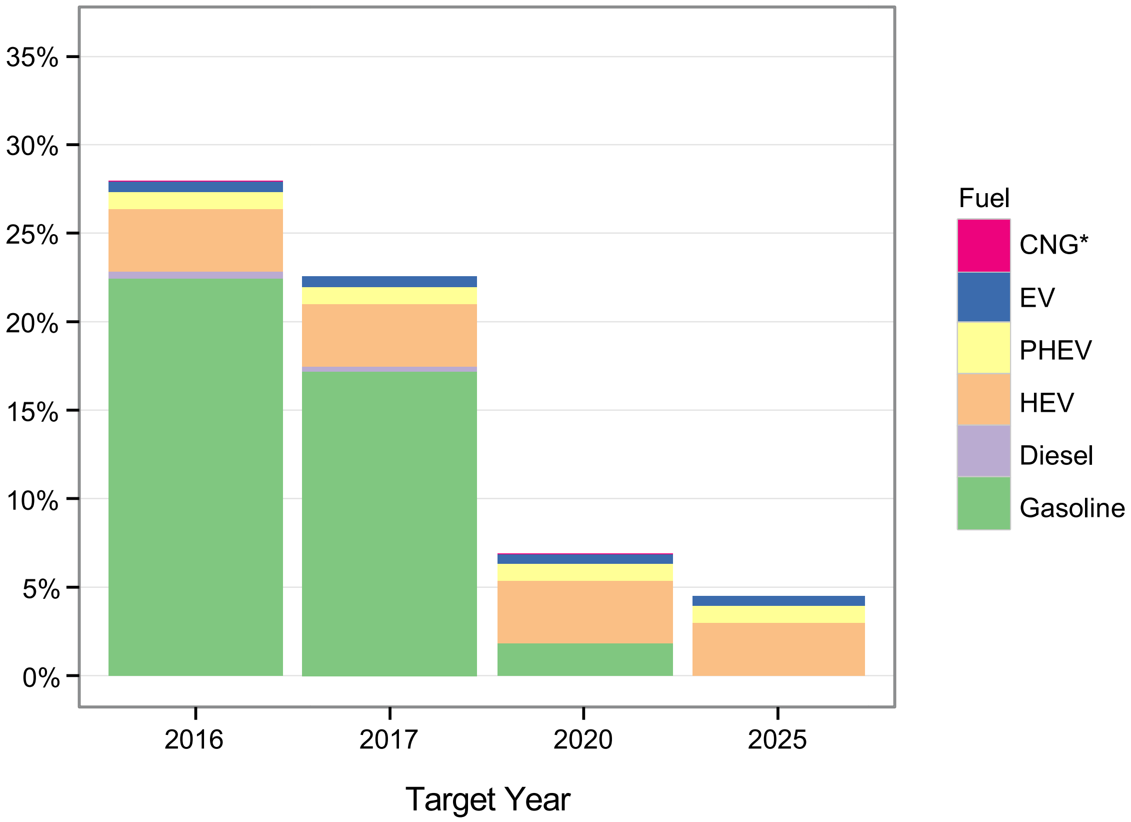
It is important to note there are no CO_2 emissions standards for individual vehicles. Rather, there are manufacturer-specific compliance levels for both passenger car and light truck fleets. The compliance levels are derived from the footprint-based CO_2 emissions target curves, and the production volume-weighted distribution of vehicles produced for sale in the U.S. by each manufacturer.

Figure 9.1 shows that 28% of projected MY 2013 vehicle production already meets the MY 2016 CO_2 targets, or can meet these targets with the addition of expected air conditioning improvements. The bulk of current vehicle production that meets the MY 2016 targets is accounted for by non-hybrid gasoline vehicles, although other technologies, including diesels, hybrids, plug-in hybrid electric vehicles, electric vehicles and compressed natural gas vehicles, are also represented.

Looking ahead, nearly 5% of projected 2013 production already meets the MY 2025 CO_2 targets. Vehicles meeting the MY 2025 CO_2 targets are comprised solely of hybrids, plug-in hybrids, and electric vehicles. Since the MY 2025 standards are over a decade away, there's considerable time for continued improvements in gasoline vehicle technology.

Figure 9.1

MY 2013 Vehicle Production Share (Projected) That Meets Future CO_2 Emissions Targets



* There is one MY 2013 CNG vehicle that meets the standards through 2020, however it only represents 0.03% of MY 2013 vehicles and may not be visible on this graph.

** There are no CO_2 emissions standards applicable to individual vehicles.

C. Comparison of EPA and NHTSA Fuel Economy Data, 1975-2013

Table 9.1 compares CAFE performance data reported by NHTSA ("Summary of Fuel Economy Performance" report dated April 25, 2013 and available at nhtsa.dot.gov/fuel-economy) with the adjusted and unadjusted, laboratory fuel economy data in this report. With only minor exceptions over 30 years ago, the NHTSA values are higher than the EPA unadjusted, laboratory values, due primarily to alternative fuel vehicle credits, and secondarily to test procedure adjustment factors for cars. In recent years for which both Agencies report final data, the NHTSA values are typically 0.6-1.0 mpg higher than the EPA unadjusted, laboratory values. MY 2011 is the most recent year for which both agencies report final data, and NHTSA's final CAFE performance value is 0.9 mpg higher than EPA's final unadjusted, laboratory value. For MY 2012, NHTSA's mid-model year value is 1.0 mpg higher than EPA's final unadjusted, laboratory value. For MY 2013, both agencies report preliminary values, and NHTSA's preliminary value is 0.5 mpg higher (1.2 mpg for cars and 0.8 mpg higher for trucks) than EPA's unadjusted, laboratory value. These preliminary MY 2013 projections are based on different data sets. The EPA MY 2013 value is based on automaker submissions in the spring and summer of 2012 to support vehicle fuel economy labels. The NHTSA MY 2013 value is based on automaker pre-model year CAFE reports later in 2012. Final MY 2013 results will be reported in next year's report.

The EPA car and truck fuel economy values shown in Table 9.1 for years prior to MY 2011 differ from the values found elsewhere in this report. Beginning with the 2011 report, EPA reclassified many small and mid-sized, 2-wheel drive SUVs from trucks to cars for the entire historical database. This reflects a regulatory change made by NHTSA for CAFE standards beginning in MY 2011 and which will apply for the joint EPA/NHTSA greenhouse gas emissions and CAFE standards that have been finalized for MY 2012-2025. These changes were not in effect for years prior to MY 2011, and accordingly NHTSA's CAFE fuel economy values prior to MY 2011 are based on the previous car and truck definitions. To enable an apples-to-apples comparison to the NHTSA values, the EPA car and truck values in Table 9.1 through model year 2010 were calculated using the previous car and truck definitions, which is not consistent with the rest of this report. While the individual car and truck values in Table 9.1 are unique, the car and truck definitions do not affect the overall (car plus truck) fuel economy values, which are consistent with the rest of this report.

