Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

GREENHOUSE GAS EMISSIONS PERFORMANCE
MODEL YEAR 2011 TO 2016 LIGHT-DUTY VEHICLE FLEET

GREENHOUSE GAS EMISSIONS PERFORMANCE FOR THE 2011 TO 2016 MODEL YEAR LIGHT-DUTY VEHICLE FLEET

- EXPANDED REPORT -

IN RELATION TO THE
PASSENGER AUTOMOBILE AND LIGHT TRUCK
GREENHOUSE GAS EMISSION REGULATIONS
UNDER THE CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999

TRANSPORTATION DIVISION

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

Environment and Climate Change Canada
Public Inquiries Centre
7th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-997-2800
Toll Free: 1-800-668-6767 (in Canada only)
Email: ec.enviroinfo.ec@canada.ca

Aussi disponible en français

List of Acronyms

AC	Air conditioner
ATV	Advanced technology vehicle
CAFE	Corporate average fuel economy
CEPA 1999	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
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
SO_x	Oxides of sulfur
TOF	Temporary optional fleet
VKT	Vehicle kilometres travelled

Table of Contents

List of Table

List of Figures

Executive Summary

The *Passenger Automobile and Light Truck Greenhouse Gas Engine 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 of the 2011-2016 model years. This report 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 insofar 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. 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. The resulting fleet average standards for passenger automobiles and for light trucks have become more stringent by 22.0% and 18.3% respectively over the 2011–2016 model years.

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 worse than their applicable standard). This allows companies to maintain regu-

1 CO_2e is used throughout this report as a common unit to standardize the environmental impacts of different greenhouse gases (e.g. N_2O & CH_4) in terms of an equivalent amount of CO_2.

latory compliance as their product mix and demands change year to year and through product cycles. 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 three years. 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.

Results from regulatory reports indicate that companies continue to be in compliance through to the 2016 model year. The average compliance value for the fleet of new passenger automobiles decreased from 255 g/mi to 228 g/mi over the 2011-2016 model year period, representing a 10.6% reduction. The compliance value for light trucks decreased by 8.0%, from 349 g/mi to 321 g/mi over the same period. 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. All companies nevertheless remained in compliance with the regulations 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 78.4 million credits, of which, approximately 32.3 million remain available for future use. A total of 9.5 million credits have been used to offset emission deficits by individual companies over the 2011-2016 model years. Some 4.5 million credits were used to offset deficits accrued in the 2016 model year, and 5.0 million credits over the course of the 2011-2015 model years. The remaining 36.5 million credits have expired.

1 Purpose of the Report

The purpose of this report is to provide in-depth, company specific results of the fleet average greenhouse gas emission performance of the Canadian fleets of passenger automobiles (PA) and of light trucks (LT) for the 2011-2016 model years. This report builds on the previous GHG emissions performance report for the 2011-2015 model years[2]. The results presented herein are based on data contained in the annual regulatory compliance reports submitted by companies pursuant to the Passenger Automobile and Light Truck Greenhouse Emission Regulations. The report will also help to identify trends in the Canadian automotive industry including the adoption and emergence of technologies that have the potential to reduce GHG emissions. It will also serve 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 Emission Regulations*[3] (Regulations) under the Canadian Environmental Protection Act, 1999 (CEPA 1999). 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 2011-2025, 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. This data is subject to ongoing validation and review and may be subject to change should new information become available.

Companies that submitted a report pursuant to the regulations during 2011-2016 model years are listed in Table 1.

2 The department has released two prior reports documenting the overall fleet performance, covering the 2011-2014 and the 2011-2015 model year results. These can be found at https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=104

3 The Regulations, along with amendments, and the accompanying regulatory impact analysis statement can be accessed at https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=104

Table 1 – Model Year Report Submission Status

Manufacturer	Common Name	Model Years					
		2011[a]	2012	2013	2014	2015	2016
Aston Martin Lagonda Ltd.	Aston Martin	✓	LVM[b]	LVM[b]	LVM[b]	LVM[b]	LVM[b]
BMW Canada Inc.	BMW	✓	✓	✓	✓	✓	✓
FCA Canada Inc.	FCA	✓	✓	✓	✓	✓	✓
Ferrari North America Inc.	Ferrari	✓	LVM[b]	LVM[b]	LVM[b]	LVM[b]	LVM[b]
Ford Motor Company of Canada Ltd.	Ford	✓	✓	✓	✓	✓	✓
General Motors of Canada Company	GM	✓	✓	✓	✓	✓	✓
Honda Canada Inc.	Honda	✓	✓	✓	✓	✓	✓
Hyundai Auto Canada Corp.	Hyundai	✓	✓	✓	✓	✓	✓
Jaguar Canada	JLR	✓	✓	✓	✓	✓	✓
Land Rover Canada		✓	✓	✓	✓	✓	✓
Kia Canada Inc.	Kia	✓	✓	✓	✓	✓	✓
Lotus Cars Ltd.	Lotus	✓	LVM[b]	LVM[b]	LVM[b]	LVM[b]	LVM[b]
Maserati North America Inc.	Maserati	✓	LVM[b]	LVM[b]	LVM[b]	LVM[b]	LVM[b]
Mazda Canada Inc.	Mazda	✓	✓	✓	✓	✓	✓
Mercedes-Benz Canada Inc.	Mercedes	✓	✓	✓	✓	✓	✓
Mitsubishi Motor Sales of Canada, Inc.	Mitsubishi	✓	✓	✓	✓	✓	✓
Nissan Canada Inc.	Nissan	✓	✓	✓	✓	✓	✓
Porsche Cars Canada, Ltd.[d]	Porsche	✓	✓	✓	✓	✓	✓
Subaru Canada Inc.	Subaru	✓	✓	✓	✓	✓	✓
Suzuki Canada Inc.	Suzuki	✓	✓	✓	NA[c]	NA[c]	NA[c]
Tesla Motors, Inc.	Tesla	✓	✓	✓	✓	✓	✓
Toyota Canada, Inc.	Toyota	✓	✓	✓	✓	✓	✓
Volkswagen Group Canada, Inc.[d]	Volkswagen	✓	✓	✓	✓	✓	✓
Volvo Cars of Canada Corp.	Volvo	✓	✓	✓	✓	✓	✓

a. All companies were required to submit a report for the 2011 model year.
b. 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.
c. No longer importing or producing vehicles for the Canadian market.
d. ECCC launched an investigation into the alleged use of defeat devices on certain vehicles. Results presented include all vehicles imported into Canada, including those allegedly equipped with defeat devices, and are subject to review.

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[4] to the first retail purchaser[5]. These standards are performance-based (i.e. establish a maximum amount of CO_2 equivalent on a gram per mile basis) which allows companies to choose the most cost-effective technologies to achieve compliance.

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

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

4 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.

5 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

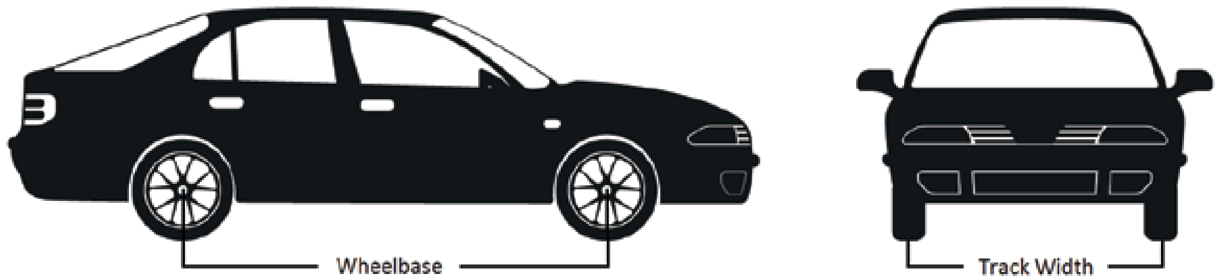


Figure 2 – 2011-2025 Targets for Passenger Automobiles

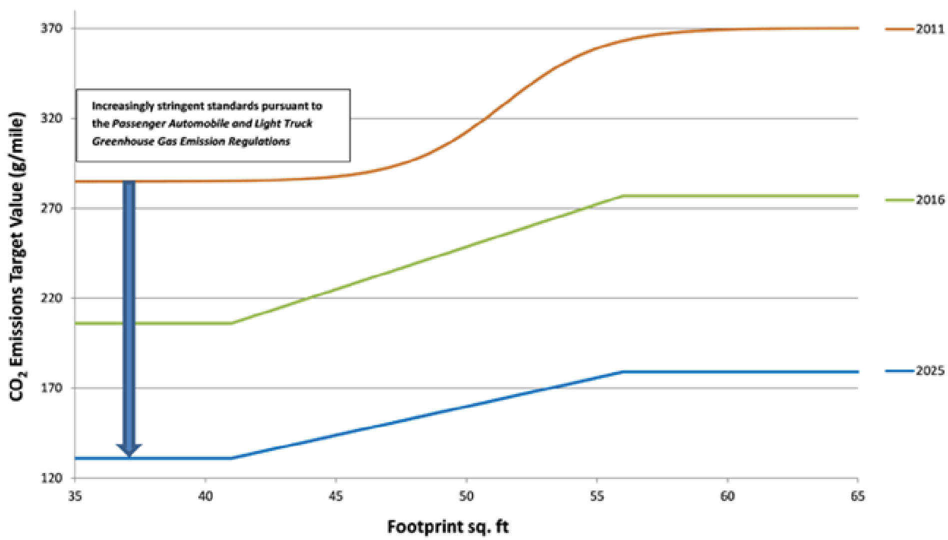
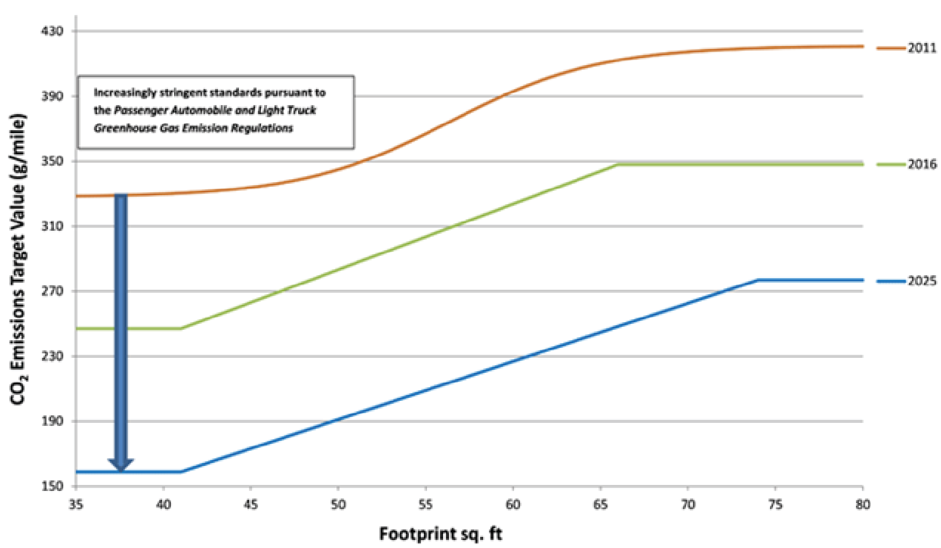


Figure 3 – 2011-2025 Targets for Light Trucks



As depicted in Figure 2 and Figure 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 one 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[6]. The CO_2e standard was derived using a conversion factor of 8,887 grams of CO_2/gallon of gasoline[7] 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:

Equation 1

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

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

6 The fuel economy target values that apply to vehicles of the 2011 model year are calculated using the following formula: $T = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)/d}}{1+e^{(x-c)/d}}}$

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

7 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.

The final company-unique fleet average CO_2e standards for the 2011-2016 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.

Since the regulations came into force, the fleet average standards for passenger automobiles and light trucks have decreased from 291 g/mi to 227 g/mi (22.0%) and 367 g/mi to 300 g/mi (18.3%), respectively. The tightening of the target curves typically result in more stringent CO_2e standards. However; the regulations provide flexibility such as the "temporary optional fleet" standards which took effect in the 2012 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 the notable increase in their standards from the 2011 to the 2012 model year.

A company's average footprint is one of the factors in establishing their CO_2e standards. Although there has been some year over year variation in footprints amongst manufacturers, the overall fleet average footprint has remained relatively consistent over the 2011 to 2016 model years (Table 3).

