The 2023 EPA Automotive Trends Report

Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975

Executive Summary

United States Environmental Protection Agency

EPA-420-S-23-002 December 2023

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.

Executive Summary

This annual report is part of the U.S. Environmental Protection Agency's (EPA) commitment to provide the public with information about new light-duty vehicle greenhouse gas (GHG) emissions, fuel economy, technology data, and auto manufacturers' performance in meeting the agency's GHG emissions standards.

Since 1975, EPA has collected data on every new light-duty vehicle model sold in the United States either from testing performed by 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 EPA criteria pollutant and GHG 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 expansive data set allows EPA to provide a uniquely comprehensive analysis of the automotive industry over the last 45+ years.

The carbon dioxide (CO_2) emissions and fuel economy data in this report fall into one of two categories. The first is **compliance** data, which are measured using laboratory tests required by law for CAFE and adopted by EPA for GHG compliance. The second is **estimated real-world** data, which are measured using additional 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 report shows real-world data, except for discussions specific to GHG compliance starting on page ES-9 in this summary and Section 5 of the report.

All data in this report for model years 1975 through 2022 are **final** and based on official data submitted to EPA and NHTSA as part of the regulatory process. In some cases, this report will show data for model year 2023, which are **preliminary** and based on data provided to EPA by manufacturers prior to the model year. These preliminary data include projected production volumes, which may change significantly before being finalized.

This report reflects the current light-duty GHG and fuel economy regulations as finalized by EPA and NHTSA, including updated standards through model year 2026. Any applicable regulatory changes finalized by EPA and NHTSA will be included in future versions of this report. To download the full report, or to explore the data using EPA's interactive data tools, visit the report website at www.epa.gov/automotive-trends.

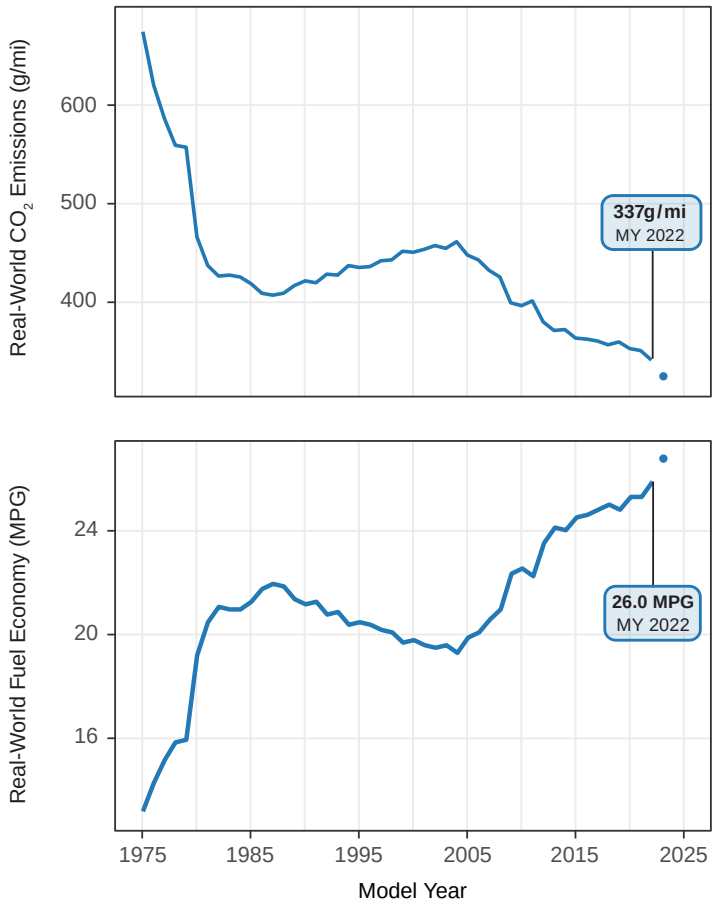
New vehicle CO_2 emissions and fuel economy had the biggest annual improvement of the last 9 years, reaching record low CO_2 emissions and record high fuel economy

In model year 2022, the average estimated real-world CO_2 emission rate for all new vehicles fell by 10 g/mi to 337 g/mi, the lowest ever measured. Real-world fuel economy increased by 0.6 mpg to a record high 26.0 mpg. This is the largest single year improvement in CO_2 emission rates and fuel economy in nine years.

Since model year 2004, CO_2 emissions have decreased 27%, or 123 g/mi, and fuel economy has increased 35%, or 6.7 mpg. Over that time, CO_2 emissions have improved in fifteen of eighteen years. The trends in CO_2 emissions and fuel economy since 1975 are shown in Figure ES-1.

Preliminary data suggest that CO_2 emissions and fuel economy in model year 2023 will improve from 2022. These data are shown in Figure ES-1 as a dot because the values are based on manufacturer projections rather than final data.