Table 9.1

EPA Adjusted, EPA Unadjusted Laboratory, and CAFE Values by Model Year

Model Year	Cars				Trucks				Both Cars and Trucks			
	EPA Adj. (MPG)	EPA Unadj., Lab (MPG)	NHTSA CAFE (MPG)	Diff. (NHTSA - Lab) (MPG)	EPA Adj. (MPG)	EPA Unadj., Lab (MPG)	NHTSA CAFE (MPG)	Diff. (NHTSA - Lab) (MPG)	EPA Adj. (MPG)	EPA Unadj., Lab (MPG)	NHTSA CAFE (MPG)	Diff. (NHTSA - Lab) (MPG)
1975	13.5	15.8	N/A	-	11.6	13.7	N/A	-	13.1	15.3	N/A	-
1976	14.9	17.5	N/A	-	12.2	14.4	N/A	-	14.2	16.7	N/A	-
1977	15.6	18.3	N/A	-	13.3	15.6	N/A	-	15.1	17.7	N/A	-
1978	16.9	19.9	19.9	0.0	12.9	15.2	N/A	-	15.8	18.6	19.9	1.3
1979	17.2	20.3	20.3	0.0	12.5	14.7	18.2	3.5	15.9	18.7	20.1	1.4
1980	20.0	23.5	24.3	0.8	15.8	18.6	18.5	-0.1	19.2	22.5	23.1	0.6
1981	21.4	25.1	25.9	0.8	17.1	20.1	20.1	-	20.5	24.1	24.6	0.5
1982	22.2	26.0	26.6	0.6	17.4	20.5	20.5	-	21.1	24.7	25.1	0.4
1983	22.1	25.9	26.4	0.5	17.8	20.9	20.7	-0.2	21.0	24.6	24.8	0.2
1984	22.4	26.3	26.9	0.6	17.4	20.5	20.6	0.1	21.0	24.6	25.0	0.4
1985	23.0	27.0	27.6	0.6	17.5	20.6	20.7	0.1	21.3	25.0	25.4	0.4
1986	23.7	27.9	28.2	0.3	18.2	21.4	21.5	0.1	21.8	25.7	25.9	0.2
1987	23.8	28.1	28.5	0.4	18.3	21.6	21.7	0.1	22.0	25.9	26.2	0.3
1988	24.1	28.6	28.8	0.2	17.9	21.2	21.3	0.1	21.9	25.9	26.0	0.1
1989	23.7	28.1	28.4	0.3	17.6	20.9	21.0	0.1	21.4	25.4	25.6	0.2
1990	23.3	27.8	28.0	0.2	17.4	20.7	20.8	0.1	21.2	25.2	25.4	0.2
1991	23.4	28.0	28.4	0.4	17.8	21.3	21.3	-	21.3	25.4	25.6	0.2
1992	23.1	27.6	27.9	0.3	17.4	20.8	20.8	-	20.8	24.9	25.1	0.2
1993	23.5	28.2	28.4	0.2	17.5	21.0	21.0	-	20.9	25.1	25.2	0.1
1994	23.3	28.0	28.3	0.3	17.2	20.8	20.8	-	20.4	24.6	24.7	0.1
1995	23.4	28.3	28.6	0.3	17.0	20.5	20.5	-	20.5	24.7	24.9	0.2
1996	23.3	28.3	28.5	0.2	17.2	20.8	20.8	-	20.4	24.8	24.9	0.1
1997	23.4	28.4	28.7	0.3	17.0	20.6	20.6	-	20.1	24.5	24.6	0.1
1998	23.4	28.5	28.8	0.3	17.1	20.9	21.0	0.1	20.1	24.5	24.7	0.2
1999	23.0	28.2	28.3	0.1	16.7	20.5	20.9	0.4	19.7	24.1	24.5	0.4
2000	22.9	28.2	28.5	0.3	16.9	20.8	21.3	0.5	19.8	24.3	24.8	0.5
2001	23.0	28.4	28.8	0.4	16.7	20.6	20.9	0.3	19.6	24.2	24.5	0.3
2002	23.1	28.6	29.0	0.4	16.7	20.6	21.4	0.8	19.5	24.1	24.7	0.6
2003	23.2	28.9	29.5	0.6	16.9	20.9	21.8	0.9	19.6	24.3	25.1	0.8
2004	23.1	28.9	29.5	0.6	16.7	20.8	21.5	0.7	19.3	24.0	24.6	0.6
2005	23.5	29.5	30.3	0.8	17.2	21.4	22.1	0.7	19.9	24.8	25.4	0.6
2006	23.3	29.2	30.1	0.9	17.5	21.8	22.5	0.7	20.1	25.2	25.8	0.6
2007	24.1	30.3	31.2	0.9	17.7	22.1	23.1	1.0	20.6	25.8	26.6	0.8
2008	24.3	30.5	31.5	1.0	18.2	22.7	23.6	0.9	21.0	26.3	27.1	0.8
2009	25.4	32.1	32.9	0.8	19.0	23.8	24.8	1.0	22.4	28.2	29.0	0.8
2010	25.8	32.7	33.9	1.2	19.1	23.8	25.2	1.4	22.6	28.4	29.3	0.9
2011	25.6	32.3	33.1	0.8	19.1	23.9	24.7	0.8	22.4	28.1	29.0	0.9
2012	27.0	34.3	35.2	0.9	19.3	24.1	25.0	0.9	23.6	29.8	30.8	1.0
2013	*27.4*	*34.8*	*36.0*	-	*19.7*	*24.5*	*25.3*	-	*24.0*	*30.3*	*30.8*	-

D. Comparison of MY 2012 Unadjusted, Laboratory and Estimated CAFE Data by Manufacturer

The primary differences between EPA unadjusted, laboratory fuel economy data and EPA estimated CAFE values are flexible fuel vehicle (FFV) credits that are available to manufacturers that produce vehicles capable of operation on an alternative fuel (E85, a blend of 85 percent ethanol and 15 percent gasoline), and test procedure adjustment (TPA) credits that apply to manufacturers of passenger cars. Any remaining offsets are due to production of alternative fuel vehicles, which are not included in the unadjusted, laboratory fuel economy values provided in this report (see Section 7, Alternative Fuel Vehicles).

Table 9.2 shows how the unadjusted, laboratory fuel economy values in this report, the production of alternative fueled vehicles (AFVs), FFV credits, and TPA credits "add up" to estimated CAFE values for each of the eleven highest volume manufacturers (excluding Hyundai and Kia) for cars, trucks, and cars plus trucks. The FFV credits, TPA credits, and estimated CAFE values in Table 9.2 were obtained directly from EPA's fuel economy compliance program (at the time of publication, EPA was in the process of submitting the manufacturer-specific CAFE values to NHTSA and individual manufacturers). The data is from the annual manufacturer CAFE Reports, and based on data provided to EPA and NHTSA by automakers. The authors calculated the impact of AFVs on CAFE levels for those manufacturers that produce AFVs. For some manufacturers, the numbers in Table 9.2 do not add up exactly due to rounding.

The CAFE program recognizes three categories, domestic passenger vehicles, import passenger vehicles, and light trucks. The passenger car FFV, TPA, and estimated CAFE numbers in Table 9.2 are calculated from the domestic and import passenger vehicle categories. The truck values were obtained directly (trucks are not eligible for TPA credits). The combined car and truck FFV and TPA credits were generated using car and truck sales. This column is shown for illustrative purposes only, since there are no CAFE standards for combined cars and trucks.

For MY 2012, five manufacturers earned FFV credits for cars and six manufacturers did so for trucks. All manufacturers were eligible for the TPA credits for cars.

