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*

List of acronyms

AC – Air conditioner

ATV – Advanced technology vehicle

CAFE – Corporate average fuel economy

CEPA – Canadian Environmental Protection Act, 1999

CO – Carbon monoxide

CO_2 – Carbon dioxide

CO_2e – 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

N_2O – 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 (CO_2e)[1] emissions value (referred to as the "compliance value") and the status of their emission credits.

The CO_2e 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 years[2]. 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 CO_2e based on standardized emissions tests simulating city and highway driving cycles. The emissions measured during these test procedures include CO_2 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 (CH_4) and nitrous oxide (N_2O). 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

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[1] CO_2e is used throughout this report as a common unit to standardize the environmental impacts of different greenhouse gases (such as N_2O & CH_4) in terms of an equivalent amount of CO_2.
[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 12.8% for the 2023 model year. More specifically, battery electric vehicles have increased from 198 to 169,106 representing 10.7% of the total fleet in 2023, and the volume of plug-in hybrid electric vehicles has increased from 0 to 32,028 representing 2.0% 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
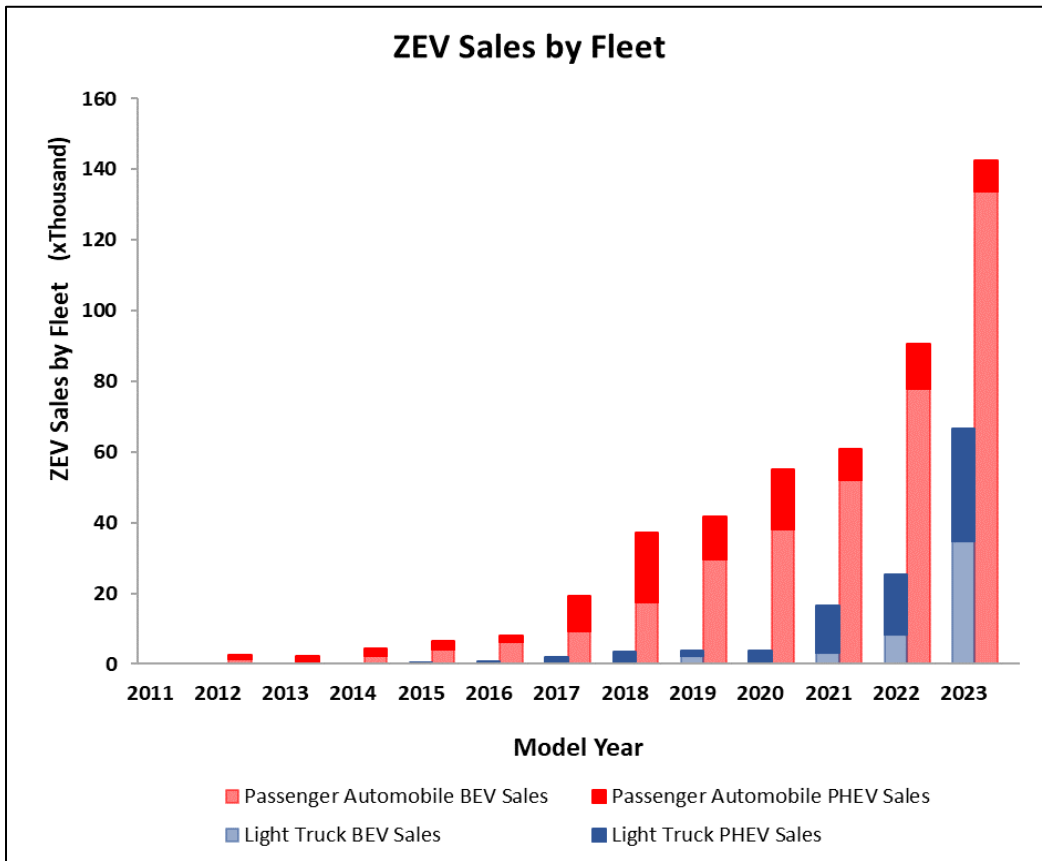
Results from annual regulatory compliance reports indicate that companies continue to be in compliance through the 2023 model year. The average compliance value for the fleet of new passenger automobiles has decreased from 255 g/mi to 128 g/mi since the introduction of the regulation, representing a 49.8% reduction.

Figure ES-2. average GHG emissions performance - passenger automobiles
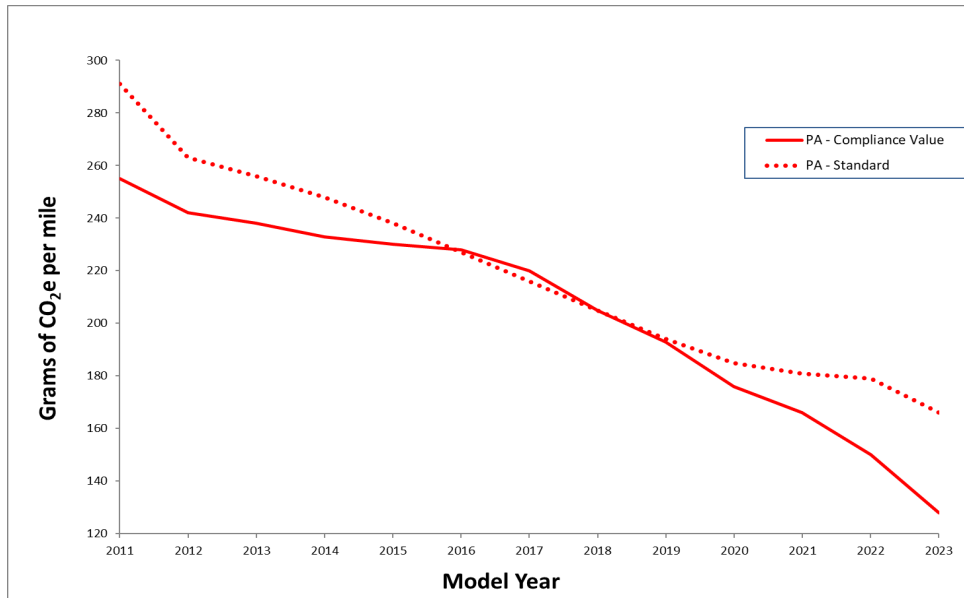
The compliance value for light trucks decreased by 30.7%, from 349 g/mi to 242 g/mi since the introduction of the regulation. All companies remained in compliance with the regulations by either meeting their applicable standard, through the use of their own accumulated emission credits or by purchasing credits from other companies.

