The 2025 EPA Automotive Trends Report

Fuel Economy and Technology since 1975

United States Environmental Protection Agency

EPA-420-R-26-001 February 2026

This technical report does not necessarily represent final EPA decisions, positions, or validation of compliance data reported to EPA by manufacturers. It is intended to present technical analysis of issues using data that are currently available and that may be subject to change. Historic data have been adjusted, when appropriate, to reflect the result of compliance investigations by EPA or any other corrections necessary to maintain data integrity.

The purpose of the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments. This edition of the report supersedes all previous versions.

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1. Introduction

Since 1975, the EPA has collected data on every new light-duty vehicle model sold in the United States either from testing performed by the EPA at the National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan or directly from manufacturers using official EPA test procedures. These data are collected to support several important national programs, including the EPA criteria pollutant standards, the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) Corporate Average Fuel Economy (CAFE) standards, and vehicle Fuel Economy and Environment labels. This report contains a uniquely comprehensive analysis of the automotive industry since 1975, based on the EPA's expansive data set, and provides transparency to the public on data collected by the Agency.

A. What's New This Year

This report is updated each year to reflect the most recent data available to the EPA for all model years, relevant regulatory changes, methodology changes, and any other changes relevant to the auto industry. These changes can affect multiple model years; therefore, this version of the report supersedes all previous reports. Significant developments relevant for this edition of the report include the following:

- In February 2026, the EPA finalized a rulemaking that eliminated greenhouse gas standards for light-, medium-, and heavy-duty vehicles and engines. Due to this action, the EPA is not publishing the portion of this report that previously focused on manufacturer greenhouse gas regulatory compliance.
- This report includes additional analysis on the impact of battery electric vehicles (BEVs) and plug-in hybrid vehicles (PHEVs) and their impact on overall vehicle and technology trends.
- The EPA has also updated the data available on the report webpage to provide more details on the data used for this report. The report data webpage can be found here: https://www.epa.gov/automotive-trends/explore-automotive-trends-data.

B. Manufacturers in this Report

The underlying data for this report include every new light-duty vehicle offered for sale in the United States. These data are presented by manufacturer throughout this report, using model year 2024 manufacturer definitions determined by the NHTSA for implementation of the CAFE program. For simplicity, figures and tables show only the top 14 manufacturers, by production volume. These manufacturers produced at least 175,000 vehicles each in model year 2024 and accounted for more than 97% of all production. Table 1.1 lists all manufacturers that produced vehicles in the U.S. for model year 2024, including their associated makes. Only vehicle brands produced in model year 2024 are shown in this table; however, this report contains data on many other manufacturers and brands that have produced vehicles for sale in the U.S. since 1975.

Table 1.1. Model Year 2024 Manufacturers and Makes

	Manufacturer	Makes in the U.S. Market
Large Manufacturers	BMW	BMW, Mini, Rolls Royce
	Ford	Ford, Lincoln, Roush, Shelby
	General Motors (GM)	Buick, Cadillac, Chevrolet, GMC
	Honda	Acura, Honda
	Hyundai	Genesis, Hyundai
	Kia	Kia
	Mazda	Mazda
	Mercedes	Maybach, Mercedes
	Nissan	Infiniti, Nissan
	Stellantis	Alfa Romeo, Chrysler, Dodge, Fiat, Jeep, Maserati, Ram
	Subaru	Subaru
	Tesla	Tesla
	Toyota	Lexus, Toyota
	Volkswagen (VW)	Audi, Bentley, Bugatti, Lamborghini, Porsche, Volkswagen
Other Manufacturers	Fisker	Fisker
	Ineos	Ineos
	Jaguar Land Rover	Jaguar, Land Rover
	Lucid	Lucid
	Mitsubishi	Mitsubishi
	Rivian	Rivian
	Vinfast	Vinfast
	Volvo	Lotus, Polestar, Volvo
	Aston Martin	Aston Martin
	Ferrari	Ferrari
	McLaren	McLaren

When a manufacturer acquires another manufacturer or make, the EPA applies the new manufacturer relationship to all prior model years throughout this report. This maintains consistent manufacturer and make relationships over time, which enables better identification of long-term trends.

C. Fuel Economy Metrics in this Report

All data in this report for model years 1975 through 2024 are **final** and based on official data submitted to the EPA and the NHTSA as part of the regulatory process. In some cases, this report will show data for model year 2025, which are **preliminary** and are based on data, including projected production volumes, provided to the EPA by automakers prior to releasing vehicles for sale to the public. All data in this report are based on production volumes delivered for sale in the U.S. by model year. The model year production volumes may vary from other publicized data based on calendar year sales. The report does not examine future model years, and past performance does not necessarily predict future industry trends.

The EPA and the NHTSA measure fuel economy for CAFE compliance purposes using the EPA's city and highway test procedures (the "2-cycle" tests). In addition, the CAFE fleetwide averages are calculated by weighting the city and highway test results by 55% and 45%, respectively. These procedures are required by law for CAFE; however, they no longer accurately reflect real-world driving. Compliance data may also encompass optional performance credits and adjustments that manufacturers can use towards meeting their regulatory requirements.

The data shown throughout this report are estimated real-world data, which supplement the CAFE compliance data using additional standardized laboratory tests to capture a wider range of operating conditions (including hot and cold weather, higher speeds, and faster accelerations) encountered by an average driver. This expanded set of tests is referred to as "5-cycle" testing. The real-world city and highway results are weighted 43% city and 57% highway, consistent with more up-to-date fleetwide driver activity data. The city and highway values are the same values found on new vehicle fuel economy labels; however, the label combined value is still weighted 55% city and 45% highway, like the CAFE compliance data. Unlike compliance data, which by statute remains unchanged, the method for calculating real-world data has evolved over time, along with technology and driving habits.

Table 1.2. Fuel Economy Metrics Used in this Report

Fuel Economy Data Category	Purpose	Current City/Highway Weighting	Current Test Basis
Compliance	Basis for manufacturer compliance with standards	55% / 45%	2-cycle
Estimated Real-World	Best estimate of real-world performance	43% / 57%	5-cycle

While compliance data is not currently included in this report, it has been included in past reports and should not be compared to real-world data. For a more detailed discussion of the fuel economy data used in this report, including the differences between real-world and compliance data, see Appendices C and D.

D. Other Sources of Data

The EPA continues to update detailed data from this report to the EPA Automotive Trends website. We encourage readers to visit https://www.epa.gov/automotive-trends and explore the data. The EPA will continue to add content and tools on the web to allow transparent access to public data.

Additional detailed vehicle data is available on www.fueleconomy.gov, which is a web resource that helps consumers make informed fuel economy choices when purchasing a vehicle and achieve the best fuel economy possible from the vehicle they own. The EPA supplies the underlying data, much of which can be downloaded at https://fueleconomy.gov/feg/download.shtml.

In addition, the EPA's Green Vehicle Guide is an accessible, transportation-focused website that provides information, data, and tools on cleaner options for moving goods and people.

Although this report is based upon data submitted by manufacturers for CAFE compliance, the focus of the report on real-world fuel economy performance means that it does not provide data about compliance with the NHTSA's CAFE program. For more information about the CAFE and manufacturer compliance with the CAFE fuel economy standards, see the CAFE Public Information Center, which can be accessed at https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-public-information-center.

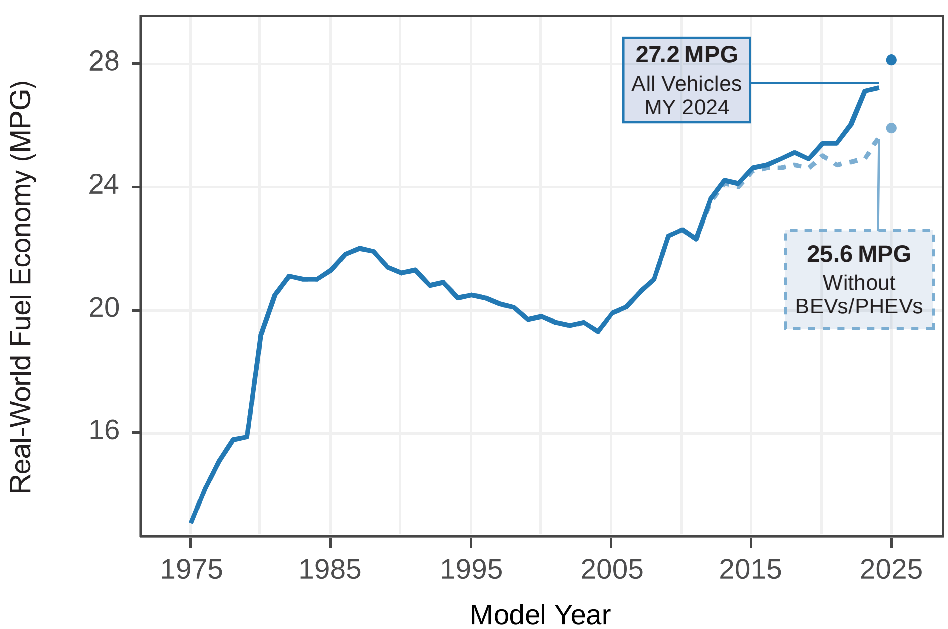
2. Fleetwide Trends Overview

The automotive industry continues to make progress towards higher fuel economy in recent years. This section provides an update on the estimated real-world fuel economy for the overall fleet, and for manufacturers, based on final model year 2024 data. The unique, historical data on which this report is based also provide an important backdrop for evaluating the more recent performance of the industry. Using that data, this section will also explore basic fleetwide trends in the automotive industry since the EPA began collecting data in model year 1975.

A. Overall Fuel Economy Trends

In model year 2024, the recent trend of increasing new vehicle real-world fuel economy continued. The average model year 2024 new vehicle increased fuel economy 0.1 mpg to a record high 27.2 mpg. Average new vehicle fuel economy has improved 16 out of the last 20 years and has increased 41% compared to model year 2004. The trends in fuel economy since 1975 are shown in Figure 2.1.

Figure 2.1. Estimated Real-World Fuel Economy



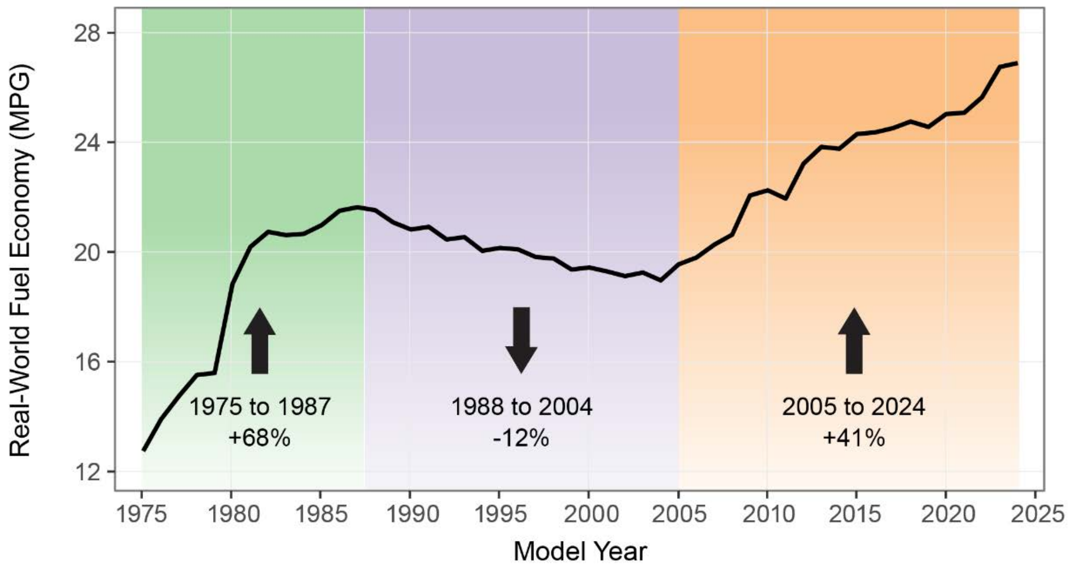
Overall fuel economy trends are due to changes in the mix of vehicles produced each year and evolving vehicle technology. New vehicle production has been trending towards sport utility vehicles (SUVs) for many years (see section 3) and many new technologies have been developed and adopted (see section 4). In particular, the production of battery electric vehicles (BEVs) and plug-in hybrids (PHEVs) have noticeably influenced overall trends in recent years. Without BEVs and PHEVs, the average new vehicle fuel economy was 1.7 mpg lower.[1,2]

Preliminary data suggest that the average new vehicle fuel economy will continue to increase in model year 2025. The preliminary model year 2025 data are based on production estimates provided to the EPA by manufacturers months before the vehicles go on sale. The data are a useful indicator, however, there is always uncertainty associated with such projections, and we caution the reader against focusing only on these data. Projected data are shown in Figure 2.1 as a dot because the values are based on manufacturer projections rather than final data.

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. The magnitude of these changes in annual fuel economy tends to be small relative to longer, multi-year trends. Figure 2.2 shows fleetwide estimated real-world fuel economy for model years 1975–2024. Over this timeframe, there have been three basic phases: 1) a rapid increase in fuel economy between 1975 and 1987, 2) a period of slowly decreasing fuel economy through 2004, and 3) increasing fuel economy through the current model year.

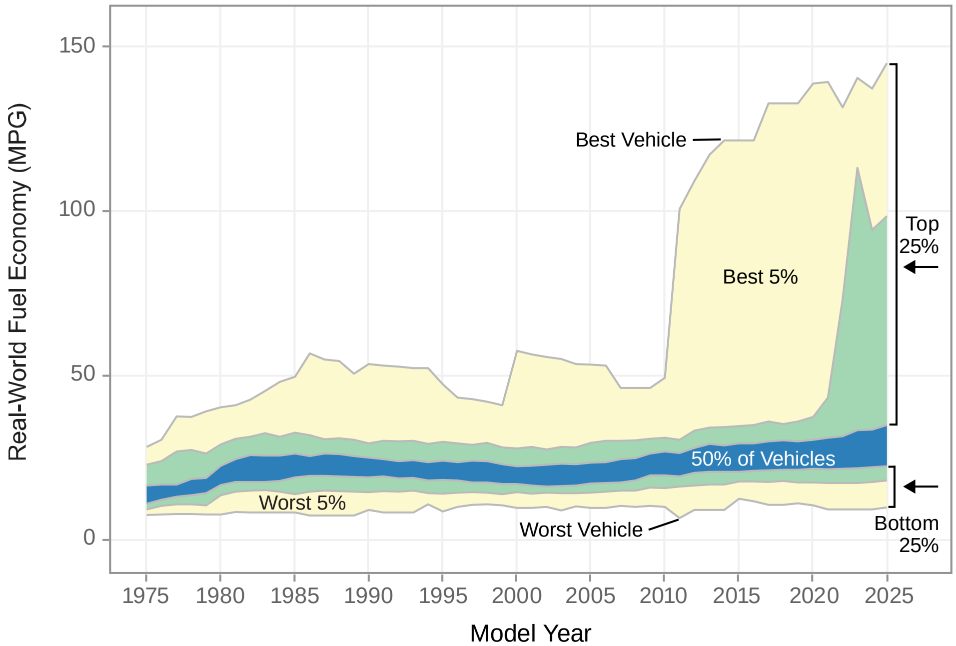
[1] Throughout this report, the fuel economy of BEVs and PHEVs are measured in terms of miles per gallon of gasoline equivalent, or mpge. These values are included in fleetwide fuel economy (mpg) values unless noted.
[2] The EPA generally uses unrounded values to calculate values in the text, figures, and tables in this report. This approach results in the most accurate data but may lead to small apparent discrepancies due to rounding.

Figure 2.2. Trends in Fuel Economy Since Model Year 1975



Another way to observe fuel economy trends over time is to examine how the distribution of new vehicle emission rates has changed. Figure 2.3 shows the distribution of real-world fuel economy for all vehicles produced within each model year. Half of the vehicles produced each year are clustered within a small band around the median fuel economy, as shown in blue. The remaining vehicles show a much wider spread, especially in recent years as the production of electric vehicles with high fuel economy has increased. The highest fuel economy vehicles have all been hybrids or battery electric vehicles since the first hybrid was introduced in model year 2000, while the lowest fuel economy vehicles are generally performance vehicles or large trucks. The introduction of BEVs in model year 2011 and their growth past 5% market share in model year 2022 are both visible in Figure 2.3.

Figure 2.3. Distribution of New Vehicle Fuel Economy by Model Year[3]



It is important to note that the methodology used in this report for calculating estimated real-world fuel economy values has changed over time to reflect changing vehicle technology and operation. For example, the estimated real-world fuel economy for a 1980s vehicle 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. See Appendices C and D for a detailed explanation of fuel economy metrics and their changes over time.

B. Production Trends

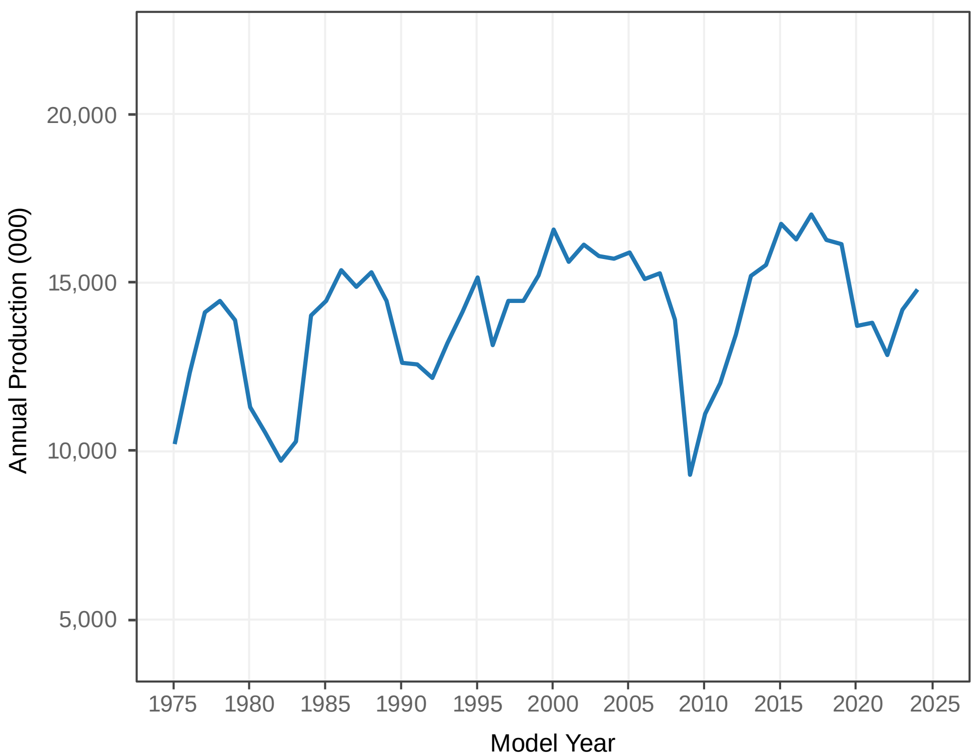
This report is based on the total number of vehicles produced by manufacturers for sale in the United States by model year. Model year is the manufacturer's annual production period, which includes January 1 of the same calendar year. A typical model year for a vehicle begins in fall of the preceding calendar year and runs until late in the next calendar year (for example, model year 2024 may cover fall 2023 through fall 2024). However, model years vary among manufacturers and can occur between January 2 of the preceding calendar year and the end of the calendar year. Model year production data is the most

[3] Electric vehicles prior to 2011 are not included in this figure due to limited data. However, those vehicles were available in small numbers only.

direct way to analyze fuel economy and technology trends because vehicle designs within a model year do not typically change. The use of model year production may lead to some short-term discrepancies with other sources, which typically report calendar year sales; however, sales based on the calendar year generally encompass more than one model year, which complicates any analysis.

Since the inception of this report, production of vehicles for sale in the United States has grown on average roughly 0.4% year over year, but there have been significant swings up or down in any given model year due to the impact of multiple market forces. For example, in model year 2009, economic conditions resulted in the lowest model year production since the start of this report, at 9.3 million vehicles. Production rebounded over the next several model years, reaching an all-time high of more than 17 million vehicles in model year 2017. Model year 2020 production fell 15% from the previous year, as the COVID-19 pandemic had wide-ranging impacts on the economy as well as vehicle production and supply chains. Figure 2.4 shows the production trends by model year for model years 1975 to 2024. Model year 2024 production was 14,799,239 vehicles.

Figure 2.4. New Vehicle Production by Model Year



C. Manufacturer Fuel Economy

Along with the overall industry, most manufacturers have increased new vehicle fuel economy in recent years. Manufacturer trends over the last five years are shown in Figure 2.5. This span covers the approximate length of a vehicle redesign cycle, and it is likely that most vehicles have undergone design changes in this period, resulting in a more accurate depiction of recent manufacturer trends than focusing on a single year. Changes over this period can be attributed to both vehicle design and changing vehicle production trends. The change in production trends, and the impact on the trends shown in Figure 2.5 are discussed in more detail in the next section.

Over the last five years, as shown in Figure 2.5, 13 of the 14 largest manufacturers selling vehicles in the U.S. increased estimated real-world fuel economy. Toyota had the highest increase between model years 2019 and 2024, at 3.3 mpg. Toyota was followed by BMW, which increased fuel economy 2.8 mpg, and Mercedes, which increased 2.4 mpg. Tesla was the only manufacturer that had decreasing fuel economy between model years 2019 and 2024 due to a large growth in production of car SUVs.

For model year 2024 alone, Tesla's all-electric fleet had the highest fuel economy of all large manufacturers at 117.1 mpg. Tesla was followed by Honda at 31.0 mpg, Hyundai at 29.8 mpg, and Kia at 29.2 mpg. Stellantis had the lowest new vehicle fuel economy of the large manufacturers in model year 2024 at 22.8 mpg, followed by GM at 22.9 mpg, and Ford at 23.4 mpg.

Increasing penetration of BEVs and PHEVs impacted fuel economy improvements between model years 2019 and 2024 for nearly all manufacturers, but to different extents. Figure 2.5 also shows the results for each manufacturer excluding BEVs and PHEVs. The largest impact of excluding these vehicles is for BMW, which achieved a 2.8 mpg increase in fuel economy overall, but had a small decrease in fuel economy when excluding BEVs and PHEVs. Seven manufacturers that had overall fuel economy improvements show decreasing fuel economy between model year 2019 and 2024 when BEVs and PHEVs are excluded. Conversely, manufacturers such as Toyota show a large increase in fuel economy between 2019 and 2024 with or without BEVs and PHEVs. For Toyota, this is due in part to increasing production of strong hybrid vehicles.

Figure 2.5. Changes in Estimated Real-World Fuel Economy by Manufacturer

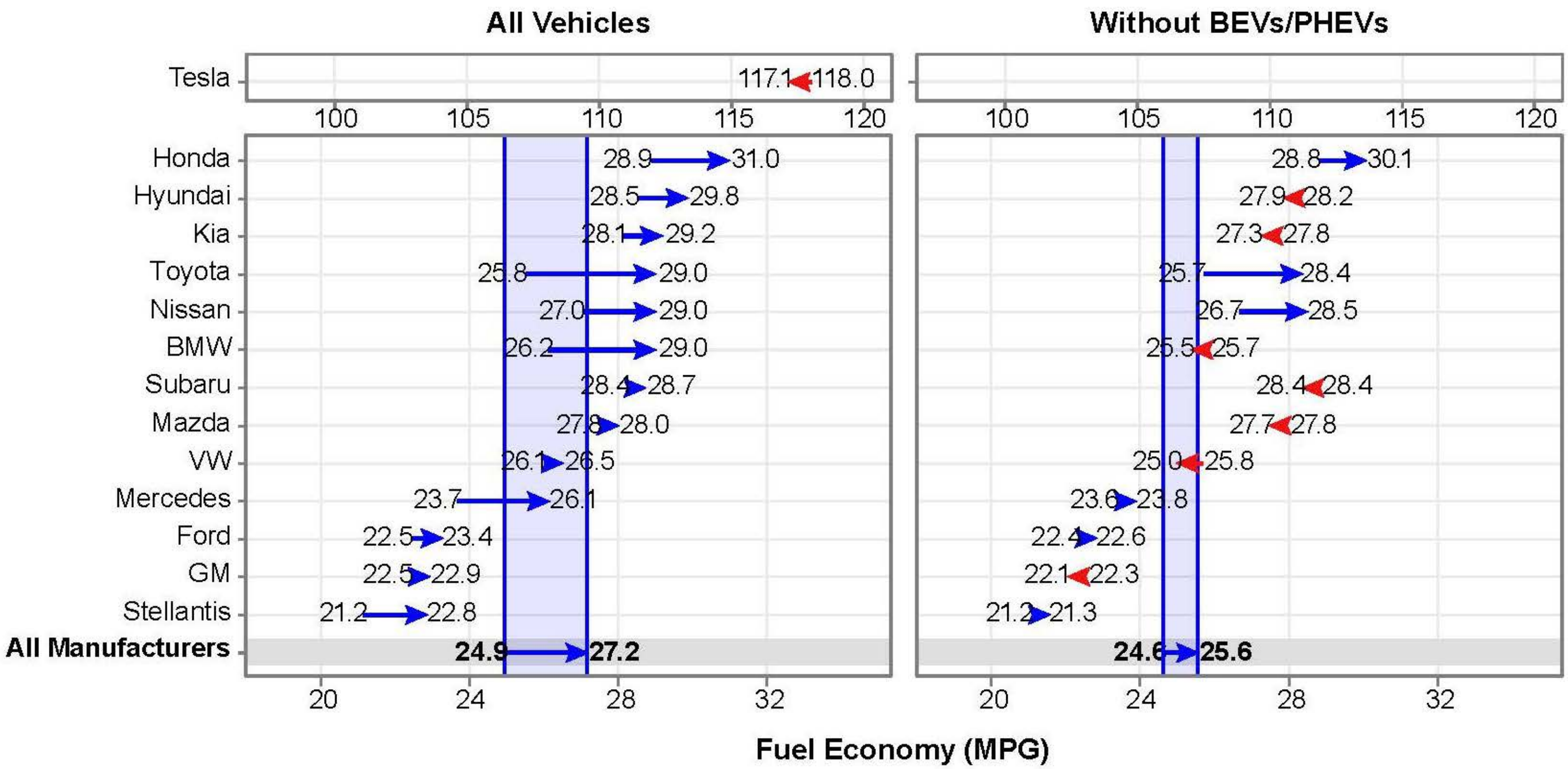


Table 2.1. Production and Fuel Economy for Model Year 1975–2025

Model Year	Production (000)	Real-World FE (MPG)
1975	10,224	13.1
1976	12,334	14.2
1977	14,123	15.1
1978	14,448	15.8
1979	13,882	15.9
1980	11,306	19.2
1981	10,554	20.5
1982	9,732	21.1
1983	10,302	21.0
1984	14,020	21.0
1985	14,460	21.3
1986	15,365	21.8
1987	14,865	22.0
1988	15,295	21.9
1989	14,453	21.4
1990	12,615	21.2
1991	12,573	21.3
1992	12,172	20.8
1993	13,211	20.9
1994	14,125	20.4
1995	15,145	20.5
1996	13,144	20.4
1997	14,458	20.2
1998	14,456	20.1
1999	15,215	19.7
2000	16,571	19.8
2001	15,605	19.6
2002	16,115	19.5
2003	15,773	19.6
2004	15,709	19.3
2005	15,892	19.9
2006	15,104	20.1
2007	15,276	20.6
2008	13,898	21.0
2009	9,316	22.4
2010	11,116	22.6
2011	12,018	22.3
2012	13,449	23.6
2013	15,198	24.2
2014	15,512	24.1
2015	16,739	24.6
2016	16,278	24.7
2017	17,016	24.9
2018	16,260	25.1
2019	16,139	24.9
2020	13,721	25.4
2021	13,812	25.4
2022	12,860	26.0
2023	14,199	27.1
2024	14,799	27.2
2025 (prelim)		*28.1*

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends.

Table 2.2. Manufacturers and Vehicles with the Highest Fuel Economy, by Year

Model Year	Manufacturer with Highest Fuel Economy[4] (mpg)	Manufacturer with Lowest Fuel Economy (mpg)	Overall Vehicle with Highest Fuel Economy[5]			Gasoline (Non-Hybrid) Vehicle with Highest Fuel Economy	
			Vehicle	Real-World FE (mpg)	Engine Type[6]	Gasoline Vehicle	Real-World FE (mpg)
1975	Honda	Ford	Honda Civic	28.3	Gas	Honda Civic	28.3
1980	VW	Ford	VW Rabbit	40.3	Diesel	Nissan 210	36.1
1985	Honda	Mercedes	GM Sprint	49.6	Gas	GM Sprint	49.6
1990	Hyundai	Mercedes	GM Metro	53.4	Gas	GM Metro	53.4
1995	Honda	Stellantis	Honda Civic	47.3	Gas	Honda Civic	47.3
2000	Hyundai	Stellantis	Honda Insight	57.4	Hybrid	GM Metro	39.4
2005	Honda	Ford	Honda Insight	53.3	Hybrid	Honda Civic	35.1
2010	Hyundai	Mercedes	Honda FCX	60.2	FCEV	Smart Fortwo	36.8
2015	Mazda	Stellantis	BMW i3	121.3	BEV	Mitsubishi Mirage	39.5
2016	Mazda	Stellantis	BMW i3	121.3	BEV	Mazda 2	37.1
2017	Honda	Stellantis	Hyundai Ioniq	132.6	BEV	Mitsubishi Mirage	41.5
2018	Tesla	Stellantis	Hyundai Ioniq	132.6	BEV	Mitsubishi Mirage	41.5
2019	Tesla	Stellantis	Hyundai Ioniq	132.6	BEV	Mitsubishi Mirage	41.6
2020	Tesla	Stellantis	Tesla Model 3	138.6	BEV	Mitsubishi Mirage	41.6
2021	Tesla	Stellantis	Tesla Model 3	139.1	BEV	Mitsubishi Mirage	41.6
2022	Tesla	Stellantis	Lucid Air G	131.4	BEV	Mitsubishi Mirage	41.6
2023	Tesla	Stellantis	Lucid Air AWD	140.3	BEV	Mitsubishi Mirage	41.6
2024	Tesla	Stellantis	Hyundai Ioniq 6	137.0	BEV	Mitsubishi Mirage	41.6
2025 (prelim)	*Tesla*	*Stellantis*	*Lucid Air Pure RWD*	*144.8*	*BEV*	*Honda Civic*	*36.6*

[4] Manufacturers below the 175,000 threshold for "large" manufacturers are excluded in years they did not meet the threshold.
[5] Vehicles are shown based on estimated real-world fuel economy as calculated for this report. These values will differ from values found on the fuel economy labels at the time of sale. For more information on fuel economy metrics see Appendix C.
[6] FCEV = Fuel Cell Electric Vehicle. For more information on engine types, see section 4.

Table 2.3. Manufacturer Estimated Real-World Fuel Economy for Model Year 2023–2025

	MY 2023 Final	MY 2024 Final		*MY 2025 Preliminary*
Manufacturer	**Real-World FE (mpg)**	**Real-World FE (mpg)**	**FE Change from MY 2022 (mpg)**	***Real-World FE (mpg)***
Tesla	120.6	117.1	-3.4	*119.4*
Honda	28.3	31.0	2.7	*29.6*
Hyundai	29.8	29.8	0.0	*30.4*
Kia	30.4	29.2	-1.1	*29.2*
BMW	27.6	29.0	1.3	*31.1*
Nissan	28.9	29.0	0.2	*29.0*
Toyota	27.5	29.0	1.6	*30.5*
Subaru	28.4	28.7	0.4	*28.7*
Mazda	27.6	28.0	0.4	*28.1*
VW	27.0	26.5	-0.5	*29.1*
Mercedes	27.5	26.1	-1.3	*28.1*
Ford	23.2	23.4	0.2	*24.4*
GM	22.4	22.9	0.6	*24.1*
Stellantis	21.8	22.8	0.9	*22.8*
All Manufacturers	**27.1**	**27.2**	**0.1**	***28.1***

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends.

3. Vehicle Attributes

Vehicle fuel economy is strongly influenced by vehicle design parameters, including weight, power, acceleration, and size. In general, vehicles that are larger, heavier, and more powerful typically have lower fuel economy than other comparable vehicles. This section focuses on several key vehicle design attributes that impact fuel economy and evaluates the impact of a changing automotive marketplace on overall fuel economy.

A. Vehicle Class and Type

Manufacturers offer a wide variety of light-duty vehicles in the United States. Under the NHTSA regulations, new vehicles are separated into two distinct regulatory classes, passenger vehicles (i.e., cars) and non-passenger vehicles (i.e., light trucks), and each vehicle class is subject to separate fuel economy standards.[7] Vehicles can qualify as light trucks based on the vehicle's functionality as defined in the regulations (for example if the vehicle can transport cargo on an open bed or the cargo carrying volume is more than the passenger carrying volume). Vehicles that have a gross vehicle weight rating (GVWR) of more than 6,000 pounds or have four-wheel drive and meet various off-highway requirements, such as ground clearance, can also qualify as non-passenger vehicles.[8] Vehicles that do not meet these requirements are considered cars. For more information on vehicle regulatory definitions, see Appendix F.

Pickup trucks, vans, and minivans are classified as light trucks under NHTSA's regulatory definitions, while sedans, coupes, and wagons are generally classified as cars. Sport utility vehicles (SUVs) can fall into either category depending on the relevant attributes of the specific vehicle. Based on the NHTSA regulatory definitions, most two-wheel drive SUVs under 6,000 pounds GVW are classified as cars, while most SUVs that have four-wheel drive or are above 6,000 pounds GVW are considered trucks. SUV models that are less than 6,000 pounds GVW can have both car and truck variants, with two-wheel drive versions classified as cars and four-wheel drive versions classified as trucks. As the fleet has changed over time, the line drawn between car and truck classes has also evolved. This

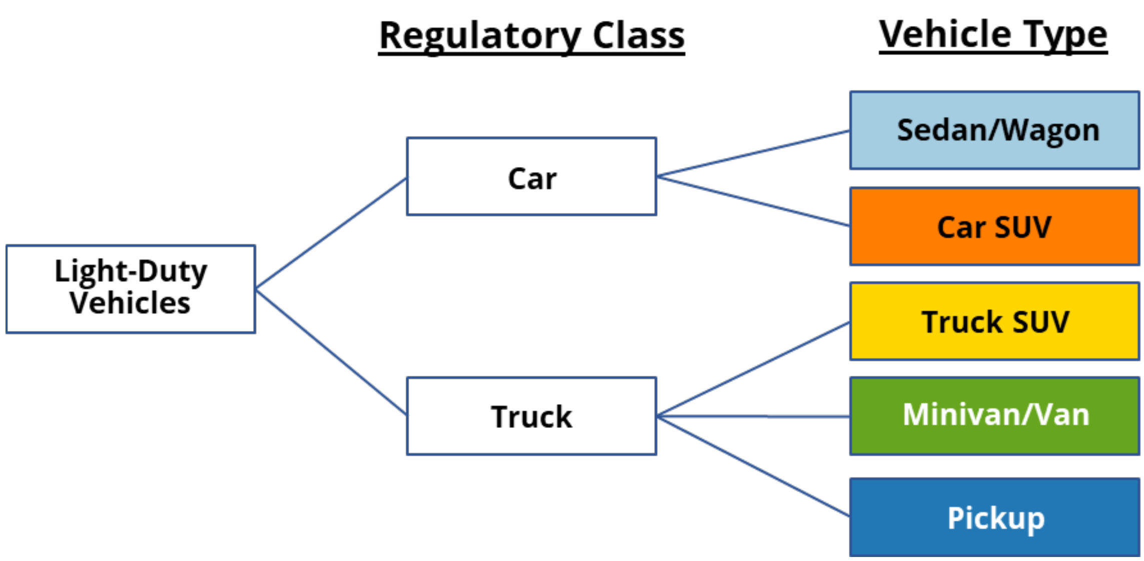
[7] Passenger vehicles (i.e., cars) and non-passenger vehicles (i.e., light trucks) are defined by regulation in the Department of Transportation's 49 CFR 523.4-523.5.