Figure ES-1. Estimated Real-World Fuel Economy and CO_2 Emissions



The four largest vehicle types are at record low CO_2 emissions; however, long term market shifts away from cars and towards sport utility vehicles (SUVs) have offset some of the fleetwide benefits

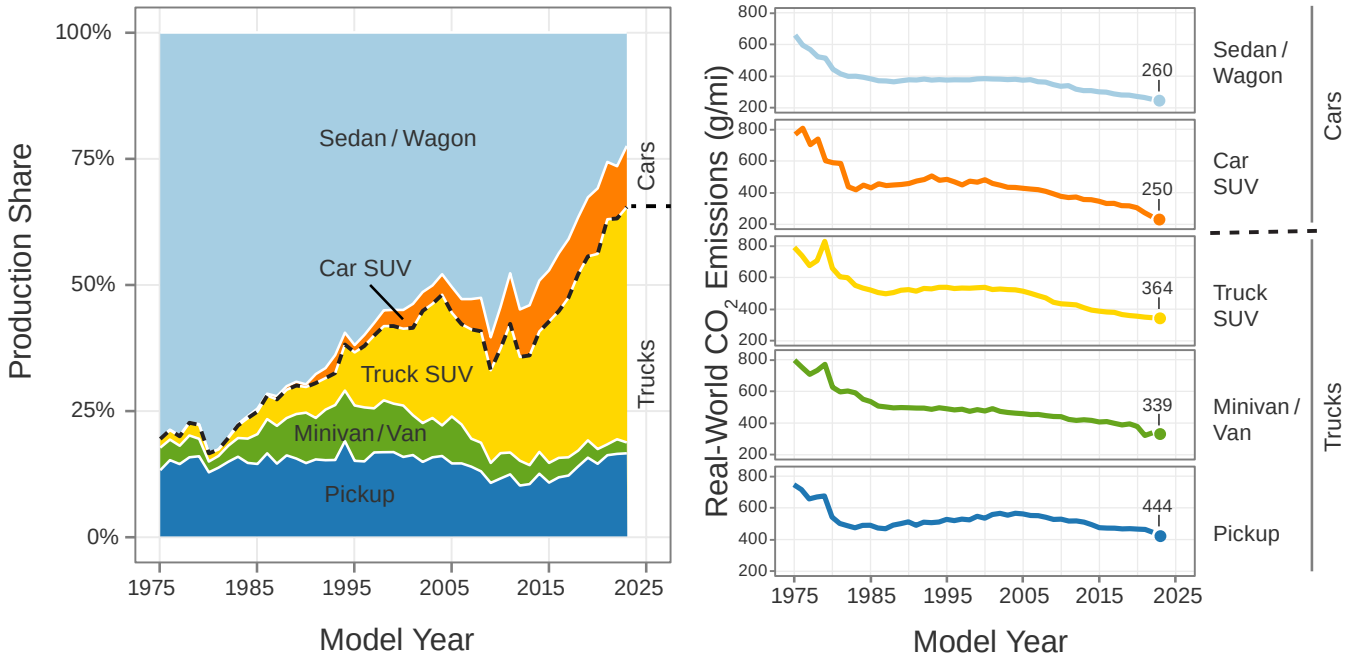
In this report, vehicles are disaggregated into five vehicle types: sedan/wagon, car SUV, truck SUV, pickup truck, and minivan/van. The distinction between car and truck SUVs is based on regulatory definitions where SUVs that are four-wheel drive (4WD) or above a weight threshold (6,000 pounds gross vehicle weight) are generally regulated as trucks and

classified as truck SUVs for this report. The remaining two-wheel drive (2WD) SUVs are subject to car standards and classified as car SUVs. In model year 2022, four of the five vehicle types had their lowest CO_2 emissions and highest fuel economy ever. Car SUVs decreased CO_2 emissions by 27 g/mi, pickups decreased by 18 g/mi, sedan/wagons decreased by 11 g/mi and truck SUVs decreased by 4 g/mi. Minivan/vans, which accounted for less than 3% of new vehicle production in model year 2022, were the only vehicle type that had higher CO_2 emissions in 2022 compared to 2021, increasing by 17 g/mi.

For many years the overall new vehicle market has been trending away from the sedan/wagon vehicle type and towards a combination of truck SUVs and car SUVs. However, in model year 2022, the market share for both car SUVs and truck SUVs fell by about one percentage point compared to model year 2021. Given the longer-term trends and projected data for model year 2023, this does not appear to be a reversal of market trends. The long-term trend away from sedan/wagons and towards vehicle types with lower fuel economy and higher CO_2 emissions has offset some of the fleetwide benefits that otherwise would have been achieved from the improvements within each vehicle type.

The sedan/wagon and car SUV vehicle types must meet the car standards under EPA's light-duty GHG regulations, while truck SUVs, pickups, and minivan/vans must meet separate truck standards. In model year 2022, 37% of all new vehicles were cars and 63% of all new vehicles were trucks under EPA's light-duty GHG regulations. This is the highest percentage of trucks since at least 1975 and is projected to increase further in model year 2023.