Figure ES-3. average GHG emissions performance - light trucks
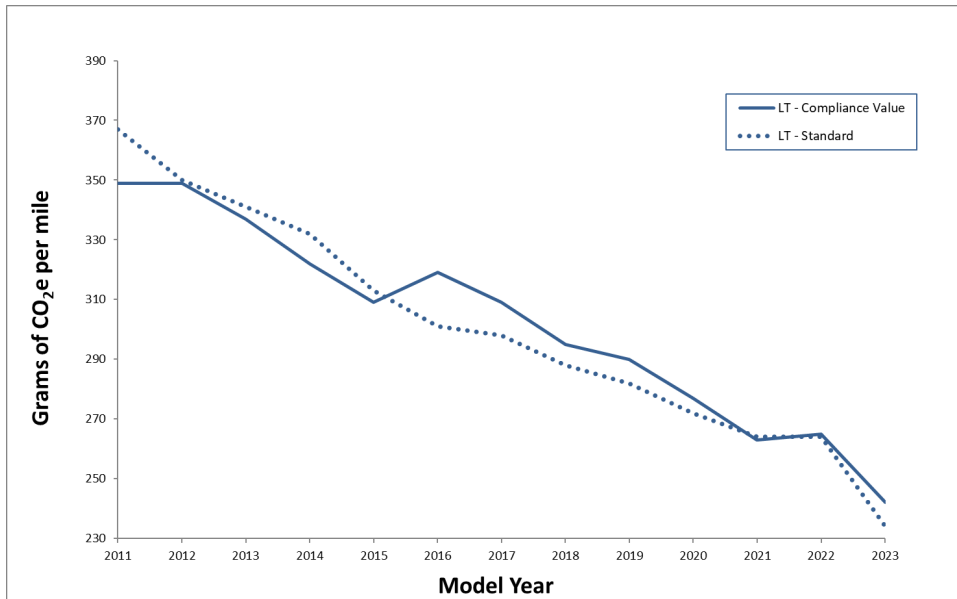
Under the regulations, companies have generated a total of approximately 115.9 million credits, of which, approximately 25.6 million are available for future use. A total of 39 million credits have been used to offset emission deficits by individual companies over the 2011 to 2023 model years, of which 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 fleets[5]. 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.

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[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	*	*	*	*

*Indicates that a report has been submitted

[a] Beginning with the 2012 model year, low volume manufacturers (LVM) may elect to exempt themselves from CO_2e standards. This exemption does not have a noticeable impact on fleet-wide performance given the small volume of vehicles.

2.1. CO_2e emission standards

The applicable standards for a given model year are based on prescribed carbon dioxide (CO_2e) 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 sale[6] to the first retail purchaser[7]. These standards are performance-based in that they establish a maximum amount of CO_2e on a gram per mile basis. This progressively more stringent approach allows companies to choose from an ever-changing

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[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

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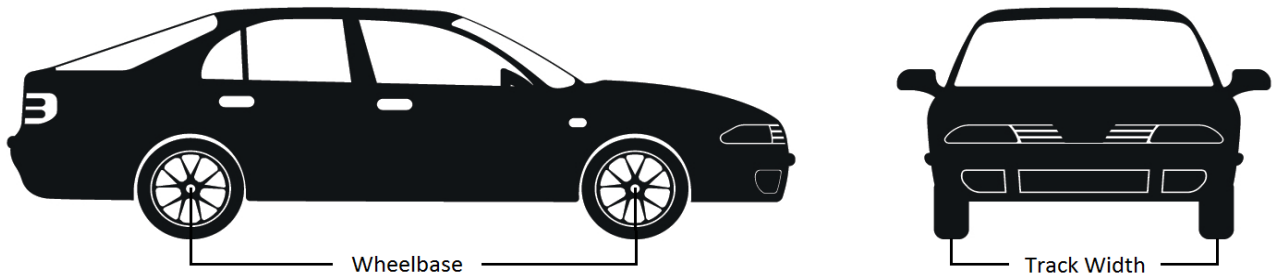
$$Footprint = \frac{front\ track\ width + rear\ track\ width}{2} \times wheelbase$$

The regulations prescribe progressively more stringent target values for a given footprint size over the 2011 through 2026 model years[8]. Figures 2 and 3 illustrate the target values for passenger automobiles and light trucks, respectively.

Figure 2: 2011 to 2026 targets for passenger automobiles

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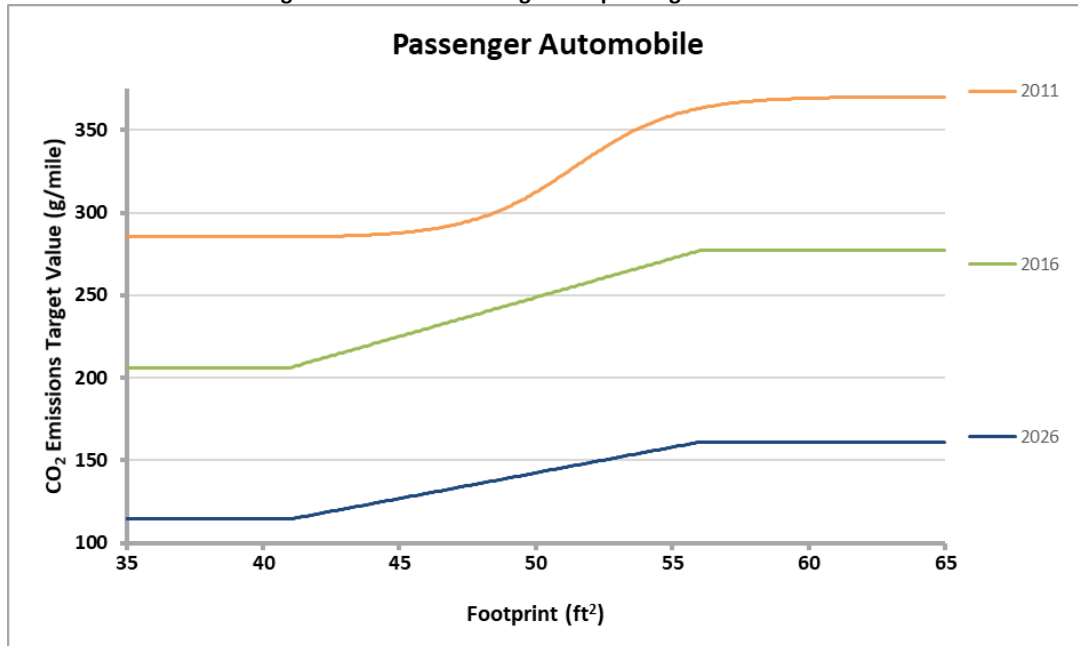
8 See footnote 2

Light Trucks
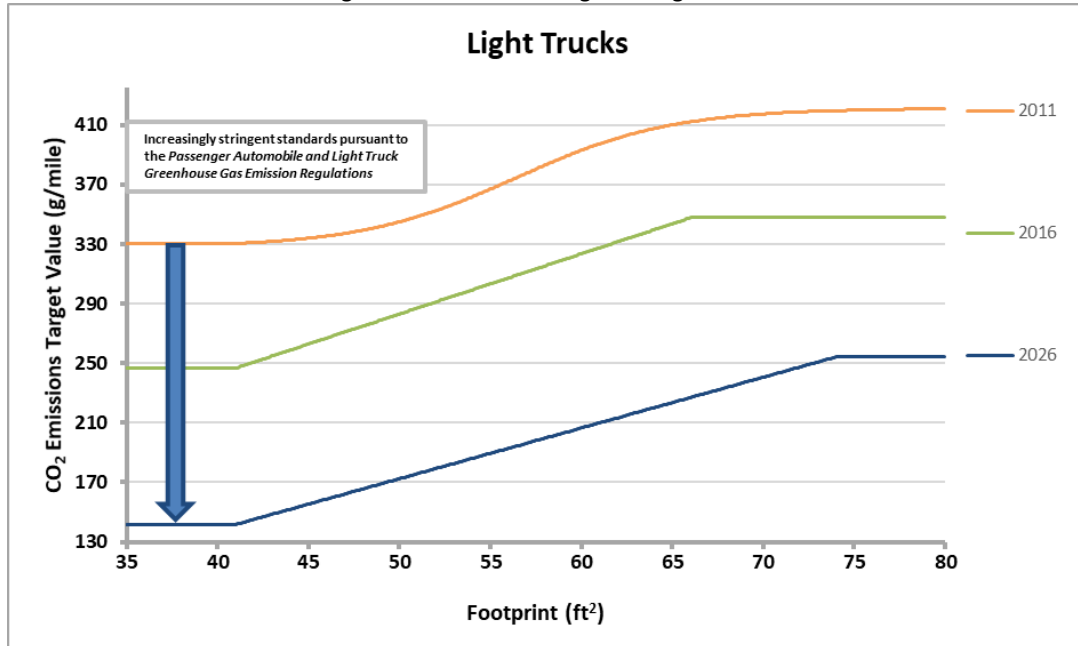
As depicted in Figures 2 and 3, the targets for the 2011 model year are unique in that they follow a smooth curve. This is because the 2011 target values were introduced 1 year prior to the U.S. Environmental Protection Agency (EPA) program and were instead based on the U.S. Corporate Average Fuel Economy (CAFE) levels. Accordingly, the regulations considered the consumption of fuel as the basis to establish reasonable approximations of GHG performance for the 2011 model year[9]. The CO_2e standard was derived using a conversion factor of 8,887 grams of CO_2 /gallon of gasoline[10] for the 2011 model year only.

