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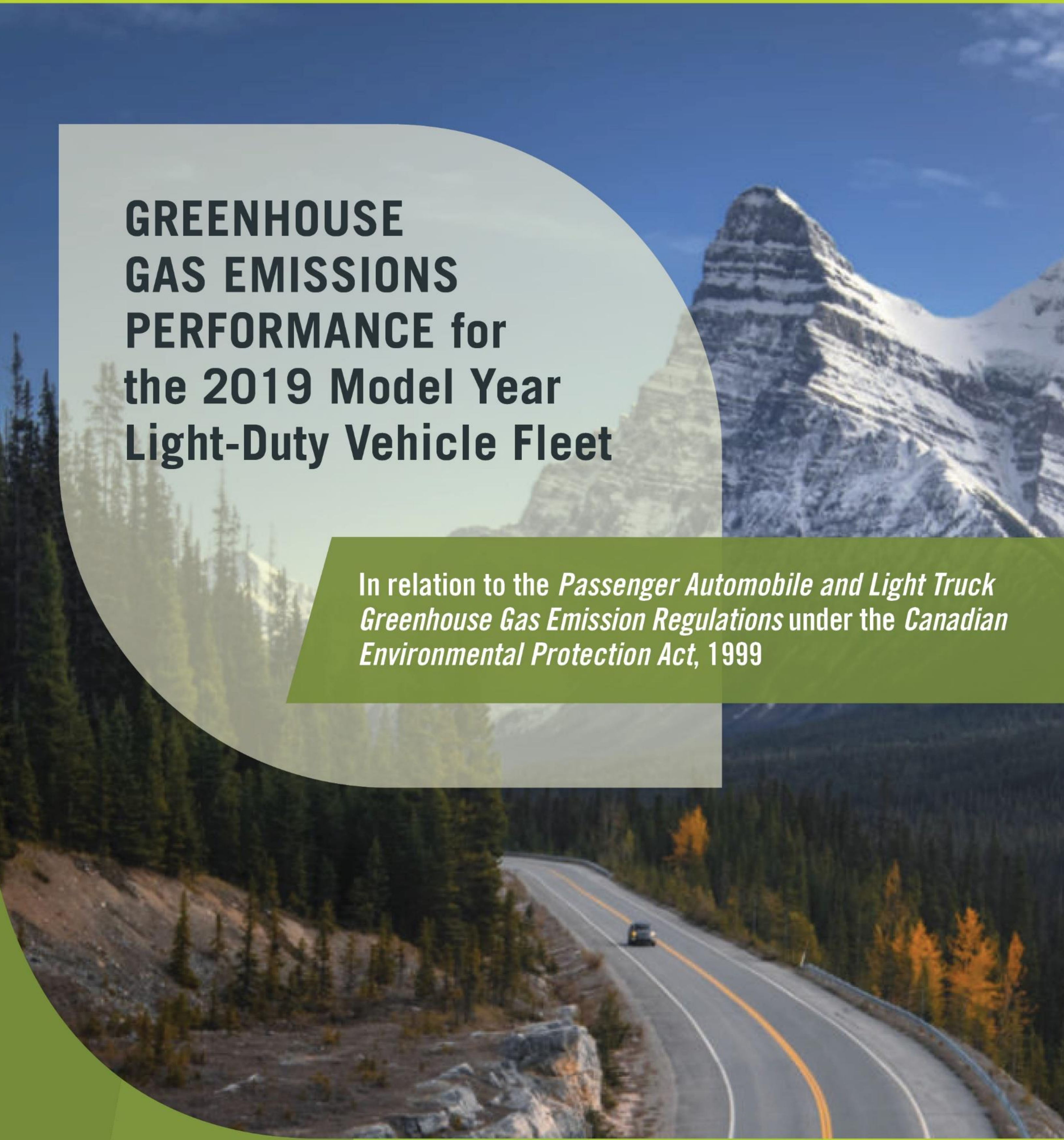

GREENHOUSE GAS EMISSIONS PERFORMANCE for the 2019 Model Year Light-Duty Vehicle Fleet

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

Notice

The information contained in this report is compiled from data reported to Environment and Climate Change Canada pursuant to the *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* under the *Canadian Environmental Protection Act, 1999*. Information presented in this report is subject to ongoing verification.

Cat. No.: En11-15E-PDF
ISSN: 2560-9017
EC21103

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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

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

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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 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 and 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 subject 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 as they are a function of 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 U.S. Environmental Protection Agency (EPA) and are progressively more stringent over the 2012 through 2025 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 33.3% and 23.2% 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

[1] CO_2e is used throughout this report as a common unit to standardize the environmental impacts of different greenhouse gases (such as N_20 & CH_4) in terms of an equivalent amount of CO_2.
[2] On February 12, 2021, the Government of Canada published the final decision document concluding the mid-term evaluation of its light-duty vehicle regulations. ECCC will continue to collaborate with the U.S. federal government and California on developing new GHG emission standards for light-duty vehicles in the short-term and for post-2025.

is incurred if a company's fleet performance is above their applicable standard). This allows companies to 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 of their new light duty vehicles available in Canada beginning with the 2011 model year. These regulations have pushed companies to meet these engineering challenges through the introduction of a wide variety of new and innovative technologies. To meet the regulatory standards, companies have not only continued to improve upon conventional internal combustion engine technologies but have incorporated an array of innovative approaches such as active aerodynamics, advanced materials for light-weighting, solar reflective paint, high efficiency lighting and more. Companies have also been driven to increase the availability of advanced technology vehicles with lower GHG emissions, which consist of battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), fuel cell electric vehicles (FCEV) and natural gas vehicles. In fact, since the introduction of the regulation the production volume of battery electric vehicles has increased from 198 to 31 425 and the production volume of plug-in hybrid electric vehicles has increased from zero to 13 930. The sum of these developments within the Canadian vehicle fleets have resulted in measureable improvements to GHG emissions performance.

Results from regulatory reports indicate that companies continue to be in compliance through to the 2019 model year. The average compliance value for the fleet of new passenger automobiles decreased from 255 g/mi to 194 g/mi since the introduction of the regulation, representing a 23.9% reduction. The compliance value for light trucks decreased by 16.9%, from 349 g/mi to 290 g/mi since the introduction of the regulation. The 2016 model year marked the first time the fleet average compliance value exceeded the fleet average emission standard for both passenger automobiles and light trucks. Although the fleet average compliance values for both passenger automobiles and light trucks continued a downward trend in the 2019 model year, they have stayed at or above the fleet average emission standard. 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. To date, companies have generated a total of approximately 86.6 million credits, of which, approximately 24.5 million remain available for future use. A total of 24.3 million credits have been used to offset emission deficits by individual companies over the 2011 to 2019 model years, of which 4.7 million credits were used to offset deficits accrued in the 2019 model year. The remaining 37.8 million credits have expired.

1. Purpose of the report

The purpose of this report is to provide company specific results of the fleet average greenhouse gas emission 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 2018 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 also helps to identify 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 Government of Canada's first 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 2025 in alignment with the U.S. national standards, thereby establishing a common North American approach.

The department monitors compliance with the fleet average requirements through annual reports submitted pursuant to the regulations. These reports are used to establish each company's fleet average GHG performance and the applicable standard for both its passenger automobile and light truck fleets. As part of the regulatory compliance mechanism, companies may accrue emission credits or deficits, depending on their fleet performance relative to the standard. These reports also enable the department to track emission credit balances and transfers. There are in excess of 10 000 data elements collected each reporting cycle. ECCC has a process to review and validate 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 2016 to 2019 model years are listed in Table 1.

Table 1: Model year report submission status

Manufacturer	Common Name	2016	2017	2018	2019
Aston Martin Lagonda Ltd.	Aston Martin	LVM[a]	LVM[a]	LVM[a]	LVM[a]
BMW Canada Inc.	BMW	*	*	*	*
FCA Canada Inc.	FCA	*	*	*	*
Ferrari North America Inc.	Ferrari	LVM[a]	LVM[a]	LVM[a]	LVM[a]

[3] The department has released 5 reports documenting the overall fleet performance from earlier model years.
[4] The regulations, along with amendments, and the accompanying regulatory impact analysis statement

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]	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	*	*	*	*
Nissan Canada Inc.	Nissan	*	*	*	*
Pagani Automobili SPA, Italy	Pagani	LVM[a]	LVM[a]	LVM[a]	LVM[a]
Porsche Cars Canada, Ltd.	Porsche	*	*	*	*
Subaru Canada Inc.	Subaru	*	*	*	*
Tesla Motors, Inc.	Tesla	*	*	*	*
Toyota Canada, Inc.	Toyota	*	*	*	*
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.

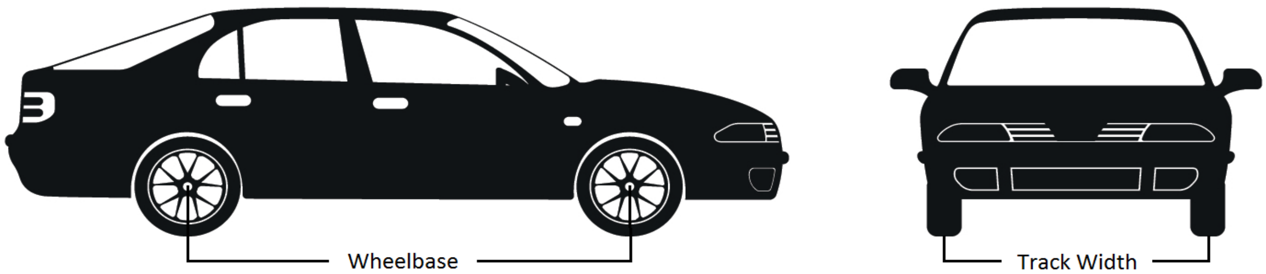
2.1. CO_2e emission standards

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[5] to the first retail purchaser[6]. These standards are performance-based in that they establish a maximum amount of CO_2e on a gram per mile basis. This approach allows companies to choose the most cost-effective technologies to achieve compliance and reduce emissions, rather than requiring a particular technology.

[5] 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.

[6] 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.