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

Table 2 – Fleet Average CO_2e Standard (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	298	--	--	--	--	--	--	--	--	--	--	--
BMW	293	348	264	336	260	321	254	314	239	299	230	286
FCA	310	369	273	355	266	347	259	336	248	315	242	303
Ferrari	294	--	--	--	--	--	--	--	--	--	--	--
Ford	292	377	261	369	262	354	250	346	240	331	232	325
GM	296	400	269	375	259	363	250	355	241	339	230	322
Honda	288	345	257	325	251	313	243	304	231	287	224	275
Hyundai	291	337	263	317	257	306	249	299	240	284	227	280
JLR	314	340	359	402	352	389	334	396	319	371	309	316
Kia	288	340	264	323	254	303	249	301	238	299	227	286
Lotus	286	--	--	--	--	--	--	--	--	--	--	--
Maserati	322	--	--	--	--	--	--	--	--	--	--	--
Mazda	287	338	255	314	250	306	249	296	238	283	223	270
Mercedes[a]	293	347	281	339	261	339	251	319	250	298	232	292
Mitsubishi	286	333	255	306	248	296	236	287	225	273	218	260
Nissan	288	355	259	335	256	322	244	316	234	297	227	278
Porsche	304	352	323	422	313	410	299	398	282	375	275	361
Subaru	287	334	257	307	249	297	240	288	231	275	221	261
Suzuki	286	333	249	306	241	296	--	--	--	--	--	--
Tesla	285	--	304	--	296	--	288	--	276	--	268	--
Toyota	288	358	258	338	251	325	245	322	234	300	223	289
Volkswagen	287	341	260	323	253	312	247	301	233	287	222	270
Volvo	289	341	336	405	327	394	321	383	307	361	293	360
Fleet Average	291	367	262	349	256	340	248	331	237	311	227	300

a. Mercedes split its production volumes into conventional and temporary optional fleets (section 2.3.7.). For the purposes of this report, a single overall fleet average standard value has been calculated.

Table 3 – Average Footprint for the 2011 – 2016 Model Years (sq. ft.)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	46.7	--	45.8	--	45.1	--	47.1	--	45.9	--	46.5	--
BMW	45.2	50.8	44.8	51.3	45.6	50.0	46.4	50.7	45.6	50.6	45.9	50.7
FCA	48.4	55.1	45.7	56.2	46.4	56.7	47.1	56.6	47.1	54.8	48.3	55.3
Ferrari	47.1	--	--	--	--	--	--	--	--	--	--	--
Ford	44.2	58.1	44.3	61.7	46.1	60.2	45.5	60.6	45.7	60.6	46.4	62.9
GM	46.9	63.4	46.4	61.8	45.6	61.3	45.5	62.6	45.9	61.5	45.8	60.3
Honda	44.3	48.4	43.7	48.5	43.9	48.1	44.1	48.1	43.9	47.6	44.6	48.0
Hyundai	45.4	46.6	45.0	46.8	45.3	46.4	45.3	46.9	46.0	46.8	45.4	49.2
JLR	49.9	48.1	50.2	47.8	50.5	47.6	49.1	51.2	49.1	49.9	49.7	50.9
Kia	44.2	47.5	45.3	48.0	44.6	45.7	45.4	47.5	45.5	50.5	45.4	50.7
Lotus	40.2	--	--	--	--	--	--	--	--	--	--	--
Maserati	50.9	--	--	--	--	--	--	--	--	--	--	--
Mazda	43.1	46.7	43.2	46.0	43.7	46.4	45.3	46.1	45.4	46.6	44.4	46.8
Mercedes	44.1	49.8	45.5	50.9	42.2	50.2	42.6	50.6	45.6	49.1	45.4	52.2
Mitsubishi	43.4	44.1	43.3	44.0	43.4	44.0	41.4	44.0	41.6	43.9	43.4	44.2
Nissan	44.0	51.4	44.1	51.2	45.0	50.4	44.3	51.1	44.0	50.1	45.1	48.7
Porsche	43.9	51.8	42.9	51.8	42.2	51.8	42.6	51.8	40.9	50.8	42.3	51.3
Subaru	43.4	44.5	43.7	44.2	43.5	44.1	43.5	44.1	44.0	44.6	44.0	44.6
Suzuki	41.7	44.0	41.5	44.0	41.3	44.0	--	--	--	--	--	--
Tesla	37.1	--	37.1	--	53.6	--	53.6	--	53.6	--	54.1	--
Toyota	43.8	52.1	43.7	52.1	43.9	51.3	44.4	53.0	44.5	51.1	44.5	51.8
Volkswagen	43.9	47.6	44.4	48.2	44.4	47.9	45.0	47.5	44.4	47.5	45.5	46.8
Volvo	45.1	48.4	46.3	48.4	46.3	48.6	47.0	48.7	47.1	48.0	47.0	51.3
Fleet Average	44.7	54.7	44.6	55.1	44.9	55.5	45.0	55.6	45.0	54.3	45.3	54.9

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 two 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 two 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 two 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.

As with the CO_2e standard, the CREE values for the 2011 model year are based on the CAFE program and therefore consider the consumption of fuel to establish reasonable approximations of equivalent GHG performance. Using this methodology, the emissions measured during the city and highway tests are used to calculate the fuel economy performance instead of directly calculating a CREE value. Once the fleet

Table 4 – Fleet Average Carbon Related Exhaust Emissions (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	468	--	--	--	--	--	--	--	--	--	--	--
BMW	307	338	277	359	264	329	259	312	258	306	263	311
FCA	307	375	283	370	274	367	281	355	276	346	297	358
Ferrari	557	--	--	--	--	--	--	--	--	--	--	--
Ford	255	364	243	373	244	357	248	357	247	348	257	376
GM	271	394	259	382	257	373	251	341	253	342	251	363
Honda	242	324	220	309	223	307	219	294	211	269	206	274
Hyundai	244	307	234	316	236	313	253	316	250	317	248	338
JLR	382	474	379	415	362	393	347	355	344	337	334	350
Kia	253	315	267	309	249	300	261	319	265	323	245	338
Lotus	321	--	--	--	--	--	--	--	--	--	--	--
Maserati	466	--	--	--	--	--	--	--	--	--	--	--
Mazda	250	331	232	295	236	268	210	267	207	276	210	259
Mercedes	302	365	315	375	266	348	264	325	257	307	260	327
Mitsubishi	250	275	244	281	244	272	219	270	224	265	231	272
Nissan	252	349	253	378	235	342	221	318	227	298	231	273
Porsche	335	369	324	368	311	365	305	361	313	347	331	336
Subaru	303	296	269	303	257	273	242	254	249	254	249	252
Suzuki	262	322	263	319	260	330	--	--	--	--	--	--
Tesla[a]	0	--	0	--	0	--	0	--	0	--	0	--
Toyota	237	335	220	343	227	331	216	342	218	329	217	329
Volkswagen	244	326	263	320	256	316	250	304	238	305	240	304
Volvo	303	355	299	340	300	345	306	349	281	332	289	299
Fleet Average	258	356	247	357	244	348	241	336	238	326	237	337

a. Tesla only produces battery electric vehicles and uses the 0 g/mi incentive for their CREE as described in section 2.3.5.

average fuel economy has been determined, it must be converted to an equivalent amount of CO_2[8].

The calculated fleet average CREE values achieved by companies over the 2011 – 2016 model years are presented in Table 4. The fleet average CREE from the 2011 – 2016 model years for passenger automobiles and light trucks has decreased from 258 g/mi to 237g/mi (8.1%) and 356 g/mi to 337 g/mi (5.3%) respectively.

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 (e.g. 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 conditioning (AC) systems have a global warming potential[9] (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 these improved 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 air conditioning system equipped 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:

Equation 2

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

Where:

A is the CO_2 equivalent 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 2011 – 2016 model years. As of the 2016 model year, a total of fifteen companies have claimed allowances for reduction in AC refrigerant leakage.

8 CREE is estimated by applying the conversion factor 8,887 to fleet average fuel economy; i.e. CREE = 8,887/FE

9 Additional information relating to GWP's can be found at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/quantification-guidance/global-warming-potentials.html

Table 5 – Allowance for Reduction in AC Refrigerant Leakage (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	3	--	--	--	--	--	--	--	--	--	--	--
BMW	4	7	4.1	6.9	4.4	7.2	4.6	7.0	4.6	7.1	4.7	7.0
FCA	6	8	6.0	8.0	6.0	8.0	8.4	10.4	11.6	13.1	13.3	14
Ford	3	7	4.0	7.0	5.0	8.0	5.7	7.7	6.3	7.8	6.2	7.8
GM	4	9	6.0	7.0	6.0	8.0	6.1	7.1	6.2	6.9	6.2	7.0
Honda	2	3	1.9	3.7	1.9	3.8	1.8	3.9	1.8	4.2	8.3	6.4
Hyundai	--	--	2.2	5.4	2.1	4.6	2.1	3.4	2.4	3.6	2.5	1.6
JLR	3	5	3.0	6.0	3.0	5.0	6.3	16.3	9.6	16.9	13.8	17.2
Kia	--	--	2.2	3.9	2.6	5.0	2.2	4.1	2.3	3.7	2.3	2.1
Mercedes	3	4	4.0	7.0	4.0	7.0	4.7	6.9	5.5	7.2	5.7	4.0
Mitsubishi	--	--	--	--	--	--	--	--	--	--	2.0	7.0
Nissan	--	--	--	--	--	--	--	--	4.0	6.5	4.5	7.1
Porsche	4	7	0.8	6.2	0.8	6.6	0.6	6.7	0.4	6.7	0.8	6.7
Toyota	2	3	3.0	4.0	2.7	4.2	3.1	4.7	3.6	4.9	3.3	6.6
Volkswagen	2	4	2.0	4.0	3.0	4.0	4.8	7.4	4.9	7.3	4.8	7.4
Fleet Average	1	5	2.9	5.7	3.0	6.2	3.5	6.8	4.0	7.6	4.8	8.4

2.3.2. Allowances for Improvement 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 (e.g. 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 (Table 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 but are capped at 5.7 g/mi.

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:

Equation 3

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

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 2011 – 2016 model years. Sixteen companies have claimed allowances for improvements in air conditioning system efficiency during this period.

Table 6 – Allowance for Improvements in AC System Efficiency (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	5	--	--	--	--	--	--	--	--	--	--	--
BMW	4	4	3.4	4.3	3.5	4.3	4.0	4.3	4.2	4.3	4.4	4.3
FCA	2	2	3.0	2.0	3.0	3.0	3.9	4.1	4.5	4.5	5.2	4.2
Ford	--	--	--	--	2.0	1.0	1.7	2.6	2.4	3.4	2.7	3.5
GM	1	1	3.0	1.0	3.0	2.0	3.1	3.9	3.2	4.1	3.5	4.2
Honda	2	2	1.2	2.0	1.2	2.1	1.3	2.0	1.4	1.9	3.3	2.9
Hyundai	--	--	2.0	1.7	2.6	3.4	3.5	3.7	3.5	3.7	3.7	4.2
JLR	2	4	2.0	3.0	2.0	4.0	5.2	5.4	5.2	5.6	5.7	5.7
Kia	--	--	2.1	2.5	2.6	3.4	3.2	2.7	3.3	3.4	3.3	3.4
Mercedes	5	5	5.0	4.9	5.0	5.0	5.4	5.4	5.4	5.5	5.2	5.3
Nissan	--	--	--	--	--	--	--	--	2.8	2.9	3.1	3.0
Porsche	4	6	4.0	5.7	3.9	5.7	3.8	5.7	3.7	5.7	3.9	5.7
Subaru	--	--	--	--	--	--	--	--	--	--	2.9	3.0
Tesla	3	--	6.0	--	6.0	--	5.7	--	5.7	--	5.7	--
Toyota	3	3	3.4	2.5	3.6	3.6	3.4	3.6	3.4	4.0	3.8	4.4
Volkswagen	4	5	4.0	5.0	4.0	6.0	3.9	4.7	3.8	4.2	4.4	5.2
Fleet Average	1	1	1.9	1.5	2.4	2.2	2.6	3.1	2.9	3.6	3.4	3.8

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, and 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:

Equation 4

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

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 2011 – 2016. In total, fourteen companies have made use of the allowance for innovative technologies during this period.

