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 40 years, one trend is strikingly clear: automakers have consistently developed and commercialized new technologies that have provided increasing 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 increasing fuel economy, reducing CO_2 emissions, increasing vehicle power and performance, increasing vehicle content and weight, or improving other vehicle attributes that are not easily quantifiable (e.g., handling, launch feel).

Data from alternative fuel vehicles (AFVs) are included in the report beginning with MY 2011 data. AFVs include electric vehicles (EVs), plug-in electric hybrids (PHEVs), hydrogen fuel cell vehicles (FCVs), and compressed natural gas (CNG) vehicles. AFVs are projected to surpass 1% of production in MY 2016. AFV production has increased in recent years and is enough to begin impacting some important trends in this report. However, making technical comparisons between AFVs and conventional vehicles is difficult due to the fact that many conventional metrics are no longer relevant for electrified vehicles (number of cylinders, for example), and that some AFVs have complex operating cycles based on multiple fuels. For these reasons, the analysis in part B of this section is limited to conventional vehicles (gasoline, diesel, and gasoline hybrid) only. Part C focuses exclusively on alternative fuel vehicles, without conventional vehicles. The rest of this section includes AFVs and conventional vehicles together. For a more detailed description of individual AFVs and the parameters used to measure fuel economy and emissions, see section 7.

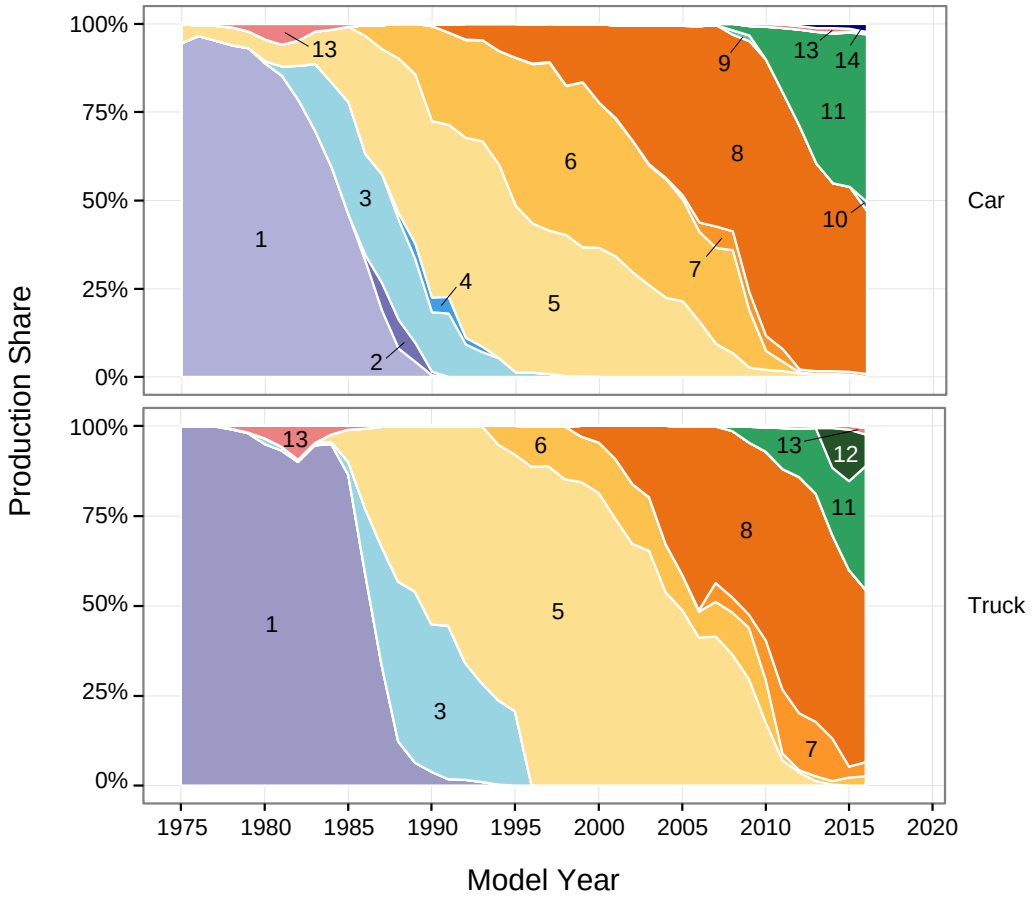
A. Overall Engine Trends

Engine technology has changed radically over the last 40 years. In 1975, the first year of this report, nearly all engines were carbureted with fixed valve timing and two valves per cylinder. In MY 2016, almost half of new vehicle production will feature engines with gasoline direct injection, variable valve timing, and multiple valves per cylinder. In addition, advanced AFVs, including PHEVs that can operate on electricity or gasoline, are in production today.

The evolution of vehicle engine technology over the last 40 years is shown in Figure 5.1. Engine technology has consistently changed as the industry evolved. One interesting aspect of Figure 5.1 is that engine technology has, at times, changed quite quickly. GDI engines were installed in less than 3% of vehicles produced in MY 2008, but are projected to reach about 49% of new vehicles in MY 2016. This is a rapid change, but not unprecedented in the industry. For example, nearly all trucks replaced carburetors with fuel injection engines in the 5 year period from MY 1985 to MY 1990.

Figure 5.1

Production Share by Engine Technology



Fuel Delivery	Valve Timing	Number of Valves	Key
Carbureted	Fixed	Two-Valve	1
		Multi-Valve	2
Throttle Body Injection	Fixed	Two-Valve	3
		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
		Two-Valve	10
	Variable	Multi-Valve	11
		Two-Valve	12
Diesel	—	—	13
Alternative Fuel	—	—	14

Table 5.1

Production Share by Powertrain

Model Year	Gasoline	Hybrid	Diesel	Plug-in Hybrid Electric	Electric	Other
1975	99.8%	-	0.2%	-	-	-
1976	99.8%	-	0.2%	-	-	-
1977	99.6%	-	0.4%	-	-	-
1978	99.1%	-	0.9%	-	-	-
1979	98.0%	-	2.0%	-	-	-
1980	95.7%	-	4.3%	-	-	-
1981	94.1%	-	5.9%	-	-	-
1982	94.4%	-	5.6%	-	-	-
1983	97.3%	-	2.7%	-	-	-
1984	98.2%	-	1.8%	-	-	-
1985	99.1%	-	0.9%	-	-	-
1986	99.6%	-	0.4%	-	-	-
1987	99.7%	-	0.3%	-	-	-
1988	99.9%	-	0.1%	-	-	-
1989	99.9%	-	0.1%	-	-	-
1990	99.9%	-	0.1%	-	-	-
1991	99.9%	-	0.1%	-	-	-
1992	99.9%	-	0.1%	-	-	-
1993	100.0%	-	-	-	-	-
1994	100.0%	-	0.0%	-	-	-
1995	100.0%	-	0.0%	-	-	-
1996	99.9%	-	0.1%	-	-	-
1997	99.9%	-	0.1%	-	-	-
1998	99.9%	-	0.1%	-	-	-
1999	99.9%	-	0.1%	-	-	-
2000	99.8%	0.0%	0.1%	-	-	-
2001	99.7%	0.1%	0.1%	-	-	-
2002	99.6%	0.2%	0.2%	-	-	-
2003	99.5%	0.3%	0.2%	-	-	-
2004	99.4%	0.5%	0.1%	-	-	-
2005	98.6%	1.1%	0.3%	-	-	-
2006	98.1%	1.5%	0.4%	-	-	-
2007	97.7%	2.2%	0.1%	-	-	-
2008	97.4%	2.5%	0.1%	-	-	-
2009	97.2%	2.3%	0.5%	-	-	-
2010	95.5%	3.8%	0.7%	-	-	0.0%
2011	97.0%	2.2%	0.8%	0.0%	0.1%	0.0%
2012	95.5%	3.1%	0.9%	0.3%	0.1%	0.0%
2013	94.8%	3.6%	0.9%	0.4%	0.3%	0.0%
2014	95.7%	2.6%	1.0%	0.4%	0.3%	0.0%
2015	95.9%	2.4%	0.9%	0.3%	0.5%	0.0%
2016 (prelim)	*95.1%*	*2.5%*	*0.7%*	*0.4%*	*1.3%*	*0.0%*

Gasoline combustion engines have long dominated sales in the United States. As shown in Table 5.1, non-hybrid gasoline engines are projected to be installed in 95.1% of all new vehicles in MY 2016. Gasoline hybrid vehicles are projected to account for less than 3% of new vehicles in MY 2016, with electric vehicles (EVs) and plug-in electric hybrids (PHEVs) capturing 1.3% and 0.4% of production. Diesel vehicles are projected to account for 0.7% of production, well below the 5.9% record high set in MY 1981. Hybrids are also below their record production level of MY 2010.

B. Trends in Conventional Engines

Conventional engine technologies include gasoline vehicles, diesel vehicles, and gasoline hybrid vehicles. In MY 2016, these vehicles are projected to account for slightly less than 99% of vehicles produced. These vehicles all rely on combustion engines and either gasoline or diesel fuel to power the vehicle. Many of the metrics in this section, such as engine displacement, are not relevant for AFVs, so the analysis presented here excludes all AFVs. It is important to note that, because AFVs are excluded from this section, some values in this section will differ slightly from those cited elsewhere in this report where AFVs are included.

Horsepower and Displacement

One of the most remarkable trends over the course of this report is the increase in vehicle horsepower 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. Average horsepower climbed consistently from MY 1982 to MY 2008. Since MY 2008, horsepower trends have been less consistent, and may be beginning to flatten out. Average horsepower for conventional vehicles is projected to be 229 hp in MY 2016, just below record highs. The long-term trend in horsepower is mainly attributable to improvements in engine technology, but increasing production of larger vehicles and an increasing percentage of truck production have also influenced the increase of average new vehicle horsepower. The trend in average new vehicle horsepower is shown in Figure 5.2.

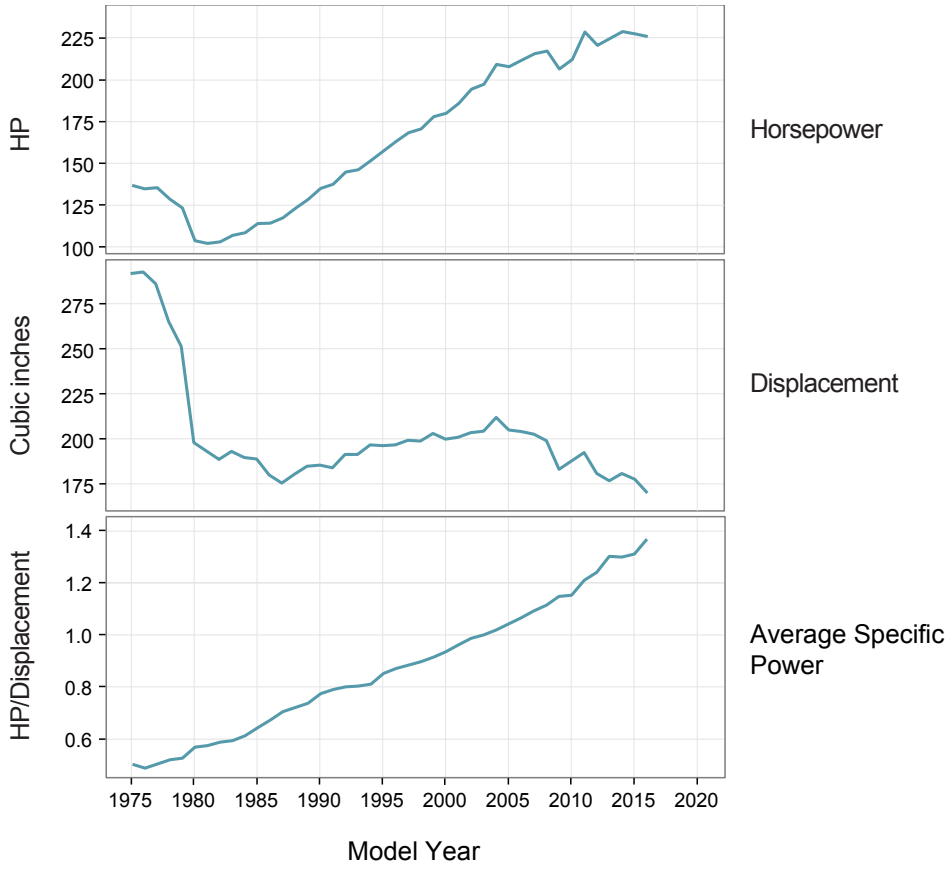
Engine size, as measured by total displacement, is also shown in Figure 5.2. Three general phases in engine displacement are discernible. From MY 1975 to 1987, the average engine displacement of new vehicles dropped dramatically by nearly 40%. From MY 1988 to 2004, displacement generally grew slowly, but the trend reversed in 2005 and engine displacement has been generally decreasing since. In MY 2016, engine displacement is projected to reach the lowest point on record, below the previous lowest average displacement reached 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., increasingly sophisticated fuel injection designs) 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 5.2

Engine Power and Displacement, AFVs Excluded

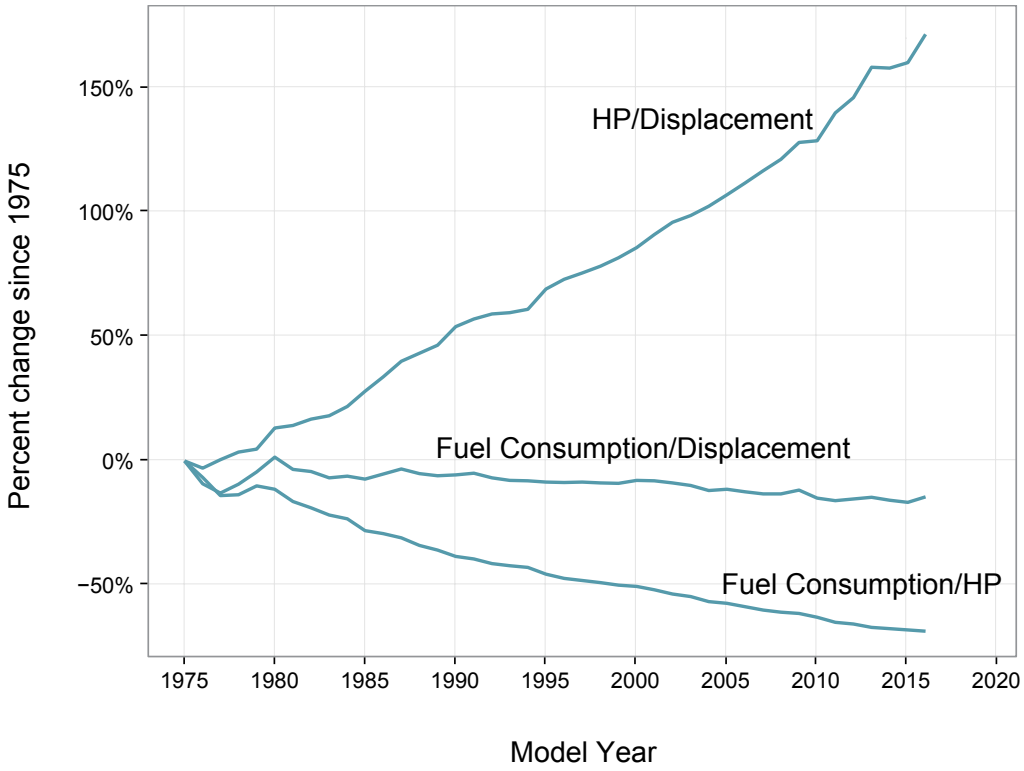


Since the beginning of this report, the average specific power of engines across the new vehicle fleet has increased at a remarkably steady rate, as shown in Figure 5.2. Since MY 1975, the specific power of new vehicle engines has increased by about 0.02 horsepower per cubic inch every year. Considering 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. Turbocharged engines, direct injection, higher compression ratios, and many other engine technologies are likely to continue increasing engine specific power.