Figure ES-2. Production Share and CO_2 Emissions by Vehicle Type

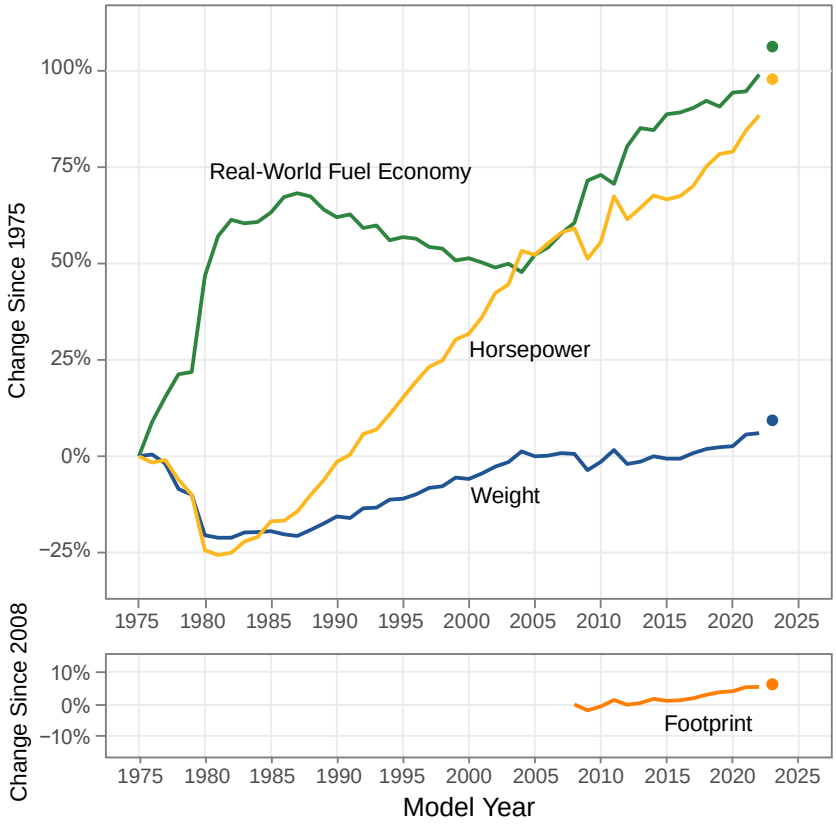


Average new vehicle fuel economy, horsepower, weight, and footprint are all at record highs

Overall vehicle trends are influenced both by vehicle technology and design, and by the changes in the distribution of vehicles being produced. For a specific vehicle, increased weight or horsepower is likely to result in higher CO_2 emissions and lower fuel economy, all else being equal. Larger vehicles, in this case measured by footprint or the area enclosed by the four tires, also tend to have higher CO_2 emissions and lower fuel economy. Footprint is also the basis for determining regulatory standards under the GHG and CAFE regulations. Electric vehicles produce zero tailpipe emissions; however, weight, horsepower, and vehicle size can still impact the vehicle fuel economy (as measured in miles per gallon of gasoline equivalent).

In the two decades prior to 2004, technology innovation and market trends generally resulted in increased vehicle power and weight (due to increasing vehicle size and content) while average new vehicle fuel economy steadily decreased and CO_2 emissions correspondingly increased. Since model year 2004, the combination of technology innovation and market trends have resulted in average new vehicle fuel economy increasing 35%, horsepower increasing 23%, and weight increasing 5%. Footprint has increased 6% since EPA began tracking it in model year 2008. These metrics are all at historic highs and are projected to increase again in model year 2023, as shown in Figure ES-3.

Figure ES-3. Percent Change in Real-World Fuel Economy, Horsepower, Weight, and Footprint



The changes within each of these metrics are due to the combination of design and technology changes within each vehicle type, and 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 and CO_2 emission benefits that otherwise would have been achieved through improving technology.

Most manufacturers have improved CO_2 emissions and fuel economy over the last 5 years