Table 7 – Allowance for the Use of Innovative Technologies (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
BMW	--	--	--	--	--	--	3.1	6.0	3.4	6.2	3.7	6.5
FCA	1	2	1.0	2.0	1.0	3.0	3.5	7.6	3.6	7.7	3.2	8.2
Ford	--	--	--	--	--	--	2.0	3.2	3.9	7.4	1.7	3.9
GM	1	1	1.0	2.0	1.0	2.0	0.5	1.6	1.7	2.5	2.4	3.8
Honda	--	--	--	--	--	--	0.5	2.1	1.3	2.2	1.7	2.5
Hyundai	--	--	--	--	--	--	0.8	1.7	1.1	2	0.8	4.8
JLR	--	--	--	--	--	--	2.4	5.4	2.4	5.8	3.2	7.4
Kia	--	--	--	--	--	--	0.6	0.8	1.1	1.6	1.0	3.6
Mercedes	--	--	--	--	--	--	4.2	1.6	3.4	4.2	3.3	4.6
Nissan	--	--	--	--	--	--	--	--	1.3	3.0	1.7	3.3
Porsche	--	--	--	--	--	--	--	--	--	0.6	2.5	4.4
Subaru	--	--	--	--	--	--	--	--	--	--	1.1	3.3
Toyota	--	--	--	--	--	--	1.8	3.6	2.2	3.1	1.1	3.3
Volkswagen	--	--	2.0	1.0	1.0	1.0	--	--	--	--	--	--
Fleet Average	0.2	0.6	0.3	0.8	0.2	0.9	1.2	3.7	1.4	4.1	1.4	4.5

2.3.4. Dual Fuel Vehicles

Alcohol dual fuel vehicles[10] [e.g. 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 up to 85% ethanol (E85). The regulations contain provisions to allow a company to improve their fleet average GHG emissions for the 2011–2015 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 2011-2015 model years.

Equation 5

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

Where:

CCREEgas 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_2 emissions.

Equation 6

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

Where:

FltAvg is the fleet average CREE value assuming all FFVs in the fleet are operated exclusively on gasoline (or diesel) fuel;

MPG_{MAX} is the maximum increase in miles per gallon for a specific model year[11]

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 operatio. Starting with the 2016 model year, companies may only make use of this provision

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

11 MPGmax is 1.2 for 2012-2014 & 1.0 for 2015

where they can demonstrate that their vehicles are using the alternative fuel in the marketplace (e.g. 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.

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

The total quantity of FFVs reported by manufacturers during the 2011–2016 model years is summarized in Table 8. During this period, six manufacturers reported FFVs, the majority of which have come from Ford, GM, and FCA. Approximately three times as many FFVs were produced for the light truck fleet than for the passenger automobile fle.

Table 9 shows the benefit of FFVs for these companies' fleet performance for the 2011 through 2016 model years. FCA, GM, and Ford, were the primary manufacturers of FFVs, and the impacts from the sale of these vehicles reduced their CREE values by approximately 4-5% over the 2011 – 2015 model years. The asterisks in Table 9 indicate that a company has reduced their CREE by the maximum annual allowable amount attributable to FFV sales. No companies reported the use of alternative fuels (e.g. E85) for the 2016 model year and hence were not eligible to reduce their CREE as a result of FFV sales.

Table 8 – FFV Production Volumes for the 2011 – 2016 Model Years

Model Year	Category	Ford	GM	FCA	Mazda	Mercedes	JLR	Volkswagen	Total
2011	LT	67,655	80,484	--	1,598	--	--	--	--
	PA	11,490	37,307	--	253	--	--	--	--
2012	LT	55,227	55,485	77,672	--	222	--	--	188,606
	PA	23,975	49,937	14,537	--	3,263	--	118	91,830
2013	LT	74,899	65,632	74,921	--	560	--	296	216,308
	PA	33,769	21,667	12,354	--	6,507	20	4,390	78,707
2014	LT	75,242	80,265	94,437	--	651	3,277	4,927	258,799
	PA	29,040	10,160	6,292	--	5,039	40	4,967	55,538
2015	LT	55,514	20,022	80,645	--	4,055	1,250	4,796	166,282
	PA	19,776	5,721	15,372	--	2,729	35	4,996	48,629
2016[a]	LT	81,192	10,428	--	--	--	--	--	91,620
	PA	17,165	4,105	--	--	5,575	--	--	26,845

a. Due to the transition of FFV provisions which require evidence of E85 usage beginning with the 2016 model year, certain companies may not have identified all FFV models in their fleets. The FFV production volumes for the 2016 model year may therefore be under-reported.

Table 9 – FFV Impact for the 2011 – 2016 Model Years (g/mi)

Model Year	Category	Ford	GM	FCA	Mazda	Mercedes	JLR	Volkswagen
2011	LT	19	22	--	16	--	--	--
	PA	9	10	--	1	--	--	--
2012	LT	22*	23*	22*	--	3	--	--
	PA	9*	10*	12*	--	12	--	1
2013	LT	20*	22*	22*	--	7	--	--
	PA	9*	10*	11*	--	9	3	7
2014	LT	20*	18*	20*	--	8	20	14*
	PA	9*	9*	12*	--	10	6	10*
2015	LT	15*	15*	15*	--	10	14*	12*
	PA	7*	6	10*	--	7	4	7*
2016	LT	--	--	--	--	--	--	--
	PA	--	--	--	--	--	--	--

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 (PHEVs), and fuel cell electric vehicles (FCEV). BEVs are completely powered by grid electricity stored in a battery, and hence produce no tailpipe emissions. PHEVs incorporate an electrical powertrain which enables them to be charged by grid electricity to operate solely on electrical power, but also contain a conventional 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 (e.g. BEVs), fuel cell vehicles, and the electric portion of plug-in hybrids (i.e. when PHEVs operate as electric vehicles) subject to the limitations described below. Additionally, companies may multiply the number of ATVs in their fleet by a factor of 1.2 to increase the impact that they have on a company's overall fleet average.

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 two options for the quantity of vehicles that can be reported as 0 g/mi. For vehicles of the 2011 - 2016 model years, a company may report 0 g/mi for: (a) the first 30,000 ATVs if it sold fewer than 3,750 ATVs in the 2012 model year; or (b) the first 45,000 ATVs if it sold 3,750 or more in model year 2012. The regulations also recognize early action for ATVs sold during the 2008 – 2010 model years. If a company claimed early action credits (discussed in section 3.1), the production volumes that were reported in the 2008 - 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 production volumes of ATVs sold by model year are presented in Table 10. ATV sales in Canada have been predominantly confined to the passenger automobile sector, though a number of ATVs have entered the market in the light truck sector in recent years. No company sold 3,750 ATVs in the 2012 model year, and no company reached the 30,000 ATV ceiling during the 2011 - 2016 model years. Thus all companies reporting were able to claim a 0 g/mi CREE for their ATVs.

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 (i.e. non application of the standards respecting CO_2 equivalent emissions[12]) 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

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

Table 10 – Production Volumes of ATVs by Model Year

Manufacturer	2011	2012	2013	2014	2015	2016	Total
BMW	--	--	--	--	670	605	1,275
Ford	--	102	338	696	297	771	2,204
GM	--	1,337	858	1,340	1,546	765	5,846
Honda	--	--	--	12	--	--	12
Kia	--	--	--	--	110	1,069	1,179
Mercedes	--	--	91	613	149	198	1,051
Mitsubishi	--	380	49	137	--	120	686
Nissan	140	534	236	406	1,703	1,620	4,639
Porsche	--	--	--	53	162	311	526
Tesla	16	303	418	971	1,913	2,963	6,584
Toyota	--	53	225	64	53	--	395
Volkswagen	--	--	--	--	--	293	293
Volvo	--	--	--	--	--	278	278
Total	156	2,709	2,215	4,292	6,603	8,993	24,968

Table 11 – Production Volumes for Small Volume Companies by Model Year

Manufacturer	2012	2013	2014	2015	2016
Ferrari	193	207	198	201	209
Maserati	152	154	561	443	344
Lotus	19	16	14	8	0
Aston Martin	100	35	124	117	91
Total	464	412	897	769	644

or imported for sale a running average of less than 750 vehicles for the three model years prior to the model year being exempted; and 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 four small volume companies for the 2012 and later model years.

2.3.7. Temporary Optional Fleets

The regulations include an option for intermediate sized companies (i.e. those with a 2009 model year total production volume of 60,000 or fewer vehicles) to meet an alternative standard for a specified time period. 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 combined total of up to 30,000 vehicles of the 2012-2015 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 combined total of up to 15,000 vehicles of the 2012-2015 model

Table 12 – Production Volumes of Temporary Optional Fleets

Manufacturer	2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
JLR	716	3,904	1,090	5,140	1,179	6,183	1,507	6,188	1,282	4,655
Mercedes	3,461	730	1,877	3,063	1,698	977	2,025	1,085	--	--
Porsche	1,242	1,102	1,556	2,023	2,018	2,599	1,549	3,340	1,585	5,081
Volvo	3,782	3,708	1,970	2,809	607	1,662	3,272	3,139	891	4,885
Total	9,201	9,444	6,493	13,035	5,502	11,421	83,53	13,752	3,758	14,621

years. 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.

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

2.4 Technological Advancements and Penetration

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 (e.g. BEVs, PHEVs etc.). There also exist, however, 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 in the Canadian new vehicle fleet in given model years. As summarized in Table 13, during the 2012-2016 period, an increasing proportion of new vehicles were equipped with one or more of the aforementioned powertrain technologies.

Turbocharging with Engine Downsizing

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 gasses 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 natural 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 (<2.0L displacement), in order to decrease the overall vehicle weight and improve fuel efficiency by as much as 8%.

Variable Valve Timing & Lift (VVT & VVL)

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 ideal for all engine speeds. VVT and 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 of 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 6 or more gears to keep the engine running at its most efficient operating point and thereby reduce CO_2 emissions.

Continuously Variable Transmissions (CVT)

CVT's are transmissions that, unlike conventional transmission configurations, do not have a fixed number of gears, but instead incorporate a system of pulleys with variable diameters that are typically driven by a belt or chain. 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 (CDS)

Cylinder deactivation systems (CDS) shut off cylinders of a 6 or 8 cylinder engine when only partial power is required (e.g. 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%[13].

Gasoline Direct Injection (GDI)

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

13 http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/16753

Table 13 – Penetration Rates of Drivetrain Technologies in the Canadian Fleet

Technology	Penetration Rate				
	2012	2013	2014	2015	2016
Turbocharging with Engine Downsizing	3.2%	12.6%	13.7%	9.7%	15.8%
VVT	88.9%	96.3%	96.3%	94.2%	94.2%
VVL	16.7%	13.6%	20.2%	16.2%	19.3%
Higher Geared Transmission	5.1%	6.6%	14.1%	17.5%	22.0%
CVT	7.1%	6.8%	12.7%	13.5%	13.3%
Cylinder Deactivation	6.8%	6.8%	11.1%	10.0%	10.0%
GDI	17.6%	19.1%	26.7%	30.7%	37.4%
Diesel	1.9%	1.8%	2.7%	3.0%	1.8%

intake manifold and are subsequently drawn into the combustion chamber. By contrast, 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

A 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[14] which translates into measurable reductions in CO_2e emissions.

The fleet-wide penetration rates of the above described technologies have been provided in Table 13, while data pertaining to company specific usage can be found in Table A-3 to Table A-10.

14 https://www.fueleconomy.gov/feg/di_diesels.shtml

2.5 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 currently have three 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 available to companies enables them 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 two gases. This method is not as commonly used as it

Table 14 – N_2O Emissions Deficits by Company for the 2012-2016 Model Years (Mg CO_2e)

Manufacturer	2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
BMW	--	2,573	--	1,391	3,613	2,332	2,088	8,066	2,062	5,853
Ford	244	30,198	531	46,745	261	2,741	272	2,755	255	4,760
GM	--	--	--	--	1,282	--	878	--	--	1,615
Honda	--	--	18,748	--	18,102	--	1,414	3,715	--	--
Mazda	--	--	--	--	--	--	--	--	--	480
Nissan	--	--	--	--	--	--	5,143	19,634	5,595	23,617
Toyota	--	--	--	--	--	--	1,381	2,302	1,729	2,647
Volkswagen	28,680	3,314	30,139	2,096	23,434	3,866	20,673	3,251	219	928
Fleet Total	28,924	36,085	49,418	50,232	46,692	8,939	31,849	39,723	9,860	39,900

Table 15 – CH_4 Emissions Deficits by Company for the 2012-2016 Model Years (Mg CO_2e)

Manufacturer	2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
BMW	--	647	--	350	454	293	263	1,015	260	737
FCA	743	3,173	173	124	20	3,342	--	1,312	3	2,384
Ford	1,403	4,457	1,791	5,803	1,328	5,484	1,083	10,649	1,017	20,409
GM	1,189	9,397	1,461	11,089	773	3,842	109	641	137	708
Nissan	--	--	--	--	--	--	431	1,647	436	1,981
Volkswagen	12,274	299	12,837	126	9,686	--	42	273	39	128
Fleet Total	15,609	17,973	16,262	17,492	12,261	12,961	1,928	15,537	1,892	26,345

counts N_2O and CH_4 emissions even for the portion of a company's fleet that does not exceed the standard. Mazda, Nissan, and Subaru have thus far been the only companies to use this option to comply with standards for N_2O and CH_4.