Figure 5.3 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% since MY 1975 and 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 5.3 clearly show that engine improvements over time have been steady, continual, and have resulted in impressive improvements to internal combustion engines.

Figure 5.3

Percent Change for Specific Engine Metrics, AFVs Excluded



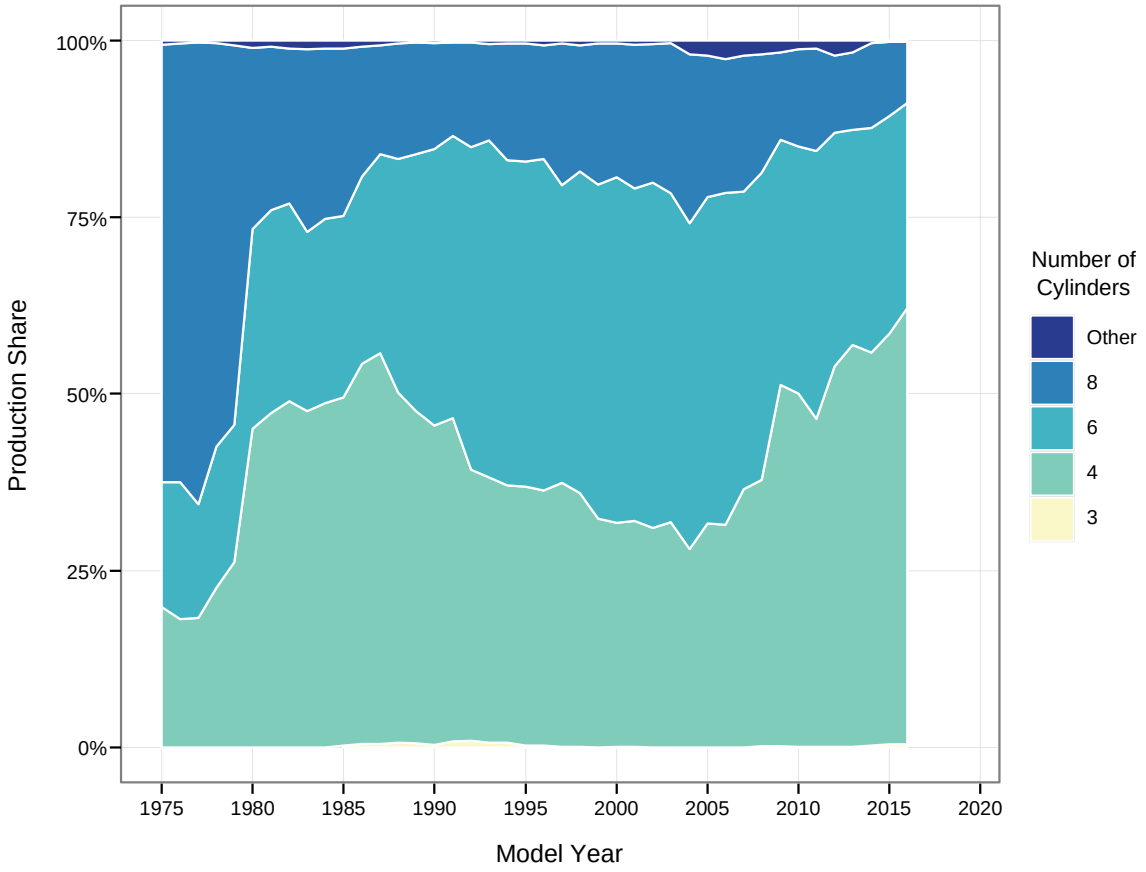
Another fundamental design parameter for internal combustion engines is the number of cylinders. Since 1975, there have been significant changes to the number of cylinders in new vehicles, as shown in Figure 5.4. In the mid and late 1970s, the 8-cylinder engine was dominant, accounting for over half 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 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 a 51% market share (an increase of 13 percentage points in a single year), followed by 6-cylinder engines with 35%, and 8-cyinder engines at 12%. Production share of 4-cylinder engines has generally increased since, and is at the highest point on record, accounting for 58% of production in MY 2015. Production share of 8-cylinder

engines has continued to decrease, to less than 11%. Projected data for MY 2016 suggests that these trends will continue.

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 5.2 is almost entirely due to the shift towards engines with fewer cylinders. In MY 2016, the production share of three cylinder engines is projected to be slightly less than 0.5%, but growing.

Figure 5.4

Production Share by Number of Engine Cylinders, AFVs Excluded



Fuel Delivery Systems

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 with very limited production in MY 2007. Only 8 years later GDI engines were installed in about 42% of MY 2015 vehicles, and are projected to achieve a 49% market share in MY 2016.

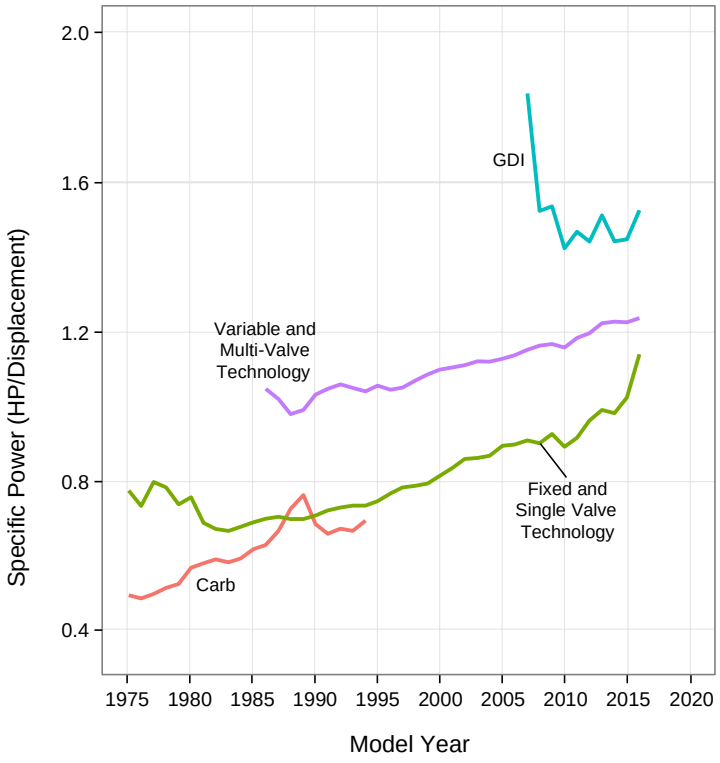
Another key aspect of engine design is the valve-train. The number of valves per cylinder and the ability to alter valve timing during the combustion cycle can result in significant power and efficiency improvements. This report began tracking multi-valve engines (i.e., engines with more than 2 valves per cylinder) for cars in MY 1986 (and for trucks in MY 1994), 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, 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 for trucks in MY 2000), and since then nearly the entire fleet has adopted this technology. Figure 5.1 shows the evolution of engine technology, including fuel delivery method and the introduction of VVT and multi-valve engines.

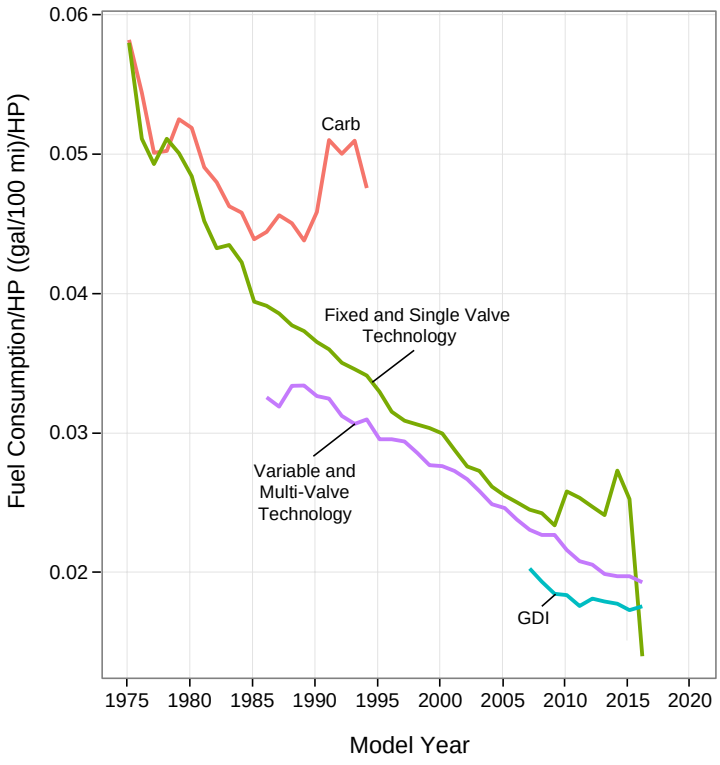
As clearly shown in Figure 5.1, fuel delivery and valve-train technologies have often developed over the same time frames. Nearly all carbureted engines relied on fixed valve timing and had two valves per cylinder, as did early port injected engines. Port injected engines largely developed into engines 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 lifetime of the Trends database.

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 also shows the reduction in fuel consumption per horsepower for each of the four engine packages.

Figure 5.5

Engine Metrics for Different Engine Technology Packages, AFVs Excluded





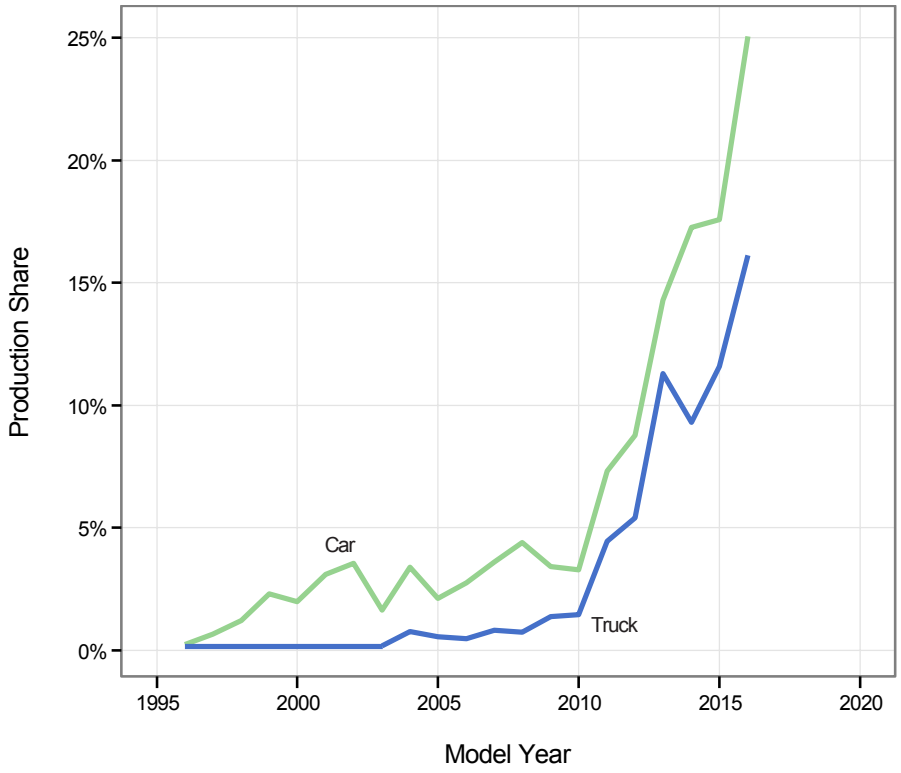
Turbo-Downsizing

Many manufacturers have introduced 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 provide more power via the turbocharger, when needed.

Turbocharged engines are projected to capture approximately 22% of new vehicle production in MY 2016, with all of the 13 largest manufacturers (as discussed in Section 4) offering turbocharged engine packages. 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 mainstream vehicles. The sales of these vehicles are driving the increase in turbocharger market share. Both cars and trucks have rapidly added turbocharged engine packages, as shown in Figure 5.6.

Figure 5.6

Market Share of Gasoline Turbo Vehicles



Turbochargers are most frequently combined with 4-cylinder engines. Excluding diesel engines, 76% of turbocharged engines are combined with 4-cylinder engines and about 19% are combined with 6-cylinder engines. Over 60% of turbocharged engines are projected to be installed in 4-cylinder cars in MY 2016. The overall breakdown of turbocharger distribution in the new vehicle fleet is shown in Table 5.2.

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 2016, more than 90% of new vehicles with gasoline turbocharged engines also use GDI.

Table 5.2

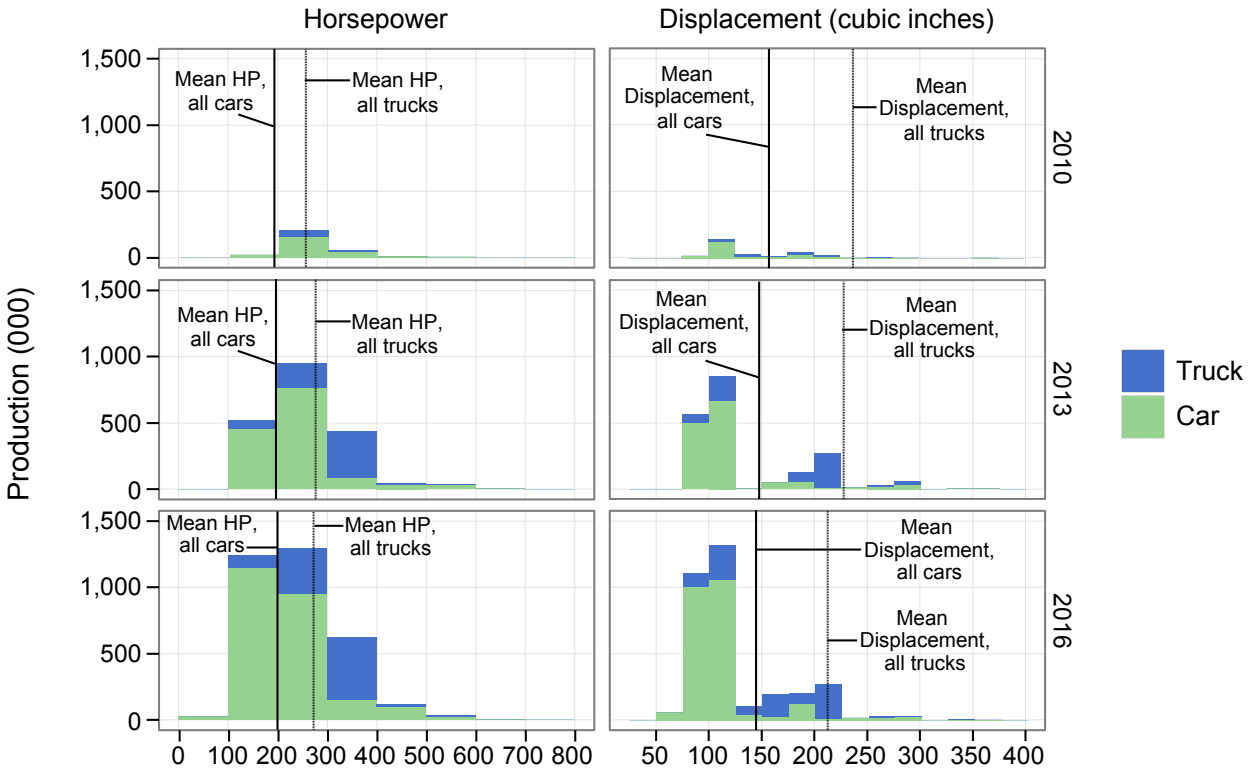
Distribution of MY 2016 (Preliminary) Gasoline Turbocharged Engines

Category	Turbo Share
Car	
4 cylinder Car	*63.0%*
6 cylinder Car	*4.5%*
8 cylinder Car	*2.0%*
Other Car	*2.3%*
Truck	
4 cylinder Truck	*13.1%*
6 cylinder Truck	*14.4%*
8 cylinder Truck	*0.5%*
Other Truck	*0.2%*

Figure 5.7 examines the distribution of engine displacement and power of turbocharged engines for MY 2010 (top) to MY 2016 (bottom). Note that the production values for cars and trucks in each bar are additive, e.g., there are projected to be about 950,000 gasoline cars with turbochargers in the 200-300 horsepower range in MY 2016, with another 385,000 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 the average displacement. Engine horsepower has been more distributed around the average, reflecting the higher power per displacement of turbocharged engines. 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.