For the 2012 and later model years, the CO_2e 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:

$$\textbf{Fleet Average Standard} = \frac{\Sigma\,(\textbf{A}\,\times\,\textbf{B})}{\textbf{C}}$$

where

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[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 CO_2e 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 CO_2e 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 CO_2e 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 CO_2e standards. Companies are responsible for meeting their own unique fleet average CO_2e 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 CO_2e 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 (CO_2), carbon monoxide (CO), and hydrocarbons (HC). This ensures that all carbon-containing exhaust emissions that ultimately contribute to the formation of CO_2 are recognized.

The CREE for each vehicle model type is calculated based on actual emission constituents (such as CO_2, 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 potential[12] (GWP) that is much higher than CO_2. 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 CO_2. 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 CO_2e leakage reduction in grams per mile (g/mi) for each of their air conditioning systems. The maximum allowance value that can be generated for

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[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 CO_2e 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 CO_2e 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 CO_2. 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 CO_2e 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 CO_2e 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 CO_2e 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 2025	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	15,874	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	--	--	--	885
Subaru	0	0	0	0	0	0	0	2,950
Tesla	18,483	32,414	47,711	62,824	328	1,450	2,811	3,359
Toyota	22	0	0	1,725	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	78,006	133,537	490	3,272	8,229	35,566

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	0	0	0	49	59	0	0	0
Mitsubishi	2,456	300	2,105	0	0	0	0	0
Nissan	0	0	0	0	0	0	0	0
Porsche	73	68	53	180	320	186	291	452
Subaru	413	0	0	0	0	259	83	174
Tesla	0	0	0	0	0	0	0	0
Toyota	0	4,254	4,175	2,100	0	0	1,904	8,103
VinFast	--	--	--	0	--	--	--	--
Volkswagen	0	10	20	7	444	70	121	320
Volvo	0	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	23,366

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

18
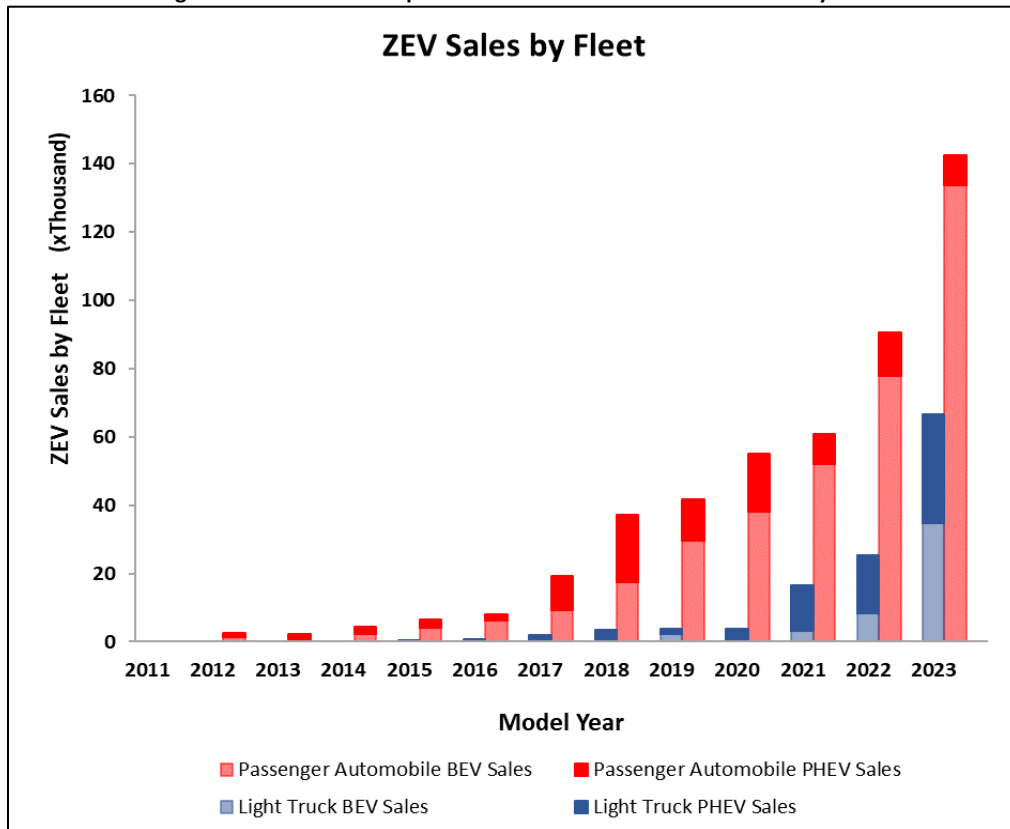
2.3.6. Provisions for small volume companies for 2012 and later model years

The regulations include provisions enabling smaller companies that may have limited product offerings to opt out of complying with the CO_2e standards (non application of the standards respecting CO_2 equivalent emissions[13]) 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 (CH_4) and nitrous oxide (N_2O). Starting with the 2012 model year, the regulations set standards for N_2O and CH_4 at 0.01 g/mi and 0.03 g/mi respectively. These standards are intended to cap vehicle N_2O and CH_4 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 N_2O and CH_4 requirements.

The first method allows companies to certify that the N_2O and CH_4 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 N_2O and CH_4 as an equivalent amount of CO_2 and include this in the determination of their overall CREE. Companies using this method must incorporate N_2O and CH_4 test data into the CREE calculation, while factoring in the higher global warming

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[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 N_2O and CH_4 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 N_2O and CH_4 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 N_2O and CH_4 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 CO_2e emissions credits. The total deficits incurred by the companies that used this method are summarized in Tables 12 and 13.

