

Greenhouse Gas Emissions Performance for the 2023 Model Year Light-Duty Vehicle Fleet

In relation to the *Passenger Automobile and Light Truck
Greenhouse Gas Emission Regulations* under the
Canadian Environmental Protection Act, 1999



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List of acronyms

AC – Air conditioner

ATV – Advanced technology vehicle

CAFE – Corporate average fuel economy

CEPA – Canadian Environmental Protection Act, 1999

CO – Carbon monoxide

CO₂ – Carbon dioxide

CO₂e – Carbon dioxide equivalent

CREE – Carbon related exhaust emissions

CWF – Carbon weight fraction

EPA – Environmental Protection Agency

FCEV – Fuel cell electric vehicle

FTP – Federal test procedure

GHG – Greenhouse gas

g/mi – grams per mile

HC – Hydrocarbons

HFET – Highway fuel economy test

LT – Light truck

NO_x – Oxides of nitrogen

N₂O – Nitrous oxide

PA – Passenger automobile

PM – Particulate matter

TOF – Temporary optional fleet

VKT – Vehicle kilometres travelled

ZEV – Zero emission vehicle

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Executive summary

The *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* (hereinafter referred to as the “regulations”) establish greenhouse gas (GHG) emission standards for new 2011 and later model year light-duty on-road vehicles offered for sale in Canada. These regulations require importers and manufacturers of new vehicles to meet fleet average emission standards for greenhouse gases. The Regulations also establish annual compliance reporting requirements. This report summarizes the fleet average greenhouse gas emission performance of the fleets of light-duty vehicles. It also provides a compliance summary for each of the obligated companies including their individual fleet average carbon dioxide equivalent (CO₂e)¹ emissions value (referred to as the “compliance value”) and the status of their emission credits.

The CO₂e emission standards are company-unique and are based on the footprint and the quantity of vehicles offered for sale in a given model year. These footprint-based target values are aligned with those of the United States Environmental Protection Agency (EPA) and have increased in stringency from the 2012 through 2026 model years². Since the Canadian greenhouse gas standards were introduced prior to the U.S. EPA program, the 2011 model year target values in Canada were instead based on the U.S. Corporate Average Fuel Economy (CAFE) levels. Since the introduction of the regulations, the fleet average standards for passenger automobiles and for light trucks have become more stringent by 43.0% and 36.2% respectively.

A company’s performance relative to its standard is determined through its sales weighted fleet average emissions performance for the given model year for its new passenger automobile and light truck offerings, expressed in grams per mile of CO₂e based on standardized emissions tests simulating city and highway driving cycles. The emissions measured during these test procedures include CO₂ and other carbon related combustion products, namely carbon monoxide (CO) and hydrocarbons (HC). This ensures that all carbon containing exhaust emissions are also recognized. These regulations also set limits for the release of other greenhouse gases such as methane (CH₄) and nitrous oxide (N₂O). A number of mechanisms are incorporated into the regulations which provide companies with a series of options to achieve the applicable greenhouse gas standards while incentivizing the deployment of new greenhouse gas reducing technologies. These mechanisms include allowances for vehicle improvements and complementary innovative technologies that contribute to the reduction of greenhouse gas emissions in ways that are not directly measured during standard tailpipe emissions testing. Flexibility mechanisms include recognition of the emission benefits of dual-fuel capability, electrification and other technologies that contribute to improved greenhouse gas performance. The regulations also include an emission credit system that allows companies to generate emission credits if their fleet average performance is superior to the standard. Emission credits can be accumulated for future use to offset emission deficits (a deficit is incurred if a company’s fleet performance is above their applicable standard). This allows companies to

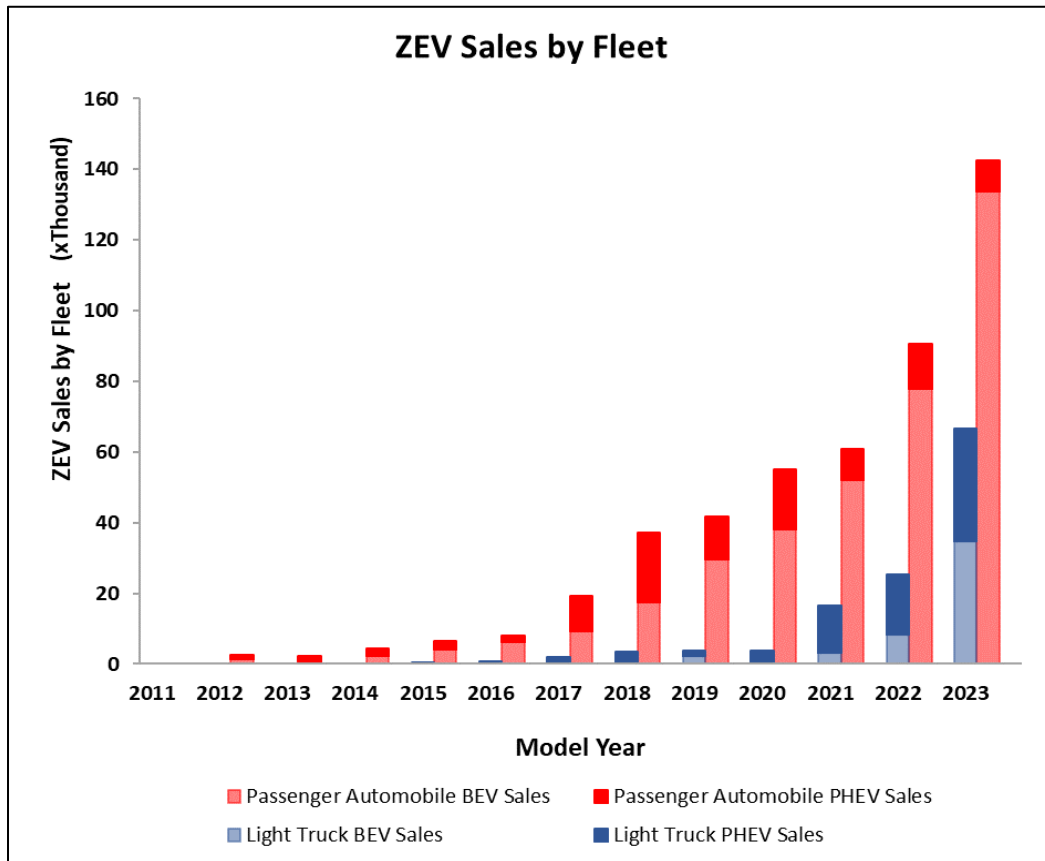
¹ CO₂e is used throughout this report as a common unit to standardize the environmental impacts of different greenhouse gases (such as N₂O & CH₄) in terms of an equivalent amount of CO₂.

² In December 2021, the U.S. EPA published its Final Rule which increased the stringency of GHG standards for model years 2023 to 2026.

maintain regulatory compliance as their product mix and demands change year to year and through product cycles which may result in fleet average performance above the standard. Companies that generate emission credits may transfer those credits to other companies. Emission credits generated for performance superior to the standard have a lifespan which is determined based on the model year in which they were generated, whereas deficits generated for performance worse than the standard must be offset within 3 years from the model year in which the deficit was incurred. Compliance to the regulations and the corresponding tracking of credits is monitored, in part, through the annual reports and companies are required to maintain all relevant records relating to their vehicle greenhouse gas emissions performance.

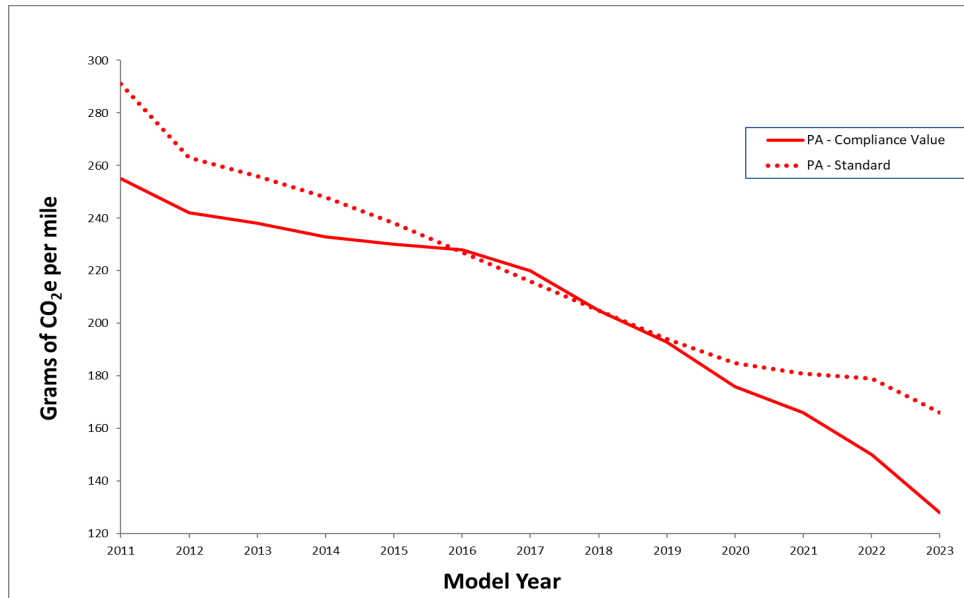
The regulations have been instrumental in influencing companies to make progressive improvements to the efficiency and GHG reductions of their new light duty vehicle fleets available in Canada since the 2011 model year. These regulations have required companies to meet progressively more stringent GHG standards which has pushed new approaches and engineering changes to meet the requirements through the introduction of a wide variety of new and innovative technologies. To meet the regulatory standards, companies have continued to refine and improve upon conventional internal combustion engine technologies as well as incorporate an array of other innovative approaches such as active aerodynamics, advanced materials for light-weighting, solar reflective paint, high efficiency lighting and more. As a result of the regulations companies have been driven to look at alternative propulsion technologies (such as hybrid electric vehicles) and increase the availability of advanced technology vehicles with lower to zero GHG emissions, which consist of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV), collectively referred to as zero emission vehicles (ZEVs), and natural gas vehicles (NGVs). In fact, since the introduction of the regulation, the volume of ZEVs reached 13.4% for the 2023 model year. More specifically, battery electric vehicles have increased from 198 to 170,167 representing 10.8% of the total fleet in 2023, and the volume of plug-in hybrid electric vehicles has increased from 0 to 40,652 representing 2.6% of the total fleet in 2023. The sum of these developments within the Canadian vehicle fleets have resulted in measurable improvements to GHG emissions performance, and an increasing number of ZEVs are expected to continue to gain market share as standards continue to increase in stringency.

Figure ES-1. Increase in ZEV production from the 2011 to 2023 model years



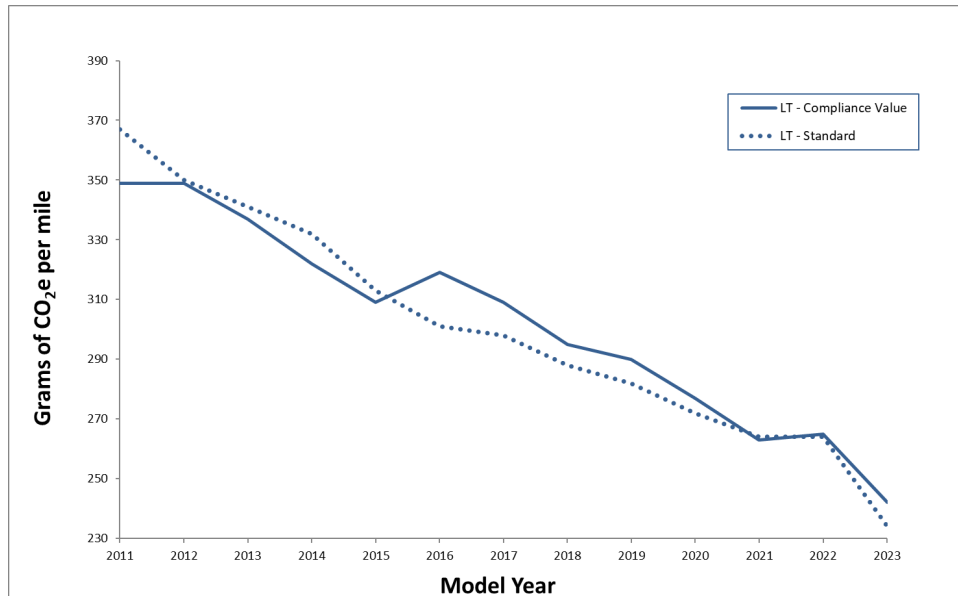
Results from annual regulatory compliance reports indicate that companies continue to be in compliance through the 2023 model year. The average compliance value for the fleet of new passenger automobiles has decreased from 255 g/mi to 128 g/mi since the introduction of the regulation, representing a 49.8% reduction.

Figure ES-2. average GHG emissions performance - passenger automobiles



The compliance value for light trucks decreased by 30.7%, from 349 g/mi to 242 g/mi since the introduction of the regulation. All companies remained in compliance with the regulations by either meeting their applicable standard, through the use of their own accumulated emission credits or by purchasing credits from other companies.

Figure ES-3. average GHG emissions performance - light trucks



Under the regulations, companies have generated a total of approximately 115.9 million credits, of which, approximately 27.3 million are available for future use. A total of 39 million credits have been used to offset emission deficits by individual companies over the 2011 to 2023 model years, of which 4.9 million credits were used to offset deficits accrued in the 2023 model year. The remaining 51.3 million credits have expired.

1. Purpose of the report

The purpose of this report is to provide company specific results for the fleet average greenhouse gas emission (GHG) performance of the Canadian fleets of passenger automobiles (PA) and of light trucks (LT)³. Building on the previous GHG emissions performance report for the 2022 model year, this report focuses on the GHG emissions performance of the last 4 model years. The results presented herein are based on data submitted by companies in their annual regulatory compliance reports, pursuant to the *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*, which have undergone a thorough review by Environment and Climate Change Canada (ECCC). The report assists with identifying trends in the Canadian automotive industry including the adoption and emergence of technologies that have the potential to reduce GHG emissions. It also serves to describe emission credit trading under the regulations.

2. Overview of the regulations

In October 2010, the Government of Canada published the *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*⁴ (regulations) under CEPA. This was the first Government of Canada regulation targeting GHG's and was a major milestone for ECCC towards addressing GHG emissions from the Canadian transportation sector. The regulations and the subsequent amendments introduced progressively more stringent GHG emission targets for new light-duty vehicles of model years 2011 to 2026 in alignment with the U.S. national standards, thereby establishing a common North American approach.

The department assesses compliance with the fleet average requirements through annual reports. These reports establish each company's fleet average GHG performance and the applicable standard for both its passenger automobile and light truck fleets⁵. The regulations include compliance provisions, including the ability for companies to accrue emission credits or deficits, depending on their fleet performance relative to the standard. The department uses these reports to monitor, track, and assess whether the regulatory requirements have been met and the number of emission credit balances and transfers. There are in excess of 10,000 data elements collected each reporting cycle. ECCC reviews and validates company data and the results may be subject to change should new information become available.

Companies that submitted a report pursuant to the regulations during 2020 to 2023 model years are listed in Table 1.

³ The department has released 9 reports documenting the overall fleet performance from earlier model years.