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 in Mg which must be offset with conventional CO_2 emissions credits. Over the 2012 – 2016 period, a growing number of manufacturers have been utilizing this method. The total deficits incurred by the companies that used this method are summarized in Table 14 and Table 15.

2.6 CO_2e Equivalent 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:

Equation 7

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

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)

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. Table 16 shows the companies' compliance values across the 2011-2016 model years.

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 2016 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. Figure 4 and Figure 5 instead refer to "tailpipe emissions"[15] as opposed to CREE so that FFV benefits can be portrayed separately. The dark green line on the top of the bar indicates a company's fleet average tailpipe emissions. The wide orange line represents the fleet average standard and the wide dark blue line represents the fleet average compliance value (i.e. accounting for compliance flexibilities). The green shaded 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.

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

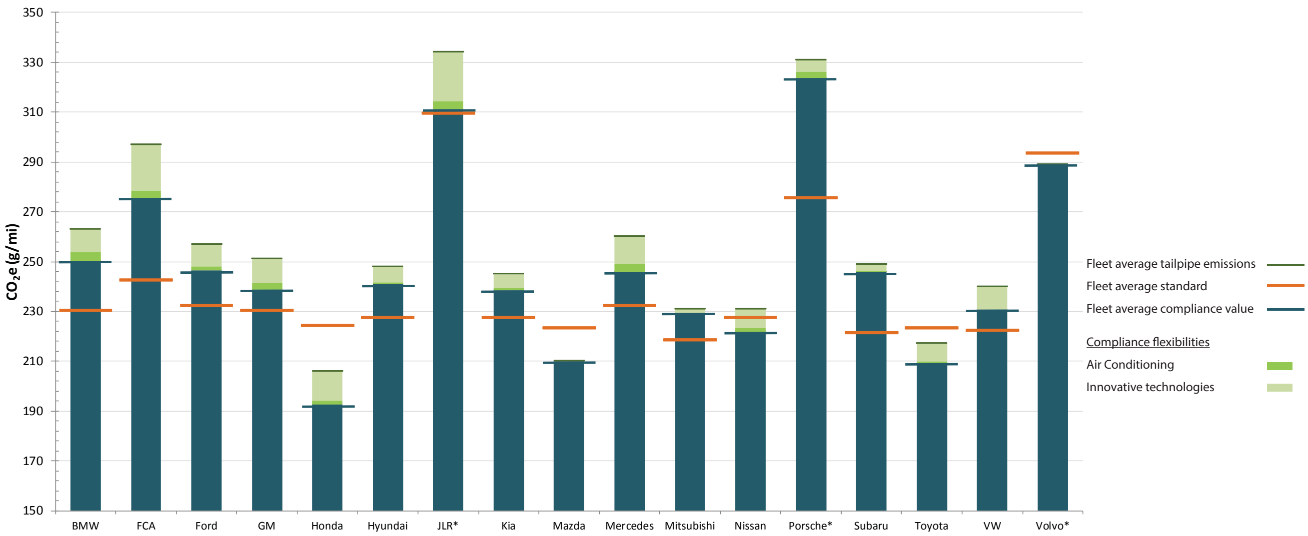
Table 16 – Compliance Values Over the 2011-2016 Model Years (g/mi)

Manufacturer	2011		2012		2013		2014		2015		2016	
	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT	PA	LT
Aston Martin	460	--	--	--	--	--	--	--	--	--	--	--
BMW	299	327	270	350	256	318	248	296	246	292	251	295
FCA	298	363	273	358	264	353	265	333	256	321	275	332
Ferrari	557	--	--	--	--	--	--	--	--	--	--	--
Ford	252	357	239	367	237	349	238	344	237	333	247	361
GM	265	383	249	372	247	362	241	328	242	328	239	348
Honda	238	319	217	303	221	301	216	286	207	261	193	262
Hyundai	244	307	230	309	231	305	247	307	243	308	241	327
JLR	377	465	374	406	357	384	333	328	327	309	311	320
Kia	253	315	263	303	244	292	255	311	258	314	238	329
Lotus	321	--	--	--	--	--	--	--	--	--	--	--
Maserati	466	--	--	--	--	--	--	--	--	--	--	--
Mazda	250	331	232	295	236	268	210	267	207	276	210	259
Mercedes	294	356	306	363	257	336	250	311	243	290	246	313
Mitsubishi	250	275	244	281	244	272	219	270	224	265	229	265
Nissan	252	349	253	378	235	342	221	318	219	287	222	262
Porsche	327	356	319	356	306	353	301	349	309	334	324	319
Subaru	303	296	269	303	257	273	242	254	249	254	246	249
Suzuki	262	322	263	319	260	330	--	--	--	--	--	--
Tesla [a]	-3	--	-6	--	-6	--	-6	--	-6	--	-6	--
Toyota	232	329	214	337	221	323	208	330	209	317	209	315
Volkswagen	238	317	260	312	252	307	244	293	231	294	231	292
Volvo	303	355	299	340	300	345	306	349	281	332	289	299
Fleet Average	255	349	242	349	238	339	234	323	230	311	228	321

Notes:

a. 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.

Figure 4 – 2016 Passenger Automobile Compliance Status with Offsets

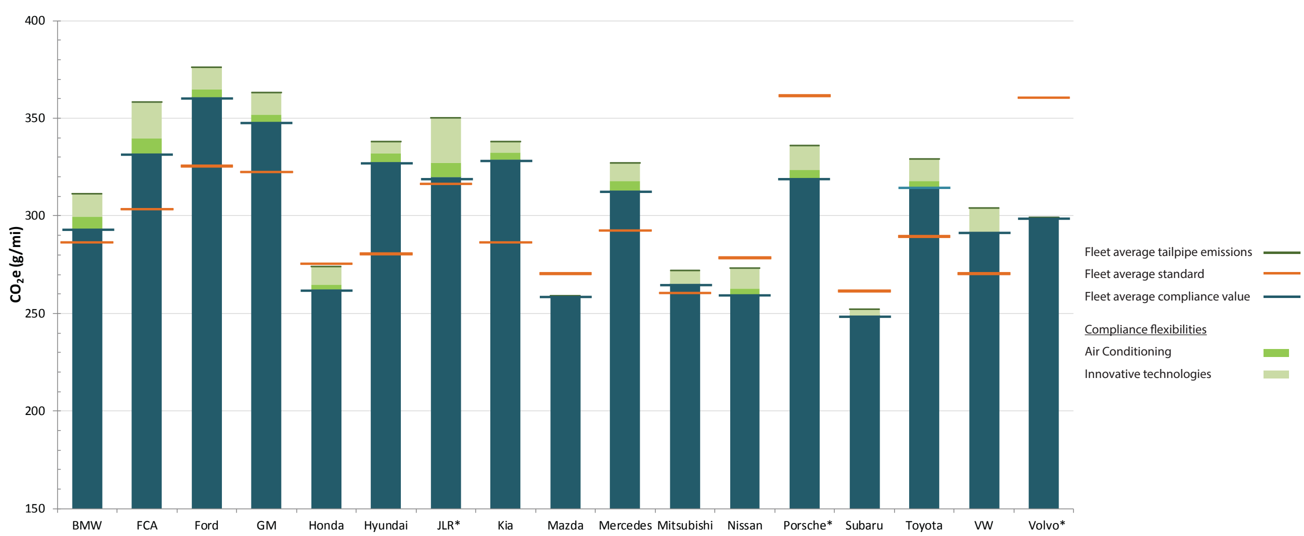


Notes:

– The asterisked companies are those that used the temporary optional fleet provisions.

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

Figure 5 – 2016 Light truck Compliance Status with Offsets



Notes:

– The asterisked companies are those that used the temporary optional fleet provisions.

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

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 worse than 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 three model years.

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

Equation 8

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

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 iis the total number of passenger automobiles or light trucks in the fleet; and

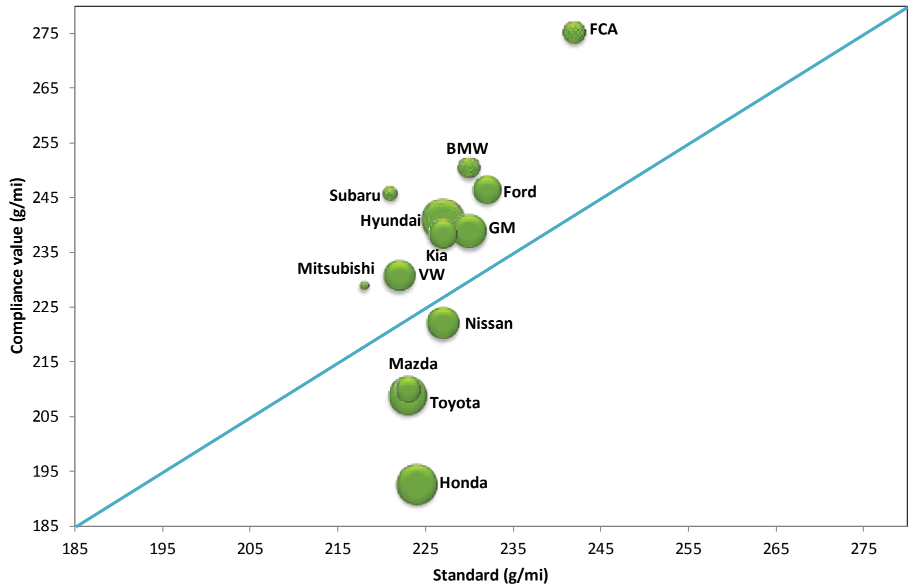
D is the is the total assumed mileage of the vehicles in question, namely,
(a) 195,264 miles for a fleet of passenger automobiles, or
(b) 225,865 miles for a fleet of light truck.

The ability to earn, bank, trade and sell credits, including early action credits, is an important aspect of the regulations and is intended to give manufacturers flexibility to meet the 2012-2016 model year standards, as well as assist with the transition to the progressively more stringent standards during the 2017-2025 model years. 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 five model years after the year in which the credits were obtained (i.e. credits had a five-year lifespan). The regulations were amended to extend the lifespan of credits earned during the 2010-2016 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 five-year lifespan.

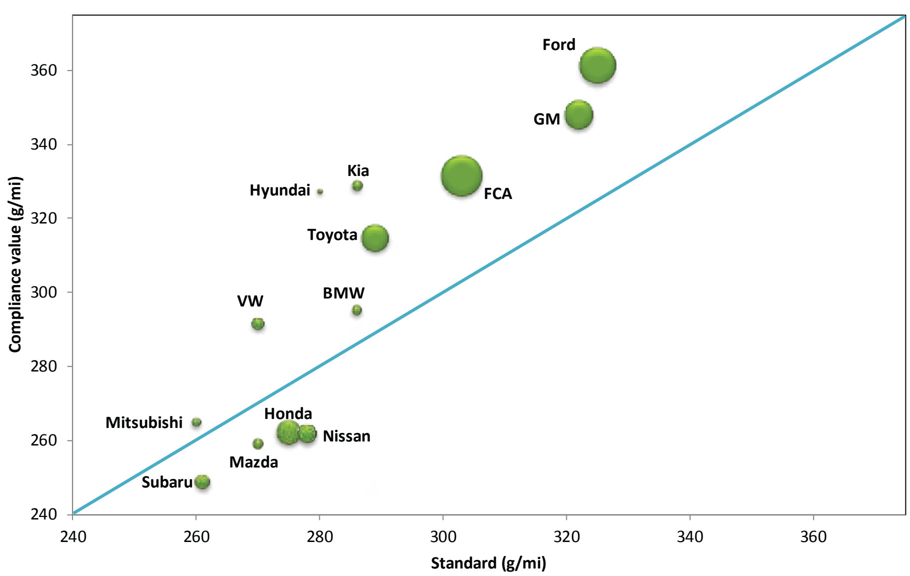
As previously noted, a company's ability to earn credits is based on its compliance value relative to its standard and its overall production volume. For this reason, the compliance margin (i.e. the difference between the compliance value and the standard) of a company with a large production volume will generate a greater number of credits (or deficits) than that of a company with a low production volume, all else being equal. Figure 6 and Figure 7 illustrate the extent to which a company will earn credits (or incur a deficit) for its fleets of passenger automobiles and light trucks in the 2016 model year. The vertical axis denotes the compliance value and the horizontal axis shows the applicable standard. The center of each circle situates the company's compliance value and standard, and the diameter is indicative of the company's production volume. Companies that are positioned below the diagonal line have emission levels that are better than their applicable standard and will generate credits. The standard values for companies that reported TOFs fall well outside the range of Figure 6 and Figure 7, and have not been included. Figure 6 illustrates that while the majority of companies are subject to a CO_2e standard that ranges between 220 g/mi to 230 g/mi for their fleet of passenger automobiles, there is a comparatively wide range of compliance values achieved by these companies. Figure 7 shows that there is variation in both compliance values and applicable CO_2e standards for companies' fleets of light trucks. Comparable charts for model years 2011-2015 can be found in Figure A-9 – Figure A-16 of the Appendix.