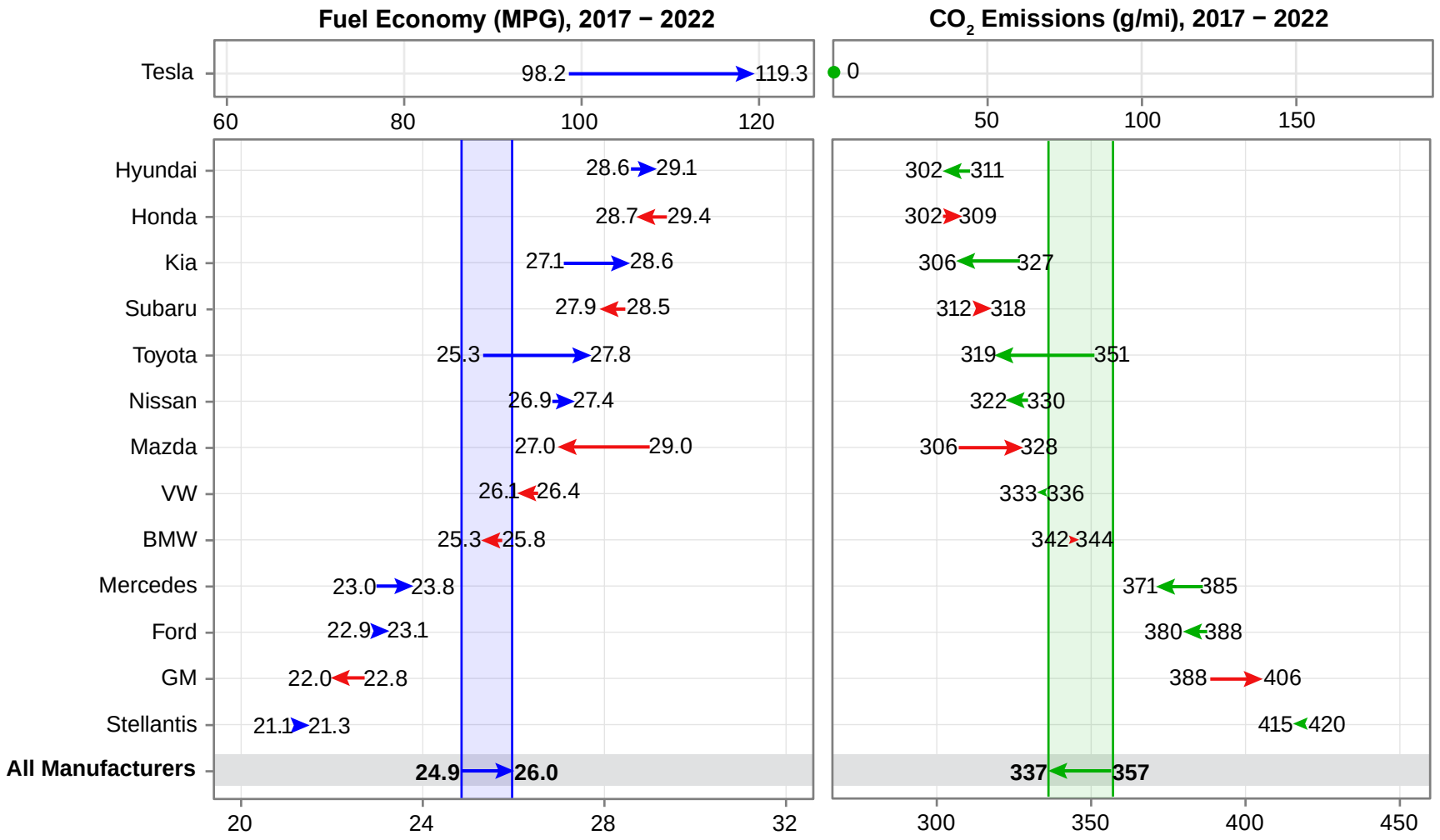
Manufacturer trends over the last five years are shown in Figure ES-4. This span covers the approximate length of a vehicle redesign cycle, and it is likely that most vehicles have undergone design changes in this period, resulting in a more accurate depiction of recent manufacturer trends than focusing on a single year. Differences in manufacturer CO_2 emission rates and fuel economy over this time period can be attributed to changes in both vehicle design, and the mix of vehicle types produced.

Over the last five years, eight of the fourteen largest manufacturers selling vehicles in the U.S. decreased new vehicle estimated real-world CO_2 emission rates. Tesla was unchanged because their all-electric fleet produces no tailpipe CO_2 emissions. Between model years 2017 and 2022, Toyota achieved the largest reduction in CO_2 emissions, at 32 g/mi. Toyota decreased emissions across all vehicle types and decreased overall emissions even as their truck SUV share increased from 27% to 38%. Kia achieved the second largest reduction in overall CO_2 tailpipe emissions, at 21 g/mi, and Mercedes had the third largest reduction in overall CO_2 tailpipe emissions at 14 g/mi. Hyundai, Ford, Nissan, Stellantis, and VW also achieved overall emission reductions.

Five manufacturers increased new vehicle CO_2 emission rates between model years 2017 and 2022. Mazda had the largest increase at 22 g/mi, due to a shift in production from 29% to 85% truck SUVs, along with increased CO_2 emission rates within their sedan/wagon vehicle types. General Motors (GM) had the second largest increase at 17 g/mi, and Honda had the third largest increase at 7 g/mi. Shifts in production towards larger vehicles combined with increased CO_2 emission rates for pickups more than offset emission improvements in all other vehicle types for GM and Honda.

For model year 2022 alone, Tesla's all-electric fleet had by far the lowest tailpipe CO_2 emissions of all large manufacturers. Tesla was followed by Hyundai at 302 g/mi, Kia at 306 g/mi, and Honda at 309 g/mi. Stellantis had the highest new vehicle average CO_2 emissions and lowest fuel economy of the large manufacturers in model year 2022, followed by GM and Ford. Tesla also had the highest overall fuel economy, followed by Hyundai at 29.1 mpg, Honda at 28.7 mpg, and Kia at 28.6 mpg.

Figure ES-4. Changes in Estimated Real-World Fuel Economy[1] and CO_2 Emissions for Large Manufacturers



[1]Electric vehicles, including Tesla's all-electric fleet, are measured in terms of miles per gallon of gasoline equivalent, or mpge.