[8] Gross vehicle weight rating (GVWR) is the combined weight of the vehicle, passengers, and cargo of a fully loaded vehicle.

report uses the current regulatory car and truck definitions, and these changes have been propagated back throughout the historical data.

This report further separates the car and truck regulatory classes into five vehicle type categories based on their body style classifications under the fuel economy labeling program. The regulatory car class is divided into two vehicle types: sedan/wagon and car SUV. The sedan/wagon vehicle type includes mini-compact, subcompact, compact, midsize, large, and two-seater cars, hatchbacks, and station wagons. Vehicles that are SUVs under the labeling program and cars under the NHTSA regulations are classified as car SUVs in this report. The truck class is divided into three vehicle types: pickup, minivan/van, and truck SUV. Vehicles that are SUVs under the labeling program and trucks under the NHTSA regulations are classified as truck SUVs. Figure 3.1 shows the two regulatory classes and five vehicle types used in this report. The distinction between these five vehicle types is important because different vehicle types have different design objectives, and different challenges and opportunities for increasing fuel economy.

Figure 3.1. Regulatory Classes and Vehicle Types Used in This Report

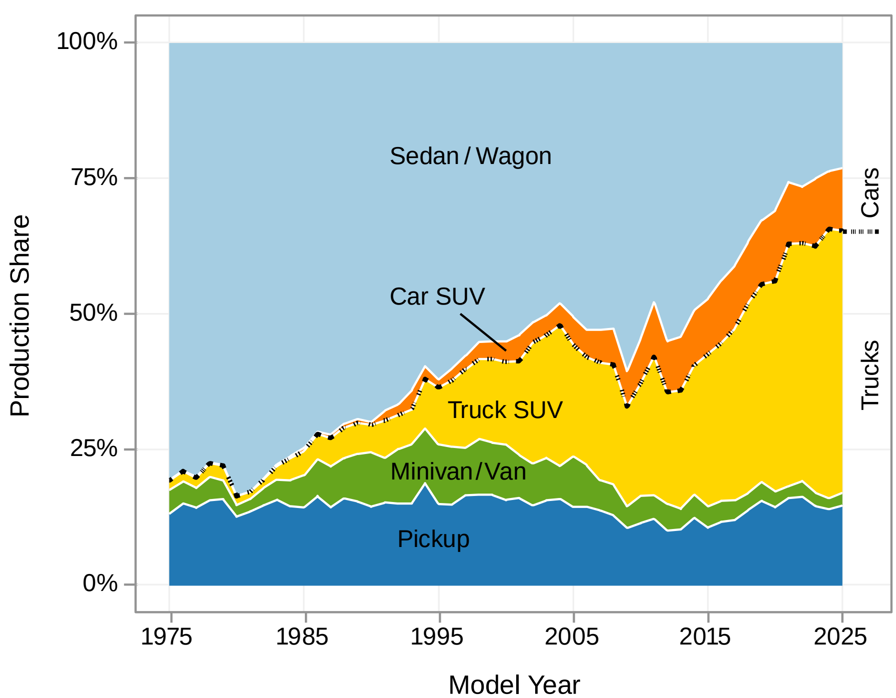


Fuel Economy by Vehicle Type

The production volume of the different vehicle types has changed significantly over time. Figure 3.2 shows the production shares of each of the five vehicle types since model year 1975. The overall new vehicle market continues to move away from the sedan/wagon vehicle type towards a combination of truck SUVs, car SUVs, and pickups. Sedan/wagons were the dominant vehicle type in 1975, when more than 80% of vehicles produced were sedan/wagons. Since then, their production share has generally been falling, and with a market share of less than 25% in model year 2024, sedans/wagons now hold less than a third of the market share they held in model year 1975. The production share of pickups has fluctuated over time, peaking at 19% in 1994, then falling to 10% in 2012, and hovering around 15% in recent years. Minivan/vans captured less than 5% of the market in 1975, increased to 11% in model year 1995 but have fallen since to less than 3% of vehicle production in recent years.

Vehicles that could be classified as a car SUV or truck SUV were a very small part of the production share in 1975 but now account for 60% of all new vehicles produced. In model year 2024, truck SUVs increased market share to almost 50% of all new vehicle production, while the production share of all other vehicle types fell. The projected 2025 data shows a vehicle type distribution that is similar to model year 2024.

Figure 3.2. Production Share and Estimated Real-World Fuel Economy



The truck regulatory class (including pickups, minivan/vans, and truck SUVs) increased production share in model year 2024 to an all-time high of 66%. Trucks are projected to maintain about the same production share in model year 2025. In Figure 3.2, the dashed line between the car SUVs and truck SUVs shows the split in car and truck regulatory class.

Figure 3.3. Production Share and Estimated Real-World Fuel Economy

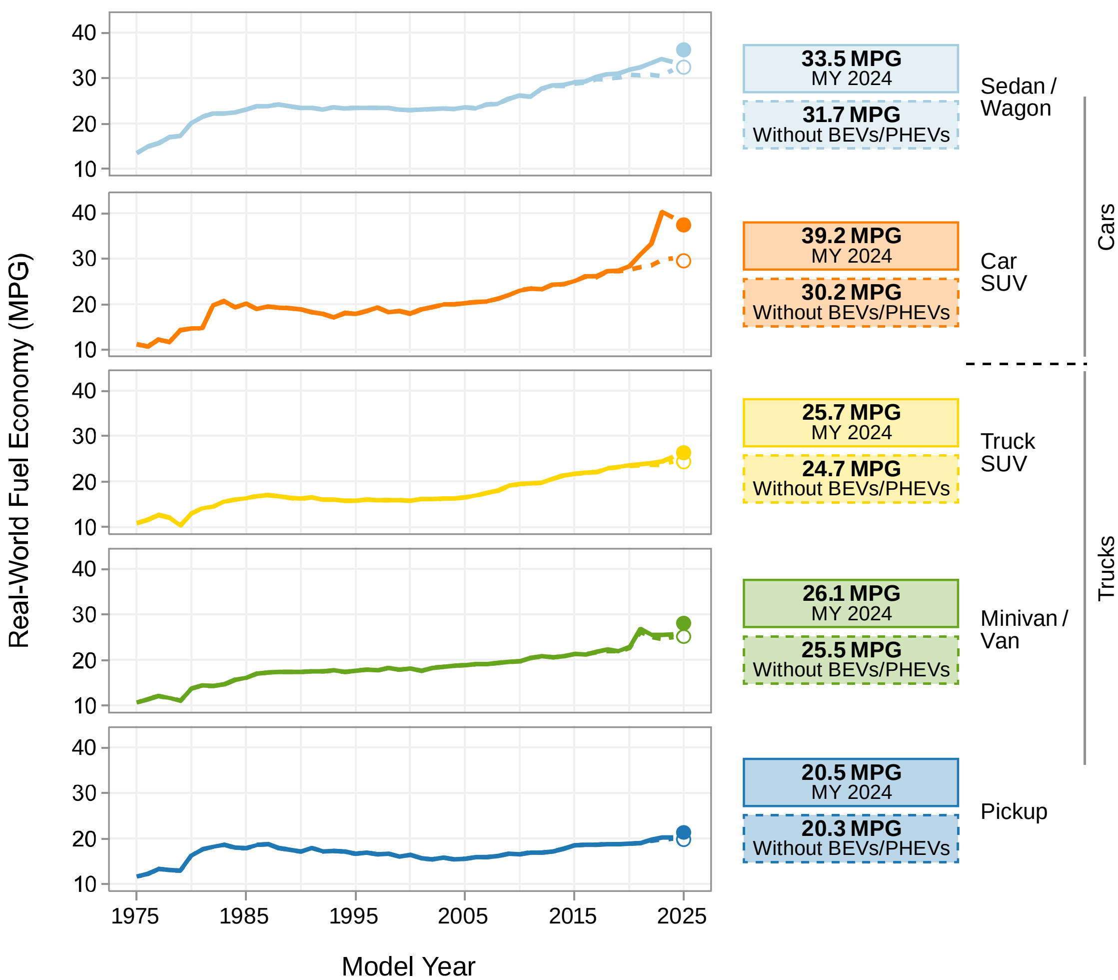


Figure 3.3 also shows estimated fuel economy for each vehicle type since 1975. In model year 2024, compared to model year 2023, fuel economy for truck SUVs increased 1.0 mpg to a new high of 25.7 mpg. Model year 2024 fuel economy for vans increased to 26.1 mpg, and fuel economy for pickups remained at 20.5 mpg. Both van and pickup fuel economy are at all-time highs. Sedan/wagons and car SUVs both had lower production shares and lower fuel economy in model year 2024 compared to model year 2023. Car SUVs remained the most fuel-efficient vehicle type but also had the largest drop in fuel economy compared to the year prior, at 1.3 mpg. Four of the five vehicle types, pickups being the exception,

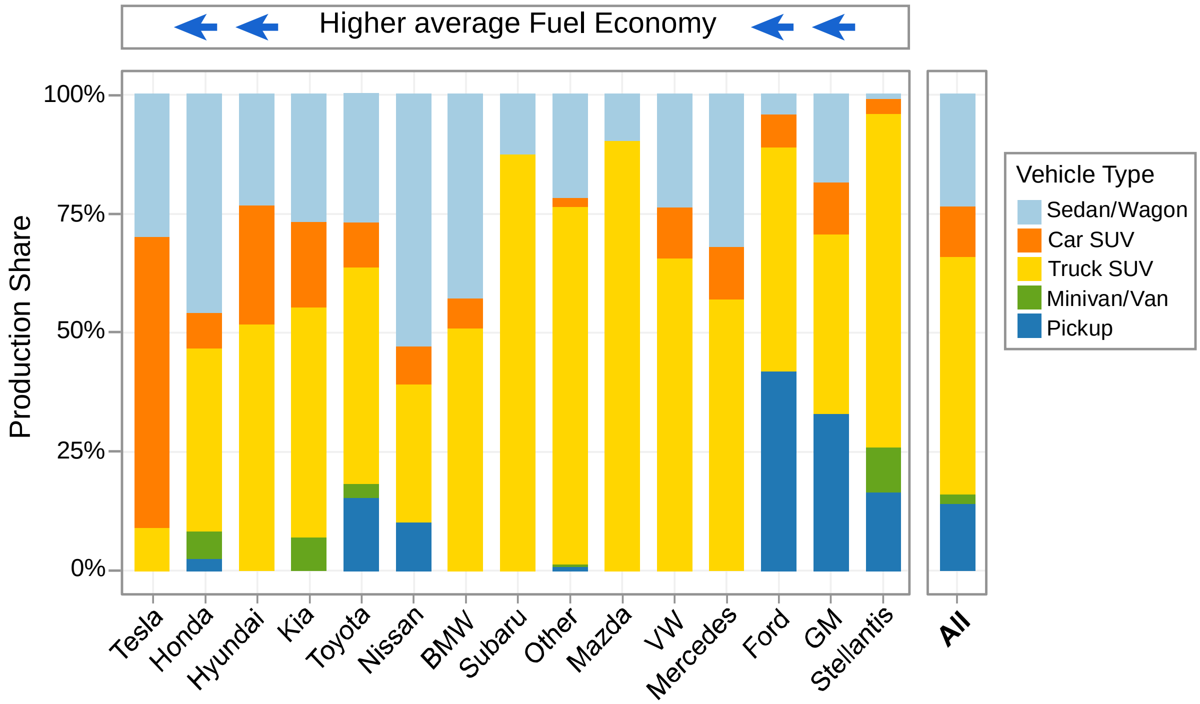
now achieve fuel economy more than double what they achieved in 1975. In the preliminary model year 2025 data (shown as a dot on Figure 3.3), all vehicle types, except car SUVs, are expected to increase fuel economy from model year 2024.

Overall fuel economy trends depend on the trends within the five vehicle types but also on the market share of each of the vehicle types. Since 1975, the market has shifted dramatically away from sedan/wagons and towards truck SUVs and car SUVs. Until recently, the sedan/wagon vehicle type had the highest fuel economy, so the market shifts toward other vehicle types with lower fuel economy offset some of the fleetwide benefits that otherwise would have been achieved from the increases within each vehicle type. However, the growth of electric vehicles is changing the relationship between vehicle types and overall average new vehicle fuel economy.

Within each vehicle type, BEVs and PHEVs increased average fuel economy to varying degrees. In model year 2024, 30% of car SUVs were BEVs, and an additional 3% were PHEVs. This led to a 9.0 mpg increase in fuel economy for car SUVs, compared to model year 2023. Sedan/wagon fuel economy was 1.8 mpg higher due to 7% BEVs and 1% PHEVs, and truck SUV fuel economy was 1.0 mpg higher due to 4% BEVs and 4% PHEVs. Minivan/van fuel economy was 0.6 mpg higher due to 5% PHEVs (and no BEVs), while pickup fuel economy was 0.3 mpg higher, due to 2% BEVs (and no PHEVs).

The model year 2024 production breakdown by vehicle type for each manufacturer is shown in Figure 3.4. There are clear variations in production distribution by manufacturer. Nissan had the highest production of sedan/wagons at 53%, Tesla had the highest percentage of car SUVs at 61%, Mazda had the highest percentage of truck SUVs at 90%, Ford had the highest percentage of pickups at 42%, and Stellantis had the highest percentage of minivan/vans at 9%.

Figure 3.4. Vehicle Type Distribution by Manufacturer for Model Year 2024



Stellantis, Mercedes, Hyundai, Kia, and Toyota all increased production of truck SUVs by more than five percentage points compared to model year 2023, mostly at the expense of sedan/wagons. Nissan was the only company with a significant shift towards sedan/wagons, away from car and truck SUVs. GM decreased their truck SUV production share by 11 percentage points, while increasing their production share of pickups. All other vehicle type production shifts within each manufacturer were less than 10 percentage points.

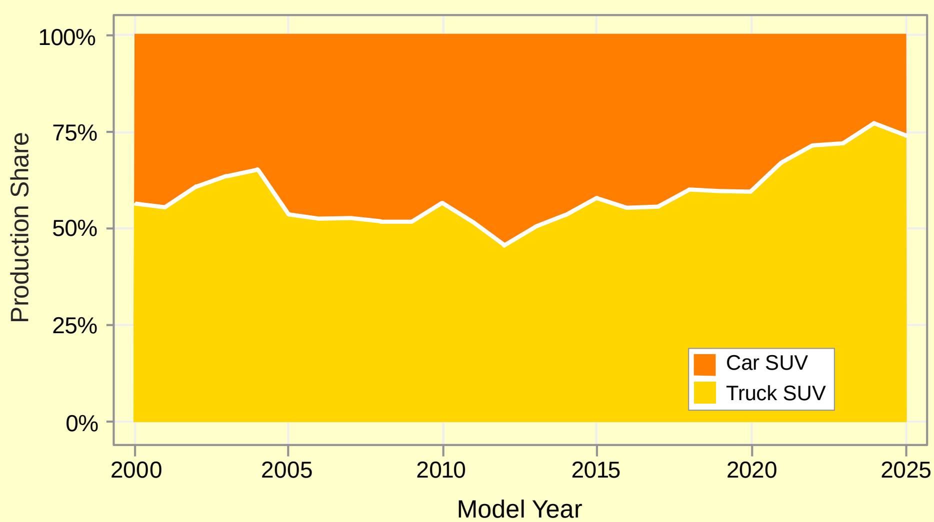
SUV Classification

Since 1975, the production share of SUVs in the United States has increased in all but 10 years and now accounts for 60% of all vehicles produced (see Figure 3.2). This includes both the car SUV and truck SUV vehicle types.

Based on the regulatory definitions of cars and trucks, SUVs that are less than 6,000 pounds GVWR can be classified as either cars or trucks, depending on design requirements such as minimum angles and clearances, and whether the vehicle has 2-wheel drive or 4-wheel drive. This definition can lead to similar vehicles having different car or truck classifications, and different requirements under the CAFE regulations. One trend of particular interest is the classification of SUVs as either car SUVs or truck SUVs.

This report does not track GVWR, but instead tracks weight using inertia weight classes, where inertia weight is the weight of the empty vehicle, plus 300 pounds (see weight discussion on the next page). Figure 3.5 shows the breakdown of SUVs into the car and truck categories over time for vehicles with an inertia weight of 4,000 pounds or less. Heavier vehicles were excluded, as these vehicles generally exceed 6,000 pounds GVWR and are classified as trucks. The relative percentage of SUVs with an inertia weight of 4,000 pounds or less that meet the current regulatory truck definition increased to 77% in model year 2024, which is the highest percentage of production since at least model year 2000. Model year 2025 data is projected to have a slightly lower ratio of truck SUVs.

Figure 3.5. Car-Truck Classification of SUVs with Inertia Weights of 4000 Pounds or Less



B. Vehicle Weight

Vehicle weight is a fundamental vehicle attribute and an important metric for analysis because vehicles with a higher weight, other factors being equal, will require more energy to move. For vehicles with an internal combustion engine (ICE), this higher energy requirement generally results in decreased fuel economy. Among BEVs, increased weight will likely decrease the overall efficiency of the vehicle, measured either in kilowatt-hours per 100 miles or mpge. Due to the weight of battery packs, electric vehicles are likely to weigh more than comparable ICE vehicles.

All vehicle weight data in this report are based on inertia weight classes. Each inertia weight class represents a range of loaded vehicle weights, or vehicle curb weights plus 300 pounds.[9] Vehicle inertia weight classes are in 250-pound increments for classes below 3,000 pounds, while inertia weight classes over 3,000 pounds are divided into 500-pound increments.

Vehicle Weight by Vehicle Type

Figure 3.6 shows the average new vehicle weight for all vehicle types since model year 1975. From model year 1975 to 1981, average vehicle weight dropped 21%, from 4,060 pounds per vehicle to about 3,200 pounds; this was likely driven by both increasing fuel economy standards (which, at the time, were universal standards, and not based on any type of vehicle attribute) and higher gasoline prices.

From model year 1981 to model year 2004, the trend reversed, and average new vehicle weight began to slowly but steadily climb. By model year 2004, average new vehicle weight had increased 28% from model year 1981 and reached 4,111 pounds per vehicle, in part because of the increasing truck share. Average vehicle weight in model year 2024 was about 6% above 2004 and is currently just below the highest point on record, at 4,354 pounds. Preliminary model year 2025 data suggest that weight will continue to increase.

In model year 1975, the difference between the heaviest and lightest vehicle types was about 215 pounds, or about 5% of the average new vehicle. In contrast, for model year 2024, the difference between the heaviest and lightest vehicle types was about 1,700 pounds, or about 39% of the average new vehicle weight. In 1975, the average new sedan/wagon outweighed the average new pickup by 46 pounds, but the different weight trends over time for each of these vehicle types led to a very different result in model year

[9] Vehicle curb weight is the weight of an empty, unloaded vehicle.

2024, with the average new pickup outweighing the average new sedan/wagon by about 1,700 pounds. Pickups are below their model year 2014 high of 5,485 pounds per vehicle, due in part to vehicle redesigns of popular truck models and the use of weight saving designs, such as aluminum bodies. However other trends, such as the growth in BEVs, appears to be pushing vehicle weights back up.

Figure 3.6. Average New Vehicle Weight by Vehicle Type

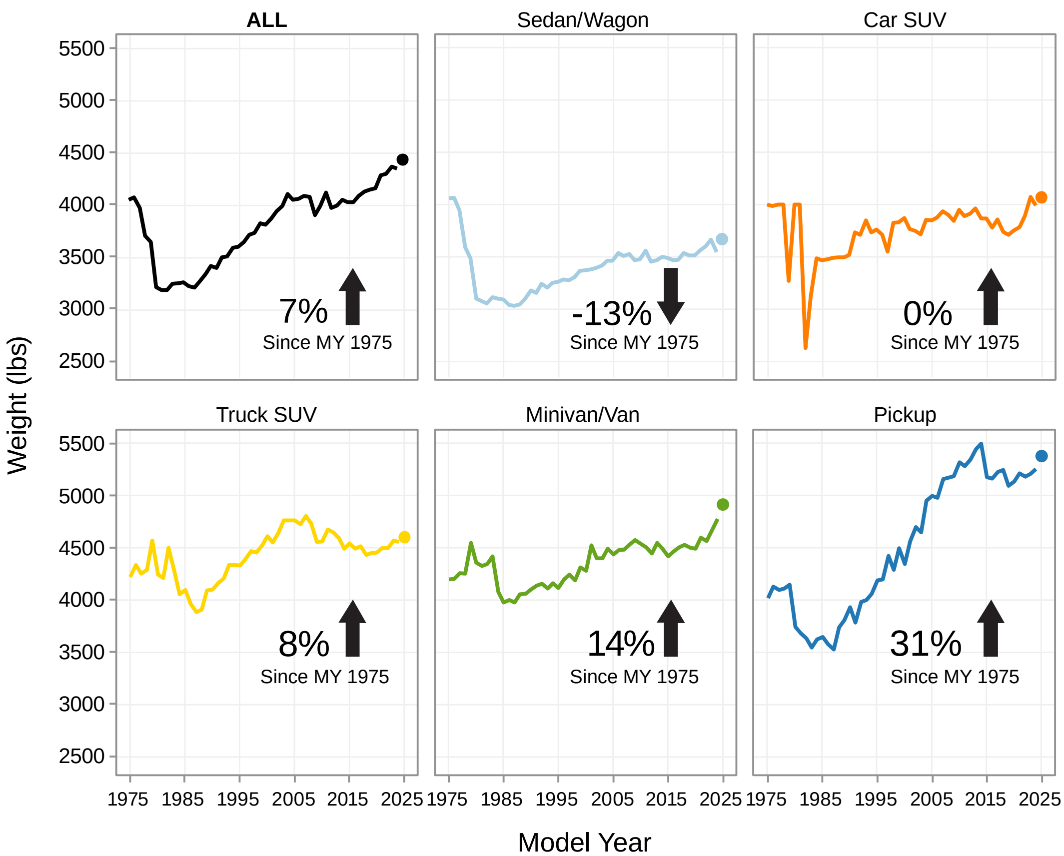
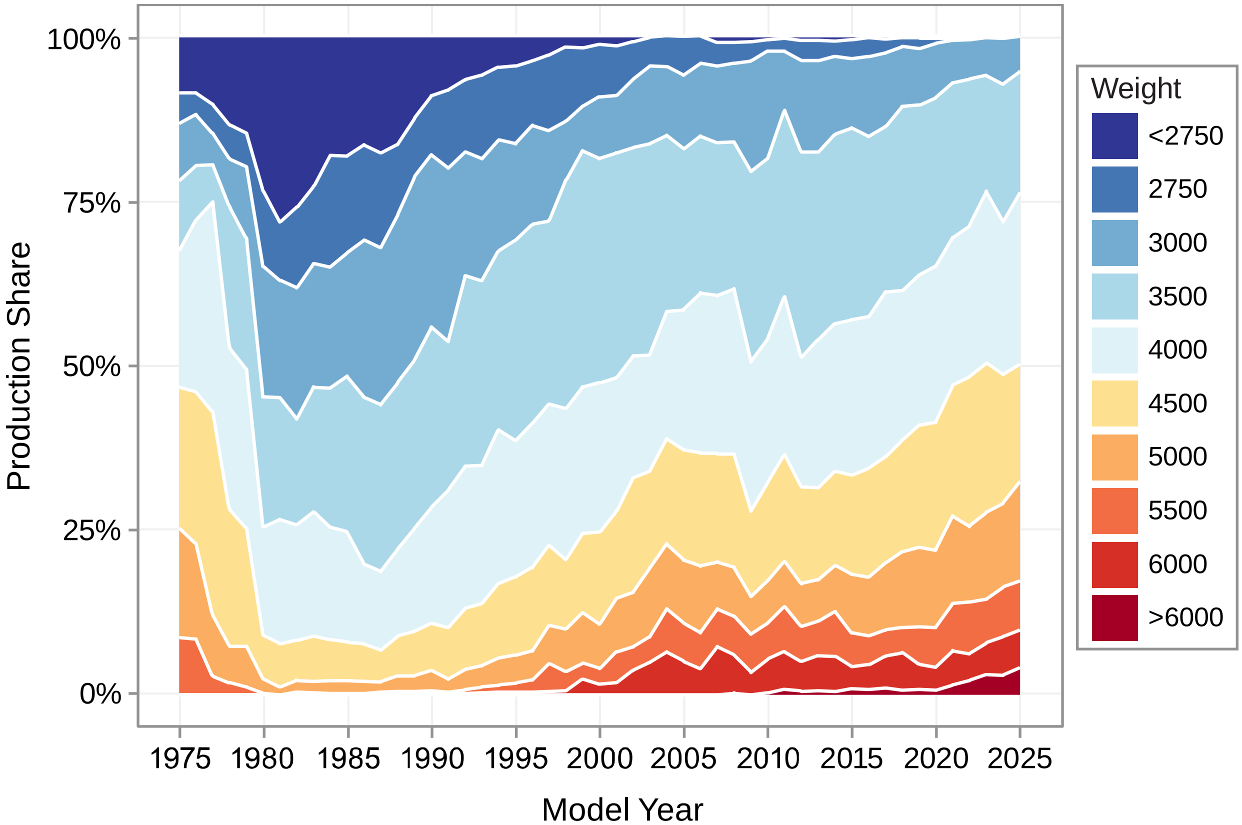


Figure 3.7 shows the annual production share of different inertia weight classes for new vehicles since model year 1975. In model year 1975, there were significant sales in all weight classes from below 2,750 pounds to 5,500 pounds. In the early 1980s, the largest vehicles disappeared from the market, and light cars below 2,750 pounds inertia weight briefly captured more than 25% of the market. Since then, cars in the below 2,750-pound inertia weight class have all but disappeared, and the market has moved towards heavier vehicles. Interestingly, the heaviest vehicles in model year 1975 were mostly large cars, whereas the heaviest vehicles today are largely pickups and truck SUVs.

Figure 3.7 Inertia Weight Class Distribution by Model Year



Vehicle Weight and Technology

In addition to the changes in vehicle type, the changing powertrain technologies used in recent model years have also impacted typical vehicle weight. For example, BEVs require a battery that can store enough energy to propel the vehicle over the design range of the vehicle, which for many current BEVs is more than 300 miles. The large battery required to hold that amount of energy increases the weight of the vehicle, often making it heavier than an equivalent ICE vehicle.

Figure 3.8 shows the average weight, by vehicle type, of ICE non-hybrid vehicles[10] compared to BEVs and PHEVs. The average of all vehicles within each vehicle type (including hybrids, PHEVs, and FCEVs) is also shown as a solid black bar. For each vehicle type, BEVs and PHEVs are heavier than their ICE non-hybrid counterparts. BEVs and PHEVs

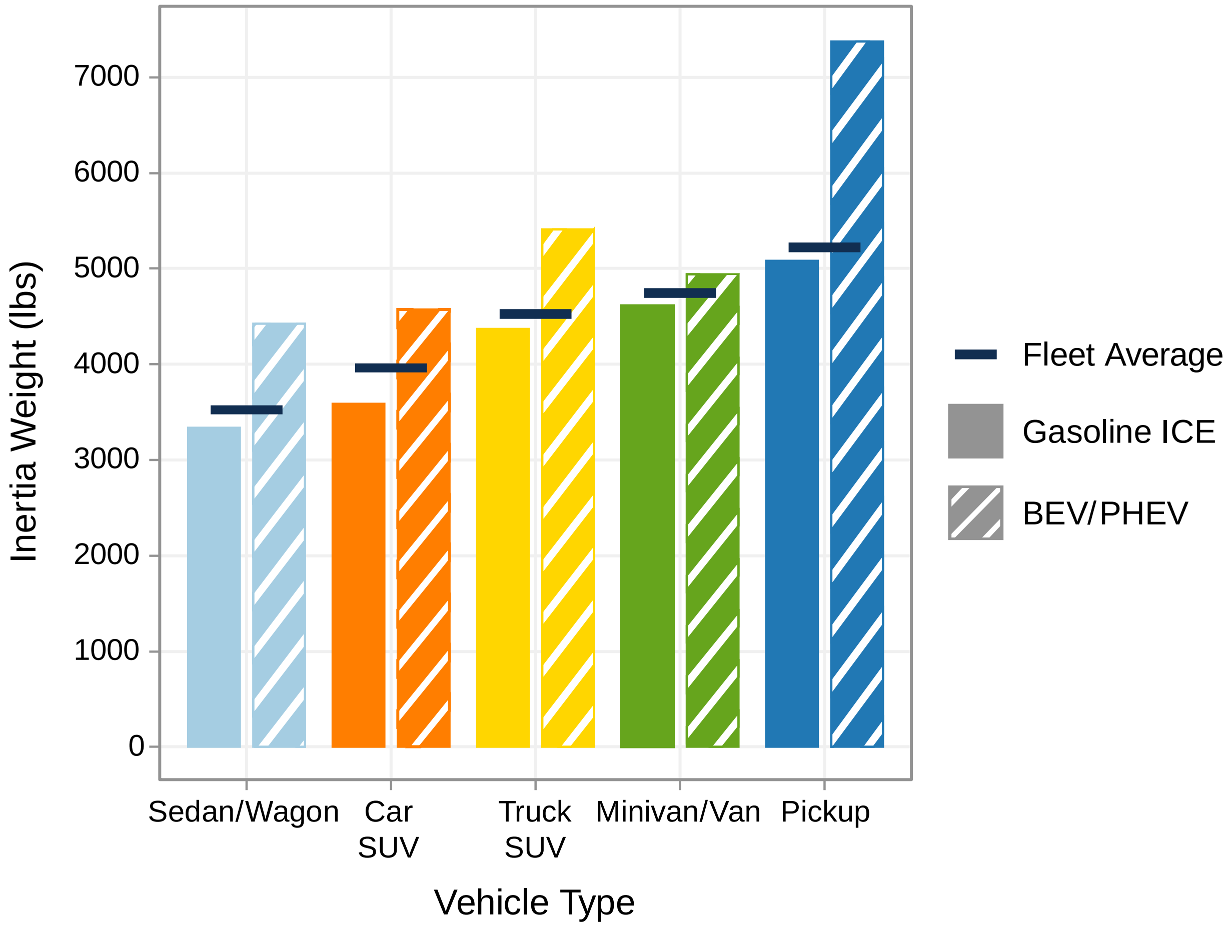
[10] See appendix G for an explanation of groupings this report uses to evaluate groupings of electrification technologies.

appear to be increasing the overall weight within each vehicle type, with the magnitude of the impact dependent on the uptake of BEVs and PHEVs within each vehicle type.

Overall vehicle weight has generally been trending upwards for several decades, as shown in Figure 3.6. This trend has been driven by many factors, including market shifts between vehicle types. The weight difference between ICE non-hybrid vehicles and BEV/PHEV vehicles shown for most model year 2024 vehicle types in Figure 3.8 is less than the difference in weight between ICE non-hybrid sedan/wagons and ICE non-hybrid truck SUVs. Overall vehicle production has been moving away from sedan/wagons towards truck SUVs for decades, as shown in Figure 3.2. This market shift has had much more of an impact on overall new vehicle average weight than the recent emergence of BEVs and PHEVs.

It is also important to note that even within vehicle types shown in Figure 3.8, the BEVs and PHEVs available may not be exactly comparable to the ICE vehicles. For example, the only electric vehicle pickup trucks are large full-sized pickups, while the ICE category includes some smaller pickup trucks. This difference is likely increasing the weight difference shown for pickups in Figure 3.8.

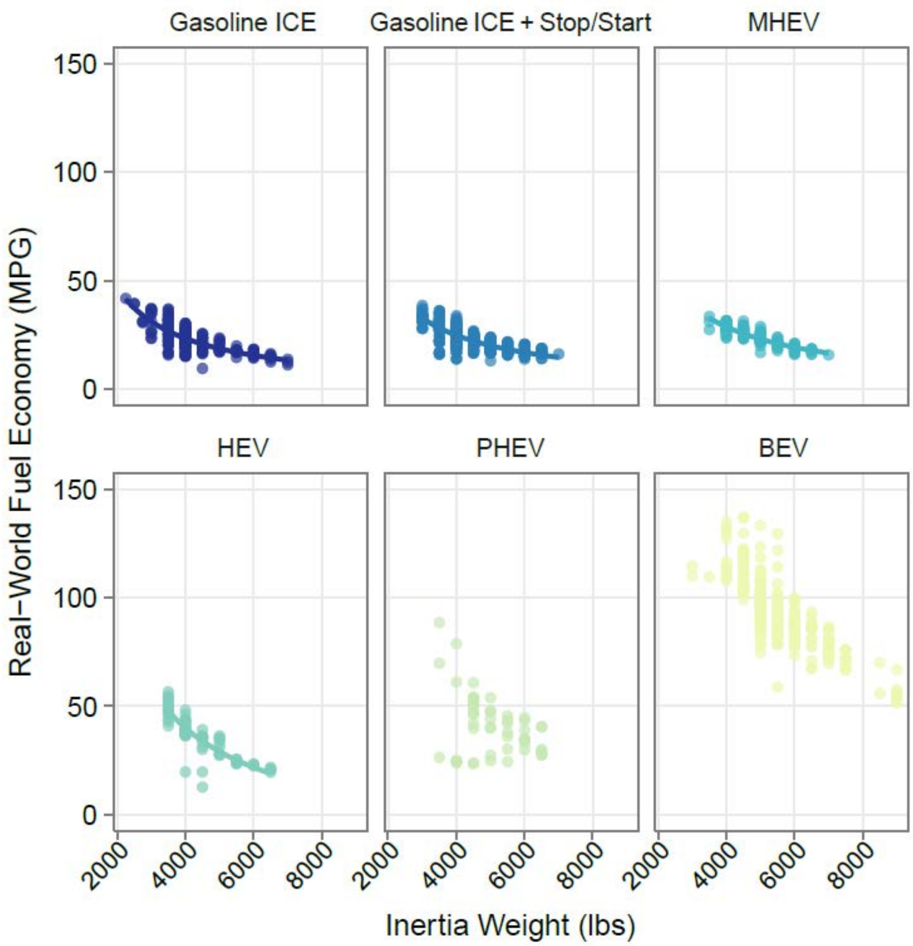
Figure 3.8. Average New Vehicle Weight by Vehicle Type and Powertrain



Vehicle Weight and Fuel Economy

Heavier vehicles require more energy to move than lower-weight vehicles and, if all other factors are the same, will have lower fuel economy. Figure 3.9 shows estimated real-world fuel economy as a function of vehicle inertia weight for several model year 2024 technologies. Increased weight correlates to lower fuel economy for ICE and hybrid technologies and may also correlate for PHEVs. For BEVs, increasing BEV weight likely correlates to reduced vehicle efficiency, as measured in mpge. Limited data did not allow for trendlines in Figure 3.9 for PHEV and BEV data.

Figure 3.9. Relationship Between Inertia Weight and Fuel Economy[11]



[11] MHEV = Mild Hybrid Electric Vehicle and HEV = Hybrid Electric Vehicle. For more information see section 4.