⁴ [The regulations, along with amendments, and the accompanying regulatory impact analysis statement](#)

⁵ Definitions of passenger automobile and light truck can be found in the Regulations

Table 1: model year report submission status

| Manufacturer | Common Name | 2020 | 2021 | 2022 | 2023 |
|---|--------------|------------------|------------------|------------------|------------------|
| Aston Martin Lagonda Ltd. | Aston Martin | LVM ^a | LVM ^a | LVM ^a | LVM ^a |
| BMW Canada Inc. | BMW | * | * | * | * |
| BYD Canada Company Limited | BYD | * | -- | -- | -- |
| FCA Canada Inc. | FCA | * | * | * | * |
| Ferrari North America Inc. | Ferrari | LVM ^a | LVM ^a | LVM ^a | LVM ^a |
| Ford Motor Company of Canada Ltd. | Ford | * | * | * | * |
| General Motors of Canada Company | GM | * | * | * | * |
| Honda Canada Inc. | Honda | * | * | * | * |
| Hyundai Auto Canada Corp. | Hyundai | * | * | * | * |
| Jaguar Land Rover Canada ULC | JLR | * | * | * | * |
| Kia Canada Inc. | Kia | * | * | * | * |
| Lotus Cars Ltd. | Lotus | LVM ^a | LVM ^a | LVM ^a | LVM ^a |
| Maserati North America Inc. | Maserati | * | * | LVM ^a | LVM ^a |
| Mazda Canada Inc. | Mazda | * | * | * | * |
| McLaren Automotive Limited | McLaren | LVM ^a | LVM ^a | LVM ^a | LVM ^a |
| Mercedes-Benz Canada Inc. | Mercedes | * | * | * | * |
| Mitsubishi Motor Sales of Canada, Inc. | Mitsubishi | * | * | * | * |
| Morgan Olson Canada Corp. | Morgan Olson | -- | -- | -- | LVM ^a |
| Nissan Canada Inc. | Nissan | * | * | * | * |
| Pagani Automobili SPA, Italy | Pagani | LVM ^a | LVM ^a | LVM ^a | LVM ^a |
| Porsche Cars Canada, Ltd. | Porsche | * | * | * | * |
| Rivian Automotive Canada Inc. | Rivian | -- | -- | -- | * |
| Subaru Canada Inc. | Subaru | * | * | * | * |
| Tesla Motors, Inc. | Tesla | * | * | * | * |
| Toyota Canada, Inc. | Toyota | * | * | * | * |
| VinFast Auto Canada Inc. | VinFast | -- | -- | -- | * |
| Volkswagen Group Canada, Inc. | Volkswagen | * | * | * | * |
| Volvo Cars of Canada Corp. | Volvo | * | * | * | * |
| <p>*Indicates that a report has been submitted</p> <p>^a Beginning with the 2012 model year, low volume manufacturers (LVM) may elect to exempt themselves from CO₂e standards. This exemption does not have a noticeable impact on fleet-wide performance given the small volume of vehicles.</p> | | | | | |

2.1. CO₂e emission standards

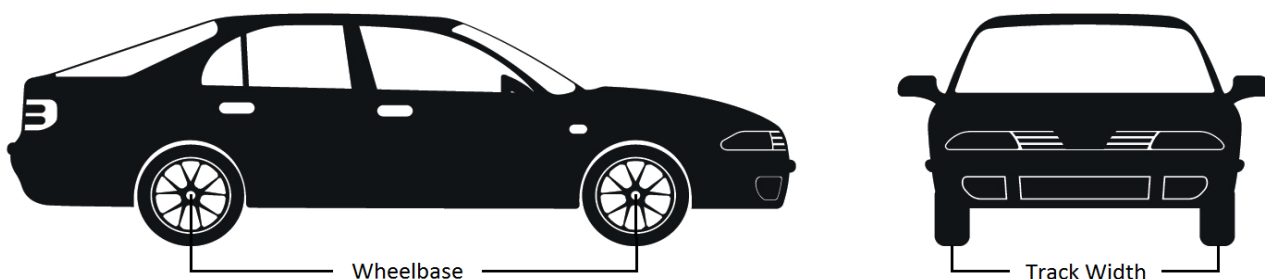
The applicable standards for a given model year are based on prescribed carbon dioxide (CO₂e) emission “target values” that are a function of the “footprint” (Figure 1) and quantity of the vehicles in each company’s fleet of passenger automobiles and light trucks offered for sale⁶ to the first retail purchaser⁷. These standards are performance-based in that they establish a maximum amount of CO₂e on a gram per mile basis. This progressively more stringent approach allows companies to choose from an ever-changing

⁶ The terms “sold”, “offered for sale” and “production volume” are used interchangeably in this report to designate the quantity of vehicles manufactured or imported in Canada for the purpose of first retail sale.

⁷ The regulations exclude “used vehicles” imported into Canada, new vehicles exported from Canada, emergency vehicles, and vehicles imported on a temporary basis for the purposes of exhibition, demonstration, evaluation and testing.

array of the most cost-effective technologies to achieve compliance and reduce emissions, rather than requiring a particular technology.

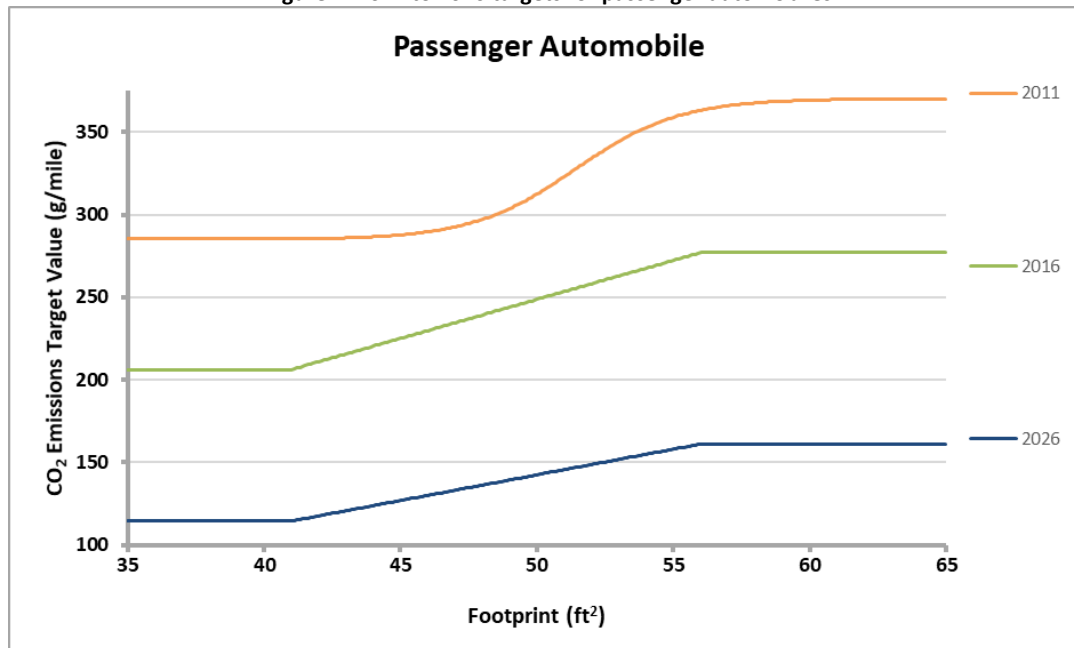
Figure 1: vehicle footprint



$$Footprint = \frac{front\ track\ width + rear\ track\ width}{2} \times wheelbase$$

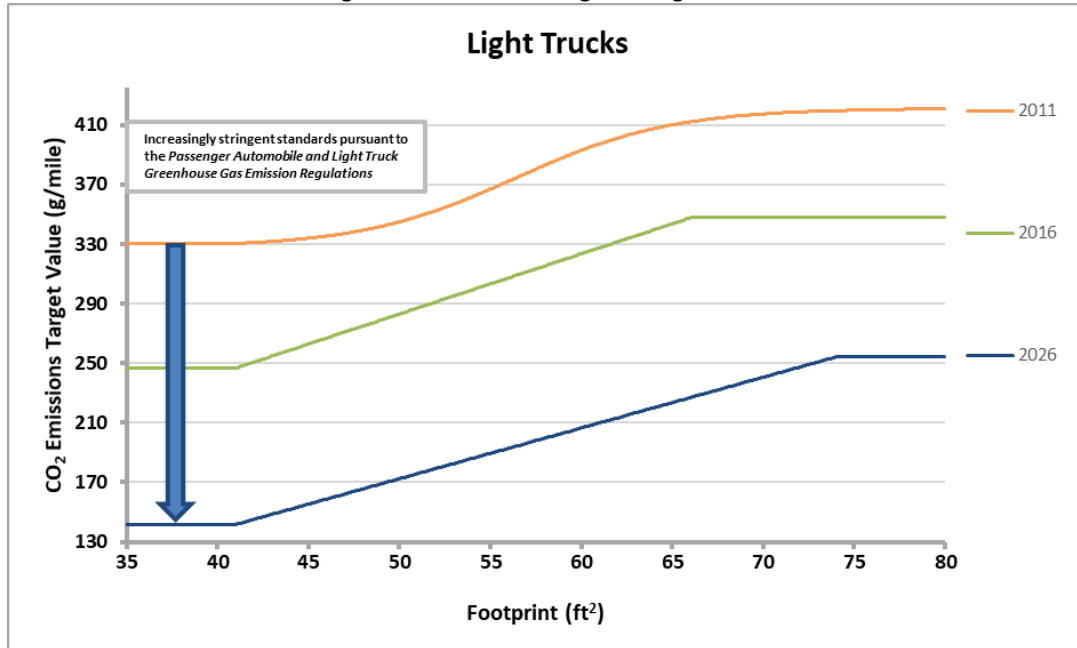
The regulations prescribe progressively more stringent target values for a given footprint size over the 2011 through 2026 model years⁸. Figures 2 and 3 illustrate the target values for passenger automobiles and light trucks, respectively.

Figure 2: 2011 to 2026 targets for passenger automobiles



⁸ See footnote 2

Figure 3: 2011 to 2026 targets for light trucks



As depicted in Figures 2 and 3, the targets for the 2011 model year are unique in that they follow a smooth curve. This is because the 2011 target values were introduced 1 year prior to the U.S. Environmental Protection Agency (EPA) program and were instead based on the U.S. Corporate Average Fuel Economy (CAFE) levels. Accordingly, the regulations considered the consumption of fuel as the basis to establish reasonable approximations of GHG performance for the 2011 model year⁹. The CO₂e standard was derived using a conversion factor of 8,887 grams of CO₂/gallon of gasoline¹⁰ for the 2011 model year only.

For the 2012 and later model years, the CO₂e emissions target values are aligned with the U.S. EPA target values.

The overall passenger automobile and light truck fleet average standard that a company must meet is ultimately determined by calculating the sales weighted average of all the target values using the following formula:

$$\text{Fleet Average Standard} = \frac{\sum (A \times B)}{C}$$

where

⁹ The fuel economy target values that apply to vehicles of the 2011 model year are calculated using the following formula:

$$T = 1 / ((1/a) + (1/b) - (1/a) * ((e^{(x-c)/d}) / (1 + e^{(x-c)/d})))$$

Where: x is the footprint for the vehicle in question, a = 31.20, b = 24.00, c = 51.41, d = 1.91 for PA's

and a = 27.10, b = 21.10, c = 56.41, d = 4.28 for LT's

¹⁰ Although the conversion factor 8,887 is specific to gasoline, it was applied fleet-wide since the proportion of vehicles using other fuel types is very low.

A is the CO₂e emission target value for each group of passenger automobiles or light trucks having the same emission target

B is the number of passenger automobiles or light trucks in the group in question

C is the total number of passenger automobiles or light trucks in the fleet

The final company-unique fleet average CO₂e standards for the 2020 to 2023 model years are presented in Table 2. These represent the regulatory values that a company's fleets of passenger automobiles and light trucks must meet.

Table 2: fleet average CO₂e standard (g/mi)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 188 | 183 | 182 | 167 | 262 | 256 | 251 | 217 |
| BYD | 194 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 206 | 205 | 203 | 187 | 290 | 282 | 291 | 255 |
| Ford | 193 | 194 | 190 | 178 | 296 | 291 | 281 | 268 |
| GM | 181 | 177 | 175 | 161 | 293 | 293 | 286 | 254 |
| Honda | 184 | 180 | 177 | 164 | 245 | 237 | 240 | 215 |
| Hyundai | 184 | 179 | 177 | 163 | 269 | 252 | 240 | 216 |
| JLR | 203 | 183 | 181 | 163 | 267 | 256 | 257 | 230 |
| Kia | 183 | 177 | 176 | 161 | 253 | 234 | 239 | 211 |
| Maserati | 218 | 212 | -- | -- | 269 | 262 | -- | -- |
| Mazda | 183 | 178 | 173 | 161 | 238 | 231 | 228 | 204 |
| Mercedes | 195 | 192 | 190 | 178 | 263 | 255 | 251 | 226 |
| Mitsubishi | 176 | 171 | 167 | 150 | 226 | 219 | 222 | 199 |
| Nissan | 190 | 179 | 176 | 162 | 245 | 234 | 247 | 210 |
| Porsche | 198 | 178 | 173 | 162 | 266 | 251 | 248 | 221 |
| Rivian | -- | -- | -- | -- | -- | -- | -- | 260 |
| Subaru | 180 | 174 | 173 | 158 | 235 | 225 | 227 | 202 |
| Tesla | 202 | 198 | 195 | 180 | 275 | 253 | 249 | 223 |
| Toyota | 183 | 179 | 176 | 163 | 261 | 249 | 246 | 221 |
| VinFast | -- | -- | -- | 187 | -- | -- | -- | -- |
| Volkswagen | 183 | 178 | 176 | 162 | 246 | 247 | 240 | 214 |
| Volvo | 212 | 191 | 185 | 168 | 263 | 249 | 246 | 219 |
| Fleet Average | 185 | 181 | 179 | 166 | 272 | 264 | 264 | 234 |

A company's average footprint (Table 3) is one of the factors in establishing their CO₂e standards. Companies are responsible for meeting their own unique fleet average CO₂e standard based on the size of vehicles they produce. However, the regulations provide additional compliance flexibilities for intermediate sized companies to make use of an alternative schedule of annual emission standards for the 2020 to 2023 model years (discussed in section 2.3.7.).

Table 3: average footprint for the 2020 to 2023 model years (sq. ft.)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 46.3 | 46.2 | 46.9 | 47.1 | 52.0 | 52.0 | 51.8 | 50 |
| BYD | 47.9 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 50.9 | 52 | 52.3 | 52.5 | 58.3 | 57.8 | 61.2 | 59.7 |
| Ford | 47.7 | 49.2 | 49.8 | 50.4 | 60.2 | 61.0 | 60.1 | 63 |
| GM | 43.5 | 43.3 | 43.9 | 45.5 | 60.1 | 61.8 | 61.3 | 59.3 |
| Honda | 45.2 | 45.7 | 45.8 | 46.1 | 48.3 | 47.8 | 49.5 | 49.5 |
| Hyundai | 45.5 | 45.3 | 45.7 | 46 | 53.5 | 51.2 | 49.4 | 49.7 |
| JLR | 47.8 | 46.4 | 46.8 | 45.8 | 51.0 | 52.0 | 53.2 | 53.2 |
| Kia | 45.3 | 44.9 | 45.3 | 45.4 | 50.0 | 47.0 | 49.2 | 48.6 |
| Maserati | 53.8 | 53.7 | -- | -- | 53.4 | 53.4 | -- | -- |
| Mazda | 45 | 44.9 | 44.4 | 44.9 | 46.8 | 46.5 | 46.7 | 46.7 |
| Mercedes | 48.1 | 48.7 | 49.4 | 50.4 | 52.1 | 51.8 | 51.9 | 52.2 |
| Mitsubishi | 42.7 | 42.4 | 41.8 | 40.4 | 44.1 | 43.9 | 45.3 | 45.6 |
| Nissan | 45.8 | 45.4 | 45.4 | 45.5 | 48.2 | 47.1 | 50.9 | 48.4 |
| Porsche | 46.6 | 45.1 | 44.5 | 45.5 | 51.0 | 50.8 | 51.1 | 50.9 |
| Rivian | -- | -- | -- | -- | -- | -- | -- | 60.7 |
| Subaru | 44.4 | 44.2 | 44.7 | 44.4 | 46.1 | 45.2 | 46.4 | 46.3 |
| Tesla | 49.8 | 50.1 | 50.3 | 50.5 | 54.8 | 51.3 | 51.5 | 51.6 |
| Toyota | 45.1 | 45.4 | 45.4 | 45.8 | 51.7 | 50.6 | 50.9 | 50.9 |
| VinFast | -- | -- | -- | 52.7 | -- | -- | -- | -- |
| Volkswagen | 45.1 | 45.2 | 45.3 | 45.6 | 48.5 | 50.1 | 49.4 | 49.3 |
| Volvo | 49.9 | 48.3 | 47.6 | 47.3 | 50.4 | 50.5 | 50.7 | 50.6 |
| Fleet Average | 45.6 | 45.8 | 46.3 | 46.8 | 54.5 | 54.4 | 55.4 | 54.4 |

2.2. Carbon-related exhaust emissions

The fleet average carbon-related exhaust emission (CREE) value is the sales-weighted average performance of a company in a given model year for its passenger automobile and light truck fleets, expressed in grams of CO₂e per mile. The CREE value is a single number that represents the average carbon exhaust emissions from a company's total fleets of passenger automobiles and light trucks. The emission values to calculate a CREE value are measured using 2 emissions test procedures: the Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). The FTP and HFET tests are more commonly referred to as the city and highway tests. These 2 tests ensure that the CREE is measured in a manner that is consistent across the automobile industry. During these tests, manufacturers measure the carbon-related combustion products including carbon dioxide (CO₂), carbon monoxide (CO), and hydrocarbons (HC). This ensures that all carbon-containing exhaust emissions that ultimately contribute to the formation of CO₂ are recognized.

The CREE for each vehicle model type is calculated based on actual emission constituents (such as CO₂, HC, and CO) from that model over the city and highway tests. The 2 test results are then combined based on a 55% city and 45% highway driving distribution. A company's final CREE value is based on the sales weighted average of the combined test results for each model, and the number of vehicles manufactured or imported into Canada for the purpose of sale.

The calculated fleet average CREE values achieved by companies over the 2020 to 2023 model years are presented in Table 4.