Table 9.2

*Comparison of MY 2012 EPA Unadjusted, Laboratory and Estimated CAFE (MPG) Values by Manufacturer**

Manufacturer	Passenger Car					Light Truck					Both Cars and Trucks				
	EPA Unadj., Lab	AFVs	FFV Credit	TPA Credit	Est. CAFE**	EPA Unadj., Lab	AFVs	FFV Credit	TPA Credit	Est. CAFE**	EPA Unadj., Lab	AFVs	FFV Credit	TPA Credit	Est. CAFE**
General Motors	31.1	0.3	1.2	0.2	32.8	22.4	0.0	1.2	0.0	23.7	27.0	0.1	1.2	0.1	28.5
Toyota	39.8	0.2	0.0	0.3	40.4	24.9	0.0	0.6	0.0	25.5	32.8	0.1	0.4	0.1	33.4
Ford	34.1	0.0	1.2	0.3	35.7	23.1	0.0	1.2	0.0	24.3	28.7	0.0	1.2	0.1	30.1
Honda	37.3	0.1	0.0	0.4	37.9	27.8	0.0	0.0	0.0	27.8	33.6	0.1	0.0	0.2	34.0
Chrysler-Fiat	29.6	0.0	1.2	0.2	30.9	23.1	0.0	1.2	0.0	24.3	25.0	0.0	1.2	0.1	26.3
Nissan	34.4	0.4	0.0	0.3	35.2	23.5	0.0	0.9	0.0	24.4	30.5	0.3	0.4	0.2	31.4
VW***	33.0	0.0	0.1	0.2	33.4	27.4	0.0	0.0	0.0	27.4	32.3	0.0	0.1	0.2	32.6
Mazda	37.4	0.0	0.0	0.5	37.9	27.8	0.0	0.0	0.0	27.8	34.6	0.0	0.0	0.3	34.9
Subaru	35.2	0.0	0.0	0.3	35.5	30.5	0.0	0.0	0.0	30.5	32.2	0.0	0.0	0.1	32.3
BMW	32.2	0.0	0.0	0.3	32.4	25.0	0.0	0.0	0.0	25.0	30.0	0.0	0.0	0.2	30.1
Daimler	28.2	0.0	0.9	0.2	29.3	23.1	0.0	0.9	0.0	23.9	26.3	0.0	0.9	0.1	27.3

* Two manufacturers, Hyundai and Kia, are not included in the table above due to a continuing investigation. On November 2, 2012, EPA announced that Hyundai and Kia would lower their fuel economy estimates for many vehicle models as the result of an EPA investigation of test data.

** EPA calculates the CAFE value for each manufacturer and provides to NHTSA per EPCA. NHTSA publishes the final CAFE values in its annual "Summary of Fuel Economy Performance" reports at nhtsa.dot.gov/fuel-economy.

*** Values for VW in this table and elsewhere in the report do not include Porsche. VW acquired Porsche in 2012; the MY 2012 combined VW-Porsche estimated CAFE values are 33.2 mpg for passenger cars, 27.3 mpg for light trucks, and 32.3 mpg for combined cars and trucks.

10 Additional Database and Report Details

This section addresses several Trends database topics in greater detail. While the key parameters of the Trends database that are of the most importance to users were highlighted in Section 1, this section will help those readers who want to further understand how the database is developed and various nuances associated with the database.

A. Sources of Input Data

Nearly all of the recent model year input for the Trends database is extracted from EPA's current vehicle compliance information system, VERIFY, into which automakers submit data required by congressional statute and EPA regulations. Prior to the beginning of each model year, automakers submit General Label information required to support the generation of the joint EPA/NHTSA Fuel Economy and Environment Labels that appear on all new personal vehicles. Automakers report pre-model year vehicle production projections for individual models to EPA in the General Label submissions; these projections are considered by EPA and automakers to be confidential business information. A few months after the end of each model year, automakers submit Final GHG/CAFE data, which EPA and NHTSA use to determine compliance with GHG emissions and CAFE standards. These end-of-the-year submissions include final production volumes. The production volume levels automakers provide in their Final CAFE reports may differ slightly from their Final GHG reports (less than 0.1%) because the EPA emissions certification regulations, including GHG regulations, require emission compliance in the 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa and the Commonwealth of the Northern Mariana Islands, whereas the CAFE program requires data from the 50 states, the District of Columbia and Puerto Rico only. To maintain consistency with previous versions of this report, the Trends database will continue to use the production volumes for CAFE reporting. Both the General Label and Final GHG/CAFE data submissions contain a broad amount of data associated with CO_2 emissions and fuel economy, vehicle and engine technology, and vehicle performance metrics. The Trends database extracts only a portion of the data in the VERIFY database.

This report reflects data from VERIFY as of August 2013. Through MY 2012, all Trends data is considered final since it is based on the Final GHG/CAFE compliance reports. For MY 2013, all Trends data is preliminary since it is based on confidential pre-model year production projections. Final MY 2013 values will be published in next year's report. See Section 10.E below for a historical comparison of preliminary and final values.

While nearly the entire Trends database comes from formal automaker submissions, it also contains a small amount of data from external sources. For example, label fuel economy data for Sections 7 and 8 are from fueleconomy.gov. As another example, we rely on published data from external sources for certain parameters of pre-MY 2011 vehicles, which are not universally available through automaker submissions: (1) engines with variable valve timing (VVT); (2) engines with cylinder deactivation; and (3) vehicle footprint, which is the product of wheelbase times average track width and upon which CO_2 emissions and CAFE standards are based. Beginning with MY 2011, automaker submissions have included data on these parameters.

In addition, automaker submissions do not include zero-to-sixty (0-to-60) miles per hour acceleration time (in seconds) so we estimate this parameter (for vehicles with conventional powertrains with gasoline-fueled engines) using this equation:

$$t = F\,(HP/WT)^{f}$$

where t is acceleration time; HP and WT reflect Trends data for horsepower and weight, respectively; and the coefficients F and f are empirical parameters determined in the literature by obtaining a least-squares fit for available test data. This report uses .892 and .805 for the F and f coefficients, respectively, for vehicles with automatic transmissions and .967 and .775, respectively, for those with manual transmissions.[19] Other authors[20] have evaluated the relationships between weight, horsepower, and 0-to-60 acceleration time and have calculated and published slightly different values for the F and f coefficients. Since the equation form and coefficients were developed for vehicles with conventional gasoline powertrains, we use published values from external sources to estimate 0-to-60 acceleration time for vehicles with hybrid powertrains or diesel engines.

We recognize that the above equation for acceleration time was initially developed in the 1970s and that more updated and sophisticated approaches for estimating acceleration time are available. For example, we are aware of a recent report[21] by the Massachusetts Institute of Technology that uses a broader set of inputs for estimating acceleration time. We intend to review this and other relevant papers and expect to revise the approach for estimating acceleration time for the entire Trends database in future reports.

B. Harmonic Averaging of Fuel Economy Values

Averaging multiple fuel economy values must be done harmonically in order to obtain a correct mathematical result. Since fuel economy is expressed in miles per gallon (mpg), one critical assumption with any harmonic averaging of multiple fuel economy values is whether

[19] "Concise Description of Auto Fuel Economy and Performance in Recent Model Years," SAE Paper 760045, Malliaris, Hsia and Gould, February 1976.
[20] "Automotive Engine -- A Future Perspective," SAE Paper 891666, Amann, 1989; "Regression Analysis of Acceleration Performance of Light-Duty Vehicles," DOT HS 807 763, Young, September 1991; and "Determinates of Multiple Measures of Acceleration," SAE Paper 931805, Santini and Anderson, 1993.
[21] MacKenzie, D., Heywood, J. (2012). Acceleration performance trends and the evolving relationship among power, weight, and acceleration in U.S. light-duty vehicles: A linear regression analysis. *Transportation Research Board,* Paper No. 12-1475, TRB 91st Annual Meeting, Washington, DC, January 2012.

the distance term (miles, in the numerator of mpg) is fixed or variable. This report makes the assumption that the distance term in all mpg values is fixed, i.e., that for purposes of calculating a harmonically averaged fuel economy value, it is assumed that the distance term (representing miles travelled) is equivalent across various vehicle fuel economies. This assumption is the standard practice with harmonic averaging of multiple fuel economy values (including, for example, in calculations for CAFE standards compliance), and simplifies the calculations involved.