C. Vehicle Power

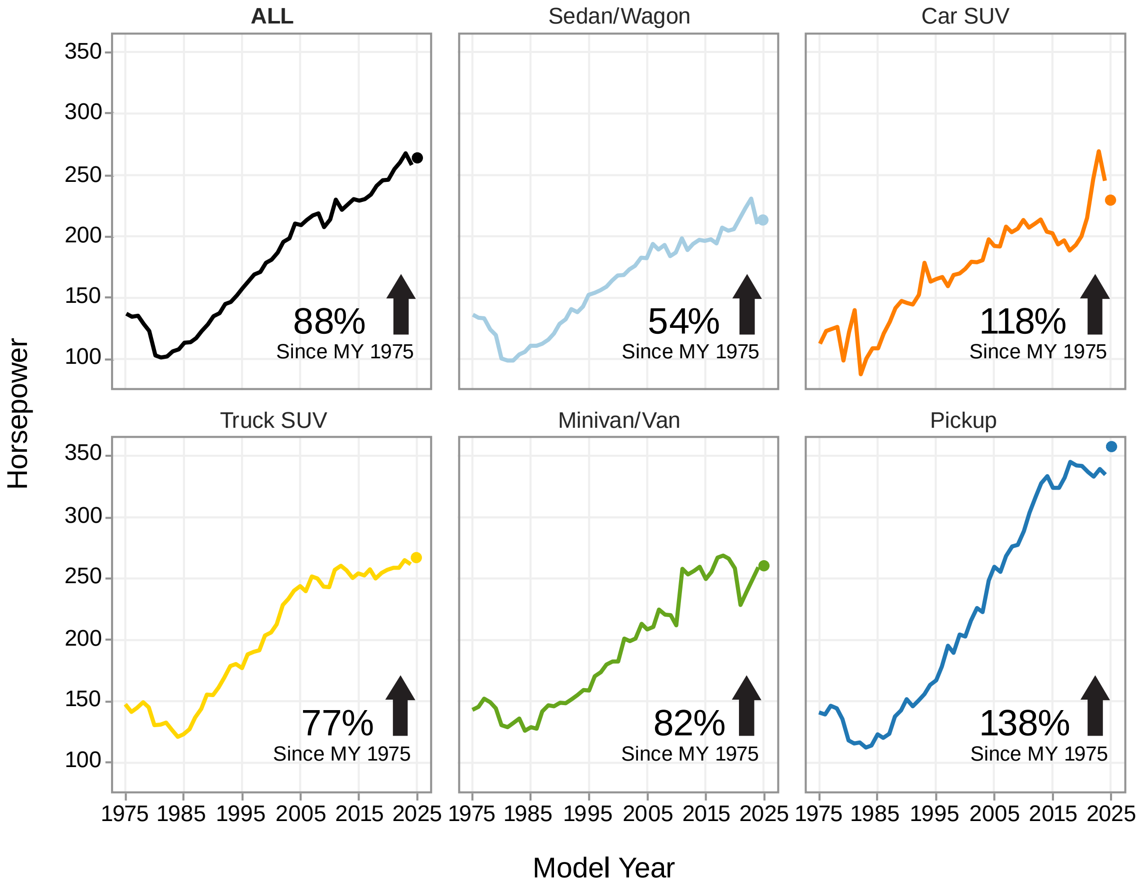
Vehicle power, measured in horsepower (hp), has changed dramatically since model year 1975. In the early years of this report, horsepower fell, from an average of 137 hp in model year 1975 to 102 hp in model year 1981. Since model year 1981, however, horsepower has increased almost every year. The average new vehicle in model year 2024 produced 88% more power than an average new vehicle in model year 1975, and 153% more power than an average new vehicle in model year 1981. The average new vehicle horsepower is 258 hp in model year 2024, which is down 10 hp from the previous model year. The preliminary value for model year 2025 is 264 hp.

Electric motors provide power differently than ICEs. For example, ICEs need to achieve a high rotation speed (rotations per minute, or RPM) before they can achieve maximum horsepower. Conversely, many BEVs have high hp ratings due to the large amount of power electric motors can generate. Determining the overall vehicle horsepower for BEVs can be complicated for vehicles that have more than one electric motor, depending on how the multiple motors are integrated. PHEVs, which have an ICE, at least one motor, and complicated control strategies, can be even more difficult to assess. Therefore, horsepower values for the increasing number of BEVs and PHEVs may have higher uncertainty.

Vehicle Power by Vehicle Type

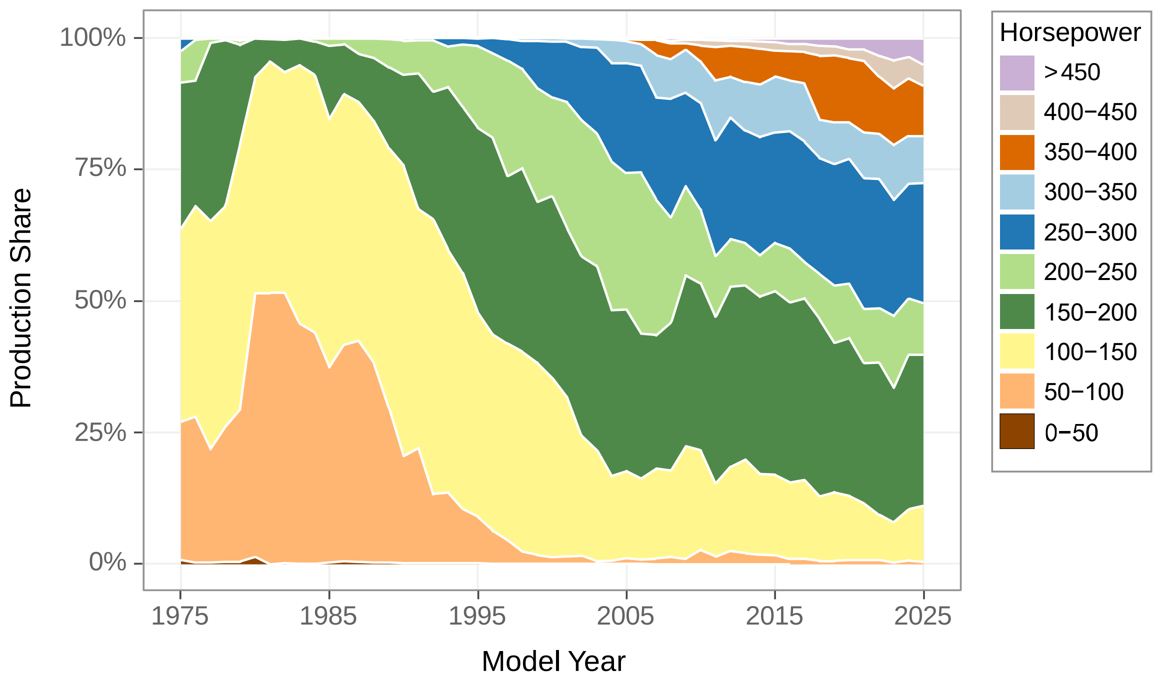
As with weight, the changes in horsepower are also different among vehicle types, as shown in Figure 3.10. Horsepower for sedan/wagons increased 54% between model year 1975 and 2024, 118% for car SUVs, 77% for truck SUVs, 82% for minivan/vans, and 138% for pickups. Horsepower has generally been increasing for all vehicle types since about 1985, but there is more variation between model types in the last decade.

Figure 3.10. Average New Vehicle Horsepower by Vehicle Type



The distribution of horsepower over time has shifted towards vehicles with higher horsepower, as shown in Figure 3.11. While few new vehicles in the early 1980s had greater than 200 hp, the average vehicle in model year 2024 had 258 hp. In addition, vehicles with more than 250 hp make up half of new vehicle production, and the maximum horsepower for an individual vehicle is now 1,600 hp. Horsepower is projected to increase again in model year 2025, with about 8% of vehicles projected to reach 400 hp or higher.

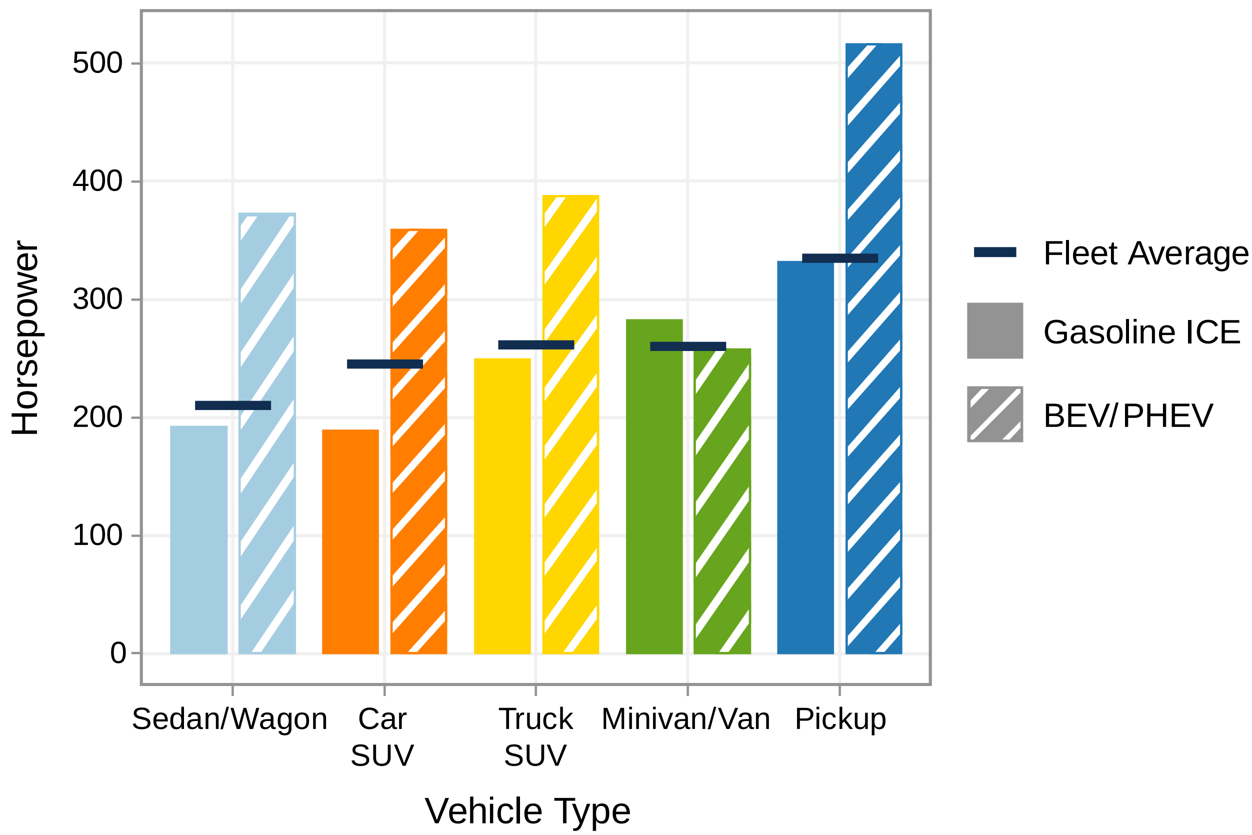
Figure 3.11. Horsepower Distribution by Model Year



Vehicle Power and Technology

Electric vehicles utilize an electric motor, instead of a gasoline ICE, to move the vehicle. Electric motors have the advantage of having maximum torque available from a standstill and can be used to enhance vehicle horsepower. Figure 3.12 shows the average horsepower, by vehicle type, of ICE non-hybrid vehicles compared to PHEVs and BEVs. For each of the four most popular vehicle types, PHEVs and BEVs have higher horsepower than their ICE non-hybrid counterparts. For minivan/vans, the average PHEV and BEV have lower horsepower, but there are also limited vehicles available to compare. The average of all vehicles within each vehicle type is also shown. PHEVs and BEVs are increasing the overall horsepower within each vehicle type (except for minivan/vans) with the overall impact dependent on the uptake of PHEVs and BEVs within each vehicle type.

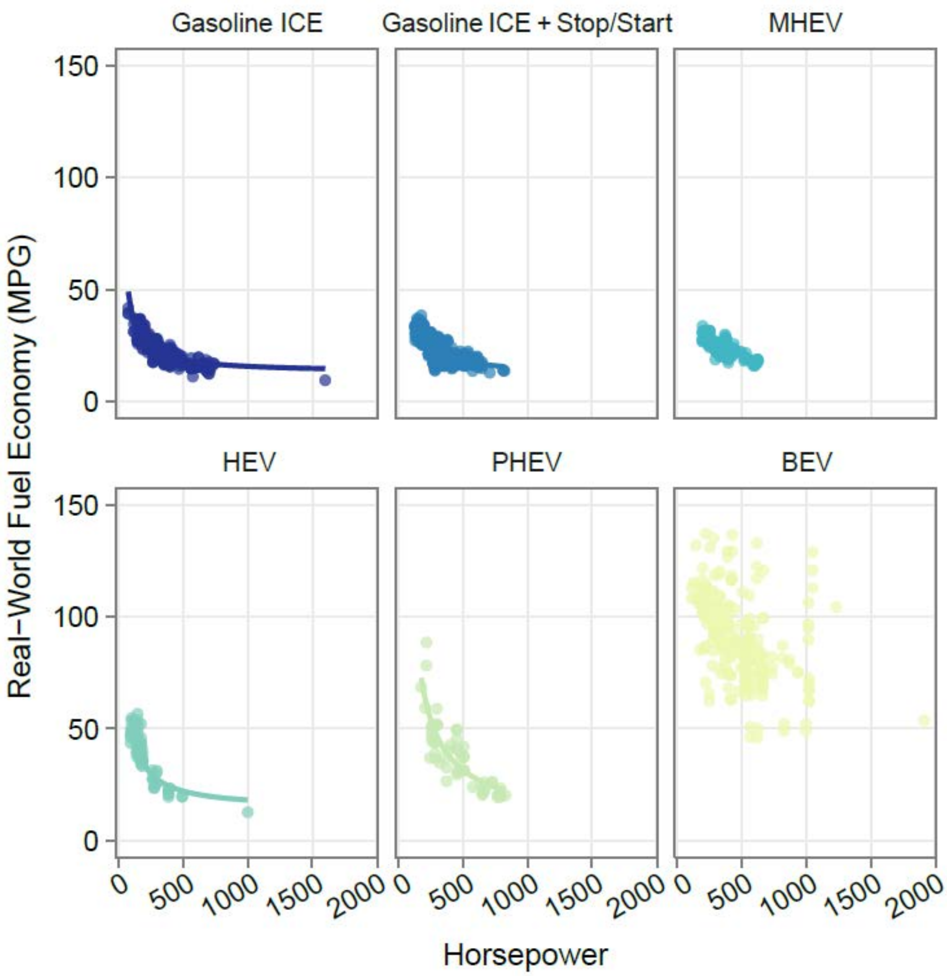
Figure 3.12. Average New Vehicle Horsepower by Vehicle Type and Powertrain



Vehicle Power and Fuel Economy

As with weight, higher horsepower vehicles are generally less efficient, if all other factors are held the same. However, the relationship between vehicle power and fuel economy has become more complex as new technologies and vehicles have emerged in the marketplace. Figure 3.13 shows estimated real-world fuel economy as a function of vehicle horsepower for several model year 2024 technologies. Increased horsepower correlates to lower fuel economy for ICE, hybrid, and PHEV vehicles. However, the relationship between increasing BEV horsepower and vehicle efficiency, as measured in mpge, is less clear. There was no clear trendline in Figure 3.13 for BEV data.

Figure 3.13. Relationship Between Horsepower and Fuel Economy



Vehicle Acceleration

Vehicle acceleration is closely related to vehicle horsepower. As new vehicles have increased horsepower, the corresponding ability of vehicles to accelerate has also increased. The most common vehicle acceleration metric, and one of the most recognized vehicle metrics overall, is the time it takes a vehicle to accelerate from 0-to-60 miles per hour, also called the 0-to-60 time. Data on 0-to-60 times are not directly submitted to the EPA but are calculated for most vehicles using vehicle attributes and calculation methods developed by MacKenzie and Heywood (2012).[12]

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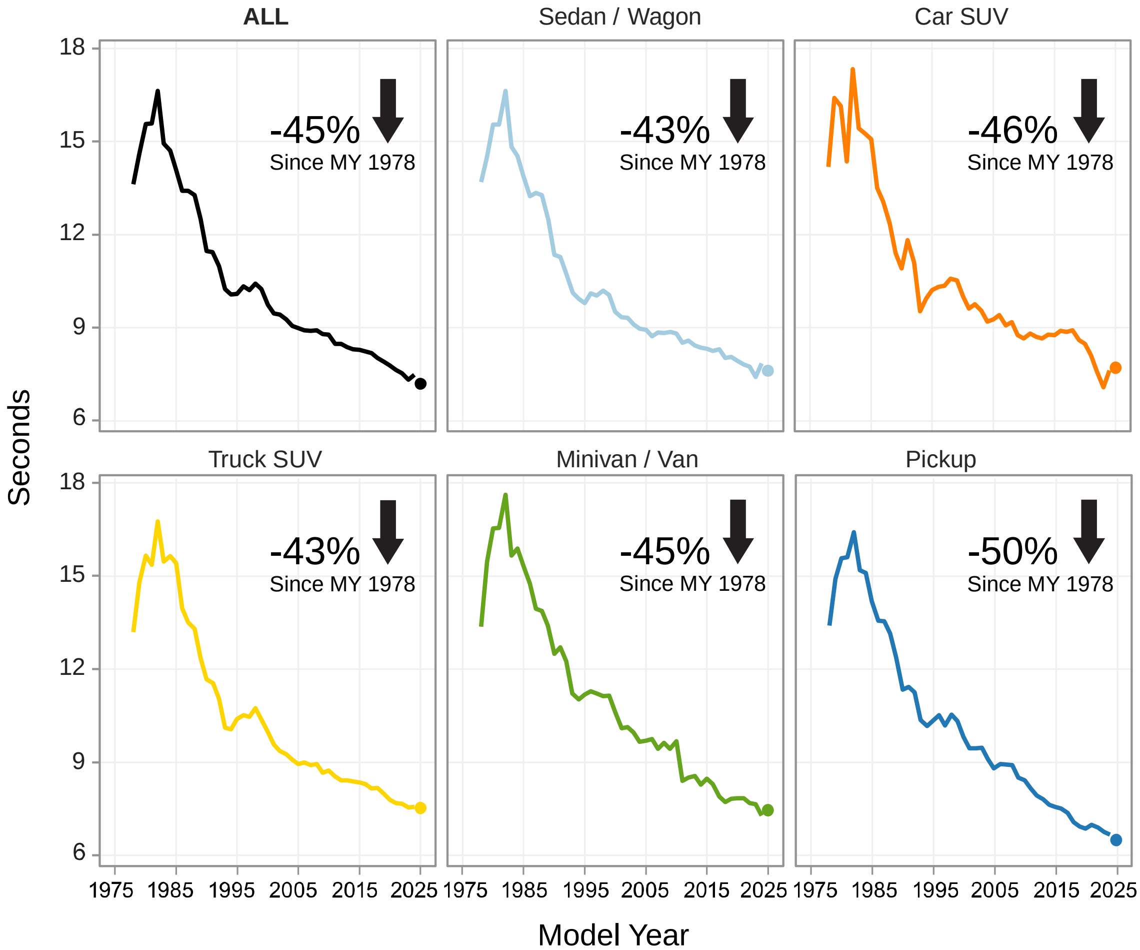
[12] MacKenzie, D. & Heywood, J. (2012). Acceleration performance trends and the evolving relationship among power, weight, and acceleration in U.S. light-duty vehicles: A linear regression analysis. *Transportation Research*

The relationship between power and acceleration is different for BEVs than for vehicles with ICEs. Electric motors generally have maximum torque available from a standstill, which is not true for ICEs. The result is that BEVs can have very fast 0-to-60 acceleration times, and the calculation methods used for vehicles with internal combustion engines are not valid for BEVs. PHEVs and hybrids may also use their motors to increase acceleration. Acceleration times for BEVs, PHEVs, and hybrids must be obtained from external sources, and as with horsepower values for these vehicles, there may be more uncertainty with these values.

Since the early 1980s, there has been a clear downward trend in 0-to-60 times. Figure 3.14 shows the average new vehicle 0-to-60 time since model year 1978. The average new vehicle in model year 2024 had a 0-to-60 time of 7.5 seconds, which is close to the fastest average 0-to-60 time for any model year and less than half of the average 0-to-60 time of the early 1980s. The calculated 0-to-60 time for model year 2025 is projected to decrease slightly to 7.3 seconds. The long-term downward trend in 0-to-60 times is consistent across all vehicle types. Increased BEV production could continue, and perhaps increase, the trend towards lower 0-to-60 acceleration times.

Board, Paper NO 12-1475, TRB 91st Annual Meeting, Washington, DC, January 2012. https://doi.org/10.1016/j.tra.2015.12.001

Figure 3.14. Calculated 0-to-60 Time by Vehicle Type



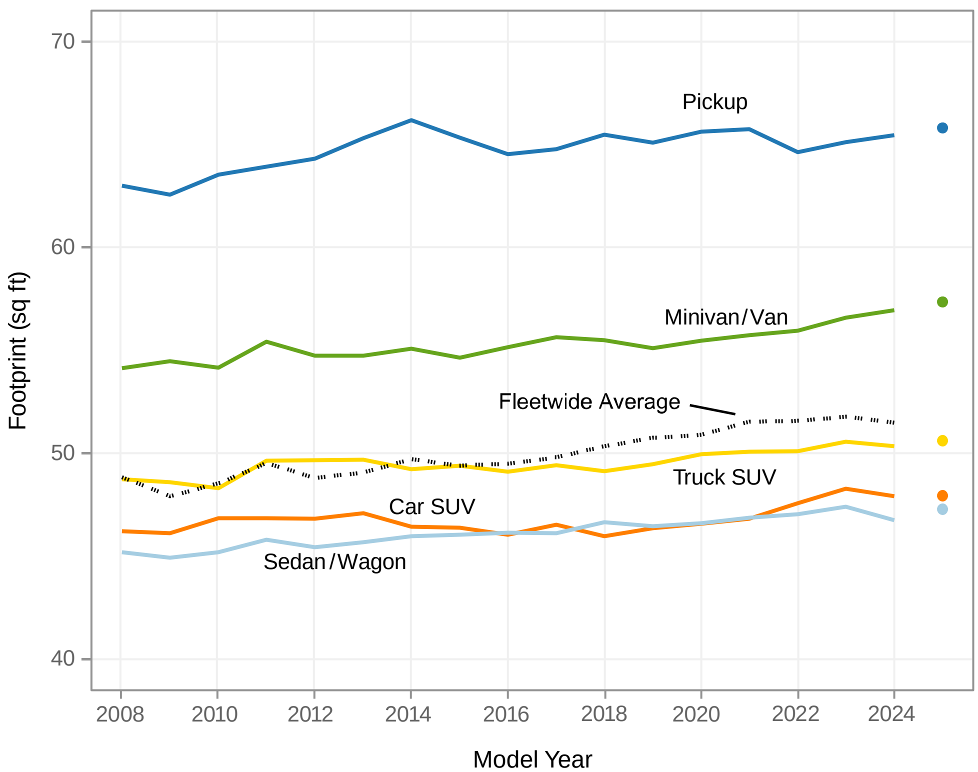
D. Vehicle Footprint

Vehicle footprint is an important attribute since it is the basis for the current fuel economy standards. Footprint is the product of wheelbase times average track width (the area defined by where the centers of the tires touch the ground). This report provides footprint data beginning with model year 2008, although footprint data from model years 2008–2010 were aggregated from various sources and the EPA has less confidence in the precision of these data than that of formal CAFE compliance data. Beginning in model year 2011, the first year when both car and truck CAFE standards were based on footprint, automakers began to submit reports to the EPA with footprint data at the end of the model year, and these official footprint data are reflected in the final data through model year 2024. The EPA projects footprint data for the preliminary model year 2025 fleet based on footprint values from the previous model year and, for new vehicle designs, publicly available data.

Vehicle Footprint by Vehicle Type

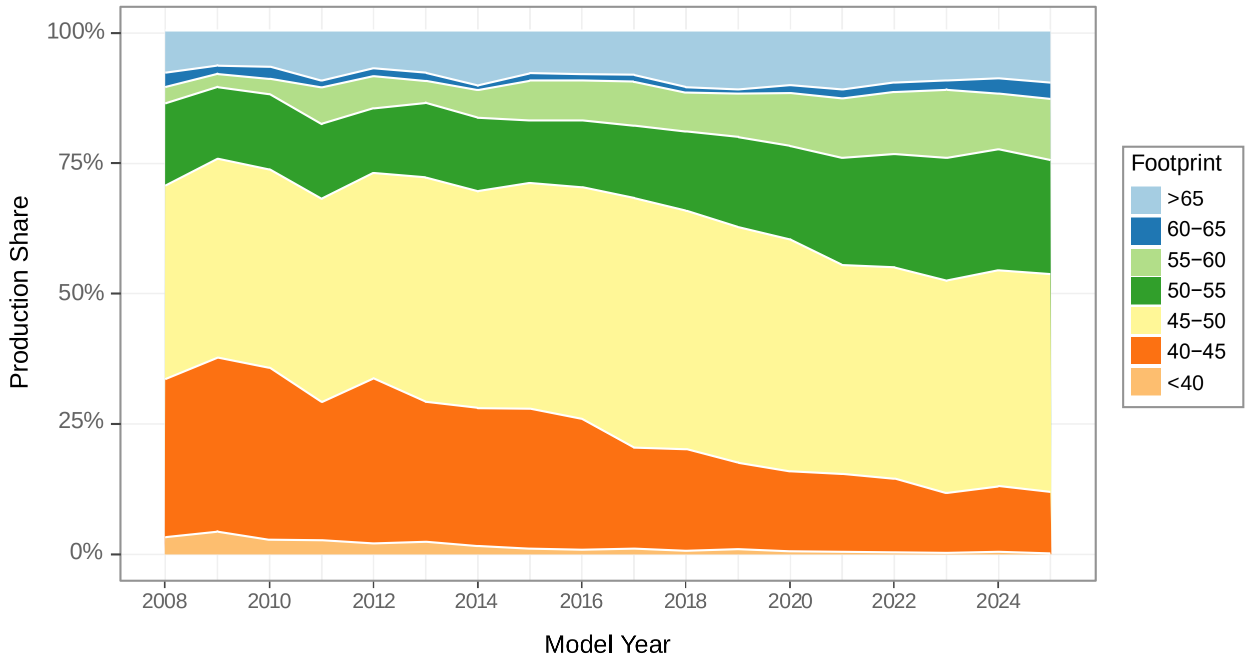
Figure 3.15 shows overall new vehicle and vehicle type footprint data since model year 2008. Between model year 2008 and 2024, the overall average footprint increased 5.4%, from 48.9 to 51.5 square feet. All five vehicle types have increased average footprint since model year 2008, with truck SUVs increasing 3.3%, sedan wagons increasing 3.4%, car SUVs increasing 3.7%, pickups increasing 3.9%, and minivans/vans increasing 5.2%. The industry wide increase in footprint is larger than the increase within any individual vehicle type, due to both the trends within each vehicle type and the changing mix of vehicles over time as the market has shifted towards larger vehicles.

Figure 3.15. Footprint by Vehicle Type for Model Years 2008–2025



The distribution of footprints across all new vehicles, as shown in Figure 3.16, also shows a slow reduction in the number of smaller vehicles with a footprint of less than 45 square feet, along with growth in larger vehicle categories. This is consistent with the changes in market trends towards larger vehicles, as seen in Figure 3.2 and elsewhere in this report. Projected data for model year 2025 suggest that overall average footprint will increase slightly to 51.8 square feet.

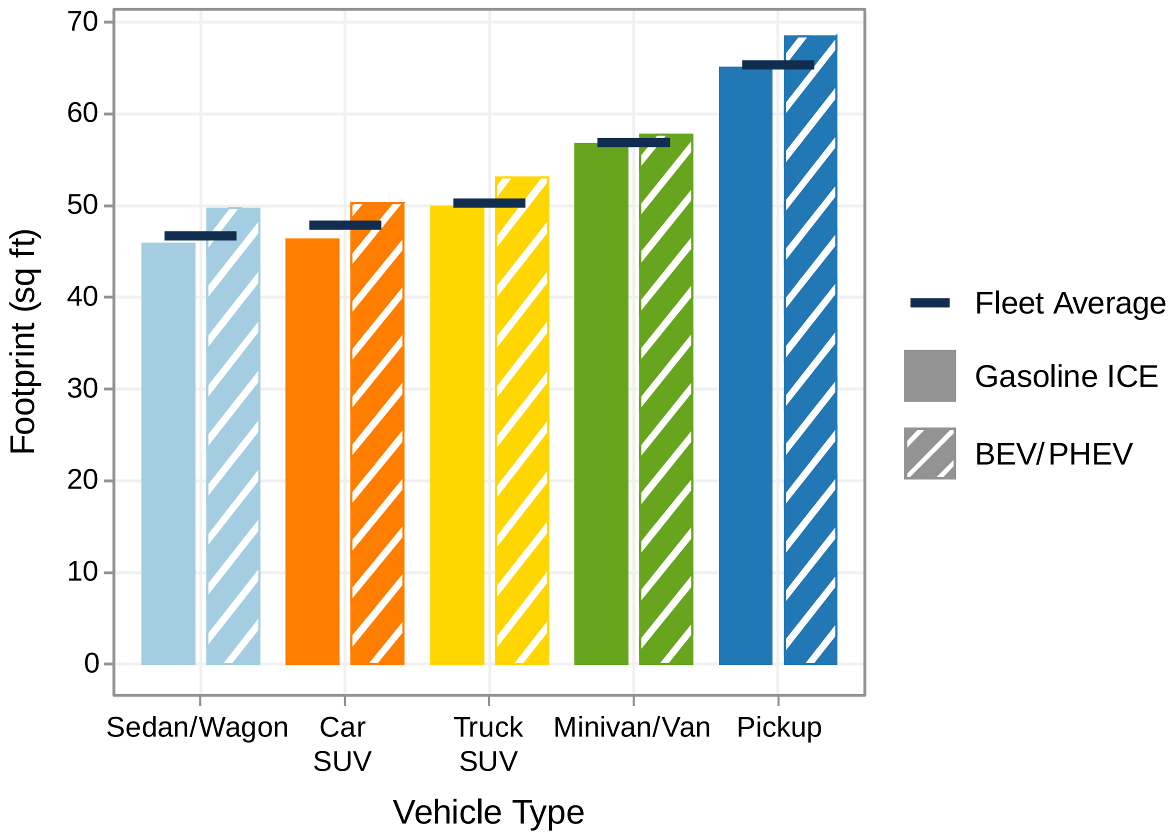
Figure 3.16. Footprint Distribution by Model Year



Vehicle Footprint and Technology

Figure 3.17 shows the average footprint, by vehicle type, of ICE non-hybrid vehicles compared to BEVs and PHEVs. For all vehicle types, BEVs and PHEVs have slightly larger footprints than their ICE counterparts. The average of all vehicles within each vehicle type is also shown, with the overall impact dependent on the uptake of BEVs and PHEVs within each vehicle type.

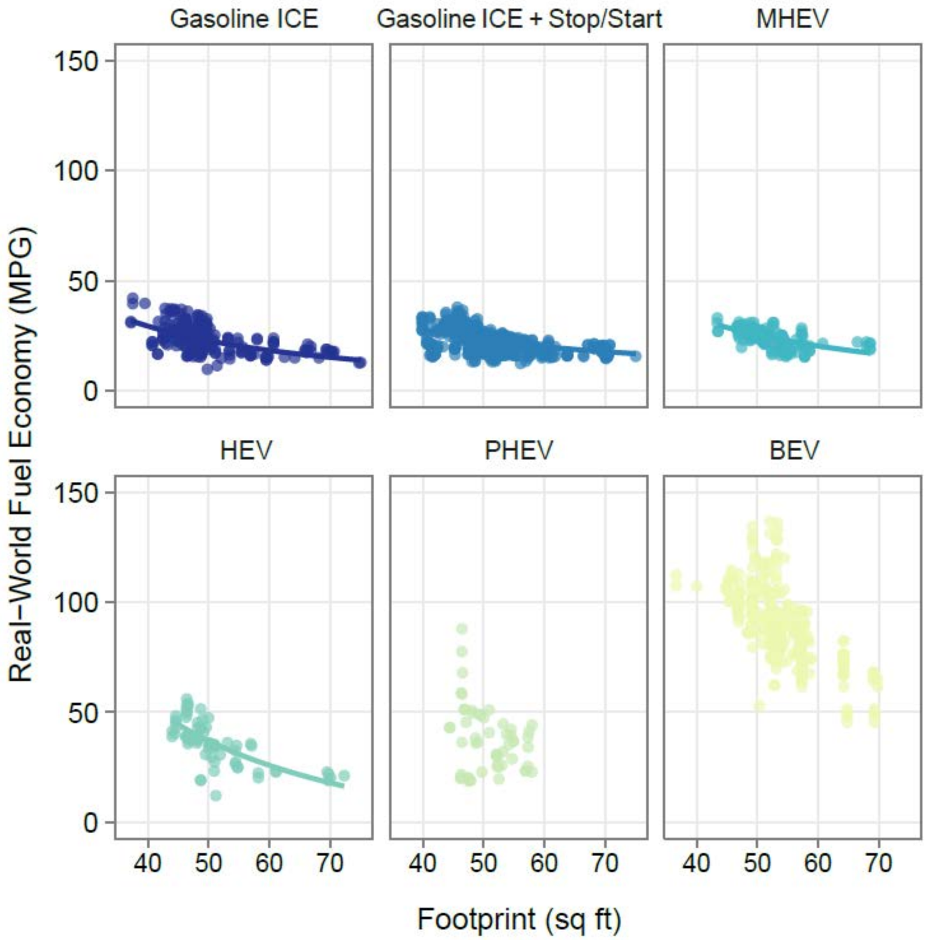
Figure 3.17. Average New Vehicle Footprint by Vehicle Type and Powertrain



Vehicle Footprint and Fuel Economy

Vehicles with a larger footprint are likely to weigh more and have more frontal area, which leads to increased aerodynamic resistance. Increased weight and aerodynamic resistance decrease fuel economy. Figure 3.18 shows estimated real-world fuel economy as a function of vehicle footprint for several model year 2024 technologies. Increased footprint correlates to lower fuel economy for ICE and hybrid technologies and may also correlate for PHEVs. For BEVs, footprint does not impact tailpipe emissions, since all BEVs have zero tailpipe emissions, however increasing BEV footprint likely correlates to reduced vehicle efficiency, as measured in mpge. There was no clear trendline in Figure 3.18 for PHEV and BEV data.

Figure 3.18. Relationship Between Footprint and Fuel Economy



E.Vehicle Type and Attribute Tradeoffs

The past 50 years of data show striking changes in the mix of vehicle types, and the attributes of those vehicles produced for sale in the United States. Between 1975 and the early 1980s, average new vehicle fuel economy increased rapidly, while the vehicle weight and horsepower fell. For the next twenty years, average new vehicle weight and horsepower steadily increased, while fuel economy steadily decreased. Model year 2004 was another inflection point, after which fuel economy, horsepower, and weight have all generally increased together. Since model year 2004, average new vehicle fuel economy has increased 41%, horsepower increased 23%, and weight increased 6%. Footprint has increased 5% since the EPA began tracking it in model year 2008. Fuel economy, weight, horsepower, and footprint are all projected to increase in model year 2025, as shown in Figure 3.19.

In model year 2024, compared to 2023, fuel economy increased while average new vehicle weight, horsepower, and footprint all fell slightly (less than 5%). This is due in part to lower production of BEVs in model year 2024, as BEVs fell from 10% to 7% of all new vehicles, and because BEVs are on average more efficient, powerful, and heavier than comparable vehicles. Without BEVs and PHEVS, the average model year 2024 new vehicle fuel economy was lower by 1.7 mpg, power was lower by 13 hp, weight was lower by 72 pounds, and footprint was slightly lower by 0.1 square feet.

The changes within each of these metrics are due to the combination of design and technology changes within each vehicle type, as well as the market shifts between vehicle types. For example, overall new vehicle footprint has increased within each vehicle type since model year 2008, but the average new vehicle footprint has increased more than the increase in any individual vehicle type over that time span, due to market shifts towards larger vehicle types. Fuel economy has also increased in all vehicle types since model year 2008, however, the market shift towards less efficient vehicle types has offset some of the fleetwide fuel economy benefits that otherwise would have been achieved through additional technology.

Vehicle fuel economy is clearly related to vehicle attributes investigated in this section, namely weight, horsepower, and footprint. Future trends in fuel economy will be dependent, at least in part, on design choices related to these attributes.