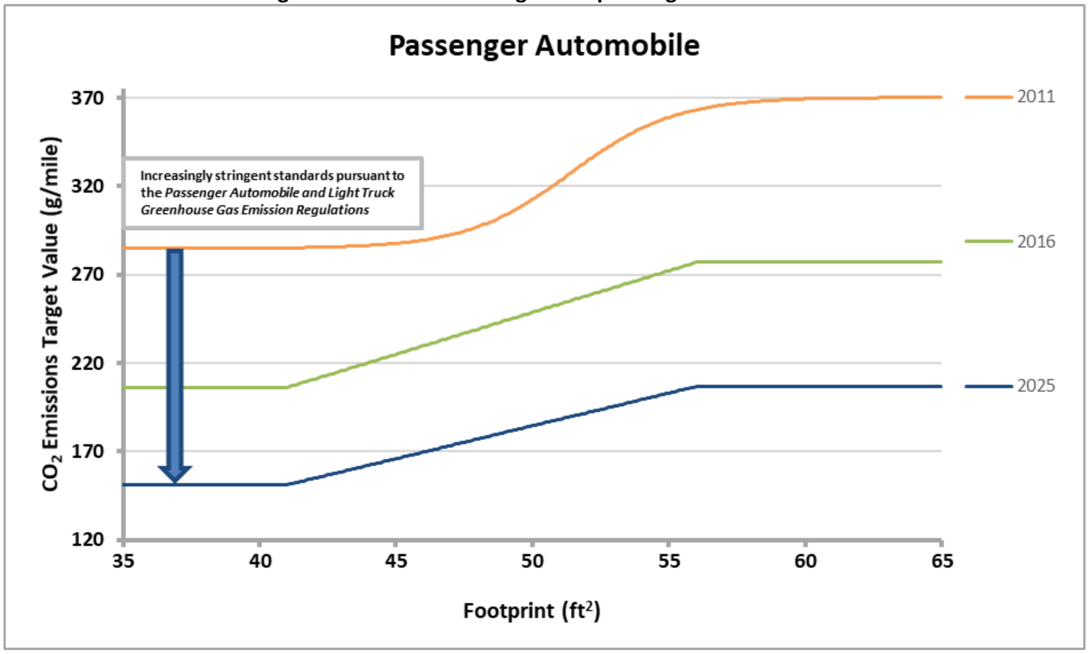
Figure 1. Vehicle footprint



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

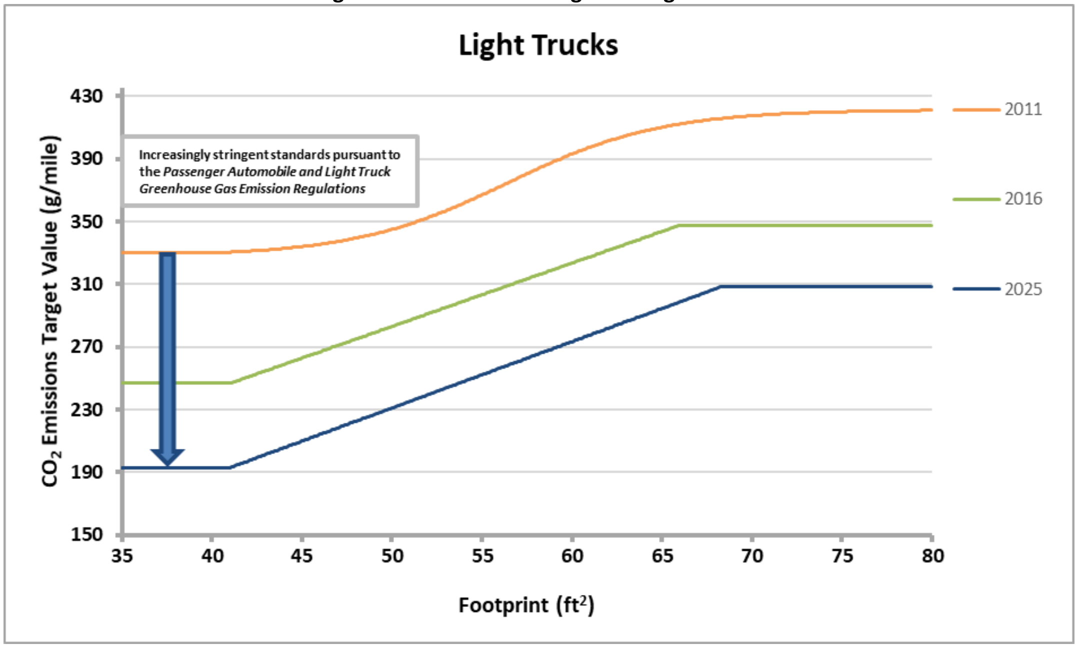
The regulations prescribe progressively more stringent target values for a given footprint size over the 2011 through 2025 model years[7]. Figures 2 and 3 illustrate the target values for passenger automobiles and light trucks, respectively.

Figure 2. 2011 to 2025 targets for passenger automobiles



[7] See footnote 2

Figure 3. 2011 to 2025 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 year[8]. The CO_2e standard was derived using a conversion factor of 8 887 grams of CO_2 /gallon of gasoline[9] 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 of the target values using the following formula:

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[8] 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

[9] 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.

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

where
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; and
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 2016 to 2019 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	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	230	216	208	196	286	283	274	270
FCA	242	234	228	218	303	312	295	301
Ford	232	220	209	202	325	308	310	303
GM	230	218	204	192	322	320	310	298
Honda	224	214	204	193	275	274	261	258
Hyundai	227	216	206	196	280	278	266	258
JLR	309	244	242	219	316	286	286	278
Kia	227	216	204	195	286	277	267	263
Maserati	--	--	--	231	--	--	--	278
Mazda	223	212	202	189	270	267	256	249
Mercedes[10]	232	225	213	205	292	287	274	263
Mitsubishi	218	203	195	183	260	253	242	234
Nissan	227	216	205	191	278	282	273	261
Porsche	275	215	224	194	361	285	284	277
Subaru	221	210	199	189	261	257	245	241
Tesla	268	254	226	211	--	--	292	284
Toyota	224	212	201	192	289	286	273	265
Volkswagen	222	211	201	190	270	273	269	264
Volvo	293	242	245	222	360	288	291	274
Fleet Average	227	216	205	194	301	298	288	282

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 flexibility such as the "temporary optional fleet" standards which were available until the 2016 model year and allowed intermediate sized companies to have a portion of their fleet comply with a standard that was 25% less stringent. This provision (discussed in greater detail in section 2.3.7.) was used by Porsche, Volvo, Mercedes, and JLR and is the reason for their elevated standard in those years.

[10] Mercedes split its production volumes into conventional and temporary optional fleets (section 2.3.7.) for the 2012 to 2016 model years. For the purposes of this report, a single overall fleet average standard value has been calculated for those years.

Table 3. Average footprint for the 2016 to 2019 model years (sq. ft.)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	45.9	45.6	46.3	45.9	50.7	50.4	50.8	51.9
FCA	48.3	49.3	50.9	51.2	55.3	57.8	56.1	59.0
Ford	46.4	46.7	46.6	47.4	62.9	58.3	61.3	60.7
GM	45.8	45.8	45.2	44.3	60.3	60.9	60.2	59.7
Honda	44.6	45.1	45.4	45.2	48.0	48.6	48.2	49.2
Hyundai	45.4	45.8	45.9	45.9	49.2	49.2	49.2	49.2
JLR	49.7	48.9	48.7	48.8	50.9	50.8	50.7	51.7
Kia	45.4	45.7	45.3	45.7	50.7	49.2	49.3	50.3
Maserati	--	--	--	54.3	--	--	--	53.4
Mazda	44.4	44.8	44.8	44.2	46.8	47.0	47.3	47.3
Mercedes	45.4	47.4	47.2	48.0	52.2	51.3	50.9	50.3
Mitsubishi	43.4	41.8	42.3	41.7	44.2	44.0	44.2	44.1
Nissan	45.1	45.4	45.5	44.6	48.7	50.4	50.8	49.9
Porsche	42.4	42.3	44.4	42.8	51.4	50.5	50.3	51.6
Subaru	44.0	44.5	44.4	44.4	44.6	44.8	44.9	45.7
Tesla	54.1	54.2	50.4	49.6	--	--	54.8	54.8
Toyota	44.6	44.8	44.7	44.9	51.8	51.7	51.1	50.9
Volkswagen	45.5	44.5	44.7	44.6	46.8	48.4	50.0	50.4
Volvo	47.0	48.7	49.2	49.7	51.3	51.2	52.1	50.9
Fleet Average	45.3	45.5	45.5	45.3	54.9	54.9	54.8	55.1

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 2016 to 2019 model years are presented in Table 4.

Table 4. Fleet average carbon related exhaust emissions (g/mi)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	263	249	258	246	311	309	300	292
FCA	297	310	314	311	358	373	360	368
Ford	257	260	241	249	376	349	347	341
GM	251	209	191	179	363	362	349	349
Honda	206	205	202	207	274	267	255	264
Hyundai	248	246	241	222	338	340	337	342
JLR	334	299	277	330	350	338	316	304
Kia	245	233	223	203	338	322	322	315
Maserati	--	--	--	376	--	--	--	421
Mazda	210	217	215	223	259	266	259	266
Mercedes	260	275	264	275	327	329	316	320
Mitsubishi	231	213	151	162	272	271	264	261
Nissan	231	236	204	202	273	293	294	288
Porsche	331	294	291	322	336	319	318	317
Subaru	249	251	254	243	252	248	242	241
Tesla[11]	0	0	0	0	--	--	0	0
Toyota	220	216	205	200	330	315	315	290
Volkswagen	241	237	255	221	304	321	296	292
Volvo	289	265	257	262	299	267	267	272
Fleet Average	238	232	220	211	337	334	323	320

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 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

[11] Tesla only produces battery electric vehicles and uses 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.

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:

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

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 2016 to 2019 model years.

Table 5. Allowance for reduction in AC refrigerant leakage (g/mi)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	4.7	13.7	13.6	13.5	7.0	16.9	16.9	17.2
FCA	13.3	13.6	13.8	13.7	14.0	14.8	15.8	15.6
Ford	5.5	11.7	12.8	12.8	7.8	14.4	15.5	16.3
GM	6.2	8.5	12.3	12.3	7.0	15.1	16.7	16.4
Honda	8.3	9.7	11.6	12.7	6.4	13.5	15.6	16.5
Hyundai	2.5	2.8	5.4	10.6	1.6	1.6	2.2	1.7
JLR	13.8	13.8	13.8	13.7	17.2	17.2	17.2	17.2
Kia	2.3	5.4	8.2	12.7	2.1	8.6	7.9	15.4
Maserati	--	--	--	5.9	--	--	--	7.7
Mazda	0.0	0.0	2.7	1.5	0.0	0.0	4.3	5.0
Mercedes	5.7	5.8	5.9	6.2	4.0	7.2	7.6	7.4
Mitsubishi	2.0	2.7	9.8	7.8	7.0	6.1	13.1	13.5
Nissan	4.5	4.2	6.2	8.6	7.1	6.8	6.9	7.4
Porsche	0.8	13.7	13.5	12.6	6.7	12.1	14.4	6.5
Subaru	0.0	1.9	1.4	1.4	0.0	5.8	4.5	9.1
Tesla	0.0	0.0	5.7	12.7	--	--	5.2	11.2
Toyota	3.3	3.3	5.2	8.1	6.6	6.5	7.5	11.1
Volkswagen	4.8	4.7	12.3	13.2	7.4	7.1	15.6	15.7
Volvo	0.0	5.3	5.1	4.9	0.0	6.5	6.9	7.4
Fleet Average	4.7	6.0	8.4	10.3	8.5	12.0	13.3	14.2

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 2012 through 2016 model years, the maximum allowance value a company could claim for improvements in air conditioning efficiency was capped at 5.7 g/mi. 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:

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

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 2016 to 2019 model years.