Figure 6 – 2016 Compliance Status of Passenger Automobile Fleetwith Company Size



Notes: Companies that used the temporary optional fleet provisions are not shown in this graph.

Figure 7 – 2016 Compliance Status of Light Truck Fleet with Company Size



Notes: Companies that used the temporary optional fleet provisions are not shown in this graph.

3.1 Early Action Credits (2008-10)

The regulations enabled companies to earn "early action" credits for their 2008 – 2010 model year vehicles to recognize early adoption of fuel efficient technologies. This provision required that companies provide a full report on their 2008 – 2010 model years and that the net credit balance be positive. Any deficits accrued during those model years had to be offset by credits acquired in those same model years before calculating any credits that may be carried forward into the 2011 model year.

To generate early action credits, companies could elect to calculate their fleet average standards using methods that corresponded to either U.S. CAFE standards, or alternatively to California's GHG emission program (Alternative Fleet Combination). California's program differed slightly from the federal program in how cars and trucks are classified, and also the applicable emission levels.

The use of early action credits generated was subject to certain limitations. For example, credits claimed in respect of the 2008 model year were only available up to the 2011 model year after which they were no longer valid. Additionally, a company that generated credits using thresholds that correspond to California's GHG emission regulations could not trade credits of the 2009 model year.

Table 17 presents a summary of the total early action credits generated by those companies that elected to use this provision. In total, almost 52 million early action credits were generated. The compliance data (i.e. compliance value and standard) used to calculate the resulting early action credits can be found in Appendices Table A-11 and Table A-12 of the appendix.

3.2 Credits Purchased from the Receiver General

Under the U.S. CAFE program, companies can meet

Table 17 – Net Early Action Credits (Mg CO_2e)

Manufacturer	2008	2009	2010	Total
BMW	154,486	165,080	117,070	436,636
FCA	1,431,356	1,497,429	1,866,599	4,795,384
Ford	1,200,368	2,036,603	2,051,415	5,288,386
GM	3,742,784	3,391,228	2,242,967	9,376,979
Honda	2,674,010	2,088,289	2,130,090	6,892,389
Hyundai	1,166,558	1,725,828	1,684,866	4,577,252
Kia	327,172	346,330	718,429	1,391,931
Lotus	189	142	-94	237
Mazda	1,008,810	588,510	1,630,325	3,227,645
Mercedes	141,136	85,808	38,987	265,931
Mitsubishi	193,030	300,460	249,375	742,865
Nissan	1,013,522	1,275,037	742,272	3,030,831
Suzuki	113,336	104,593	123,345	341,274
Tesla	0	0	2,292	2,292
Toyota	2,478,694	3,609,296	3,921,376	10,009,366
Volkswagen	263,128	570,434	461,130	1,294,692
Volvo	29,016	27,030	38,880	94,926
Total	15,937,595	17,812,097	18,019,324	51,800,232

the mandatory fuel economy standards by paying a monetary penalty. To provide companies with comparable compliance flexibility for the 2011 model year exclusively, companies were able to purchase credits from the Receiver General of Canada at a rate of $20/Mg CO_2e to offset an emissions deficit. The option to purchase credits from the Receiver General was used by Porsche, Lotus, and Aston Martin. The quantities of credits purchased can be found in Table 18.

3.3 Credit Transfers

Table 18 summarizes transactions by company and the model year in which the credits were generated. There have been more than 5.6 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 indicative of when a credit transfer occurred (e.g. it is possible to transfer credits for the 2012 model year during the 2016 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.

3.4 Total Credits Generated and Final Status

Table 19 shows the credits earned (or deficits incurred) by all companies over the 2011 – 2016 model years. Credit values have been provided for Mercedes, JLR, Porsche and Volvo, however the use and lifespan of these credits are subject to restrictions since they were generated under less stringent temporary optional fleet (TOF) standards (see section 2.3.7.). 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 78.4 million emis-

Table 18 – Credit Transactions by Model Year (Mg CO_2e)

	Company	Early Action	2011	2012	2013	2014	2015	2016	Total
Transferred out	Honda	2,138,563	658,254	1,208,565	503,091	--	--	--	4,508,473
	Nissan	480,020	95,000	--	50,000	--	--	--	625,020
	Suzuki	123,345	30,431	--	--	--	--	--	153,776
	Tesla	2,292	897	7,264	24,649	55,496	105,226	158,088	353,912
	Toyota	3,740	--	--	--	--	--	--	3,740
	Receiver General	--	6,906	--	--	--	--	--	6,906
Transferred in	Aston Martin	--	2,626	--	--	--	--	--	2,626
	BMW	--	--	496,909	503,091	--	--	--	1,000,000
	FCA	2,655,727	689,582	218,920	24,649	55,496	105,226	158,088	3,907,688
	Ferrari	8,473	--	--	--	--	--	--	8,473
	JLR	80,020	--	--	--	--	--	--	80,020
	Lotus	--	139	--	--	--	--	--	139
	Mercedes	--	95,000	500,000	50,000	--	--	--	645,000
	Maserati	3,740	--	--	--	--	--	--	3,740
	Porsche	--	4,141	--	--	--	--	--	4,141

Table 19 – Net Credits by Model Year and Current Credit Balance (Mg CO_2e)

Manufacturers	2011	2012	2013	2014	2015	2016	Total	Current Balance[b]
Aston Martin	-2,626	--	--	--	--	--	-2,626	0
BMW	4,748	-50,195	29,159	76,292	-19,542	-157,579	-117,117	1,082,449
FCA	236,411	-118,954	-178,514	96,459	-374,769	-1,785,437	-2,124,804	3,828,313
Ferrari	-8,473	--	--	--	--	--	-8,473	0
Ford	1,387,005	448,046	705,226	309,403	-32,381	-1,721,565	1,238,013	945,453
GM	1,154,591	502,386	228,964	924,918	345,331	-843,657	2,258,713	2,899,980
Honda	733,309	1,208,565	687,153	736,428	928,500	950,638	5,244,593	2,799,628
Hyundai	873,419	665,198	937,254	27,708	-114,794	-386,195	2,002,590	3,637,702
JLRa	-80,020	-5,624	4,741	95,310	84,779	-10,433	88,753	0
Kia	423,722	42,124	157,572	-88,387	-266,800	-284,258	-16,027	758,977
Lotus	-376	--	--	--	--	--	-376	0
Maserati	-3,740	--	--	--	--	--	-3,740	0
Mazda	442,628	302,618	235,306	500,316	319,793	155,330	1,955,991	3,456,398
Mercedes[a]	-19,613	-153,246	24,805	29,934	63,486	-127,010	-181,644	500,104
Mitsubishi	241,953	68,907	52,152	92,072	22,872	-26,763	451,193	678,422
Nissan	370,954	-198,166	36,154	244,132	405,330	255,759	1,114,163	1,696,121
Porsche[a]	-4,141	17,325	28,218	28,352	22,794	32,868	125,416	0
Subaru	109,435	-18,625	44,651	202,146	107,662	16,955	462,224	462,224
Suzuki	30,431	-11,621	-6,481	--	--	--	12,329	0
Tesla	900	7,264	24,649	55,686	105,226	158,354	352,079	459
Toyota	1,506,331	922,973	641,786	718,341	95,134	-323,954	3,560,611	7,369,438
Volkswagen	582,643	60,523	52,088	66,649	4,334	-218,714	501,418	914,946
Volvo[a]	-9,466	81,762	41,474	14,541	37,172	68,000	233,483	41,835
Total	7,970,025	3,771,260	3,746,357	4,130,300	1,734,127	-4,247,661	17,146,762	31,072,449

a. Used temporary optional fleet provisions. Credits are subject to restrictions as described in section 2.3.7

b. The current balance accounts for any expired credits, remaining early action credits, transactions,

Table 20 – Passenger Automobile Compliance Summary for the 2011 – 2016 Model Years (g/mi)

Model Year	Tailpipe emissions	FFV	Innovative Technologies	A/C	CH_4 & N_2O	Compliance value	Standard	Compliance margin
2011	260	2.8	0.2	3.3	--	255	291	36
2012	250	3.3	0.3	4.8	0.2	242	262	20
2013	247	3.4	0.2	5.4	0.2	238	256	18
2014	244	3.7	1.2	6.0	0.2	234	248	14
2015	240	2.6	1.4	6.9	0.2	230	237	7
2016	237	0	1.4	8.2	0.1	228	227	-1

sion credits (including early action credits and TOF credits), of which approximately 32.3 million credits remain valid for future use through the 2021 model year. A total of 9.5 million credits have been used to offset deficits and 36.5 million credits have expired.

4 Estimated GHG Reductions

The overall fleet average compliance information for passenger automobiles and light trucks is summarized in Table 20 and Table 21. Additionally, Figures 8 and 9 illustrate the year over year performance for both passenger automobile and for light truck fleets.

Figure 8 – Average GHG Emissions Performance - Passenger Automobiles

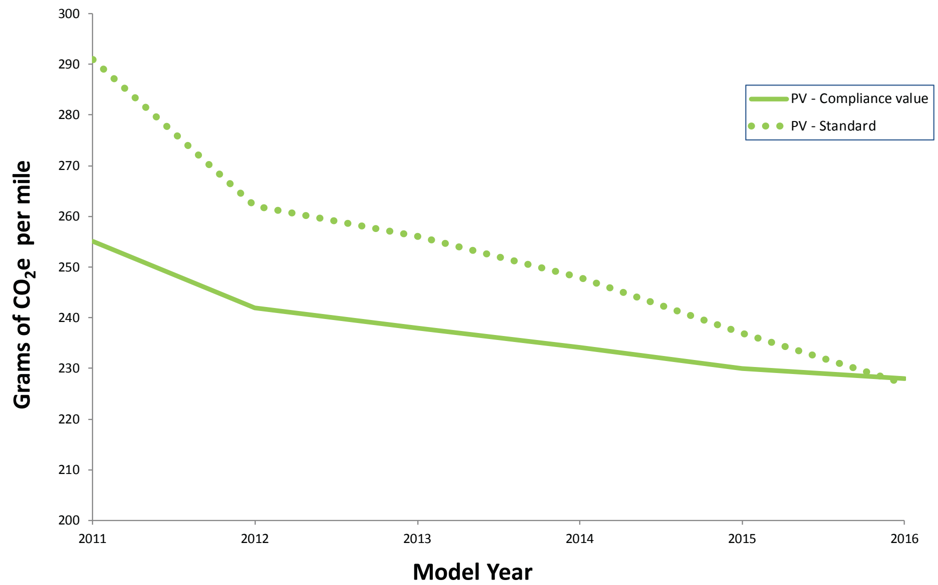
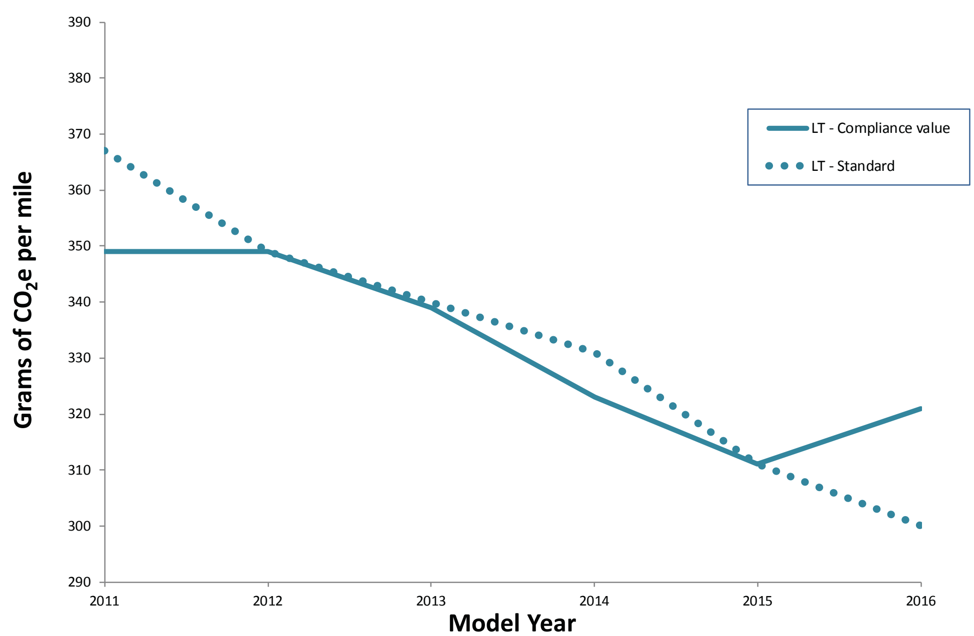