Figure 3.19. Relative Change in Fuel Economy, Weight, Horsepower, and Footprint

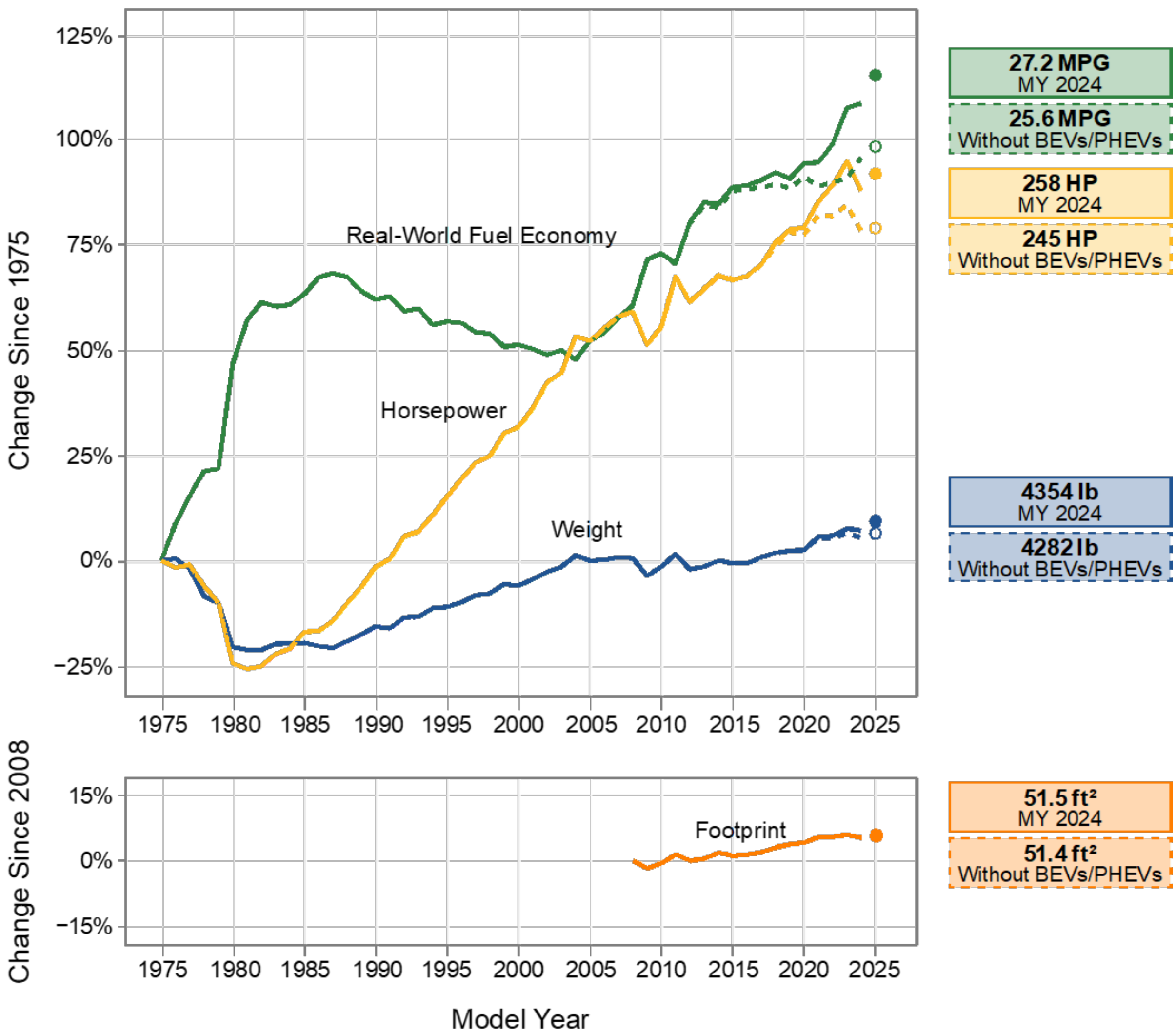


Table 3.1. Vehicle Attributes by Model Year

Model Year	Real-World FE (mpg)	Weight (lbs)	Horsepower (HP)	0 to 60 (s)	Footprint (ft^2)	Car Production Share	Truck Production Share
1975	13.1	4,060	137	-	-	80.7%	19.3%
1980	19.2	3,228	104	15.6	-	83.5%	16.5%
1985	21.3	3,271	114	14.1	-	75.2%	24.8%
1990	21.2	3,426	135	11.5	-	70.4%	29.6%
1995	20.5	3,613	158	10.1	-	63.5%	36.5%
2000	19.8	3,821	181	9.8	-	58.8%	41.2%
2005	19.9	4,059	209	9.0	-	55.6%	44.4%
2010	22.6	4,001	214	8.8	48.5	62.8%	37.2%
2011	22.3	4,126	230	8.5	49.5	57.8%	42.2%
2012	23.6	3,979	222	8.5	48.8	64.4%	35.6%
2013	24.2	4,003	226	8.4	49.1	64.1%	35.9%
2014	24.1	4,060	230	8.3	49.7	59.3%	40.7%
2015	24.6	4,035	229	8.3	49.4	57.4%	42.6%
2016	24.7	4,035	230	8.3	49.5	55.3%	44.7%
2017	24.9	4,093	234	8.2	49.8	52.6%	47.4%
2018	25.1	4,137	241	8.0	50.4	48.0%	52.0%
2019	24.9	4,156	245	7.9	50.8	44.4%	55.6%
2020	25.4	4,166	246	7.8	50.9	43.9%	56.1%
2021	25.4	4,289	254	7.7	51.5	37.1%	62.9%
2022	26.0	4,303	260	7.6	51.6	36.9%	63.1%
2023	27.1	4,372	268	7.3	51.8	37.5%	62.5%
2024	27.2	4,354	258	7.5	51.5	34.3%	65.7%
2025 (prelim)	*28.1*	*4,441*	*264*	*7.3*	*51.8*	*34.7%*	*65.3%*

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends

Table 3.2. Estimated Real-World Fuel Economy by Vehicle Type

Model Year	Sedan/Wagon		Car SUV		Truck SUV		Minivan/Van		Pickup	
	Prod Share	Real-World FE (mpg)	Prod Share	Real-World FE (mpg)	Prod Share	Real-World FE (mpg)	Prod Share	Real-World FE (mpg)	Prod Share	Real-World FE (mpg)
1975	80.6%	13.5	0.1%	11.1	1.7%	11.0	4.5%	11.1	13.1%	11.9
1980	83.5%	20.0	0.0%	14.6	1.6%	13.2	2.1%	14.1	12.7%	16.5
1985	74.6%	23.0	0.6%	20.1	4.5%	16.5	5.9%	16.5	14.4%	18.2
1990	69.8%	23.3	0.5%	18.8	5.1%	16.4	10.0%	17.8	14.5%	17.4
1995	62.0%	23.4	1.5%	17.8	10.5%	16.0	11.0%	18.1	15.0%	16.9
2000	55.1%	22.9	3.7%	17.9	15.2%	16.0	10.2%	18.6	15.8%	16.7
2005	50.5%	23.5	5.1%	20.2	20.6%	16.7	9.3%	19.3	14.5%	15.8
2010	54.5%	26.2	8.2%	23.0	20.7%	19.7	5.0%	20.1	11.5%	16.9
2011	47.8%	25.8	10.0%	23.5	25.5%	19.8	4.3%	20.9	12.3%	17.2
2012	55.0%	27.6	9.4%	23.3	20.6%	20.0	4.9%	21.3	10.1%	17.2
2013	54.1%	28.4	10.0%	24.3	21.8%	20.8	3.8%	21.1	10.4%	17.5
2014	49.2%	28.4	10.1%	24.4	23.9%	21.6	4.3%	21.3	12.4%	18.0
2015	47.2%	29.0	10.2%	25.1	28.1%	21.9	3.9%	21.8	10.7%	18.8
2016	43.8%	29.2	11.5%	26.2	29.1%	22.2	3.9%	21.7	11.7%	18.9
2017	41.0%	30.2	11.6%	26.1	31.7%	22.3	3.6%	22.2	12.1%	18.9
2018	36.7%	30.8	11.3%	27.4	35.0%	23.1	3.1%	22.8	13.9%	19.1
2019	32.7%	30.9	11.7%	27.5	36.5%	23.5	3.4%	22.4	15.6%	19.0
2020	30.9%	31.7	13.0%	28.4	38.7%	23.8	2.9%	23.4	14.4%	19.2
2021	25.7%	32.2	11.4%	31.0	44.7%	24.1	2.2%	27.3	16.1%	19.3
2022	26.5%	33.2	10.4%	33.4	43.8%	24.2	2.9%	26.0	16.4%	20.0
2023	25.0%	34.1	12.5%	40.5	45.4%	24.7	2.5%	25.9	14.7%	20.5
2024	23.7%	33.5	10.6%	39.2	49.6%	25.7	2.0%	26.1	14.1%	20.5
2025 (prelim)	*23.1%*	*36.2*	*11.6%*	*37.6*	*48.3%*	*26.3*	*2.3%*	*28.2*	*14.8%*	*21.3*

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends

Table 3.3. Model Year 2024 Vehicle Attributes by Manufacturer

Manufacturer	Real-World FE (mpg)	Weight (lbs)	Horsepower (HP)	0-to-60 (s)	Footprint (ft^2)
BMW	29.0	4679	345	5.9	50.6
Ford	23.4	4782	303	6.8	56.5
GM	22.9	4685	277	7.6	56.2
Honda	31.0	3903	202	7.9	48.7
Hyundai	29.8	3923	214	7.9	49.2
Kia	29.2	3899	212	8.1	49.2
Mazda	28.0	4043	213	8.6	48.4
Mercedes	26.1	5082	332	5.7	52.5
Nissan	29.0	3993	217	8.4	48.6
Stellantis	22.8	4955	324	6.7	54.9
Subaru	28.7	3836	191	9.1	45.8
Tesla	117.1	4410	420	5.6	50.8
Toyota	29.0	4274	231	7.5	50.8
VW	26.5	4273	260	7.2	48.0
Other	28.0	4499	293	7.6	48.8
All Manufacturers	**27.2**	**4354**	**258**	**7.5**	**51.5**

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends

Table 3.4. Model Year 2024 Estimated Real-World Fuel Economy by Manufacturer and Vehicle Type

	Sedan/Wagon		Car SUV		Truck SUV		Minivan/Van		Pickup	
Manufacturer	**Prod Share**	**Real-World FE (mpg)**	**Prod Share**	**Real-World FE (mpg)**	**Prod Share**	**Real-World FE (mpg)**	**Prod Share**	**Real-World FE (mpg)**	**Prod Share**	**Real-World FE (mpg)**
BMW	42.9%	33.3	6.3%	26.0	50.8%	26.5	-	-	-	-
Ford	4.4%	21.9	6.9%	44.3	46.8%	22.6	-	-	41.8%	22.8
GM	18.6%	28.7	11.0%	30.3	37.6%	23.2	-	-	32.8%	18.9
Honda	46.0%	33.6	7.4%	34.8	38.2%	30.1	5.8%	23.6	2.5%	20.9
Hyundai	23.4%	35.9	25.0%	35.9	51.6%	25.7	-	-	-	-
Kia	26.9%	32.8	17.9%	41.5	48.0%	25.9	7.1%	22.9	-	-
Mazda	10.0%	31.1	-	-	90.0%	27.7	-	-	-	-
Mercedes	32.1%	30.8	11.1%	35.3	56.8%	23	-	-	-	-
Nissan	53.0%	34.3	8.0%	32.8	28.8%	25.1	-	-	10.2%	20.1
Stellantis	1.1%	39.1	3.2%	46.5	69.8%	22.7	9.4%	25.3	16.5%	19.3
Subaru	12.8%	28.7	-	-	87.2%	28.7	-	-	-	-
Tesla	30.0%	125.5	60.9%	113.7	9.1%	114.8	-	-	-	-
Toyota	27.0%	36	9.5%	31.5	45.4%	28.6	2.9%	35.6	15.3%	21.1
VW	23.9%	28	10.6%	37.3	65.5%	24.9	-	-	-	-
Other	21.9%	37.2	1.9%	68.0	74.7%	25.6	0.5%	27.3	1.0%	71.7
All Manufacturers	**23.7%**	**33.5**	**10.6%**	**39.2**	**49.6%**	**25.7**	**2.0%**	**26.1**	**14.1%**	**20.5**

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends

Table 3.5. Footprint by Manufacturer for Model Year 2023–2025 (ft^2)

	Final MY 2023			Final MY 2024			*Preliminary MY 2025*		
Manufacturer	**Car**	**Truck**	**All**	**Car**	**Truck**	**All**	***Car***	***Truck***	***All***
BMW	48.6	52.0	50.2	48.8	52.3	50.6	*48.3*	*51.9*	*50.2*
Ford	49.2	59.2	58.2	48.2	57.6	56.5	*48.4*	*58.3*	*57.1*
GM	46.3	59.0	55.7	46.6	60.2	56.2	*47.0*	*60.4*	*56.2*
Honda	46.9	51.9	49.4	46.8	50.9	48.7	*46.7*	*51.5*	*49.2*
Hyundai	47.6	50.3	48.7	48.1	50.3	49.2	*48.4*	*50.2*	*49.3*
Kia	46.2	50.0	47.9	46.5	51.4	49.2	*46.7*	*51.1*	*49.0*
Mazda	44.0	47.0	46.7	44.5	48.8	48.4	*44.2*	*48.6*	*48.3*
Mercedes	50.7	53.9	52.3	50.8	53.8	52.5	*50.5*	*53.2*	*51.8*
Nissan	46.6	50.6	48.4	46.3	52.2	48.6	*46.6*	*50.7*	*48.4*
Stellantis	52.8	56.6	56.0	46.4	55.2	54.9	*48.1*	*58.0*	*57.5*
Subaru	45.0	46.2	46.0	45.1	46.0	45.8	*45.2*	*45.9*	*45.8*
Tesla	50.7	51.5	50.7	50.8	51.4	50.8	*50.2*	*66.1*	*50.6*
Toyota	46.9	52.6	50.4	46.6	53.2	50.8	*46.9*	*54.1*	*51.2*
VW	46.5	50.3	48.8	45.7	49.2	48.0	*46.0*	*50.0*	*48.8*
Other	47.6	51.6	50.8	43.5	50.5	48.8	*50.8*	*53.2*	*52.9*
All Manufacturers	**47.7**	**54.2**	**51.8**	**47.1**	**53.8**	**51.5**	***47.4***	***54.2***	***51.8***

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends

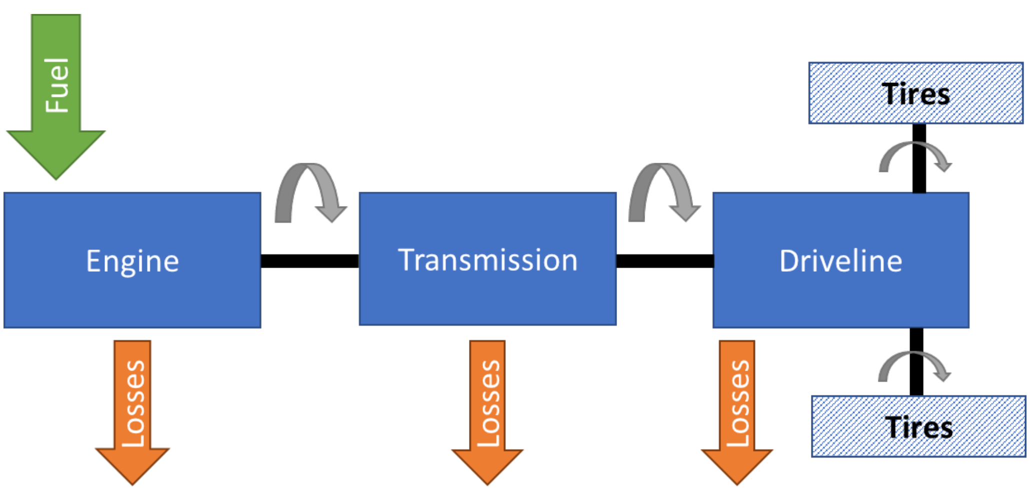
4. Vehicle Technology

Since model year 1975, the technology used in vehicles has continually evolved. Today's vehicles utilize an increasingly wide array of technological solutions developed by the automotive industry to improve vehicle attributes discussed previously in this report, including fuel economy, vehicle power, and acceleration. Automotive engineers and designers are constantly creating and evaluating new technology and deciding how, or if, it should be applied to their vehicles. This section of the report looks at vehicle technology from two perspectives; first, how the industry has adopted specific technologies over time, and second, how those technologies have impacted fuel economy.

Vehicle Architecture

All vehicles use some type of engine or electric motor to convert energy stored on the vehicle, usually in a fuel or battery, into rotational energy to propel the vehicle forward. The generalized vehicle architecture for a vehicle with a gasoline ICE is shown in Figure 4.1. ICEs typically combust gasoline or diesel fuel to rotate an output shaft. The engine is paired with a transmission to convert the rotational energy from the relatively narrow range of speeds available at the engine to the appropriate speed required for driving conditions. The transmission is connected to a driveline that transfers the rotational energy from the transmission to the two or four wheels being used to move the vehicle. Each of these components has energy losses, or inefficiencies, which ultimately decrease fuel economy.

Figure 4.1. Vehicle Energy Flow for an Internal Combustion Engine Vehicle



The general vehicle design shown in Figure 4.1 was nearly universal in the automotive industry for decades, but more recent technology developments have created vehicle architectures that look quite different.

Vehicles that have stop/start systems generally use a larger alternator and enhanced low-voltage battery, which enables the vehicle to turn off the engine at idle to save fuel. Hybrid vehicles use a larger, higher-voltage battery to recapture braking energy and provide traction power when necessary, allowing for a smaller, more efficiently operated engine. Hybrids can be separated into "mild" hybrid systems (MHEVs) that provide launch assist but cannot propel the vehicle on their own, and "strong" hybrid systems (HEVs) that can temporarily power the vehicle without engaging the engine. PHEVs have both a battery that can be charged from an external electricity source and a gasoline engine and operate on electricity until the battery is depleted or cannot meet driving needs. HEVs and PHEVs often have much more complicated architectures that allow for complex energy optimization strategies that ultimately improve some combination of vehicle fuel economy and vehicle performance. These vehicles use a combination of an engine and one or more electric motors to power the wheels, and recapture braking energy.

BEVs employ a battery pack that is externally charged and an electric motor exclusively for propulsion, and do not have an onboard gasoline engine. BEVs can have very simple powertrain architecture layouts, as vehicles with one electric motor can be directly connected to the driveline without a traditional transmission.[13] However, some manufacturers are producing electric vehicles with 2-speed transmissions, and others have developed vehicles with two or more electric motors that propel the vehicle in combination.

Vehicles with diesel engines are also present in the light-duty automotive market and briefly reached 6% of all production in model year 1981. Vehicles relying on the combustion of a fuel other than gasoline or diesel, such as compressed natural gas (CNG), have occasionally been produced for sale in the U.S. Fuel cell electric vehicles (FCEVs) which use a fuel cell stack to create electricity from an onboard fuel source (usually hydrogen) to power an electric motor, have also been produced in recent years. These vehicles are

[13] For more information on electric vehicles, see EPA's Green Vehicle Guide (https://www.epa.gov/greenvehicles) or the U.S. Department of Energy's Alternative Fuels Data Center (https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work), or www.fueleconomy.gov (https://fueleconomy.gov/feg/evtech.shtml)

included in the data for this report but generally have not been produced in large volumes.[14]

Overall Industry Trends

Innovation in the automobile industry has led to a wide array of technologies available to manufacturers to achieve fuel economy and performance goals and meet regulatory requirements. Figure 4.3 illustrates manufacturer-specific technology usage for model year 2024 for technologies that represent increasing levels of vehicle electrification, as well as the recent adoption trends of those technologies across the industry. The technologies in Figure 4.3 are being used by manufacturers, in part, to increase fuel economy. Manufacturers' strategies to develop and adopt these technologies are unique and vary significantly. Each manufacturer is choosing technologies that best meet the design requirements of their vehicles. In model year 2024, gasoline vehicles with stop/start, MHEVs, HEVs, and PHEVs all gained market share and captured their largest market shares on record.

In addition to electrification technologies, other technologies continue to improve the performance of ICEs, including the engines found in hybrids and PHEVS. These technologies include a combination of turbocharged engines (Turbo), gasoline direct injection (GDI), fuel injection systems that can alternate between GDI or port fuel injection (GDPI), and cylinder deactivation (CD). Higher speed transmissions and continuous variable transmissions (CVT) also enable the engine to operate in the most efficient way possible. Table 4.1 shows the implementation of several of these technologies, as used in conjunction with the electrification technologies identified in Figure 4.2.

[14] Vehicles converted to an alternative fuel in the aftermarket are not included in this data.

Figure 4.2. Manufacturer Use of Electrification Technologies for Model Year 2024

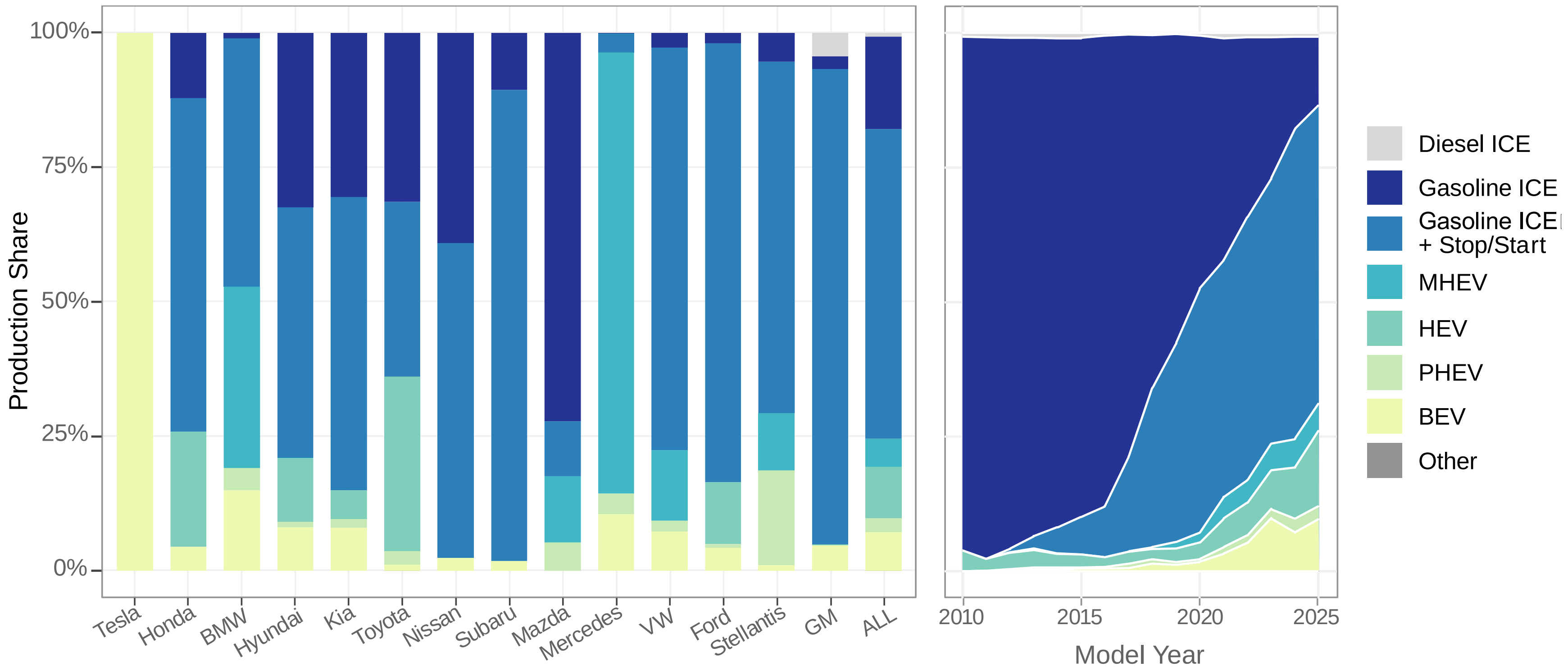


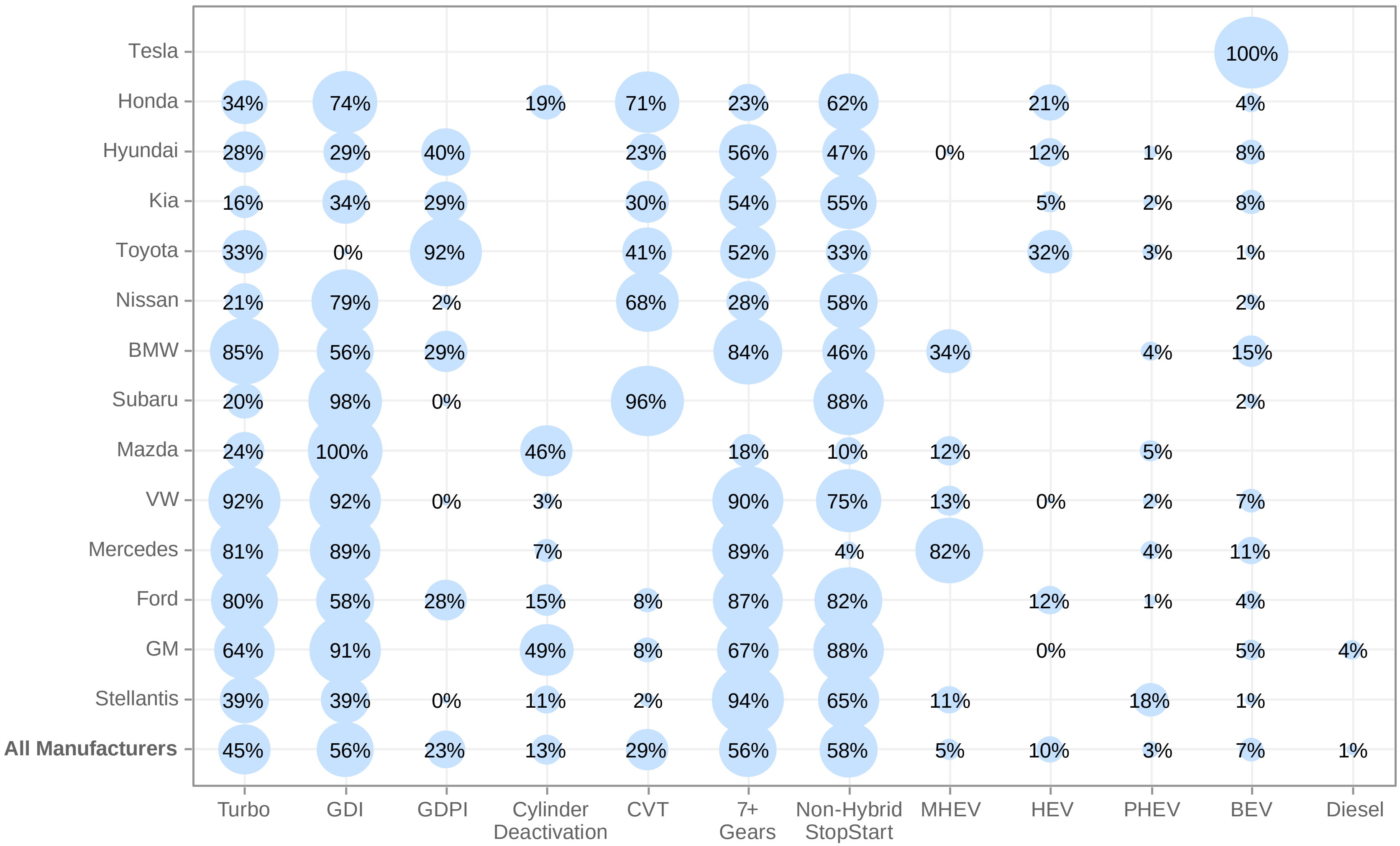
Table 4.1. Production Share by Drive Technology for Model Year 2024

Technology	Diesel	Gasoline ICE without Stop/Start	Gasoline ICE with Stop/Start	Mild Hybrid (MHEV)	Strong Hybrid (HEV)	Plug-In Hybrid (PHEV)	Battery Electric (BEV)	Fuel Cell (FCEV)	All
Production Share	0.7%	17.2%	57.6%	5.3%	9.5%	2.5%	7.2%	0.0%	100.0%
Stop/Start	100.0%	-	100.0%	93.2%	100.0%	86.7%	-	-	74.9%
GDI	-	33.3%	71.8%	73.7%	35.5%	74.7%	-	-	56.2%
GDPI	-	33.2%	19.7%	13.4%	53.9%	16.5%	-	-	23.3%
Turbo	100.0%	20.6%	57.1%	75.3%	23.3%	67.7%	-	-	45.1%
7+ Gears	100.0%	33.8%	71.1%	100.0%	12.9%	61.5%	-	-	55.6%
CVT	-	45.8%	22.5%	-	75.5%	23.8%	-	100%	28.6%
Average Fuel Economy (mpge)	23.6	26.8	24.3	23.9	35.5	36.8	99.9	73.3	27.2
Average # Cylinders	6	4.5	4.7	5.5	4.2	4.2	-	-	4.7

Table 4.1 shows the current adoption rates of electrification and engine improvement technologies for the fourteen largest manufacturers. The technologies in Table 4.1 have emerged as significant technology developments within the last 10-15 years (some, like turbocharged engines, were available before this timeframe, but in small numbers). Manufacturers are continuing to implement both electrification and engine technology improvements across their vehicles to improve fuel economy and performance.

The following sections provide a deeper look into many of the technology trends identified here, beginning with engine/propulsion technologies, then transmissions, and drivelines. While the evolution of vehicles in more recent years challenges the breakdown of technology into these traditional categories, it is still a useful context for evaluating different aspects of vehicle technology and the many changes taking place across the automotive industry.

Figure 4.3. Manufacturer Use of Advanced Technologies for Model Year 2024[15]



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[15] In some cases, manufacturers have adopted a technology on a small number of vehicles that round to 0% of production. On this figure and throughout the report, these instances are denoted as "0%" while technologies that have not been adopted in any amount are left blank.

A. Vehicle Propulsion

As discussed above, all vehicles use at least one engine or electric motor to convert stored energy into rotational energy to propel the vehicle forward. Over the 50 years that the EPA has been collecting data, the technology used in engines, and now electric motors, has continually evolved. The industry continues to develop new and innovative technologies to improve vehicle efficiency, reduce emissions, increase vehicle performance, and increase vehicle utility. The following analysis will look at technology trends within gasoline engine vehicles, hybrids, PHEVs, and EVs, and diesels. Each of these categories of engine technologies has unique properties, metrics, and trends over time.

Gasoline Engines

Since the EPA began tracking vehicle data in 1975, more than 700 million vehicles have been produced for sale in the United States. While electric vehicles have been capturing a growing share of the market in recent years, as shown in Figure 4.2, vehicles with gasoline engines still make up most of the vehicle market today and in past years have often been nearly the only option available.

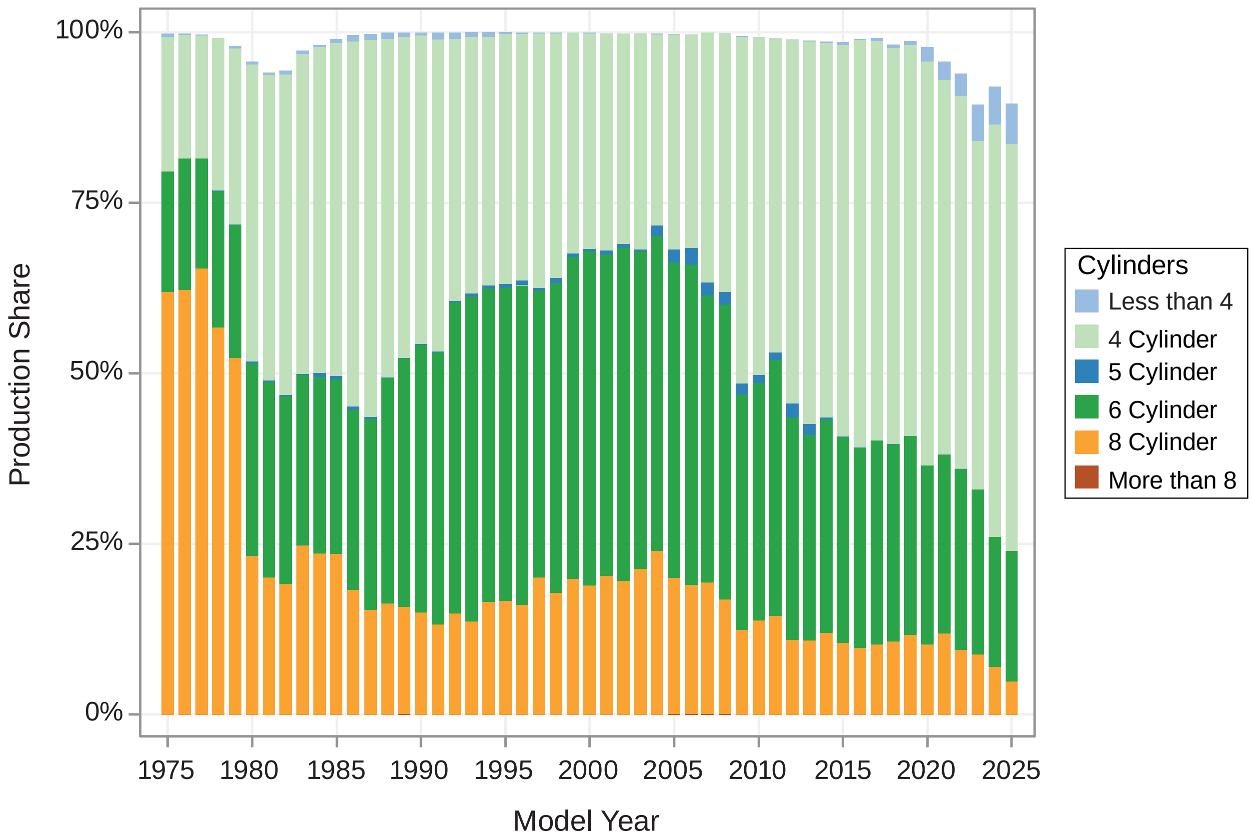
The following analysis focuses on engine technology and metrics for gasoline engines. Hybrid and plug-in hybrid vehicles are included in this data unless they are explicitly excluded. For the purposes of this report, "flex fuel" vehicles that are capable of operating on gasoline or a blend of 85% ethanol and 15% gasoline (E85) are included with gasoline engines and are not evaluated separately.

Engine Size and Displacement

Measuring and tracking new vehicle engine size is one of the most basic and important ways to track engine trends, because larger engines strongly correlate with higher fuel use. Engine size is generally described in one of two ways, either the number of cylinders or the total displacement of the engine (the total volume of the cylinders). Figure 4.4 shows the production share of gasoline engines by number of cylinders over time.

In the mid and late 1970s, the 8-cylinder gasoline engine was dominant, accounting for well over half of all new vehicle production. Between model year 1979 and 1980, there was a significant change in the market, as 8-cylinder engine production share dropped, as larger engines were replaced with smaller 4-cylinder and some 6-cylinder engines. From model year 1987 through 2004, production moved back towards larger 6-cylinder and 8-cylinder engines. This trend reversed again in 2005 as production began trending back towards 4-cylinder engines. Four-cylinder gasoline engines are the most popular engine option, capturing 60% of the market in model year 2024.