Table 6. Allowance for improvements in AC system efficiency (g/mi)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	4.4	4.8	4.9	4.9	4.3	5.5	6.3	7.0
FCA	5.2	4.8	4.7	4.7	4.2	5.6	5.9	5.8
Ford	2.7	3.4	4.0	4.3	3.5	6.1	6.8	6.7
GM	3.5	3.8	4.2	3.9	4.2	6.4	6.6	6.5
Honda	3.3	3.3	3.6	3.7	2.9	5.5	5.8	6.3
Hyundai	3.6	3.3	3.4	3.5	4.2	5.4	5.2	5.4
JLR	5.7	5.0	5.0	5.0	5.7	7.2	7.2	7.2
Kia	3.3	3.1	3.2	3.6	3.4	5.2	5.2	5.4
Maserati	--	--	--	4.9	--	--	--	7.2
Mazda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mercedes	5.2	4.9	5.0	5.0	5.3	7.1	7.1	5.8
Mitsubishi	0.0	0.4	2.2	1.9	0.0	2.9	3.0	3.0
Nissan	3.1	3.5	3.9	4.0	3.0	4.2	4.0	4.2
Porsche	3.9	5.0	5.0	5.0	5.7	7.2	7.2	7.2
Subaru	2.9	3.1	3.2	3.2	3.0	4.7	4.8	5.8
Tesla	5.7	5.0	5.0	5.0	--	--	7.2	7.2
Toyota	3.9	4.4	4.2	4.6	4.3	6.9	6.0	6.4
Volkswagen	4.4	4.1	4.8	4.9	5.2	5.9	7.1	7.1
Volvo	0.0	4.2	4.0	4.8	0.0	5.4	6.2	6.2
Fleet Average	3.4	3.5	3.7	3.9	3.7	5.8	6.0	6.0

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:

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

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 2016 to 2019.

Table 7. Allowance for the use of innovative technologies (g/mi)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	3.7	3.2	3.6	4.4	6.5	6.7	8.1	10.8
FCA	3.7	3.7	4.3	4.8	8.6	8.1	10.4	11.6
Ford	3.2	5.3	5.5	6.3	8.5	11.4	13.4	14.9
GM	4.4	5.3	7.0	5.9	6.2	7.7	8.8	9.9
Honda	1.7	3.9	4.1	4.1	2.5	8.3	8.5	9.4
Hyundai	1.1	1.5	2.4	2.1	5.3	5.6	5.7	5.3

JLR	3.2	4.2	6.9	5.5	7.4	7.4	12.4	12.2
Kia	1.2	1.9	2.0	2.8	4.1	3.4	4.5	4.7
Maserati	--	--	--	6.0	--	--	--	13.1
Mazda	0.0	0.0	1.4	1.9	0.0	0.0	4.6	5.1
Mercedes	3.3	1.0	3.9	1.5	4.6	2.1	3.3	2.5
Mitsubishi	0.0	0.0	2.4	1.7	0.0	0.0	1.4	1.4
Nissan	1.7	2.2	2.2	2.0	3.3	5.7	6.0	5.9
Porsche	2.5	2.7	3.2	2.0	4.4	3.5	3.1	9.8
Subaru	0.3	0.9	2.0	2.1	0.1	0.7	4.9	6.2
Tesla	0.0	0.0	4.8	4.6	0.0	0.0	8.3	8.3
Toyota	1.2	3.7	4.1	4.4	3.2	7.1	6.8	8.4
Volkswagen	2.1	2.8	0.0	0.0	1.7	5.7	0.0	0.0
Volvo	0.0	3.6	6.7	4.7	0.0	5.7	11.4	8.4
Fleet Average	2.0	3.0	3.3	3.1	5.9	7.5	8.5	9.6

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:

$$\boldsymbol{H} = \frac{\boldsymbol{\Sigma}\,(\mathbf{A}_{\mathrm{H}} \times \mathbf{B}_{\mathrm{H}}) + \boldsymbol{\Sigma}\,(\mathbf{A}_{\mathrm{R}} \times \mathbf{B}_{\mathrm{R}})}{\mathbf{C}}$$

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 2019 model year no companies made use of the allowance for certain full-size pick-up trucks.

2.3.5. Dual fuel vehicles

Alcohol dual fuel vehicles[13] [for example, flexible fuel vehicles (FFVs)] are vehicles with a traditional internal combustion engine that can operate on conventional fuels, but are also capable of operating on fuel blends of up to 85% ethanol (E85). The regulations contain provisions to allow a company to improve their fleet average GHG emissions for the 2011 to 2015 model years through the sale of such vehicles. Beginning with the 2016 model year the regulations require a manufacturer to establish whether ethanol is actually used to benefit from this allowance.

The following formula is used to calculate the emissions benefit resulting from FFVs for the 2011 to 2015 model years.

$$\mathrm{CREE} = \frac{\mathrm{CREEgas} + (\mathrm{CREEalt} \times 0.15)}{2}$$

where
CREEgas is the combined model type carbon related exhaust emissions value for operation on gasoline or diesel;
CREEalt is the combined model type carbon related exhaust emissions value for operation on alternative fuels;

The regulations limit the improvements to the fleet average CREE value that a company can achieve through the use of FFVs in a manner that is consistent with the CAFE program. Under the CAFE program, fuel economy improvements are limited to a pre-set amount based on the model year in question. The following formula is used to quantify the CAFE fuel economy limits in terms of CO_2e emissions.

$$\text{Maximum Decrease} = \frac{8887}{\frac{8887}{\mathrm{FltAvg}} - \mathrm{MPGmax}} - \mathrm{FltAvg}$$

where

[13] Natural gas dual fuel vehicles are not discussed in this report due to negligible (<10) production volumes in Canada.

FltAvg is the fleet average CREE value assuming all FFVs in the fleet are operated exclusively on gasoline (or diesel) fuel;
$\boldsymbol{MPG_{MAX}}$ is the maximum increase in miles per gallon for a specific model year[14]

The treatment of FFVs for the 2011 to 2015 model years assumes equal weighting for both conventional and alternative fuel usage, and did not require evidence that the alternative fuel was used during real-world operation. Starting with the 2016 model year, companies can only make use of this provision where they can demonstrate that their vehicles are using the alternative fuel in the marketplace (such as E85). The following formula is used to determine the CREE for FFVs beginning with the 2016 model year, where the weighting factor "F" is 0 unless the company can provide evidence that an alternate value is more appropriate.

$$\mathrm{CREE} = [(1 - \mathrm{F}) \times \mathrm{CREEgas}] + (\mathrm{CREEalt} \times \mathrm{F})$$

No companies reported the use of alternative fuels (such as E85) for the 2016 to 2019 model years and hence were not eligible to reduce their CREE as a result of FFV sales.

2.3.6. 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) subject to the limitations described in the following paragraph. 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

[14] MPGmax is 1.2 for 2012 to 2014 & 1.0 for 2015

2022 to 2025	1.5	1.3	1.0

While the production of the electricity required to charge BEVs and PHEVs and the production of hydrogen for FCEVs result in upstream emissions, the approach of allowing companies to report 0 g/mi is intended to promote the adoption of advanced technology vehicles over the short term. The regulations provide 2 options for the quantity of vehicles that can be reported as 0 g/mi. For vehicles of the 2011 to 2016 model years, a company may report 0 g/mi for:

a. the first 30 000 cumulative ATVs if it sold fewer than 3 750 ATVs in the 2012 model year, or
b. the first 45 000 cumulative ATVs if it sold 3 750 or more in model year 2012.

The regulations also recognize early action for ATVs sold during the 2008 to 2010 model years. If a company claimed early action credits (discussed in section 3.1), the production volumes that were reported in the 2008 to 2010 model years will also be counted towards this ATV cap. Any ATVs sold in excess of these caps are required to adjust the 0 g/mi CREE such that it incorporates the CO_2 contribution from upstream emissions. The regulations do not limit the number of ATVs that can be reported as 0 g/mi between model years 2017 to 2021 inclusive. 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	2016	2017	2018	2019
BMW	18	96	70	69
FCA	--	--	--	--
Ford	136	522	682	--
GM	45	2 133	1 474	5 445
Honda	--	--	--	--
Hyundai	--	653	394	4 573
JLR	--	--	--	365
Kia	1 063	477	964	1 186
Mazda	--	--	--	--
Mercedes	190	106	442	141
Mitsubishi	120	85	--	--
Nissan	1 620	884	4 440	4 340
Porsche	--	--	--	--
Subaru	--	--	--	--
Tesla	2 963	3 483	8 961	13 364
Toyota	--	--	--	--
Volkswagen	293	705	808	1942
Volvo	--	--	--	--
Total	6 454	9 144	18 235	31 425

Table 10. Production volumes of PHEVs by model year

Manufacturer	2016	2017	2018	2019
BMW	587	712	1 047	656
FCA	--	739	1 578	600
Ford	635	1 991	2 106	1 513
GM	720	5 728	5 400	2 675
Honda	--	--	850	910
Hyundai	55	128	1 024	1 622

JLR	--	--	--	--
Kia	--	110	45	1 150
Mazda	--	--	--	--
Mercedes	8	76	330	147
Mitsubishi	--	--	5 380	2 088
Nissan	--	--	--	--
Porsche	311	417	692	415
Subaru	--	--	--	--
Tesla	--	--	--	--
Toyota	--	1 164	3 606	1 600
Volkswagen	--	483	609	--
Volvo	278	615	538	554
Total	2 594	12 163	23 205	13 930

2.3.7. 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[15]) 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	2016	2017	2018	2019
Aston Martin	91	82	44	148
Ferrari	135	275	247	364
Maserati	344	1 369	1 000	--
McLaren	121	112	220	195
Lotus	0	13	12	0
Pagani	1	0	0	0
Total	692	1 851	1 523	707

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

2.3.8. Flexibilities for intermediate sized companies

The regulations included an option for intermediate sized companies to meet an alternative standard between the 2012 to 2016 model years inclusive. The regulation defines an intermediate sized company as one with a 2009 model year total production volume of 60 000 or fewer vehicles. This provision was intended to provide intermediate sized companies that have a less varied product line additional time to transition to the more stringent standards. Companies using this option could place a portion of their fleet into a temporary optional fleet (TOF) in which the standard is 25% less stringent than what would otherwise be required. The total number of vehicles that a company could put into a temporary optional fleet was subject to limitations based on the quantity of vehicles offered for sale. A company that sold between 750 and 7 500 new vehicles of the 2009 model year could create a TOF with a cumulative total of up to 30 000 vehicles of the 2012 to 2015 model years, and up to 7 500 vehicles of the 2016 model year. A company that sold between 7 500 and 60 000 new vehicles of the 2009 model year could only include a cumulative total of up to 15 000 vehicles of the 2012 to 2015 model years but could not include any vehicles of the 2016 model year. Companies that elect to create TOFs cannot use the resulting credits to offset a deficit incurred for a non-TOF portion of their fleet, nor could they bank credits earned by a non-TOF portion of their fleets.