Mathematically, when assuming a fixed distance term as discussed above, harmonic averaging of multiple fuel economy values can be defined as the inverse of the average of the reciprocals of the individual fuel economy values. It is best illustrated by a simple example.

Consider a round trip of 600 miles. For the first 300-mile leg, the driver is alone, with no other passengers or cargo, and, aided by a tailwind, uses 10 gallons of gasoline, for a fuel economy of 30 mpg. On the return 300-mile trip, with several passengers, some luggage, and a headwind, the driver uses 15 gallons of gasoline, for a fuel economy of 20 mpg. Many people will assume that the average fuel economy for the entire 600-mile trip is 25 mpg, the arithmetic (or simple) average of 30 mpg and 20 mpg. But, since the driver consumed 10 + 15 = 25 gallons of fuel during the trip, the actual fuel economy is 600 miles divided by 25 gallons, or 24 mpg.

Why is the actual 24 mpg less than the simple average of 25 mpg? Because the driver used more gallons while (s)he was getting 20 mpg than when (s)he was getting 30 mpg.

This same principle is often demonstrated in elementary school mathematics when an airplane makes a round trip, with a speed of 400 mph one way and 500 mph the other way. The average speed of 444 mph is less than 450 mph because the airplane spent more time going 400 mph than it did going 500 mph.

As in both of the examples above, a harmonic average will typically yield a result that is slightly lower than the arithmetic average.

The following equation illustrates the use of harmonic averaging to obtain the correct mathematical result for the fuel economy example above:

$$\text{Average mpg} = \frac{2}{\left(\frac{1}{30} + \frac{1}{20}\right)} = 24 \text{ mpg}$$

The above example was for a single vehicle with two different fuel economies over two legs of a single round trip. But, the same mathematical principle holds for averaging the fuel economies of any number of vehicles. For example, the average fuel economy for a set of 10 vehicles, with three 30 mpg vehicles, four 25 mpg vehicles, and three 20 mpg vehicles would be (note that, in order to maintain the concept of averaging, the total number of vehicles in the numerator of the equation must equal the sum of the individual numerators in the denominator of the equation):

$$\text{Average mpg} = \frac{10}{\left(\frac{3}{30} + \frac{4}{25} + \frac{3}{20}\right)} = 24.4 \text{ mpg}$$

Note that arithmetic averaging, not harmonic averaging, provides the correct mathematical result for averaging fuel consumption values (in gallons per mile, the inverse of fuel economy) and CO_2 emissions (in grams per mile). In the first, round trip, example above, the first leg had a fuel consumption rate of 10 gallons over 300 miles, or 0.03333 gallons per mile. The second leg had a fuel consumption of 15 gallons over 300 miles, or 0.05 gallons per mile. Arithmetically averaging the two fuel consumption values, i.e., adding them up and dividing by two, yields 0.04167 gallons per mile, and the inverse of this is the correct fuel economy average of 24 mpg. Arithmetic averaging also works for CO_2 emissions values, i.e., the average of 200 g/mi and 400 g/mi is 300 g/mi CO_2 emissions.

In summary, fuel economy values must be harmonically averaged to maintain mathematical integrity, while fuel consumption values (in gallons per mile) and CO_2 emissions values (in grams per mile) can be arithmetically averaged.

C. Adjusted vs. Unadjusted, Laboratory Values

Change in Emphasis from Unadjusted, Laboratory Data to Adjusted Data

Prior to 2001, EPA's Trends reports only included unadjusted, laboratory fuel economy values, which are used as the basis for compliance with standards and passenger car gas guzzler taxes. Beginning in 2001, Trends reports also included adjusted values which are EPA's best estimate of real world CO_2 emissions and fuel economy performance. Now, most of the tables and figures in this report exclusively show adjusted CO_2 emissions and fuel economy values.

One important distinction between the adjusted values and the unadjusted, laboratory values is that the methodology for determining the former has evolved over time to better reflect real world performance (see the proceeding section for more details). Some of the changes to the adjusted value methodology are intended to account for changes in consumer driving behavior over time (e.g., higher speeds, higher acceleration rates, greater use of air conditioning). Since adjusted Trends values are intended to represent real world performance at any given time, modifications to the adjusted value methodology that reflect changes in consumer driving behavior have not been "propagated back" through the historical Trends database. We note that this is an exception to our general policy of "propagating back" changes throughout the historical Trends database, but in this case doing so would skew the historical data (for example, by assuming that drivers in 1975 used air conditioning much more frequently, or traveled at higher speeds, than they did).

On the other hand, the methodology for determining unadjusted, laboratory values has not changed since this series began in the mid-1970s. Unadjusted values therefore provide an excellent basis with which to compare long-term trends in vehicle design, apart from the factors that affect real world performance that are reflected in the adjusted values.

Table 10.1 shows both unadjusted, laboratory and adjusted fuel economy values, for the overall new car and truck fleet for MY 1975-2013, for city, highway, and combined city/highway. It also shows how the ratio of adjusted-to-unadjusted fuel economy has changed over time, reflecting that the methodology for adjusted fuel economy values has changed over time, while the methodology for unadjusted fuel economy values has not changed.

In addition to Table 10.1, the following tables also include unadjusted, laboratory values: Tables 2.3, 4.4, 4.5, 9.1, 9.2, 10.2, and 10.4.

Table 10.1

Unadjusted, Laboratory and Adjusted Fuel Economy (MPG) for MY 1975-MY 2013: Cars and Trucks

Model Year	Unadjusted City (MPG)	Unadjusted Highway (MPG)	Unadjusted Combined (55/45) (MPG)	Adjusted City (MPG)	Adjusted Highway (MPG)	Adjusted Combined (43/57) (MPG)	Ratio of Adjusted Combined to Unadjusted Combined
1975	13.4	18.7	15.3	12.0	14.6	13.1	85.2%
1976	14.6	20.2	16.7	13.2	15.7	14.2	85.1%
1977	15.6	21.3	17.7	14.0	16.6	15.1	85.1%
1978	16.3	22.5	18.6	14.7	17.5	15.8	85.1%
1979	16.5	22.3	18.7	14.9	17.4	15.9	85.1%
1980	19.6	27.5	22.5	17.6	21.5	19.2	85.2%
1981	20.9	29.5	24.1	18.8	23.0	20.5	85.2%
1982	21.3	30.7	24.7	19.2	23.9	21.1	85.2%
1983	21.2	30.6	24.6	19.0	23.9	21.0	85.3%
1984	21.2	30.8	24.6	19.1	24.0	21.0	85.3%
1985	21.5	31.3	25.0	19.3	24.4	21.3	85.3%
1986	22.1	32.2	25.7	19.8	25.0	21.8	85.0%
1987	22.2	32.6	25.9	19.8	25.3	22.0	84.7%
1988	22.1	32.7	25.9	19.6	25.2	21.9	84.4%
1989	21.7	32.3	25.4	19.1	24.8	21.4	84.2%
1990	21.4	32.2	25.2	18.7	24.6	21.2	83.9%
1991	21.6	32.5	25.4	18.8	24.7	21.3	83.6%
1992	21.0	32.1	24.9	18.2	24.4	20.8	83.4%
1993	21.2	32.4	25.1	18.2	24.4	20.9	83.1%
1994	20.8	31.6	24.6	17.8	23.8	20.4	82.9%
1995	20.8	32.1	24.7	17.7	24.1	20.5	82.7%
1996	20.8	32.2	24.8	17.6	24.0	20.4	82.4%
1997	20.6	31.8	24.5	17.4	23.6	20.2	82.2%
1998	20.6	31.9	24.5	17.2	23.6	20.1	81.9%
1999	20.3	31.2	24.1	16.9	23.0	19.7	81.7%
2000	20.5	31.4	24.3	16.9	23.0	19.8	81.3%
2001	20.5	31.1	24.2	16.8	22.8	19.6	81.0%
2002	20.4	30.9	24.1	16.6	22.5	19.5	80.7%
2003	20.6	31.3	24.3	16.7	22.7	19.6	80.4%
2004	20.2	31.0	24.0	16.3	22.4	19.3	80.2%
2005	21.0	32.1	24.8	16.8	23.1	19.9	79.8%
2006	21.2	32.6	25.2	17.0	23.4	20.1	79.8%
2007	21.8	33.4	25.8	17.4	24.0	20.6	79.6%
2008	22.1	34.0	26.3	17.7	24.4	21.0	79.5%
2009	23.8	36.4	28.2	18.9	26.0	22.4	79.1%
2010	24.1	36.6	28.4	19.1	26.2	22.6	79.0%
2011	23.6	36.4	28.1	18.8	26.1	22.4	79.4%
2012	25.1	38.6	29.8	19.9	27.6	23.6	78.9%
2013	*25.5*	*39.3*	*30.3*	*20.2*	*28.1*	*24.0*	*78.8%*