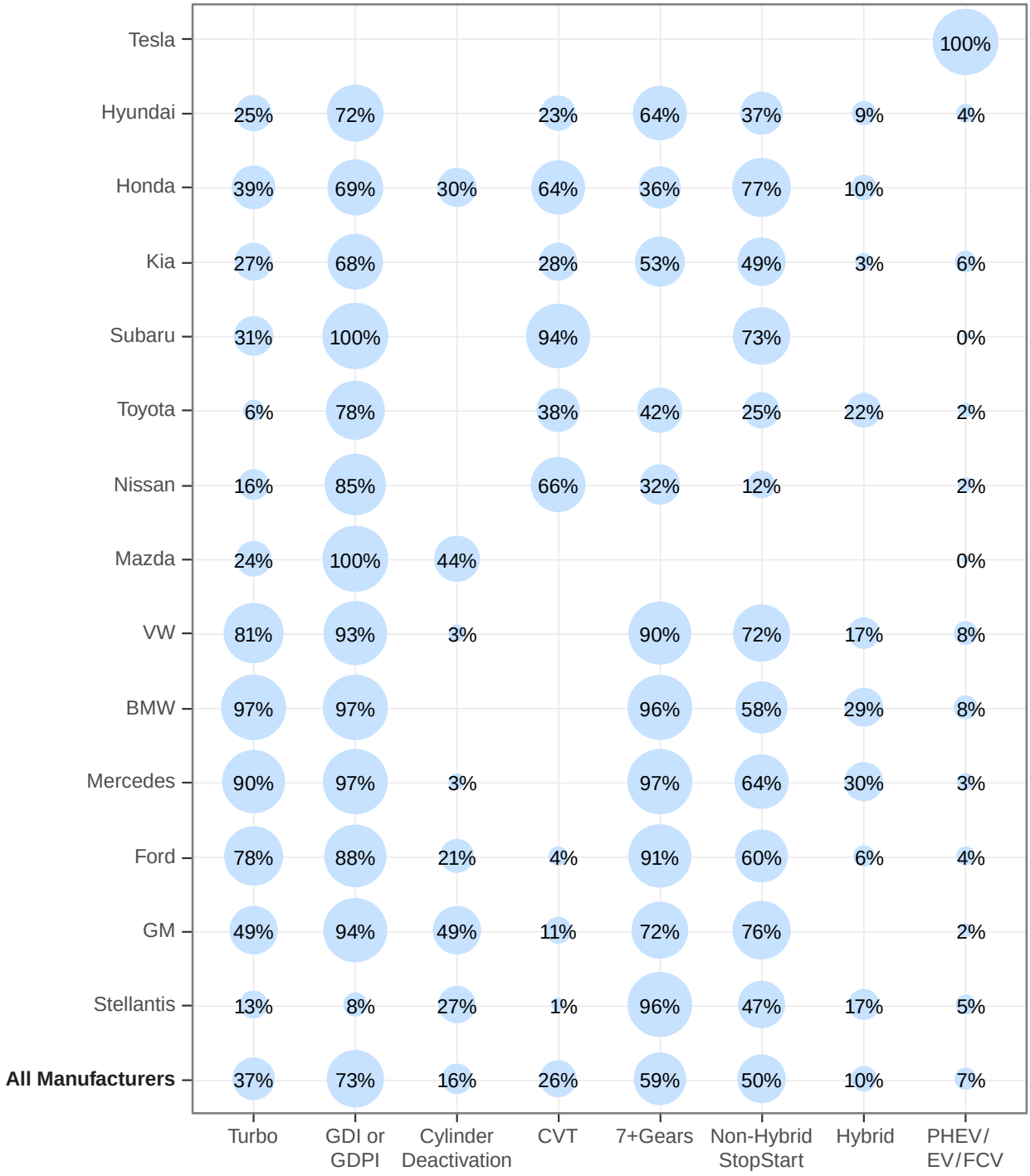
Manufacturers continue to use a wide array of advanced technologies

Innovation in the automobile industry has led to a wide array of technology available to manufacturers to achieve CO_2 emissions, fuel economy, and performance goals. Figure ES-5 illustrates manufacturer-specific technology usage for model year 2022, with larger circles representing higher usage rates. The technologies in Figure ES-5 are all being used by manufacturers to, in part, reduce CO_2 emissions and increase fuel economy. Each of the fourteen largest manufacturers have adopted several of these technologies into their vehicles, with many manufacturers achieving very high penetrations of several technologies. It is also clear that manufacturers' strategies to develop and adopt new technologies are unique and vary significantly. Each manufacturer is choosing technologies that best meet the design requirements of their vehicles, and in many cases, that technology is changing quickly.

Engine technologies such as turbocharged engines (Turbo) and gasoline direct injection (GDI) allow for more efficient engine design and operation. A growing number of engines can use GDI or port fuel injection (GDPI) depending on conditions – these engines are included with GDI engines in Figure ES-5 for the first time this year. Cylinder deactivation (CD) allows for use of only a portion of the engine when less power is needed, while stop/start systems can turn off the engine entirely at idle to save fuel. Hybrid vehicles use a larger battery to recapture braking energy and provide power when necessary, allowing for a smaller, more efficiently operated engine. The hybrid category includes "strong" hybrid systems that can temporarily power the vehicle without engaging the engine and smaller "mild" hybrid systems that cannot propel the vehicle on their own. Transmissions that have more gear ratios, or speeds, allow the engine to more frequently operate near peak efficiency. Two categories of advanced transmissions are shown in Figure ES-5: transmissions with seven or more discrete speeds (7+Gears), and continuously variable transmissions (CVTs).