Table 12: N_2O emissions deficits by company for the 2020 to 2023 model years (Mg CO_2e)

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: CH_4 emissions deficits by company for the 2020 to 2023 model years (Mg CO_2e)

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. CO_2e emissions value

The fleet average CO_2e emissions value, referred to as the "compliance value" is the final average CO_2e 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:

$$Compliance\ value = D-E-F-G-H$$

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 CO_2e 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 CO_2e 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

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[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

Passenger Automobile Performance for 2020 to 2023

Greenhouse Gas Emissions (CO_2e g/mi)
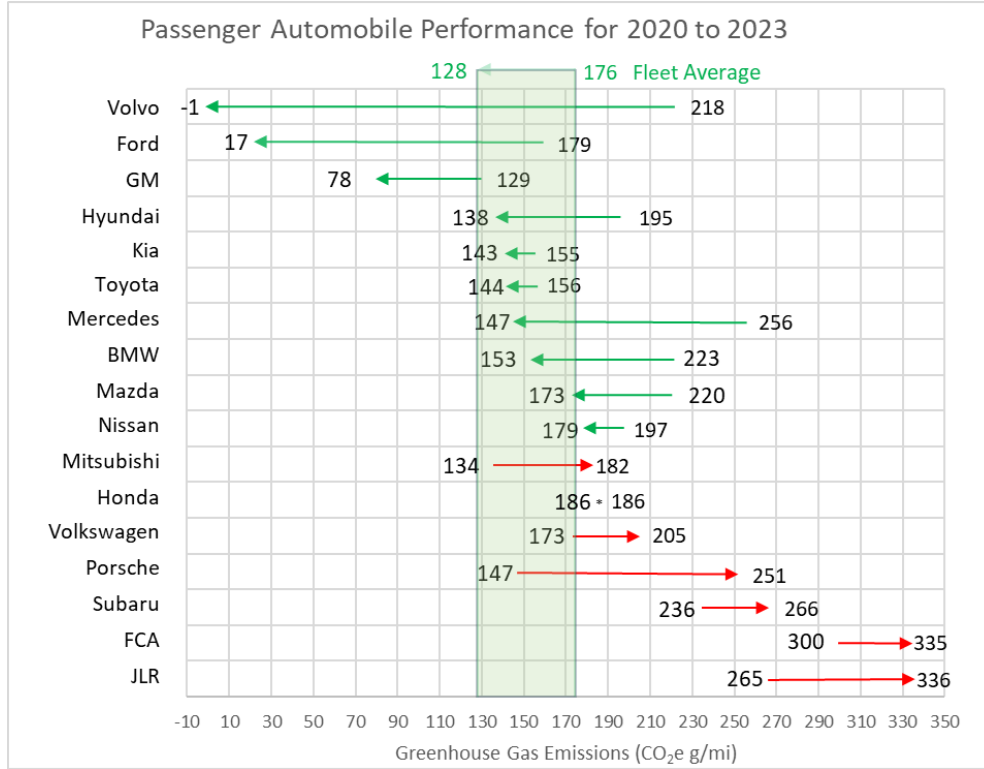
Table 15: LT compliance and standard values over the 2020 to 2023 model years (g/mi)

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

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

Light Truck Performance for 2020 to 2023

Company	Values
Fleet Average	242 ... 277
Mitsubishi	163 ← 234
Volkswagen	186 ← 270
Subaru	187 ← 205
BMW	191 ← 258
Toyota	201 ← 261
Volvo	205 ← 236
Nissan	208 ← 247
Hyundai	220 ← 308
Honda	223 * 223
Kia	223 ← 282
Mazda	226 ← 247
Mercedes	251 ← 290
Ford	259 ← 284
GM	296 ← 304
JLR	278 → 300
FCA	308 ← 325
Porsche	320 → 333