Methodological Approaches for Adjusted Fuel Economy Values

EPA has improved its methodology for estimating adjusted (or real world) fuel economy and CO_2 emissions performance over time and is committed to continuing to do so in the future. Most recently, EPA revised the methodology by which EPA calculates city, highway, and combined fuel economy label estimates for cars and light-duty trucks in a December 2006 rulemaking.[22]

This current methodology incorporates equations that directly account for several important factors that affect fuel economy and CO_2 emissions performance in the real world, such as high speeds, aggressive accelerations and decelerations, the use of air conditioning, and operation in cold temperatures, and indirectly account for a number of other factors that are not reflected in EPA laboratory test data such as changing fuel composition, road conditions, etc. While some of these factors may not have changed (or may not have changed much) over time and therefore new estimation methods that account for these factors could be "propagated back" throughout the historical Trends database, we believe that many of the factors have changed significantly over time (e.g., highway speeds, acceleration rates, use of air conditioning), and therefore new estimation methods could not be fully "propagated back" through the historical Trends database without impacting the integrity of the historical database with respect to real world fuel economy and CO_2 emissions performance.

There are two important consequences of this approach for users of this report. First, every adjusted fuel economy value in this report for 1986 and later model years is lower than shown in pre-2007 reports. Second, we employed unique approaches for generating adjusted fuel economy and CO_2 emissions values in the historical Trends database for three distinct time frames. The following discussion will first address the MY 1975-1985 time frame, then the MY 2005-2013 time frame, and then, finally, the approach for the MY 1986-2004 time frame that represents a "phased-in" approach from the former to the latter time frame.

For the MY 1975-1985 time frame, the adjusted values in the Trends database are calculated using the methodology adopted by EPA in an April 1984 rulemaking that established universal fuel economy label adjustment factors of 0.9 for city fuel economy and 0.78 for highway fuel economy that took effect for MY 1985 vehicles.[23] A single, combined adjusted fuel economy value is based on a 55% city/45% highway weighting factor We believe that these adjustment factors are appropriate for new vehicles through the 1985 model year.

For the MY 2005-2013 time frame, the adjusted city and highway values in the Trends database for vehicles that undergo full "5-cycle" fuel economy and CO2 emissions testing (Federal Test Procedure for urban stop-and-go driving, Highway Fuel Economy Test for rural driving, US06 test for high speeds and aggressive driving, SCO3 test for air conditioning

[22] 71 Federal Register 77872 (December 27, 2006).
[23] 49 Federal Register 13832 (April 6, 1984).

operation, and cold FTP test for cold temperature operation) are calculated by weighting the 5-cycle test data according to the "composite" 5-cycle equations.[24] The combined city/highway adjusted value for these vehicles is based on a 43% city/57% highway weighting. In MY 2013, about 13% of all vehicle data were generated from the full 5-cycle test protocol.

It is important to emphasize that the 43% city/57% highway weighting used for adjusted 5-cycle values beginning in MY 2005 is different from the 55% city/45% highway weighting used to generate adjusted fuel economy values for MY 1975-1985 in the Trends database. EPA's analysis of real world driving activity underlying the 5-cycle fuel economy methodology assumed a "speed cutpoint" of 45 miles per hour to differentiate between (and "bin" the amount of) city and highway driving.[25] Based on this speed cutpoint, the correct weighting for correlating the new city and highway fuel economy values with real world driving, on a miles driven basis, is 43% city/57% highway, and therefore this weighting is necessary in order to maintain the integrity of projections of fleetwide fuel economy and CO_2 emissions performance based on Trends data. The 55% city/45% highway weighting is still used for both Fuel Economy and Environment Labels and the CAFE and GHG emissions compliance programs.

Most current vehicles do not undergo full 5-cycle testing; instead manufacturers derive 5-cycle values from 2-cycle fuel economy test results (EPA Federal Test Procedure and Highway Fuel Economy Test) based on the relationship between 2-cycle and 5-cycle fuel economy data for the industry as a whole. Beginning with MY 2011, manufacturers are required to evaluate whether the fuel economy estimates for certification vehicles from 5-cycle tests are comparable to results from the less resource-intensive "derived 5-cycle" method. If the results are comparable, manufacturers can use the derived 5-cycle method for all vehicle models represented by the certification vehicle. If the full 5-cycle method yields significantly lower fuel economy estimates than the derived 5-cycle method, then the manufacturer must use the full 5-cycle method for all models represented by the certification vehicle.

For vehicles that can use the derived 5-cycle method, the following equations are used to convert unadjusted, laboratory values for city and highway to adjusted values.

$$\textbf{ADJ CITY} = \frac{1}{\left(0.003259 + \frac{1.1805}{\text{LAB CITY}}\right)}$$

$$\textbf{ADJ HWY} = \frac{1}{\left(0.001376 + \frac{1.3466}{\text{LAB HWY}}\right)}$$

As above, these values are weighted 43% city/57% highway in order to calculate a single, adjusted combined fuel economy value.

[24] 71 Federal Register 77883-77886 (December 27, 2006).
[25] 71 Federal Register 77904 (December 27, 2006).