In model year 2022, hybrid vehicles reached a new high of 10% of all production. Strong and mild hybrid production grew, with mild hybrids accounting for 41% of overall hybrid production. The combined category of electric vehicles (EVs), plug-in hybrid vehicles (PHEVs), and fuel cell electric vehicles (FCVs) increased from 4% of production in model year 2021 to 7% of production in model year 2022 and are projected to reach 12% of production in model year 2023. This trend will likely continue as EV production is expected to grow across the industry in coming years.

Figure ES-5. Technology Share for Large Manufacturers, Model Year 2022

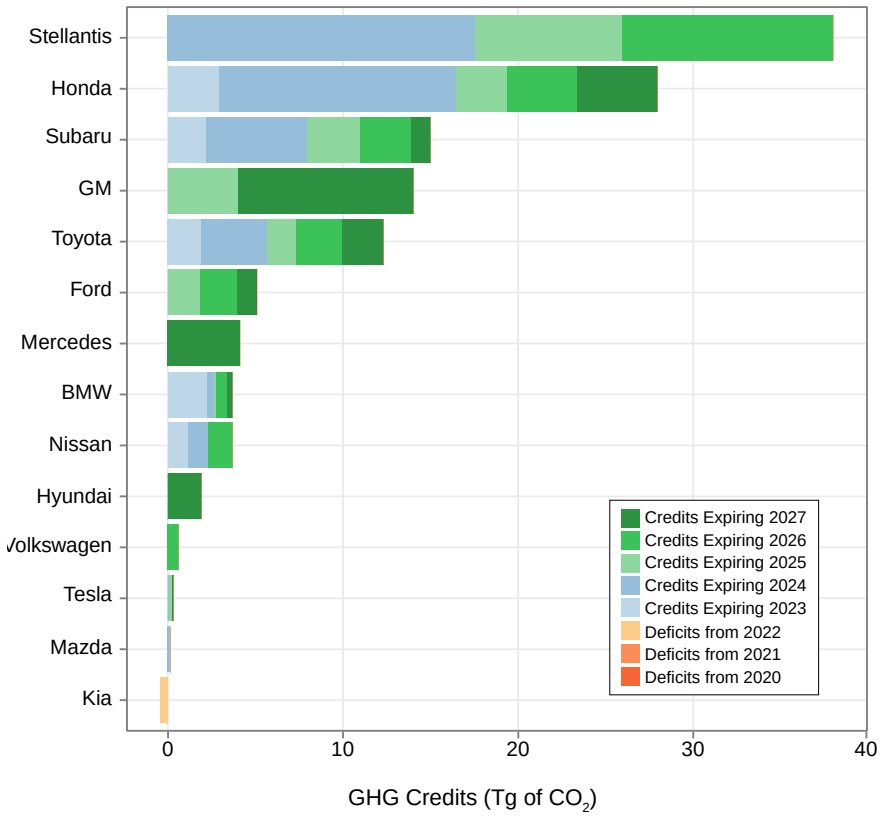


Through the model year 2022 reporting period, all large manufacturers are in compliance with the light-duty GHG program requirements

EPA's GHG program is an averaging, banking, and trading (ABT) program. An ABT program means that the standards may be met on a fleet **average** basis, manufacturers may earn and **bank** credits to use later, and manufacturers may **trade** credits with other manufacturers. This provides manufacturers flexibility in meeting the standards while accounting for vehicle design cycles, introduction rates of new technologies and emission improvements, and evolving consumer preferences.

Within a model year, manufacturers with average fleet emissions lower than the standards generate credits, and manufacturers with average fleet emissions higher than the standards generate deficits. Any manufacturer with a deficit at the end of the model year has up to three years to offset the deficit with credits earned in future model years or purchased from another manufacturer. A manufacturer may not report deficits for more than 3 years in a row.