Volvo and Porsche were able to place all of their vehicles of the 2012 to 2016 model years into temporary optional fleets which are valid up to the 2016 model year because their 2009 sales were between 750 and 7 500. Mercedes and JLR also created TOFs; however, as larger companies, they were limited to 15 000 vehicles over the 2012 to 2015 model years which required them to split their fleets of vehicles into both conventional fleets and TOFs.

Table 12. Production volumes of temporary optional fleets

Manufacturer	2014 PA	2015 PA	2016 PA	2014 LT	2015 LT	2016 LT
JLR	1 179	1 507	1 282	6 183	6 188	4 655
Mercedes	1 698	2 025	--	977	1 085	--
Porsche	2 018	1 549	1 585	2 599	3 340	5 081
Volvo	607	3 272	891	1 662	3 139	4 885
Total	5 502	8 353	3 758	11 421	13 752	14 621

Starting with the 2017 model year, any intermediate volume companies that were eligible to use temporary optional fleets are allowed to follow an alternative schedule of annual target values for model years 2017 to 2020, as shown in Table 13. As of model year 2021, these companies will have to comply with the prescribed target value for that model year. Any company that elects to use the alternative schedule will not be permitted to sell any emission credits obtained against these standards to any other regulated company.

Table 13. Alternative schedule of fleet average CO2e emission standards for eligible intermediate volume companies

Model Year	Applicable Fleet Average CO_2e Emission Standard
2017	2016
2018	2016
2019	2018
2020	2019

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 conform to the standards for N_2O and CH_4.

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 potential of these 2 gases. 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 14 and 15.

Table 14. N_2O emissions deficits by company for the 2016 to 2019 model years (Mg CO_2e)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	-2 062	-1 215	-2 284	--	-5 853	-3 276	-3 920	--
FCA	--	--	--	--	--	-10 957	-23 275	-6 269
Ford	-248	-2 124	-715	-847	-4 733	-47 486	-17 047	-10 562
GM	--	-645	-1 166	-236	-1 615	-3 114	-6 146	-4 501
Hyundai	--	--	-331	-999	--	--	--	--
JLR	--	-1 379	-1 999	-62	--	-2 830	-9 638	-3 935
Kia	--	--	-2 211	-1 447	--	--	--	--
Mazda	--	-807	-1 449	-360	-480	-5 436	-4 324	-12 750
Nissan	-5 595	-930	-414	--	-23 617	--	--	--
Toyota	-1 729	-2 219	-1 306	-1 466	-2 647	-3 599	-2 289	-3 490
Volkswagen	-215	--	--	--	-852	--	--	-300
Fleet Total	-9 849	-9 319	-11 875	-5 417	-39 797	-76 698	-66 639	-41 807

Table 15. CH_4 emissions deficits by company for the 2016 to 2019 model years (Mg CO_2e)

Manufacturer	2016 PA	2017 PA	2018 PA	2019 PA	2016 LT	2017 LT	2018 LT	2019 LT
BMW	-260	-153	-288	--	-737	-412	-493	--
FCA	-3	-7	-3	-3	-2 384	-1 296	-3 215	-3 001

Ford	-964	-532	-152	-155	-20 322	-8 296	-18 801	-13 041
GM	-137	-81	-357	-137	-708	-1 791	-1 969	-762
Mazda	--	-136	-340	-474	--	-475	-121	-401
Nissan	-436	--	--	--	-1 981	--	--	--
Volkswagen	-40	-85	-74	-15	-115	--	--	--
Fleet Total	-1 840	-994	-1 214	-784	-26 247	-12 270	-24 599	-17 205

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 16 and 17 show both the companies' compliance and standard values for the passenger automobiles and light truck fleets across the 2016 to 2019 model years.

Table 16. PA Compliance and Standard values over the 2016 to 2019 model years (g/mi)

Manufacturer	2016 Compliance	2017 Compliance	2018 Compliance	2019 Compliance	2016 Std.	2017 Std.	2018 Std.	2019 Std.
BMW	250	227	236	223	230	216	208	196
FCA	275	288	291	288	242	234	228	218
Ford	246	240	219	226	232	220	209	202
GM	237	191	168	157	230	218	204	192
Honda	193	188	183	187	224	214	204	193
Hyundai	241	238	230	206	227	216	206	196
JLR	311	276	251	306	309	244	242	219
Kia	238	223	210	184	227	216	204	195
Maserati	--	--	--	359	--	--	--	231
Mazda	210	217	211	220	223	212	202	189
Mercedes	246	263	249	262	232	225	213	205
Mitsubishi	229	210	137	151	218	203	195	183
Nissan	222	226	192	187	227	216	205	191
Porsche	324	273	269	302	275	215	224	194
Subaru	246	245	247	236	221	210	199	189

Tesla[16]	-6	-5	-16	-22	268	254	226	211
Toyota	212	205	192	183	224	212	201	192
Volkswagen	230	225	238	203	222	211	201	190
Volvo	289	252	241	248	293	242	245	222
Fleet Average	228	220	205	194	227	216	205	194

Table 17. LT Compliance and Standard values over the 2016 to 2019 model years (g/mi)

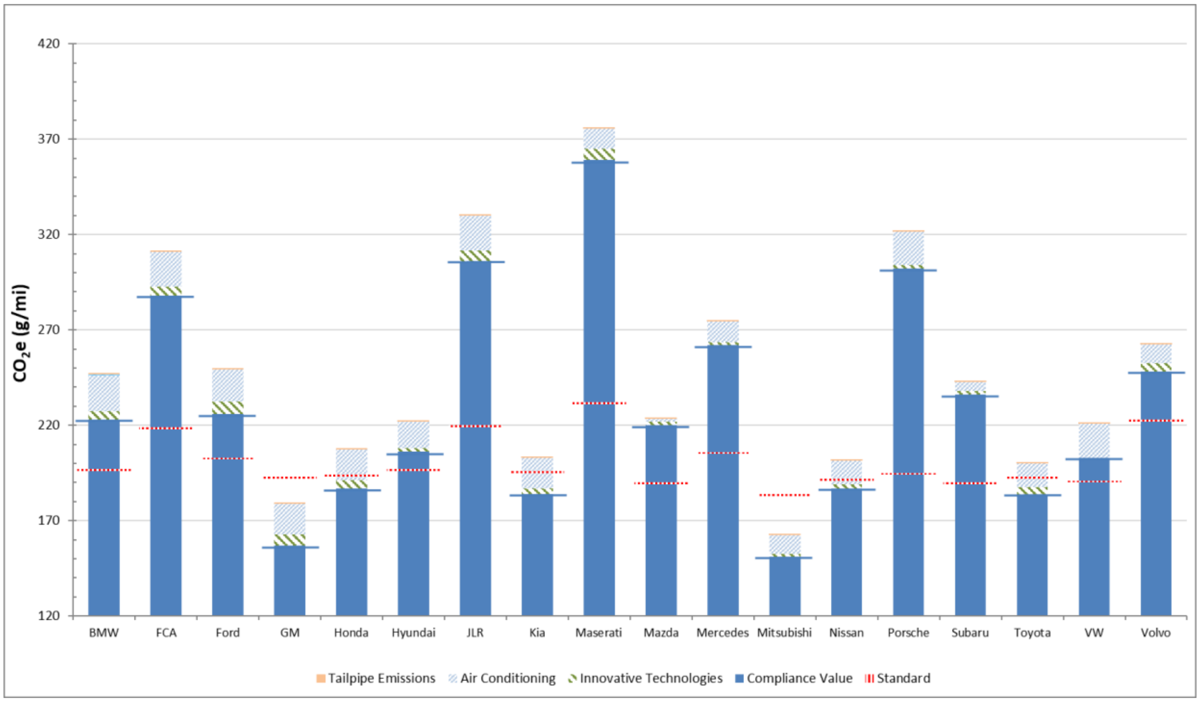
Manufacturer	2016 Compliance	2017 Compliance	2018 Compliance	2019 Compliance	2016 Std.	2017 Std.	2018 Std.	2019 Std.
BMW	293	280	269	257	286	283	274	270
FCA	331	345	327	335	303	312	295	301
Ford	356	317	311	303	325	308	310	303
GM	346	333	317	316	322	320	310	298
Honda	262	240	225	232	275	274	261	258
Hyundai	327	327	324	330	280	278	266	258
JLR	320	306	279	267	316	286	286	278
Kia	328	305	304	290	286	277	267	263
Maserati	--	--	--	393	--	--	--	278
Mazda	259	266	250	256	270	267	256	249
Mercedes	313	313	298	304	292	287	274	263
Mitsubishi	265	262	247	243	260	253	242	234
Nissan	260	276	277	271	278	282	273	261
Porsche	319	296	293	294	361	285	284	277
Subaru	249	237	228	220	261	257	245	241
Tesla[16]	--	--	-21	-27	--	--	292	284
Toyota	316	295	295	264	289	286	273	265
Volkswagen	290	302	273	269	270	273	269	264
Volvo	299	249	243	250	360	288	291	274
Fleet Average	319	309	295	290	301	298	288	282

Figures 4 and 5 provide a graphical representation of the role that compliance flexibilities play in arriving at a company's overall compliance status for their 2019 model year passenger automobile and light truck fleets. Note that under the regulations, a company's CREE value is calculated to include the benefits from FFVs. Figures 4 and 5 instead refer to "tailpipe emissions"[17] as opposed to CREE so that FFV benefits can be portrayed separately. The orange line on the top of the bar indicates a company's fleet average tailpipe emissions. 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.

[16] Tesla only produces electric vehicles, and is 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.

[17] For the purposes of this report, the term "tailpipe emissions" refers to the CREE without factoring in FFV benefits.