For more details on the specific equations that allow an automaker to calculate new label values using either the vehicle-specific 5-cycle test data or the derived 5-cycle approach, and the impact of these changes on average fuel economy label values, see the preamble to the 2006 regulations.[26]

How much of a difference, on average, are the fuel economy values based on the derived 5-cycle method from the values based on the universal adjustment factors for MY 1975-1985? These derived 5-cycle method values are lower than values based on he universal adjustment factors, and the differences are greater for higher fuel economy vehicles than for lower fuel economy vehicles. For example, compared to the use of the universal adjustment factors for MY 1975-1985, a 15 mpg city value will be reduced by an additional 10%, while a 50 mpg city value will be reduced by an additional 18%. Likewise, a 20 mpg highway value will be reduced by an additional 7%, while a 50 mpg highway value will be reduced by an additional 11%. In the 2006 rulemaking, EPA projected an overall average fleetwide adjustment of 11% lower for city fuel economy and 8% lower for highway fuel economy, beyond that in the older label adjustment methodology. The appropriate fleetwide factors to convert adjusted MY 1975-1985 fuel economy values to the adjusted derived 5-cycle, 43% city/57% highway weighting, fuel economy values are dependent on the city fuel economy-to-highway fuel economy ratios in the fleet. On average, for the current fleet, combining the 11% lower adjustment for city fuel economy, the 8% lower adjustment for highway fuel economy, and the shift to the 43% city/57% highway weighting, the combined city/highway fuel economy values are 7% lower than those based on the older label adjustment methodology. This 7% lower value is the average impact for a fleet with the mpg and city fuel economy-to-highway fuel economy characteristics of the current fleet, and would not be the appropriate value for individual models, partial fleet segments, or for past or future fleets with different mpg and city fuel economy-to-highway fuel economy distributions.

Finally, manufacturers have the option of voluntarily using lower fuel economy label estimates than those resulting from the full 5-cycle or derived 5-cycle approaches discussed above. In the rare cases where automakers choose to do so, we base adjusted values on these voluntary lower fuel economy labels, again using the 43% city/57% highway weighting.

For the MY 1986-2004 time frame, we calculated adjusted fuel economy values based on the simplifying assumption that the impacts of the factors that have led to lower real world fuel economy, as outlined in the 2006 rulemaking discussed above, have occurred in a gradual (i.e., linear) manner over the 20 years from 1986 through 2005. We did not attempt to perform a year-by-year analysis to determine the extent to which the many relevant factors (including higher highway speed limits, more aggressive driving, increasing vehicle horsepower-to-weight ratios, suburbanization, congestion, greater use of air conditioning, gasoline composition, et al) that have affected real world fuel economy since 1985 have changed over time. We simply assumed 1/20 of the fully phased-in downward adjustment for city and highway values would be reflected in the 1986 data, 2/20 of this adjustment

[26] 71 Federal Register 77881-77893 (December 27, 2006).

would be reflected in the 1987 data, etc., up to 19/20 of this adjustment in 2004 and the full adjustment in 2005 and later years. Likewise, EPA has assumed the 55/45 city/highway weighting changes to a 43/57 city/highway weighting in a linear fashion over the 1986 to 2005 time period as well.

One consequence of the approaches used in this report is that the ratio of the adjusted-to-unadjusted fuel economy values have been, and will likely continue, changing over time. As shown in Table 9.1, the adjusted-to-unadjusted fuel economy ratio is around 0.85 for MY 1975-1985 data, and decreased during the phase-in period from MY 1986-2004, and has been approximately 0.80 since MY 2005. The ratio is 0.79 in MY 2012, and is projected to remain at 0.79 in MY 2013.

Illustrative Example of Multiple Fuel Economy Metrics and Values for One Vehicle

One potentially confusing element of any discussion of historical fuel economy values is the various metrics by which fuel economy can be expressed. As an illustration to help the reader understand the various fuel economy values that can be associated with an individual vehicle, Table 10.2 shows four different ways to express the fuel economy of the MY 2005 Honda Insight.

Unadjusted, laboratory city and highway fuel economy values are direct fuel economy measurements from the formal EPA 2-cycle city (Federal Test Procedure, or urban commute) and highway laboratory tests. These values form the basis for automaker compliance with CAFE standards, and are harmonically averaged, and weighted 55% city and 45% highway, to generate a combined value. The 2005 Honda Insight had an unadjusted city value of 68 mpg, an unadjusted highway value of 84 mpg, and an unadjusted combined value of 74 mpg.

At the time, the MY 2005 Honda Insight had an original city label value of 61 mpg, which was calculated by multiplying its unadjusted city test value of 68 mpg by 0.9. Likewise, its original highway value was 66 mpg, calculated by multiplying its unadjusted highway test value of 84 mpg by 0.78. Harmonically averaging these values, with a 55% city/45% highway weighting, led to a combined original MY 2005 label value of 63 mpg.

Today, as a used car, the 2005 Honda Insight would have lower label values based on the 5-cycle method (reflecting, in addition to 2-cycle urban commuting and rural highway operation, additional conditions such as high speed/high acceleration, high temperature/air conditioning, and cold temperature operation) for determining city and highway values, first implemented in MY 2008, and discussed in the previous sub-section. For the 2005 Insight, the 5-cycle method yields a city label value of 48 mpg and a highway value of 58 mpg. Today's labels continue to use a 55% city/45% highway weighting, and the harmonically averaged, 55% city/45% highway weighted, combined value for the 2005 Insight is 52 mpg.

These current label values, based on the 5-cycle methodology, are considerably lower than the original label values.

Finally, for the MY 2005 Honda Insight, this Trends report uses the adjusted fuel economy methodology discussed in the previous sub-section, that is used in the Trends report for all vehicles beginning in MY 2005. The adjusted Trends city and highway values are the same as those for the current label, since both the current label and the adjusted Trends approach use the same 5-cycle methodology. But, the adjusted Trends approach uses a city/highway weighting of 43% city/57% highway to best correlate with the driving activity studies underlying the 5-cycle methodology. This different city/highway weighting leads to a 53 mpg combined value, slightly higher than the 52 mpg combined value for the current label.

Table 10.2

Four Different Fuel Economy Metrics for the MY 2005 Honda Insight

	Fuel Economy Value (MPG)				
Fuel Economy Metric	**Comb**	**City**	**Hwy**	**Basis**	**City/Highway Weighting**
Unadjusted, Laboratory	74	68	84	Unadjusted 2-cycle city and highway test values	55%/45%
Original MY 2005 Label	63	61	66	City test x 0.9 Highway test x 0.78	55%/45%
Current Label	52	48	58	Adjusted 5-cycle methodology	55%/45%
Adjusted Trends	53	48	58	Adjusted 5-cycle methodology	43%/57%

D. Other Database Methodology Issues

CO_2 Emissions Data and Approximating "Missing" CO_2 Values

CO_2 emissions data were added to the entire historical Trends database beginning with the 2009 report. CO_2 emissions values are calculated from corresponding fuel economy values using the fuel-specific emissions factors described below.

While CO_2 emissions data is included in several key summary tables and figures in the report, there are many tables and figures that present fuel economy values but not CO_2 emissions values. This section provides a simple method that a reader can use to estimate CO_2 emissions values from any fuel economy value in the report.

If a fuel economy value is given for a single gasoline vehicle, or a 100% gasoline vehicle fleet, one can calculate the corresponding CO_2 emissions value by simply dividing 8887 (which is a typical value for the grams of CO_2 per gallon of gasoline test fuel, assuming all the carbon is converted to CO_2) by the fuel economy value in miles per gallon. For example, 8887 divided by a gasoline vehicle fuel economy of 30 mpg would yield an equivalent CO_2 emissions value of 296 grams per mile. This is the methodology used to generate the adjusted CO_2 emissions values for all of the gasoline vehicles in the Trends database.

Since gasoline vehicle production has accounted for 99+% of all light-duty vehicle production for most of the model years since 1975, this simple approach yields very accurate results for most model years.

Diesel fuel has 14.5% higher carbon content per gallon than gasoline. To calculate a CO_2 equivalent value for a diesel vehicle, one should divide 10,180 by the diesel vehicle fuel economy value. Accordingly, a 30 mpg diesel vehicle would have a CO_2 equivalent value of 339 grams per mile. This is the methodology used to generate the adjusted CO_2 emissions values for the relatively small number of diesel vehicles in the Trends database.