Table 4: fleet average carbon related exhaust emissions (g/mi)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 249 | 233 | 223 | 178 | 295 | 274 | 266 | 228 |
| BYD | 0 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 324 | 326 | 336 | 356 | 357 | 347 | 360 | 341 |
| Ford | 204 | 107 | 107 | 40 | 324 | 316 | 311 | 295 |
| GM | 152 | 206 | 160 | 100 | 339 | 351 | 347 | 333 |
| Honda | 207 | 213 | 201 | 209 | 257 | 252 | 269 | 259 |
| Hyundai | 211 | 187 | 178 | 159 | 325 | 293 | 242 | 253 |
| JLR | 291 | 309 | 342 | 360 | 315 | 320 | 332 | 340 |
| Kia | 176 | 181 | 174 | 164 | 310 | 265 | 271 | 255 |
| Maserati | 370 | 379 | -- | -- | 410 | 390 | -- | -- |
| Mazda | 226 | 229 | 197 | 194 | 260 | 261 | 262 | 255 |
| Mercedes | 269 | 278 | 260 | 170 | 308 | 316 | 314 | 280 |
| Mitsubishi | 155 | 183 | 157 | 200 | 261 | 261 | 251 | 189 |
| Nissan | 214 | 219 | 208 | 197 | 265 | 246 | 284 | 240 |
| Porsche | 147 | 217 | 263 | 251 | 320 | 329 | 335 | 333 |
| Rivian | -- | -- | -- | -- | -- | -- | -- | 0 |
| Subaru | 250 | 268 | 256 | 284 | 235 | 229 | 246 | 213 |
| Tesla ¹¹ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Toyota | 176 | 187 | 187 | 166 | 289 | 248 | 250 | 221 |
| VinFast | -- | -- | -- | 0 | -- | -- | -- | -- |
| Volkswagen | 193 | 223 | 236 | 229 | 300 | 288 | 270 | 220 |
| Volvo | 241 | 87 | 43 | 21 | 267 | 249 | 245 | 240 |
| Fleet Average | 195 | 188 | 173 | 149 | 309 | 298 | 300 | 274 |

2.3. Compliance flexibilities

The regulations provide various compliance flexibilities that reduce the compliance burden on low and intermediate volume companies, to encourage the introduction of advanced technologies which reduce GHG emissions, and to account for innovative technologies whose impacts are not easily measured during standard emissions tests. The regulations also recognize the GHG reduction potential of vehicles capable of operating on fuels produced from renewable sources (such as ethanol). The aforementioned compliance flexibilities are discussed in the following sub-sections.

2.3.1. Allowances for reduction in refrigerant leakage (E)

Refrigerants currently used by air conditioner (AC) systems have a global warming potential¹² (GWP) that is much higher than CO₂. Consequently, the release of these refrigerants into the environment has a more significant impact on the formation of greenhouse gases than an equal amount of CO₂. The regulations include provisions which recognize the reduced GHG emissions from improved AC systems designed to minimize refrigerant leakage into the environment. Based on the performance of the AC system components, manufacturers can calculate a total annual refrigerant leakage rate for an AC system which, in combination with the type of refrigerant, determines the CO₂e leakage reduction in grams per mile (g/mi) for each of their air conditioning systems. The maximum allowance value that can be generated for

¹¹ Tesla, BYD, and VinFast only produce battery electric vehicles and use the 0 g/mi incentive for their CREE as described in section 2.3.5.

¹² Additional information relating to GWP's can be found on [Canada's action on climate change website](#).

an improved air conditioning system in a passenger automobile is 12.6 g/mi for systems using traditional HFC-134a refrigerant, and 13.8 g/mi for systems using refrigerant with a lower GWP. These maximum allowance values for air conditioning systems equipped in light trucks is 15.6 g/mi and 17.2 g/mi, respectively.

The total fleet average allowance for reduction in AC refrigerant leakage is calculated using the following formula:

$$E = \frac{\Sigma (A \times B)}{C}$$

where

A is the CO₂e leakage reduction for each of the air conditioning systems in the fleet that incorporates those technologies;

B is the total number of vehicles in the fleet equipped with the air conditioning system; and

C is the total number of vehicles in the fleet.

Table 5 shows the leakage allowances in g/mi for the 2020 to 2023 model years.

Table 5: allowance for reduction in AC refrigerant leakage (g/mi)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 13.6 | 13.6 | 13.7 | 13.7 | 17.2 | 17.2 | 17.2 | 17.2 |
| BYD | 0.0 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 13.8 | 13.8 | 13.8 | 13.8 | 15.7 | 17.2 | 17.2 | 17.2 |
| Ford | 13.6 | 13.8 | 13.8 | 13.8 | 17.1 | 17.2 | 17.2 | 17.2 |
| GM | 12.9 | 13.6 | 13.6 | 13.8 | 16.7 | 17.2 | 17.2 | 17.2 |
| Honda | 12.8 | 13.5 | 12.3 | 12.1 | 16.5 | 17.2 | 16.7 | 15.7 |
| Hyundai | 9.0 | 13.7 | 13.6 | 13.6 | 4.3 | 16.9 | 17.1 | 17.1 |
| JLR | 13.8 | 13.7 | 12.3 | 13.7 | 17.2 | 17.2 | 16.7 | 17.0 |
| Kia | 13.3 | 13.5 | 13.5 | 13.6 | 16.3 | 16.9 | 16.6 | 16.9 |
| Maserati | 13.8 | 13.8 | -- | -- | 17.2 | 17.2 | -- | -- |
| Mazda | 1.9 | 12.0 | 13.5 | 13.4 | 5.0 | 15.1 | 16.8 | 17.0 |
| Mercedes | 6.2 | 13.8 | 13.8 | 14.3 | 8.4 | 17.2 | 17.2 | 16.8 |
| Mitsubishi | 13.5 | 13.1 | 13.4 | 13.3 | 16.7 | 15.9 | 16.4 | 16.3 |
| Nissan | 10.1 | 13.3 | 13.3 | 12.1 | 7.2 | 16.7 | 16.7 | 16.6 |
| Porsche | -- | -- | -- | -- | -- | -- | -- | -- |
| Rivian | -- | -- | -- | -- | -- | -- | -- | -- |
| Subaru | 7.9 | 12.1 | 12.0 | 12.0 | 14.9 | 15.1 | 15.1 | 15.1 |
| Tesla | 13.7 | 13.6 | 13.5 | 13.6 | 15.4 | 17.0 | 16.6 | 16.4 |
| Toyota | 10.8 | 12.7 | 12.0 | 12.9 | 12.8 | 15.9 | 15.7 | 3.8 |
| VinFast | -- | -- | -- | 13.8 | -- | -- | -- | -- |
| Volkswagen | 10.5 | 13.5 | 13.3 | 13.2 | 13.0 | 16.7 | 16.6 | 16.6 |
| Volvo | 13.2 | 13.8 | 13.8 | 13.8 | 16.6 | 17.1 | 17.2 | 17.2 |
| Fleet Average | 10.7 | 13.2 | 13.0 | 13.1 | 14.7 | 16.6 | 16.7 | 14.9 |

2.3.2. Allowances for improvements in air conditioning efficiency (F)

Improvements to the efficiency of vehicle air conditioning systems can result in significant reductions in CO₂e emissions that are not directly measurable during standard emissions test procedures. Implementing specific technologies (for example, more efficient compressors, motors, fans etc.) can reduce the amount of engine power required to operate the air conditioning system which, in turn, reduces the quantity of fuel that is consumed and converted into CO₂. The regulations contain provisions which recognize the reduced GHG emissions from AC systems with improved efficiency. Manufacturers can claim these allowances by either submitting proof of U.S. EPA approval for the efficiency-improving technology, or by selecting, during reporting, the applicable technologies from a pre-approved menu (Appendix A-2) that have an assigned value. These allowance values are aligned with those established by the U.S. EPA and may be applied cumulatively to an AC system. For the 2017 and later model years, the maximum allowance value for improvements in air conditioning efficiency is 5.0 g/mi for passenger automobiles and 7.2 g/mi for light trucks.

Once the air conditioning efficiency allowances are determined for each AC system, the overall allowance applicable to a company's fleet of vehicles is determined with the following formula:

$$F = \frac{\Sigma (A \times B)}{C}$$

where

A is the air conditioning efficiency allowance for each of the air conditioning systems in the fleet that incorporate those technologies

B is the total number of vehicles in the fleet equipped with the air conditioning system; and

C is the total number of vehicles in the fleet.

Table 6 shows the fleet average allowance values in g/mi for the 2020 to 2023 model years.

Table 6: allowance for improvements in AC system efficiency (g/mi)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 4.9 | 4.9 | 5.0 | 5.0 | 7.0 | 7.1 | 7.2 | 7.2 |
| BYD | 0.0 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 4.8 | 5.0 | 4.8 | 5.0 | 6.2 | 6.9 | 7.0 | 7.0 |
| Ford | 4.4 | 4.7 | 4.9 | 4.7 | 6.4 | 7.1 | 7.1 | 7.1 |
| GM | 3.9 | 3.7 | 3.5 | 4.4 | 6.7 | 7.0 | 6.8 | 7.0 |
| Honda | 3.6 | 3.6 | 4.5 | 4.2 | 5.2 | 5.3 | 6.5 | 7.2 |
| Hyundai | 3.1 | 3.2 | 3.3 | 3.6 | 4.0 | 4.4 | 4.9 | 5.0 |
| JLR | 5.0 | 5.0 | 5.0 | 5.0 | 7.2 | 7.2 | 7.2 | 7.2 |
| Kia | 3.3 | 3.3 | 3.2 | 3.4 | 4.2 | 3.6 | 4.0 | 4.4 |
| Maserati | 5.0 | 5.0 | -- | -- | 7.2 | 7.2 | -- | -- |
| Mazda | 1.4 | 1.4 | 3.6 | 4.4 | 1.1 | 1.2 | 4.7 | 5.2 |
| Mercedes | 5.0 | 5.0 | 5.0 | 5.2 | 7.1 | 7.2 | 6.9 | 7.0 |
| Mitsubishi | 4.6 | 4.4 | 4.5 | 4.3 | 5.3 | 5.3 | 6.3 | 5.9 |
| Nissan | 4.1 | 4.1 | 4.3 | 4.2 | 4.8 | 5.4 | 5.2 | 6.3 |
| Porsche | -- | -- | -- | -- | -- | -- | -- | -- |
| Rivian | -- | -- | -- | -- | -- | -- | -- | -- |
| Subaru | 3.6 | 3.4 | 4.1 | 4.2 | 6.6 | 6.5 | 6.6 | 6.1 |
| Tesla | 5.0 | 5.0 | 5.0 | 5.0 | 7.2 | 7.2 | 7.2 | 7.2 |
| Toyota | 4.6 | 4.8 | 4.7 | 4.6 | 6.3 | 6.6 | 6.7 | 6.3 |
| VinFast | -- | -- | -- | 5.0 | -- | -- | -- | -- |
| Volkswagen | 3.8 | 4.8 | 4.6 | 4.2 | 5.5 | 7.0 | 6.7 | 6.8 |
| Volvo | 4.7 | 4.0 | 3.7 | 3.5 | 6.3 | 6.3 | 6.5 | 6.2 |
| Fleet Average | 3.8 | 3.9 | 4.2 | 4.2 | 6.0 | 6.2 | 6.5 | 6.5 |

2.3.3. Allowances for the use of innovative technologies (G)

The regulations recognize that a variety of innovative technologies that have the potential to reduce CO₂e emissions cannot be measured during standard emissions test procedures. Innovative technologies can range from advanced thermal controls that reduce operator reliance on engine driven heating/cooling systems, to solar panels which can charge the battery of an electrified vehicle. Starting with the 2014 model year, companies were given the option to select applicable technologies from a menu of pre-set allowance values. This menu includes allowances for the following systems:

- waste heat recovery
- high efficiency exterior lights
- solar panels
- active aerodynamic improvements
- engine idle start-stop
- active transmission warm-up
- active engine warm-up
- thermal control technologies

Companies can report any combination of innovative technologies from this menu; however, the total allowance value for a fleet of passenger automobiles or light trucks is capped at 10 g/mi.

The total fleet average allowance for the use of innovative technologies is calculated using the following formula:

$$G = \frac{\Sigma (A \times B)}{C}$$

where

A is the allowance for each of those innovative technologies incorporated into the fleet;

B is the total number of vehicles in the fleet equipped with the innovative technology; and

C is the total number of vehicles in the fleet.

Table 7 summarizes the total innovative technology allowances reported by companies for model years 2020 to 2023.

Table 7: allowance for the use of innovative technologies (g/mi)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|---------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 7.3 | 7.5 | 6.2 | 6.0 | 13.3 | 13.4 | 12.4 | 12.3 |
| BYD | 0.0 | -- | -- | -- | -- | -- | -- | -- |
| FCA | 5.2 | 11.5 | 4.7 | 2.6 | 10.6 | 10.8 | 11.1 | 9.0 |
| Ford | 7.1 | 5.5 | 5.8 | 4.2 | 16.1 | 17.1 | 14.7 | 11.5 |
| GM | 6.0 | 6.1 | 6.0 | 3.8 | 12.1 | 12.2 | 13.3 | 13.2 |
| Honda | 4.4 | 5.0 | 7.9 | 6.3 | 12.7 | 12.8 | 16.8 | 12.9 |
| Hyundai | 4.0 | 4.5 | 5.2 | 3.5 | 8.5 | 12.8 | 14.1 | 11.2 |
| JLR | 6.8 | 5.9 | 6.1 | 5.0 | 12.9 | 13.2 | 15.6 | 15.6 |
| Kia | 4.7 | 4.5 | 4.7 | 3.8 | 7.5 | 9.2 | 9.9 | 10.4 |
| Maserati | 7.0 | 6.7 | -- | -- | 13.8 | 13.8 | -- | -- |
| Mazda | 2.4 | 2.6 | 3.8 | 3.5 | 6.6 | 6.8 | 9.5 | 7.0 |
| Mercedes | 1.4 | 2.2 | 2.5 | 3.2 | 2.9 | 3.7 | 4.3 | 5.3 |
| Mitsubishi | 3.0 | 2.8 | 2.8 | 0.9 | 4.7 | 4.8 | 5.7 | 3.9 |
| Nissan | 3.0 | 3.1 | 5.0 | 2.0 | 6.2 | 6.5 | 6.5 | 8.9 |
| Porsche | -- | -- | -- | -- | -- | -- | -- | -- |
| Rivian | -- | -- | -- | -- | -- | -- | -- | -- |
| Subaru | 2.3 | 1.9 | 2.5 | 1.4 | 8.5 | 8.0 | 8.7 | 5.1 |
| Tesla | 4.6 | 4.7 | 4.7 | 4.7 | 8.3 | 6.8 | 6.9 | 6.9 |
| Toyota | 5.1 | 5.5 | 5.5 | 4.5 | 8.8 | 11.2 | 11.5 | 10.2 |
| VinFast | -- | -- | -- | -- | -- | -- | -- | -- |
| Volkswagen | 5.6 | 8.1 | 8.7 | 7.1 | 11.9 | 13.0 | 13.8 | 11.1 |
| Volvo | 5.0 | 4.3 | 4.5 | 4.3 | 8.5 | 8.8 | 11.2 | 11.9 |
| Fleet Average | 4.4 | 4.8 | 5.6 | 4.1 | 11.0 | 11.6 | 12.2 | 10.5 |

2.3.4. Allowance for certain full-size pick-up trucks

The 2017 model year introduced additional allowances which companies may elect to claim in respect of their full-sized pick-up trucks. These new flexibilities recognize both the hybridization and emission reduction of vehicles that can serve some utility function in the Canadian marketplace.

2.3.4.1. Allowance for the use of hybrid technologies on full-size pick-up trucks

Companies may elect to calculate an allowance associated with the presence of hybrid technology on full-size pick-up trucks if that technology is present on the prescribed percentage of that company's fleet of full-size pick-up trucks for that model year. The penetration rate depends on the model year in question and whether the vehicles employ "mild" or "strong" hybrid electric technology. "Mild hybrid electric technology" means a technology that has start/stop capability and regenerative braking capability, where the recaptured braking energy is between 15% and 65% of the total braking energy. "Strong hybrid electric technology" means a technology that has start/stop capability and regenerative braking capability, where the recaptured braking energy is more than 65% of the total braking energy.

2.3.4.2. Allowance for full-size pick-up trucks that achieve a significant emission reduction below the applicable target

Companies may claim an allowance for the models of full-size pick-up trucks that have a CREE that is between 80% and 85% of its CO₂e emission target value and comprise a prescribed percentage of the fleet. The regulations also allow companies to claim an allowance for full-size pick-up trucks that have a CREE that is less than or equal to 80% of its CO₂e target value and comprise at least 10% of that company's full-size pick-up truck fleet for model years 2017 to 2025.

A company can only use one of the allowances for full-size pick-up trucks for a given vehicle.

The total fleet average allowance for certain full-size pick-up trucks is calculated using the following formula:

$$H = \frac{\Sigma (A_H \times B_H) + \Sigma (A_R \times B_R)}{C}$$

where

A_H is the allowance for the use of hybrid electric technologies;

B_H is the number of full-size pick-up trucks in the fleet that are equipped with hybrid electric technologies;

A_R is the allowance for full-size pick-up trucks that achieve a certain carbon-related exhaust emission value;

B_R is the number of full-size pick-up trucks in the fleet that achieve a certain carbon-related exhaust emission value; and

C is the total number of vehicles in the fleet.

As of the 2023 model year no companies made use of the allowance for certain full-size pick-up trucks.

2.3.5. Advanced technology vehicles

The regulations offer a number of additional provisions to encourage the deployment of "advanced technology vehicles" (ATVs) which consist of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), fuel cell electric vehicles (FCEV) and natural gas vehicles. BEVs are completely powered by electrical energy stored in a battery, and hence produce no tailpipe emissions. PHEVs incorporate an electrical powertrain which enables them to be charged with electricity to operate solely on electrical power, but also contain an internal combustion engine to extend the operating range of the vehicle. FCEVs

are propelled solely by an electric motor where the energy for the motor is supplied by an electrochemical cell that produces electricity without combustion. When calculating a CREE, the regulations allow companies to report 0 g/mi for electric vehicles (for example, BEVs), fuel cell vehicles, and the electric portion of plug-in hybrids (when PHEVs operate as electric vehicles). Additionally, companies may multiply the number of ATVs in their fleet by a specified factor to increase the impact that they have on a company's overall fleet average. The applicable multiplying factors and the associated model years can be found in Table 8.