Figure ES-6. GHG Credit Balance for Large Manufacturers, after Model Year 2022



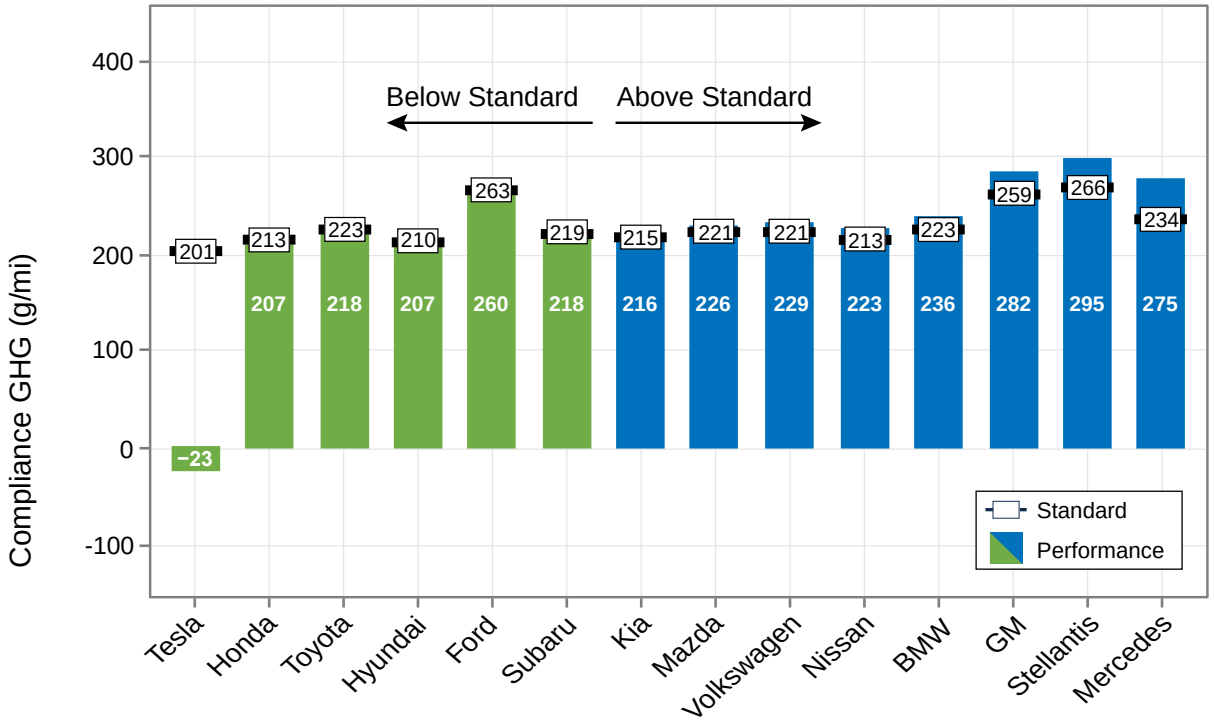
Thirteen of the fourteen largest manufacturers ended model year 2022 with positive or zero credit balances and are thus in compliance for model year 2022 and all previous years of the GHG program, as credits may not be carried forward unless deficits from all prior model years have been resolved. Kia ended model year 2022 with a deficit, which is their second straight model year reporting a deficit. Kia must offset all deficits by the model year 2024 reporting period to remain in compliance.

Total credits in Figure ES-6 are shown in **Teragrams** (Tg; one million Megagrams), and account for manufacturer performance compared to their standards, expected vehicle lifetime miles driven, and the number of vehicles produced by each manufacturer, for all years of the GHG program. The credits accumulated by each manufacturer will be carried forward for use in future model years or until they expire. Credit expiration dates are based on the model year in which they were earned.

Manufacturers used different combinations of technology improvements and credit strategies in model year 2022

Determining manufacturer compliance with EPA's GHG program requires accounting for a manufacturer's credit balance over the life of the program. However, it is also useful to look at manufacturer performance within the most recent model year. Figure ES-7 illustrates the performance of individual large manufacturers in model year 2022 compared to their effective overall standard, in terms of an average vehicle grams per mile emission rate. This "snapshot" provides insight into how the large manufacturers performed against the standards in model year 2022, however it cannot be used to determine individual manufacturer compliance status with the overall program.

Figure ES-7. CO_2 Performance and Standards by Manufacturer, Model Year 2022



Tesla, Honda, Toyota, Hyundai, Ford, and Subaru ended model year 2022 with their average new vehicle GHG emissions performance below their respective standards. This result, combined with the fact that these manufacturers all had a credit balance at the end of model year 2021, allowed these manufacturers to achieve compliance with the GHG program through model year 2022 and bank or sell additional credits in model year 2022.