To make the most accurate conversions of industry-wide fuel economy values to CO_2 emissions values, readers should divide model year-specific industry-wide values for grams of CO_2 per gallon in Table 10.3, which are based on actual light-duty gasoline and diesel vehicle production in that year, by industry-wide fuel economy values in miles per gallon.

Readers must make judgment calls about how to best convert fuel economy values that do not represent industry-wide values (e.g., just cars or vehicles with 5-speed automatic transmissions). If the user knows the gasoline/diesel production volume fractions for the vehicles of interest, it is best to generate a weighted value of grams of CO_2 per gallon based on the 8887 (gasoline) and 10,180 (diesel) factors discussed above. Otherwise, the reader can choose between the model year-specific CO_2 emissions per gallon weightings in Table 10.3 (which implicitly assume that the diesel fraction for the vehicles of interest is similar to that for the overall fleet in that year) or the gasoline value of 8887 (implicitly assuming no diesels in that database component). In nearly all cases, any error associated with either of these approaches will be negligible.

Table 10.3

Factors for Converting Industry-wide Fuel Economy Values from this Report to Carbon Dioxide Emissions Values

Model Year	Gasoline Production Share	Diesel Production Share	Weighted CO_2 per Gallon (grams)
1975	99.8%	0.2%	8890
1976	99.8%	0.2%	8890
1977	99.6%	0.4%	8892
1978	99.1%	0.9%	8899
1979	98.0%	2.0%	8913
1980	95.7%	4.3%	8943
1981	94.1%	5.9%	8963
1982	94.4%	5.6%	8959
1983	97.3%	2.7%	8922
1984	98.2%	1.8%	8910
1985	99.1%	0.9%	8899
1986	99.6%	0.4%	8892
1987	99.7%	0.3%	8891
1988	99.9%	0.1%	8888
1989	99.9%	0.1%	8888
1990	99.9%	0.1%	8888
1991	99.9%	0.1%	8888
1992	99.9%	0.1%	8888
1993	100.0%	-	8887
1994	100.0%	0.0%	8887
1995	100.0%	0.0%	8887
1996	99.9%	0.1%	8888
1997	99.9%	0.1%	8888
1998	99.9%	0.1%	8888
1999	99.9%	0.1%	8888
2000	99.9%	0.1%	8888
2001	99.9%	0.1%	8888
2002	99.8%	0.2%	8890
2003	99.8%	0.2%	8890
2004	99.9%	0.1%	8888
2005	99.7%	0.3%	8891
2006	99.6%	0.4%	8892
2007	99.9%	0.1%	8888
2008	99.9%	0.1%	8888
2009	99.5%	0.5%	8893
2010	99.3%	0.7%	8896
2011	99.2%	0.8%	8897
2012	99.1%	0.9%	8899
2013	*99.1%*	*0.9%*	*8899*

Changes in Car-Truck Classification Definitions

Car-truck definitions through the 2010 report were based EPA's engineering judgment. Until recently, EPA and NHTSA had slightly different regulatory definitions for car-truck classifications with respect to health-related emissions and fuel economy, respectively, and the Trends report followed a third approach, though in practice there was broad (though not universal) agreement among the three approaches.

Beginning with the 2011 report, Trends car-truck classifications followed current regulatory definitions used by both EPA and NHTSA for CO_2 emissions and fuel economy standards. See definitions for passenger automobiles (cars) and non-passenger automobiles (trucks) later in this section. These current definitions differ from those used in older versions of this report, and reflect a decision by NHTSA to reclassify many small, 2-wheel drive, sport utility vehicles (SUVs) from the truck category to the car category, beginning with MY 2011. When this re-classification was initiated in the 2011 report, the absolute truck share decreased by approximately 10%.

The current car-truck definitions have been "propagated back" throughout the entire historical Trends database to maintain the integrity of long-term trends of car and truck production share. Since we did not have all of the requisite technical information on which to make retroactive car-truck classifications, we used engineering judgment to classify past models.

Inclusion of Medium-Duty Passenger Vehicles

Beginning with the 2011 report, medium-duty passenger vehicles (MDPVs), those SUVs and passenger vans (but, not pickup trucks) with gross vehicle weight ratings between 8500 and 10,000 pounds, are included in the light-duty truck category. This coincided with new regulations by NHTSA to treat these vehicles as light-duty, rather than heavy-duty, vehicles beginning in MY 2011. This represents a minor change to the database, since the number of MDPVs is much smaller than it once was (e.g., only 6500 MDPVs were sold in MY 2012). It should be noted that this is one change to the database that has not been "propagated back" through the historic database, as we do not have MDPV data prior to MY 2011. Accordingly, this represents a small inflection point for the database--for the overall car and truck fleet in MY 2011, the inclusion of MDPVs decreased average adjusted fuel economy by 0.01 mpg and increased average adjusted CO_2 emissions by 0.3 g/mi, compared to the fleet without MDPVs. The impacts on the truck fleet only were about twice as high, but still very small in absolute terms.

E. Comparison of Preliminary and Final Fleetwide Fuel Economy Values

In recent years, the data for the last model year included in each report has been preliminary (i.e., based on projected vehicle production volumes provided by automakers prior to the beginning of the model year), while the data for all other model years has been final. This leads to the logical question, how accurate have the preliminary projections been?

Table 10.4 compares the preliminary and final fleetwide fuel economy values for recent years (note that the differences for CO_2 emissions data would be similar, on a percentage basis).

For the adjusted fuel economy data, values are only shown beginning in MY 2007, as final adjusted values in this report reflect the revised methodology for calculating adjusted fuel economy values beginning with the 2007 report and therefore the comparable preliminary values prior to MY 2007 would not reflect an apples-to-apples comparison. Since MY 2007, the final adjusted fuel economy values have typically been a little higher than the preliminary adjusted fuel economy values. The major exceptions have been MY 2009, when the final value was 1.3 mpg higher, and MY 2011, when the final value was 0.4 mpg lower.

Comparative unadjusted fuel economy data are shown back to MY 2000. For a majority of the years, the final unadjusted fuel economy values have been higher than the preliminary fuel economy values, and typically the final value is within 0.5 mpg of the preliminary value. As with the adjusted data, the biggest outlier was MY 2009, when the final unadjusted value was 1.8 mpg higher than the preliminary value. There was considerable market turmoil in MY 2009 driven by the economic recession.

Table 10.4

Comparison of Preliminary and Final Adjusted and Unadjusted Fuel Economy Values: Both Cars and Trucks

	Adjusted Fuel Economy (MPG)			Unadjusted Fuel Economy (MPG)		
Model Year	Preliminary Value	Final Value	Final Minus Preliminary	Preliminary Value	Final Value	Final Minus Preliminary
2000	-	-	-	24.0	24.3	+0.3
2001	-	-	-	23.9	24.2	+0.3
2002	-	-	-	24.0	24.1	+0.1
2003	-	-	-	24.4	24.3	-0.1
2004	-	-	-	24.4	24.0	-0.4
2005	-	-	-	24.6	24.8	+0.2
2006	-	-	-	24.6	25.2	+0.6
2007	20.2	20.6	+0.4	25.3	25.8	+0.5
2008	20.8	21.0	+0.2	26.0	26.3	+0.3
2009	21.1	22.4	+1.3	26.4	28.2	+1.8
2010	22.5	22.6	+0.1	28.3	28.4	+0.1
2011	22.8	22.4	-0.4	28.6	28.1	-0.5
2012	23.8	23.6	-0.2	30.0	29.8	-0.2
2013	*24.0*	-	-	*30.3*	-	-

F. Definitions and Acronyms

Electric vehicle (EV) means a motor vehicle that is powered solely by an electric motor drawing current from a rechargeable energy storage system, such as from storage batteries or other portable electrical energy storage devices. For the Trends report, electric vehicles do not generally include fuel cell vehicles.