Table 8: multiplying factors for advanced technology vehicles

| Model year | BEV and FCEV multiplier | PHEV multiplier | Natural gas |
|--------------|-------------------------|-----------------|-------------|
| 2011 to 2016 | 1.2 | 1.2 | 1.2 |
| 2017 | 2.5 | 2.1 | 1.6 |
| 2018 | 2.5 | 2.1 | 1.6 |
| 2019 | 2.5 | 2.1 | 1.6 |
| 2020 | 2.25 | 1.95 | 1.45 |
| 2021 | 2.0 | 1.8 | 1.3 |
| 2022 to 2024 | 1.5 | 1.3 | 1.0 |

The production volumes of BEVs and PHEVs sold by model year are presented in Tables 9 and 10.

Table 9: production volumes of BEVs by model year

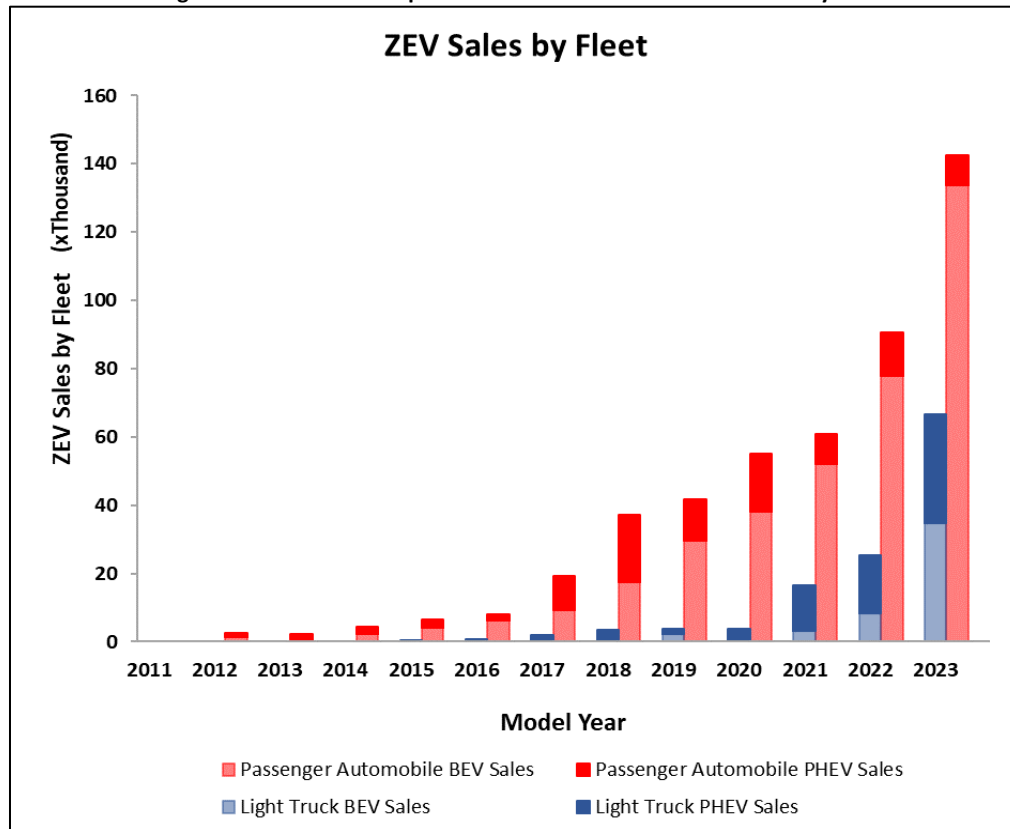
| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|--------------|---------|---------|---------|---------|---------|---------|---------|---------|
| BMW | 158 | 391 | 1,013 | 2,743 | 0 | 0 | 406 | 1,792 |
| BYD | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FCA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ford | 0 | 5,267 | 6,013 | 10,219 | 0 | 0 | 2,122 | 9,507 |
| GM | 5,236 | 1,561 | 5,549 | 17,966 | 0 | 0 | 0 | 0 |
| Honda | -- | -- | 0 | 0 | 0 | 0 | 0 | 0 |
| Hyundai | 5,573 | 8,130 | 9,481 | 15,881 | 0 | 0 | 0 | 0 |
| JLR | 0 | 0 | 0 | 0 | 139 | 39 | 52 | 46 |
| Kia | 3,677 | 2,130 | 2,878 | 6,187 | 0 | 0 | 0 | 0 |
| Mazda | 0 | 0 | 1,068 | 809 | 0 | 0 | 0 | 0 |
| Mercedes | 0 | 0 | 400 | 3,437 | 0 | 0 | 0 | 1,069 |
| Mitsubishi | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nissan | 1,848 | 439 | 916 | 4,650 | 0 | 0 | 0 | 0 |
| Porsche | 1,039 | 507 | 614 | 640 | 0 | 0 | 0 | 0 |
| Rivian | -- | -- | -- | 0 | -- | -- | -- | 883 |
| Subaru | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,950 |
| Tesla | 18,483 | 32,414 | 47,711 | 63,824 | 328 | 1,450 | 2,811 | 3,359 |
| Toyota | 22 | 0 | 22 | 1,738 | 0 | 0 | 0 | 4,804 |
| VinFast | -- | -- | -- | 801 | -- | -- | -- | -- |
| Volkswagen | 1,929 | 329 | 409 | 1,190 | 23 | 1,783 | 2,838 | 11,200 |
| Volvo | -- | 877 | 1,954 | 4,472 | 0 | 0 | 0 | 0 |
| Total | 37,990 | 52,045 | 78,028 | 134,557 | 490 | 3,272 | 8,229 | 35,610 |

Table 10: production volumes of PHEVs by model year

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|--------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | 277 | 592 | 1,026 | 1,215 | 46 | 1,098 | 1,788 | 1,251 |
| BYD | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FCA | 0 | 0 | 0 | 0 | 1,026 | 5,138 | 6,786 | 7,170 |
| Ford | 1,906 | 2,010 | 3,946 | 4,668 | 208 | 141 | 140 | 228 |
| GM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Honda | 747 | 172 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hyundai | 1,396 | 900 | 381 | 0 | 0 | 0 | 3,651 | 2,233 |
| JLR | 0 | 0 | 0 | 0 | 207 | 140 | 0 | 37 |
| Kia | 1,361 | 488 | 749 | 351 | 0 | 0 | 674 | 1,914 |
| Mazda | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mercedes | 9 | 0 | 0 | 49 | 59 | 0 | 0 | 0 |
| Mitsubishi | 2,456 | 300 | 2,105 | 0 | 0 | 0 | 0 | 8,624 |
| Nissan | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Porsche | 73 | 68 | 53 | 180 | 320 | 186 | 291 | 452 |
| Subaru | 0 | 0 | 0 | 0 | 413 | 259 | 83 | 174 |
| Tesla | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Toyota | 8,659 | 4,254 | 4,175 | 2,100 | 0 | 4,939 | 1,904 | 8,103 |
| VinFast | -- | -- | -- | 0 | -- | -- | -- | -- |
| Volkswagen | 0 | 10 | 20 | 7 | 444 | 70 | 121 | 320 |
| Volvo | 86 | 99 | 95 | 92 | 688 | 1,395 | 1,611 | 1,484 |
| Total | 16,970 | 8,893 | 12,550 | 8,662 | 3,411 | 13,366 | 17,049 | 31,990 |

Figure 4 provides a graphical representation of the overall growth in ZEV production for 2011 to 2023 model years.

Figure 4: Increase in ZEV production from the 2011 to 2023 model years



2.3.6. Provisions for small volume companies for 2012 and later model years

The regulations include provisions enabling smaller companies that may have limited product offerings to opt out of complying with the CO₂e standards (non application of the standards respecting CO₂ equivalent emissions¹³) for 2012 and subsequent model years. This exemption is available to companies that:

- a. have manufactured or imported less than 750 passenger automobiles and light trucks for either the 2008 or 2009 model years
- b. have manufactured or imported for sale a running average of less than 750 vehicles for the 3 model years prior to the model year being exempted
- c. submit a small volume declaration to ECCC

A small volume company must submit an annual report to obtain credits. These companies are still required to comply with the standards for nitrous oxide and methane (refer to section 2.5 for further details).

Table 11 summarizes the production volumes reported by small volume companies. This flexibility was claimed by 6 small volume companies for the 2012 and later model years.

Table 11: production volumes for small volume manufacturers by model year

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|------|-------|-------|-------|
| Aston Martin | 74 | 132 | 83 | 219 |
| Ferrari | 370 | 313 | 493 | 345 |
| Lotus | 15 | 18 | 0 | 0 |
| Maserati | 268 | 474 | 677 | 1,238 |
| McLaren | 157 | 84 | 79 | 111 |
| Morgan Olson | -- | -- | -- | 902 |
| Total | 884 | 1,021 | 1,332 | 2,815 |

2.4. Standards for nitrous oxide and methane

The regulations also limit the release of other GHG's, such as emissions of methane (CH₄) and nitrous oxide (N₂O). Starting with the 2012 model year, the regulations set standards for N₂O and CH₄ at 0.01 g/mi and 0.03 g/mi respectively. These standards are intended to cap vehicle N₂O and CH₄ emissions at levels that are attainable by existing technologies and ensure that levels do not increase with future vehicles. Companies have 3 methods by which they can meet the N₂O and CH₄ requirements.

The first method allows companies to certify that the N₂O and CH₄ emissions for all its vehicles of a given model year are below the cap-based standards. This method does not impact the calculation of a company's CREE.

The second method allows companies to quantify the emissions of N₂O and CH₄ as an equivalent amount of CO₂ and include this in the determination of their overall CREE. Companies using this method must incorporate N₂O and CH₄ test data into the CREE calculation, while factoring in the higher global warming

¹³ This exemption does not have a noticeable impact on fleet-wide performance given the small volume of vehicles.

potential of these 2 pollutants. This method is not as commonly used as it counts N₂O and CH₄ emissions even for the portion of a company's fleet that does not exceed the standard.

The third method allows companies to certify vehicles to alternative N₂O and CH₄ emissions standards. This method generally offers the greatest flexibility to companies as they are left to establish alternative standards that apply only to those vehicles that would not meet the cap-based value as opposed to impacting the entire fleet. Additionally, companies using this method can comply with standards of N₂O and CH₄ separately by setting alternative standards for either emission as needed. The g/mi difference between the alternative standard and the cap-based standard that would otherwise apply is used to determine a deficit which must be offset with conventional CO₂e emissions credits. The total deficits incurred by the companies that used this method are summarized in Tables 12 and 13.

Table 12: N₂O emissions deficits by company for the 2020 to 2023 model years (Mg CO₂e)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|--------------|------------|------------|------------|------------|------------|------------|------------|------------|
| BMW | -- | -99 | -256 | -271 | -- | -- | -83 | -108 |
| FCA | -49 | -- | -- | -- | -10,333 | -9,788 | -11,612 | -1,158 |
| Ford | -10 | -15 | -11 | -- | -713 | -5,998 | -6,932 | -7,149 |
| GM | -- | -- | -- | -- | -35,225 | -105,252 | -52,624 | -36,969 |
| Hyundai | -917 | -541 | -1,042 | -1,153 | -- | -- | -- | -- |
| JLR | -- | -- | -- | -- | -1,322 | -797 | -- | -- |
| Kia | -1,104 | -754 | -1,410 | -1,099 | -- | -- | -- | -- |
| Mazda | -179 | -2,001 | -547 | -690 | -3,439 | -9,740 | -5,330 | -7,797 |
| Subaru | -- | -- | -- | -352 | -- | -- | -- | -- |
| Toyota | -1,267 | -1,295 | -149 | -117 | -8,913 | -10,602 | -5,065 | -4,691 |
| Volkswagen | -- | -28 | -137 | -142 | -120 | -149 | -242 | -138 |
| Fleet Total | -3,526 | -4,733 | -3,552 | -3,824 | -60,065 | -142,326 | -81,888 | -58,010 |

Table 13: CH₄ emissions deficits by company for the 2020 to 2023 model years (Mg CO₂e)

| Manufacturer | 2020 PA | 2021 PA | 2022 PA | 2023 PA | 2020 LT | 2021 LT | 2022 LT | 2023 LT |
|--------------|------------|------------|------------|------------|------------|------------|------------|------------|
| FCA | -37 | -- | -55 | -- | -186 | -149 | -259 | -74 |
| Ford | -240 | -299 | -275 | -81 | -10,361 | -1,879 | -1,829 | -1,462 |
| GM | -64 | -52 | -- | -- | -310 | -9 | -36 | -5 |
| Mazda | -122 | -194 | -96 | -28 | 0 | -20 | -- | -- |
| Volkswagen | -51 | -27 | -36 | -- | -- | -- | -- | -- |
| Fleet Total | -514 | -572 | -462 | -109 | -10,857 | -2,057 | -2,124 | -1,541 |

2.5. CO₂e emissions value

The fleet average CO₂e emissions value, referred to as the “compliance value” is the final average CO₂e performance of a company's fleets of passenger automobiles and of light trucks, reported as CREE, after being adjusted for all available compliance flexibilities, using the following equation:

$$\text{Compliance value} = D - E - F - G - H$$

where

D is the fleet average carbon-related exhaust emission value for each fleet (section 2.2);

E is the allowance for reduction of air conditioning refrigerant leakage (section 2.3.1);

F is the allowance for improving air conditioning system efficiency (section 2.3.2); and

G is the allowance for the use of innovative technologies that have a measurable CO₂e emission reduction (section 2.3.3);

H is the allowance for certain full-size pick-up trucks (section 2.3.4).

A company's compliance value for its fleet of passenger automobiles and light trucks is what is ultimately compared to its CO₂e standard for both aforementioned categories to determine compliance and to establish a company's emission credit balance. Tables 14 and 15 show both the companies' compliance and standard values for the passenger automobiles and light truck fleets across the 2020 to 2023 model years. Figures 5 and 6 shows the trends in manufacturer performance over the 2020 to 2023 model years.

Table 14: PA compliance and standard values over the 2020 to 2023 model years (g/mi)

| Manufacturer | 2020 Compliance | 2021 Compliance | 2022 Compliance | 2023 Compliance | 2020 Std. | 2021 Std. | 2022 Std. | 2023 Std. |
|---------------------|-----------------|-----------------|-----------------|-----------------|-----------|-----------|-----------|-----------|
| BMW | 223 | 207 | 198 | 153 | 188 | 183 | 182 | 167 |
| BYD | 0 | -- | -- | -- | 194 | -- | -- | -- |
| FCA | 300 | 296 | 313 | 335 | 206 | 205 | 203 | 187 |
| Ford | 179 | 83 | 83 | 17 | 193 | 194 | 190 | 178 |
| GM | 129 | 183 | 137 | 78 | 181 | 177 | 175 | 161 |
| Honda | 186 | 191 | 176 | 186 | 184 | 180 | 177 | 164 |
| Hyundai | 195 | 166 | 156 | 138 | 184 | 179 | 177 | 163 |
| JLR | 265 | 284 | 319 | 336 | 203 | 183 | 181 | 163 |
| Kia | 155 | 160 | 153 | 143 | 183 | 177 | 176 | 161 |
| Maserati | 344 | 354 | -- | -- | 218 | 212 | -- | -- |
| Mazda | 220 | 213 | 176 | 173 | 183 | 178 | 173 | 161 |
| Mercedes | 256 | 257 | 239 | 147 | 195 | 192 | 190 | 178 |
| Mitsubishi | 134 | 163 | 136 | 182 | 176 | 171 | 167 | 150 |
| Nissan | 197 | 199 | 185 | 179 | 190 | 179 | 176 | 162 |
| Porsche | 147 | 217 | 263 | 251 | 198 | 178 | 173 | 162 |
| Rivian | -- | -- | -- | -- | -- | -- | -- | -- |
| Subaru | 236 | 251 | 237 | 266 | 180 | 174 | 173 | 158 |
| Tesla ¹⁴ | -23 | -23 | -23 | -23 | 202 | 198 | 195 | 180 |
| Toyota | 156 | 164 | 165 | 144 | 183 | 179 | 176 | 163 |
| VinFast | -- | -- | -- | -19 | -- | -- | -- | 187 |
| Volkswagen | 173 | 197 | 209 | 205 | 183 | 178 | 176 | 162 |
| Volvo | 218 | 65 | 21 | -1 | 212 | 191 | 185 | 168 |
| Fleet Average | 176 | 166 | 150 | 128 | 185 | 181 | 179 | 166 |

¹⁴ Tesla, VinFast, and Rivian only produce electric vehicles, and are able to use the 0 g/mi incentive for its entire fleet. The compliance value is negative once its AC allowances have been factored in.