Figure 5.7

Distribution of Gasoline Turbo Vehicles by Displacement and Horsepower, MY 2010, 2013, and 2016

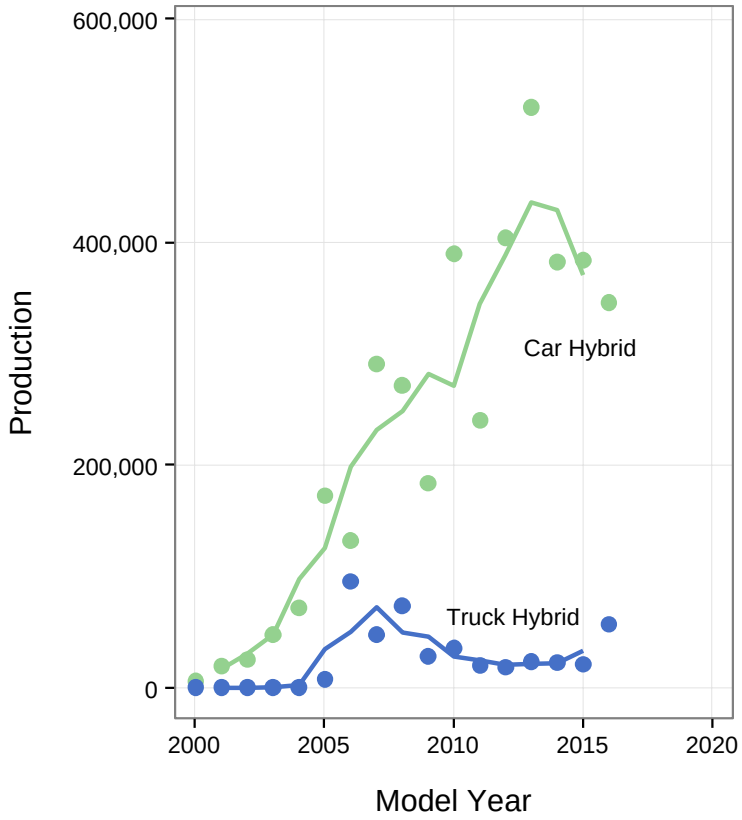


Hybrids

Hybrid vehicles utilize larger battery packs, electric motor(s), and other components that can increase vehicle fuel economy. Benefits of hybrids include: 1) regenerative braking which can capture energy that is otherwise lost in conventional friction braking to charge the battery, 2) availability of two sources of on-board power which can allow the engine to be operated at or near its peak efficiency more often, and 3) shutting off the engine at idle. The introduction of the first hybrid into the U.S. marketplace occurred in MY 2000 with the Honda Insight. Hybrid production and market share increased throughout the 2000s, with hybrid production peaking in MY 2013 at over 500,000 units, as shown in Figure 5.8, and market share peaking in MY 2010 at 3.8%. In the last few years, hybrid production has fluctuated, with hybrids accounting for 2.4% market share in MY 2015. Their market share is projected to reach 2.5% in MY 2016. A large factor in the fluctuating hybrid production 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, as well as by a shortened model year in MY 2009 due to the introduction of a redesigned vehicle.

Figure 5.8

Hybrid Production MY 2000–2016 (With 3-Year Moving Average), AFVs Excluded

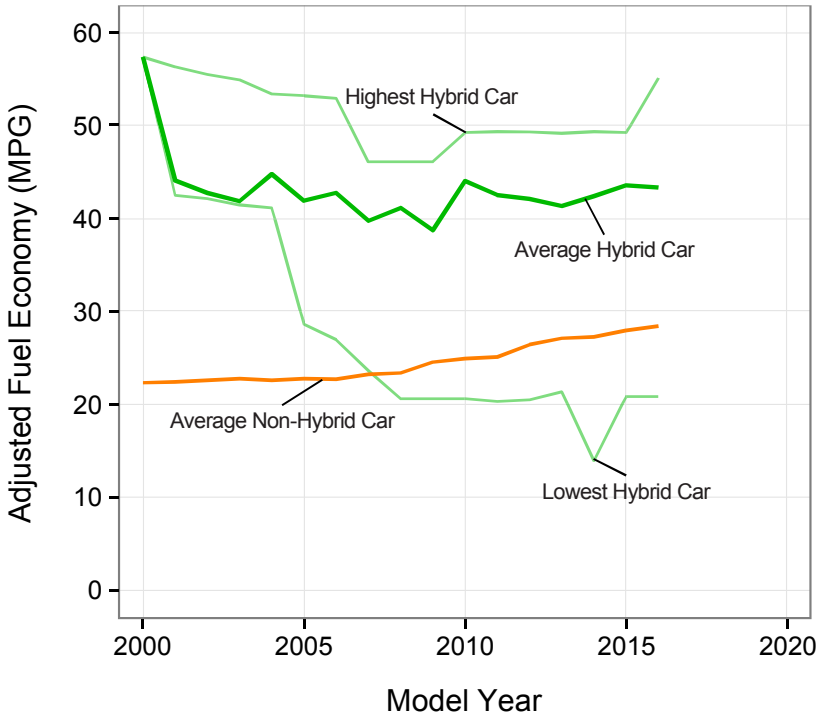


The first U.S. hybrid vehicle in MY 2000, the Honda Insight, was a low production, specialty vehicle with very high fuel economy (Table 10.2 shows various fuel economy metrics for the 2005 Insight). The Toyota Prius was first introduced in the U.S. market in MY 2001, and over time, more hybrid models were introduced. Hybrids now represent a much broader range of vehicle types and are now frequently offered as powertrain options on many popular models that are nearly indistinguishable from their non-hybrid counterparts. 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 cars by year. Hybrid cars, on average, have fuel economy more than 50% higher than the average non-hybrid car in MY 2016. As a production weighted average, hybrid cars achieved 43 mpg for MY 2016, while the average non-hybrid car achieved about 29 mpg. From MY 2000 to MY 2016, the number of hybrid models available increased from 1 to 33. The increasing spread between the highest and lowest fuel economy of available hybrid cars is a reflection of the widening availability of hybrid models. Figure 5.9 is presented for cars only since the production of hybrid trucks has been limited.

Figure 5.9

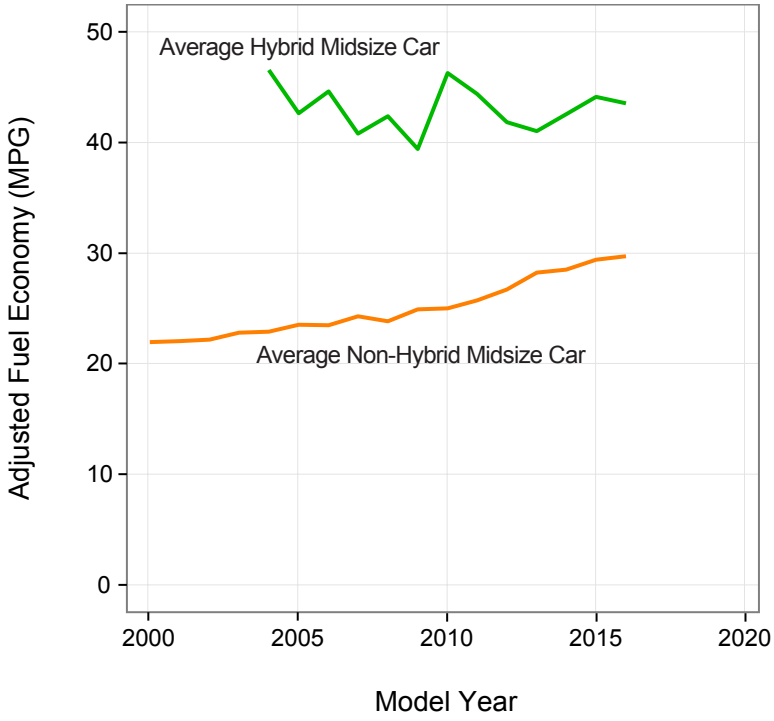
Hybrid Adjusted Fuel Economy Distribution by Year, Car Only, AFVs Excluded



While the average fuel economy of hybrid cars remains higher than the average fuel economy of non-hybrid cars, the difference appears to be narrowing. Average hybrid car fuel economy has been relatively stable since MY 2001, while the fuel economy of the average non-hybrid car has increased more than 27%. Figure 5.10 further explores this trend by examining midsize cars. While generally this report has moved away from using vehicle sub-classes such as midsize sedans, it is a well-established and recognized category and more than 50% of hybrid vehicles are in the midsize car class. Comparing average midsize hybrids to average midsize non-hybrid cars, gasoline only, is an apples-to-apples comparison.

Figure 5.10

Hybrid and Non-Hybrid Fuel Economy for Midsize Cars, MY 2000–2016, Gasoline Only

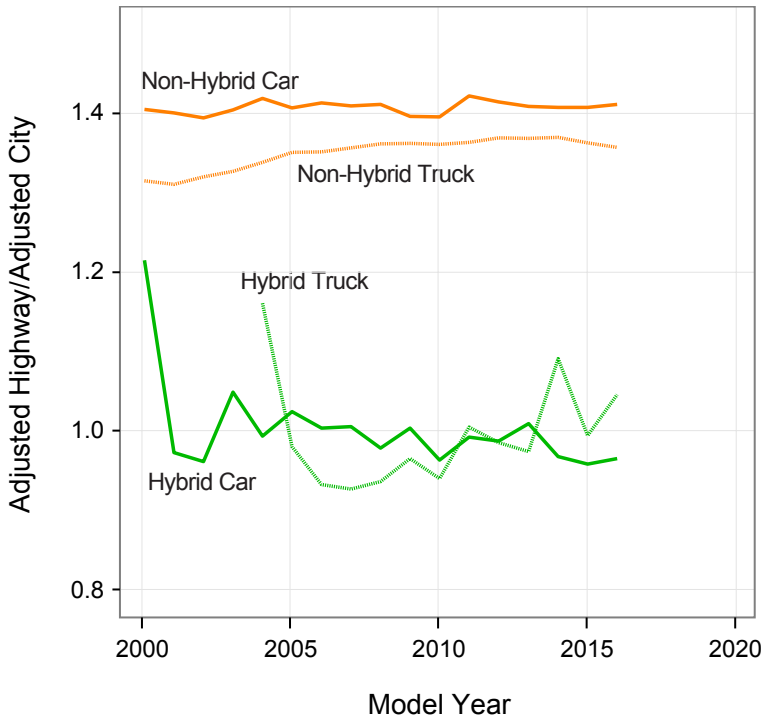


Since MY 2004, the difference in fuel economy between the average hybrid midsize car and the average non-hybrid midsize gasoline car has narrowed from about 25 mpg to about 14 mpg. The primary reason for this trend is continued improvements to the internal combustion engine. Additionally, many technologies introduced or emphasized in early hybrids, such as improved aerodynamics, low rolling resistance tires, and increased use of lightweight materials, have also become more common on non-hybrid vehicles. The lower fuel economy differential between midsize hybrid cars and midsize non-hybrid cars may be one reason why hybrid production share has fluctuated in recent years.

One unique 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 typically similar to, if not higher than, their highway fuel economy. Figure 5.11 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 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 5.11

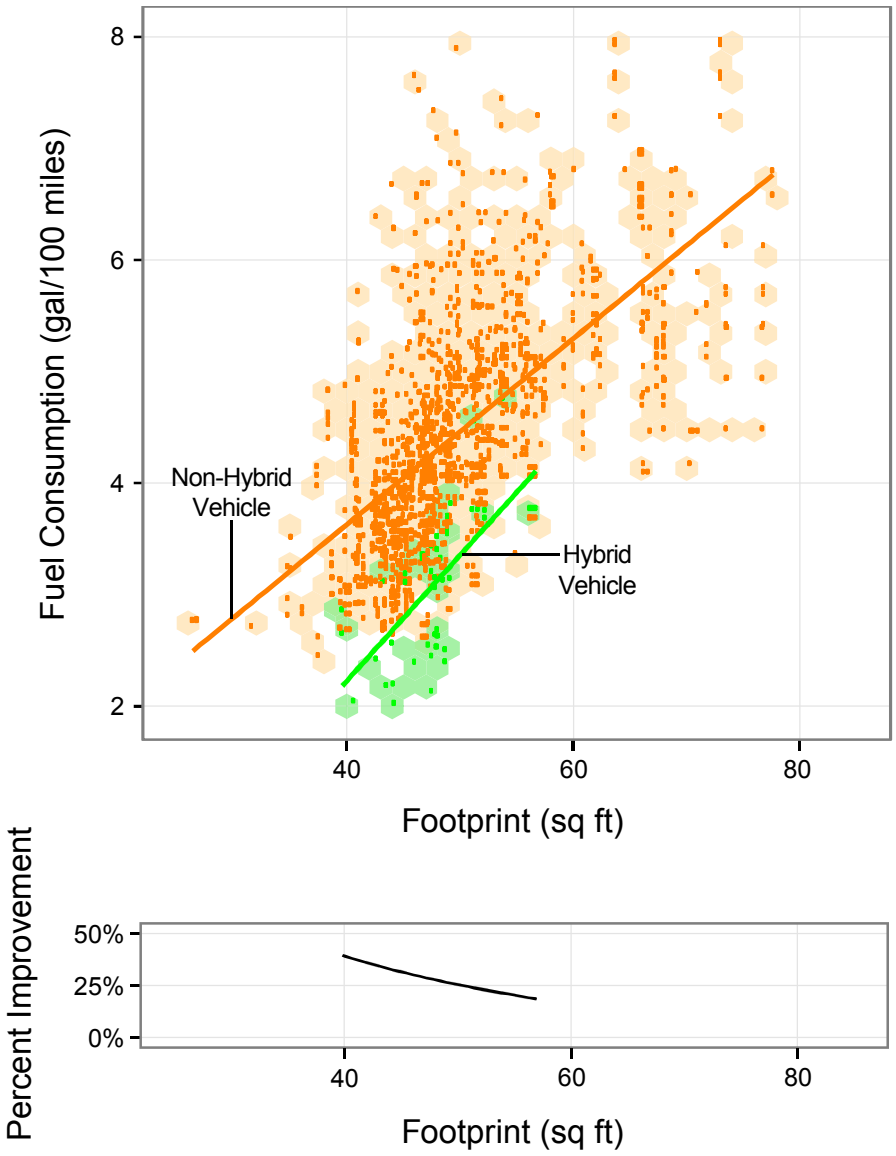
Highway/City Fuel Economy Ratio for Hybrids and Non-Hybrids, AFVs Excluded



The relationship between hybrids and non-hybrids is clearer if vehicles of the same footprint are compared directly. As shown in Figure 5.12, the fuel consumption of vehicles increases as the footprint increases at about the same rate for both hybrid and non-hybrid vehicles. Hybrids do achieve a higher percentage improvement in smaller vehicles, and achieve more than 30% 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 5.12 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 5.12.