Table 21 – Light Truck Compliance Summary for the 2011 – 2016 Model Years (g/mi)

Model Year	Tailpipe emissions	FFV	Innovative Technologies	A/C	CH_4 & N_2O	Compliance value	Standard	Compliance margin
2011	364	8.0	0.6	6.9	--	349	367	18
2012	370	13.2	0.8	7.2	0.3	349	349	0
2013	361	13.2	0.9	8.4	0.4	339	340	1
2014	348	12.7	3.7	9.8	0.1	323	331	8
2015	335	9.2	4.1	11.2	0.3	311	311	0
2016	337	0	4.5	12.2	0.3	321	300	-21

Figure 9 – Average GHG Emissions Performance - Light Trucks



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 aggregated values for all companies, and are intended to depict the average results.

As depicted in Figure 8 and Figure 9, during the 2011 -2015 model years as the stringency of the regulations has increased, the overall passenger automobile fleet continued to outperform the applicable standard. From 2011 to 2015 the average compliance values from passenger automobiles decreased from 255 to 230 g/mi, a reduction of 9.8%. During the 2011-2015 period, compliance values for the light truck fleet have also continued to trend downwards (Figure 8) from 349 to 311 g/mi, a reduction of 10.9%.

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 2016 model year saw the overall compliance value for passenger automobiles decrease only slightly to 228 g/mi, and the overall compliance value for light trucks increase to 321 g/mi. This resulted in an overall net improvement of 10.6% and 8.0% relative to the 2011 model year for passenger automobiles and light trucks respectively.

Results to date indicate that all companies have met their regulatory obligations through to the 2016 model year. Despite the fact that the majority of companies incurred a deficit in the 2016 model year, a sufficient number of credits generated from earlier model years were available to ensure that industry was able to fulfil their regulatory obligations.

APPENDIX

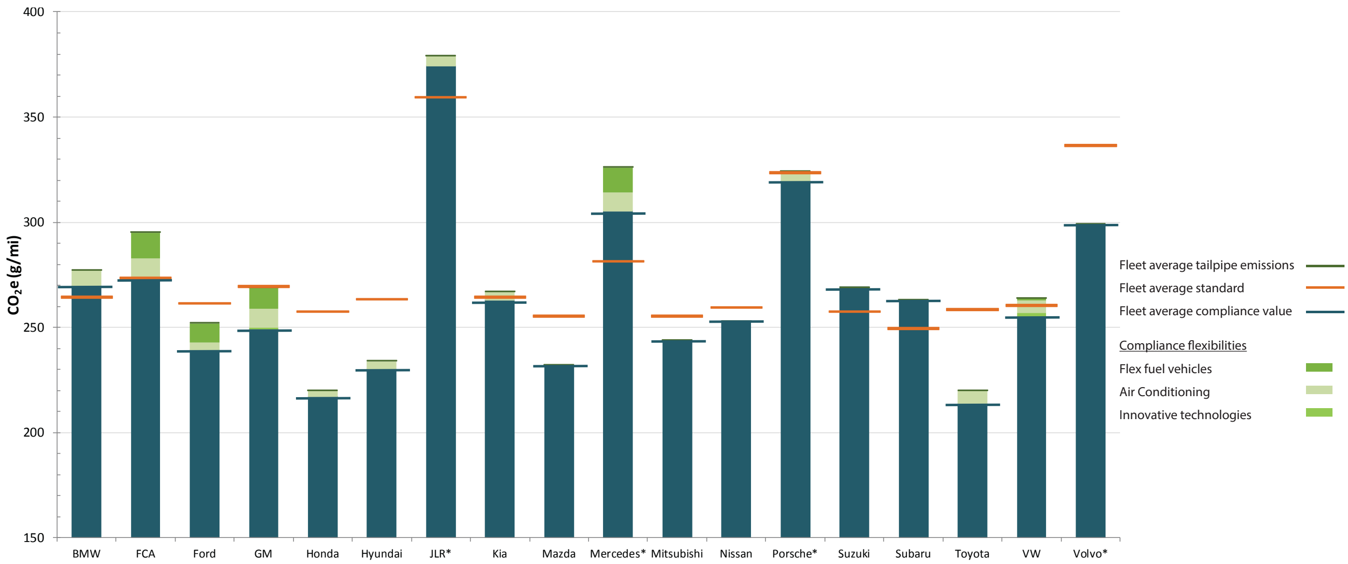
Table A-1 Production Volumes by Company (2011-2013)

Manufacturer	2011			2012			2013		
	PA	LT	All	PA	LT	All	PA	LT	All
Aston Martin	83	--	83	100	--	100	35	--	35
BMW	35,012	9,649	44,661	24,326	7,823	32,149	27,682	12,421	40,103
FCA	19,798	140,217	160,015	60,247	169,774	230,021	65,853	150,484	216,337
Ferrari	165	--	165	193	--	193	207	--	207
Ford	87,258	156,171	243,429	95,288	110,699	205,987	101,453	195,429	296,882
GM	121,574	109,040	230,614	116,845	83,620	200,465	84,413	96,783	181,196
Honda	41,213	56,354	97,567	124,852	47,123	171,975	94,346	49,470	143,816
Hyundai	80,088	20,428	100,516	97,012	19,837	116,849	186,335	9,616	195,951
JLR	354	2,680	3,034	716	3,904	4,620	1,090	5,140	6,230
Kia	47,574	17,460	65,034	59,105	5,886	64,991	73,310	4,490	77,800
Lotus	55	--	55	19	--	19	16	--	16
Maserati	133	--	133	152	--	152	154	--	154
Mazda	59,781	6,783	66,564	54,806	13,161	67,967	50,978	11,179	62,157
Mercedes	14,223	8,282	22,505	17,519	13,152	30,671	20,763	13,462	34,225
Mitsubishi	7,364	14,518	21,882	9,394	8,630	18,024	8,715	8,365	17,080
Nissan	48,030	24,592	72,622	66,253	28,396	94,649	47,146	34,793	81,939
Porsche	730	955	1,685	1,242	1,102	2,344	1,556	2,023	3,579
Subaru	13,949	17,828	31,777	14,458	16,883	31,341	10,813	11,353	22,166
Suzuki	5,244	2,357	7,601	2,863	1,292	4,155	805	455	1,260
Tesla	16	--	16	120	--	120	418	--	418
Toyota	88,886	81,584	170,470	103,878	66,056	169,934	102,219	91,026	193,245
Volkswagen	53,950	12,259	66,209	63,303	14,742	78,045	74,480	15,540	90,020
Volvo	1,427	1,760	3,187	3,782	3,708	7,490	1,970	2,809	4,779
Fleet Total	726,907	682,917	1,409,824	916,473	615,788	1,532,261	954,757	714,838	1,669,595

Table A-1 ProductionVolumes by Company (cont'd) (2014-2016)

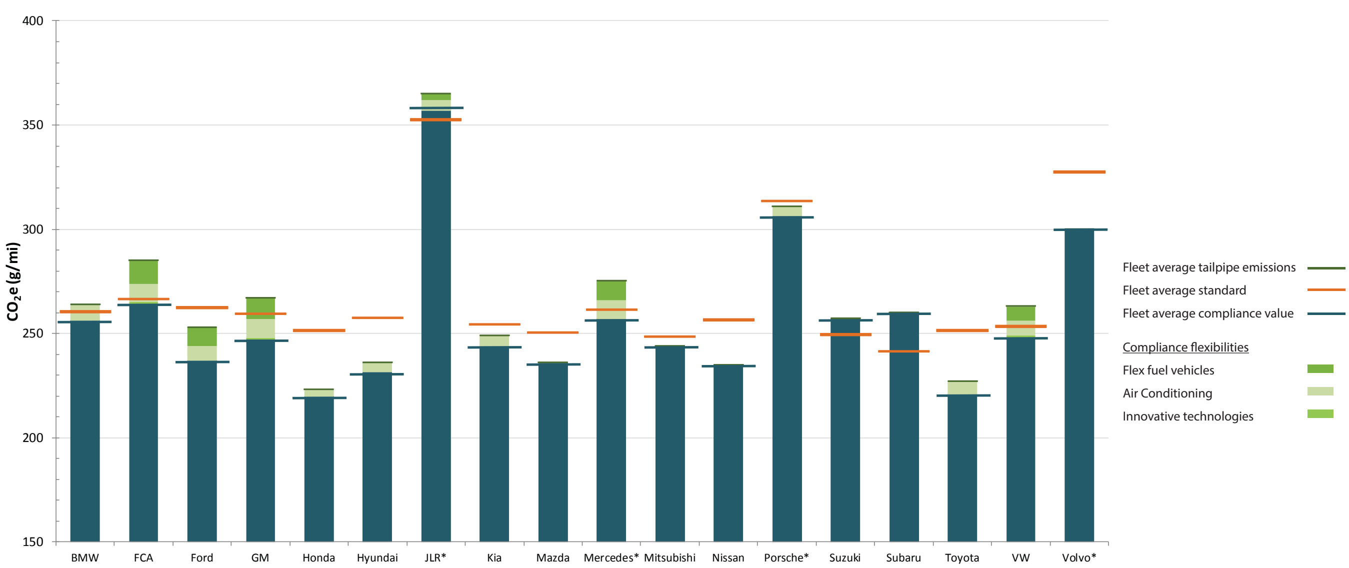
2014			2015			2016			Manufacturer
PA	LT	All	PA	LT	All	PA	LT	All	
124	--	124	117	--	117	91	--	91	Aston Martin
26,185	11,178	37,363	29,027	12,711	41,738	31,789	14,316	46,105	BMW
50,620	230,088	280,708	53,772	222,388	276,160	35,676	240,114	275,790	FCA
198	--	198	201	--	201	209	--	209	Ferrari
94,639	185,694	280,333	67,630	150,536	218,166	55,121	191,204	246,325	Ford
107,540	119,868	227,408	104,360	143,127	247,487	82,065	118,958	201,023	GM
89,628	66,780	156,408	111,045	67,740	178,785	114,360	87,060	201,420	Honda
96,281	9,402	105,683	97,784	10,744	108,528	123,676	4,493	128,169	Hyundai
1,179	6,183	7,362	1,507	6,188	7,695	1,282	11,564	12,846	JLR
66,909	4,256	71,165	63,479	4,392	67,871	58,583	15,878	74,461	Kia
14	--	14	8	--	8	--	--	--	Lotus
561	--	561	443	--	443	344	--	344	Maserati
50,546	17,617	68,163	48,554	16,373	64,927	46,386	15,317	61,703	Mazda
22,793	13,310	36,103	22,997	20,083	43,080	24,178	12,980	37,158	Mercedes
13,561	12,255	25,816	14,600	11,080	25,680	6,100	12,097	18,197	Mitsubishi
59,385	49,964	109,349	94,731	59,371	154,102	71,221	51,416	122,637	Nissan
2,071	2,599	4,670	1,549	3,340	4,889	1,585	5,081	6,666	Porsche
11,187	26,892	38,079	17,593	35,735	53,328	14,603	32,079	46,682	Subaru
--	--	--	--	--	--	--	--	--	Suzuki
971	--	971	1,913	--	1,913	2,963	--	2,963	Tesla
117,713	75,979	193,692	110,456	115,816	226,272	102,858	104,187	207,045	Toyota
54,003	21,178	75,181	86,456	23,083	109,539	67,074	21,133	88,207	Volkswagen
607	1,662	2,269	3,272	3,139	6,411	891	4,885	5,776	Volvo
866,715	854,905	1,721,620	931,494	905,846	1,837,340	840,711	942,762	1,783,473	Fleet Total