Figure 4.4. Gasoline Engine Production Share by Number of Cylinders

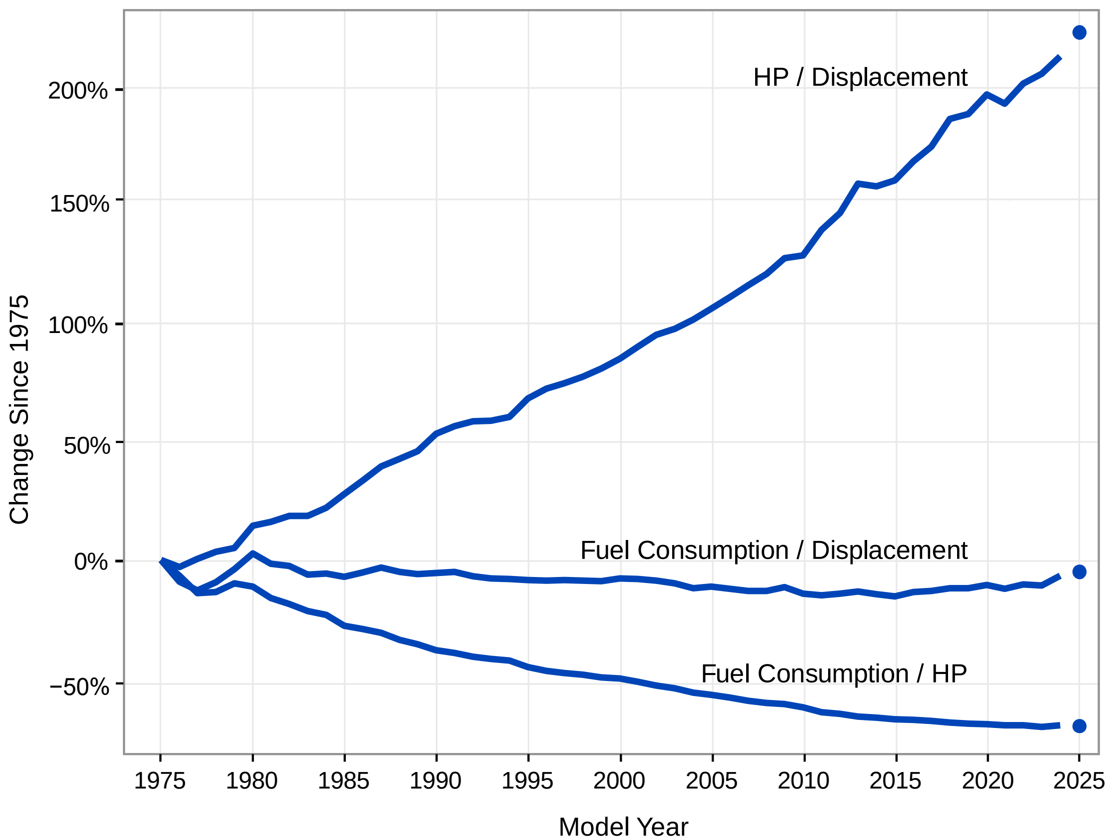


Overall engine size, as measured by the total volume of all the engine's cylinders, is directly related to the number of cylinders. As vehicles have moved towards engines with a lower number of cylinders, the total engine size, or displacement, is also at an all-time low. The average new vehicle in model year 1975 had a displacement of nearly 300 cubic inches (or just under five liters), compared to an average of 159 cubic inches (about 2.6 liters) in model year 2024. Gasoline engine displacement per cylinder has been relatively stable over the time of this report (around 34 cubic inches, or 0.6 liters, per cylinder since 1980), so the reduction in overall new vehicle engine displacement is almost entirely due to the shift towards engines with fewer cylinders.

Even as gasoline engine displacement has fallen over time, horsepower has generally increased. One way to examine the relationship between gasoline engine horsepower and displacement is to look at the trend in *specific* power (HP/Displacement), which is a metric to compare the power output of an engine relative to its size. Specific power has more than doubled between model year 1975 and model year 2024. The rate at which specific power has increased has been remarkably steady, as shown in Figure 4.5. The specific power of new vehicle gasoline engines (excluding hybrids and PHEVs) has increased by about 0.02 horsepower per cubic inch every year for 50 years. 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 4.5 also shows two other important engine metrics, the amount of fuel consumed compared to the overall size of the engine (Fuel Consumption/Displacement), and the amount of fuel consumed relative to the amount of power produced by an engine (Fuel Consumption/HP). For Figure 4.5, gasoline engines in hybrids and PHEVs have been excluded. The amount of fuel consumed by a gasoline engine in model year 2024, relative to the total displacement, is about 7% lower than in model year 1975. Fuel consumption relative to engine horsepower has fallen more than 70% since model year 1975. Taken as a whole, the trend lines in Figure 4.5 clearly show that gasoline engine improvements over time have been steady and continual and have resulted in impressive performance and efficiency improvements to internal combustion engines.

Figure 4.5. Percent Change for Specific Gasoline Non-Hybrid Engine Metrics



Fuel Delivery Systems and Valvetrains

All gasoline engines require a fuel delivery system that controls the flow of fuel delivered into the engine. The process for controlling fuel flow has changed significantly over time, allowing for much more control over the combustion process and thus more efficient engines. Figure 4.6 shows many different engine designs as they have entered, and in many cases exited, the automotive market. Some fleetwide changes occurred gradually, but in some cases (for example trucks in the late 1980s), engine technology experienced widespread change in only a few years. Evolving technology offers opportunities to improve fuel economy, power, and other vehicle parameters.

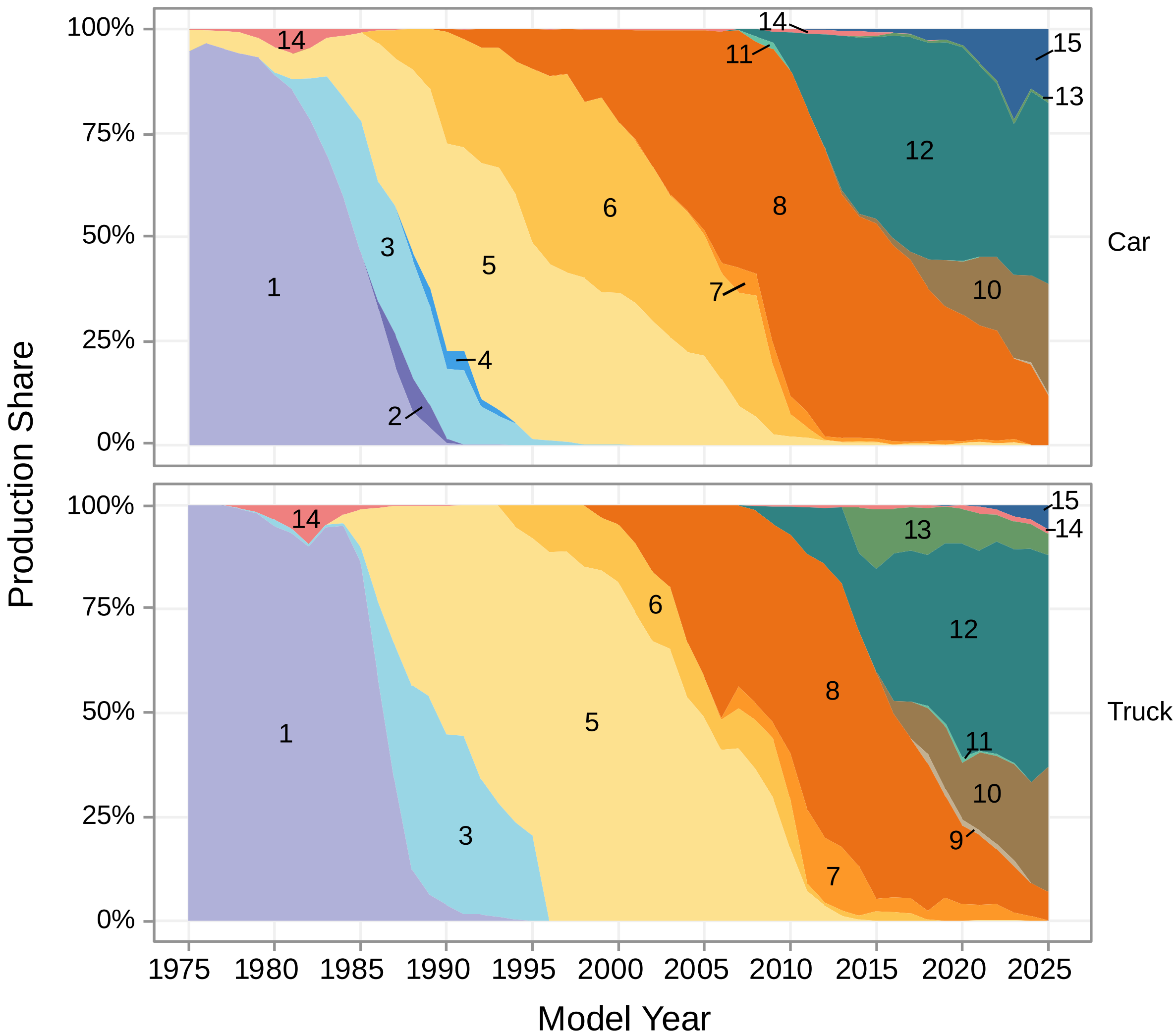
In the 1970s and early 1980s, nearly all gasoline engines used carburetors to meter fuel delivered to the engine. Carburetors were replaced over time with fuel injection systems; first throttle body injection (TBI) systems, then port fuel injection (PFI) systems, and more recently gasoline direct injection (GDI) and combined gasoline direct and port injection engines (GDPI), as shown in Figure 4.6. TBI and PFI systems use fuel injectors to electronically deliver fuel and mix it with air outside of the engine cylinder; the resulting air and fuel mixture is then delivered to the engine cylinders for combustion. Engines that utilize GDI spray fuel directly into the air in the engine cylinder for better control of the combustion process. Engines using GDI were first introduced into the market with very limited production in model year 2007. The use of GDI has increased in subsequent years to the point where almost 80% of the model year 2024 fleet had either GDI or GDPI. In model year 2024, GDI engines were installed in 56% of new vehicles, while GDPI engines were installed in 23% of new vehicles.

Another key aspect of engine design is the valvetrain. Each engine cylinder must have a set of valves that allow for air (or an air/fuel mixture) to flow into the engine cylinder prior to combustion and for exhaust gases to exit the cylinder after combustion. The number of valves per cylinder and the method of controlling the valves (i.e., the valvetrain) directly impacts the overall efficiency of the engine. Generally, engines with four valves per cylinder instead of two, and valvetrains that can alter valve timing during the combustion cycle can provide more precise control of the combustion process and therefore increase engine power and efficiency.

This report began tracking multi-valve engines (i.e., engines with more than two valves per cylinder) for cars in model year 1986 and for trucks in model year 1994. Since that time, almost 90% of the fleet has converted to gasoline multi-valve engines. While some 3- and 5-valve engines have been produced, the majority of multi-valve engines are based on four valves per cylinder. Engines with four valves generally use two valves for air intake and two valves for exhaust. In addition, this report began tracking variable valve timing (VVT) technology for cars in model year 1990 and for trucks in model year 2000, and since then nearly the entire fleet has adopted this technology. Figure 4.6 shows the evolution of engine technology, including fuel delivery method and the introduction of VVT and multi-valve engines.

As shown in Figure 4.6, fuel delivery and valvetrain technologies have often been developed simultaneously. 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 timespan covered by this report.

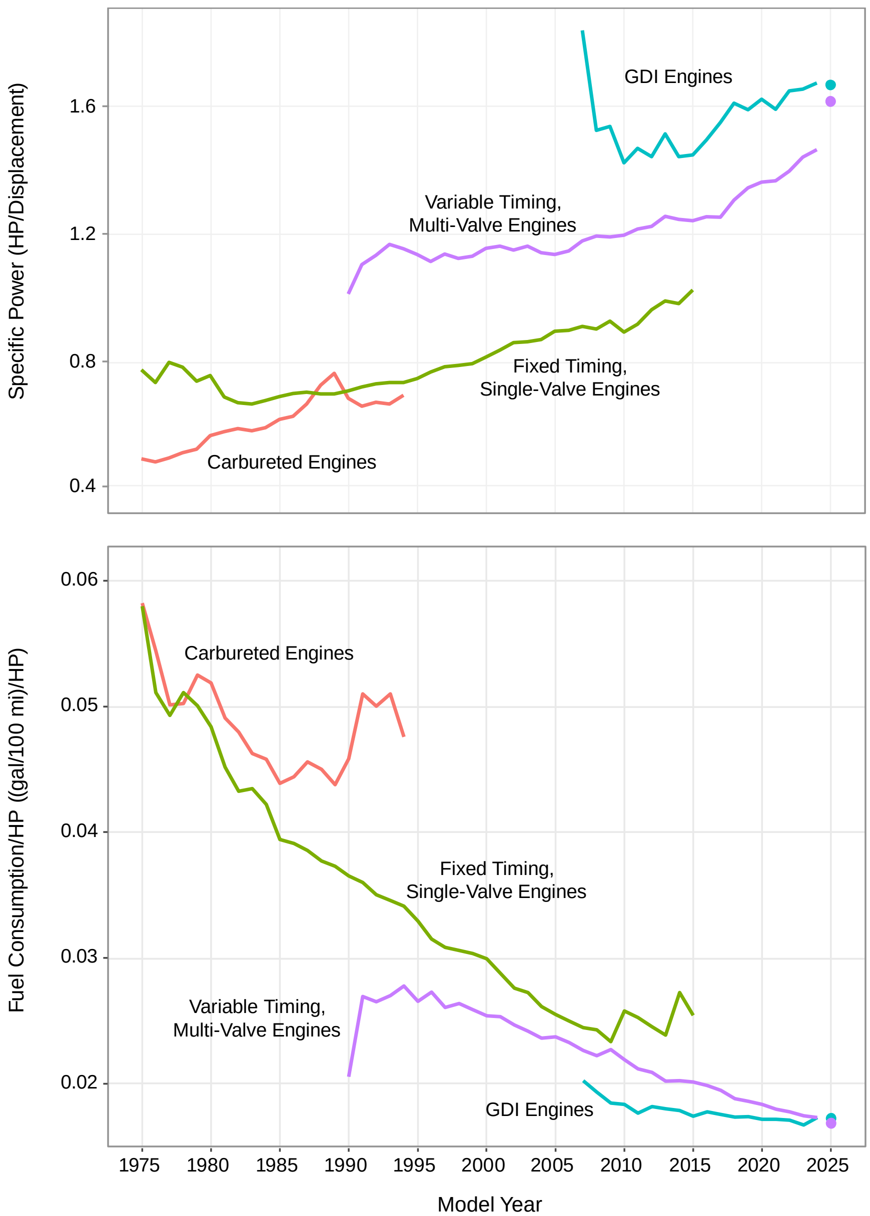
Figure 4.6. Production Share by Engine Technology



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 (GDPI)	Fixed	Multi-Valve	9
	Variable	Multi-Valve	10
Gasoline Direct Injection (GDI)	Fixed	Multi-Valve	11
	Variable	Multi-Valve	12
		Two-Valve	13
Diesel	—	—	14
BEV/FCEV	—	—	15

Figure 4.7 shows the changes in specific power and fuel consumption per horsepower for 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 engines with two valves, fixed timing, and port fuel injection, then to engines with multi-valve VVT and port fuel injection, and finally to GDI engines. Some of the increase for GDI engines may also be due to the pairing of GDI engines with turbochargers to further increase power. Vehicles with fixed valve timing and two valves per cylinder have been limited in recent years and are no longer included in Figure 4.7 after model year 2015 due to very limited production.

Figure 4.7. Engine Metrics for Different Gasoline Technology Packages



Turbocharging

Turbochargers increase the power that an engine can produce by forcing more air, and thus fuel, into the engine. An engine with a turbocharger can produce more power than an identically sized engine that is naturally aspirated or does not have a turbocharger. Turbochargers are powered using the pressure of the engine exhaust as it leaves the engine. Superchargers operate the same way as turbochargers but are directly connected to the engine for power, instead of using the engine exhaust. Alternate turbocharging and supercharging methods, such as electric superchargers, are also beginning to emerge. A limited number of new vehicles utilize both a turbocharger and supercharger in one engine package. Most current gasoline turbocharged engines also use GDI and VVT. This allows for more efficient engine operation, helps prevent premature combustion (engine knock), and reduces turbo lag (the amount of time it takes for a turbocharger to engage).

Gasoline turbocharged engines (including HEVs and PHEVs) have grown steadily in the marketplace, accounting for more than 44% of all vehicle production in model year 2024, as shown in Figure 4.8. Many of these engines are applying turbochargers to create “turbo downsized” engine packages that can combine the improved fuel economy of smaller engines during normal operation but can provide the power of a larger engine by engaging the turbocharger when necessary. As evidence of this turbo downsizing, most gasoline turbocharged engines in model year 2024 are 4-cylinder engines. Model year 2025 is projected to be a similar distribution, as shown in Figure 4.9.

Figure 4.8. Gasoline Turbo Engine Production Share by Vehicle Type

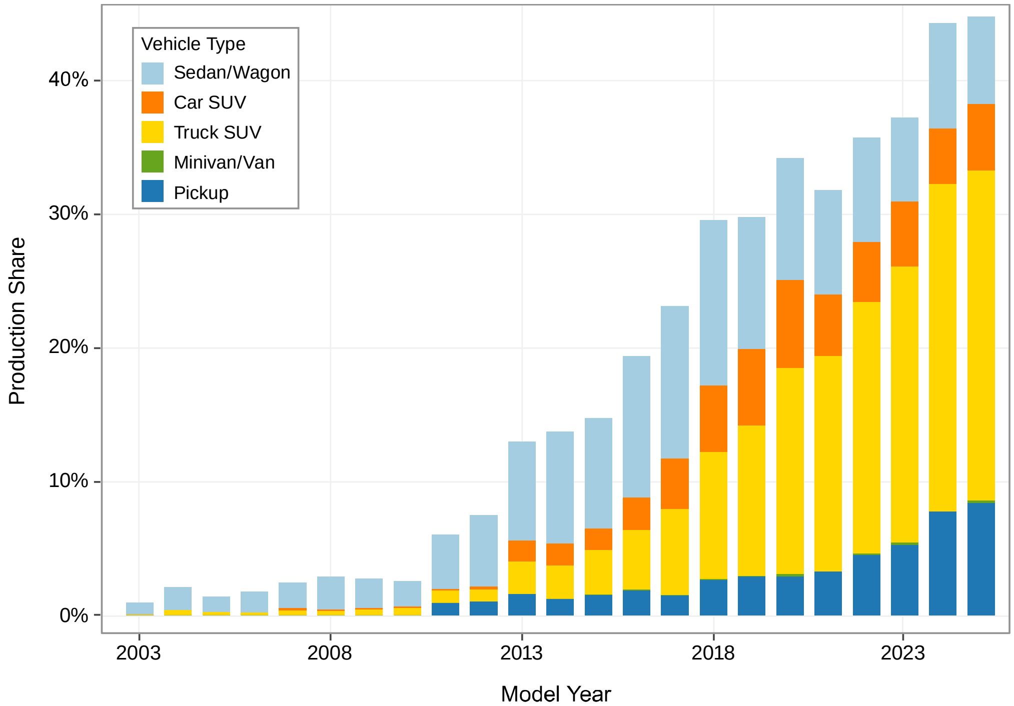
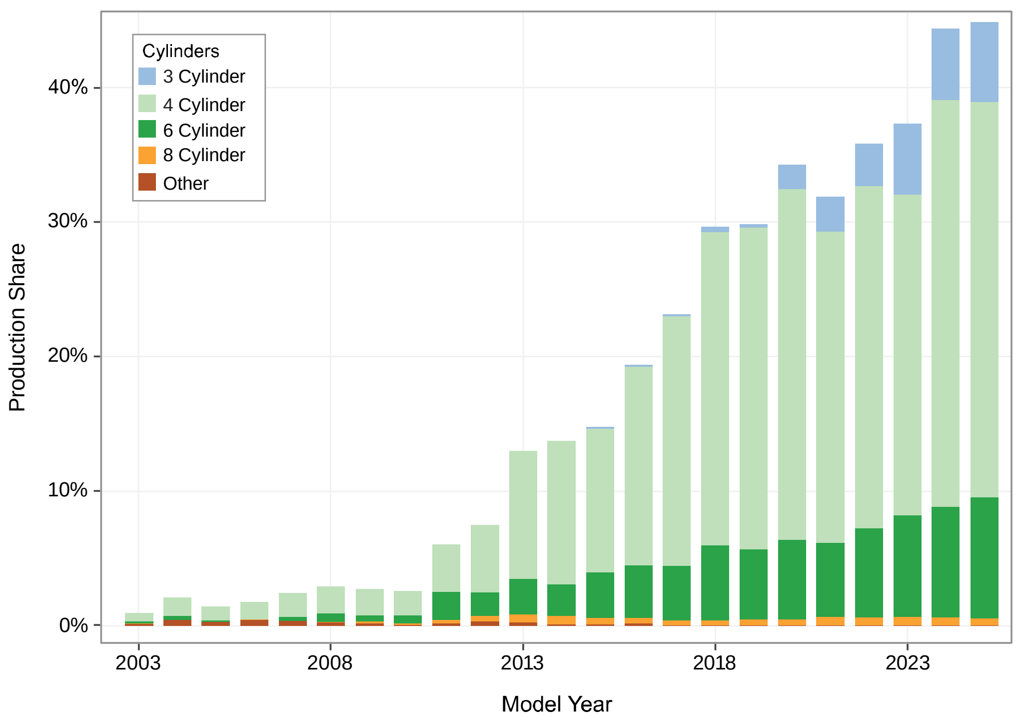


Figure 4.9. Gasoline Turbo Engine Production Share by Number of Cylinders



Cylinder Deactivation

Cylinder deactivation is an engine management approach that turns off the flow of fuel to one or more engine cylinders and electricity to the corresponding spark plugs when driving conditions do not require full engine power. This effectively allows a large engine to act as a smaller engine when the additional cylinders are not needed, increasing engine efficiency and fuel economy. The use of cylinder deactivation in gasoline vehicles steadily climbed through model year 2021 but has fallen slightly since to 13% of all new model year 2024 vehicles. Projected model year 2025 data suggests another small drop in the use of cylinder deactivation across all new vehicles.

Non-hybrid Stop/Start

Engine stop/start technology allows the engine to be automatically turned off at idle and restarted when the driver releases the brake pedal. By turning the engine off, a vehicle can eliminate the fuel use that would have occurred if the engine was left running. This report began tracking stop/start technology in model year 2012 at less than one percent. Since then, the use of stop/start has increased to 58% of all new gasoline non-hybrid vehicles in model year 2024. Non-hybrid stop/start systems have been used in a wide range of applications, including all vehicle types, as shown in Figure 4.10 and Figure 4.11.

Figure 4.10. Gasoline Non-Hybrid Stop/Start Production Share by Vehicle Type

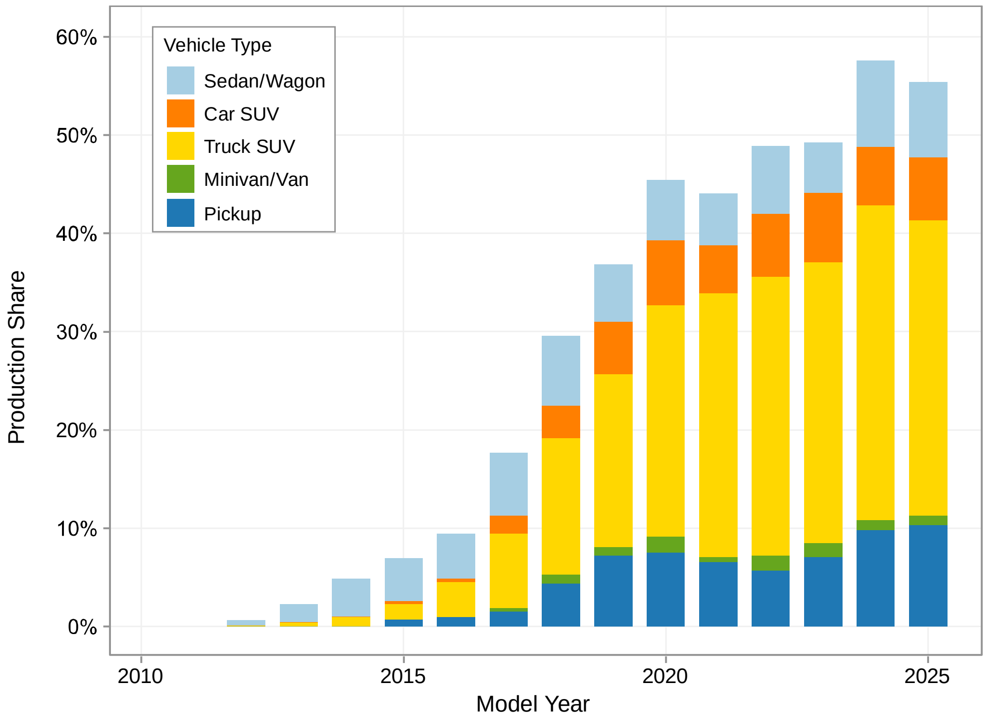
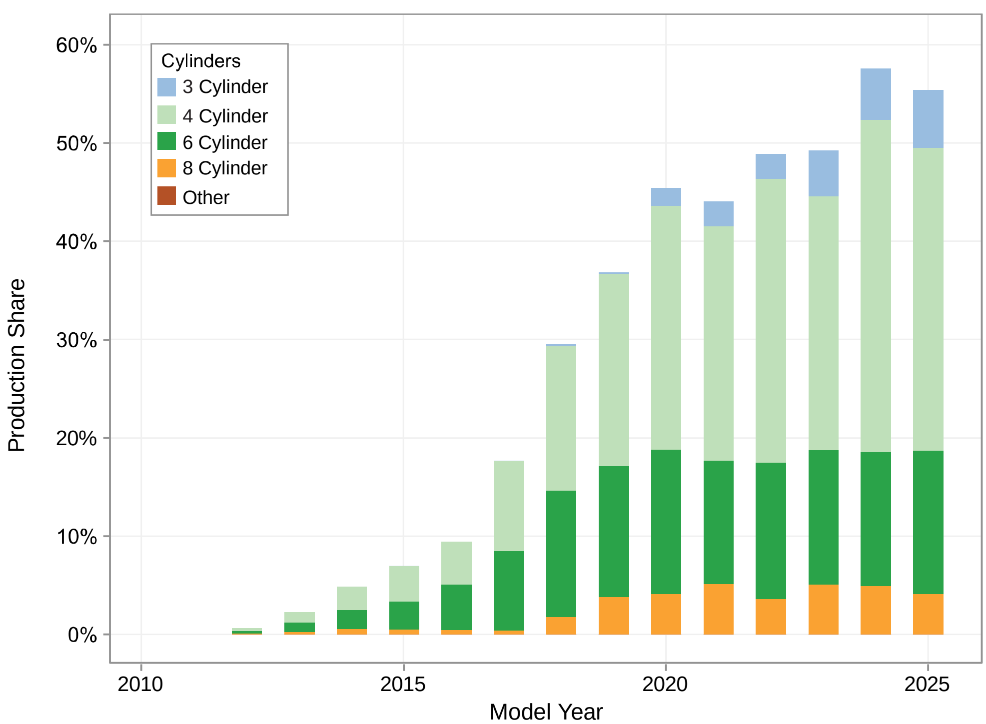


Figure 4.11. Gasoline Non-Hybrid Stop/Start Production Share by Number of Cylinders



Hybrids

Gasoline hybrid vehicles feature a battery pack that is larger and higher-voltage than the battery found on a typical gasoline vehicle, which allows these vehicles to store and strategically apply electrical energy to supplement the gasoline engine. The result is that the engine can be smaller than what would be needed in a non-hybrid vehicle, and the engine can be operated near its peak efficiency more often. Hybrids also frequently utilize regenerative braking, which uses an electric motor/generator to capture energy from braking instead of losing that energy to friction and heat, as in traditional friction braking, and stop/start technology to turn off the engine at idle. The combination of these strategies can result in significant reductions in fuel use.

The hybrid category includes "mild" hybrids (MHEVs), which employ a low voltage electrical system that can provide launch assist and engine assist but cannot directly propel the vehicle. "Strong" hybrid systems (HEVs) can temporarily power the vehicle without engaging the engine and may be able to capture more regenerative braking. For the purposes of this report, new vehicles with a 48V DC or less electrical system are classified as mild hybrids, while high voltage electrical systems are classified as strong hybrids.

Hybrids were first introduced in the U.S. marketplace in model year 2000 with the Honda Insight. As more models and options were introduced into the market, hybrid production increased to 4% of all vehicles in model year 2010 before slowly declining to less than 2% of new vehicle production in model year 2016. Since model year 2016 however, the percent of new vehicles that are hybrids has steadily grown and reached a new high of 15% of all new vehicles in model year 2024. Hybrid growth is projected to continue growing in model year 2025, to 19% of new vehicle production.

Early hybrids were mostly the sedan/wagon vehicle type, but recent growth in other vehicle types, particularly truck SUVs, has propelled recent growth, as shown in Figure 4.12. In model year 2020, the production of hybrids in the truck SUV category surpassed the production of sedan/wagon hybrids for the first time and did so by more than 50%. Hybrids are also being used in the pickup and minivan/van vehicle types. Sedan/wagon hybrids accounted for less than 25% of all hybrid production in model year 2024. Hybrid vehicles typically use a 4-cylinder engine, although an increasing number of 6-cylinder engines are being used in hybrid systems, as shown in Figure 4.13.

Figure 4.12. Gasoline Hybrid Engine Production Share by Vehicle Type

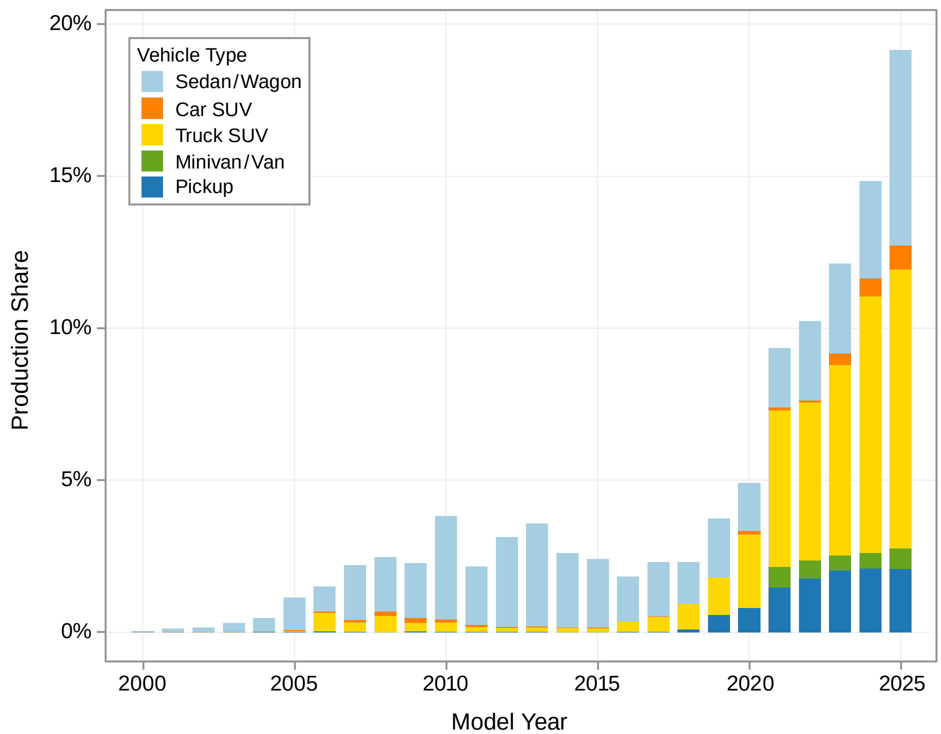


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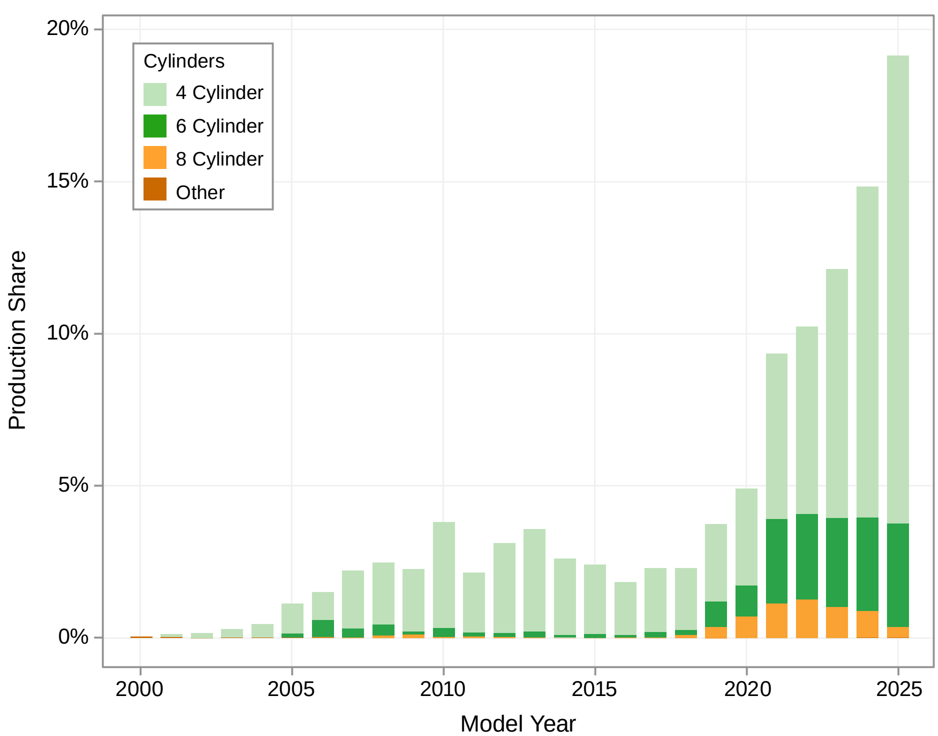
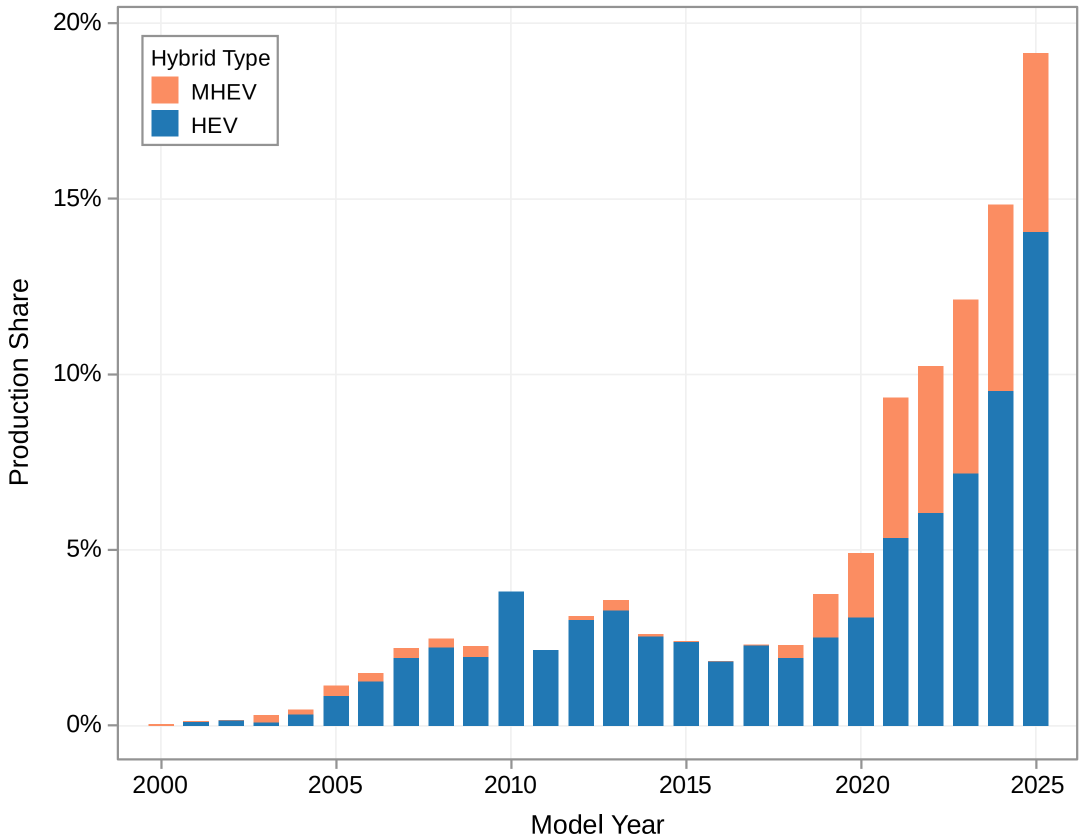
Figure 4.13. Gasoline Hybrid Engine Production Share by Number of Cylinders



While strong hybrids have increased market penetration in recent years, the growth of mild hybrids from very limited numbers to current production has contributed to the overall market share rise for hybrids. Mild hybrids accounted for about 35% of hybrid production in model year 2024, as shown in Figure 4.14.