Figure 5: Change to PA performance over the 2020 to 2023 model years

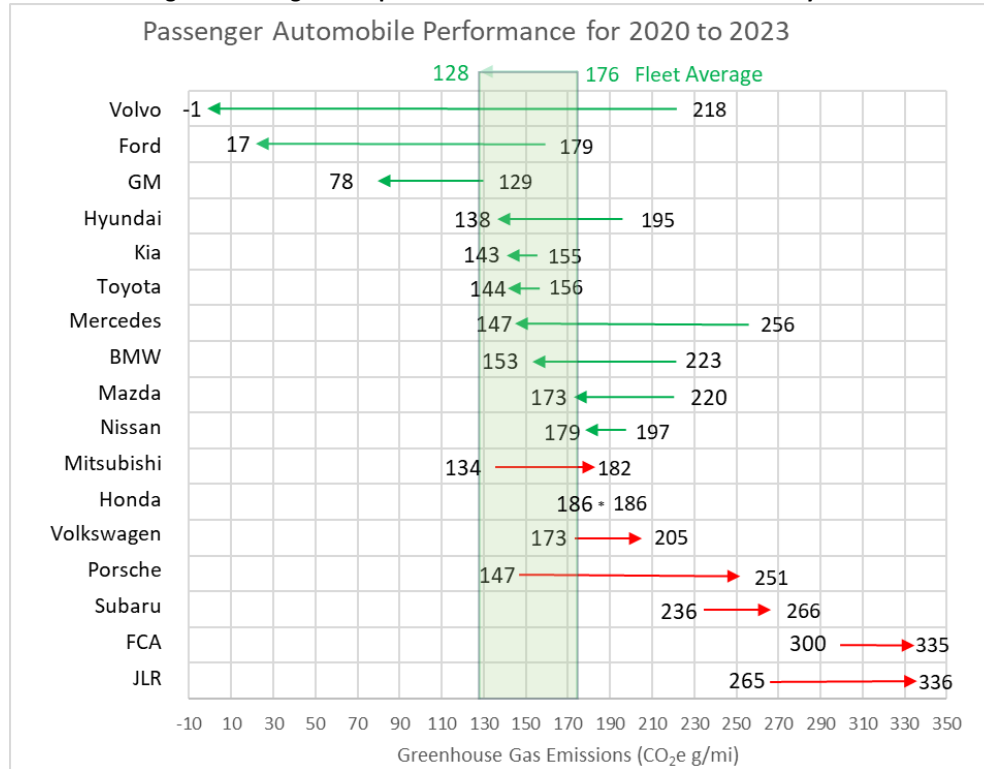
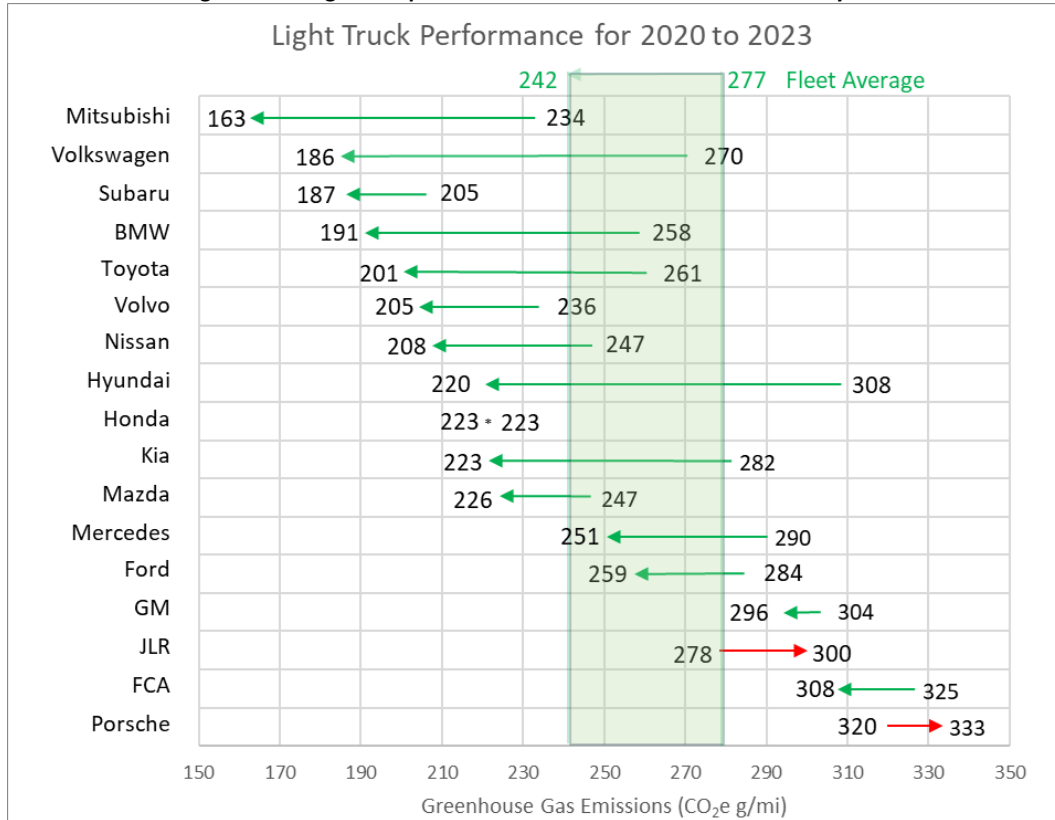


Table 15: LT compliance and standard values over the 2020 to 2023 model years (g/mi)

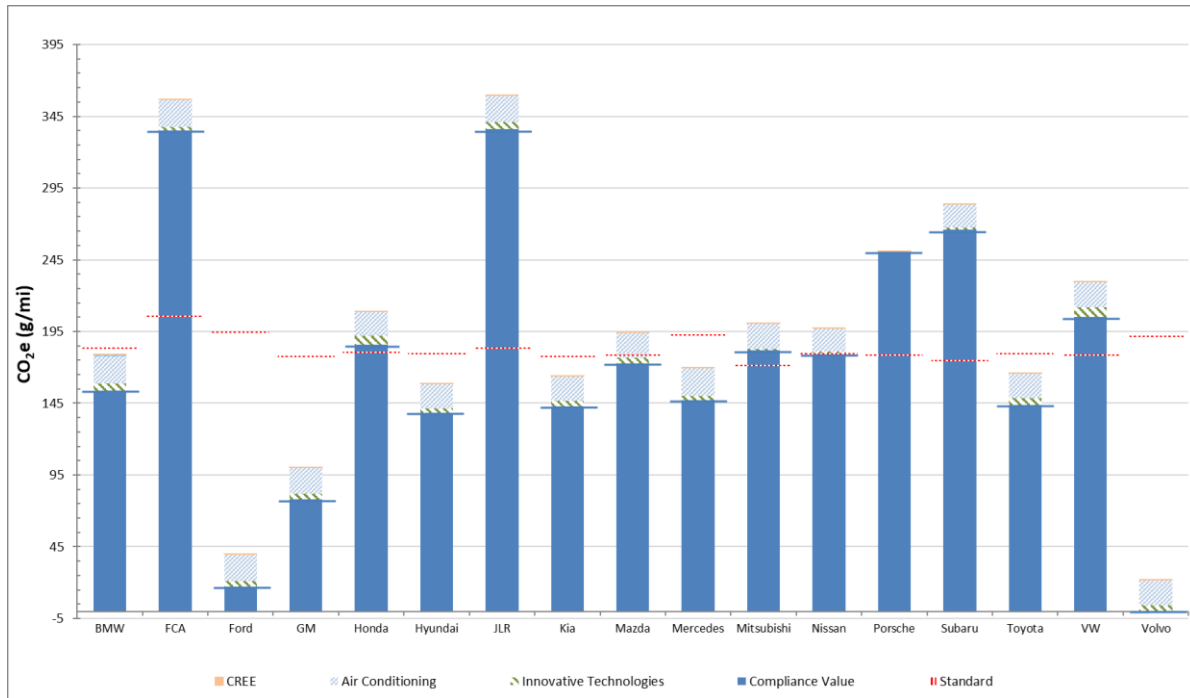
| Manufacturer | 2020 Compliance | 2021 Compliance | 2022 Compliance | 2023 Compliance | 2020 Std. | 2021 Std. | 2022 Std. | 2023 Std. |
|---------------------|-----------------|-----------------|-----------------|-----------------|-----------|-----------|-----------|-----------|
| BMW | 258 | 236 | 229 | 191 | 262 | 256 | 251 | 217 |
| FCA | 325 | 312 | 325 | 308 | 290 | 282 | 291 | 255 |
| Ford | 284 | 275 | 272 | 259 | 296 | 291 | 281 | 268 |
| GM | 304 | 315 | 310 | 296 | 293 | 293 | 286 | 254 |
| Honda | 223 | 217 | 229 | 223 | 245 | 237 | 240 | 215 |
| Hyundai | 308 | 259 | 206 | 220 | 269 | 252 | 240 | 216 |
| JLR | 278 | 282 | 293 | 300 | 267 | 256 | 257 | 230 |
| Kia | 282 | 235 | 241 | 223 | 253 | 234 | 239 | 211 |
| Maserati | 372 | 352 | -- | -- | 269 | 262 | -- | -- |
| Mazda | 247 | 238 | 231 | 226 | 238 | 231 | 228 | 204 |
| Mercedes | 290 | 288 | 286 | 251 | 263 | 255 | 251 | 226 |
| Mitsubishi | 234 | 235 | 223 | 163 | 226 | 219 | 222 | 199 |
| Nissan | 247 | 217 | 256 | 208 | 245 | 234 | 247 | 210 |
| Porsche | 320 | 329 | 335 | 333 | 266 | 251 | 248 | 221 |
| Rivian | -- | -- | -- | 0 | -- | -- | -- | 260 |
| Subaru | 205 | 199 | 216 | 187 | 235 | 225 | 227 | 202 |
| Tesla ¹⁴ | -31 | -31 | -31 | -31 | 275 | 253 | 249 | 223 |
| Toyota | 261 | 214 | 216 | 201 | 261 | 249 | 246 | 221 |
| VinFast | -- | -- | -- | -- | -- | -- | -- | -- |
| Volkswagen | 270 | 251 | 233 | 186 | 246 | 247 | 240 | 214 |
| Volvo | 236 | 217 | 210 | 205 | 263 | 249 | 246 | 219 |
| Fleet Average | 277 | 263 | 265 | 242 | 272 | 264 | 264 | 234 |

Figure 6: Change to LT performance over the 2020 to 2023 model years



Figures 7 and 8 provide a graphical representation of the role that compliance flexibilities play in arriving at a company's overall compliance status for their 2023 model year passenger automobile and light truck fleets. The orange line on the top of the bar indicates a company's fleet average CREE. The wide red line represents the fleet average standard and the wide dark blue line represents the fleet average compliance value (accounting for compliance flexibilities). The bars show the extent to which companies incorporate the previously described compliance flexibilities into their products to achieve their fleet average compliance value. Figures showing this information for prior model years are located in the appendix.

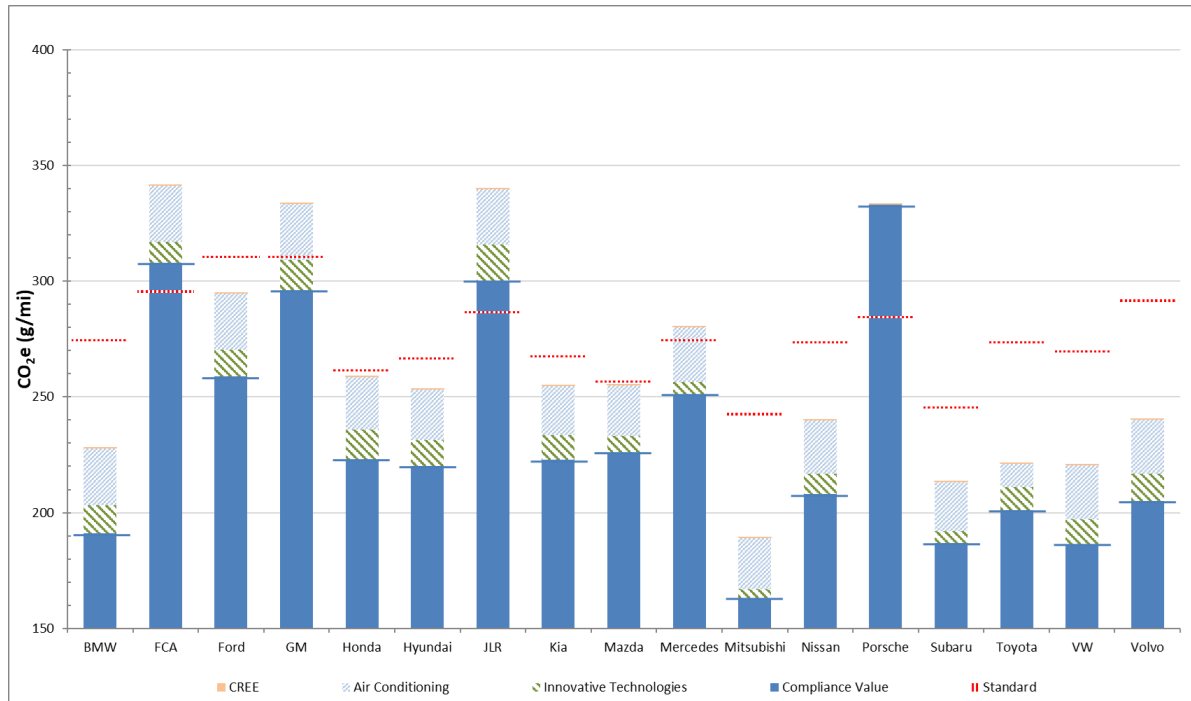
Figure 7: 2023 passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

Figure 8: 2023 light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

2.6. Technological advancements and penetration rates

As fleet average emission standards have become more stringent, automobile manufacturers have developed a variety of technologies to reduce their CO₂e emissions. Some of these technologies seek to reduce or eliminate the use of conventional fuels by introducing electrical powertrain components (BEVs, PHEVs etc.). There also exists a wide range of technologies used by companies to improve the efficiency of transmissions and conventional engines and reduce emissions. Some examples include turbocharged engines, cylinder deactivation, and continuously variable transmissions.

This section, while not an exhaustive list, describes some of the commonly used technology types, along with their corresponding penetration rates in the Canadian new vehicle fleet in given model years.

Turbocharging

Turbochargers improve the power and efficiency of an internal combustion engine by extracting some of the waste heat energy otherwise lost through the exhaust pipe. These exhaust gases are used to drive a turbine that is connected to a compressor which provides greater amounts of air into the combustion chamber (forced induction). This results in greater power than a naturally aspirated engine of similar displacement, and greater efficiency than a naturally aspirated engine of the same power and torque. This permits the use of smaller displacement, lighter engines that can produce the same power as larger, heavier engines without turbocharging. For this reason, it is becoming increasingly common to see turbochargers incorporated into vehicles with smaller engines in order to decrease the overall vehicle weight and improve fuel efficiency by as much as 8%.

Variable valve timing & lift

Engine intake and exhaust valves are responsible for letting air into the cylinders and exhaust gases out. This is an important function since optimal engine performance requires precise “breathing” of the engine. In most conventional engines, the timing and lift of the valves is fixed, and not optimized across all engine speeds. Variable valve timing (VVT) and variable valve lift (VVL) systems adjust the timing, duration and amount that the intake and exhaust valves open based on the engine speed. This optimization of the engines ‘breathing’ improves engine efficiency resulting in reduced fuel consumption and emissions. Variable valve timing and lift technologies can result in efficiency improvements of 3-4%.

Higher geared transmissions (>6 speeds)

Fuel efficiency, and by extension, CO₂e emissions coming from a vehicle are dependent on the efficient operation of all the elements that make up a vehicle. An engine that is operating at speeds outside its most efficient range will result in increased fuel consumption and CO₂e emissions. Transmissions with more gear ratios (or speeds), allows the engine to operate at a more efficient speed more frequently. It is becoming increasingly common for vehicles to be equipped with transmissions that have more than 6 gears to keep the engine running at its most efficient operating point and thereby reduce CO₂e emissions.

Continuously variable transmissions

Continuously variable transmissions (CVT) are transmissions that, unlike conventional transmission configurations, do not have a fixed number of gears. Because CVT's do not have a discrete number of shift points, they can operate variably across an infinite number of driving situations to provide the optimal speed ratio between the engine and the wheels. This ensures that the engine is able to operate as efficiently as possible and consume only as much fuel as is required, thereby lowering CO₂e emissions. Typically CVT's can improve fuel efficiency by as much as 4%.

Cylinder deactivation system

Cylinder deactivation systems (CDS) shut off cylinders of a 6 or 8 cylinder engine when only partial power is required (for example, travelling at constant speed, decelerating etc.). The CDS works by deactivating the intake and exhaust valves for a particular set of cylinders in the engine. A CDS can reduce CO₂e emissions by improving the overall fuel consumption of the vehicle by 4 to 10%¹⁵.

Gasoline direct injection

A proper air-fuel mixture is critical to the performance of any conventional internal combustion engine and has direct impacts on the resulting emissions. Over the past several decades, the most common mechanism for preparing the air-fuel mixture has been "port fuel injection". In port fuel injection systems, the air and fuel are mixed in the intake manifold and are subsequently drawn into the combustion chamber. By contrast, gasoline direct injection (GDI) systems spray fuel directly into the combustion chamber resulting in a slightly cooler air-fuel mixture allowing for higher compression ratios and improved fuel consumption. GDI systems are also better at precisely timing and metering the fuel delivered to the cylinder, which results in more efficient combustion.