Greenhouse Gas Emissions (CO_2e g/mi)
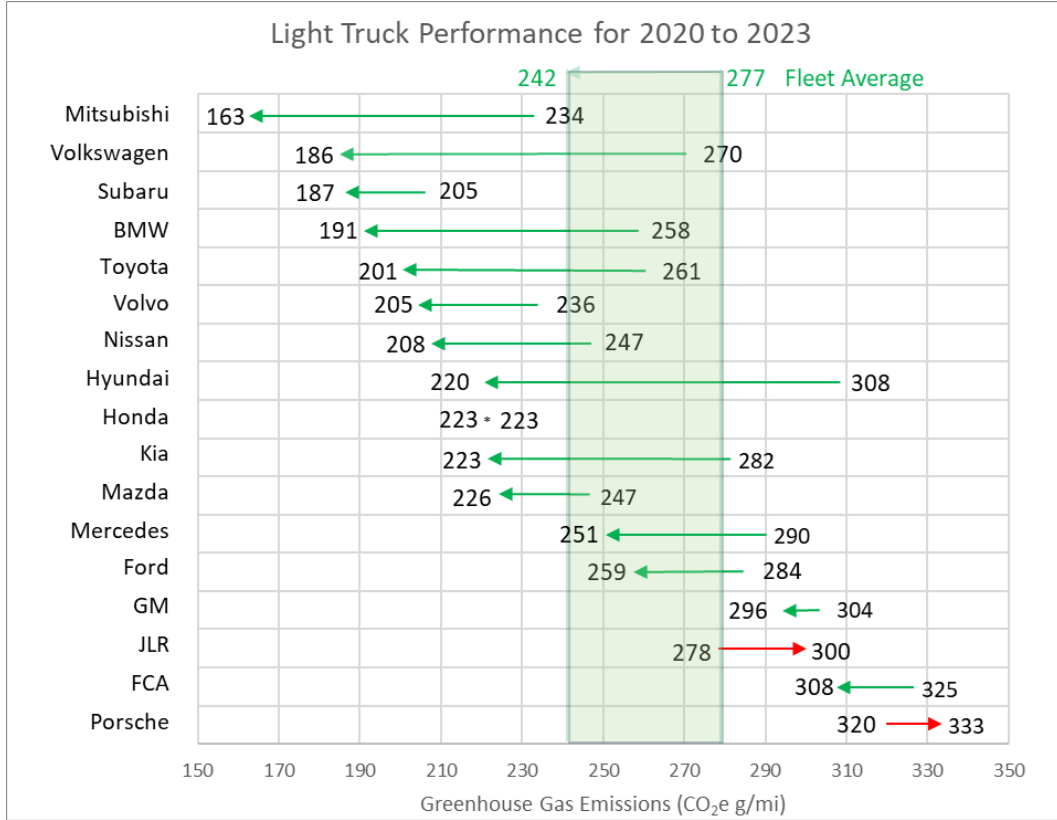
Figures 7 and 8 provide a graphical representation of the role that compliance flexibilities play in arriving at a company's overall compliance status for their 2023 model year passenger automobile and light truck fleets. The orange line on the top of the bar indicates a company's fleet average CREE. 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
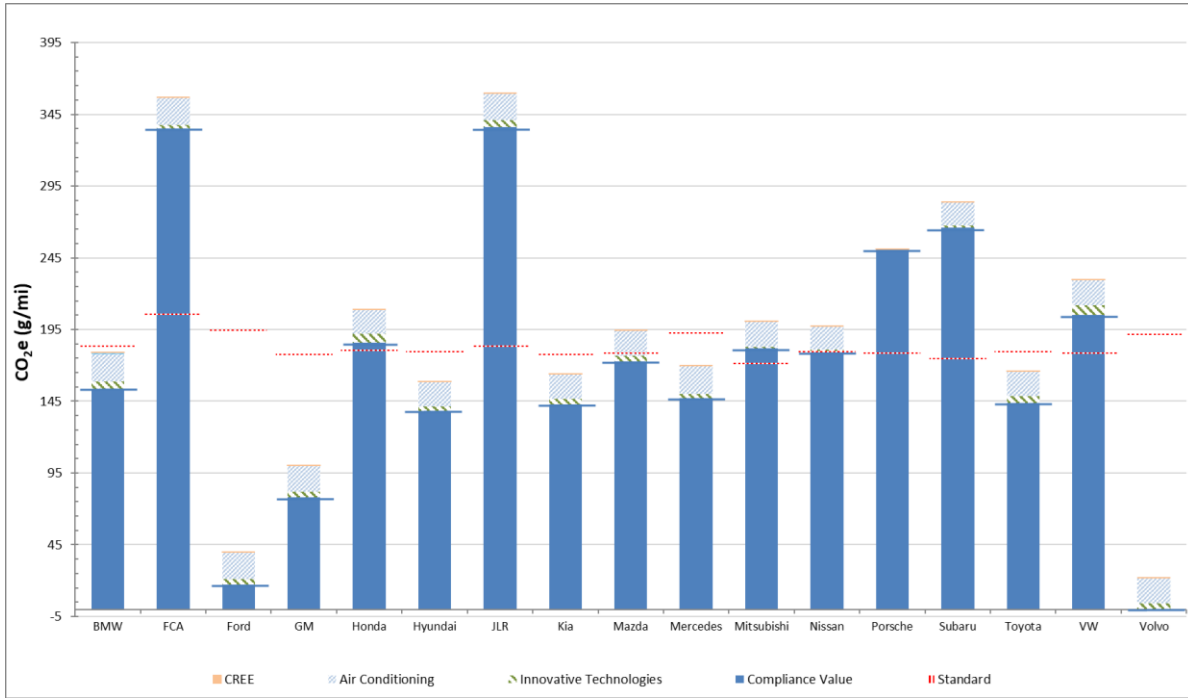
Notes:
1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VInFast produce electric vehicles, whose compliance values fall outside of the range of this graph.
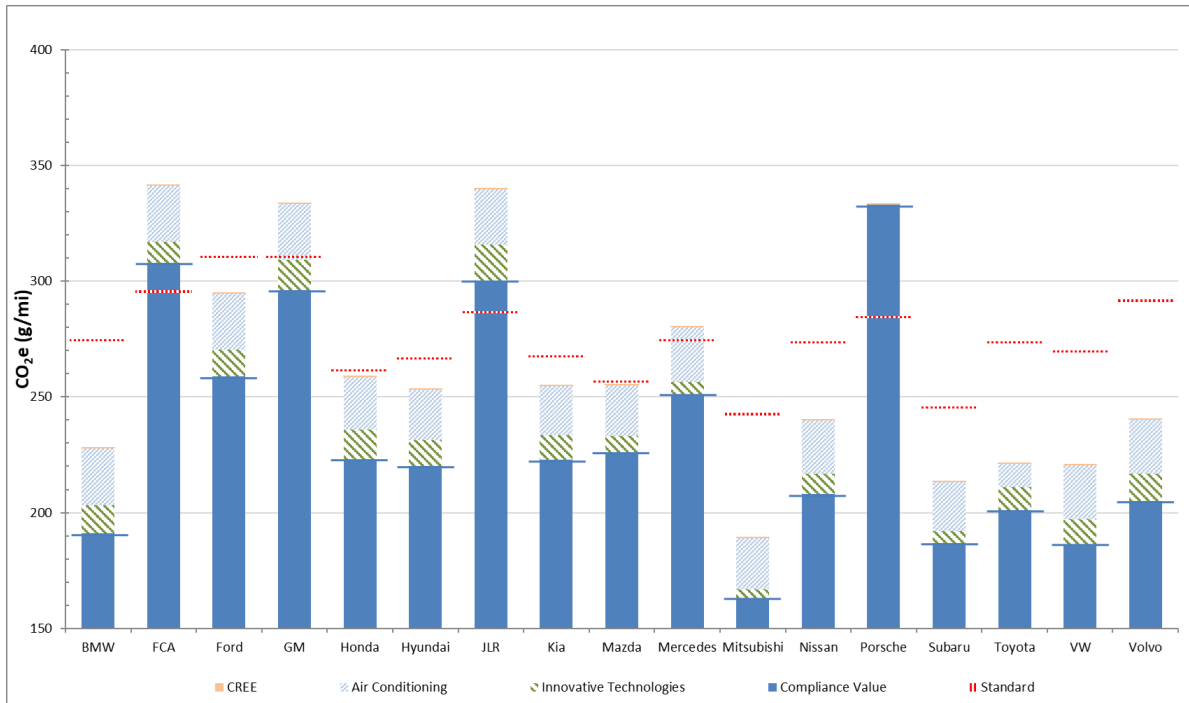
Figure 8: 2023 light truck compliance status with offsets

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 CO_2e 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, CO_2e 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 CO_2e 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 CO_2e 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 discreet 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 CO_2e 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 CO_2e 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 then a gasoline based equivalent[16] which translates into measurable reductions in CO_2e 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.

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[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 CO_2e 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 formula[17]:

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

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 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.

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[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 CO$_2$e)

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 CO$_2$e)

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	1,000,000
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	250,000
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 25.6 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	1,171,718
Honda	-281,930	1,557,221
Hyundai	422,690	1,421,004
JLR	-174,307	0
Kia	9,304	541,471
Mazda	-266,581	273,747
Mercedes	-15,310	1,086,194
Mitsubishi	229,188	389,171
Nissan	-155,488	205,084
Porsche	-240,887	0
Subaru	-32,611	1,018,477
Tesla	4,088,908	6,741,698
Toyota	874,884	4,131,814
VinFast	48,303	48,303
Volkswagen	185,455	295,132
Volvo	275,253	721,831
Total	3,290,360	25,618,928

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.

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[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