Figure 5.12

Percent Improvement in Adjusted Fuel Consumption for Hybrid Vehicles, MY 2015, AFVs Excluded



Diesels

Over the last several years, several new diesel vehicles have been introduced in the U.S. market. Production increased in MY 2014 and 2015 to 1% of production, but is projected to fall back to about 0.8% of production in MY 2016. This is the highest penetration of diesel engines since the early 1984, but well below the 5.9% of new vehicles diesel engines reached in 1981. As with hybrid vehicles, diesels generally achieve higher fuel economy than non-diesel vehicles. The relationship between diesel vehicles and all new vehicles is shown in Figure 5.13.

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 5.14 shows the impact of diesel vehicles on CO_2 emissions by comparing the CO_2 emissions of MY 2015 diesel and gasoline vehicles by footprint.

It is important to note that the Department of Justice, on behalf of EPA, alleged violations of the Clean Air Act by Volkswagen and certain subsidiaries based on the sale of certain MY 2009-2016 diesel vehicles equipped with software designed to cheat on federal emissions tests. In this report, EPA uses the CO_2 emissions and fuel economy data from the initial certification of these vehicles. Should the investigation and corrective actions yield different CO_2 and fuel economy data, the revised data will be used in future reports. For more information on actions to resolve these violations, see www.epa.gov/vw.

Other Technologies

Table 5.3.1 presents comprehensive annual data for the historic MY 1975-2016 database for all of the engine technologies and parameters discussed above and several additional technologies. This report added engine stop/start technology (for non-hybrid vehicles) for the first time last year, and already stop/start technology is projected to be included on nearly 9% of new non-hybrid vehicle production in MY 2016 (note that total use of stop/start is nearly 12% 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 9% of production in MY 2016. Tables 5.3.2 and 5.3.3 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 5.13

Percent Improvement in Adjusted Fuel Consumption for Diesel Vehicles, MY 2015, AFVs Excluded

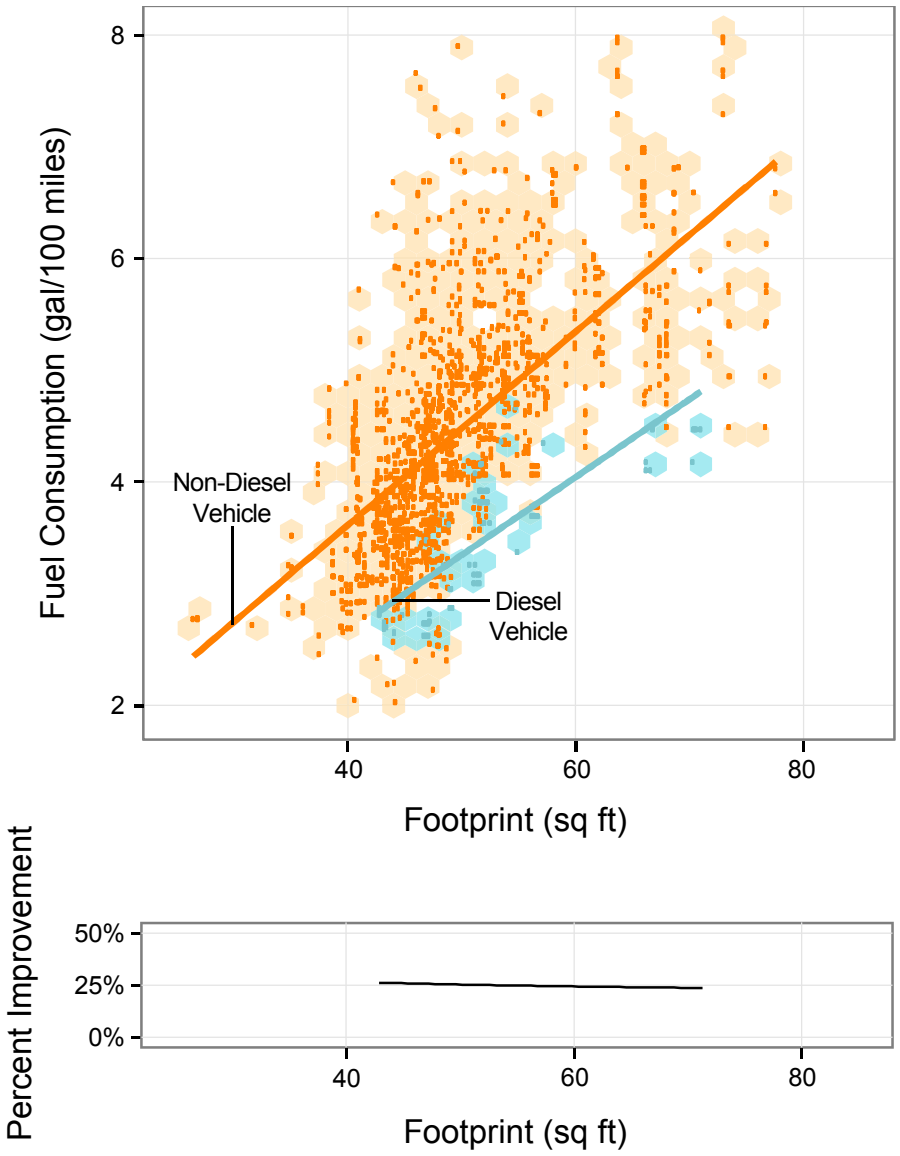


Figure 5.14

Percent Improvement in CO_2 Emissions for Diesel Vehicles, MY 2015, AFVs Excluded

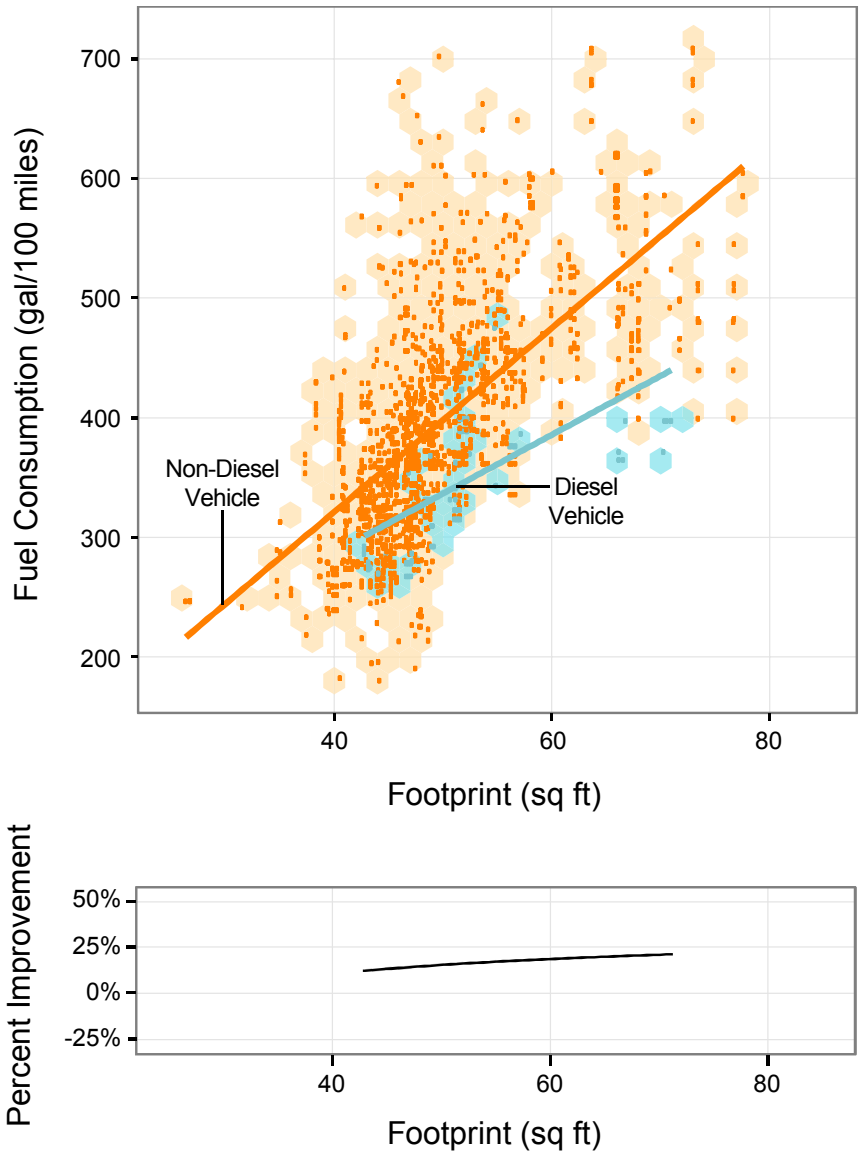


Table 5.3.1

Engine Technologies and Parameters, Both Car and Truck, AFVs Excluded

	Powertrain			Fuel Delivery Method					Avg. No. of							
Model Year	Gasoline	Gasoline Hybrid	Diesel	Carbureted	GDI	Port	TBI	Diesel	Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Stop/ Start
1975	99.8%	-	0.2%	95.7%	-	4.1%	0.0%	0.2%	6.8	293	137	-	-	-	-	-
1976	99.8%	-	0.2%	97.3%	-	2.5%	0.0%	0.2%	6.9	294	135	-	-	-	-	-
1977	99.6%	-	0.4%	96.2%	-	3.4%	0.0%	0.4%	6.9	287	136	-	-	-	-	-
1978	99.1%	-	0.9%	95.2%	-	3.9%	0.0%	0.9%	6.7	266	129	-	-	-	-	-
1979	98.0%	-	2.0%	94.2%	-	3.7%	0.1%	2.0%	6.5	252	124	-	-	-	-	-
1980	95.7%	-	4.3%	89.7%	-	5.2%	0.8%	4.3%	5.6	198	104	-	-	-	-	-
1981	94.1%	-	5.9%	86.7%	-	5.1%	2.4%	5.9%	5.5	193	102	-	-	-	-	-
1982	94.4%	-	5.6%	80.6%	-	5.8%	8.0%	5.6%	5.4	188	103	-	-	-	-	-
1983	97.3%	-	2.7%	75.2%	-	7.3%	14.8%	2.7%	5.5	193	107	-	-	-	-	-
1984	98.2%	-	1.8%	67.6%	-	11.9%	18.7%	1.8%	5.5	190	109	-	-	-	-	-
1985	99.1%	-	0.9%	56.1%	-	18.2%	24.8%	0.9%	5.5	189	114	-	-	-	-	-
1986	99.6%	-	0.4%	41.4%	-	32.5%	25.7%	0.4%	5.3	180	114	3.4%	-	-	-	-
1987	99.7%	-	0.3%	28.4%	-	39.9%	31.4%	0.3%	5.2	175	118	10.6%	-	-	-	-
1988	99.9%	-	0.1%	15.0%	-	50.6%	34.3%	0.1%	5.3	180	123	14.0%	-	-	-	-
1989	99.9%	-	0.1%	8.7%	-	57.3%	33.9%	0.1%	5.4	185	129	16.9%	-	-	-	-
1990	99.9%	-	0.1%	2.1%	-	70.8%	27.0%	0.1%	5.4	185	135	23.1%	-	-	-	-
1991	99.9%	-	0.1%	0.6%	-	70.6%	28.7%	0.1%	5.3	184	138	23.1%	-	-	-	-
1992	99.9%	-	0.1%	0.5%	-	81.6%	17.8%	0.1%	5.5	191	145	23.3%	-	-	-	-
1993	100.0%	-	-	0.3%	-	85.0%	14.6%	-	5.5	191	147	23.5%	-	-	-	-
1994	100.0%	-	0.0%	0.1%	-	87.7%	12.1%	0.0%	5.6	197	152	26.7%	-	-	-	-
1995	100.0%	-	0.0%	-	-	91.6%	8.4%	0.0%	5.6	196	158	35.6%	-	-	-	-
1996	99.9%	-	0.1%	-	-	99.3%	0.7%	0.1%	5.6	197	164	39.3%	-	-	0.2%	-
1997	99.9%	-	0.1%	-	-	99.5%	0.5%	0.1%	5.7	199	169	39.6%	-	-	0.4%	-
1998	99.9%	-	0.1%	-	-	99.8%	0.1%	0.1%	5.6	199	171	40.9%	-	-	0.8%	-
1999	99.9%	-	0.1%	-	-	99.9%	0.1%	0.1%	5.8	203	179	43.4%	-	-	1.4%	-
2000	99.8%	0.0%	0.1%	-	-	99.8%	0.0%	0.1%	5.7	200	181	44.8%	15.0%	-	1.3%	-
2001	99.7%	0.1%	0.1%	-	-	99.9%	-	0.1%	5.8	201	187	49.0%	19.6%	-	2.0%	-
2002	99.6%	0.2%	0.2%	-	-	99.8%	-	0.2%	5.8	203	195	53.3%	25.3%	-	2.2%	-
2003	99.5%	0.3%	0.2%	-	-	99.8%	-	0.2%	5.8	204	199	55.5%	30.6%	-	1.2%	-
2004	99.4%	0.5%	0.1%	-	-	99.9%	-	0.1%	5.9	212	211	62.3%	38.5%	-	2.3%	-
2005	98.6%	1.1%	0.3%	-	-	99.7%	-	0.3%	5.8	205	209	65.6%	45.8%	0.8%	1.7%	-
2006	98.1%	1.5%	0.4%	-	-	99.6%	-	0.4%	5.7	204	213	71.7%	55.4%	3.6%	2.1%	-
2007	97.7%	2.2%	0.1%	-	-	99.8%	-	0.1%	5.6	203	217	71.7%	57.3%	7.3%	2.5%	-
2008	97.4%	2.5%	0.1%	-	2.3%	97.6%	-	0.1%	5.6	199	219	76.4%	58.2%	6.7%	3.0%	-
2009	97.2%	2.3%	0.5%	-	4.2%	95.2%	-	0.5%	5.2	183	208	83.8%	71.5%	7.3%	3.3%	-
2010	95.5%	3.8%	0.7%	-	8.3%	91.0%	-	0.7%	5.3	188	214	85.5%	83.8%	6.4%	3.3%	-
2011	97.1%	2.2%	0.8%	-	15.4%	83.8%	-	0.8%	5.4	192	230	86.4%	93.1%	9.5%	6.8%	-
2012	95.9%	3.1%	0.9%	-	22.6%	76.5%	-	0.9%	5.1	181	222	91.9%	96.7%	8.1%	8.4%	0.6%
2013	95.5%	3.6%	0.9%	-	30.7%	68.4%	-	0.9%	5.1	176	226	93.1%	97.7%	7.7%	14.0%	2.3%
2014	96.3%	2.6%	1.0%	-	37.7%	61.3%	-	1.0%	5.1	180	231	89.4%	97.9%	10.7%	14.9%	5.1%
2015	96.6%	2.4%	1.0%	-	42.2%	56.9%	-	1.0%	5.0	177	229	91.6%	97.7%	10.6%	15.8%	7.2%
2016 (prelim)	*96.7%*	*2.6%*	*0.8%*	-	*48.5%*	*50.8%*	-	*0.8%*	*4.9*	*170*	*228*	*92.8%*	*96.8%*	*8.9%*	*22.3%*	*9.2%*