Diesel

Diesel engines provide greater low-end torque and fuel efficiency than a comparably sized gasoline engine. Diesel fuel contains more energy per unit volume than an equivalent amount of gasoline. As a result, diesel vehicles can travel, on average, 20 to 35% further per litre of fuel than a gasoline based equivalent¹⁶ which translates into measurable reductions in CO₂e emissions.

The fleet-wide penetration rates of the above described technologies have been provided in Table 16, while data pertaining to company specific usage can be found in Appendices A-3 to A-10.

¹⁵ [Natural Resources Canada](#)

¹⁶ [US EPA website](#)

Table 16: penetration rates of drivetrain technologies in the Canadian fleet

| Technology | 2020 | 2021 | 2022 | 2023 |
|----------------------------|------|------|------|------|
| Turbocharging | 32.7 | 33.6 | 37.1 | 40.7 |
| VVT | 94.2 | 92.8 | 90.7 | 86.6 |
| VVL | 18 | 14.9 | 16.6 | 15.2 |
| Higher Geared Transmission | 57.4 | 64.4 | 68.7 | 64.4 |
| CVT | 28.4 | 22.7 | 22.5 | 25.3 |
| Cylinder Deactivation | 13.7 | 16.2 | 17.7 | 15 |
| GDI | 48 | 50.5 | 49.1 | 47 |
| Diesel | 0.7 | 1.6 | 1.4 | 1.0 |

3. Emission credits

The regulations include a system of emission credits to help meet overall environmental objectives in a manner that provides the regulated industry with compliance flexibility. A company must calculate emission credits and deficits in units of megagrams (Mg) of CO₂e for each of its passenger automobile and light truck fleets of a given model year. Credits are weighted based on vehicle kilometers traveled (VKT) to account for the greater number of kilometres travelled by light trucks over their lifetime than by passenger automobiles. Using the mathematical formula below, a company will generate credits in a given model year if the result of the calculation is positive or better than the GHG emission standard. If the result of the calculation is negative or below the applicable standard, the company will incur a deficit. A company that incurs an emissions deficit must offset it with an equivalent number of emission credits from past model years or within the subsequent 3 model years.

The total credit balance is determined according to the following formula¹⁷:

$$\text{Credits} = \frac{(A - B) \times C \times D}{1,000,000}$$

Where

A is the fleet average standard for passenger automobiles or light trucks

B is the fleet average compliance value for passenger automobiles or light trucks

C is the total number of passenger automobiles or light trucks in the fleet

D is the total assumed mileage of the vehicles in question, namely:

- (a) 195,264 miles for a fleet of passenger automobiles, or
- (b) 225,865 miles for a fleet of light trucks

The credits represent the emission reductions that manufacturers have achieved in excess of those required by the regulations. The ability to accumulate credits allows manufacturers to plan and implement an orderly phase-in of emissions control technology through product cycle planning to meet future, more stringent emission standards.

¹⁷ In October 2021, the Department published an [Interim Order](#) to correct the multiplier formula used to determine carbon dioxide (CO₂) equivalent emission credits for advanced technology vehicles.

The regulations initially established that credits could be banked to offset a future deficit for up to 5 model years after the year in which the credits were obtained (the credits had a 5-year lifespan). The regulations were amended to extend the lifespan of credits earned during the 2010 to 2016 model years to 2021. Emission credits that can be used to offset a deficit incurred in the 2022 and later model years can only be generated beginning with the 2017 model year and have a 5-year lifespan.

3.1. Credit transfers

Table 17 summarizes transactions by company and the model year in which the credits were generated. There have been more than 21 million credits transferred between companies for either immediate use to offset a deficit or in anticipation of a possible future deficit, including those purchased from the Receiver General. It should be noted that the model year is not necessarily indicative of when a credit transfer occurred. For example, it is possible to transfer credits for the 2012 model year during the 2017 calendar year. As well, the total quantity transferred in or out from a company for a given model year may be the result of multiple transactions.

Table 17: credit transactions (transferred out) by model year (Mg CO₂e)

| Manufacturer | Early Action | 2011 to 2019 | 2020 | 2021 | 2022 | 2023 | Total |
|------------------|--------------|--------------|-----------|-----------|-----------|-----------|------------|
| FCA | 0 | 30,103 | 0 | 0 | 0 | 0 | 30,103 |
| Honda | 2,138,563 | 3,069,910 | 0 | 0 | 0 | 0 | 5,208,473 |
| Mazda | 0 | 113,000 | 0 | 0 | 0 | 0 | 113,000 |
| Mitsubishi | 63,349 | 0 | 0 | 0 | 0 | 0 | 63,349 |
| Nissan | 822,292 | 402,728 | 0 | 0 | 0 | 0 | 1,225,020 |
| Subaru | 0 | 86,500 | 0 | 0 | 0 | 0 | 86,500 |
| Suzuki | 123,345 | 30,431 | 0 | 0 | 0 | 0 | 153,776 |
| Tesla | 2,292 | 3,367,080 | 1,880,526 | 2,987,365 | 1,315,527 | 1,928,061 | 11,480,851 |
| Toyota | 2,623,142 | 2,780,598 | 0 | 0 | 0 | 0 | 5,403,740 |
| Volkswagen | 0 | 77,000 | 0 | 0 | 0 | 0 | 77,000 |
| Receiver General | -- | 6,906 | -- | -- | -- | -- | 6,906 |

Table 17: credit transactions (transferred in) by model year (Mg CO₂e)

| Manufacturer | Early Action | 2011 to 2019 | 2020 | 2021 | 2022 | 2023 | Total |
|--------------|--------------|--------------|-----------|-----------|-----------|-----------|------------|
| Aston Martin | 0 | 2,626 | 0 | 0 | 0 | 0 | 2,626 |
| BMW | 0 | 1,000,000 | 0 | 0 | 0 | 0 | 1,000,000 |
| FCA | 4,775,129 | 6,110,057 | 1,648,770 | 969,820 | 0 | 0 | 13,503,776 |
| Ferrari | 8,473 | 0 | 0 | 0 | 0 | 0 | 8,473 |
| Ford | 342,272 | 257,728 | 0 | 0 | 0 | 0 | 600,000 |
| GM | 0 | 87,962 | 131,756 | 417,545 | 1,015,527 | 1,928,061 | 3,580,851 |
| JLR | 143,369 | 86,500 | 0 | 0 | 0 | 0 | 229,869 |
| Lotus | 0 | 139 | 0 | 0 | 0 | 0 | 139 |
| Maserati | 3,740 | 30,103 | 0 | 0 | 0 | 0 | 33,843 |
| Mazda | 0 | 0 | 0 | 500,000 | 0 | 0 | 500,000 |
| Mercedes | 0 | 1,745,000 | 0 | 1,100,000 | 300,000 | 0 | 3,145,000 |
| Porsche | 0 | 344,141 | 100,000 | 0 | 0 | 0 | 444,141 |
| Subaru | 0 | 300,000 | 0 | 0 | 0 | 0 | 300,000 |
| Volkswagen | 500,000 | 0 | 0 | 0 | 0 | 0 | 500,000 |

4.2. Total credits generated and final status

Table 18 shows the credits earned (or deficits incurred) by all companies over the 2023 model year. This table also shows the total number of credits remaining in each company's bank, taking into account the credits that have expired, been transferred, or used to offset a deficit.

Since the regulations came into force, companies have generated approximately 115.9 million emission credits (including early action credits), of which approximately 27.3 million credits remain for future use. A total of 39 million credits have been used to offset deficits and 51.4 million credits have expired.

Table 18: net credits by model year and current credit balance (Mg CO₂e)

| Manufacturers | Generated Credit/Deficit in 2023 | Current Balance ¹⁸ |
|---------------|----------------------------------|-------------------------------|
| BMW | 168,274 | 382,819 |
| BYD | 0 | 2,121 |
| FCA | -1,786,576 | 2,191,955 |
| Ford | 891,185 | 3,361,416 |
| GM | -1,037,697 | 3,752,569 |
| Honda | -281,930 | 2,684,278 |
| Hyundai | 422,690 | 1,421,004 |
| JLR | -174,307 | 0 |
| Kia | 9,304 | 541,471 |
| Mazda | -226,581 | 273,747 |
| Mercedes | -15,310 | 1,086,194 |
| Mitsubishi | 229,188 | 540,143 |
| Nissan | -155,488 | 205,084 |
| Porsche | -240,887 | 0 |
| Rivian | 85,826 | 85,826 |
| Subaru | -32,611 | 1,077,608 |
| Tesla | 4,088,908 | 4,202,665 |
| Toyota | 874,884 | 4,346,375 |
| VinFast | 48,303 | 48,303 |
| Volkswagen | 185,455 | 295,132 |
| Volvo | 275,253 | 803,973 |
| Total | 3,327,883 | 27,302,683 |

5. Overall industry performance

The overall fleet average compliance information for passenger automobiles and light trucks is summarized in Tables 19 and 20. Additionally, Figures 6 and 7 illustrate the year over year performance for both passenger automobile and for light truck fleets. These trend lines depict the average standard applicable to the overall fleet (dotted line) and the compliance value (solid line) for each fleet.

Because each manufacturer's fleet is unique, the data presented in the tables and graphs are based on the sales weighted values for all companies and are intended to depict the average results.

¹⁸ The current balance accounts for any expired credits, remaining early action credits, transactions, and offsets.

Table 19: passenger automobile compliance summary for the 2011 to 2023 model years (g/mi)

| Model Year | CREE | Innovative Technologies | AC Refrigerant Leakage Reduction | AC Efficiency Improvements | Compliance value | Standard | Compliance margin |
|------------|------|-------------------------|----------------------------------|----------------------------|------------------|----------|-------------------|
| 2011 | 258 | 0.2 | 2.0 | 1.3 | 255 | 291 | 36 |
| 2012 | 247 | 0.5 | 2.9 | 2.0 | 242 | 263 | 21 |
| 2013 | 244 | 0.4 | 3.0 | 2.4 | 238 | 256 | 18 |
| 2014 | 241 | 1.5 | 3.5 | 2.6 | 233 | 248 | 15 |
| 2015 | 238 | 1.8 | 4.0 | 2.9 | 230 | 238 | 8 |
| 2016 | 238 | 2.0 | 4.7 | 3.4 | 228 | 227 | -1 |
| 2017 | 232 | 3.0 | 6.0 | 3.5 | 220 | 216 | -4 |
| 2018 | 221 | 3.7 | 8.4 | 3.7 | 205 | 205 | 0 |
| 2019 | 211 | 3.7 | 10.3 | 3.8 | 193 | 194 | 1 |
| 2020 | 195 | 4.4 | 10.7 | 3.8 | 176 | 185 | 9 |
| 2021 | 188 | 4.8 | 13.2 | 3.9 | 166 | 181 | 15 |
| 2022 | 173 | 5.6 | 13.0 | 4.2 | 150 | 179 | 29 |
| 2023 | 149 | 4.1 | 13.1 | 4.2 | 128 | 166 | 38 |

Figure 9: average GHG emissions performance - passenger automobiles

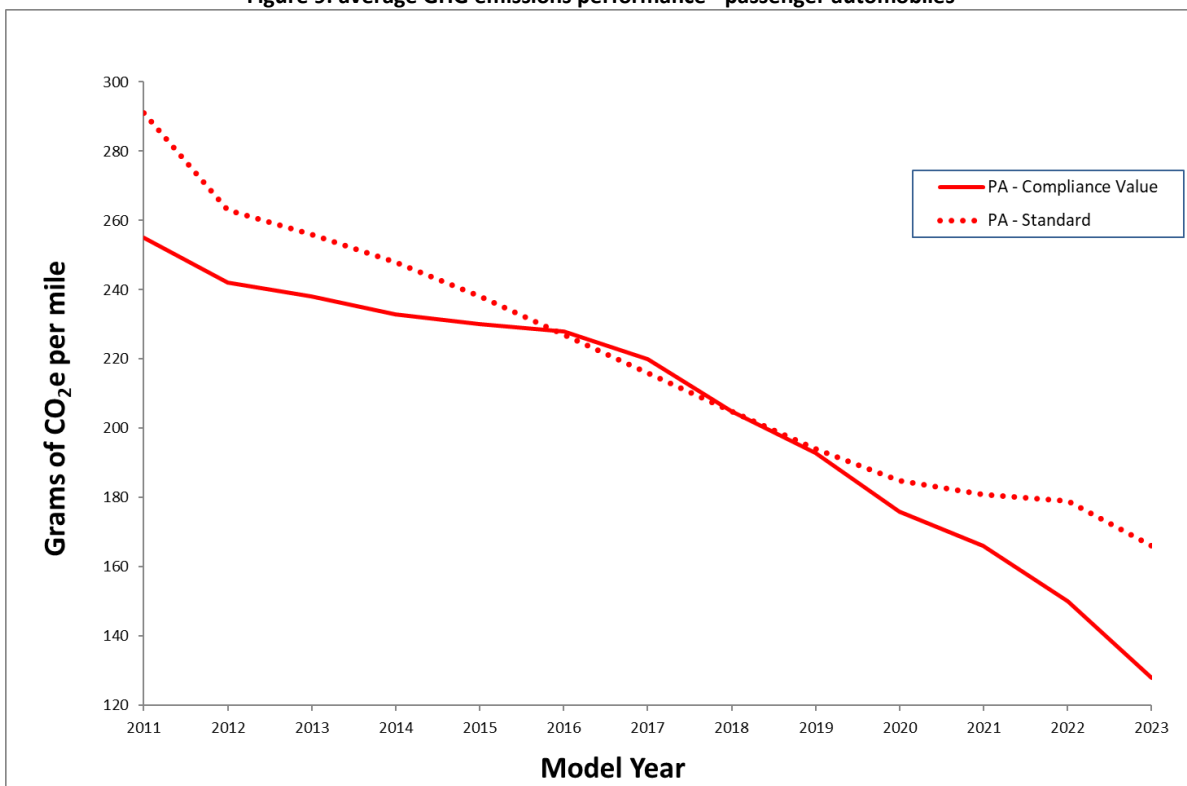
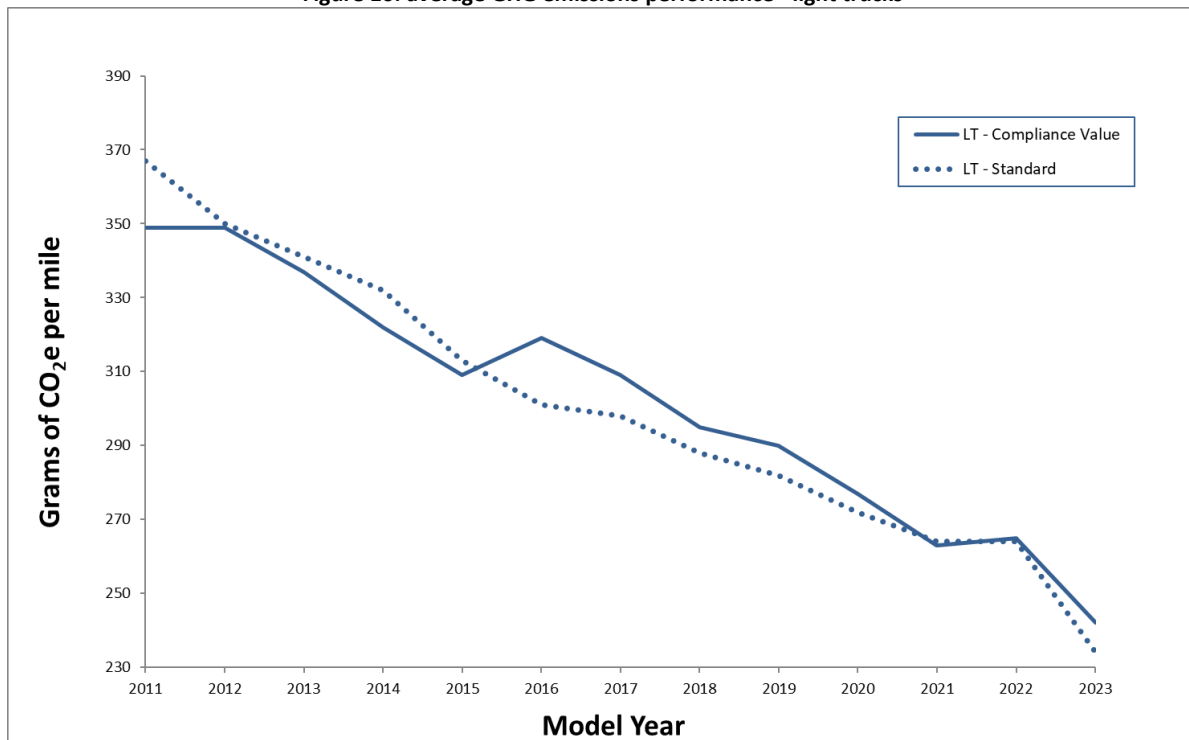


Table 20: light truck compliance summary for the 2011 to 2023 model years (g/mi)

| Model Year | CREE | Innovative Technologies | AC Refrigerant Leakage Reduction | AC Efficiency Improvements | Compliance value | Standard | Compliance margin |
|------------|------|-------------------------|----------------------------------|----------------------------|------------------|----------|-------------------|
| 2011 | 356 | 0.7 | 5.5 | 1.3 | 349 | 367 | 18 |
| 2012 | 357 | 1.2 | 5.8 | 1.5 | 349 | 350 | 1 |
| 2013 | 347 | 1.3 | 6.2 | 2.2 | 337 | 341 | 4 |
| 2014 | 337 | 4.3 | 6.8 | 3.1 | 322 | 332 | 10 |
| 2015 | 326 | 5.2 | 7.6 | 3.6 | 309 | 313 | 4 |
| 2016 | 337 | 5.9 | 8.5 | 3.7 | 319 | 301 | -18 |
| 2017 | 334 | 7.5 | 12.0 | 5.7 | 309 | 298 | -11 |
| 2018 | 323 | 8.5 | 13.3 | 6.1 | 294 | 288 | -6 |
| 2019 | 320 | 9.7 | 14.2 | 6.0 | 290 | 282 | -8 |
| 2020 | 309 | 10.7 | 14.7 | 6.0 | 277 | 272 | -6 |
| 2021 | 298 | 11.6 | 16.6 | 6.2 | 263 | 264 | 1 |
| 2022 | 300 | 12.2 | 16.7 | 6.5 | 265 | 264 | -1 |
| 2023 | 274 | 10.5 | 14.9 | 6.5 | 242 | 234 | -8 |

Figure 10: average GHG emissions performance - light trucks



As depicted in Figures 9 and 10, the 2023 model year saw the overall compliance value for passenger automobiles decrease to 128 g/mi, and the overall compliance value for light trucks decrease to 242 g/mi. This has resulted in an overall net improvement of 49.8% and 30.7% relative to the 2011 model year for passenger automobiles and light trucks respectively.