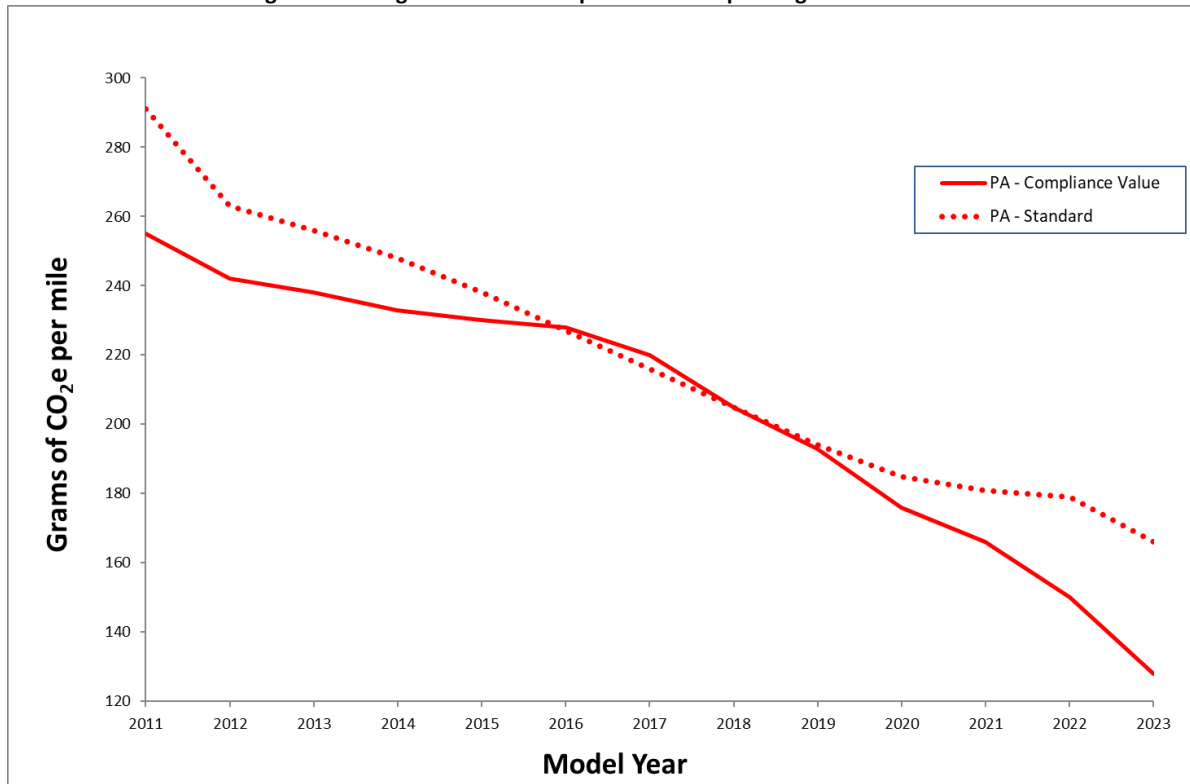**Figure 9: average GHG emissions performance - passenger automobiles**

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
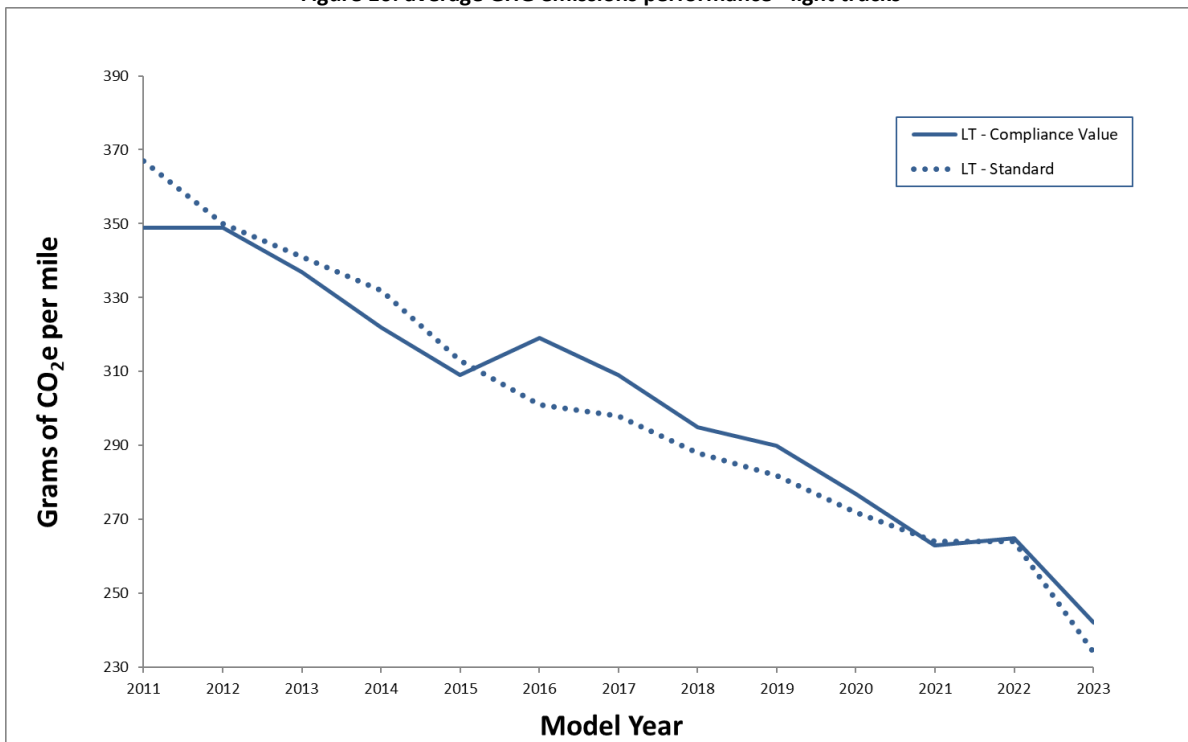
As depicted in Figures 9 and 10, the 2023 model year saw the overall compliance value for passenger automobiles decrease to 128 g/mi, and the overall compliance value for light trucks decrease to 242 g/mi. This has resulted in an overall net improvement of 49.8% and 30.7% relative to the 2011 model year 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
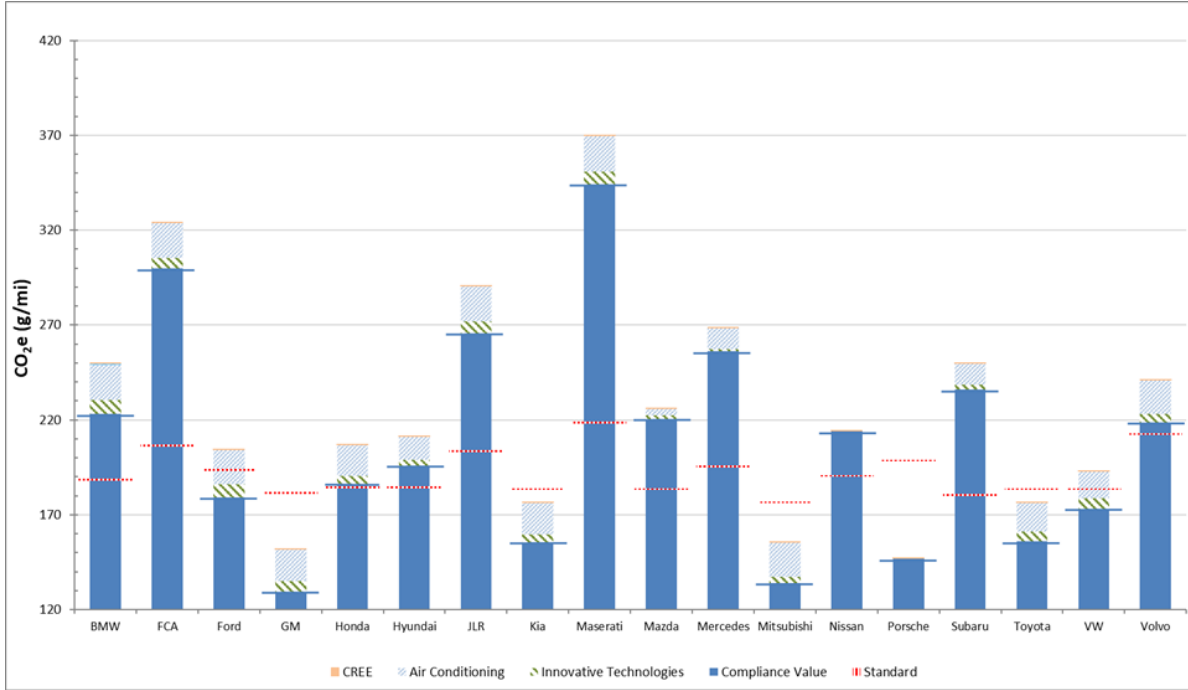
Notes:
1. The final compliance value may be lower than the CREE through the application of compliance flexibilities
2. Tesla, Rivian and VInFast produce electric vehicles, whose compliance values fall outside of the range of this graph.
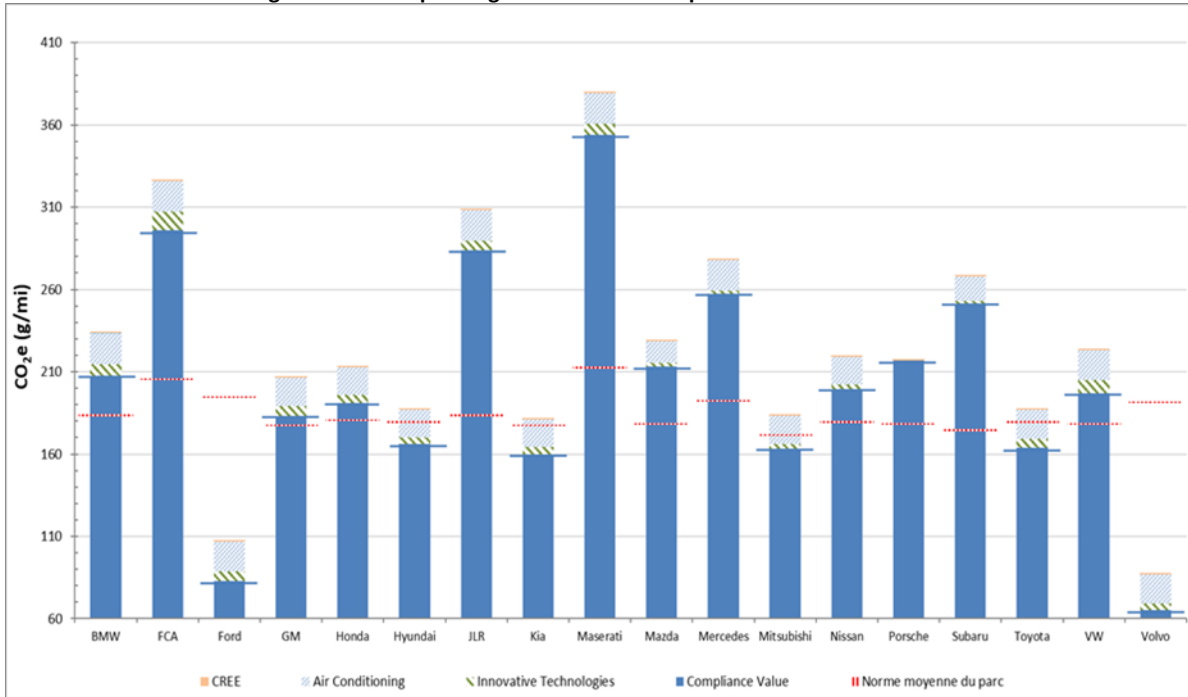
Figure A-2: 2021 passenger automobile compliance status with offsets