Figure 4.14. Gasoline Hybrid Engine Production Share Hybrid Type



Plug-In Hybrid Electric, Battery Electric, and Fuel Cell Electric Vehicles

PHEVs and BEVs are two types of vehicles that can store electricity from an external source onboard the vehicle, utilizing that stored energy to propel the vehicle. PHEVs are similar to gasoline hybrids discussed previously, but the battery packs in PHEVs can be charged from an external electricity source; this cannot be done in mild or strong hybrids. BEVs operate using only energy stored in a battery from external charging. Fuel cell electric vehicles use a fuel cell stack to create electricity from an onboard fuel source (usually hydrogen), which then powers an electric motor or motors to propel the vehicle. The use of electricity instead of gasoline as a fuel source complicates the comparison of BEVs (and PHEVs) to ICE vehicles, requiring different metrics[16] and an evolving analysis of vehicle technology.

BEVs rely on electricity stored in a battery for fuel. Combustion does not occur onboard the vehicle, and therefore there are no tailpipe emissions created by the vehicle. The electricity used to charge BEVs can create emissions at the power plant. The amount of emission varies depending on the fuel source of the electricity, which can in turn vary based on geographical location, time of day, and weather.

Since BEVs do not use gasoline, the familiar metric of miles per gallon cannot be applied to BEVs. Instead, BEVs are rated in terms of miles per gallon-equivalent (mpge), which is the number of miles that a BEV travels on an amount of electrical energy equivalent to the energy in a gallon of gasoline. This metric enables a direct comparison of energy efficiency between BEVs and gasoline-powered vehicles. BEVs generally have a much higher energy efficiency than gasoline vehicles because electric motors are much more efficient than gasoline engines.

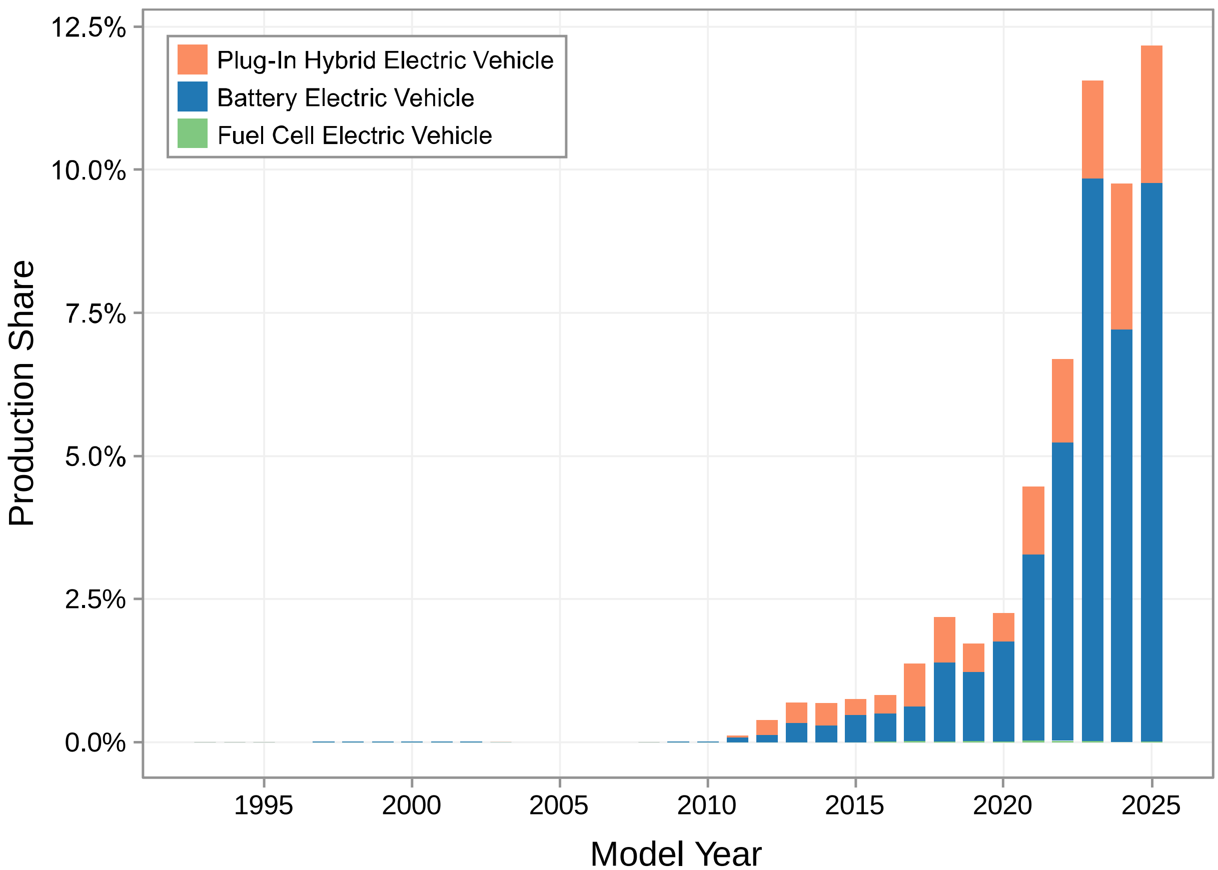
PHEVs can operate either on electricity stored in a battery, or gasoline, allowing for a wide range of engine designs and strategies for the utilization of stored electrical energy during typical driving. Most PHEVs will operate on electricity only, like a BEV, for a limited range, and then will operate like a strong hybrid until their battery is recharged from an external source. The use of electricity to provide some or all of the energy required for propulsion can significantly lower fuel consumption. For a much more detailed discussion of BEV and PHEV metrics, as well as upstream emissions from electricity, see Appendix E.

The production of BEVs and PHEVs has increased in recent years. Prior to model year 2011, BEVs were available, but generally only in small numbers for lease in California.[17] In model year 2011, the first PHEV, the Chevrolet Volt, was introduced along with the Nissan Leaf BEV. Many additional models have been introduced since, and in model year 2024 combined BEV/PHEV production accounted for almost 10% of all new vehicles. Combined BEV and PHEV production is projected to reach a new high of 12% of all production in model year 2025. In recent model years, there have been only two hydrogen FCEV models produced, and they have only been available in small numbers in the states of California and Hawaii. A third vehicle that can operate on hydrogen is included in the model year 2025 data, although that vehicle can also operate as a PHEV using electricity from an external source. This vehicle is classified as a FCEV for this report since it is expected to

[16] See Appendix E for a detailed discussion of BEV and PHEV metrics.
[17] At least over the timeframe covered by this report. BEVs were initially produced more than 100 years ago.

operate primarily on hydrogen and be released in limited markets. While there are limited FCEV vehicles available today, there continues to be interest in FCEVs as a future technology. The trend in production shares for BEVs, PHEVs, and FCEVs is shown in Figure 4.15.

Figure 4.15. Production Share of BEVs, PHEVs, and FCEVs[18]



[18] BEV production data were supplemented with data from Ward's and other publicly available production data for model years prior to 2011. The data only include offerings from original equipment manufacturers and does not include data on vehicles converted to alternative fuels in the aftermarket.

The inclusion of model year 2024 BEV and PHEV production increased new vehicle average fuel economy by 1.7 mpg, as shown in Figure 4.16. Without BEV and PHEV production, the fuel economy of the remaining new vehicles was relatively flat.

Figure 4.16. Impact of BEVs and PHEVs

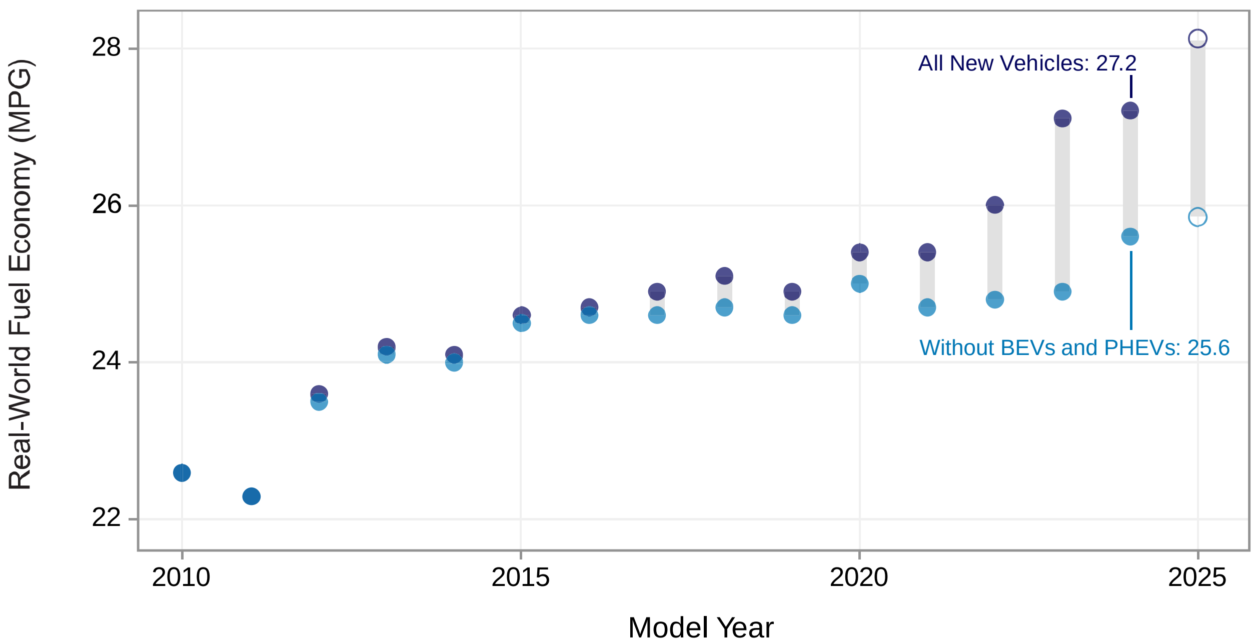


Figure 4.17 and Figure 4.18 show the production share by vehicle type for BEVs and PHEVs. Early production of BEVs was mostly in the sedan/wagon vehicle type, but recent model years have shown growth in car SUVs and truck SUVs. Electric pickup trucks first entered the market in model year 2022, along with new BEV models across many of the vehicle types. Production of PHEVs has shifted from exclusively sedan/wagons to mostly truck SUVs, with limited production across the sedan/wagon, car SUV, and minivan/van vehicle types.

Figure 4.17. Battery Electric Vehicle Production Share by Vehicle Type

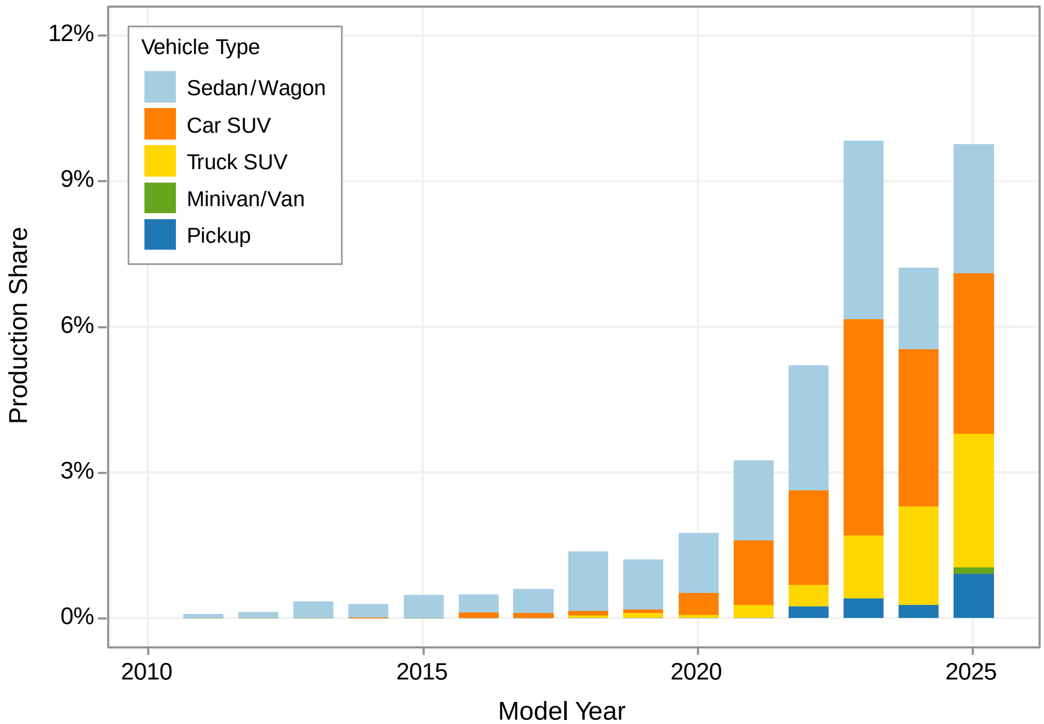


Figure 4.18. Plug-In Hybrid Vehicle Production Share by Vehicle Type

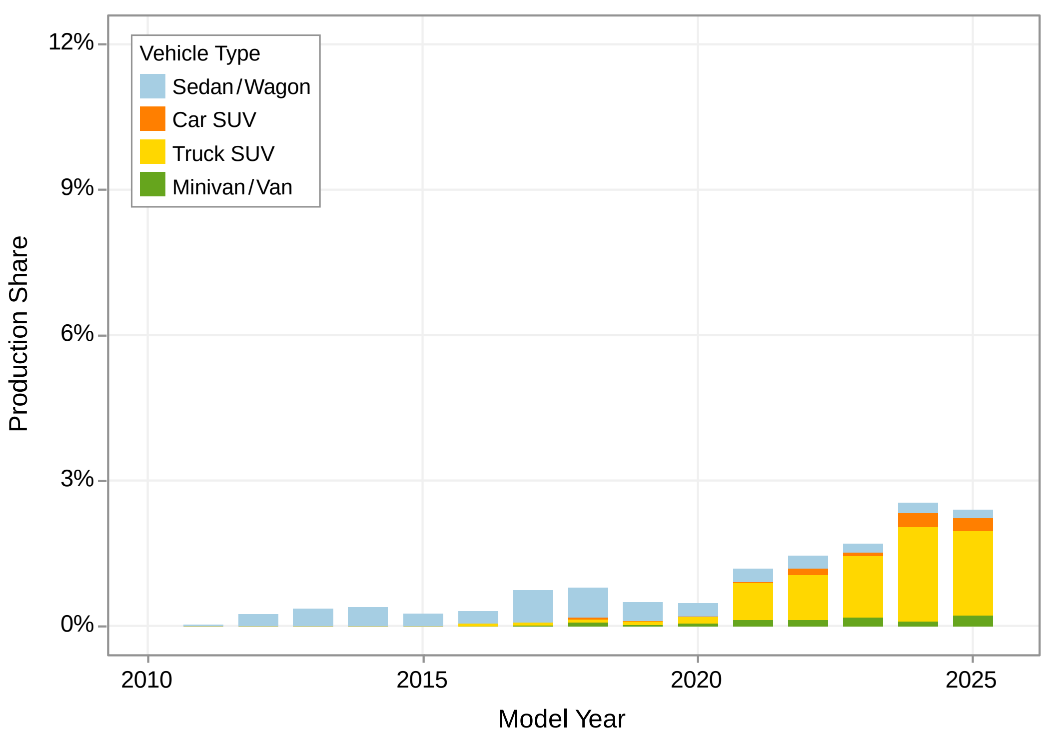
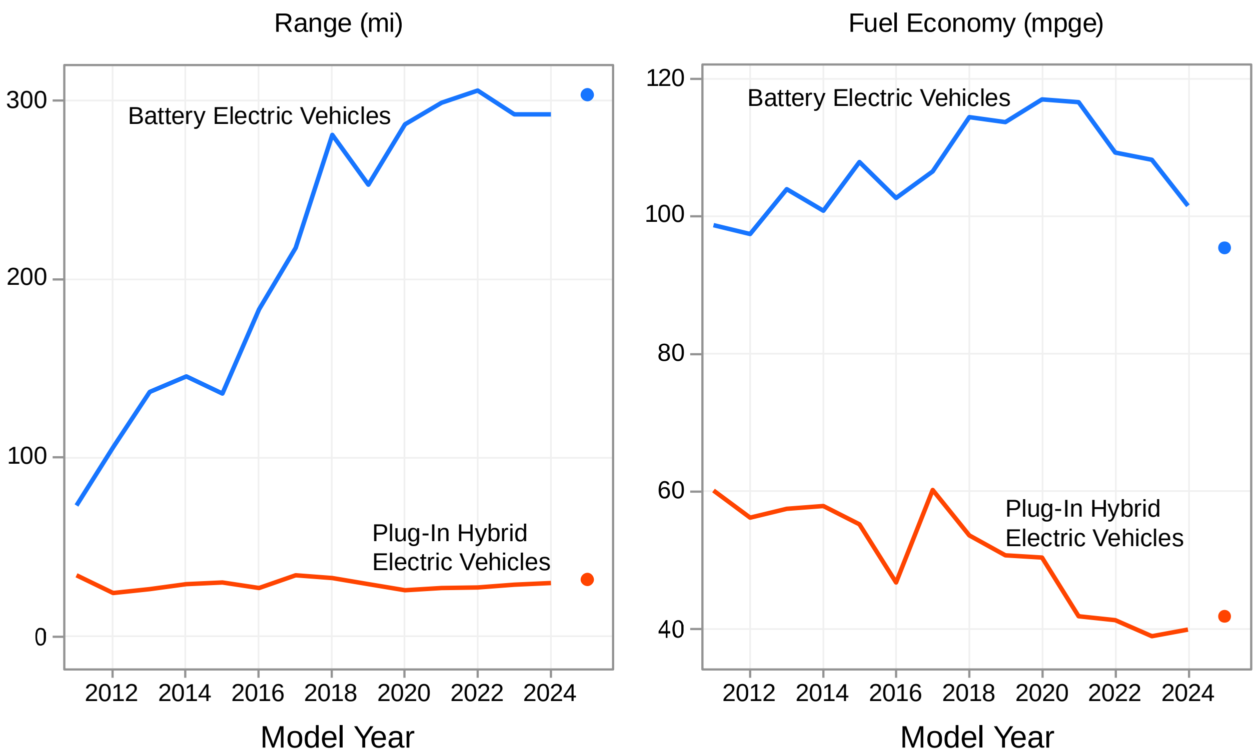


Figure 4.19 shows the range and fuel economy trends for BEVs and PHEVs.[19] The average range of new BEVs has climbed substantially since their introduction. In model year 2024, the average new BEV range is 292 miles, or almost four times the range of an average BEV in 2011. The range values shown for PHEVs are the charge-depleting range, where the vehicle is operating on energy in the battery from an external source. This is generally the all-electric range of the PHEV, although some vehicles also use the gasoline engine in small amounts during charge depleting operation. The average charge depleting range for PHEVs has remained largely unchanged since model year 2011.

Figure 4.19. Charge Depleting Range and Fuel Economy for BEVs and PHEVs



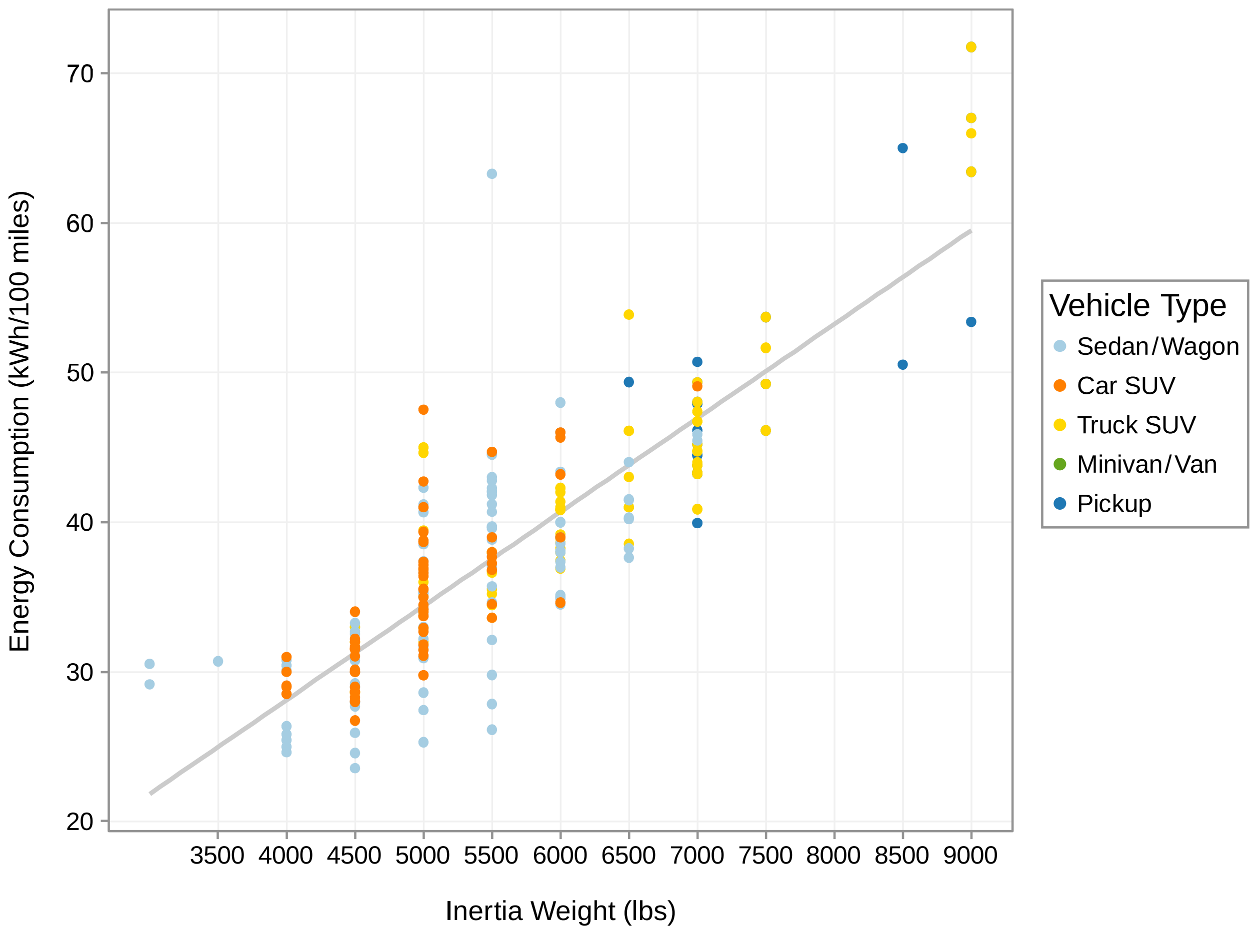
The fuel economy of electric vehicles improved between model year 2011 and 2020 but has been falling since, mostly due to the introduction of larger vehicles that have lower overall fuel economy ratings. The combined fuel economy of PHEVs has been more variable but is about 35% lower in model year 2024 than in model year 2011. This may be attributable to

[19] The range and fuel economy values in this figure are the combined values from the fuel economy label, which weights city and highway driving 55% and 45%, as compared to the rest of the report, which uses a 43% city and 57% highway weighting. See Appendix C for more information.

the growth of truck SUV PHEVs, as shown in Figure 4.18. For more information about BEV and PHEV metrics, see Appendix E.

Figure 4.20 shows the distribution of BEV energy consumption, in terms of kWh per 100 miles, compared to vehicle inertia weight class. There is a general trend that heavier EVs have a higher energy consumption, but there is a large spread at each inertia weight class. Pickups and truck SUVs represent the heaviest BEVs and are somewhat less efficient than other vehicle types, consistent with trends across the broader industry.

Figure 4.20. BEV Energy Consumption by Weight and Vehicle Type



Diesel Engines

Vehicles with diesel engines have been available in the U.S. at least as long as the EPA has been collecting data. However, sales of diesel vehicles have rarely broken more than 1% of the overall light-duty market. Diesel vehicle sales peaked at 6% of the market in model year 1981 but have been at or below 1% of production per year since 1985. In MY 2024, diesel vehicles remained below 1% of all new vehicles produced. Vehicles that rely on diesel fuel often achieve higher fuel economy than gasoline vehicles, largely because the energy density of diesel fuel is about 15% higher than that of gasoline.

Figure 4.21 shows the production share of diesel engines by vehicle type. Diesel engines have historically been more prevalent in the sedan/wagon vehicle type, however, since model year 2015 there have been very few sedan/wagon vehicles with diesel engines and most light-duty diesel production has been pickups. This report does not include the largest heavy-duty pickup trucks, work vans, or vocational trucks, which have a higher penetration of diesel engines. As shown in Figure 4.22, current production of diesel engines for light-duty vehicles is entirely comprised of 6-cylinder engines

Diesel engines, as with gasoline engines, have improved over time. Figure 4.23 shows the same metrics and trends that are explored in Figure 4.5 for gasoline engines. The specific power (HP/displacement) for diesel engines has increased more than 200% since model year 1975. Fuel consumption per displacement dropped in the 1980s but increased back to about 20% below model year 1975. Finally, fuel consumption per horsepower for diesel engines has declined about 75% since model year 1975.

Figure 4.21. Diesel Engine Production Share by Vehicle Type

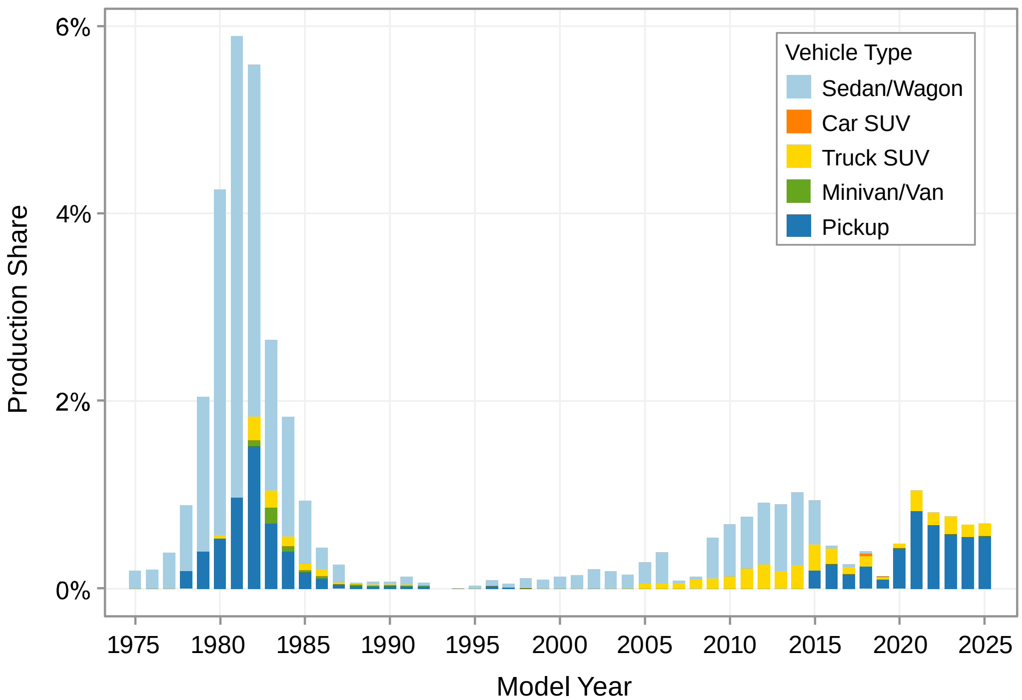


Figure 4.22. Diesel Engine Production Share by Number of Cylinders

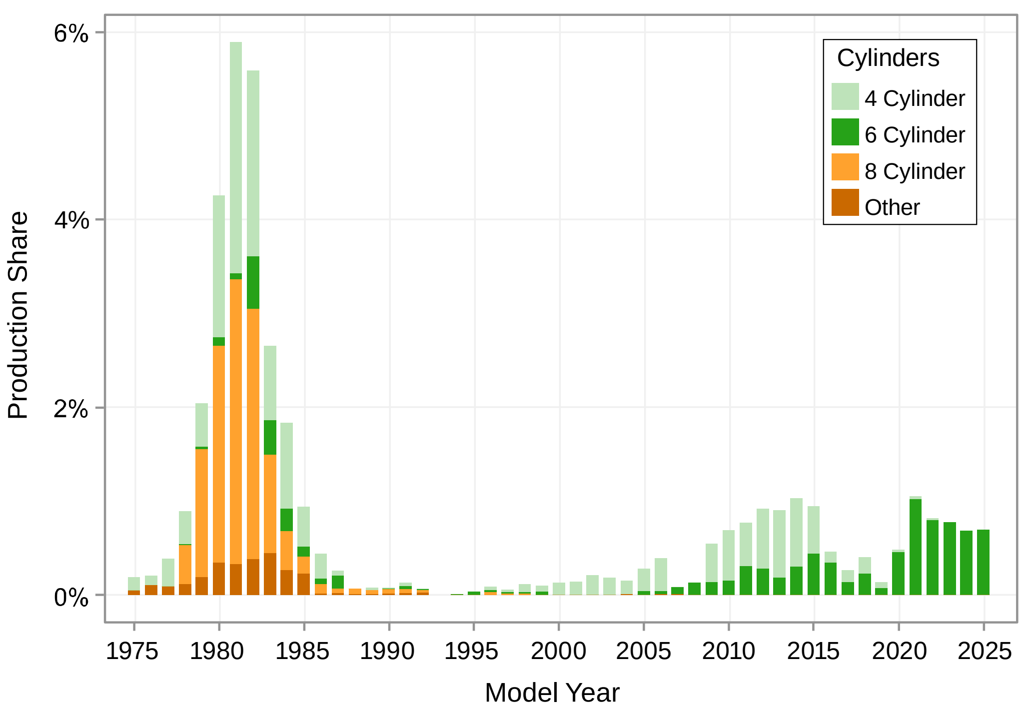
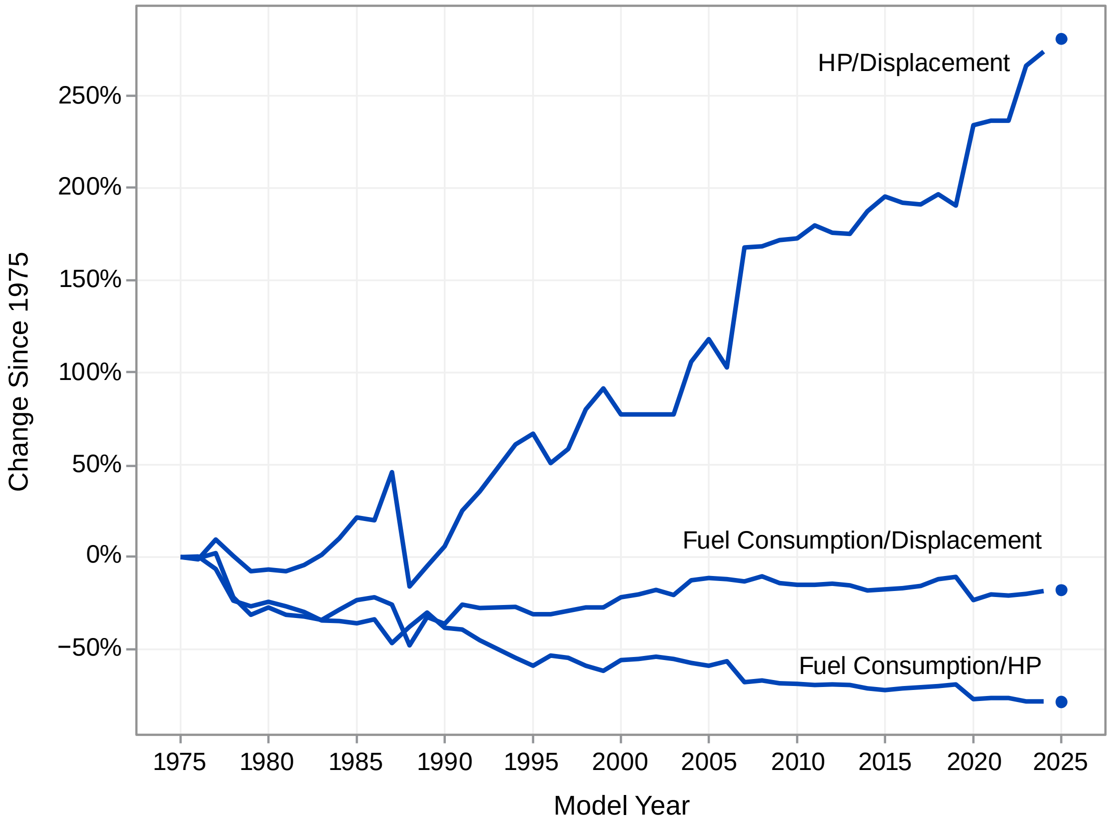


Figure 4.23. Percent Change for Specific Diesel Engine Metrics



Other Engine Technologies

In addition to the engine technologies described above, there have been a small number of other technologies available in the U.S. marketplace over the years. Vehicles that operate on compressed natural gas (CNG) are one example, but there are currently no CNG vehicles available from vehicle manufacturers (aftermarket conversions are not included here). This report will continue to track all vehicles produced for sale in the U.S., and if CNG or other technologies reach widespread availability they will be included in future versions of this report.

B. Vehicle Drivetrain

A vehicle drivetrain includes all components responsible for transmitting rotational energy from an engine or electric motor to the wheels. The design of the drivetrain impacts fuel economy in two ways; first through direct energy losses or inefficiencies within the drivetrain, and second by allowing a vehicle's engine, or electric motor, to operate in a more efficient manner.

For non-hybrid vehicles with an internal combustion engine, the drivetrain includes a transmission and the driveline (a driveshaft, differential, axle shafts and related components), as shown in Figure 4.1. Mild hybrids generally use a conventional transmission and drivetrain, but strong hybrids often replace the transmission entirely with a planetary gearset or some other enabling configuration. PHEVs generally resemble strong hybrids but can have numerous configurations that allow for complicated energy optimization. Battery electric vehicles generally use a single speed transmission and do not need the numerous gears required by combustion engines. However, some high-performance electric vehicles are now being produced with 2-speed transmissions (e.g., Porsche Taycan).

Transmissions

There are two important aspects of transmissions that impact overall vehicle efficiency and fuel economy. First, as torque (rotational force) is transferred through the transmission, a small amount is lost to friction, which reduces vehicle efficiency. Second, the design of the transmission impacts how the engine is operated, and generally transmissions with more speeds offer more opportunity to operate the engine in the most efficient way possible. For example, a vehicle with an 8-speed transmission will have more flexibility in determining engine operation than a vehicle with a 5-speed transmission. This can lead to reduced fuel consumption compared to a vehicle that is identical except for the number of transmission gears.