Table 5.3.2

Engine Technologies and Parameters, Car Only, AFVs Excluded

	Powertrain			Fuel Delivery Method					Avg. No. of							
Model Year	Gasoline	Gasoline Hybrid	Diesel	Carbureted	GDI	Port	TBI	Diesel	Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Stop/ Start
1975	99.8%	-	0.2%	94.6%	-	5.1%	-	0.2%	6.7	288	136	-	-	-	-	-
1976	99.7%	-	0.3%	96.6%	-	3.2%	-	0.3%	6.8	287	134	-	-	-	-	-
1977	99.5%	-	0.5%	95.3%	-	4.2%	-	0.5%	6.9	279	133	-	-	-	-	-
1978	99.1%	-	0.9%	94.0%	-	5.1%	-	0.9%	6.5	251	124	-	-	-	-	-
1979	97.9%	-	2.1%	93.2%	-	4.7%	-	2.1%	6.4	238	119	-	-	-	-	-
1980	95.6%	-	4.4%	88.7%	-	6.2%	0.7%	4.4%	5.5	188	100	-	-	-	-	-
1981	94.1%	-	5.9%	85.3%	-	6.1%	2.6%	5.9%	5.4	182	99	-	-	-	-	-
1982	95.3%	-	4.7%	78.4%	-	7.2%	9.8%	4.7%	5.2	175	99	-	-	-	-	-
1983	97.9%	-	2.1%	69.7%	-	9.4%	18.8%	2.1%	5.4	182	104	-	-	-	-	-
1984	98.3%	-	1.7%	59.1%	-	14.9%	24.3%	1.7%	5.3	179	106	-	-	-	-	-
1985	99.1%	-	0.9%	46.0%	-	21.3%	31.8%	0.9%	5.3	177	111	-	-	-	-	-
1986	99.7%	-	0.3%	34.4%	-	36.5%	28.7%	0.3%	5.1	167	111	4.7%	-	-	-	-
1987	99.8%	-	0.2%	26.5%	-	42.4%	30.8%	0.2%	5.0	162	113	14.6%	-	-	-	-
1988	100.0%	-	0.0%	16.1%	-	53.7%	30.2%	0.0%	5.0	161	116	19.7%	-	-	-	-
1989	100.0%	-	0.0%	9.6%	-	62.2%	28.1%	0.0%	5.1	163	121	24.1%	-	-	-	-
1990	100.0%	-	0.0%	1.4%	-	77.4%	21.2%	0.0%	5.1	163	129	32.8%	0.6%	-	-	-
1991	99.9%	-	0.1%	0.1%	-	77.2%	22.6%	0.1%	5.1	164	133	33.2%	2.4%	-	-	-
1992	99.9%	-	0.1%	0.0%	-	88.9%	11.0%	0.1%	5.2	171	141	34.0%	4.4%	-	-	-
1993	100.0%	-	-	0.0%	-	91.5%	8.5%	-	5.2	170	140	34.8%	4.5%	-	-	-
1994	100.0%	-	0.0%	-	-	94.8%	5.2%	0.0%	5.2	169	144	39.9%	7.7%	-	-	-
1995	99.9%	-	0.1%	-	-	98.6%	1.3%	0.1%	5.2	168	153	51.4%	9.6%	-	-	-
1996	99.9%	-	0.1%	-	-	98.8%	1.1%	0.1%	5.2	167	155	56.4%	11.3%	-	0.3%	-
1997	99.9%	-	0.1%	-	-	99.2%	0.8%	0.1%	5.1	165	156	58.4%	10.8%	-	0.7%	-
1998	99.8%	-	0.2%	-	-	99.7%	0.1%	0.2%	5.2	167	160	59.6%	17.4%	-	1.4%	-
1999	99.8%	-	0.2%	-	-	99.8%	0.1%	0.2%	5.2	168	164	63.2%	16.4%	-	2.5%	-
2000	99.7%	0.1%	0.2%	-	-	99.7%	0.1%	0.2%	5.2	168	168	63.2%	22.2%	-	2.2%	-
2001	99.5%	0.2%	0.2%	-	-	99.8%	-	0.2%	5.2	167	169	65.3%	26.9%	-	3.3%	-
2002	99.3%	0.3%	0.4%	-	-	99.6%	-	0.4%	5.1	167	173	69.9%	32.8%	-	3.9%	-
2003	99.1%	0.6%	0.3%	-	-	99.7%	-	0.3%	5.1	166	176	73.4%	39.8%	-	2.0%	-
2004	98.9%	0.9%	0.3%	-	-	99.7%	-	0.3%	5.2	170	184	77.1%	43.7%	-	3.6%	-
2005	97.6%	1.9%	0.4%	-	-	99.6%	-	0.4%	5.1	168	183	77.2%	49.4%	1.0%	2.4%	-
2006	97.9%	1.5%	0.6%	-	-	99.4%	-	0.6%	5.2	173	194	81.3%	58.2%	2.0%	3.2%	-
2007	96.7%	3.2%	0.0%	-	-	99.7%	-	0.0%	5.0	167	191	84.6%	63.3%	0.9%	3.6%	-
2008	96.7%	3.3%	0.1%	-	3.1%	96.9%	-	0.1%	5.0	166	194	88.0%	62.7%	2.0%	4.5%	-
2009	96.4%	2.9%	0.6%	-	4.2%	95.2%	-	0.6%	4.7	157	186	92.2%	79.1%	1.8%	4.0%	-
2010	93.5%	5.6%	0.9%	-	9.2%	89.9%	-	0.9%	4.7	158	190	93.8%	91.8%	2.1%	4.1%	-
2011	95.6%	3.4%	0.9%	-	18.4%	80.7%	-	0.9%	4.7	161	200	94.6%	94.9%	1.3%	8.2%	-
2012	94.3%	4.7%	1.0%	-	27.6%	71.4%	-	1.0%	4.6	151	192	98.2%	97.7%	1.7%	9.7%	0.9%
2013	93.5%	5.4%	1.1%	-	37.7%	61.2%	-	1.1%	4.5	147	197	98.5%	98.1%	1.9%	15.3%	3.0%
2014	94.5%	4.2%	1.3%	-	43.2%	55.5%	-	1.3%	4.5	148	198	98.1%	97.9%	2.2%	18.4%	6.8%
2015	95.1%	4.0%	0.8%	-	44.6%	54.6%	-	0.8%	4.4	146	197	98.4%	98.5%	2.2%	18.3%	8.3%
2016 (prelim)	*96.3%*	*3.6%*	*0.1%*	-	*51.6%*	*48.3%*	-	*0.1%*	*4.4*	*144*	*199*	*96.3%*	*97.4%*	*2.3%*	*25.2%*	*8.3%*

Table 5.3.3

Engine Technologies and Parameters, Truck Only, AFVs Excluded

	Powertrain			Fuel Delivery Method					Avg. No. of							
Model Year	Gasoline	Gasoline Hybrid	Diesel	Carbureted	GDI	Port	TBI	Diesel	Cylinders	CID	HP	Multi-Valve	VVT	CD	Turbo	Stop/ Start
1975	100.0%	-	-	99.9%	-	-	0.1%	-	7.3	311	142	-	-	-	-	-
1976	100.0%	-	-	99.9%	-	-	0.1%	-	7.3	320	141	-	-	-	-	-
1977	100.0%	-	-	99.9%	-	-	0.1%	-	7.3	318	147	-	-	-	-	-
1978	99.2%	-	0.8%	99.1%	-	-	0.1%	0.8%	7.3	315	146	-	-	-	-	-
1979	98.2%	-	1.8%	97.9%	-	-	0.3%	1.8%	7.1	299	138	-	-	-	-	-
1980	96.5%	-	3.5%	94.9%	-	-	1.7%	3.5%	6.2	248	121	-	-	-	-	-
1981	94.4%	-	5.6%	93.3%	-	-	1.1%	5.6%	6.2	247	119	-	-	-	-	-
1982	90.6%	-	9.4%	89.9%	-	-	0.7%	9.4%	6.3	244	120	-	-	-	-	-
1983	95.2%	-	4.8%	94.6%	-	-	0.6%	4.8%	6.1	232	118	-	-	-	-	-
1984	97.6%	-	2.4%	95.0%	-	2.0%	0.6%	2.4%	6.0	225	118	-	-	-	-	-
1985	98.9%	-	1.1%	86.5%	-	8.9%	3.5%	1.1%	6.0	225	124	-	-	-	-	-
1986	99.3%	-	0.7%	59.4%	-	22.1%	17.8%	0.7%	5.7	212	123	-	-	-	-	-
1987	99.7%	-	0.3%	33.6%	-	33.3%	32.8%	0.3%	5.7	211	131	-	-	-	-	-
1988	99.8%	-	0.2%	12.4%	-	43.2%	44.3%	0.2%	6.0	228	141	-	-	-	-	-
1989	99.8%	-	0.2%	6.5%	-	45.9%	47.5%	0.2%	6.0	234	146	-	-	-	-	-
1990	99.8%	-	0.2%	3.8%	-	55.0%	40.9%	0.2%	6.2	237	151	-	-	-	-	-
1991	99.9%	-	0.1%	1.7%	-	55.3%	42.8%	0.1%	6.0	229	150	-	-	-	-	-
1992	99.9%	-	0.1%	1.6%	-	65.7%	32.6%	0.1%	6.1	236	155	-	-	-	-	-
1993	100.0%	-	-	1.0%	-	71.5%	27.5%	-	6.1	235	160	-	-	-	-	-
1994	100.0%	-	-	0.4%	-	76.2%	23.4%	-	6.2	241	166	5.2%	-	-	-	-
1995	100.0%	-	-	-	-	79.4%	20.6%	-	6.2	245	168	8.0%	-	-	-	-
1996	99.9%	-	0.1%	-	-	99.9%	-	0.1%	6.3	245	179	11.2%	-	-	-	-
1997	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.5	251	189	11.1%	-	-	-	-
1998	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.3	244	188	14.8%	-	-	-	-
1999	100.0%	-	0.0%	-	-	100.0%	-	0.0%	6.5	252	199	15.7%	-	-	-	-
2000	100.0%	-	-	-	-	100.0%	-	-	6.5	245	199	18.6%	4.6%	-	-	-
2001	100.0%	-	-	-	-	100.0%	-	-	6.6	249	212	25.9%	9.3%	-	-	-
2002	100.0%	-	-	-	-	100.0%	-	-	6.6	249	223	32.8%	16.0%	-	-	-
2003	100.0%	-	-	-	-	100.0%	-	-	6.6	248	224	34.6%	19.7%	-	0.2%	-
2004	100.0%	0.0%	0.0%	-	-	100.0%	-	0.0%	6.7	258	240	46.2%	32.9%	-	0.8%	-
2005	99.8%	0.1%	0.1%	-	-	99.9%	-	0.1%	6.6	251	242	51.1%	41.2%	0.5%	0.7%	-
2006	98.4%	1.5%	0.1%	-	-	99.9%	-	0.1%	6.5	247	240	58.4%	51.5%	5.9%	0.6%	-
2007	99.1%	0.8%	0.1%	-	-	99.9%	-	0.1%	6.6	253	254	53.3%	48.7%	16.4%	1.0%	-
2008	98.5%	1.3%	0.2%	-	1.1%	98.7%	-	0.2%	6.4	246	254	59.5%	51.6%	13.5%	1.0%	-
2009	98.8%	0.9%	0.3%	-	4.2%	95.4%	-	0.3%	6.2	236	252	66.7%	56.0%	18.3%	1.7%	-
2010	98.8%	0.9%	0.4%	-	6.8%	92.9%	-	0.4%	6.2	237	253	71.5%	70.5%	13.8%	1.8%	-
2011	99.1%	0.4%	0.5%	-	11.3%	88.1%	-	0.5%	6.2	236	271	75.2%	90.7%	20.6%	4.9%	-
2012	98.9%	0.4%	0.7%	-	13.5%	85.8%	-	0.7%	6.2	234	276	80.6%	94.9%	19.6%	6.1%	0.2%
2013	99.1%	0.4%	0.5%	-	18.4%	81.1%	-	0.5%	6.1	228	277	83.5%	96.9%	18.0%	11.7%	1.1%
2014	99.0%	0.4%	0.6%	-	29.7%	69.6%	-	0.6%	6.0	227	277	76.9%	98.0%	22.9%	9.9%	2.5%
2015	98.6%	0.3%	1.1%	-	39.0%	59.9%	-	1.1%	5.9	218	271	82.7%	96.7%	21.7%	12.6%	5.6%
2016	*97.3%*	*0.9%*	*1.8%*	-	*43.5%*	*54.8%*	-	*1.8%*	*5.8*	*211*	*273*	*87.2%*	*95.7%*	*19.5%*	*17.6%*	*10.6%*

C. Trends in Alternative Fuel Vehicles

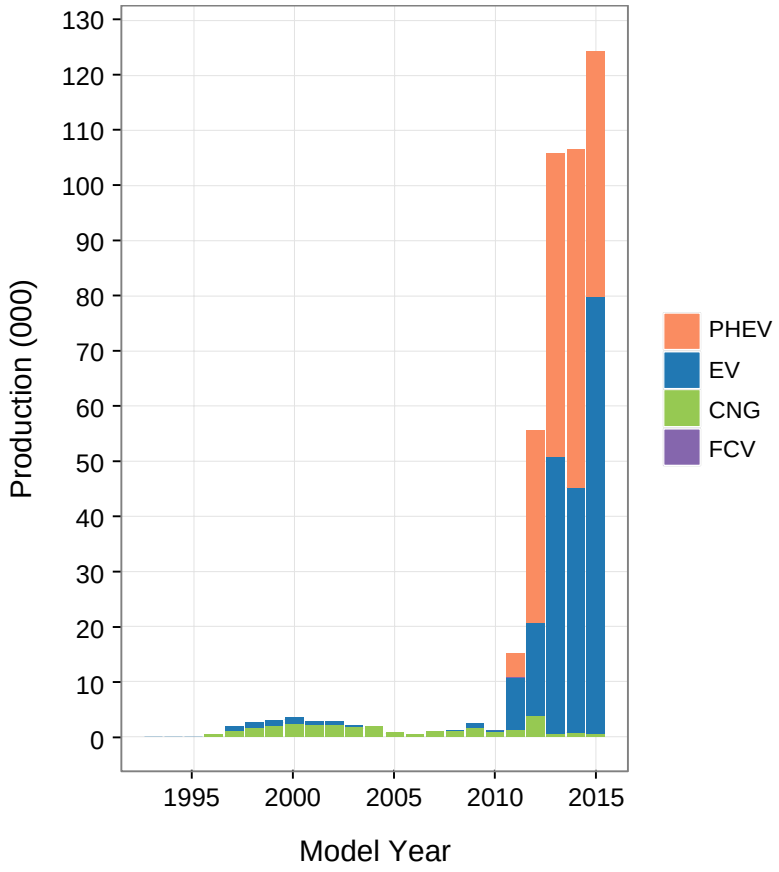
Alternative fuel vehicles have a long history in the U.S. automotive market. Electric vehicles, for example, were available at least as far back as the early 1900s. Gasoline and diesel vehicles, however, have long dominated new light vehicles sales. Over the course of this report, OEM vehicles that operate frequently on alternative fuels have been available only in small numbers,[5] though those limited production vehicles have in some cases created significant consumer and media interest. AFVs are projected to surpass 1% of production in MY 2016 (see Table 5.1), though we will not have final production data until next year's report.