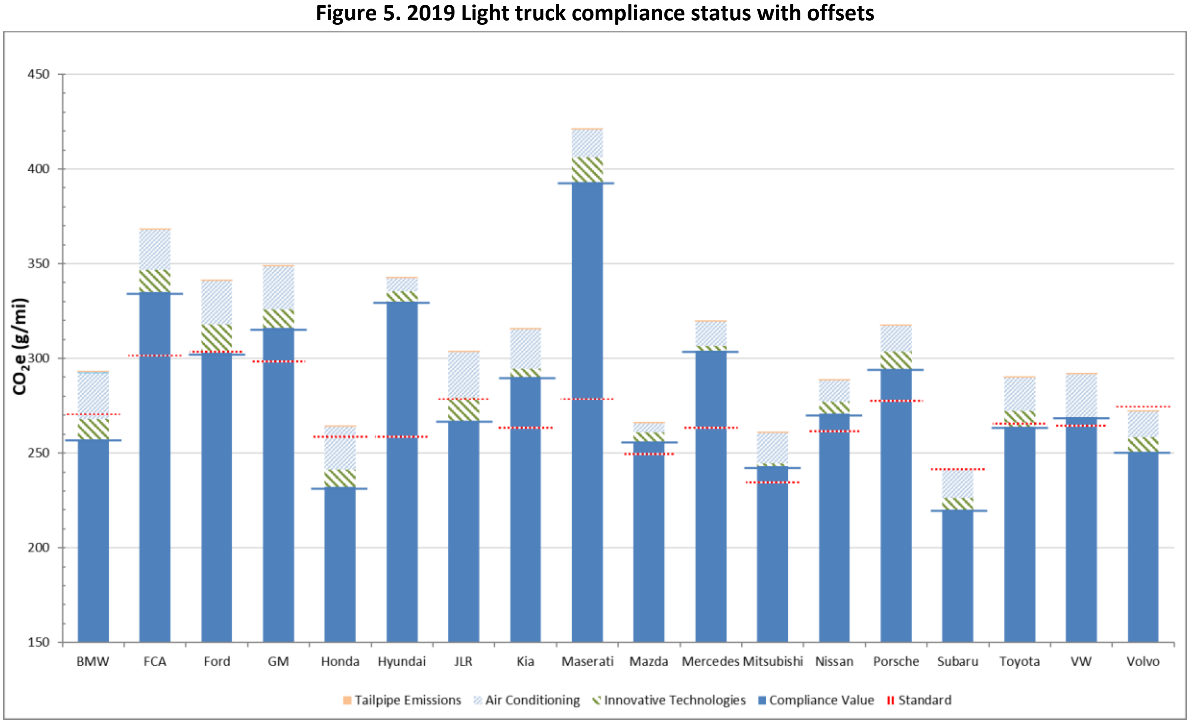
Figure 4. 2019 Passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
2. Tesla has a fleet average standard of 211 g/mi and fleet average compliance value of -22 g/mi. Tesla's compliance value falls outside of the range of this graph.

Figure 5. 2019 Light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
2. Tesla has a fleet average standard of 284 g/mi and fleet average compliance value of -27 g/mi. Tesla's compliance value falls 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 of 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%[18].

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 – 35% further per litre of fuel then a gasoline based equivalent[19] which translates into measurable reductions in CO_2e emissions.

The fleet-wide penetration rates of the above described technologies have been provided in Table 19, while data pertaining to company specific usage can be found in Appendices A-3 to A-10.

Table 18. Penetration rates of drivetrain technologies in the Canadian fleet

Technology	2016	2017	2018	2019
Turbocharging	23.1%	27.7%	34.3%	33.7%
VVT	94.5%	96.9%	95.6%	97.1%
VVL	19.3%	16.6%	18.1%	18.5%
Higher Geared Transmission	22.1%	27.0%	39.8%	55.9%
CVT	20.3%	19.9%	21.1%	21.1%
Cylinder Deactivation	10.0%	14.3%	12.6%	16.6%
GDI	37.5%	38.2%	46.1%	42.7%
Diesel	1.8%	0.6%	1.2%	0.5%

[18] Natural Resources Canada
[19] US EPA website

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 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:

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

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; and

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.

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 19 summarizes transactions by company and the model year in which the credits were generated. There have been more than 13 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 19. Credit transactions (transferred out) by model year (Mg CO_2e)

Manufacturer	Early Action	2011 to 2016	2017	2018	2019	Total
Honda	2 138 563	3 069 910	--	--	--	5 208 473
Mitsubishi	63 349	--	--	--	--	63 349
Nissan	822 292	402 728	--	--	--	1 225 020
Suzuki	123 345	30 431	--	--	--	153 776
Tesla	2 292	352 079	176 147	433 130	615 273	1 578 921
Toyota	2 623 142	2 680 598	--	--	--	5 303 740
Receiver General	--	6 906	--	--	--	6906

Table 19. Credit transactions (transferred in) by model year (Mg CO_2e)

Manufacturer	Early Action	2011 to 2016	2017	2018	2019	Total
Aston Martin	--	2 626	--	--	--	2626
BMW	--	1 000 000	--	--	--	1 000 000
FCA	4 775 129	3 333 018	176 147	433 130	465 273	9 182 697
Ferrari	8 473	--	--	--	--	8 473
Ford	342 272	257 728	--	--	--	600 000
JLR	143 369	--	--	--	--	143 369
Lotus	--	139	--	--	--	139
Mercedes	--	1 645 000	--	--	--	1 645 000
Maserati		3 740	--	--	--	3 740
Porsche	--	4 141	--	--	150 000	154 141
Subaru	--	300 000	--	--	--	300 000
Volkswagen	500 000	--	--	--	--	500 000

3.2. Total credits generated and final status

Table 20 shows the credits earned (or deficits incurred) by all companies over the 2019 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 86.6 million emission credits (including early action credits and TOF credits), of which approximately 24.5 million credits remain for future use. A total of 24.3 million credits have been used to offset deficits and 37.8 million credits have expired.

Table 20. Net credits by model year and current credit balance (Mg CO_2e)

Manufacturers	Generated Credit/Deficit in 2019	Current Balance[20]
BMW	-68 888	787 199
FCA	-1 869 581	3 854 774
Ford	-154 492	950 462

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

GM	-356 510	3 137 871
Honda	734 632	5 161 374
Hyundai	-278 110	1 930 817
JLR	14 352	7 928
Kia	-80 891	222 615
Maserati	-11 865	-11 865
Mazda	-298 644	3 053 272
Mercedes	-378 401	483 928
Mitsubishi	5 394	666 044
Nissan	-50 589	1 112 140
Porsche	-66 413	-8 406
Subaru	86 341	874 546
Tesla	615 273	0
Toyota	178 983	1 733 422
Volkswagen	-256 181	345 482
Volvo	46 028	203 180
Total	-2 189 562	24 504 783

4. Overall industry performance

The overall fleet average compliance information for passenger automobiles and light trucks is summarized in Tables 21 and 22. 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.

Table 21. Passenger automobile compliance summary for the 2011 to 2019 model years (g/mi)

Model Year	Tailpipe emissions	Flex Fuel Vehicles	Innovative Technologies	AC Refrigerant Leakage Reduction	AC Efficiency Improvements	Compliance value	Standard	Compliance margin
2011	261	2.8	0.2	2.0	1.3	255	291	36
2012	251	3.3	0.5	2.9	2.0	242	263	21
2013	247	3.3	0.4	3.0	2.4	238	256	18
2014	244	3.7	1.5	3.5	2.6	233	248	15
2015	241	2.6	1.8	4.0	2.9	230	238	8
2016	238	0	2.0	4.7	3.4	228	227	-1
2017	232	0	3.0	6.0	3.5	220	216	-4
2018	220	0	3.3	8.4	3.7	205	205	0
2019	211	0	3.1	10.3	3.9	194	194	0

Figure 6. Average GHG emissions performance - passenger automobiles

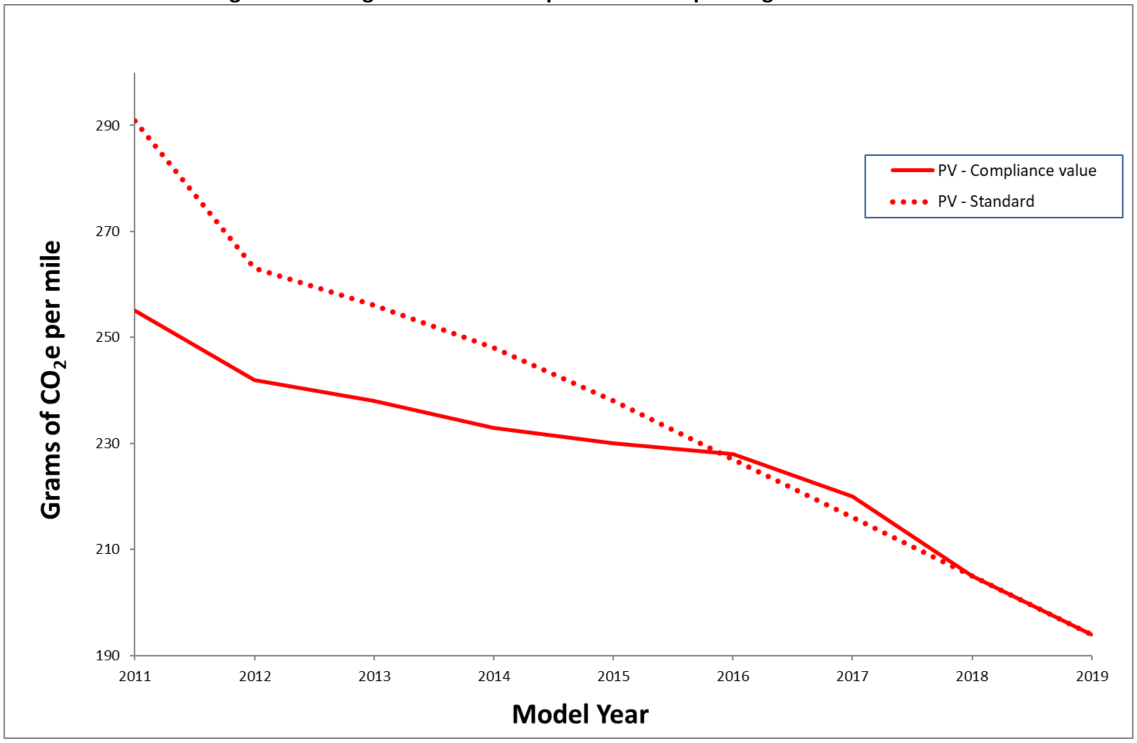
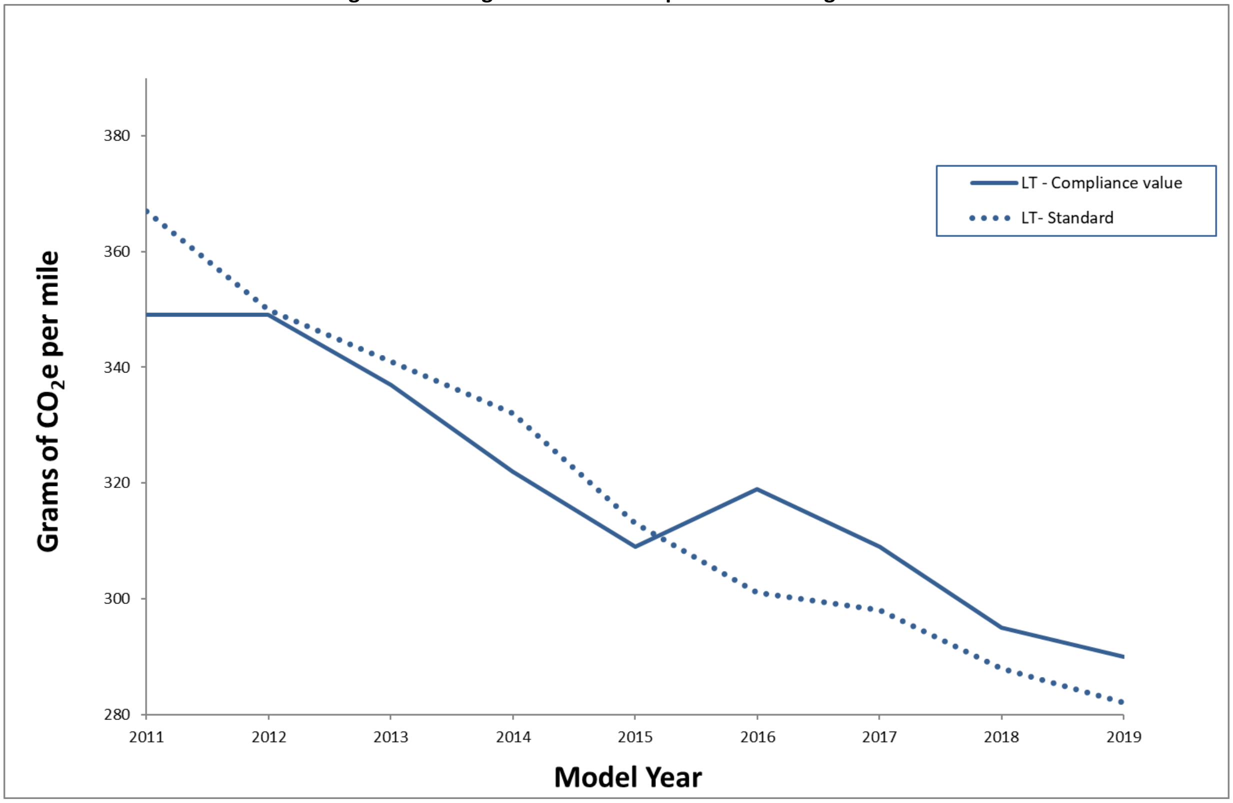