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.
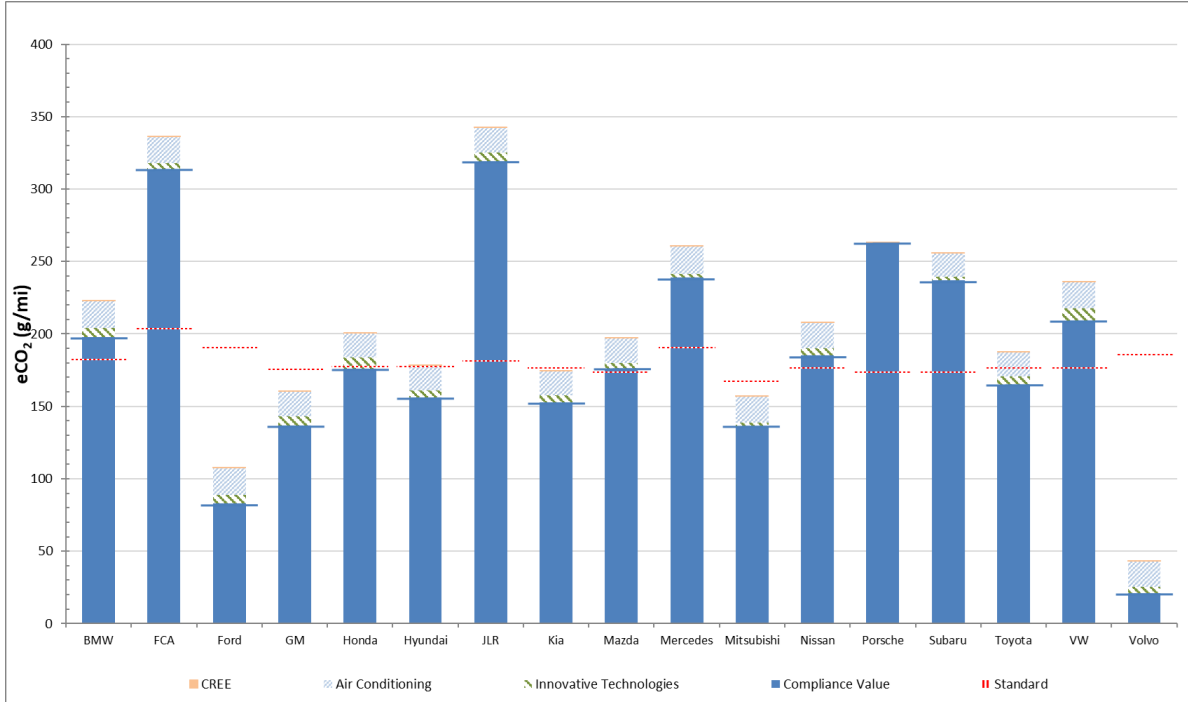
Figure A-5: 2021 light truck compliance status with offsets
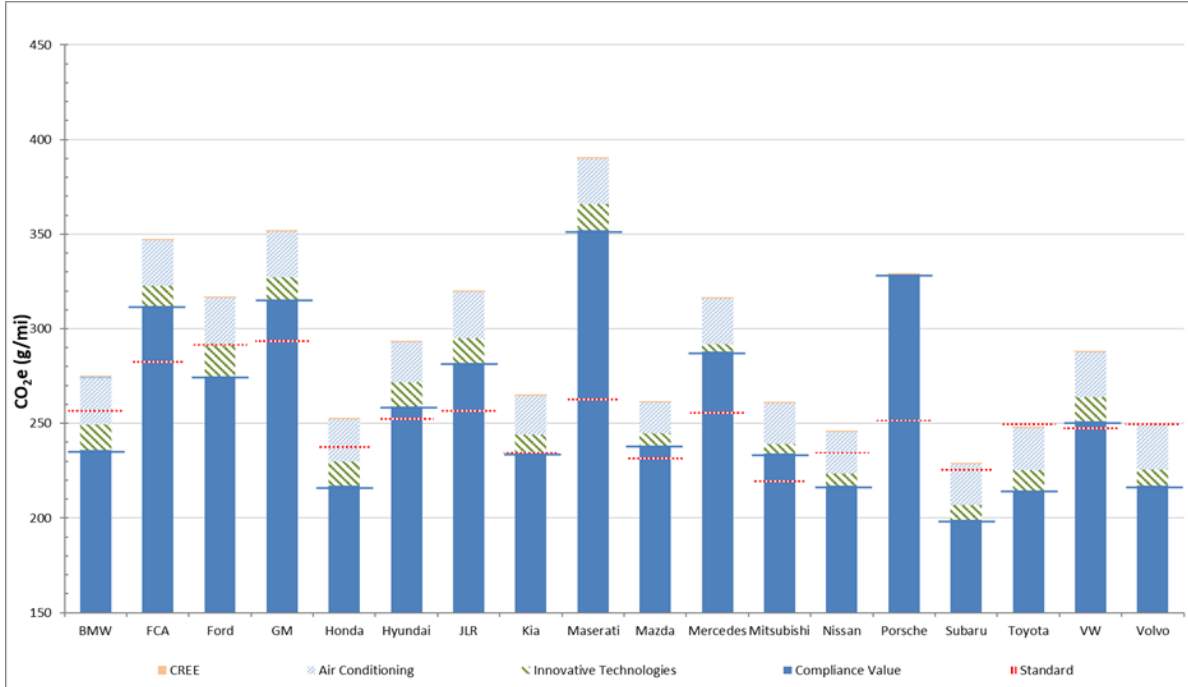
Notes:
1.   The final compliance value may be lower than the CREE through the application of compliance flexibilities
2.   Tesla, Rivian and VInFast produce electric vehicles, whose compliance values fall outside of the range of this graph.
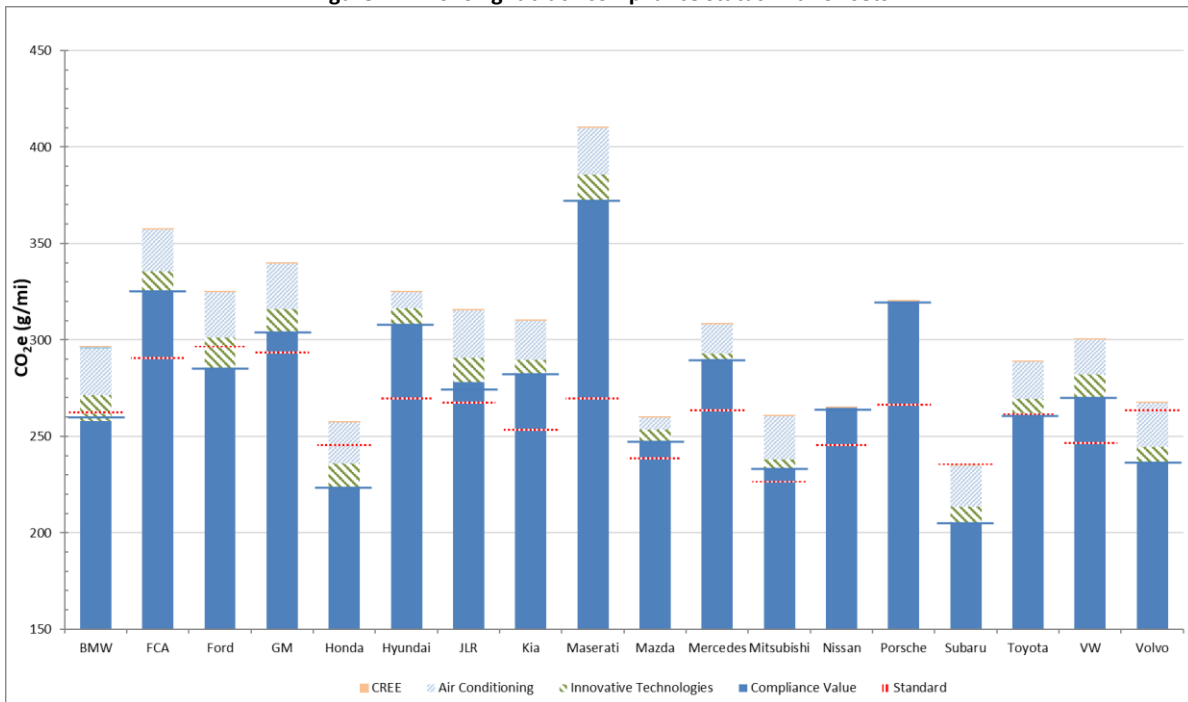
Figure A-6: 2022 light truck compliance status with offsets