As shown in Figure 5.15, the production of AFVs has increased dramatically in recent years. Prior to MY 2011, the AFVs available to consumers were only available in small numbers, and generally only as lease vehicles. The AFV market began to change in MY 2011, with the introduction of several new vehicles, including the high profile launches of the Chevrolet Volt plug in hybrid electric vehicle (PHEV) and the Nissan Leaf electric vehicle (EV). In MY 2016, there are now 14 PHEVs available, and 12 EVs, 2 fuel cell vehicles, and one dual fuel natural gas vehicle. Dedicated CNG vehicles have been available from at least one OEM with some regularity, but have never sold more than a few thousand vehicles in any year. Figure 5.15 shows the historical sales of EVs, PHEVs, and dedicated CNG vehicles since 1995 (we do not have reliable data on alternative fuel vehicles back to 1975).

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

Figure 5.15

Historical Production of EVs, PHEVs, FCVs, and CNG Vehicles, MY 1995–2015



Consistent with the rest of this report, Figure 5.15 was largely compiled from manufacturer CAFE submissions. Some of the historical production data was supplemented with data from Ward's and other publically available production data. Figure 5.15 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 OEMs, and does not include data on vehicles converted to alternative fuels in the aftermarket. For a more detailed description of individual AFVs and the parameters used to measure fuel economy and emissions, see section 7.

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 shares across the fleet. This section presents analysis of trends in transmission technologies, including AFVs.

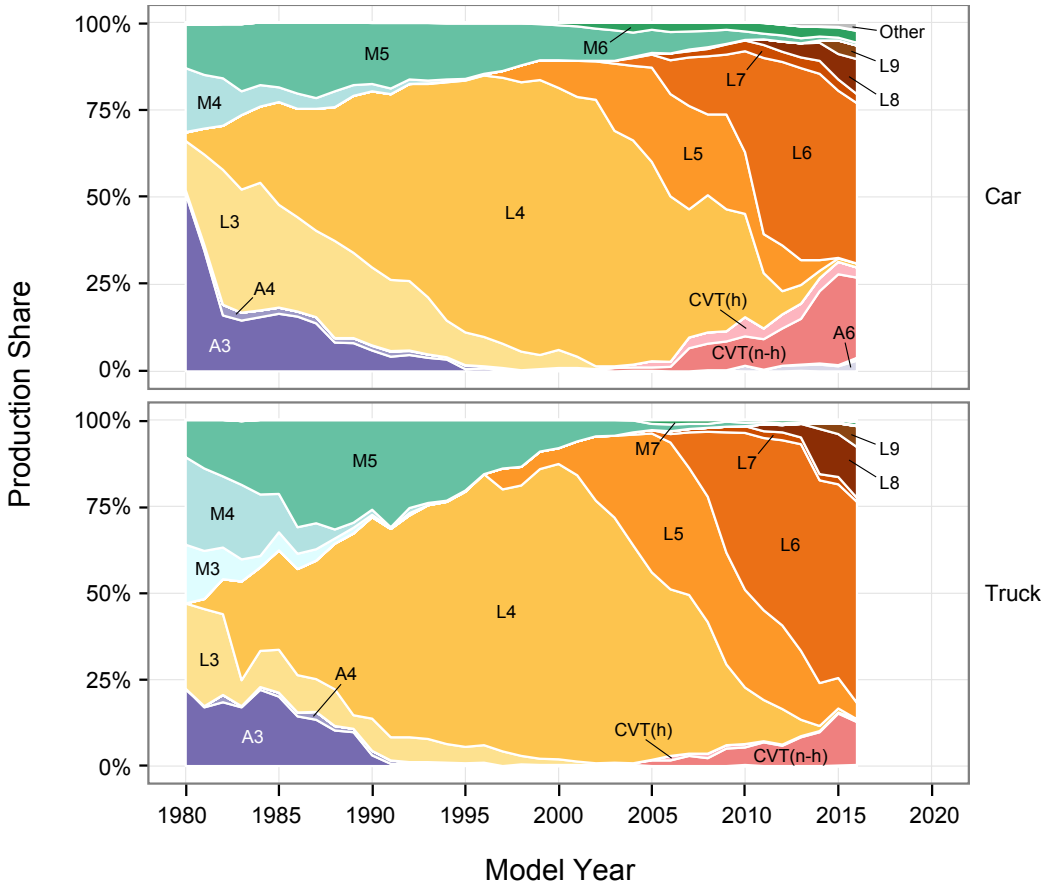
Figure 5.16 shows the evolution of transmission production share for cars and trucks since MY 1980. For this analysis, transmissions are separated into manual transmissions, CVTs, and automatic transmissions. Automatic transmissions are further separated into those with and without lockup mechanisms, which can lock up the torque converter in an automatic transmission under certain driving conditions and improve efficiency. CVT transmissions have also been split into hybrid and non-hybrid versions to reflect the fact that hybrid CVT transmissions are generally very different mechanically from traditional CVT transmissions.

Dual clutch transmissions (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 Tables 5.4.1 through 5.4.3 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 transmission classifications in general, to be able to quantify DCTs in future Trends reports.

Figure 5.16 shows transmission production share for the individual car and truck fleets, beginning 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 5.16) 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.

Figure 5.16

Transmission Production Share



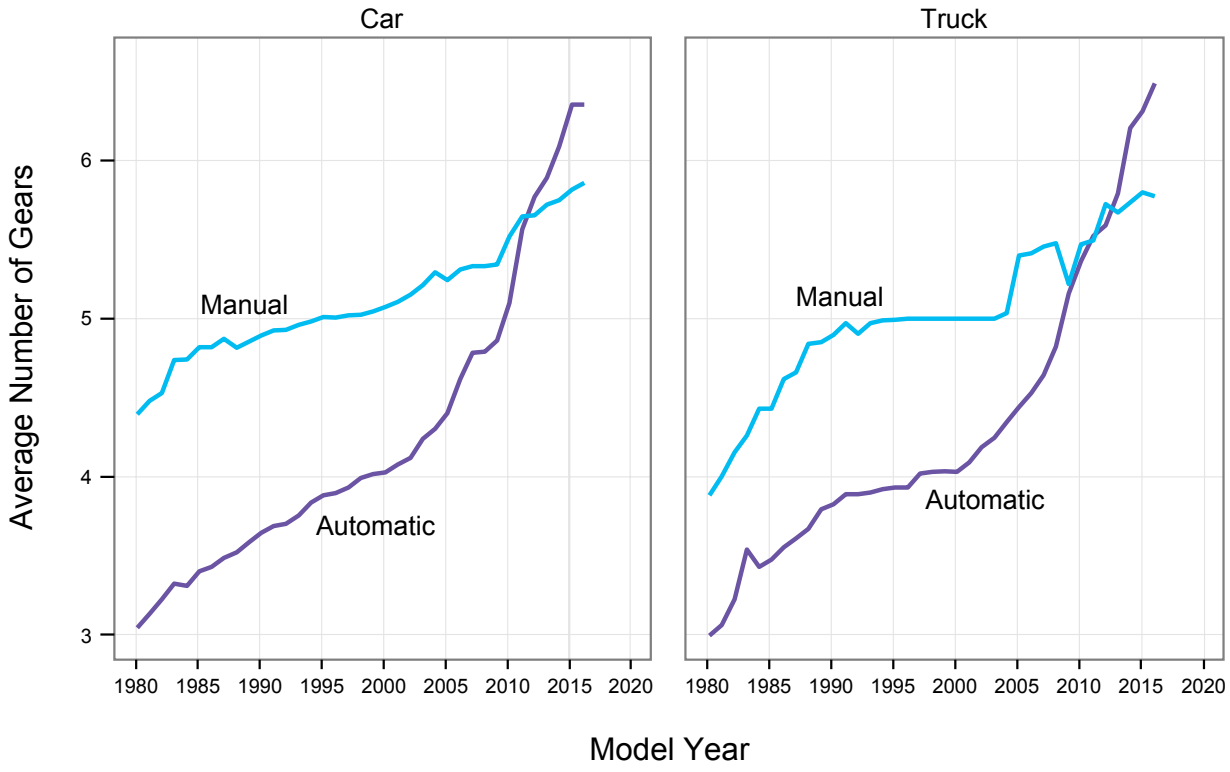
Transmission	Lockup?	Number of Gears	Key
Automatic Semi-Automatic Automated Manual	No	3	A3
		4	A4
		5	A5
		6	A6
		7	A7
	Yes	2	L2
		3	L3
		4	L4
		5	L5
		6	L6
		7	L7
		8	L8
		9	L9
Manual	–	3	M3
		4	M4
		5	M5
		6	M6
		7	M7
Continuously Variable (non-hybrid)	–	–	CVT(n-h)
Continuously Variable (hybrid)	–	–	CVT(h)
Other	–	–	Other

Six speed transmissions became the most popular transmission choice in MY 2010 and reached 60% of new vehicle production in MY 2013. However, six speed transmissions may already have peaked, as transmissions with more than six speeds and CVTs have begun to expand quickly. CVTs are projected to be installed in over 20% of all new vehicles in MY 2016 (including hybrids). This is a significant increase considering that, as recently as MY 2006, CVTs were installed on less than 3% of vehicles produced. Transmissions with 7 or more speeds are projected to be installed in almost 20% of vehicles in MY 2016, and are also quickly increasing. 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 5.17 shows the average number of gears in new vehicle transmissions since MY 1980 for automatic and manual transmissions. During that time, the average number of gears in a new vehicle has grown from 3.5 to a projected level of 6.0 in MY 2016. The average number of gears in new vehicles is climbing for car, trucks, automatic transmissions, and manual transmissions.

Figure 5.17

Average Number of Transmission Gears for New Vehicles

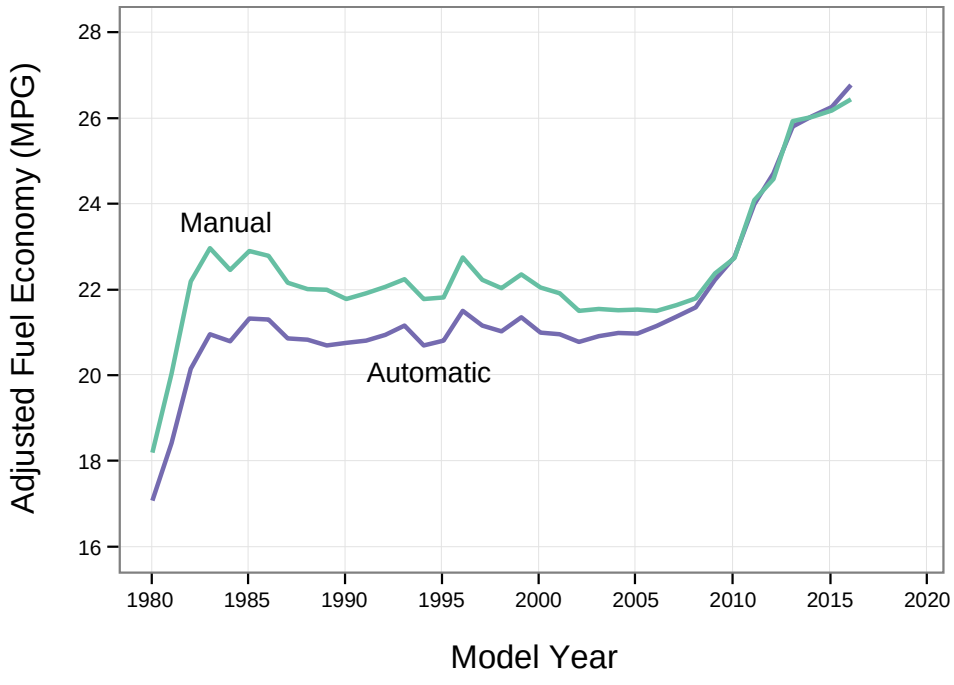


In MY 1980, automatic transmissions, on average, had fewer gears than manual transmissions. However, automatic transmissions have added gears faster than manual transmissions and now the average automatic transmission has more gears than the average manual transmission. There has also been a large shift away from manual transmissions. Manual transmission production peaked in MY 1980 at nearly 35% of production, and has since fallen to 2.6% in MY 2015. Today, manual transmissions are used primarily in small vehicles, some sports cars, and a few pickups.

In the past, automatic transmissions have generally been less efficient than manual transmissions, largely due to inefficiencies in the automatic transmission torque converter. Figure 5.18 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 average fuel economy of vehicles with automatic transmissions appears to have increased to a point where it is now slightly higher than the average 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 faster than in manual transmissions.