Figure A-1 2012 Passenger Automobile Compliance Status with Offsets



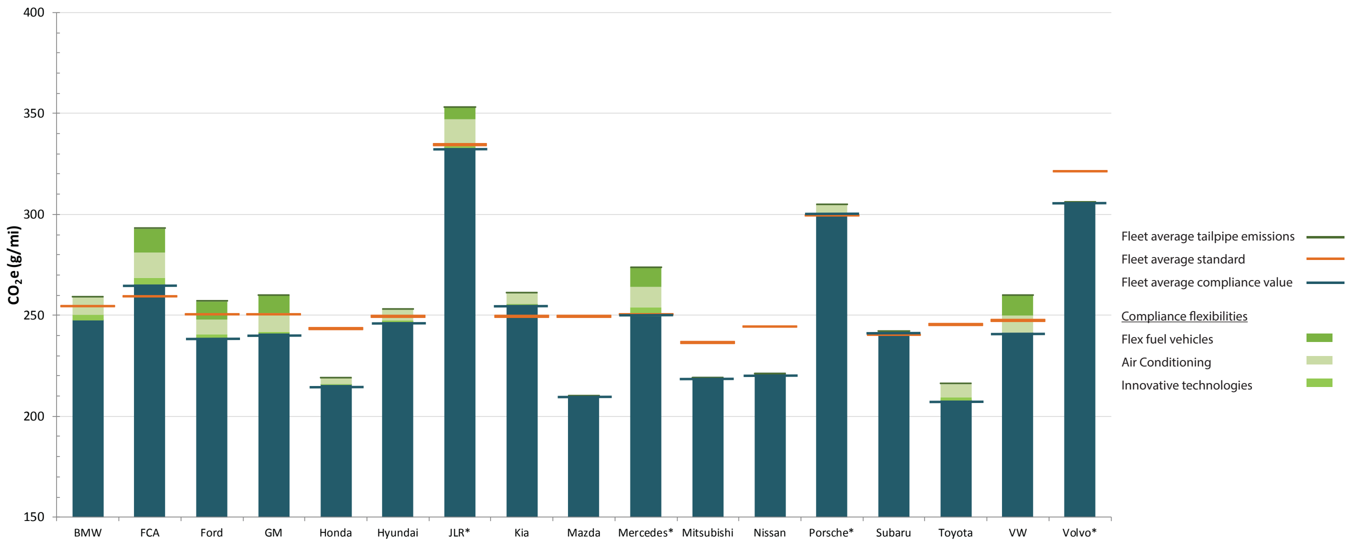
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-2 2013 Passenger Automobile Compliance Status with Offsets



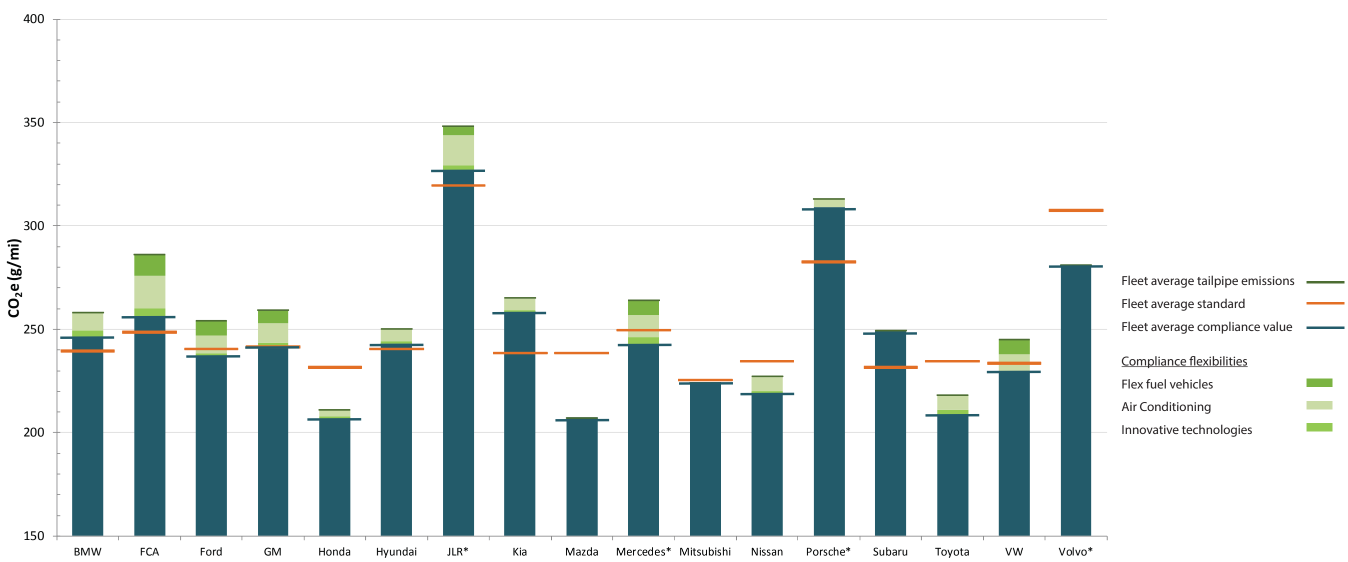
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-3 2014 Passenger Automobile Compliance Status with Offsets



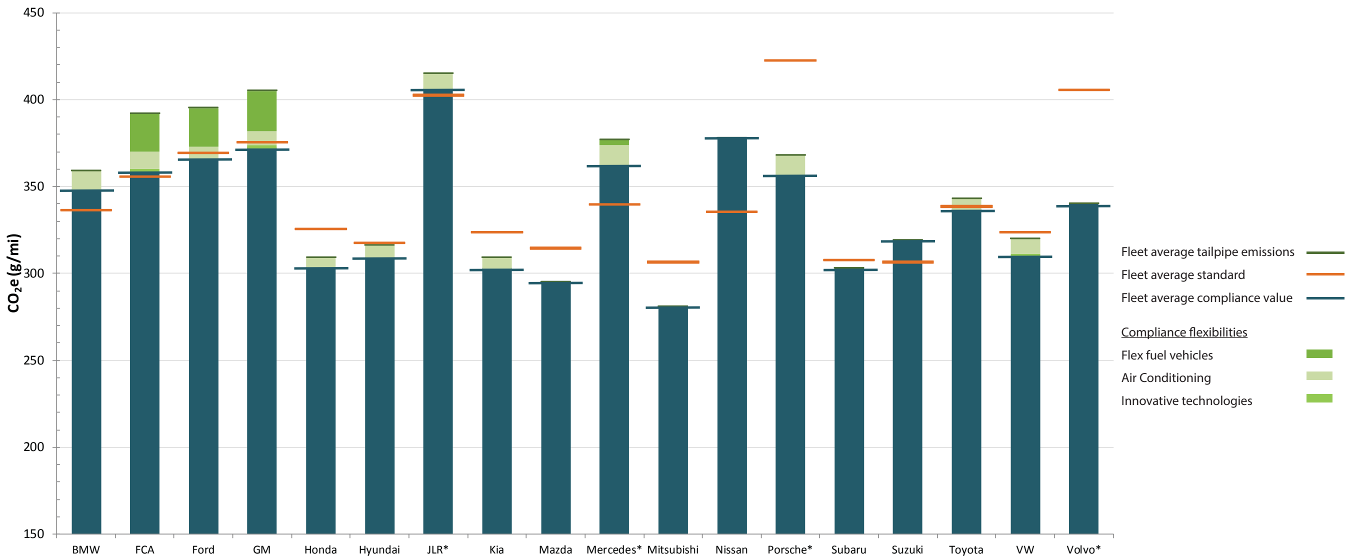
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-4 2015 Passenger Automobile Compliance Status with Offsets



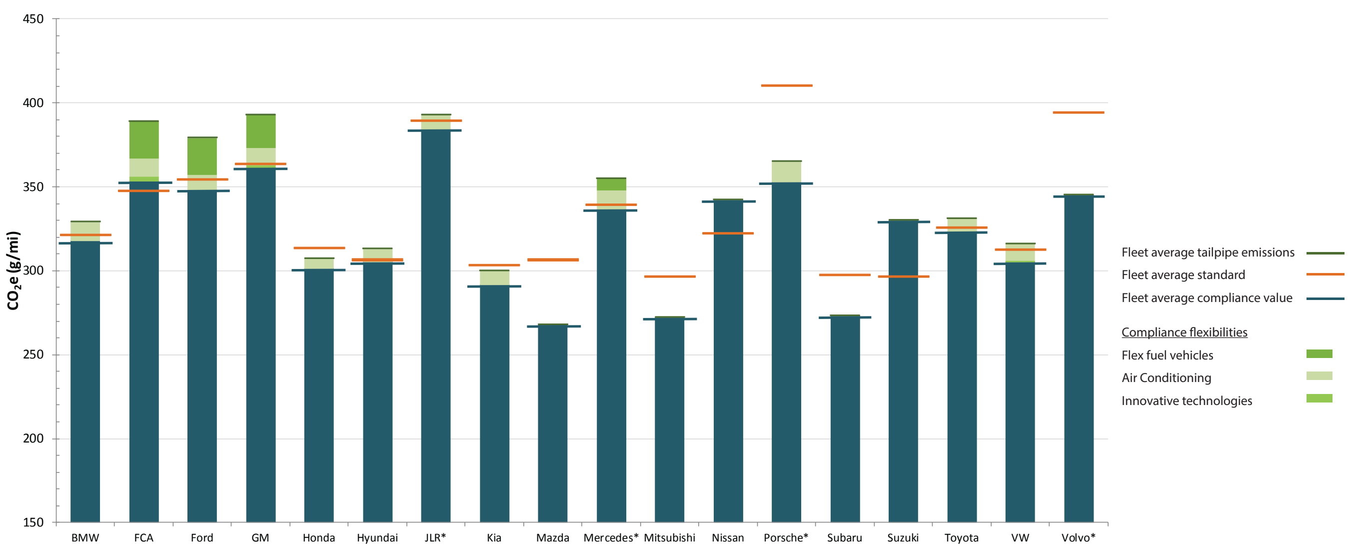
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-5 2012 Light Truck Compliance Status with Offsets



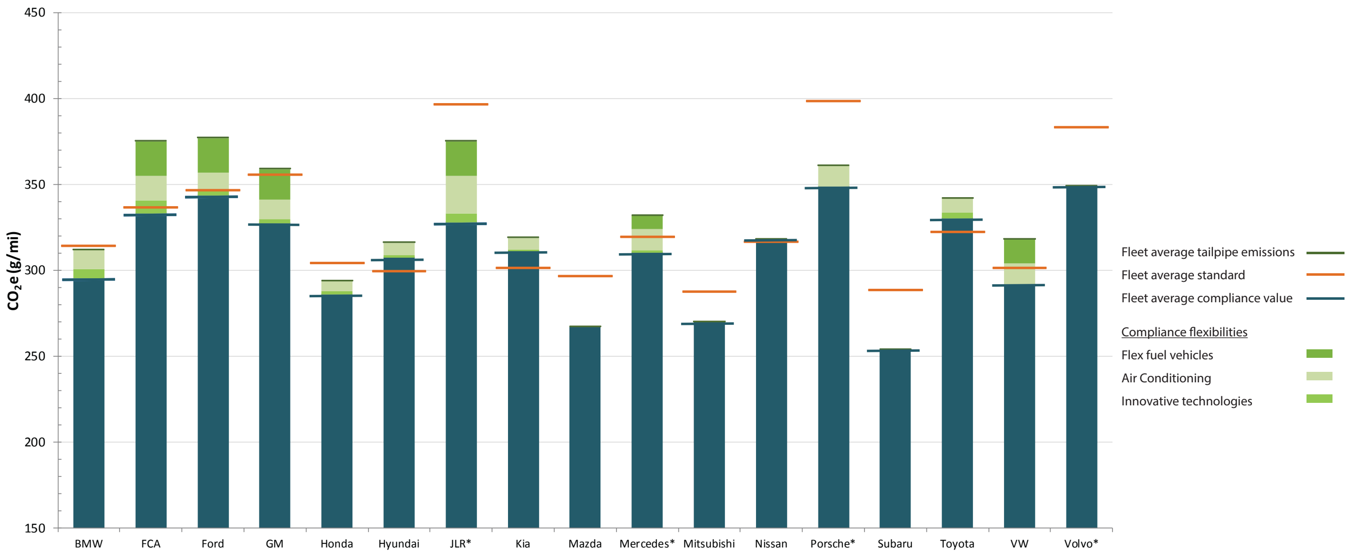
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-6 2013 Light Truck Compliance Status with Offsets