Table 22. Light truck compliance summary for the 2011 to 2019 model years (g/mi)

Model Year	Tailpipe emissions	Flex Fuel Vehicles	Innovative Technologies	AC Refrigerant Leakage Reduction	AC Efficiency Improvements	Compliance value	Standard	Compliance margin
2011	365	8.0	0.7	5.5	1.3	349	367	18
2012	371	13.3	1.2	5.8	1.5	349	350	1
2013	360	13.1	1.3	6.2	2.2	337	341	4
2014	349	12.9	4.3	6.8	3.1	322	332	10
2015	335	9.2	5.2	7.6	3.6	309	313	4
2016	337	0	5.9	8.5	3.7	319	301	-18
2017	334	0	7.5	12.0	5.8	309	298	-11
2018	323	0	8.5	13.3	6.0	295	288	-7
2019	320	0	9.6	14.2	6.0	290	282	-8

Figure 7. Average GHG emissions performance - light trucks



As depicted in Figures 6 and 7, during the 2011 to 2015 model years, as the stringency of the regulations increased, the overall passenger automobile fleet continued to outperform the applicable standard. The 2016 model year marked the first year in which the compliance values for both passenger automobile and light truck fleets exceeded the applicable standard. The changes to the flex-fuel vehicle (FFV) provisions for the 2016 model year were a significant factor in the shift towards a negative compliance margin for the 2016 model year. The 2019 model year saw the overall compliance value for passenger automobiles decrease to 194 g/mi, and the overall compliance value for light trucks decrease to 290 g/mi. This has resulted in an overall net improvement of 23.9% and 16.9% relative to the 2011 model year for passenger automobiles and light trucks respectively.

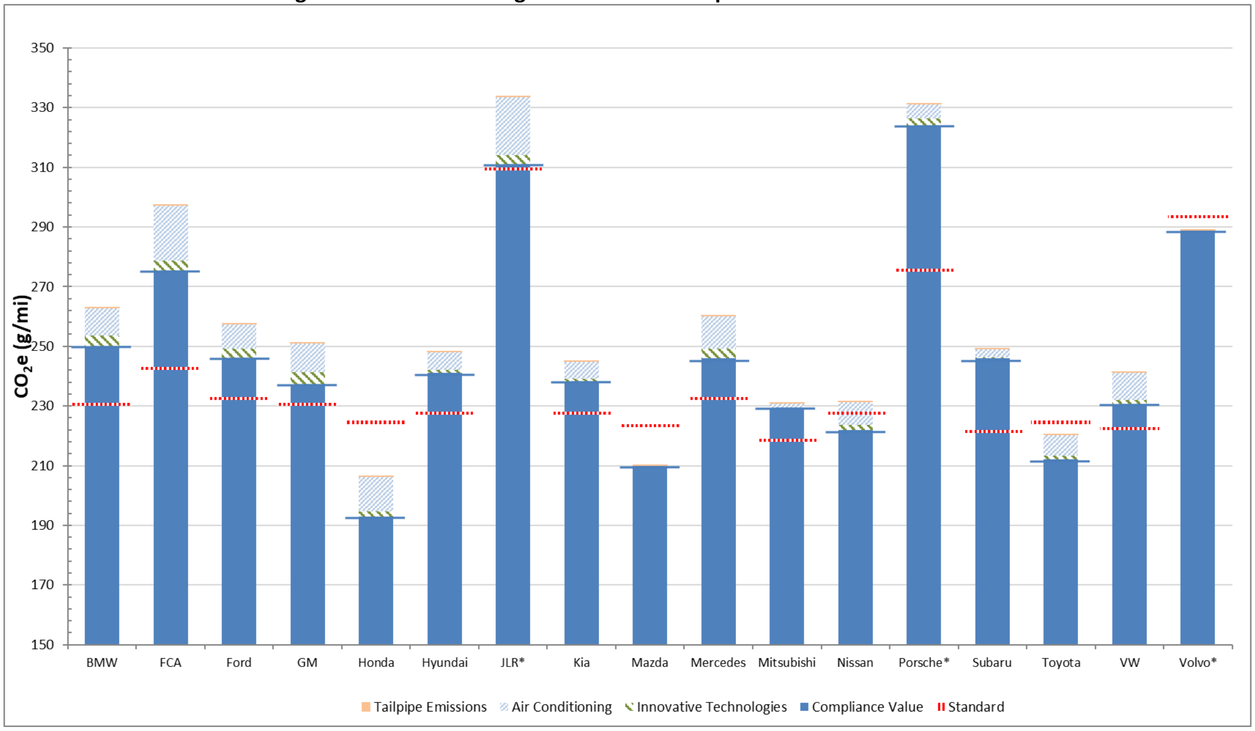
Although the fleet average compliance values for both passenger automobiles and light trucks continued a downward trend in the 2019 model year, they have stayed at or above the fleet average emission standard. All companies remained in compliance with the regulations through the use of their own accumulated 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 2019 model year.

Appendix

Table A-1. Production volumes by company

Manufacturer	2016 PA	2016 LT	2016 All	2017 PA	2017 LT	2017 All	2018 PA	2018 LT	2018 All	2019 PA	2019 LT	2019 All
Aston Martin	91	0	91	82	0	82	44	0	44	148	0	0
BMW	31 789	14 316	46 105	25 882	17 059	42 941	34 831	17 207	52 038	23 245	18 585	41 830
FCA	35 676	240 114	275 790	20 591	242 874	263 465	15 144	170 242	185 386	11 522	221 797	233 319
Ferrari	135	0	135	275	0	275	247	0	247	364	0	364
Ford	54 569	190 662	245 231	72 230	205 393	277 623	41 855	233 897	275 752	27 203	200 523	227 726
GM	82 065	118 958	201 023	96 569	173 949	270 518	81 077	188 187	269 264	60 593	186 381	246 974
Honda	114 360	87 060	201 420	112 783	81 780	194 563	110 320	81 930	192 250	102 062	102 252	204 314
Hyundai	123 676	4 493	128 169	161 646	11 171	172 817	117 473	6 050	123 523	111 853	3 900	115 753
JLR	1 282	6 909	8 191	2 345	11 870	14 215	1 654	11 646	13 300	567	11 678	12 245
Kia	58 583	15 878	74 461	42 768	25 637	68 405	55 202	22 719	77 921	42 547	28 680	71 227
Lotus	0	0	0	13	0	13	12	0	12	0	0	0
Maserati	--	--	0	--	--	0	--	--	0	172	291	463
Mazda	46 389	15 317	61 706	35 910	23 202	59 112	55 953	26 762	82 715	39 613	30 779	70 392
McLaren	121	0	121	112	0	112	220	0	220	195	0	195
Mercedes	24 178	12 980	37 158	22 371	22 371	44 742	25 562	29 596	55 158	17 214	19 918	37 132
Mitsubishi	6 100	12 097	18 197	13 686	11 301	24 987	9 004	15 434	24 438	5 158	13 252	18 410
Nissan	71 221	51 416	122 637	87 293	62 006	149 299	82 124	57 229	139 353	88 662	52 623	141 285
Pagani	1	0	1	0	0	0	0	0	0	0	0	0
Porsche	1 585	5 081	6 666	2 357	6 829	9 186	3 589	7 837	11 426	2 130	5 723	7 853
Subaru	14 603	32 079	46 682	17 744	33 502	51 246	16 574	42 019	58 593	16 350	49 803	66 153
Tesla	2 963	NULL	2 963	3 483	--	3 483	8 511	450	8 961	13 101	263	13 364
Toyota	105 798	101 247	207 045	107 989	121 998	229 987	112 328	121 236	233 564	90 548	113 360	203 908
Volkswagen	67 071	21 019	88 090	72 212	26 667	98 879	61 658	68 060	129 718	78 118	50 314	128 432
Volvo	891	4 885	5 776	1 331	5 008	6 339	1 256	6 691	7 947	1 762	10 116	11 878
Fleet Total	843 147	934 511	1 777 658	899 672	1 082 617	1 982 289	834 638	1 107 192	1 941 830	733 127	1 120 238	1 853 365