Figure 5.18

Comparison of Manual and Automatic Transmission Adjusted Fuel Economy



E. Trends in Drive Types

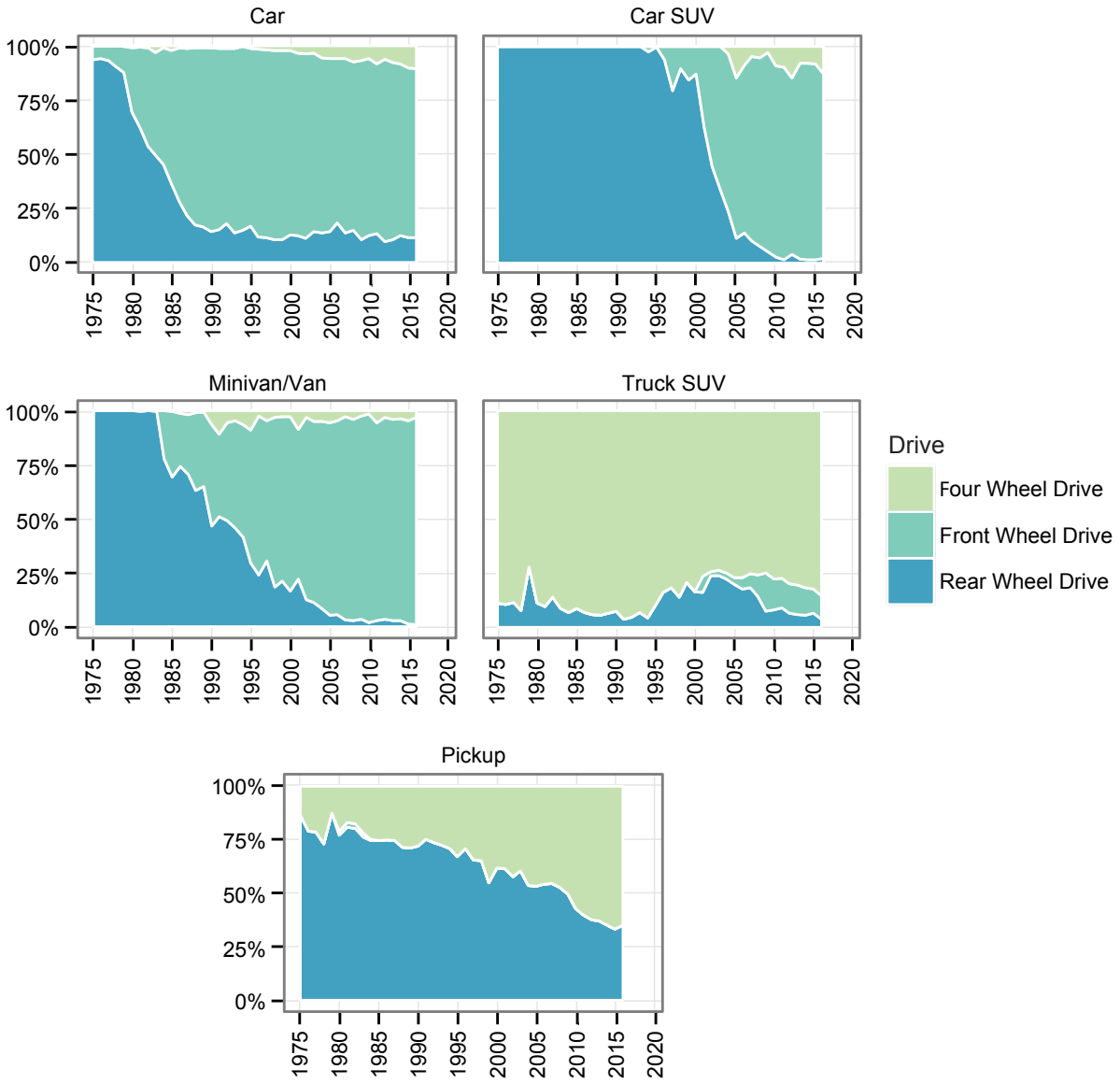
There has been a long and steady trend in new vehicle drive type away from rear wheel drive vehicles towards front wheel drive and four wheel drive vehicles, as shown in Figure 5.19. In MY 1975, over 91% of new vehicles were produced with rear wheel drive. During the 1980s, production of rear wheel drive 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 11% for MY 2016. 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 to date. 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 34% in MY 2016, 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 5.19

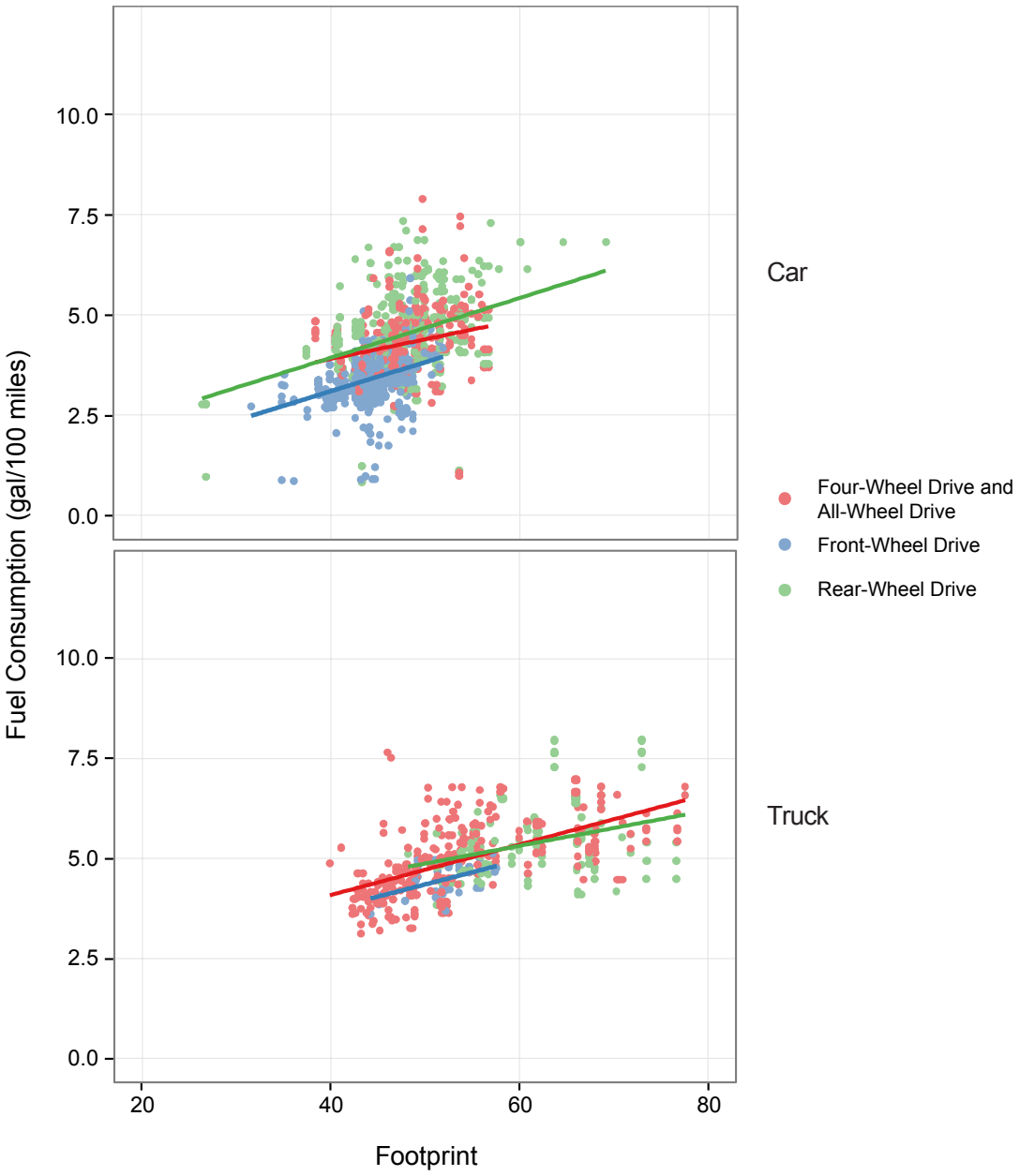
Front, Rear, and Four Wheel Drive Usage - Production Share by Vehicle Type



There are noticeable differences in fuel economy between vehicles with different drive types. Figure 5.20 shows the fuel consumption of MY 2015 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 20% lower. There are certainly other factors involved (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 5.20 are generated for each combination of adjusted fuel consumption and footprint.

Figure 5.20

Differences in Adjusted Fuel Consumption Trends for FWD, RWD, and 4WD/AWD Vehicles, MY 2015



Tables 5.4.1, 5.4.2, and 5.4.3 summarize transmission production data by year for the combined car and truck fleet, cars only, and trucks only, respectively. Tables 5.5 summarizes the drive characteristics by year for the combined car and truck fleet, cars only, and trucks only, respectively.

Table 5.4.1

Transmission Technologies, Both Car and Truck

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT (Hybrid)	CVT (Non-Hybrid)	Other	4 Gears or Fewer	5 Gears	6 Gears	7 Gears	8 Gears	9+ Gears	CVT (Hybrid)	CVT (Non-Hybrid)	Average Number of Gears
1975	23.0%	0.2%	76.8%	-	-	-	99.0%	1.0%	-	-	-	-	-	-	-
1976	20.9%	-	79.1%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1977	19.8%	-	80.2%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1978	22.7%	5.5%	71.9%	-	-	-	92.7%	7.3%	-	-	-	-	-	-	-
1979	24.2%	7.3%	68.1%	-	-	0.4%	93.8%	6.2%	-	-	-	-	-	-	3.3
1980	34.6%	18.1%	46.8%	-	-	0.5%	87.9%	12.1%	-	-	-	-	-	-	3.5
1981	33.6%	33.0%	32.9%	-	-	0.5%	85.6%	14.4%	-	-	-	-	-	-	3.5
1982	32.4%	47.8%	19.4%	-	-	0.4%	84.4%	15.6%	-	-	-	-	-	-	3.6
1983	30.5%	52.1%	17.0%	-	-	0.4%	80.9%	19.1%	-	-	-	-	-	-	3.7
1984	28.4%	52.8%	18.8%	-	-	0.0%	81.3%	18.7%	-	-	-	-	-	-	3.7
1985	26.5%	54.5%	19.1%	-	-	-	80.7%	19.3%	-	-	-	-	-	-	3.8
1986	29.8%	53.5%	16.7%	-	-	-	76.8%	23.2%	-	-	-	-	-	-	3.8
1987	29.1%	55.4%	15.5%	-	-	0.0%	76.2%	23.8%	-	-	-	-	-	-	3.9
1988	27.6%	62.2%	10.2%	-	-	-	76.8%	23.2%	-	-	-	-	-	-	3.9
1989	24.6%	65.5%	9.9%	-	0.1%	0.0%	78.5%	21.4%	0.0%	-	-	-	-	0.1%	3.9
1990	22.2%	71.2%	6.5%	-	0.0%	0.0%	79.9%	20.0%	0.1%	-	-	-	-	0.0%	4.0
1991	23.9%	71.6%	4.5%	-	0.0%	-	77.3%	22.6%	0.0%	-	-	-	-	0.0%	4.0
1992	20.7%	74.8%	4.5%	-	0.0%	-	80.8%	19.2%	0.1%	-	-	-	-	0.0%	4.0
1993	19.8%	76.5%	3.7%	-	0.0%	-	80.9%	19.0%	0.1%	-	-	-	-	0.0%	4.0
1994	19.5%	77.6%	3.0%	-	-	-	80.8%	19.0%	0.2%	-	-	-	-	-	4.1
1995	17.9%	80.7%	1.4%	-	-	-	82.0%	17.7%	0.2%	-	-	-	-	-	4.1
1996	15.2%	83.5%	1.3%	-	0.0%	0.0%	84.7%	15.1%	0.2%	-	-	-	-	0.0%	4.1
1997	14.0%	85.5%	0.5%	-	0.0%	-	82.4%	17.3%	0.2%	-	-	-	-	0.0%	4.1
1998	12.8%	86.7%	0.5%	-	0.0%	-	82.1%	17.7%	0.2%	-	-	-	-	0.0%	4.1
1999	10.1%	89.4%	0.5%	-	0.0%	-	84.4%	15.3%	0.3%	-	-	-	-	0.0%	4.1
2000	9.7%	89.5%	0.7%	-	0.0%	-	83.7%	15.8%	0.5%	-	-	-	-	0.0%	4.1
2001	9.0%	90.3%	0.6%	0.1%	0.0%	-	80.7%	18.5%	0.7%	-	-	-	0.1%	0.0%	4.2
2002	8.2%	91.4%	0.3%	0.1%	0.1%	-	77.1%	21.6%	1.1%	-	-	-	0.1%	0.1%	4.2
2003	8.0%	90.8%	0.1%	0.3%	0.8%	-	69.2%	28.1%	1.7%	-	-	-	0.3%	0.8%	4.3
2004	6.8%	91.8%	0.3%	0.4%	0.7%	-	63.9%	31.8%	3.0%	0.2%	-	-	0.4%	0.7%	4.4
2005	6.2%	91.5%	0.1%	1.0%	1.3%	-	56.0%	37.3%	4.1%	0.2%	-	-	1.0%	1.3%	4.5
2006	6.5%	90.6%	0.0%	1.5%	1.4%	-	47.7%	39.2%	8.8%	1.4%	-	-	1.5%	1.4%	4.6
2007	5.6%	87.1%	0.0%	2.1%	5.1%	-	40.5%	36.1%	14.4%	1.5%	0.2%	-	2.1%	5.1%	4.8
2008	5.2%	86.8%	0.2%	2.4%	5.5%	-	38.8%	31.9%	19.4%	1.8%	0.2%	-	2.4%	5.5%	4.8
2009	4.8%	85.6%	0.2%	2.1%	7.3%	-	31.2%	32.2%	24.5%	2.5%	0.1%	-	2.1%	7.3%	5.0
2010	3.8%	84.1%	1.2%	3.8%	7.2%	-	24.6%	23.5%	38.1%	2.7%	0.2%	-	3.8%	7.2%	5.2
2011	3.2%	86.5%	0.3%	2.0%	8.0%	-	14.2%	18.7%	52.3%	3.1%	1.7%	-	2.0%	8.0%	5.5
2012	3.6%	83.4%	1.1%	2.7%	9.2%	-	8.1%	18.2%	56.3%	2.8%	2.6%	-	2.7%	9.2%	5.5
2013	3.5%	80.4%	1.4%	2.9%	11.8%	-	5.4%	12.8%	60.1%	2.8%	4.1%	-	2.9%	11.8%	5.6
2014	2.8%	76.7%	1.6%	2.3%	16.6%	-	2.2%	7.8%	58.4%	3.3%	8.4%	1.1%	2.3%	16.6%	5.9
2015	2.6%	72.3%	1.4%	2.2%	21.5%	-	1.5%	4.5%	54.2%	3.1%	9.5%	3.5%	2.2%	21.5%	5.9
2016 (prelim)	*3.1%*	*72.0%*	*3.5%*	*2.1%*	*19.2%*	-	*1.9%*	*2.4%*	*55.0%*	*2.8%*	*11.8%*	*4.7%*	*2.1%*	*19.2%*	*6.0*