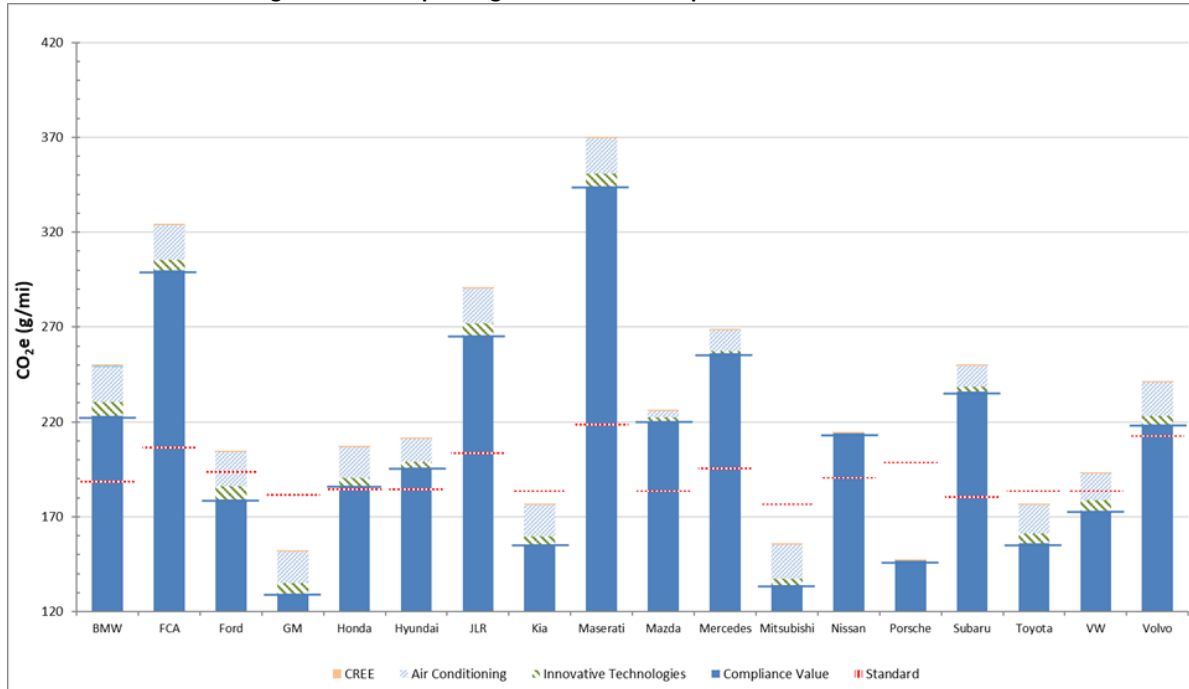
All companies remained in compliance with the regulations through the use of their own accumulated emission credits or by purchasing credits from other companies. Results to date indicate that all companies continue to meet their vehicle GHG regulatory obligations for the 2023 model year.

Appendix

Table A-1: production volumes by company

| Manufacturer | 2020 PA | 2020 LT | 2020 All | 2021 PA | 2021 LT | 2021 All | 2022 PA | 2022 LT | 2022 All | 2023 PA | 2023 LT | 2023 All |
|---------------|------------|------------|-------------|------------|------------|-------------|------------|------------|-------------|------------|------------|-------------|
| Aston Martin | 74 | 0 | 74 | 38 | 94 | 132 | 45 | 38 | 83 | 95 | 124 | 219 |
| BMW | 18,188 | 13,506 | 31,694 | 14,450 | 15,221 | 29,671 | 12,983 | 18,202 | 31,185 | 13,240 | 20,052 | 33,292 |
| BYD | 25 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FCA | 2,936 | 137,799 | 140,735 | 5,834 | 161,482 | 167,316 | 7,350 | 161,888 | 169,238 | 9,066 | 125,645 | 134,711 |
| Ferrari | 370 | 0 | 370 | 313 | 0 | 313 | 493 | 0 | 493 | 345 | 0 | 345 |
| Ford | 15,349 | 172,413 | 187,762 | 13,091 | 174,247 | 187,338 | 15,597 | 194,354 | 209,951 | 16,939 | 186,341 | 203,280 |
| GM | 24,622 | 128,565 | 153,187 | 18,572 | 172,203 | 190,775 | 23,379 | 164,729 | 188,108 | 33,157 | 178,316 | 211,473 |
| Honda | 80,531 | 73,611 | 154,142 | 39,703 | 64,463 | 104,166 | 60,849 | 58,365 | 119,214 | 37,664 | 63,275 | 100,939 |
| Hyundai | 122,929 | 8,298 | 131,227 | 84,131 | 19,949 | 104,080 | 80,506 | 51,671 | 132,177 | 84,984 | 50,157 | 135,141 |
| JLR | 423 | 14,985 | 15,408 | 268 | 7,873 | 8,141 | 92 | 5,111 | 5,203 | 241 | 10,445 | 10,686 |
| Kia | 47,977 | 33,467 | 81,444 | 34,294 | 40,668 | 74,962 | 25,897 | 33,646 | 59,543 | 40,783 | 53,798 | 94,581 |
| Lotus, | 15 | 0 | 15 | 18 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| Maserati | 120 | 362 | 482 | 212 | 262 | 474 | 183 | 484 | 667 | 153 | 1,085 | 1,238 |
| Mazda | 18,368 | 21,827 | 40,195 | 25,103 | 51,399 | 76,502 | 12,026 | 25,552 | 37,578 | 9,238 | 39,814 | 49,052 |
| McLaren, | 157 | 0 | 157 | 84 | 0 | 84 | 79 | 0 | 79 | 111 | 0 | 111 |
| Mercedes | 13,543 | 26,523 | 40,066 | 8,446 | 25,324 | 33,770 | 8,354 | 23,756 | 32,110 | 11,891 | 17,655 | 29,546 |
| Mitsubishi | 4,151 | 14,435 | 18,586 | 1,181 | 6,879 | 8,060 | 4,640 | 24,298 | 28,938 | 3,295 | 28,007 | 31,302 |
| Morgan,Olson | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 902 | 0 | 902 |
| Nissan | 56,966 | 43,810 | 100,776 | 55,002 | 32,241 | 87,243 | 33,663 | 27,340 | 61,003 | 52,483 | 57,152 | 109,635 |
| Porsche | 2,944 | 4,856 | 7,800 | 2,380 | 6,663 | 9,043 | 3,320 | 4,453 | 7,773 | 3,196 | 6,989 | 10,185 |
| Rivian | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 883 | 0 | 883 |
| Subaru | 12,845 | 38,408 | 51,253 | 5,794 | 53,396 | 59,190 | 7,453 | 31,274 | 38,727 | 7,598 | 33,181 | 40,779 |
| Tesla | 18,483 | 328 | 18,811 | 32,414 | 1,450 | 33,864 | 47,711 | 2,811 | 50,522 | 63,824 | 3,359 | 67,183 |
| Toyota | 99,295 | 118,030 | 217,325 | 77,815 | 152,741 | 230,556 | 71,183 | 129,656 | 200,839 | 45,683 | 156,813 | 202,496 |
| VinFast | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 801 | 0 | 801 |
| Volkswagen | 22,059 | 32,233 | 54,292 | 26,775 | 53,433 | 80,208 | 27,245 | 46,739 | 73,984 | 28,064 | 62,500 | 90,564 |
| Volvo | 953 | 9,061 | 10,014 | 1,807 | 8,638 | 10,445 | 2,628 | 8,204 | 10,832 | 5,168 | 8,404 | 13,572 |
| Fleet, Total | 563,323 | 892,517 | 1,455,840 | 447,725 | 1,048,626 | 1,496,351 | 444,676 | 1,012,571 | 1,458,247 | 469,804 | 1,103,112 | 1,572,916 |

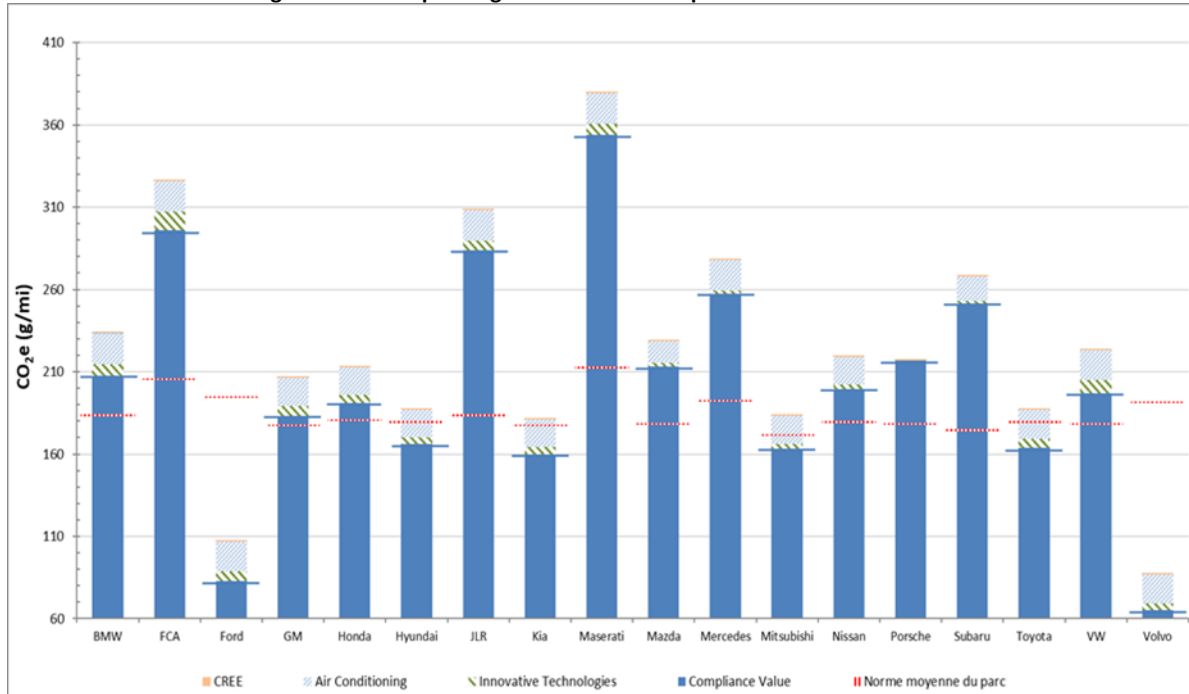
Figure A-1: 2020 passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

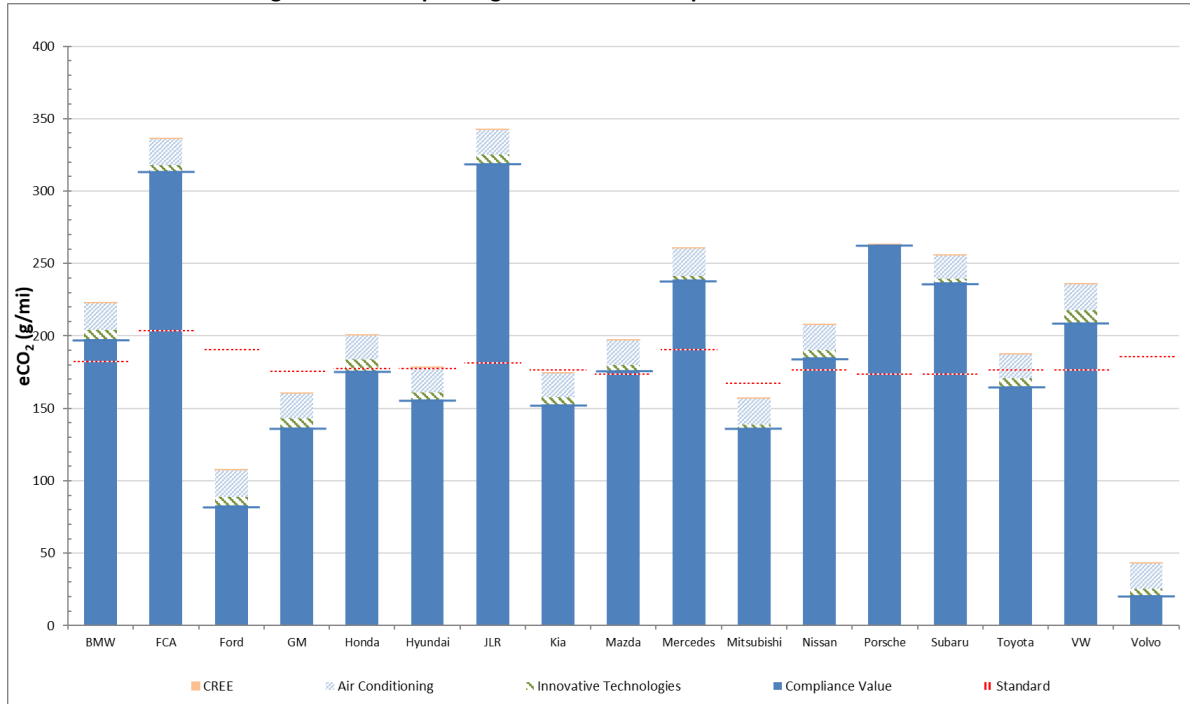
Figure A-2: 2021 passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

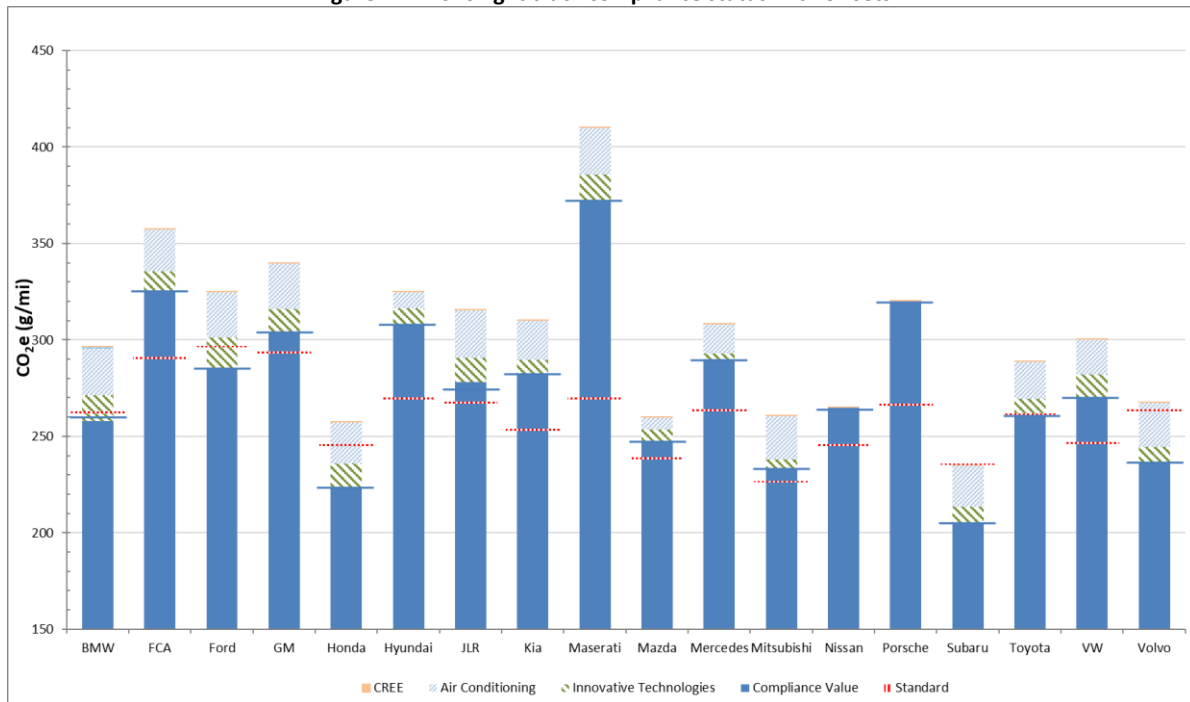
Figure A-3: 2022 passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