Flexible fuel vehicle (FFV) means any motor vehicle engineered and designed to be operated on a petroleum fuel and on a methanol or ethanol fuel, or any mixture of the petroleum fuel and methanol or ethanol. Methanol-fueled and ethanol-fueled vehicles that are only marginally functional when using gasoline (e.g., the engine has a drop in rated horsepower of more than 80 percent) are not flexible fuel vehicles.

Footprint means the product of average track width (rounded to the nearest tenth of an inch) and wheelbase (measured in inches and rounded to the nearest tenth of an inch), divided by 144 and then rounded to the nearest tenth of a square foot, where the average track width is the average of the front and rear track widths, where each is measured in inches and rounded to the nearest tenth of an inch.

Fuel cell vehicle (FCV) means an electric vehicle propelled solely by an electric motor where energy for the motor is supplied by an electrochemical cell that produces electricity via the non-combustion reaction of a consumable fuel, typically hydrogen.

Gasoline gallon equivalent means an amount of electricity or fuel with the energy equivalence of one gallon of gasoline. For purposes of the Trends report, one gallon of gasoline is equivalent to 33.705 kilowatt-hours of electricity or 121.5 standard cubic feet of natural gas.

Hybrid electric vehicle (HEV) means a motor vehicle which draws propulsion energy from onboard sources of stored energy that are both an internal combustion engine or heat engine using consumable fuel, and a rechargeable energy storage system such as a battery, capacitor, hydraulic accumulator, or flywheel, where recharge energy for the energy storage system comes solely from sources on board the vehicle.

Light Truck means an automobile that is not a car or a work truck and includes vehicles described in paragraphs (a) and (b) below:

(a) An automobile designed to perform at least one of the following functions:
(1) Transport more than 10 persons;
(2) Provide temporary living quarters;
(3) Transport property on an open bed;
(4) Provide, as sold to the first retail purchaser, greater cargo-carrying than passenger-carrying volume, such as in a cargo van; if a vehicle is sold with a second-row seat, its cargo-carrying volume is determined with that seat installed, regardless of whether the manufacturer has described that seat as optional; or
(5) Permit expanded use of the automobile for cargo-carrying purposes or other

nonpassenger-carrying purposes through:

(i) For non-passenger automobiles manufactured in model year 2008 and beyond, for vehicles equipped with at least 3 rows of designated seating positions as standard equipment, permit expanded use of the automobile for cargo-carrying purposes or other nonpassenger-carrying purposes through the removal or stowing of foldable or pivoting seats so as to create a flat, leveled cargo surface extending from the forwardmost point of installation of those seats to the rear of the automobile's interior.

(b) An automobile capable of off-highway operation, as indicated by the fact that it:

(1)(i) Has 4-wheel drive; or

(ii) Is rated at more than 6000 pounds gross vehicle weight; and

(2) Has at least four of the following characteristics calculated when the automobile is at curb weight, on a level surface, with the front wheels parallel to the automobile's longitudinal centerline, and the tires inflated to the manufacturer's recommended pressure—

(i) Approach angle of not less than 28 degrees.

(ii) Breakover angle of not less than 14 degrees.

(iii) Departure angle of not less than 20 degrees.

(iv) Running clearance of not less than 20 centimeters.

(v) Front and rear axle clearances of not less than 18 centimeters each.

**Please see Section 10.C for Changes in Car-Truck Classification Definitions over time.*

Minivan means a light truck which is designed primarily to carry no more than eight passengers, having an integral enclosure fully enclosing the driver, passenger, and load-carrying compartments, and rear seats readily removed, folded, stowed, or pivoted to facilitate cargo carrying. A minivan typically includes one or more sliding doors and a rear liftgate. Minivans typically have less total interior volume or overall height than full sized vans and are commonly advertised and marketed as "minivans."

Mpg means miles per gallon.

Mpge means miles per gasoline gallon equivalent (see gasoline gallon equivalent above).

Pickup truck means a light truck which has a passenger compartment and an open cargo bed.

Plug-in hybrid electric vehicle (PHEV) means a hybrid electric vehicle that has the capability to charge the battery from an off-vehicle electric source, such that the off-vehicle source cannot be connected to the vehicle while the vehicle is in motion.

Special purpose vehicles means automobiles with GVWR less than or equal to 8,500 pounds and medium-duty passenger vehicles which possess special features and which the Administrator determines are more appropriately classified separately from typical automobiles.

**For purposes of the Trends report, we used engineering judgment to allocate the very small number of vehicles, labeled as special purpose vehicles at fuel economy.gov, to the three truck types: truck SUV,* *van/minivan, or truck*

Sport utility vehicle (SUV) means a light truck with an extended roof line to increase cargo or passenger capacity, cargo compartment open to the passenger compartment, and one or more rear seats readily removed or folded to facilitate cargo carrying. Generally, 2-wheel drive SUVs equal to or less than 6000 lbs GVWR are passenger cars for CAFE and GHG standards compliance, but continue to be labeled as SUVs.

Station wagon means cars with an extended roof line to increase cargo or passenger capacity, cargo compartment open to the passenger compartment, a tailgate, and one or more rear seats readily removed or folded to facilitate cargo carrying.

Track width –means the lateral distance between the centerlines of the base tires at ground, including the camber angle.

Van means any light truck having an integral enclosure fully enclosing the driver compartment and load carrying compartment. The distance from the leading edge of the windshield to the foremost body section of vans is typically shorter than that of pickup trucks and SUVs.

Wheelbase is the longitudinal distance between front and rear wheel centerlines.

G. Links for More Information

This report, *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2013* (EPA-420-R-13-011) is available on the EPA's Office of Transportation and Air Quality's (OTAQ) web site at: epa.gov/otaq/fetrends.htm. The Executive Summary of this report (EPA-420-S-13-002) is available at the same we site.

A copy of the *Fuel Economy Guide* giving city and highway fuel economy data for individual models is available at: fueleconomy.gov or by calling the U.S. Department of Energy at (800) 423-1363.

The website fueleconomy.gov provides fuel economy and environmental information for vehicles from model year 1984 through the present. The site has many tools that allow users to search for vehicles and find information on vehicle fuel economy, fuel consumption, estimated annual fuel cost, and CO_2 emissions. The site also allows users to personalize fuel economy and fueling cost estimates based on personalized inputs for fuel cost, annual mileage, and percentage of city versus highway driving.

EPA's Green Vehicle Guide (epa.gov/greenvehicles) is designed to help car buyers identify the cleanest, most fuel-efficient vehicle that meets their needs. The site includes information on SmartWay certified vehicles, how advanced technology vehicles work, and infographics and videos that provide tips on saving money and reducing emissions through smarter vehicle choices.

For detailed information about EPA's GHG emissions standards for motor vehicles, see: epa.gov/otaq/climate/regulations.htm.

For detailed information about DOT's Corporate Average Fuel Economy (CAFE) program, including a program overview, related rulemaking activities, and summaries of the formal CAFE performance of individual manufacturers since 1978, see: nhtsa.dot.gov/fuel-economy.

For more information about the EPA/Department of Transportation (DOT) Fuel Economy and Environment Labels, see: epa.gov/otaq/carlabel.

H. Authors and Acknowledgements

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