Transmission designs have been rapidly evolving to increase the number of gears available and allow for both better engine operation and improved efficiency. The number of gears in new vehicles continues to increase, as does the use of continuously variable transmissions (CVTs). Figure 4.24 shows the evolution of transmission production share for cars and trucks since model year 1980.[20] For this analysis, transmissions are separated into

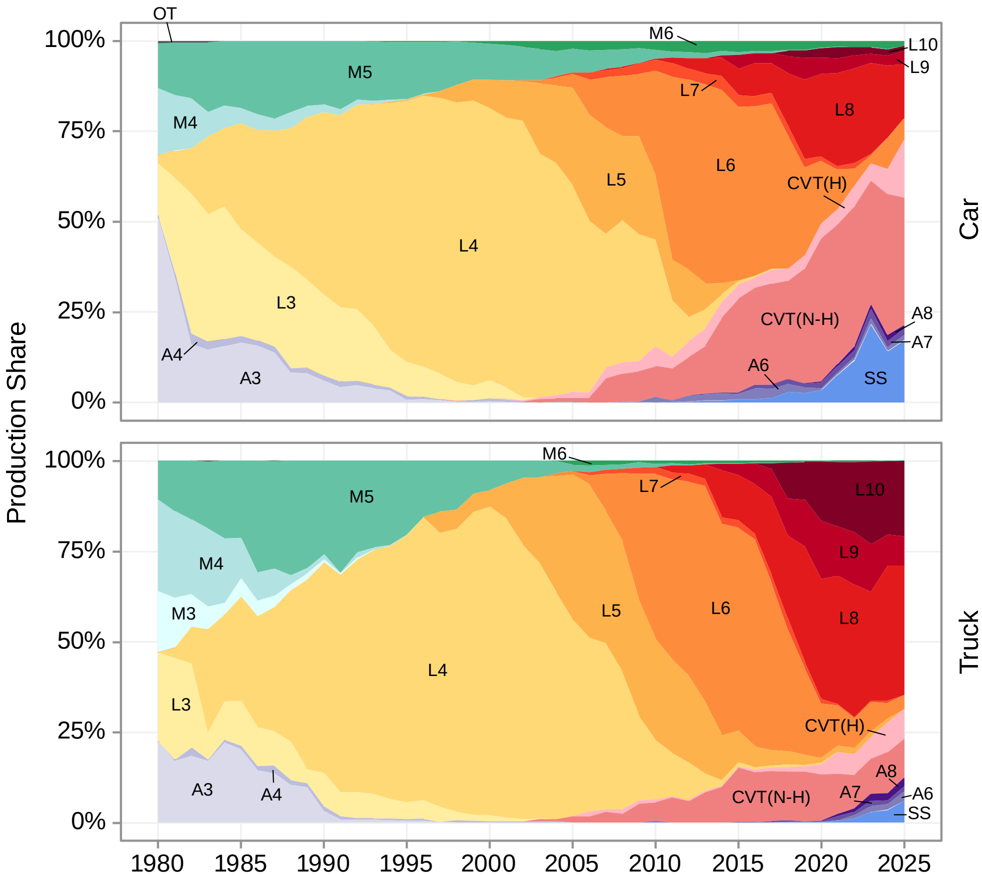
[20] The EPA has incomplete transmission data prior to model year 1980.

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. CVTs have also been split into hybrid and non-hybrid versions to reflect the fact that hybrid CVTs are generally very different mechanically from traditional CVTs. The hybrid CVT category includes CVTs used for PHEVs.

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 the EPA do not explicitly identify DCTs as a separate transmission category. Thus, the introduction of DCTs shows up in Figure 4.24 as a slight increase in automatic transmissions without torque converters (although some DCTs may still be reported as traditional automatic transmissions).

In the early 1980s, 3-speed automatic transmissions, both with and without lockup torque converters (shown as L3 and A3), were the most popular transmissions, but by model year 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 model year 1999 were equipped with a 4-speed transmission. After model year 1999, the production share of 4-speed transmissions slowly decreased as 5- and 6-speed transmissions were introduced into the market. 6-speed transmissions peaked in model year 2013 at 60% of new vehicle production, but then fell quickly, down to 8% by model year 2024. 8-speed transmissions became the most popular transmission in model year 2019. In model year 2024, vehicles with 8-speed transmissions accounted for 33% of all new vehicles, while vehicles with non-hybrid CVTs or vehicles with transmissions of nine or more speeds each accounted for more than 20% of new vehicle production.

Figure 4.24. Transmission Production Share

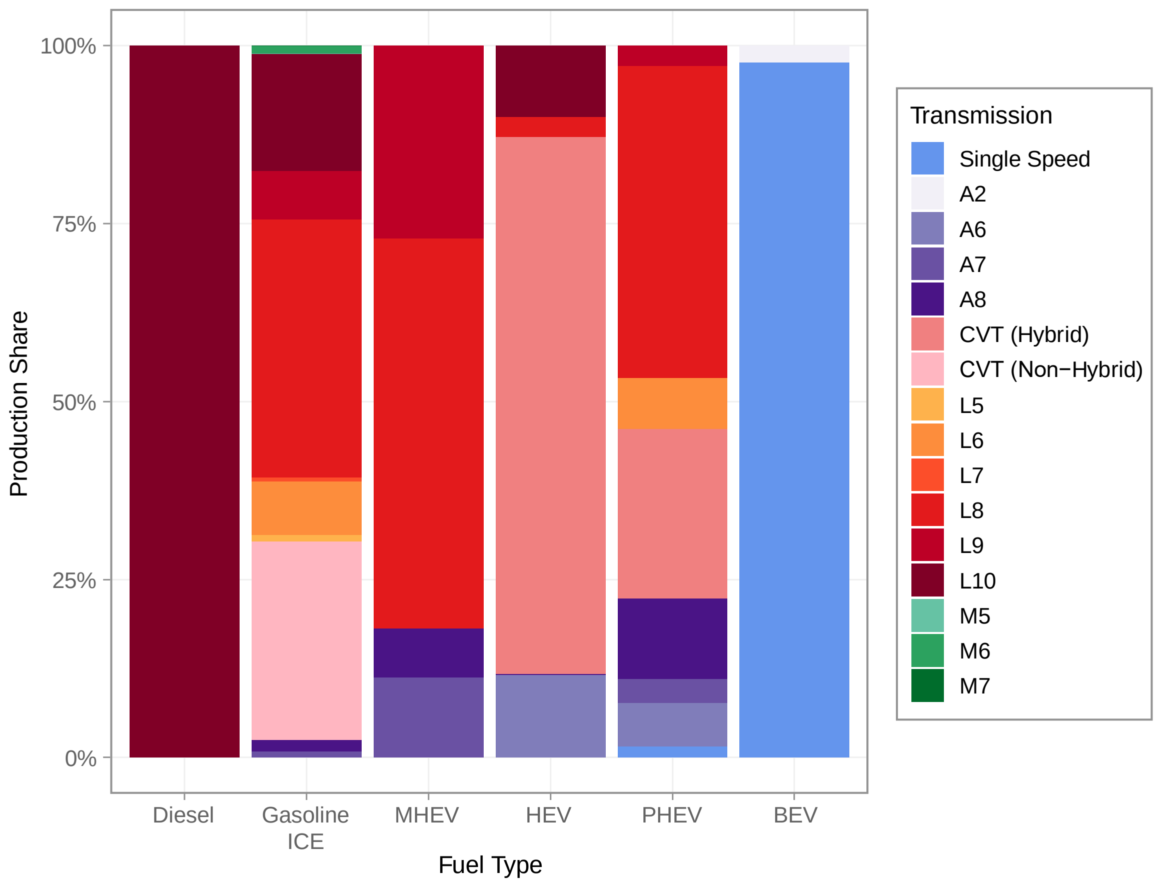


Transmission	Lockup?	Number of Gears	Key
Single Speed	–	1	SS
Automatic Semi-Automatic Automated Manual	No	2	A2*
		3	A3
		4	A4
		5	A5*
		6	A6
		7	A7
		8	A8
	Yes	2	L2*
		3	L3
		4	L4
		5	L5
		6	L6
		7	L7
		8	L8
		9	L9
		10	L10
Manual	–	3	M3
		4	M4
		5	M5
		6	M6
		7	M7*
ContinuouslyVariable (Non-Hybrid)	–	–	CVT(N-H)
ContinuouslyVariable (Hybrid)	–	–	CVT(H)
Other	–	–	OT

*Categories A2, A5, L2, and M7 are too small to depict in the area plot.

Transmission trends also vary by vehicle engine technology, as shown in Figure 4.25. For model year 2024, diesel engines were most often paired with a ten-speed lockup transmission, with some 8-speed transmissions. Gasoline engines were paired with a wide variety of transmissions, including CVTs, lockup transmissions from 10 to five speeds, a small number of manual transmissions, and a small number of non-lockup transmissions (likely DCTs). Mild hybrids are most often paired with an 8- or 9-speed transmission, while strong hybrids most often use a hybrid CVT transmission. PHEVs currently use a wide array of transmission technologies, including traditional automatic transmissions, CVTs, and single-speed transmissions. BEVs are generally designed without a traditional transmission and utilize a single speed design. However, a limited number of high-performance EVs do have a 2-speed transmission.

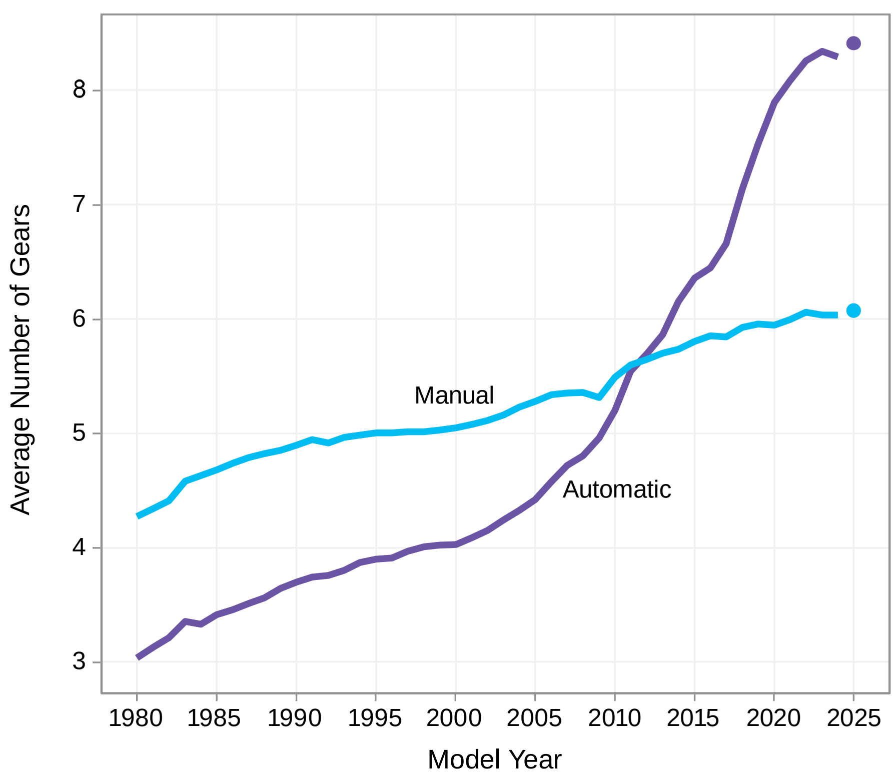
Figure 4.25. Transmission By Powertrain Technology, Model Year 2024



Another notable trend in Figure 4.24 is the decline in manual transmissions. Manual transmissions were included in almost 35% of new vehicles in model year 1980 but have gradually declined and have been below 1% of all production since model year 2021. Today, manual transmissions are available only in a limited number of vehicles.

Part of the reason for the decline in manual transmission is because modern automatic transmissions are now generally more efficient and can offer better performance than manual transmissions. In the past, automatic transmissions have generally been less efficient than manual transmissions, largely due to inefficiencies in the automatic transmission torque converter and fewer gears. Over time, both manual and automatic transmissions added gears, but automatic transmissions added gears faster. In model year 2012, the average number of gears in an automatic transmission passed the average number of gears in a manual transmission. Figure 4.26 shows the average number of gears in new vehicle transmissions since model year 1980 for automatic and manual transmissions (excluding BEVs, PHEVs, and vehicles with CVTs). The continued shrinking availability of manual transmissions in each model year limits the relevance of analyses comparing current manual transmissions to automatic transmissions.

Figure 4.26. Average Number of Transmission Gears

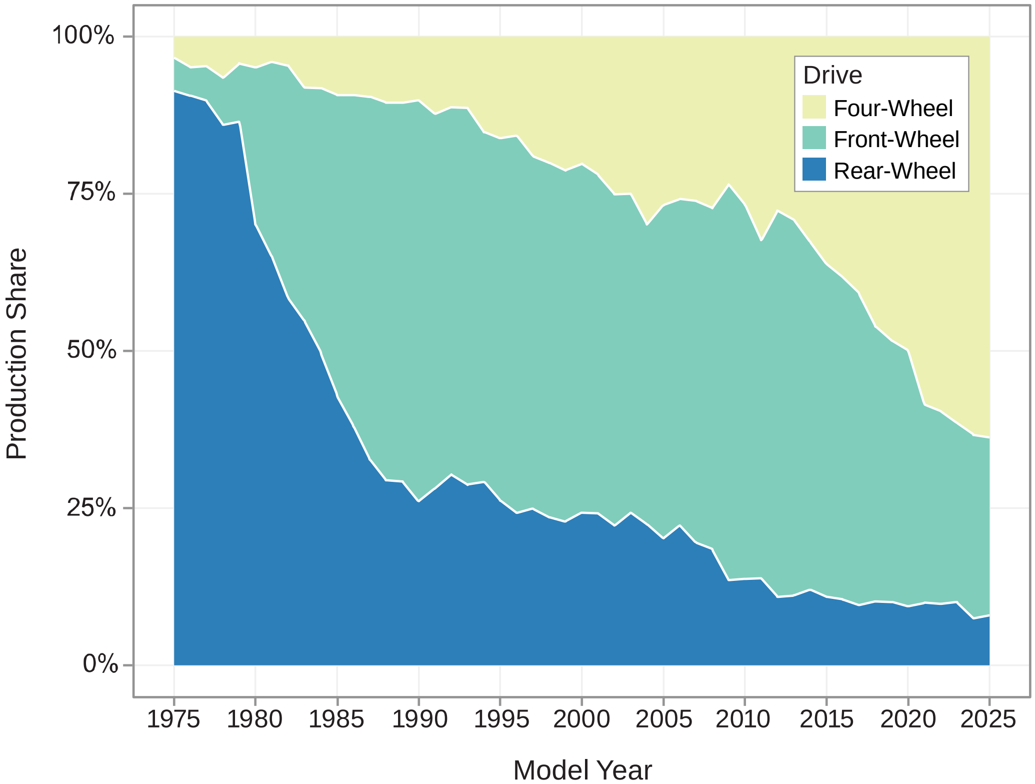


Drive Types

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 (including all-wheel drive) vehicles, as shown in Figure 4.27. In model year 1975, over 91% of new vehicles were produced with rear-wheel drive. Since then, production of rear-wheel drive vehicles has steadily declined to about 10% in model year 2024. Most vehicles available today with rear wheel drive are performance-oriented sedan/wagons and pickup trucks, but there are limited rear wheel drive vehicles available in all vehicle types.

Production of front-wheel drive vehicles increased from 5% of new vehicle production in model year 1975 to 64% in model year 1990 and 63% in model year 2009. Since 2009 however, the production of front-wheel vehicles has also been declining and is down to 29% in model year 2024. Four-wheel drive systems have steadily increased from 3% of new vehicle production in model year 1975 to 63% of production in model year 2024. Four-wheel drive systems have increased for both cars and trucks, but the high market penetration rate of 86% within trucks (including pickups, truck SUVs, and minivan/vans) and the market shifts towards these vehicles has accelerated the trend towards four-wheel drive vehicles.

Figure 4.27. Front-, Rear-, and Four-Wheel Drive Production Share



C. Technology Adoption and Comparison

One additional way to evaluate the evolution of technology in the automotive industry is to focus on how technology has been adopted over time. Understanding how the industry has adopted technology can lead to a better understanding of past changes in the industry and how emerging technology may be integrated in the future. The following analysis provides more details about how manufacturers and the overall industry have adopted new technology.

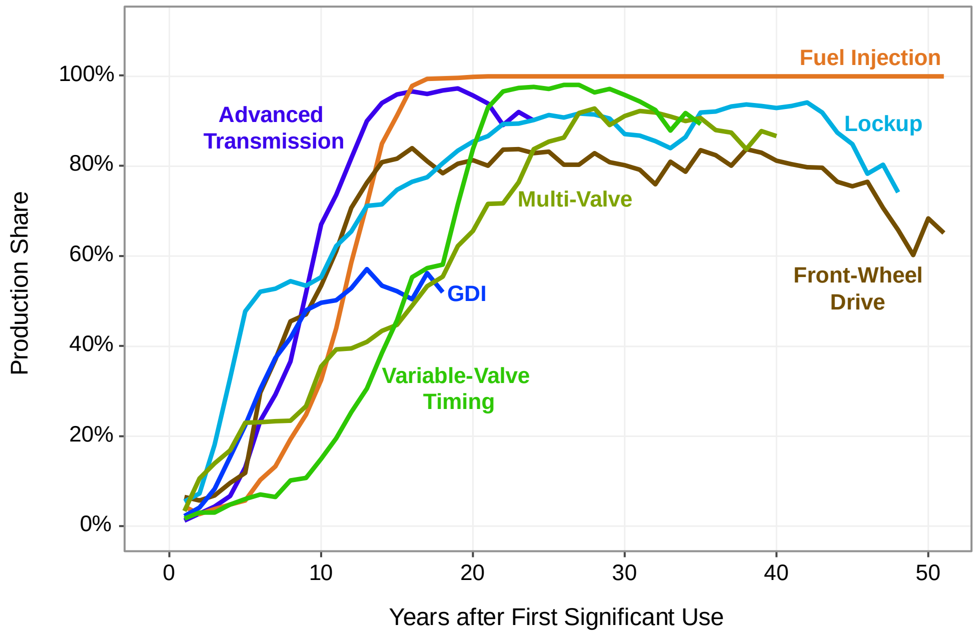
Industry-Wide Technology Adoption Since 1975

Figure 4.28 shows industry-wide adoption rates for seven technologies in passenger cars. These technologies 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, lockup transmissions, advanced transmissions (transmissions with six or more speeds, and CVTs), and gasoline direct injection engines. To provide a common scale, the adoption rates are plotted in terms of the number of years after the technology achieved first significant use in the industry. First significant use generally represents a production threshold of 1%, though in some cases, where full data are not available, first significant use represents a slightly higher production share.

The technology adoption pattern shown in Figure 4.28 is roughly similar for each of the seven technologies, even though they vary widely in application, complexity, and when they were initially introduced. It has taken on average approximately 15-20 years for new technologies to reach maximum market penetration across the industry. GDI is a newer technology that has likely not reached maximum penetration across the industry but appears to be following the adoption trend of other more mature technologies. While some of these technologies may eventually be adopted in 100% of new vehicles, there may be reasons that other technologies, like front-wheel drive, will likely never be adopted in all vehicles. Adoption rates for these technologies in trucks are similar, with the exception of front-wheel drive.

The analysis for Figure 4.28 focuses on technologies that have achieved widespread use by multiple manufacturers and does not look at narrowly adopted technologies which never achieved widespread use. One limitation to the data in this report is that the EPA does not begin tracking technology production share data until after the technologies had achieved some limited market share. For example, the EPA did not begin to track multi-valve engine data until model year 1986 for cars and model year 1994 for trucks, and in both cases multi-valve engines had captured about 5% market share by that time. Likewise, turbochargers were not tracked in this report until model year 1996 for cars and model year 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.

Figure 4.28. Industry-Wide Car Technology Penetration after First Significant Use



Technology Adoption by Manufacturers

The rate at which the overall industry adopts technology is 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 4.28 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 4.29 begins to disaggregate the industry-wide trends to examine how individual manufacturers have adopted new technologies.[21] For each technology, Figure 4.29 shows the amount of time it took specific manufacturers to move from initial introduction to 80% penetration for each technology, as well as the same data for the overall industry. After 80% penetration, the technology is assumed to be largely incorporated into the manufacturer's fleet, and changes between 80% and 100% are not highlighted.

[21] This figure is based on available data. Some technologies may have been introduced into the market before this report began tracking them. Generally, these omissions are limited, with the exception of multi-valve engine data for Honda. Honda had already achieved 70% penetration of multi-valve engines when this report began tracking them in 1986, so this figure does not illustrate Honda's prior trends.

Of the seven technologies shown in Figure 4.29, five are now at or near full market penetration for the included manufacturers, and two are still in the process of adoption by manufacturers. The technologies shown in Figure 4.29 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 VVT, for example, show that several manufacturers adopted the technology much faster than the overall industry, which achieved 80% penetration in just over 20 years. It was not the rate of technology adoption alone, but rather the staggered implementation timeframes among manufacturers that resulted in the longer industry-wide average.

Fuel injection systems show the least amount of variation in initial adoption timing between manufacturers, which resulted in a faster adoption by the industry overall than technologies like VVT. One important driver for adoption of fuel injection was increasingly stringent emissions standards. Advanced transmissions, which have been available in small numbers for some time, have very rapidly increased market penetration in recent years and are now widely adopted. GDI engines appear to be following a similar path of quick uptake in recent years. Turbocharged engines have long been available, but the focus on turbo downsized engine packages is leading to much higher market penetration, although it is too early to predict the level of penetration they will ultimately achieve industry wide.

There are many factors outside the scope of this report that influence the rate and timing of when technology is adopted by individual manufacturers (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 variation between manufacturers for given technologies can be masked when only the industry-wide trends are evaluated. Technology adoption by individual manufacturers is often more rapid than the overall industry trend would suggest.

Figure 4.29. Manufacturer Specific Technology Adoption over Time for Key Technologies

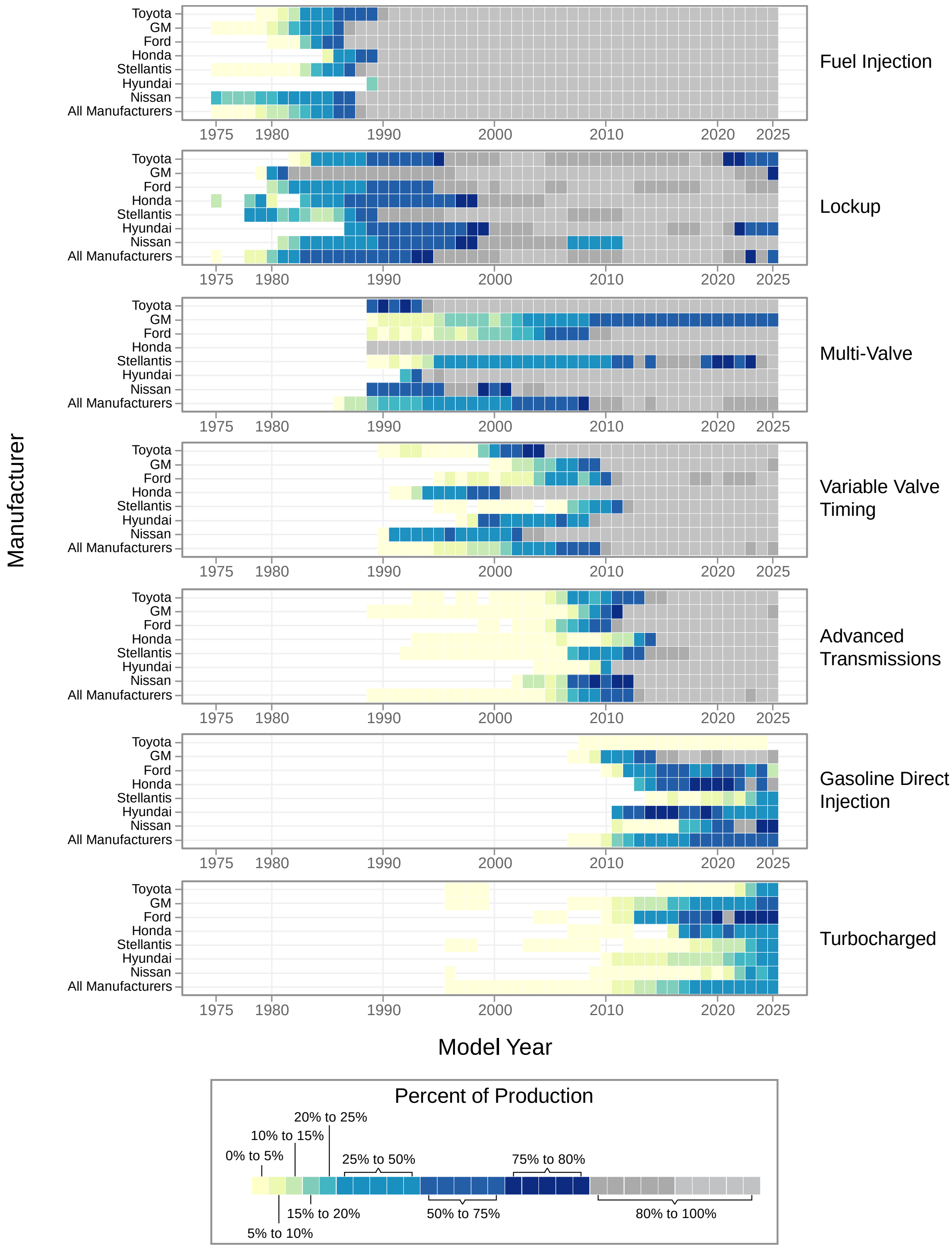


Table 4.2. Production Share by Powertrain

Model Year	Diesel ICE	Gasoline ICE without Stop/Start	Gasoline ICE with Stop/Start	Mild Hybrid (MHEV)	Strong Hybrid (HEV)	Plug-in Hybrid (PHEV)	Battery Electric (BEV)	Fuel Cell Electric (FCEV)	Other
1975	0.2%	99.8%	-	-	-	-	-	-	-
1980	4.3%	95.7%	-	-	-	-	-	-	-
1985	0.9%	99.1%	-	-	-	-	-	-	-
1990	0.1%	99.9%	-	-	-	-	-	-	-
1995	0.0%	100.0%	-	-	-	-	-	-	-
2000	0.1%	99.8%	-	0.0%	-	-	-	-	-
2005	0.3%	98.6%	-	0.3%	0.8%	-	-	-	-
2010	0.7%	95.5%	-	0.0%	3.8%	-	-	0.0%	-
2011	0.8%	97.0%	-	-	2.2%	0.0%	0.1%	0.0%	0.0%
2012	0.9%	95.2%	0.6%	0.1%	3.0%	0.3%	0.1%	0.0%	0.0%
2013	0.9%	92.6%	2.3%	0.3%	3.3%	0.4%	0.3%	-	0.0%
2014	1.0%	90.8%	4.9%	0.1%	2.5%	0.4%	0.3%	0.0%	0.0%
2015	0.9%	88.9%	7.0%	0.0%	2.4%	0.3%	0.5%	0.0%	0.0%
2016	0.5%	87.5%	9.4%	0.0%	1.8%	0.3%	0.5%	0.0%	0.0%
2017	0.3%	78.4%	17.7%	0.0%	2.3%	0.8%	0.6%	0.0%	-
2018	0.4%	65.5%	29.6%	0.4%	1.9%	0.8%	1.4%	0.0%	-
2019	0.1%	57.6%	36.8%	1.3%	2.5%	0.5%	1.2%	0.0%	-
2020	0.5%	46.9%	45.4%	1.8%	3.1%	0.5%	1.8%	0.0%	-
2021	1.0%	41.1%	44.0%	4.0%	5.3%	1.2%	3.2%	0.0%	-
2022	0.8%	33.4%	48.9%	4.2%	6.0%	1.5%	5.2%	0.0%	-
2023	0.8%	26.3%	49.2%	4.9%	7.2%	1.7%	9.8%	0.0%	-
2024	0.7%	17.2%	57.6%	5.3%	9.5%	2.5%	7.2%	0.0%	-
2025 (prelim)	*0.7%*	*12.6%*	*55.4%*	*5.1%*	*14.0%*	*2.4%*	*9.8%*	*0.0%*	-

To explore this data in more depth, please see the report website at https://www.epa.gov/automotive-trends.

Table 4.3. Production Share by Fuel Delivery Method

	Gasoline Engines - Fuel Delivery Method					Diesel	BEV	Other
Model Year	**Carbureted**	**TBI**	**Port**	**GDI**	**GDPI**			
1975	95.7%	0.0%	4.1%	-	-	0.2%	-	-
1980	89.7%	0.8%	5.2%	-	-	4.3%	-	-
1985	56.1%	24.8%	18.2%	-	-	0.9%	-	-
1990	2.1%	27.0%	70.8%	-	-	0.1%	-	-
1995	-	8.4%	91.6%	-	-	0.0%	-	-
2000	-	0.0%	99.8%	-	-	0.1%	-	-
2005	-	-	99.7%	-	-	0.3%	-	-
2010	-	-	91.0%	8.3%	-	0.7%	-	0.0%
2011	-	-	83.8%	15.4%	-	0.8%	0.1%	0.0%
2012	-	-	76.4%	22.5%	0.1%	0.9%	0.1%	0.0%
2013	-	-	67.7%	30.5%	0.6%	0.9%	0.3%	-
2014	-	-	60.9%	37.4%	0.4%	1.0%	0.3%	0.0%
2015	-	-	56.0%	41.9%	0.7%	0.9%	0.5%	0.0%
2016	-	-	48.7%	48.0%	2.3%	0.5%	0.5%	0.0%
2017	-	-	44.2%	49.7%	5.2%	0.3%	0.6%	0.0%
2018	-	-	37.7%	50.2%	10.3%	0.4%	1.4%	0.0%
2019	-	-	31.6%	52.9%	14.2%	0.1%	1.2%	0.0%
2020	-	-	26.6%	57.1%	14.0%	0.5%	1.8%	0.0%
2021	-	-	23.6%	53.4%	18.7%	1.0%	3.2%	0.0%
2022	-	-	21.0%	52.3%	20.6%	0.8%	5.2%	0.0%
2023	-	-	16.0%	50.5%	22.9%	0.8%	9.8%	0.0%
2024			12.5%	56.2%	23.3%	0.7%	7.2%	0.0%
2025 (prelim)	-	-	*8.7%*	*52.0%*	*28.9%*	*0.7%*	*9.8%*	*0.0%*

Table 4.4. Production Share by Gasoline[22] Engine Technologies

Model Year	Avg. No. of Cylinders	Displacement (CID)	Horsepower (HP)	Multi-Valve	Variable Valve Timing (VVT)	Cylinder Deactivation (CD)	Turbo-charged	Non-hybrid Stop/Start
1975	6.8	293	137	-	-	-	-	-
1980	5.6	196	105	-	-	-	-	-
1985	5.5	189	114	-	-	-	-	-
1990	5.4	185	135	23.1%	-	-	-	-
1995	5.6	196	158	35.5%	-	-	-	-
2000	5.7	200	181	44.8%	15.0%	-	1.2%	-
2005	5.8	205	209	65.5%	45.7%	0.8%	1.4%	-
2010	5.3	188	214	84.8%	83.8%	6.4%	2.6%	-
2011	5.4	193	230	85.6%	93.0%	9.5%	6.1%	-
2012	5.1	181	222	90.9%	96.5%	8.1%	7.5%	0.6%
2013	5.1	177	227	91.9%	97.4%	7.7%	13.0%	2.3%
2014	5.1	181	231	88.2%	97.6%	10.6%	13.8%	4.9%
2015	5.0	177	229	90.2%	97.2%	10.5%	14.8%	7.0%
2016	5.0	173	230	91.8%	98.0%	10.4%	19.4%	9.4%
2017	5.0	173	233	91.7%	98.1%	11.9%	23.2%	17.7%
2018	5.0	172	239	90.6%	96.4%	12.5%	29.6%	29.6%
2019	5.1	174	244	89.9%	97.2%	14.9%	29.8%	36.8%
2020	4.9	169	243	90.2%	95.8%	14.7%	34.2%	45.4%
2021	5.0	176	251	86.9%	94.4%	16.6%	31.8%	44.0%
2022	4.9	171	251	86.7%	92.5%	15.9%	35.8%	48.9%
2023	4.9	170	255	83.0%	87.9%	15.1%	37.3%	49.2%
2024	4.7	159	247	87.1%	91.8%	13.3%	44.4%	57.6%
2025 (prelim)	*4.6*	*156*	*248*	*86.0%*	*89.4%*	*11.7%*	*44.8%*	*55.4%*

[22] This table includes technology penetration rates for new vehicles with gasoline engines, including hybrids and PHEVs (except for non-hybrid stop/start, which excludes hybrids and PHEVs), as compared to all new vehicles. The values in this table are slightly lower than values elsewhere this report that include other technologies. For example, most vehicles that operate on diesel fuel are turbocharged, and when included, as in Table 4.1, will slightly increase the overall share of vehicles that are turbocharged.

Table 4.5. Production Share by Transmission Technologies

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	Average No. of Gears
1975	23.0%	0.2%	76.8%	-	-	-	99.0%	1.0%	-	-	-	-	-
1980	34.6%	18.1%	46.8%	-	-	0.5%	87.9%	12.1%	-	-	-	-	3.5
1985	26.5%	54.5%	19.1%	-	-	-	80.7%	19.3%	-	-	-	-	3.7
1990	22.2%	71.2%	6.5%	-	0.0%	0.0%	79.9%	20.0%	0.1%	-	-	-	4.0
1995	17.9%	80.7%	1.4%	-	-	-	82.0%	17.7%	0.2%	-	-	-	4.1
2000	9.7%	89.5%	0.7%	-	0.0%	-	83.7%	15.8%	0.5%	-	-	-	4.1
2005	6.2%	91.5%	0.1%	1.0%	1.3%	-	56.0%	37.3%	4.1%	0.2%	-	-	4.5
2010	3.8%	84.1%	1.2%	3.8%	7.2%	-	24.6%	23.5%	38.1%	2.7%	0.2%	-	5.2
2011	3.2%	86.5%	0.3%	2.0%	8.0%	-	14.2%	18.7%	52.3%	3.1%	1.7%	-	5.5
2012	3.6%	83.4%	1.1%	2.9%	8.9%	-	8.1%	18.2%	56.3%	2.8%	2.6%	-	5.5
2013	3.5%	80.4%	1.4%	3.3%	11.4%	-	5.4%	12.8%	60.1%	2.8%	4.1%	-	5.6
2014	2.8%	76.7%	1.6%	2.7%	16.3%	-	2.2%	7.8%	58.4%	3.3%	8.4%	1.1%	6.0
2015	2.6%	72.3%	1.4%	2.4%	21.3%	-	1.5%	4.5%	54.2%	3.1%	9.5%	3.5%	6.0
2016	2.2%	72.3%	2.6%	1.8%	21.0%	-	1.1%	3.0%	54.9%	2.9%	11.2%	4.1%	6.0
2017	2.1%	71.5%	2.6%	2.5%	21.2%	-	1.0%	2.4%	49.0%	3.4%	14.6%	5.9%	6.1
2018	1.6%	72.8%	3.2%	2.2%	20.1%	-	1.9%	2.0%	37.6%	3.7%	19.0%	13.5%	6.5
2019	1.4%	72.1%	2.4%	2.4%	21.7%	-	1.5%	1.6%	26.1%	2.6%	27.5%	16.5%	6.8
2020	1.1%	68.3%	2.7%	3.3%	24.5%	-	1.8%	0.8%	17.3%	2.1%	28.8%	21.2%	7.1
2021	0.9%	67.0%	5.4%	5.4%	21.2%	-	3.2%	1.1%	12.2%	2.0%	32.5%	22.4%	7.0
2022	0.9%	65.2%	8.1%	5.7%	20.1%	-	5.0%	1.1%	8.7%	2.1%	33.8%	23.5%	7.1
2023	0.8%	59.9%	14.9%	5.5%	18.9%	-	9.9%	1.0%	8.3%	2.4%	29.9%	24.1%	7.1
2024	0.9%	59.0%	11.5%	7.8%	20.8%	-	7.2%	0.7%	7.9%	1.8%	33.2%	20.5%	7.0
2025 (prelim)	*0.6%*	*54.4%*	*14.9%*	*11.0%*	*19.2%*	-	*9.8%*	*0.0%*	*7.3%*	*1.6%*	*30.4%*	*20.6%*	*7.0*

Table 4.6. Production Share by Drive Technology

Model Year	Car			Truck			All		
	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%
1980	29.7%	69.4%	0.9%	1.4%	73.6%	25.0%	25.0%	70.1%	4.9%
1985	61.1%	36.8%	2.1%	7.3%	61.4%	31.3%	47.8%	42.9%	9.3%
1990	84.0%	15.0%	1.0%	15.8%	52.4%	31.8%	63.8%	26.1%	10.1%
1995	80.1%	18.8%	1.1%	18.4%	39.3%	42.3%	57.6%	26.3%	16.2%
2000	80.4%	17.7%	2.0%	20.0%	33.8%	46.3%	55.5%	24.3%	20.2%
2005	79.2%	14.2%	6.6%	20.1%	27.7%	52.2%	53.0%	20.2%	26.8%
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	79.8%	9.1%	11.0%	15.9%	12.2%	72.0%	51.2%	10.5%	38.3%
2017	79.7%	8.3%	12.0%	16.1%	11.1%	72.8%	49.6%	9.6%	40.8%
2018	76.5%	9.4%	14.1%	13.4%	10.9%	75.6%	43.7%	10.2%	46.1%
2019	75.5%	10.1%	14.4%	14.4%	10.2%	75.4%	41.6%	10.1%	48.3%
2020	76.5%	8.8%	14.7%	12.5%	10.0%	77.5%	40.6%	9.4%	49.9%
2021	70.7%	11.2%	18.0%	8.5%	9.2%	82.3%	31.6%	10.0%	58.5%
2022	65.9%	11.2%	22.9%	10.0%	8.9%	81.0%	30.6%	9.8%	59.6%
2023	60.3%	14.9%	24.8%	9.5%	7.2%	83.4%	28.5%	10.1%	61.4%
2024	68.4%	10.8%	20.8%	8.8%	5.7%	85.5%	29.2%	7.5%	63.3%
2025 (prelim)	*65.1%*	*10.2%*	*24.7%*	*8.8%*	*6.8%*	*84.4%*	*28.3%*	*7.9%%*	*63.7%*

Appendices: Methods and Additional Data

A. Sources of Input Data

Nearly all the data for this report are based on automakers' direct submissions to the EPA. The EPA has required manufacturers to provide vehicle fuel economy to consumers since 1977 and has collected data on every new light-duty vehicle model sold in the United States since 1975. The data are obtained either from testing performed by the EPA at the National Vehicle and Fuel Emissions Laboratory in Ann Arbor, Michigan or directly from manufacturers using official EPA test procedures.