Table 5.4.2

Transmission Technologies, Car Only

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT (Hybrid)	CVT (Non-Hybrid)	Other	4 Gears or Fewer	5 Gears	6 Gears	7 Gears	8 Gears	9+ Gears	CVT (Hybrid)	CVT (Non-Hybrid)	Average Number of Gears
1975	19.7%	0.3%	80.0%	-	-	-	98.7%	1.3%	-	-	-	-	-	-	-
1976	17.2%	-	82.8%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1977	16.9%	-	83.1%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1978	19.9%	7.1%	73.0%	-	-	-	90.7%	9.3%	-	-	-	-	-	-	-
1979	21.1%	8.8%	69.6%	-	-	0.5%	93.1%	6.9%	-	-	-	-	-	-	3.3
1980	30.9%	16.8%	51.6%	-	-	0.6%	87.6%	12.4%	-	-	-	-	-	-	3.5
1981	29.9%	33.3%	36.2%	-	-	0.6%	85.5%	14.5%	-	-	-	-	-	-	3.5
1982	29.2%	51.3%	19.1%	-	-	0.5%	84.6%	15.4%	-	-	-	-	-	-	3.6
1983	26.0%	56.7%	16.8%	-	-	0.5%	80.8%	19.2%	-	-	-	-	-	-	3.7
1984	24.1%	58.3%	17.5%	-	-	0.0%	82.1%	17.9%	-	-	-	-	-	-	3.7
1985	22.8%	58.9%	18.4%	-	-	-	81.4%	18.6%	-	-	-	-	-	-	3.7
1986	24.7%	58.1%	17.1%	-	-	-	79.7%	20.3%	-	-	-	-	-	-	3.8
1987	24.8%	59.7%	15.5%	-	-	-	78.4%	21.6%	-	-	-	-	-	-	3.8
1988	24.3%	66.2%	9.5%	-	-	-	80.2%	19.8%	-	-	-	-	-	-	3.8
1989	21.1%	69.3%	9.5%	-	0.1%	-	81.9%	17.9%	0.0%	-	-	-	-	0.1%	3.9
1990	19.8%	72.8%	7.4%	-	0.0%	-	82.4%	17.5%	0.1%	-	-	-	-	0.0%	3.9
1991	20.6%	73.7%	5.7%	-	0.0%	-	81.0%	18.9%	0.1%	-	-	-	-	0.0%	3.9
1992	17.6%	76.4%	6.0%	-	0.0%	-	83.6%	16.3%	0.1%	-	-	-	-	0.0%	3.9
1993	17.5%	77.6%	4.9%	-	0.0%	-	83.2%	16.6%	0.2%	-	-	-	-	0.0%	4.0
1994	16.9%	78.9%	4.1%	-	-	-	83.4%	16.3%	0.3%	-	-	-	-	-	4.0
1995	16.3%	81.9%	1.8%	-	-	-	83.4%	16.2%	0.4%	-	-	-	-	-	4.1
1996	14.9%	83.6%	1.5%	-	0.0%	-	84.9%	14.7%	0.3%	-	-	-	-	0.0%	4.1
1997	13.9%	85.2%	0.8%	-	0.1%	-	84.1%	15.5%	0.3%	-	-	-	-	0.1%	4.1
1998	12.2%	87.4%	0.3%	-	0.1%	-	82.8%	16.8%	0.3%	-	-	-	-	0.1%	4.1
1999	10.8%	88.6%	0.6%	-	0.0%	-	83.4%	16.1%	0.5%	-	-	-	-	0.0%	4.1
2000	10.8%	88.1%	1.0%	-	0.0%	-	81.3%	17.9%	0.8%	-	-	-	-	0.0%	4.1
2001	11.0%	88.0%	0.8%	0.2%	0.0%	-	78.5%	20.2%	1.2%	-	-	-	0.2%	0.0%	4.2
2002	10.9%	88.4%	0.2%	0.3%	0.1%	-	77.4%	20.3%	1.9%	-	-	-	0.3%	0.1%	4.2
2003	10.9%	87.7%	-	0.5%	1.0%	-	67.5%	27.9%	3.1%	-	-	-	0.5%	1.0%	4.3
2004	9.8%	88.2%	0.2%	0.8%	0.9%	-	64.5%	28.4%	5.0%	0.4%	-	-	0.8%	0.9%	4.4
2005	8.8%	88.4%	0.1%	1.7%	1.1%	-	57.3%	33.7%	5.8%	0.4%	-	-	1.7%	1.1%	4.5
2006	8.8%	88.4%	0.1%	1.5%	1.2%	-	47.5%	35.4%	12.5%	1.9%	-	-	1.5%	1.2%	4.7
2007	7.8%	82.5%	0.0%	3.0%	6.7%	-	36.8%	34.7%	16.5%	1.9%	0.4%	-	3.0%	6.7%	4.8
2008	7.2%	81.7%	0.3%	3.2%	7.7%	-	39.3%	28.2%	19.0%	2.2%	0.4%	-	3.2%	7.7%	4.8
2009	6.2%	82.4%	0.3%	2.8%	8.3%	-	35.1%	31.4%	19.3%	2.9%	0.2%	-	2.8%	8.3%	4.9
2010	5.0%	79.4%	1.6%	5.5%	8.4%	-	29.5%	20.2%	33.0%	3.1%	0.3%	-	5.5%	8.4%	5.1
2011	4.6%	83.0%	0.5%	3.1%	8.8%	-	15.9%	12.9%	53.7%	3.9%	1.6%	-	3.1%	8.8%	5.6
2012	4.9%	78.4%	1.8%	4.0%	11.0%	-	6.9%	14.8%	57.2%	3.2%	2.9%	-	4.0%	11.0%	5.5
2013	4.8%	75.0%	2.2%	4.3%	13.7%	-	5.8%	8.6%	60.0%	3.3%	4.2%	-	4.3%	13.7%	5.5
2014	4.0%	68.4%	2.7%	3.7%	21.3%	-	2.6%	4.4%	58.0%	4.3%	5.2%	0.6%	3.7%	21.3%	5.8
2015	3.9%	63.9%	2.3%	3.6%	26.3%	-	1.8%	1.1%	52.4%	3.8%	7.3%	3.8%	3.6%	26.3%	5.9
2016 (prelim)	*4.3%*	*64.3%*	*5.1%*	*3.0%*	*23.3%*	-	*2.8%*	*0.8%*	*52.7%*	*3.6%*	*10.0%*	*3.9%*	*3.0%*	*23.3%*	*5.9*

Table 5.4.3

Transmission Technologies, Truck Only

Model Year	Manual	Automatic with Lockup	Automatic without Lockup	CVT (Hybrid)	CVT (Non-Hybrid)	Other	4 Gears or Fewer	5 Gears	6 Gears	7 Gears	8 Gears	9+ Gears	CVT (Hybrid)	CVT (Non-Hybrid	Average Number of Gears
1975	36.9%	-	63.1%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1976	34.7%	-	65.3%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1977	31.6%	-	68.4%	-	-	-	100.0%	-	-	-	-	-	-	-	-
1978	32.1%	-	67.9%	-	-	-	99.3%	0.7%	-	-	-	-	-	-	-
1979	35.1%	2.1%	62.8%	-	-	-	96.0%	4.0%	-	-	-	-	-	-	3.3
1980	53.0%	24.5%	22.4%	-	-	-	89.2%	10.8%	-	-	-	-	-	-	3.5
1981	51.6%	31.1%	17.3%	-	-	-	86.1%	13.9%	-	-	-	-	-	-	3.6
1982	45.9%	33.4%	20.7%	-	-	-	83.8%	16.2%	-	-	-	-	-	-	3.7
1983	46.3%	36.0%	17.4%	-	-	0.3%	81.6%	18.4%	-	-	-	-	-	-	3.9
1984	42.5%	34.6%	22.9%	-	-	0.0%	78.6%	21.4%	-	-	-	-	-	-	3.9
1985	37.6%	41.1%	21.2%	-	-	-	78.6%	21.4%	-	-	-	-	-	-	3.8
1986	43.0%	41.5%	15.5%	-	-	-	69.1%	30.9%	-	-	-	-	-	-	4.0
1987	40.5%	43.8%	15.7%	-	-	0.1%	70.1%	29.9%	-	-	-	-	-	-	4.0
1988	35.8%	52.5%	11.7%	-	-	-	68.4%	31.6%	-	-	-	-	-	-	4.1
1989	32.8%	56.4%	10.8%	-	-	0.0%	70.3%	29.7%	-	-	-	-	-	-	4.1
1990	28.1%	67.5%	4.4%	-	-	0.0%	74.1%	25.9%	-	-	-	-	-	-	4.1
1991	31.5%	66.8%	1.7%	-	-	-	69.0%	31.0%	-	-	-	-	-	-	4.2
1992	27.5%	71.3%	1.2%	-	-	-	74.6%	25.4%	-	-	-	-	-	-	4.2
1993	24.7%	74.2%	1.1%	-	-	-	76.0%	24.0%	-	-	-	-	-	-	4.2
1994	23.7%	75.3%	1.0%	-	-	-	76.7%	23.3%	-	-	-	-	-	-	4.2
1995	20.7%	78.5%	0.9%	-	-	-	79.6%	20.4%	-	-	-	-	-	-	4.2
1996	15.6%	83.4%	1.0%	-	-	0.0%	84.4%	15.6%	-	-	-	-	-	-	4.1
1997	14.1%	85.8%	0.1%	-	-	-	79.9%	20.1%	-	-	-	-	-	-	4.2
1998	13.6%	85.8%	0.6%	-	-	-	81.1%	18.9%	-	-	-	-	-	-	4.2
1999	9.2%	90.4%	0.4%	-	-	-	85.8%	14.2%	-	-	-	-	-	-	4.1
2000	8.2%	91.5%	0.3%	-	-	-	87.3%	12.7%	-	-	-	-	-	-	4.1
2001	6.3%	93.4%	0.3%	-	-	-	84.0%	16.0%	-	-	-	-	-	-	4.2
2002	4.7%	94.9%	0.3%	-	0.0%	-	76.7%	23.3%	-	-	-	-	-	0.0%	4.2
2003	4.6%	94.4%	0.3%	-	0.6%	-	71.1%	28.2%	-	-	-	-	-	0.6%	4.3
2004	3.5%	95.6%	0.3%	-	0.6%	-	63.2%	35.5%	0.8%	-	-	-	-	0.6%	4.4
2005	2.9%	95.3%	-	0.1%	1.7%	-	54.3%	41.9%	2.1%	-	-	-	0.1%	1.7%	4.5
2006	3.3%	93.7%	-	1.5%	1.6%	-	48.0%	44.3%	3.8%	0.8%	-	-	1.5%	1.6%	4.6
2007	2.6%	93.8%	-	0.7%	2.9%	-	45.8%	38.0%	11.5%	1.0%	-	-	0.7%	2.9%	4.7
2008	2.2%	94.1%	-	1.3%	2.3%	-	37.9%	37.4%	19.9%	1.2%	-	-	1.3%	2.3%	4.8
2009	2.0%	92.0%	-	0.9%	5.1%	-	23.4%	33.7%	35.2%	1.6%	-	-	0.9%	5.1%	5.2
2010	1.8%	91.9%	0.4%	0.8%	5.1%	-	16.4%	29.1%	46.7%	1.9%	-	-	0.8%	5.1%	5.4
2011	1.3%	91.4%	0.0%	0.4%	6.9%	-	11.9%	26.5%	50.5%	1.9%	1.9%	-	0.4%	6.9%	5.5
2012	1.4%	92.4%	-	0.3%	5.9%	-	10.4%	24.4%	54.6%	2.2%	2.2%	-	0.3%	5.9%	5.6
2013	1.1%	90.2%	-	0.4%	8.4%	-	4.7%	20.2%	60.3%	2.0%	4.0%	-	0.4%	8.4%	5.7
2014	0.9%	88.9%	-	0.3%	9.8%	-	1.5%	12.7%	59.1%	1.8%	13.0%	1.8%	0.3%	9.8%	6.1
2015	0.9%	83.6%	0.2%	0.3%	15.0%	-	1.1%	9.0%	56.7%	2.2%	12.5%	3.1%	0.3%	15.0%	6.0
2016 (prelim)	*1.2%*	*84.6%*	*0.9%*	*0.8%*	*12.5%*	-	*0.6%*	*5.0%*	*58.9%*	*1.5%*	*14.8%*	*6.0%*	*0.8%*	*12.5%*	*6.2*

Table 5.5

Production Share by Drive Technology

	Car			Truck			Both		
Model Year	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive	Front Wheel Drive	Rear Wheel Drive	Four Wheel Drive
1975	6.5%	93.5%	-	-	82.8%	17.2%	5.3%	91.4%	3.3%
1976	5.8%	94.2%	-	-	77.0%	23.0%	4.6%	90.6%	4.8%
1977	6.8%	93.2%	-	-	76.2%	23.8%	5.5%	89.8%	4.7%
1978	9.6%	90.4%	-	-	70.9%	29.1%	7.4%	86.0%	6.6%
1979	11.9%	87.8%	0.3%	-	81.9%	18.1%	9.2%	86.5%	4.3%
1980	29.7%	69.4%	0.9%	1.4%	73.6%	25.0%	25.0%	70.1%	4.9%
1981	37.0%	62.2%	0.7%	1.9%	78.0%	20.1%	31.0%	65.0%	4.0%
1982	45.6%	53.6%	0.8%	1.7%	78.1%	20.2%	37.0%	58.4%	4.6%
1983	47.1%	49.9%	3.1%	1.4%	72.5%	26.1%	37.0%	54.8%	8.1%
1984	53.5%	45.5%	1.0%	5.0%	63.5%	31.5%	42.1%	49.8%	8.2%
1985	61.1%	36.8%	2.1%	7.3%	61.4%	31.3%	47.8%	42.9%	9.3%
1986	70.7%	28.2%	1.0%	5.9%	63.4%	30.7%	52.6%	38.0%	9.3%
1987	76.4%	22.6%	1.1%	7.6%	60.2%	32.2%	57.7%	32.8%	9.6%
1988	80.9%	18.3%	0.8%	9.2%	56.7%	34.1%	60.0%	29.5%	10.5%
1989	81.6%	17.4%	1.0%	10.1%	57.1%	32.8%	60.2%	29.3%	10.5%
1990	84.0%	15.0%	1.0%	15.8%	52.4%	31.8%	63.8%	26.1%	10.1%
1991	81.1%	17.5%	1.3%	10.3%	52.3%	37.3%	59.6%	28.1%	12.3%
1992	78.4%	20.5%	1.1%	14.5%	52.1%	33.4%	58.4%	30.4%	11.2%
1993	80.6%	18.3%	1.1%	16.8%	50.6%	32.7%	59.9%	28.8%	11.3%
1994	81.3%	18.3%	0.4%	13.8%	47.0%	39.2%	55.6%	29.2%	15.2%
1995	80.1%	18.8%	1.1%	18.4%	39.3%	42.3%	57.6%	26.3%	16.2%
1996	83.7%	14.8%	1.4%	20.9%	39.8%	39.2%	60.0%	24.3%	15.7%
1997	83.8%	14.5%	1.7%	14.2%	40.6%	45.2%	56.1%	24.9%	19.0%
1998	82.9%	15.0%	2.1%	19.3%	35.5%	45.1%	56.4%	23.5%	20.1%
1999	83.2%	14.7%	2.1%	17.5%	34.4%	48.1%	55.8%	22.9%	21.3%
2000	80.4%	17.7%	2.0%	20.0%	33.8%	46.3%	55.5%	24.3%	20.2%
2001	80.3%	16.7%	3.0%	16.3%	34.8%	48.8%	53.8%	24.2%	22.0%
2002	82.9%	13.5%	3.6%	15.4%	33.1%	51.6%	52.7%	22.3%	25.0%
2003	80.9%	15.9%	3.2%	15.4%	34.1%	50.4%	50.7%	24.3%	25.0%
2004	80.2%	14.5%	5.3%	12.5%	31.0%	56.5%	47.7%	22.4%	29.8%
2005	79.2%	14.2%	6.6%	20.1%	27.7%	52.2%	53.0%	20.2%	26.8%
2006	75.9%	18.0%	6.0%	18.9%	28.0%	53.1%	51.9%	22.3%	25.8%
2007	81.0%	13.4%	5.6%	16.1%	28.4%	55.5%	54.3%	19.6%	26.1%
2008	78.8%	14.1%	7.1%	18.4%	24.8%	56.8%	54.2%	18.5%	27.3%
2009	83.5%	10.2%	6.3%	21.0%	20.5%	58.5%	62.9%	13.6%	23.5%
2010	82.5%	11.2%	6.3%	20.9%	18.0%	61.0%	59.6%	13.7%	26.7%
2011	80.1%	11.3%	8.6%	17.7%	17.3%	65.0%	53.8%	13.8%	32.4%
2012	83.8%	8.8%	7.5%	20.9%	14.8%	64.3%	61.4%	10.9%	27.7%
2013	83.0%	9.3%	7.7%	18.1%	14.5%	67.5%	59.7%	11.1%	29.1%
2014	81.3%	10.6%	8.2%	17.5%	14.2%	68.3%	55.3%	12.1%	32.6%
2015	80.4%	9.7%	9.9%	16.0%	12.6%	71.4%	52.9%	10.9%	36.1%
2016 (prelim)	*79.2%*	*9.9%*	*10.9%*	*16.0%*	*12.4%*	*71.6%*	*55.2%*	*10.8%*	*34.0%*