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.
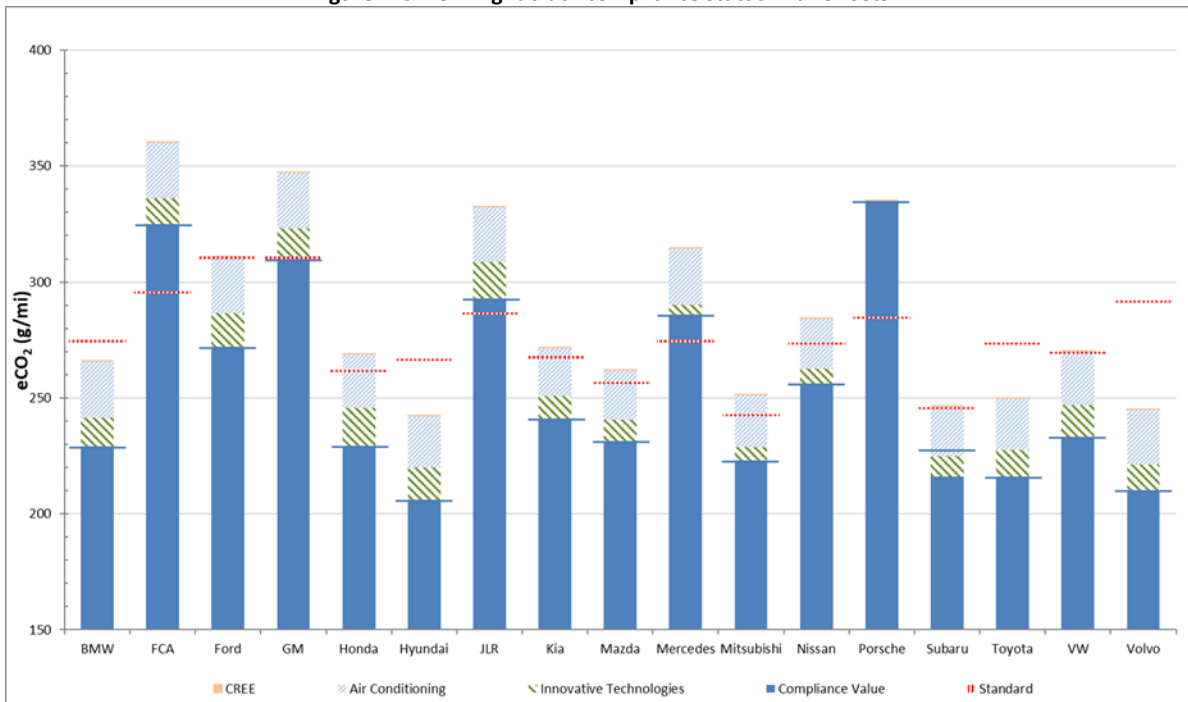
Technology	Passenger automobiles (g/mi)	Light Trucks (g/mi)
Reduced reheat, with externally-controlled, variable-displacement compressor (for example, a compressor that controls displacement based on temperature set point and/or cooling demand of the air conditioning system control settings inside the 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