National fuel economy standards have been in place in the United States for cars and light trucks since 1978. The Department of Transportation (DOT), 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 CAFE, the EPA has been responsible for establishing test procedures and calculation methods and for collecting data used to determine vehicle fuel economy levels. The EPA calculates the CAFE value for each manufacturer and provides it to the NHTSA. The NHTSA publishes the final CAFE values in its annual "Summary of Fuel Economy Performance" reports at https://one.nhtsa.gov/cafe_pic/home.

The data that the EPA collects for this report comprise the most comprehensive database of its kind. For recent model years, the vast majority of data in this report comes from the Engines and Vehicles Compliance Information System (EV-CIS) database maintained by the EPA. This database contains a broad amount of data associated with fuel economy, vehicle and engine technology, and other vehicle performance metrics. This report extracts only a portion of the data from the EV-CIS database.

In some cases, the data submitted by automakers are supplemented by data that were obtained through independent research by the EPA. For example, the EPA relied on published data from external sources for certain parameters of pre-model year 2011 vehicles: (1) engines with variable valve timing (VVT), (2) engines with cylinder deactivation, and (3) vehicle footprint, as automakers did not submit this data until model year 2011. The EPA projects footprint data for the preliminary model year 2025 fleet based on footprint values for existing models from previous years and footprint values for new vehicle designs available through public sources. In addition, vehicle 0-to-60 acceleration values are not provided by automakers, but are either calculated from other Trends data, as discussed in Section 3, or taken from external sources.

The website for this report has been expanded with an emphasis on allowing users to access and evaluate more of the data behind this report. The EPA plans to continue to add content and tools on the web to allow transparent access to public data. To explore the data using the EPA's interactive data tools, visit the report webpage at https://www.epa.gov/automotive-trends.

Preliminary vs Final Data

For each model year, automakers submit two phases of data: **preliminary data** provided to the EPA for vehicle certification and labeling prior to the model year sales, and **final data** submitted after the completion of the model year for compliance with the EPA and the NHTSA regulatory programs.

Preliminary data are collected prior to the beginning of each model year and are not used for manufacturer compliance. 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. As part of these submissions, automakers report pre-model year vehicle production projections for individual models and configurations to the EPA.

Final data are submitted a few months after the end of each model year and include detailed final production volumes. The EPA and the NHTSA use this final data to determine compliance with the CAFE standards. These end-of-the-year submissions include detailed final production volumes. All data in this report for model years 1975 through 2024 are considered final.

Since the preliminary fuel economy values provided by automakers are based on projected vehicle production volumes, they usually vary slightly from the final fuel economy values that reflect the actual sales at the end of the model year. With each publication of this report, the preliminary values from the previous year are updated to reflect the final values. This allows a comparison to gauge the accuracy of preliminary projections.

Table A.1 compares the preliminary and final fleetwide real-world fuel economy values for recent years. Since model year 2011, the final real-world fuel economy values have generally been close to the preliminary fuel economy values. In eight out of the last ten years, manufacturer projections have led to preliminary estimates that were higher than final data.

It is important to note that there is no perfect apples-to-apples comparison for model years 2011–2014 due to several small differences in data, such as inclusion of alternative fuel vehicle (AFV) data. The preliminary values in Table A.1 through model year 2014 did not integrate AFV data, while the final values in Table A.1 are the values reported elsewhere in this report and do include AFV data. The differences due to this would be small, on the order of 0.1 mpg or less.

Table A.1. Comparison of Preliminary and Final Real-World Fuel Economy Values (mpg)

Model Year	Preliminary Value	Final Value	Final Minus Preliminary
2011	22.8	22.3	-0.5
2012	23.8	23.6	-0.2
2013	24.0	24.2	+0.2
2014	24.2	24.1	-0.1
2015	24.7	24.6	-0.2
2016	25.6	24.7	-0.9
2017	25.2	24.9	-0.3
2018	25.4	25.1	-0.3
2019	25.5	24.9	-0.6
2020	25.7	25.4	-0.3
2021	25.3	25.4	+0.1
2022	26.4	26.0	-0.4
2023	26.9	27.1	+0.2
2024	28.0	27.2	-0.8
2025 (prelim)	*28.1*		

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 the distance term (miles, in the numerator of mpg) is fixed or variable. This report assumes 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 traveled) 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 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:

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

Though the above example was for a single vehicle with two different fuel economies over two legs of a single round trip, 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

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

(Note that, 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.)

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 emissions values (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 0.033 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.

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

C. Fuel Economy Metrics

The fuel economy data in this report are **estimated real-world data**. The following sections discuss the differences between CAFE compliance data and real-world data and how they relate to raw vehicle emissions test results.

2-Cycle Test Data

In 1975 when the Corporate Average Fuel Economy (CAFE) regulation was put into place, the EPA tested vehicles using two dynamometer-based test cycles, one based on city driving and one based on highway driving. CAFE was—and continues to be—required by law to use these "2-cycle tests".

Originally, the fuel economy values generated from the "2-cycle" test procedure were used both to determine compliance with CAFE requirements and to inform consumers of their expected fuel economy via the fuel economy label. Today, the raw 2-cycle test data are used primarily in a regulatory context as the basis for determining the final compliance values for CAFE.

The 2-cycle testing methodology has remained largely unchanged since the early 1970s.[23] Because of this, the 2-cycle fuel economy values can serve as a useful comparison of long-term trends. Previous versions of this report included 2-cycle fuel economy data, referred to as "unadjusted" or "laboratory" values. These 2-cycle fuel economy values are still available on the report website for reference.

Estimated Real-World Fuel Economy Data

Estimated real-world (previously called "adjusted") data is the EPA's best estimate of real-world fuel economy, as reported in Sections 1–4 of this report. The real-world values are the best data for researchers to evaluate new vehicle fuel economy performance. Unlike compliance data, the method for calculating real-world data has evolved over time, along

[23] There were some relatively minor test procedure changes made in the late 1970s that, in the aggregate, made the city and highway tests slightly more demanding, i.e., the unadjusted fuel economy values for a given car after these test procedure changes were made are slightly lower relative to prior to the changes. The EPA has long provided CAFE "test procedure adjustments" (TPAs) for passenger cars in recognition of the fact that the original CAFE standards were based on the EPA test procedures in place in 1975 (there are no TPAs for light trucks). The resulting impacts on the long-term unadjusted fuel economy trends are very small. The TPAs for cars vary but are typically in the range of 0.2–0.5 mpg for cars, or 0.1–0.3 mpg when the car TPAs are averaged over the combined car/truck fleet.

with technology and driving habits. These changes in methodology are detailed in Appendix D.

Calculating estimated real-world fuel economy

Estimated real-world fuel economy data are currently measured based on the “5-cycle” test procedure that utilizes high-speed, cold start, and air conditioning tests in addition to the 2-cycle tests to provide data more representative of real-world driving. These additional laboratory tests capture a wider range of operating conditions (including hot/cold weather and higher acceleration) that an average driver will encounter. City and highway results are weighted 43% / 57%, consistent with fleetwide driver activity data.

Example Comparison of Fuel Economy Metrics

The multiple ways of measuring fuel economy can understandably lead to confusion. As an illustration to help the reader understand the various fuel economy values that can be associated with an individual vehicle, Table 1.2 shows three different fuel economy metrics for the model year 2024 Toyota Prius. The 2-cycle city and highway fuel economy values are direct fuel economy measurements from the 2-cycle tests and are harmonically averaged with a 55% city / 45% highway weighting to generate a combined value. The 2-cycle laboratory tested Prius results in a city fuel economy of 83 mpg, a highway fuel economy of 78 mpg, and a combined 2-cycle value of 80 mpg.

Using the 5-cycle methodology, the Toyota Prius has a vehicle fuel economy label value of 57 mpg city and 56 mpg highway. On the vehicle label, these values are harmonically averaged using a 55% city / 45% highway weighting to determine a combined value of 57 mpg. The estimated real-world fuel economy for the Prius, which is the set of values used in calculations for this report, has the same city and highway fuel economy as the label, but the 43% city and 57% highway weighting leads to a combined value of 56 mpg, which is one mpg less than the values found on the label.

Table C.1. Fuel Economy Metrics for the Model Year 2024 Toyota Prius

Fuel Economy Metric	Purpose	City/Highway Weighting	Test Basis	Fuel Economy Value (MPG)		
				Combined City/Hwy	City	Hwy
2-cycle Test (unadjusted)	Basis for manufacturer compliance with standards	55% / 45%	2-cycle	80	83	78
Label	Consumer information to compare individual vehicles	55% / 45%	5-cycle	57	57	56
Estimated Real-World	Best estimate of real-world performance	43% / 57%	5-cycle	56	57	56

D. Historical Changes in the Database and Methodology

Over the course of this report's publication, there have been some instances where relevant methodologies and definitions have been updated. Since the goal of this report is to provide the most accurate data and science available, updates are generally propagated back through the historical database. The current version of this report supersedes all previous reports.

Changes in Estimated Real-world Fuel Economy

The estimated real-world fuel economy values in this report are closely related to the label fuel economy values. Over the course of this report, there have been three updates to the fuel economy label methodology (for model years 1985, 2008, and 2017), and these updates were propagated through the Trends database. However, there are some important differences in how the label methodology updates have been applied in this report. This section discusses how these methodologies have been applied, partially or in full, to the appropriate model years based on the authors' technical judgement. The changes are intended to provide accurate real-world values for vehicles at the time they were produced to better reflect available technologies, changes in driving patterns, and composition of the fleet.

Model year 1975–1985: Universal Multipliers

The first change to the label methodology occurred when the EPA recognized that changing technology and driving habits led to real-world fuel economy results that over time were diverging from the fuel economy values measured using the 2-cycle tests. To address this issue, the EPA introduced an alternative calculation methodology in 1985 that applied a multiplication factor to the 2-cycle test data of 0.9 for city and 0.78 for highway. The estimated real-world fuel economy values from model year 1975–1985 in this report were calculated using the same multiplication factors that were required for the model year 1985 label update. The authors believe that these correction factors were appropriate for new vehicles from model year 1975 through 1985. The combined fuel economy values are based on a 55% city / 45% highway weighting factor, consistent with the CAFE.

Model year 1986–2010: The 2006 5-cycle methodology and 43% City / 57% Highway Weighting

In 2006, the EPA established a major change to the fuel economy label calculations by introducing the 5-cycle methodology.[24] In addition to the city and highway tests required for 2-cycle fuel economy, the 5-cycle methodology introduces tests for high speeds (US06), air-conditioning (SC03), and a cold temperature test. It also indirectly accounts for several factors that are not reflected in EPA laboratory test data (e.g., changing fuel composition, wind, road conditions) using a 9.5% universal downward adjustment factor. The change from the universal adjustment factors to the 2006 5-cycle method lowered estimated real-world fuel economy values, particularly for high fuel economy vehicles. In the 2006 rulemaking, the EPA projected an overall average fleetwide adjustment of 11% lower for city fuel economy and 8% lower for highway fuel economy.

For model year 1986–2004, the authors implemented the 2006 5-cycle methodology by assuming the changes in technology and driver behavior that led to lower real-world fuel economy occurred in a gradual, linear manner over 20 years. 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, etc.) that have affected real-world fuel economy since 1985 have changed over time.

Under the 5-cycle methodology, manufacturers could either: 1) perform all five tests on each vehicle (the "full 5-cycle" method), 2) use an alternative analytical "derived 5-cycle" method based on 2-cycle testing if certain conditions were met, or 3) voluntarily use lower fuel economy label estimates than those resulting from the full 5-cycle or derived 5-cycle. If manufacturers are required to perform all five tests, the results are weighted according to composite 5-cycle equations.[25] To use the derived 5-cycle method, manufacturers are required to evaluate whether fuel economy estimates using the full 5-cycle tests are comparable to results using the derived 5-cycle method. In recent years, the derived 5-cycle approach has been used to generate approximately 85% of all vehicle label fuel economy values.

For vehicles that were eligible to use the 2006 derived 5-cycle methodology, the following equations were used to convert 2-cycle city and highway fuel economy values to label

[24] See 71 Federal Register 77872, December 27, 2006.
[25] See 71 Federal Register 77883-77886, December 27, 2006.

economy values. These equations were based on the relationship between 2-cycle and 5-cycle fuel economy data for the industry as a whole.

$$\textbf{Label CITY} = \frac{1}{\left(0.003259 + \frac{1.1805}{\text{2CYCLE CITY}}\right)}$$

$$\textbf{Label HWY} = \frac{1}{\left(0.001376 + \frac{1.3466}{\text{2CYCLE HWY}}\right)}$$

Over the same timeframe, the EPA phased in a change in the city and highway weightings used to determine a single combined fuel economy. The 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.[26] Based on this speed cutpoint, the correct weighting for correlating the new city and highway fuel economy values with real-world driving activity data from on-road vehicle studies, on a miles driven basis, is 43% city and 57% highway; this updated weighting is necessary to maintain the integrity of fleetwide fuel economy performance based on Trends data. The 55% city and 45% highway weighting is still used for both Fuel Economy and Environment Labels and EPA and NHTSA compliance programs. The authors used the same gradual, linear approach to phase in the change in city and highway weightings along with the phase-in of the 2006 5-cycle methodology.

From model year 2005 to model year 2010, the 2006 5-cycle methodology and the 43% city and 57% highway weightings were used to determine the real-world fuel economy values for this report. This required using the derived 5-cycle equations and the 43% city and 57% highway weightings to recalculate real-world fuel economy values for model year 2005 to 2007, because the 2006 5-cycle methodology was not required until 2008. Model year 2008 to model year 2010 real-world fuel economy values were the same as the label fuel economy values, except for the city and highway weightings.

Model year 2011–present: Implementing the 2017 derived 5-cycle updates

In 2015, the EPA released a minor update to the derived 5-cycle equations that modified the coefficients used to calculate derived 5-cycle fuel economy from 2-cycle test data.[27] This

[26] See 71 Federal Register 77904, December 27, 2006.
[27] See https://www.epa.gov/fueleconomy/basic-information-fuel-economy-labeling and http://iaspub.epa.gov/otaqpub/display_file.jsp?docid=35113&flag=1

update was required under existing regulations and applies to fuel economy label calculations for all model year 2017 and later vehicles. The following equations are used to convert 2-cycle test data values for city and highway to label fuel economy values:

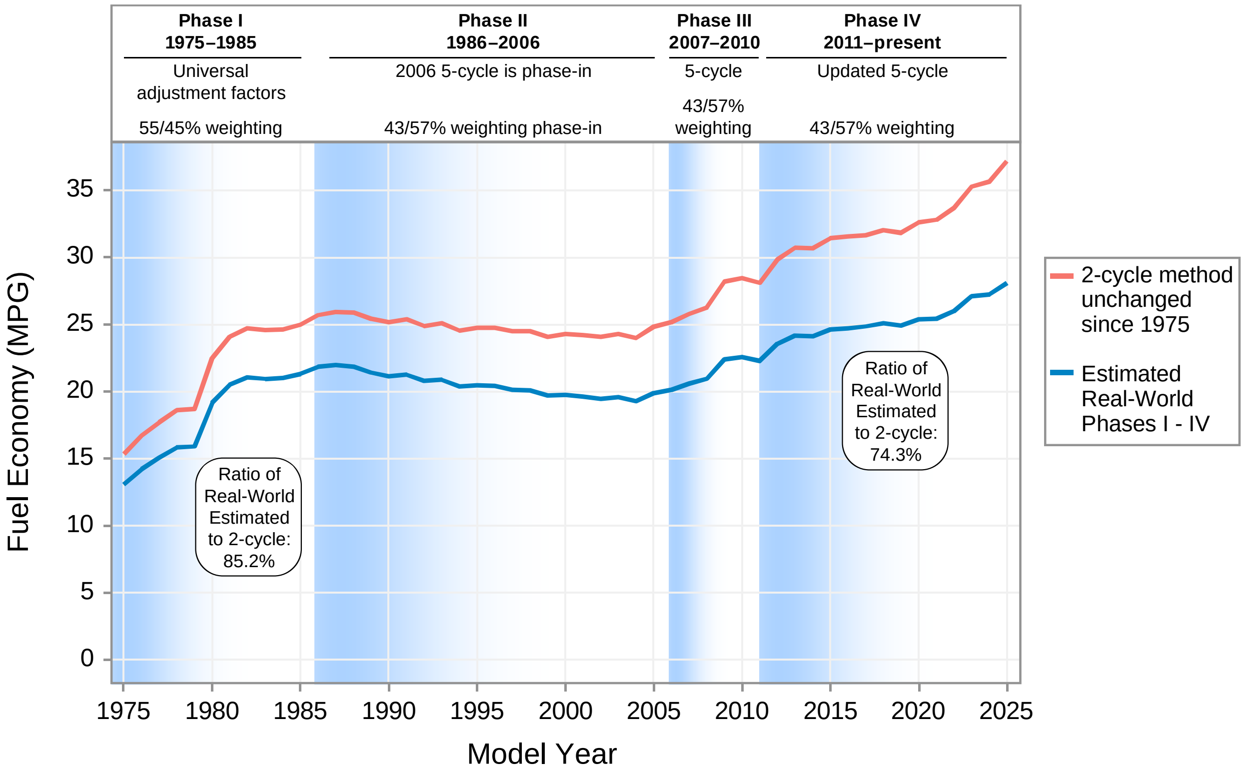
$$\textbf{Label CITY} = \frac{1}{\left(0.004091 + \frac{1.1601}{\text{2CYCLE CITY}}\right)}$$

$$\textbf{Label HWY} = \frac{1}{\left(0.003191 + \frac{1.2945}{\text{2CYCLE HWY}}\right)}$$

The updated 5-cycle calculations introduced for model year 2017 and later labels were based on test data from model year 2011 to model year 2016 vehicles. Therefore, the authors chose to retroactively apply the updated 5-cycle methodology to model years 2011 to 2016. This required recalculating the real-world fuel economy of vehicles from model year 2011 to 2016 using the new derived 5-cycle equations. Vehicles that conducted full 5-cycle testing or voluntarily lowered fuel economy values were unchanged. The 43% city and 57% highway weightings were maintained. The changes for model years 2011-2016 due to the 5-cycle update were relatively small (0.1 to 0.2 mpg overall) and did not noticeably alter the general data trends, therefore the authors determined that a phase-in period was not required for this update.

Figure D.1 below summarizes the impact of the changes in real-world data methodology relative to the 2-cycle test data, which has had a consistent methodology since 1975. Over time, the estimated real-world fuel economy of new vehicles has continued to slowly diverge from 2-cycle test data, due largely to changing technology, driving patterns, and vehicle design. See Appendix C for more information.

Figure D.1. Estimated Real-World versus 2-Cycle Fuel Economy since Model Year 1975



Other Database Changes

Addition of Medium-Duty Passenger Vehicles

Beginning in 2011, medium-duty passenger vehicles (MDPVs), those SUVs and passenger vans (but not pickup trucks) with gross vehicle weight ratings between 8,500 and 10,000 pounds, are included in the light-duty truck category. This coincided with new regulations by the NHTSA to treat these vehicles as light-duty, rather than heavy-duty, vehicles beginning in model year 2011. This represents a minor change to the database since the number of MDPVs is much smaller than it once was (e.g., only 6,500 MDPVs were sold in model year 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 model year 2011. Accordingly, this represents a small inflection point for the database for the overall car and truck fleet in model year 2011; the inclusion of MDPVs decreased average real-world fuel economy by 0.01 mpg 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. Pickup trucks above 8,500 pounds are not included in this report.

Addition of Alternative Fuel Vehicles

Data from alternative fuel vehicles are integrated into the overall database, beginning with MY 2011 data. These vehicles include electric vehicles, plug-in hybrid electric vehicles, fuel cell electric vehicles, and compressed natural gas vehicles. Fuel economy for these vehicles is reported as mpge (miles per gallon of gasoline equivalent), or the miles an alternative fuel vehicle can travel on an amount of energy equivalent to that in a gallon of gasoline. Sales data prior to MY 2011 are included in some cases based on available industry reports (e.g., Ward's Automotive data).

Changes in Vehicle Classification Definitions

The car-truck classifications in this report follow the current regulatory definitions used by the EPA and the NHTSA for compliance with CAFE standards (see definitions for passenger automobiles (cars) and non-passenger automobiles (trucks) in 49 CFR § 523). These current definitions differ from those used in the 2010 and older versions of the *Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends* report, and reflect a decision by the NHTSA to reclassify many small, 2-wheel drive sport utility vehicles (SUVs) from the light truck category to the passenger car category, beginning with model year 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 the authors did not have all the requisite technical information on which to make retroactive car-truck classifications, we used engineering judgment to classify past models.

This report previously presented data on more vehicle types, but recent vehicle design has led to far less distinction between vehicle types and reporting on more disaggregated vehicle types was no longer useful.

Manufacturer Definitions

When a manufacturer grouping changes under the CAFE programs, the current manufacturer definitions are generally applied to all prior model years. This maintains consistent manufacturer and make definitions over time, which enables better identification of long-term trends. However, some of the compliance data maintain the previous manufacturer definitions where necessary to preserve the integrity of compliance data as they were accrued.

Differences in Production Data Between CAFE and previous GHG Regulations

The data used to discuss real-world trends this report are based on production volumes reported under CAFE prior to model year 2017. Beginning in model year 2018, the production volumes are based on EPA's previous GHG regulations. The production volume levels automakers provided in their final CAFE reports may differ slightly from their final GHG reports (typically less than 0.1%) because of different reporting requirements. The EPA 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. The differences in production volumes are very small and do not impact the long-term trends or analysis. Future production volumes will be determined based on available data.

E. Plug-In Hybrid Fleet Average Data

Calculating fuel economy values for PHEVs is a complicated process, as discussed in this section. The examples given for individual vehicles were based on calculations behind the EPA/DOT Fuel Economy and Environment Labels. In addition to the approach used for the labels, there are multiple methods for determining utility factors depending on the intended use of the value. The standardized utility factor calculations are defined in the Society of Automobile Engineers (SAE) document SAE J2841.

The utility factors that are used for fleetwide calculations are somewhat different than those used to create label values. For label values, multi-day individual utility factors (MDIUF) are used to incorporate "a driver's day to day variation into the utility calculation." For fleetwide calculations, fleet utility factors (FUF) are applied to "calculate the expected fuel and electric consumption of an entire fleet of vehicles." Since the Trends report is generally a fleetwide analysis, the FUF utility factors were applied, instead of the MDIUF utility factors, when the data were integrated with the rest of the fleet data. Additionally, since Trends uses a 43% city / 57% highway weighting for combining real-world fuel economy data, the FUF utility factors created for Trends were based on that weighting, not on 55% city / 45% highway weighting used on the fuel economy label.

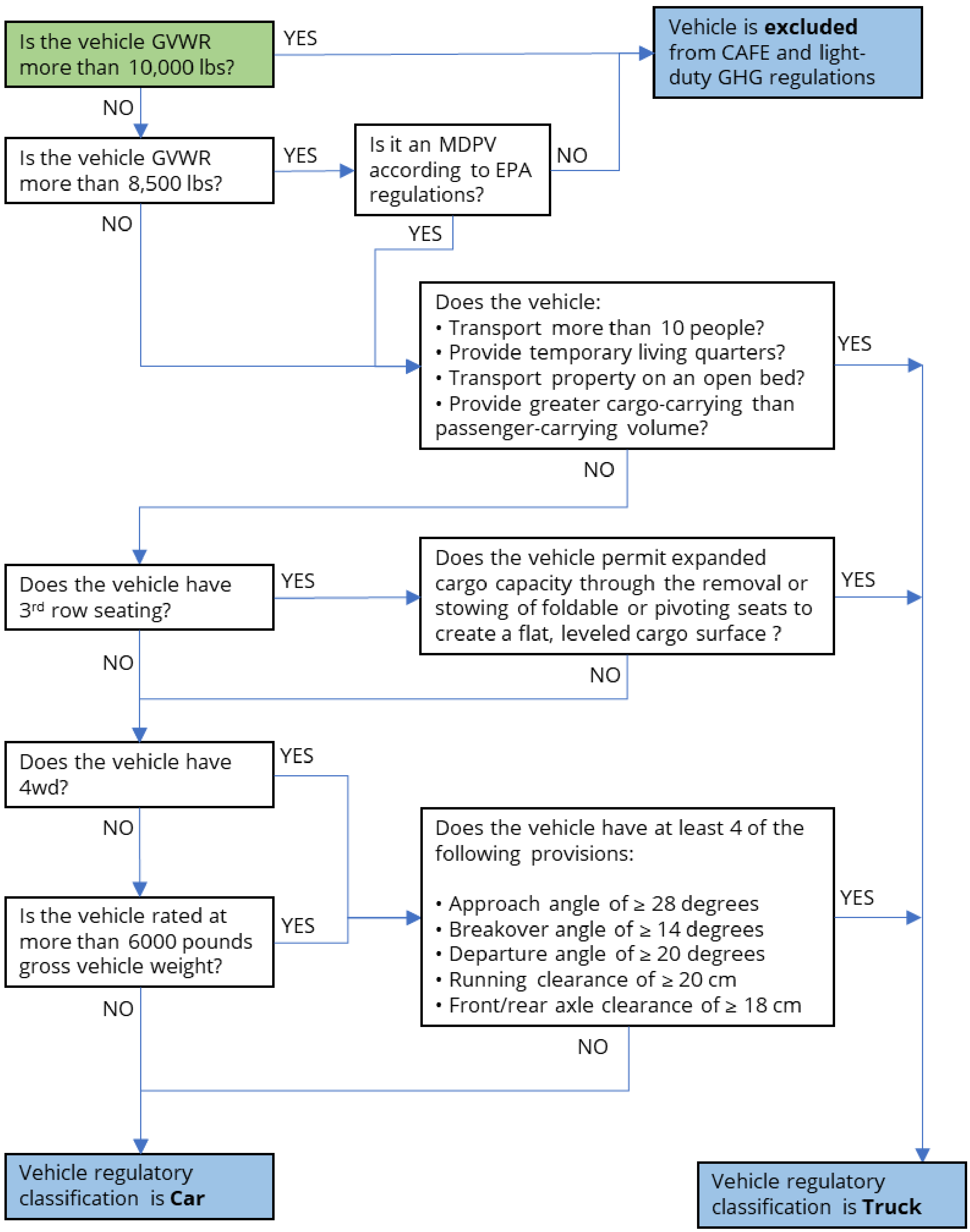
F. Regulatory Car and Truck Definitions

Under the NHTSA's fuel economy standards, new vehicles are separated into two distinct regulatory classes, passenger cars and light trucks. Each regulatory class has separate and unique fuel economy standards. The regulatory definitions of passenger vehicles (cars) and light trucks (trucks) are in NHTSA's CAFE regulations (49 CFR § 523.5). The NHTSA's regulatory definitions are based in part on statutory definitions included in the Energy Policy and Conservation Act of 1975 and the Energy Independence and Security Act of 2007 (49 USC § 32901).

Figure F.1 shows the generalized decision tree for determining if a vehicle is a car or a truck under the regulatory definitions, for model year 2012 and later vehicles. First, vehicles that are above 10,000 gross vehicle weight rating (GVWR), or above 8,500 GVWR and not considered a MDPV are excluded from CAFE. If the vehicle is below 8,500 pounds GVWR or an MDPV, then a vehicle can qualify as a light truck based on the vehicle's functionality or off-highway capabilities. Any light-duty vehicles that do not meet the above functionality or off-highway requirements are considered cars for regulatory purposes.

Note that Figure F.1 and the description of car and truck regulations presented here, are an overview of the regulatory definitions. They should not be considered a guidance document or used for compliance purposes. Any compliance related questions as to the car or truck classifications of specific vehicles should be referred directly to the agencies.

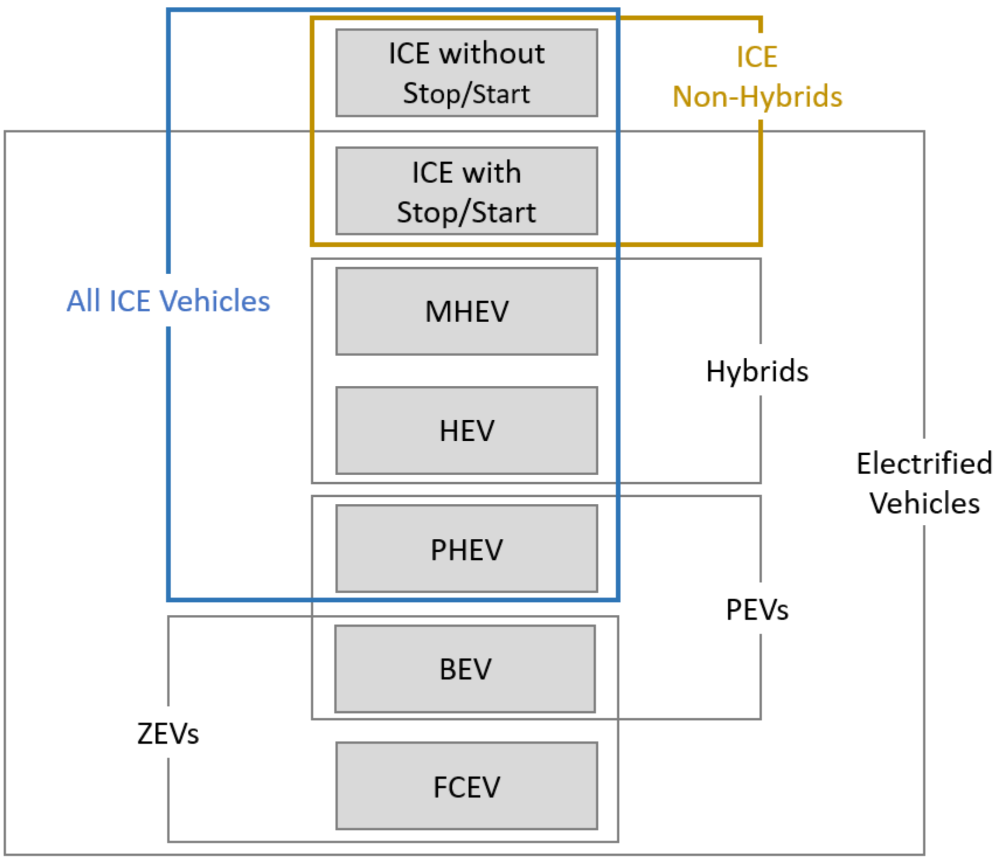
Figure F.1. Regulatory Car or Truck Flow Chart



G. Naming Conventions for Electrified Vehicles

This report identifies several electrification technologies currently being deployed on new vehicles. This report uses the conventions shown in Figure G.1 to identify specific vehicle technology types and groupings.

Figure G.1. Electrification Groupings of Vehicles



The technology categories are:

- **Internal Combustion Engine (ICE) Vehicle:** These vehicles are powered by an internal combustion engine, in which energy released from the combustion of fuel is used to power the vehicle. ICE vehicles included in the report include those powered by gasoline, diesel, and compressed natural gas (CNG).
- **ICE with Stop/Start:** These vehicles have technology that can turn off the internal combustion engine when the vehicle is stopped and very quickly restart the engine when the driver releases the brake pedal.

- **Mild Hybrid Electric Vehicle (MHEV):** These vehicles generally have an electric motor and battery that can assist the engine with moving the vehicle forward at launch, stop-start systems, and regenerative braking capabilities. However, their electrical system cannot directly propel the vehicle. For the purposes of this report, new vehicles with a 48V DC or less electrical system and have an internal combustion engine are classified as “mild” hybrids.
- **Strong Hybrid Electric Vehicle (HEV):** These vehicles generally have a larger motor and a high-voltage battery that can temporarily power the vehicle without engaging the engine; strong hybrids typically capture more energy from regenerative braking than a mild hybrid. For the purposes of this report, new vehicles equipped with an electrical system more than 48V DC and an internal combustion engine are classified as “strong” hybrids.
- **Plug-in Hybrid Electric Vehicle (PHEV):** These vehicles have a battery that can be charged from an external electrical source as well as by an internal combustion engine, and the vehicle can operate on electricity until the battery is depleted or cannot meet driving needs.
- **Battery Electric Vehicle (BEV):** These vehicles operate solely from energy stored in an onboard battery that can be charged from external electrical source. The energy from the battery is used to power one or more electric motors to propel the vehicle.
- **Fuel Cell Electric Vehicle (FCEV):** These vehicles use a fuel cell stack to create electricity from an onboard fuel source (usually hydrogen), which then powers one or more electric motors to propel the vehicle.

In addition to the specific technology categories above, this report uses the following technology groupings:

- **All ICE Vehicles:** Any vehicle that includes an internal combustion engine.
- **ICE Non-Hybrids:** Any vehicle that relies on an internal combustion engine but is not a hybrid vehicle.
- **Electrified vehicles:** Any vehicle with powertrain electrification, including stop/start, MHEVs, HEVs, PHEVs, and BEVs.
- **Hybrids:** refers collectively to HEVs and MHEVs.
- **Plug-in Electric Vehicle (PEV):** Vehicles that can operate on grid electricity, including BEVs and PHEVs.
- **Zero-Emission Vehicle (ZEV):** Vehicles with zero tailpipe emissions, including BEVs and FCEVs

H. Authors and Acknowledgments

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