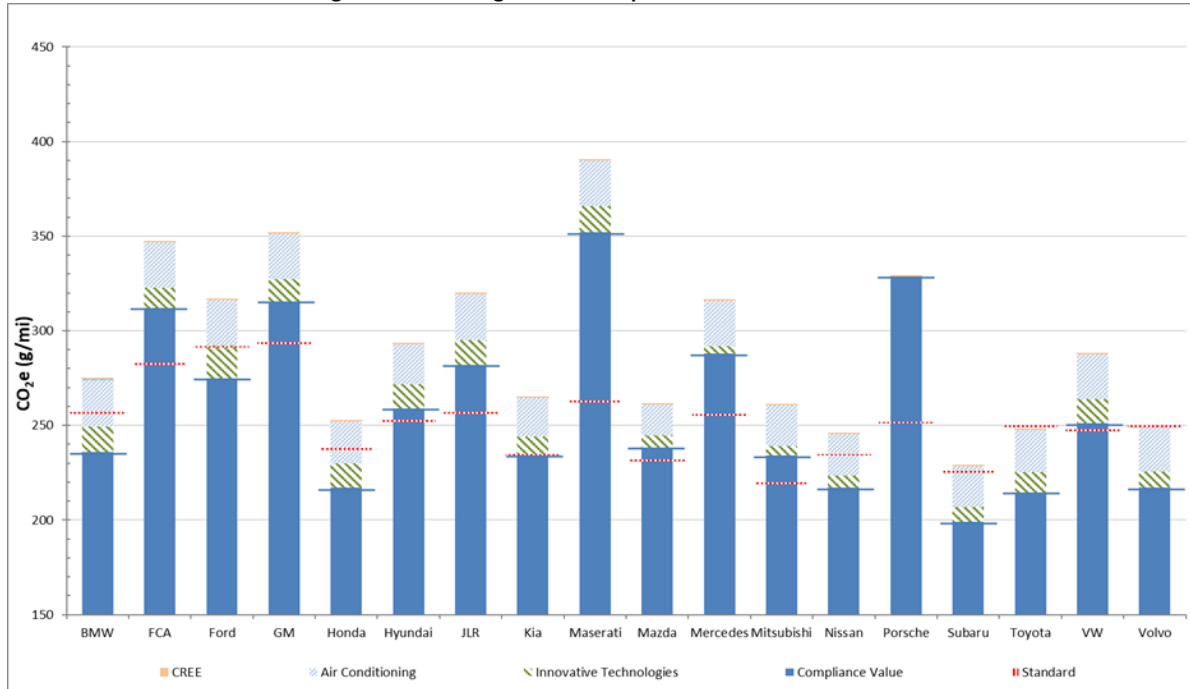
Figure A-4: 2020 light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

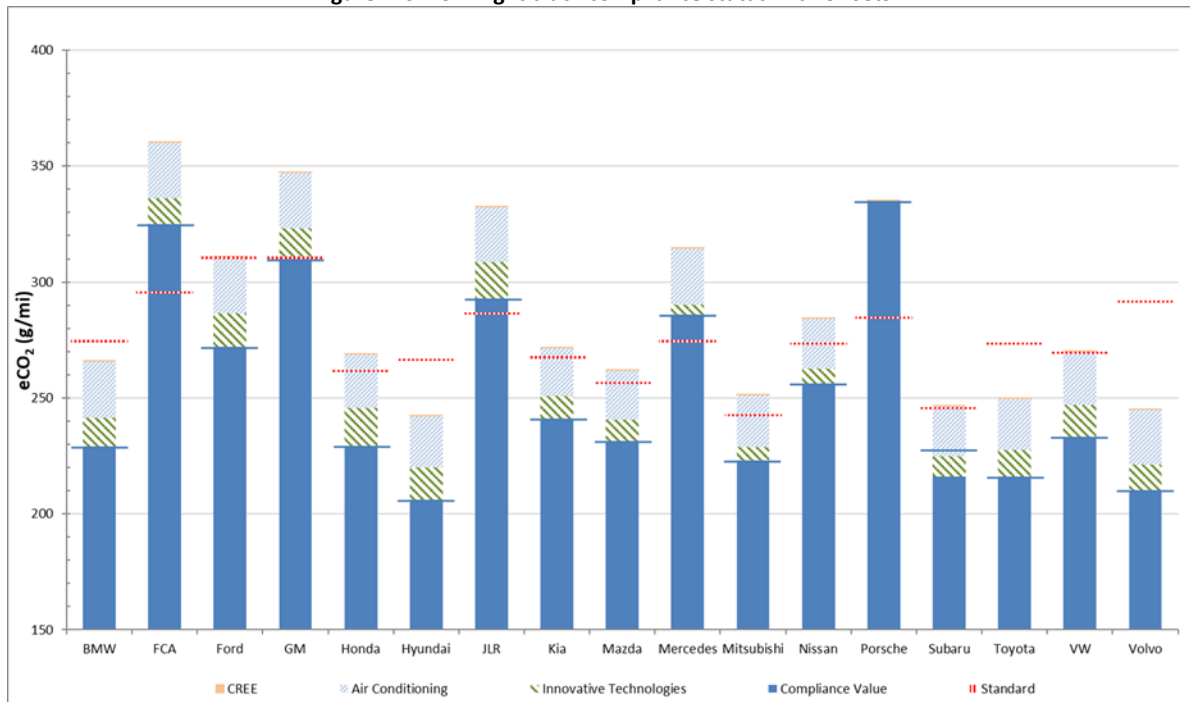
Figure A-5: 2021 light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

Figure A-6: 2022 light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VinFast produce electric vehicles, whose compliance values fall outside of the range of this graph.

Table A-2: preapproved menu of efficiency improving technologies for AC systems

| Technology | Passenger automobiles (g/mi) | Light Trucks (g/mi) |
|--|-------------------------------------|----------------------------|
| Reduced reheat, with externally-controlled, variable-displacement compressor (for example, a compressor that controls displacement based on temperature set point and/or cooling demand of the air conditioning system control settings inside the passenger compartment). | 1.5 | 2.2 |
| Reduced reheat, with externally-controlled, fixed-displacement or pneumatic variable displacement compressor (for example, a compressor that controls displacement based on conditions within, or internal to, the air conditioning system, such as head pressure, suction pressure, or evaporator outlet temperature). | 1.1 | 1.4 |
| Default to recirculated air with closed-loop control of the air supply (sensor feedback to control interior air quality) whenever the ambient temperature is 75 °F or higher: Air conditioning systems that operated with closed-loop control of the air supply at different temperatures may receive credits by submitting an engineering analysis to the Administrator for approval. | 1.5 | 2.2 |
| Default to recirculated air with open-loop control air supply (no sensor feedback) whenever the ambient temperature is 75 °F or higher. Air conditioning systems that operate with open-loop control of the air supply at different temperatures may receive credits by submitting an engineering analysis to the Administrator for approval. | 1.0 | 1.4 |
| Blower motor controls which limit wasted electrical energy (for example, pulse width modulated power controller). | 0.8 | 1.1 |
| Internal heat exchanger (for example, a device that transfers heat from the high-pressure, liquid-phase refrigerant entering the evaporator to the low-pressure, gas-phase refrigerant exiting the evaporator). | 1.0 | 1.4 |
| Improved condensers and/or evaporators with system analysis on the component(s) indicating a coefficient of performance improvement for the system of greater than 10% when compared to previous industry standard designs. | 1.0 | 1.4 |
| Oil separator. The manufacturer must submit an engineering analysis demonstrating the increased improvement of the system relative to the baseline design, where the baseline component for comparison is the version which a manufacturer most recently had in production on the same vehicle design or in a similar or related vehicle model. The characteristics of the baseline component shall be compared to the new component to demonstrate the improvement. | 0.5 | 0.7 |
| Advanced technology air conditioning compressor with improved efficiency relative to fixed-displacement compressors achieved through the addition of a variable crankcase suction valve | 1.1 | 1.1 |

Table A-3: production volume of vehicles with turbocharging

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|---------|---------|---------|---------|
| BMW | 31,481 | 29,190 | 29,766 | 28,757 |
| FCA | 14,687 | 23,257 | 13,364 | 42,094 |
| Ford | 132,368 | 138,751 | 157,860 | 149,263 |
| GM | 56,807 | 65,865 | 85,352 | 99,932 |
| Honda | 76,355 | 64,217 | 52,608 | 57,211 |
| Hyundai | 16,152 | 14,721 | 34,665 | 37,689 |
| JLR | 12,771 | 3,248 | 1,533 | 5,576 |
| Kia | 2,675 | 12,627 | 11,437 | 16,165 |
| Maserati | 268 | 482 | -- | -- |
| Mazda | 5,416 | 17,909 | 8,860 | 12,769 |
| Mercedes | 40,066 | 33,770 | 31,710 | 25,040 |
| Mitsubishi | 4,173 | 0 | 6,134 | 5,425 |
| Nissan | 3,365 | 3,457 | 9,216 | 35,835 |
| Porsche | 6,354 | 8,145 | 6,373 | 8,894 |
| Subaru | 12,249 | 9,046 | 13,463 | 11,452 |
| Toyota | 7,444 | 8,336 | 13,575 | 31,207 |
| Volkswagen | 50,140 | 66,229 | 62,025 | 67,329 |
| Volvo | 3,549 | 3,591 | 3,540 | 4,007 |
| Total | 476,320 | 502,841 | 541,481 | 638,645 |

Table A-4: production volume of vehicles with variable valve timing

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|-----------|-----------|-----------|-----------|
| BMW | 31,481 | 29,190 | 29,766 | 28,757 |
| FCA | 135,261 | 161,489 | 160,477 | 130,049 |
| Ford | 159,409 | 157,435 | 180,099 | 164,765 |
| GM | 142,300 | 169,906 | 165,978 | 177,814 |
| Honda | 154,142 | 104,166 | 119,214 | 100,939 |
| Hyundai | 125,654 | 95,950 | 122,696 | 119,260 |
| JLR | 14,287 | 7,510 | 5,151 | 10,640 |
| Kia | 77,767 | 72,832 | 56,665 | 88,394 |
| Maserati | 268 | 482 | -- | -- |
| Mazda | 40,195 | 76,502 | 36,510 | 48,243 |
| Mercedes | 40,066 | 33,770 | 31,710 | 25,040 |
| Mitsubishi | 18,586 | 8,060 | 28,938 | 31,302 |
| Nissan | 98,928 | 86,804 | 60,087 | 104,985 |
| Porsche | 6,761 | 8,536 | 7,159 | 9,545 |
| Subaru | 51,253 | 59,190 | 38,727 | 37,829 |
| Toyota | 217,303 | 230,556 | 200,817 | 195,954 |
| Volkswagen | 49,087 | 78,027 | 70,596 | 78,167 |
| Volvo | 10,014 | 9,568 | 8,878 | 9,100 |
| Total | 1,372,762 | 1,389,973 | 1,323,468 | 1,360,783 |

Table A-5: production volume of vehicles with variable valve lift

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|---------|---------|---------|---------|
| BMW | 31,481 | 29,190 | 29,766 | 28,571 |
| FCA | 8,156 | 10,474 | 12,376 | 4,182 |
| GM | 4,933 | 13,138 | 24,488 | 38,877 |
| Honda | 95,409 | 57,245 | 76,500 | 84,919 |
| JLR | 14,287 | 7,510 | 5,151 | 10,640 |
| Mercedes | 18,149 | 18,800 | 18,197 | 14,570 |
| Mitsubishi | 5,545 | 0 | 0 | 0 |
| Nissan | 1,903 | 1,428 | 1,302 | 1,716 |
| Porsche | 6,761 | 8,536 | 5,186 | 6,654 |
| Toyota | 39,288 | 29,153 | 25,151 | 570 |
| Volkswagen | 36,835 | 47,582 | 43,944 | 48,779 |
| Total | 262,747 | 223,056 | 242,061 | 239,478 |

Table A-6: production volume of vehicles with higher geared transmissions

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|---------|---------|-----------|-----------|
| BMW | 30,975 | 28,489 | 29,248 | 27,992 |
| FCA | 116,342 | 164,272 | 164,822 | 131,799 |
| Ford | 165,213 | 171,375 | 187,707 | 174,418 |
| GM | 101,414 | 148,952 | 153,916 | 176,538 |
| Honda | 60,188 | 39,191 | 61,383 | 37,642 |
| Hyundai | 33,571 | 28,398 | 54,278 | 52,779 |
| JLR | 15,269 | 8,102 | 5,151 | 10,640 |
| Kia | 21,058 | 38,286 | 30,941 | 57,805 |
| Maserati | 268 | 482 | -- | -- |
| Mercedes | 40,066 | 33,770 | 31,710 | 25,040 |
| Mitsubishi | 4,173 | 0 | 18,294 | 13,821 |
| Nissan | 30,762 | 54,751 | 39,168 | 82,178 |
| Porsche | 6,317 | 8,280 | 6,640 | 9,244 |
| Subaru | 45,076 | 53,639 | 36,579 | 34,262 |
| Toyota | 106,374 | 102,408 | 105,006 | 91,984 |
| Volkswagen | 49,028 | 73,805 | 69,076 | 75,942 |
| Volvo | 10,014 | 9,568 | 8,878 | 9,100 |
| Total | 836,108 | 963,768 | 1,002,797 | 1,011,184 |

Table A-7: production volume of vehicles with continuously variable transmissions

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|---------|---------|---------|---------|
| FCA | 1,026 | 968 | 2,412 | 1,789 |
| Ford | 11,772 | 9,262 | 12,219 | 10,604 |
| GM | 12,178 | 10,472 | 16,099 | 7,081 |
| Honda | 109,601 | 74,779 | 83,143 | 71,743 |
| Hyundai | 46,969 | 28,991 | 49,661 | 48,951 |
| Kia | 31,660 | 42,490 | 25,806 | 39,090 |
| Mitsubishi | 14,333 | 7,735 | 26,648 | 22,517 |
| Nissan | 95,193 | 83,400 | 44,136 | 88,410 |
| Subaru | 45,489 | 53,898 | 36,662 | 34,436 |
| Toyota | 45,664 | 28,484 | 31,102 | 72,591 |
| Total | 413,885 | 340,479 | 327,888 | 397,212 |

Table A-8: production volume of vehicles with cylinder deactivation

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|---------|---------|---------|---------|
| FCA | 52,737 | 51,655 | 82,676 | 48,602 |
| Ford | 16,696 | 42,801 | 42,311 | 12,033 |
| GM | 83,485 | 103,566 | 92,496 | 120,732 |
| Honda | 23,086 | 14,727 | 26,107 | 20,759 |
| Mazda | 20,472 | 24,226 | 10,709 | 29,090 |
| Mercedes | 1,817 | 2,793 | 1,459 | 1,633 |
| Porsche | 0 | 623 | 546 | 738 |
| Volkswagen | 778 | 2,220 | 1,746 | 2,370 |
| Total | 199,071 | 242,611 | 258,050 | 235,957 |

Table A-9: production volume of vehicles with gasoline direct injection

| Manufacturer | 2020 | 201 | 2022 | 2023 |
|--------------|---------|---------|---------|---------|
| BMW | 31,481 | 29,190 | 29,766 | 22,189 |
| FCA | 11,126 | 15,782 | 5,069 | 18,257 |
| Ford | 77,783 | 71,989 | 95,823 | 64,592 |
| GM | 129,927 | 161,893 | 160,805 | 177,814 |
| Honda | 103,952 | 79,172 | 78,708 | 76,322 |
| Hyundai | 58,513 | 56,674 | 72,712 | 55,371 |
| JLR | 14,287 | 7,510 | 5,151 | 10,640 |
| Kia | 44,780 | 20,887 | 18,527 | 15,495 |
| Maserati | 268 | 482 | -- | -- |
| Mazda | 40,195 | 76,502 | 36,510 | 48,243 |
| Mercedes | 40,059 | 33,770 | 31,707 | 24,978 |
| Mitsubishi | 0 | 0 | 12,160 | 8,396 |
| Nissan | 32,920 | 55,765 | 45,334 | 82,926 |
| Porsche | 0 | 254 | 7,159 | 9,545 |
| Subaru | 49,459 | 58,414 | 38,138 | 36,318 |
| Toyota | 2,655 | 497 | 355 | 570 |
| Volkswagen | 52,340 | 78,096 | 70,410 | 77,358 |
| Volvo | 10,014 | 9,568 | 8,878 | 9,100 |
| Total | 699,759 | 756,445 | 717,212 | 738,114 |

Table A-10: production volume of diesel vehicles

| Manufacturer | 2020 | 2021 | 2022 | 2023 |
|--------------|--------|--------|--------|--------|
| FCA | 3,489 | 3,305 | 3,921 | 391 |
| Ford | 265 | 501 | 0 | 0 |
| GM | 5,651 | 19,308 | 16,581 | 15,693 |
| JLR | 982 | 592 | 0 | 0 |
| Total | 10,387 | 23,706 | 20,502 | 16,084 |