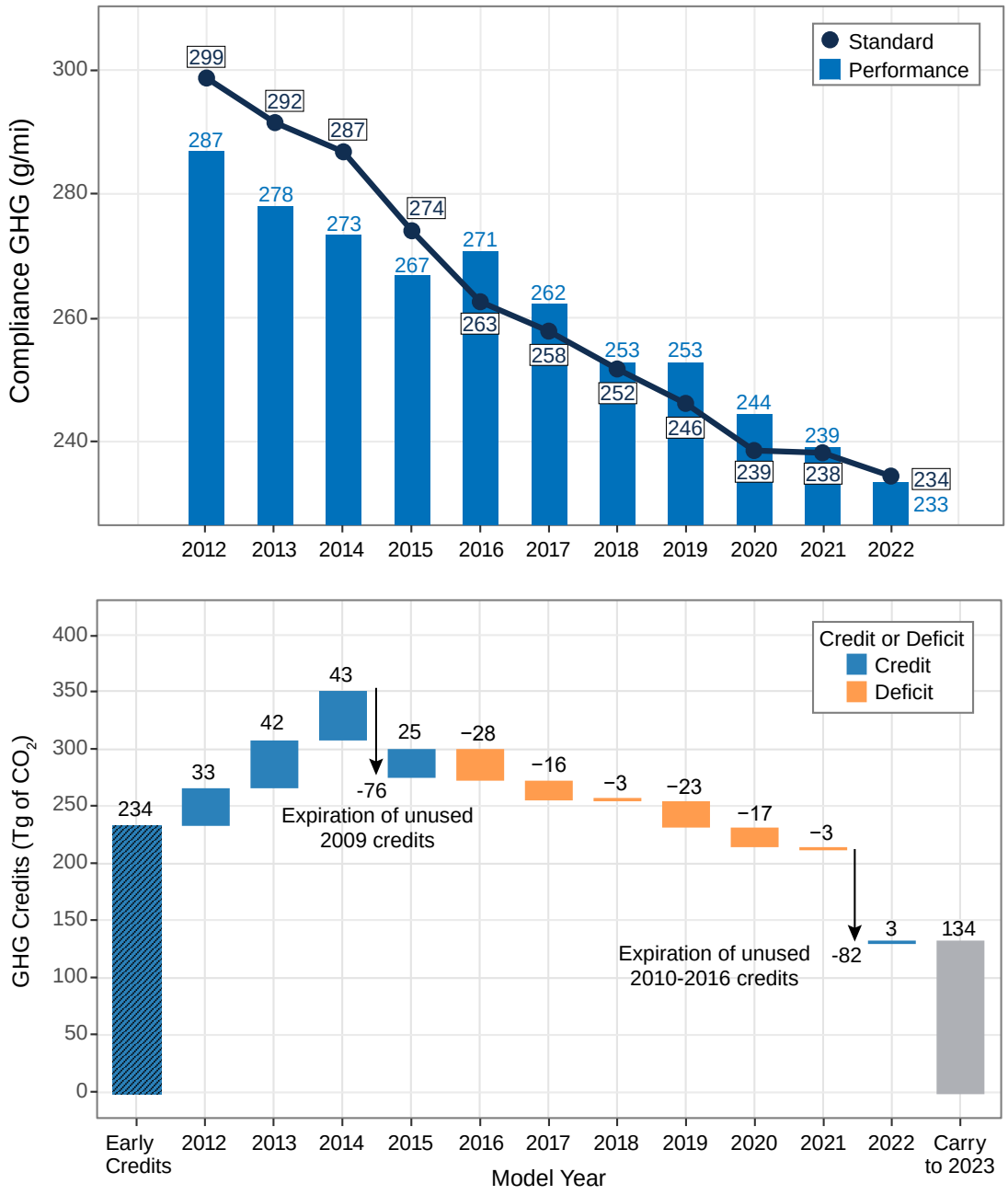
Eight of the fourteen large manufacturers ended model year 2022 with emission performance above their overall standard. Seven of these manufacturers used banked or purchased credits, along with technology improvements, to achieve compliance in model year 2022. As noted above, Kia ended the model year with deficits, but the program allows manufacturers up to three years to offset any deficits and remain in compliance.

The manufacturer performance values shown in Figure ES-7 are based on the average new vehicle tailpipe emissions for each manufacturer and include optional credits available to manufacturers in model year 2022 for improved air conditioning systems or technologies that are not directly measured on standard EPA tests (off-cycle credits). These credits vary between manufacturers, but the industry averaged 21 g/mi of credits due to improved air conditioning systems, and 9 g/mi of credits due to off-cycle technologies. Tesla produces electric vehicles with zero tailpipe emissions, but also claimed air conditioning and off-cycle credits to achieve the negative performance value shown in Figure ES-7.

The overall industry generated credits, adding to a large bank of credits for future years

The industry ended model year 2022 with a credit balance of 134 Tg. This credit balance is the result of the overall industry performance against the standards within each model year, as well as the generation of early credits, credit expirations, and the sum of all credit averaging, banking, and trading allowed by EPA's GHG program. Under the GHG Program, manufacturers were able to accrue "early credits," before the GHG standards took effect in model year 2012, for early deployment of efficient vehicles and technology. Overall, the industry was able to accrue a large volume of credits due to this provision, although some of these credits had restrictions on their use, and all credits have regulatory expiration dates. In model years 2012 through 2014, manufacturers continued to generate credits, as the industry GHG performance was below the industry-wide average standard. At the end of model year 2014, unused early credits generated from model year 2009 expired, which reduced the overall credit balance. In model year 2015, the industry again generated credits, however from model year 2016-2021 the industry GHG performance was above the standard, resulting in net withdrawals from the bank of credits to maintain compliance. In addition, unused credits generated in model years 2010-2016 expired at the end of model year 2021, which further drew down the overall industry credit balance.

Figure ES-8. Industry Performance and Standards, and Overall Credit Balance



In model year 2022, the overall industry GHG performance fell 6 g/mi to 233 g/mi, while the standard fell 4 g/mi to 234 g/mi. As a result, the overall industry performance was below the standard for the first time since model year 2015, and the industry generated about 3 Tg of credits. The overall industry emerged from model year 2022 with a bank of 134 Tg of GHG credits available for future use, as seen in Figure ES-8.

The credits available at the end of model year 2022 will expire according to the schedule defined by the GHG Program and detailed in Section 5 of this report. The next group of credits to expire will be credits earned in model year 2017, which will expire at the end of model year 2023. An active credit market has allowed manufacturers to purchase credits to demonstrate compliance, with ten manufacturers selling credits, fourteen manufacturers purchasing credits, and approximately 110 credit trades since 2012. As of October 31, 2023, about 194 Tg of credits have been traded between manufacturers.

The automobile industry continues to innovate, improve, and meet the GHG standards

The analysis here is a snapshot of the data collected by EPA in support of several important regulatory programs and is presented with the intent of providing as much transparency to the public as possible. The data show the change and innovation in the industry since model year 1975, and the manufacturers' performance under EPA's GHG standards.

To download the full report, or to explore the data using EPA's interactive data tools, visit the report webpage at www.epa.gov/automotive-trends.