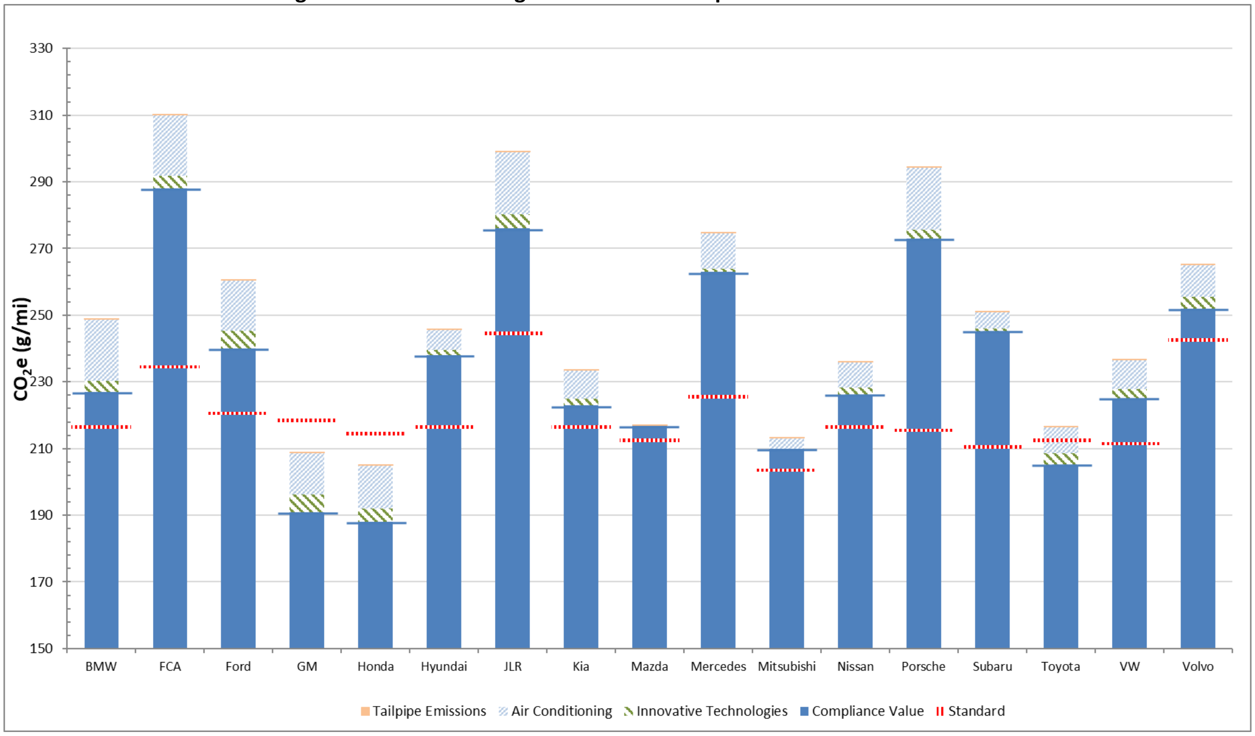
Figure A-1. 2016 Passenger automobile compliance status with offsets



Notes:

1. The asterisked companies are those that used the temporary optional fleet provisions
2. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
3. Tesla has a fleet average standard of 268 g/mi and fleet average compliance value of -6 g/mi. Tesla's compliance value falls outside of the range of this graph.

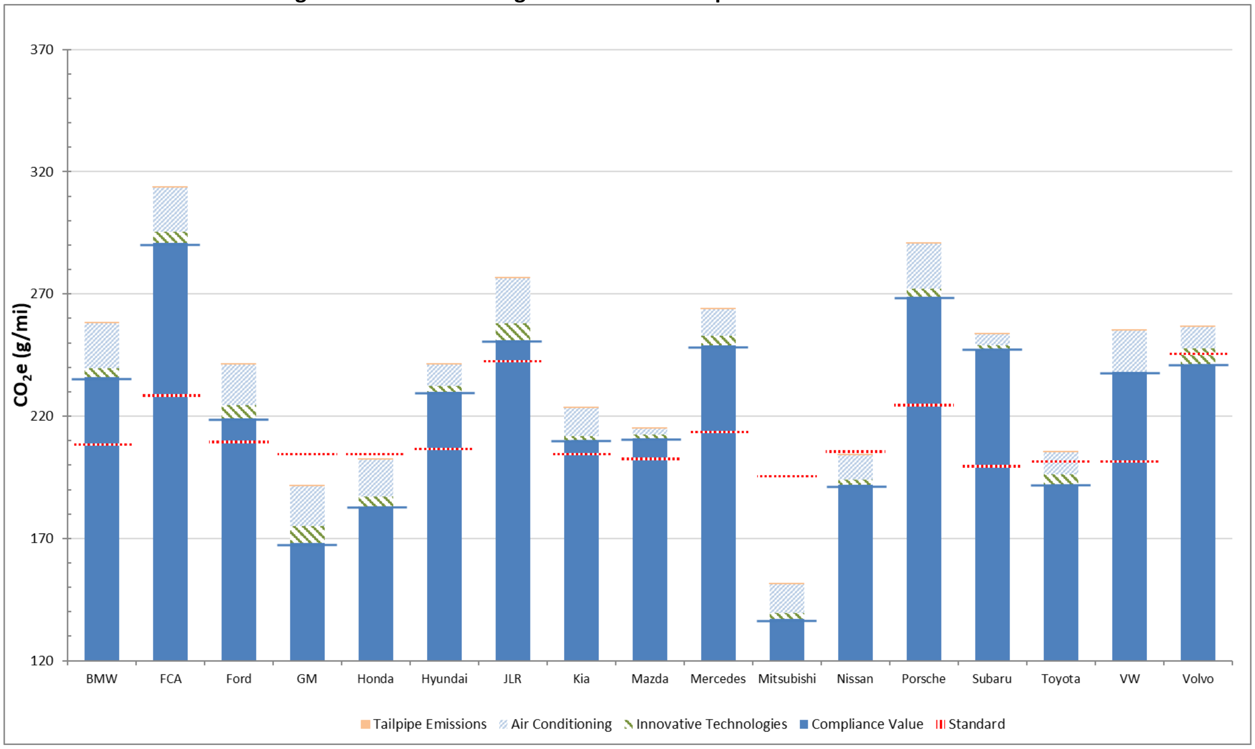
Figure A-2. 2017 Passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
2. Tesla has a fleet average standard of 254 g/mi and fleet average compliance value of -5 g/mi. Tesla's compliance value falls outside of the range of this graph

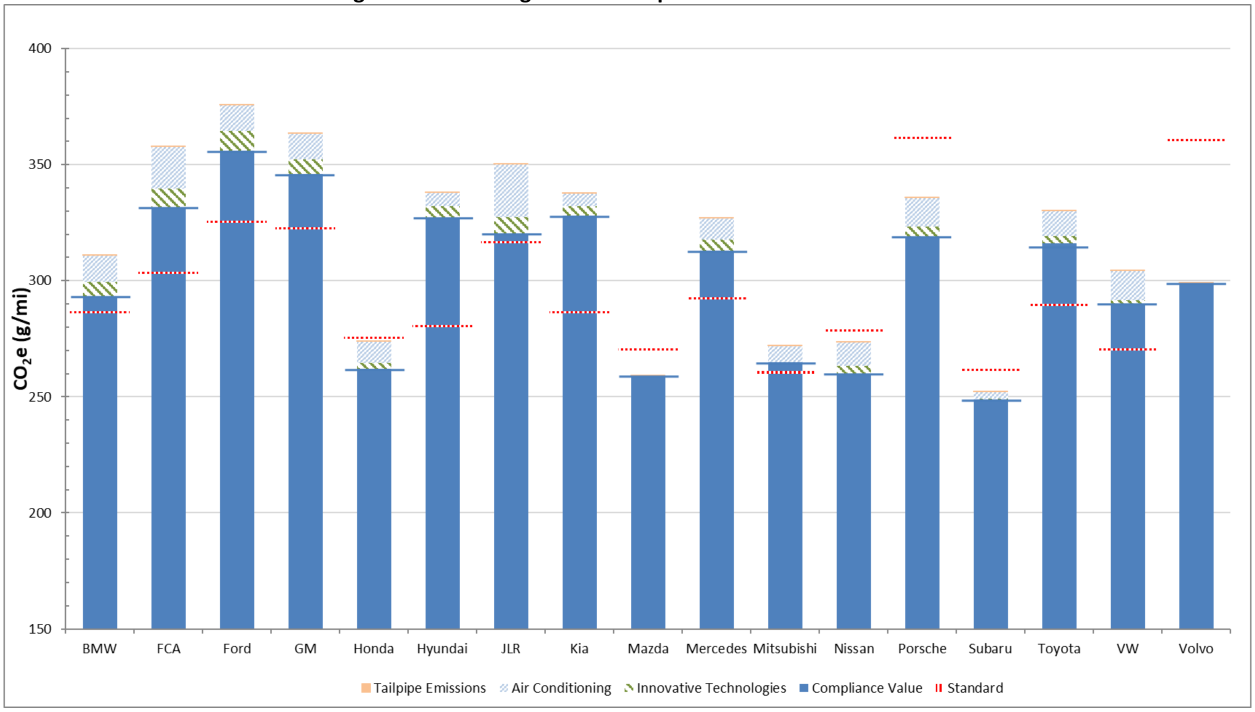
Figure A-3. 2018 Passenger automobile compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
2. Tesla has a fleet average standard of 226 g/mi and fleet average compliance value of -16 g/mi. Tesla's compliance value falls outside of the range of this graph.

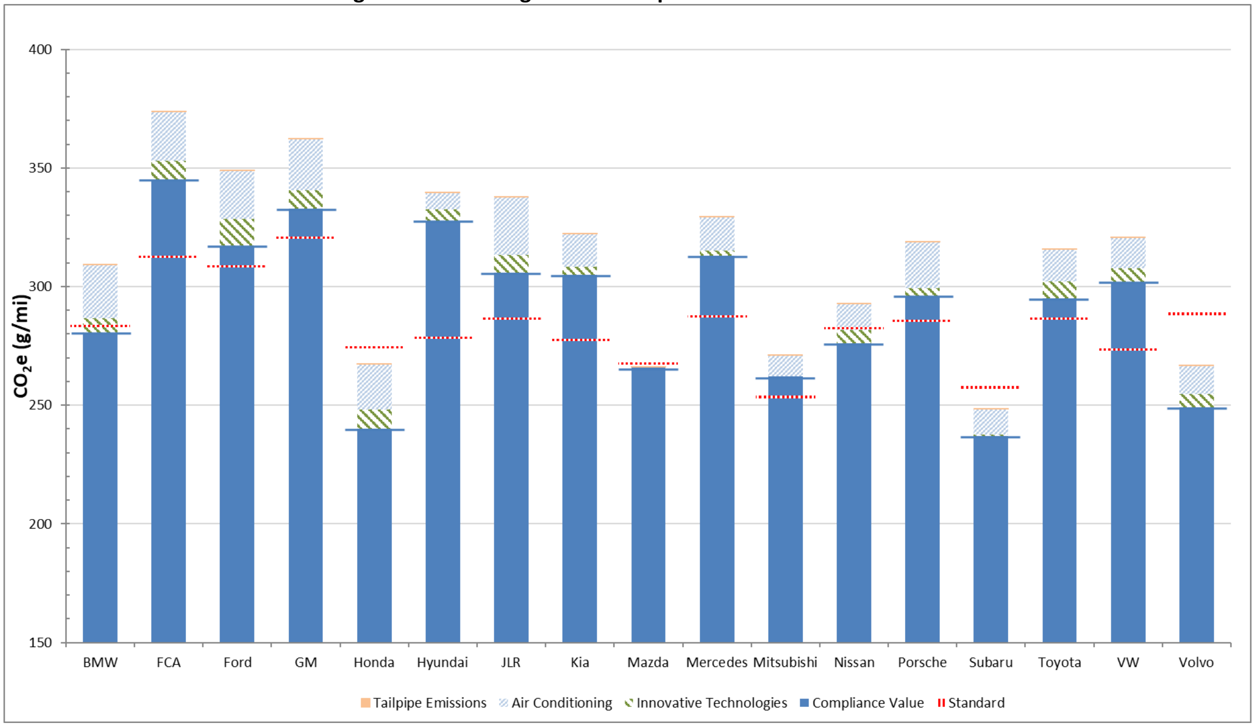
Figure A-4. 2016 Light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities

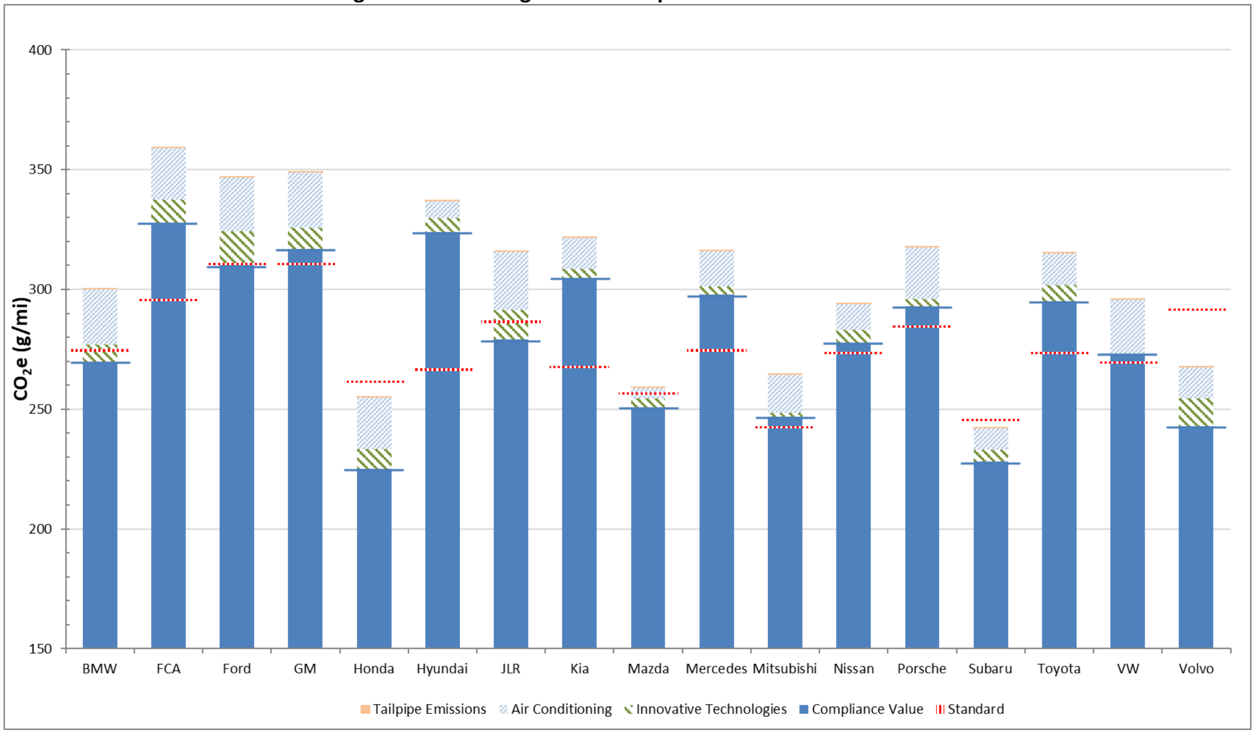
Figure A-5. 2017 Light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities

Figure A-6. 2018 Light truck compliance status with offsets



Notes:

1. The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities
2. Tesla has a fleet average standard of 292 g/mi and fleet average compliance value of -21 g/mi. Tesla's compliance value falls outside of the range of this graph.

Table A-2. Preapproved menu of efficiency improving technologies for AC systems

Technology	Allowance value (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).	1.7
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
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.	1.7
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.	1.1
Blower motor controls which limit wasted electrical energy (for example, pulse width modulated power controller).	0.9
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).	1.1
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).	1.1
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.	0.6

Table A-3. Production volume of vehicles with turbocharging

Manufacturer	2016	2017	2018	2019
BMW	46 009	42 508	51 729	41 633
FCA	15 930	6 412	13 340	10 693
Ford	115 015	164 219	164 992	161 201
GM	52 054	62 935	102 272	82 820
Honda	18 150	72 053	92 935	92 538
Hyundai	18 148	18 680	15 002	17 376
JLR	6 909	6 904	7 665	6 080
Kia	8 422	6 772	6 740	2 301
Maserati	--	--	--	452
Mazda	1 784	3 351	5 943	12 735
Mercedes	36 563	44 636	54 716	36 991
Mitsubishi	0	0	3 051	3 848
Nissan	7 185	8 776	4 013	8 486
Porsche	3 026	8 086	102 06	7 401
Subaru	5 115	6 969	7 540	8 696
Toyota	5 617	7 756	4 969	6 884
Volkswagen	82 204	88 174	108 768	111 198
Volvo	2 839	2 299	2 088	3 192
Total	424 970	550 530	655 969	614 525

Table A-4. Production volume of vehicles with variable valve timing

Manufacturer	2016	2017	2018	2019
BMW	42 953	40 874	49 292	41 633
FCA	258 715	256 770	174 949	222 283
Ford	185 730	236 387	216 872	191 796
GM	193 764	265 518	262 223	238 873
Honda	201 420	194 563	189 280	204 314
Hyundai	128 167	172 162	123 129	111 169
JLR	10 398	11 321	10 833	9 817
Kia	73 392	67 928	76 957	70 041
Maserati	--	--	--	463
Mazda	61 706	59 112	82 715	70 208
Mercedes	36 968	44 636	54 716	36 991
Mitsubishi	13 109	21 579	24 438	18 410
Nissan	121 017	148 415	134 913	136 945
Porsche	6 666	9 186	11 426	7 853
Subaru	46 682	51 246	58 593	66 153
Toyota	207 045	229 987	233 514	203 712
Volkswagen	86 454	98 759	128 910	126 490
Volvo	5 776	6 339	7 947	11 878
Total	1 679 962	1 914 782	1 840 707	1 769 029

Table A-5. Production volume of vehicles with variable valve lift

Manufacturer	2016	2017	2018	2019
BMW	42 192	40 250	49 292	41 633
FCA	32 956	3 390	20 691	12 547
GM	7 294	5 318	3 940	62
Honda	201 420	194 563	132 525	131 803
JLR	10 398	11 321	10 833	9 817
Mercedes	0	0	0	9 587
Mitsubishi	8 819	6 600	6 425	4 862
Nissan	5 284	12 249	8 325	4 394
Porsche	6 666	9 186	11 426	7 853
Toyota	3 877	6 012	13 514	9 804

Volkswagen	24 552	39 030	91 365	105 248
Total	343 458	327 919	348 336	337 610

Table A-6. Production volume of vehicles with higher geared transmissions

Manufacturer	2016	2017	2018	2019
BMW	38 414	36 967	48 365	36 184
FCA	143 185	140 612	124 854	184 880
Ford	0	32 228	142 121	153 389
GM	25 666	57 092	79 811	124 530
Honda	42 156	38 550	45 711	77 951
Hyundai	9 627	8 284	8 757	25 507
JLR	12 814	14 192	13 294	11 873
Kia	374	1 162	2 440	20 537
Maserati	--	--	--	452
Mercedes	34 967	44 346	54 716	36 991
Mitsubishi	0	0	3 051	3 848
Nissan	30 340	43 356	30 409	47 354
Porsche	6 205	9 030	10 935	7 607
Subaru	2 434	10 924	33 738	56 211
Toyota	25 860	63 640	68 806	115 112
Volkswagen	17 917	28 174	90 782	104 054
Volvo	3 037	6 339	7 947	11 878
Total	392 996	534 896	765 737	1 018 358

Table A-7. Production volume of vehicles with continuously variable transmissions

Manufacturer	2016	2017	2018	2019
FCA	519	178	0	600
Ford	1 801	3 173	2 860	5 390
GM	3 203	12 217	10 944	22 050
Honda	142 680	131 295	141 280	137 294
Kia	0	0	0	12 300
Mitsubishi	11 937	19 002	15 846	14 497
Nissan	100 047	114 907	112 790	114 857
Subaru	39 886	43 218	49 919	59 598
Toyota	60 131	71 042	73 312	23 416
Volkswagen	15	0	0	0
Total	360 219	395 032	406 951	390 002

Table A-8. Production volume of vehicles with cylinder deactivation

Manufacturer	2016	2017	2018	2019
FCA	56 549	98 158	48 374	96 115
GM	77 537	137 599	137 688	131 428
Honda	42 630	44 490	33 245	42 749
Mazda	0	0	23 102	28 751
Mercedes	0	0	0	2 142
Volkswagen	1 263	1 682	1 044	569
Total	177 979	281 929	243 453	301 754

Table A-9. Production volume of vehicles with gasoline direct injection

Manufacturer	2016	2017	2018	2019
BMW	42 953	40 874	49 292	41 633
FCA	13 294	886	3257	7 744
Ford	0	0	102 948	22 051
GM	166 895	244 125	240 931	211 556

Honda	157 680	120 523	125 220	142 381
Hyundai	100 695	113 544	73 000	74 035
JLR	10 398	11 321	10 833	9 817
Kia	67 140	59 381	65 121	56 952
Maserati	--	--	--	452
Mazda	60 819	56 102	82 715	70 208
Mercedes	29 777	44 636	54 687	36 966
Nissan	7 440	41 163	41 087	40 129
Subaru	4 195	14 903	29 505	52 667
Toyota	1 829	676	434	317
Volvo	3 037	6 339	7 947	11 878
Total	666 152	754 473	886 977	778 786

Table A-10. Production volume of diesel vehicles

Manufacturer	2016	2017	2018	2019
BMW	3 060	1 643	2 437	0
FCA	15 077	4 174	9 880	2 661
Ford	0	0	3 030	1 913
GM	1 200	2 867	5 567	2 656
JLR	2 448	2 894	2 467	2 063
Mazda	0	0	0	184
Mercedes	7 191	0	0	0
Porsche	527	0	0	0
Volkswagen	1 636	0	0	0
Total	31 139	11 578	23 381	9 477