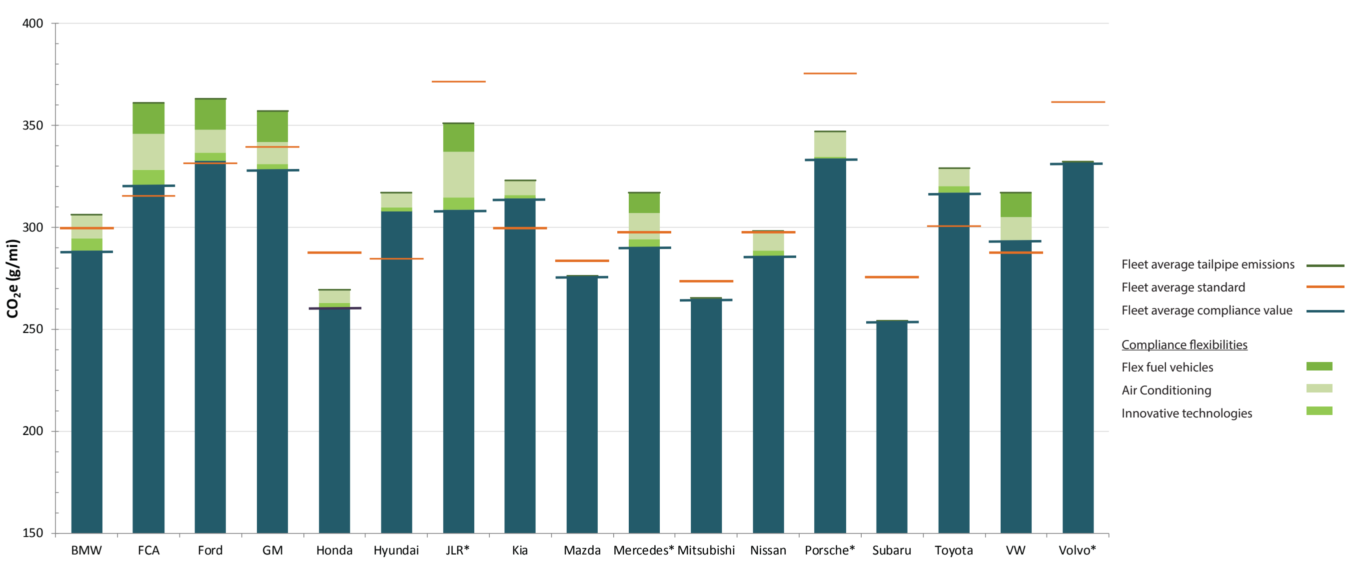
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-7 2014 Light Truck Compliance Status with Offsets



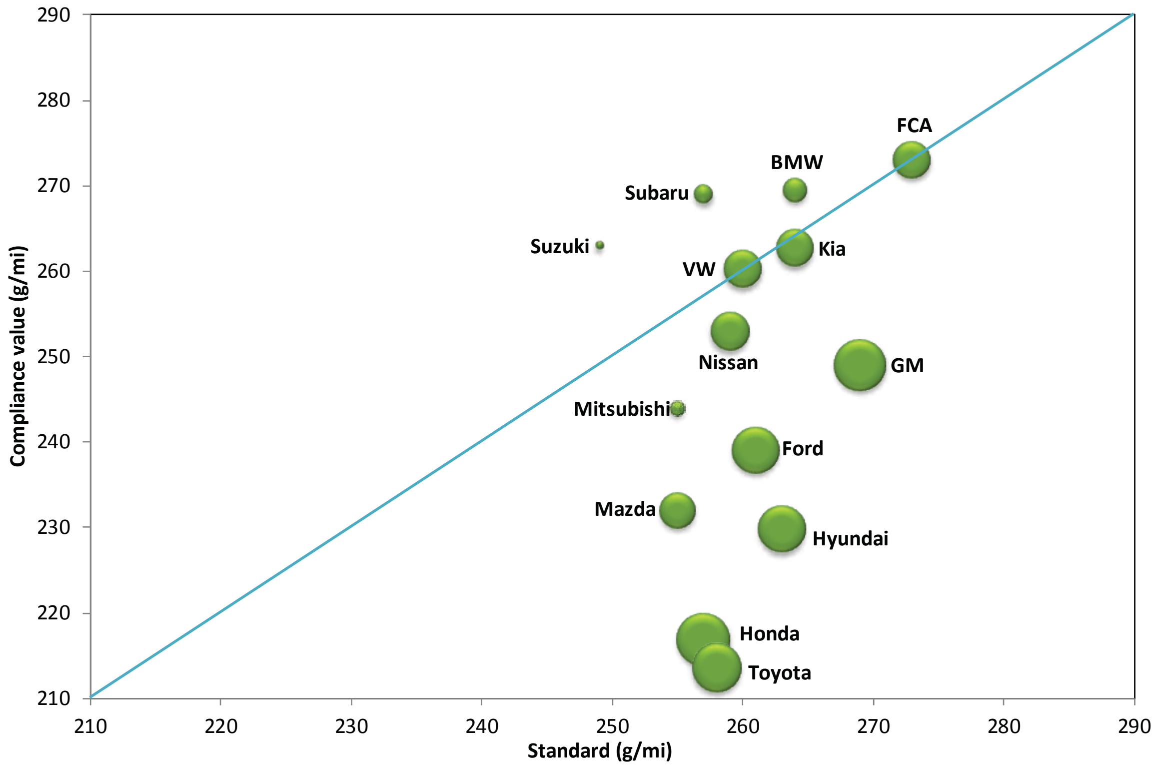
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-8 2015 Light Truck Compliance Status with Offsets



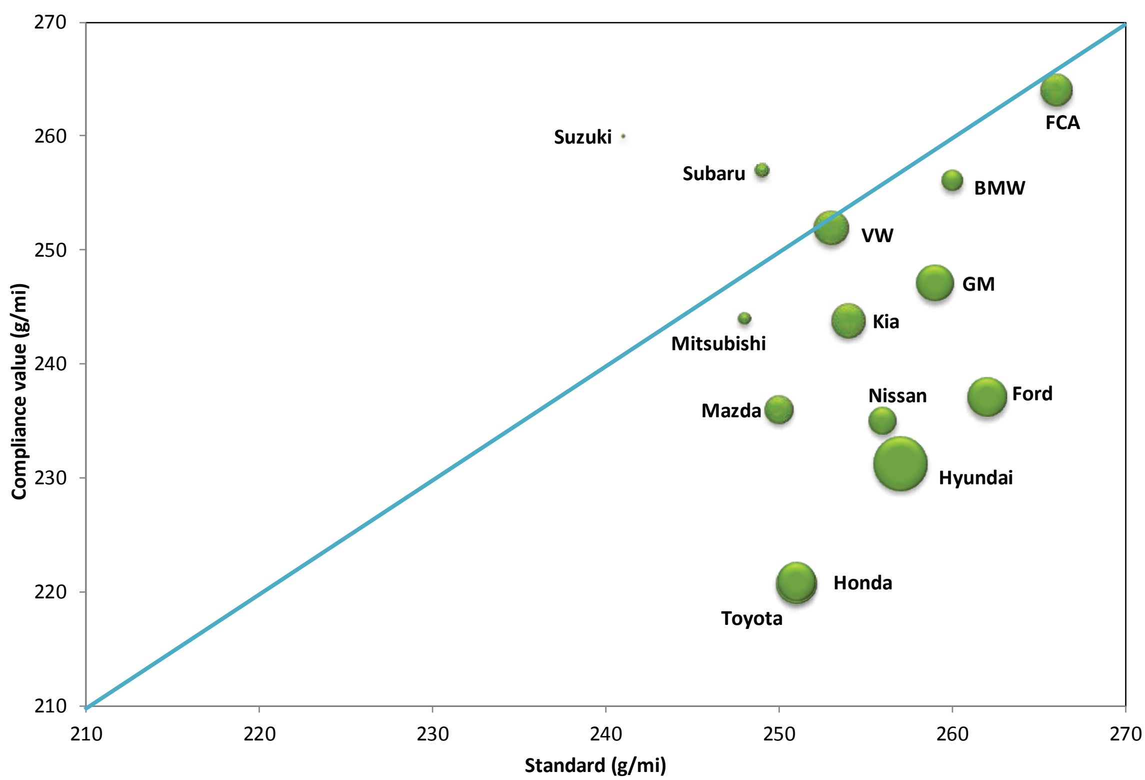
Notes:
- The asterisked companies are those that used the temporary optional fleet provisions.
- The final compliance value may be lower than the tailpipe emissions through the application of compliance flexibilities.

Figure A-9 2012 Compliance Status of Passenger Automobile Fleet with Company Size



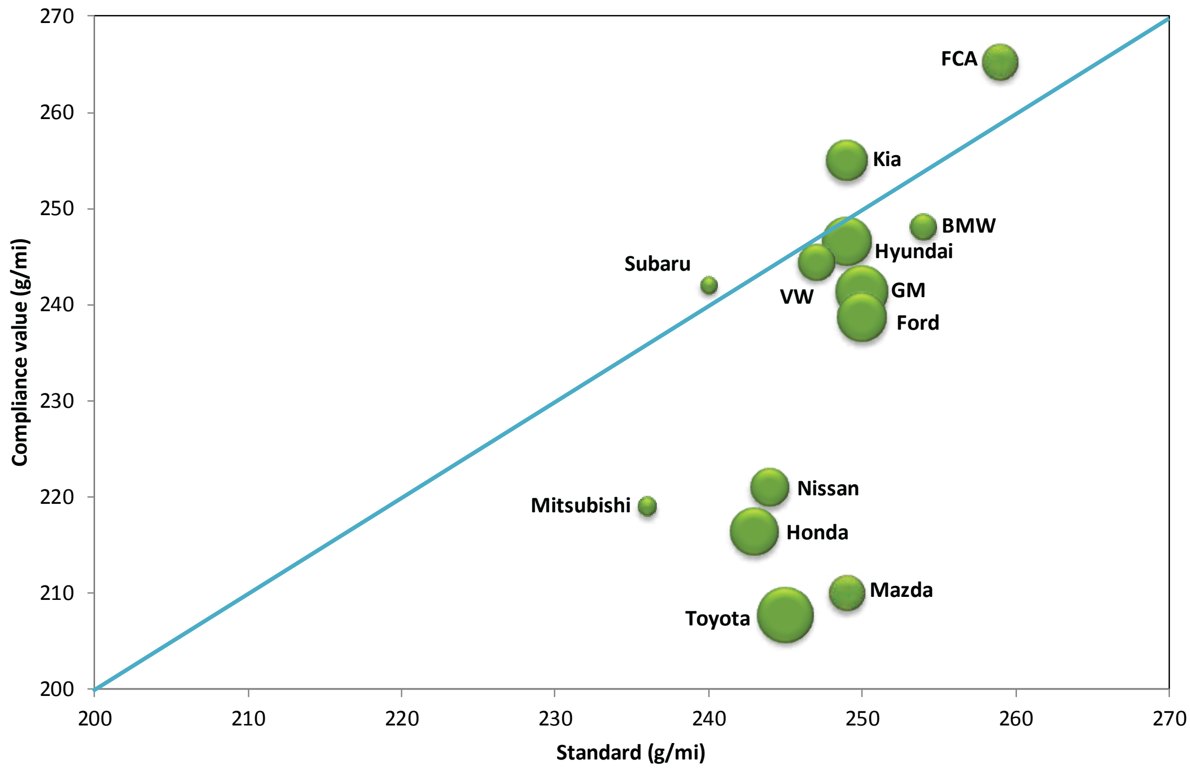
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-10 2013 Compliance Status of Passenger Automobile Fleet with Company Size



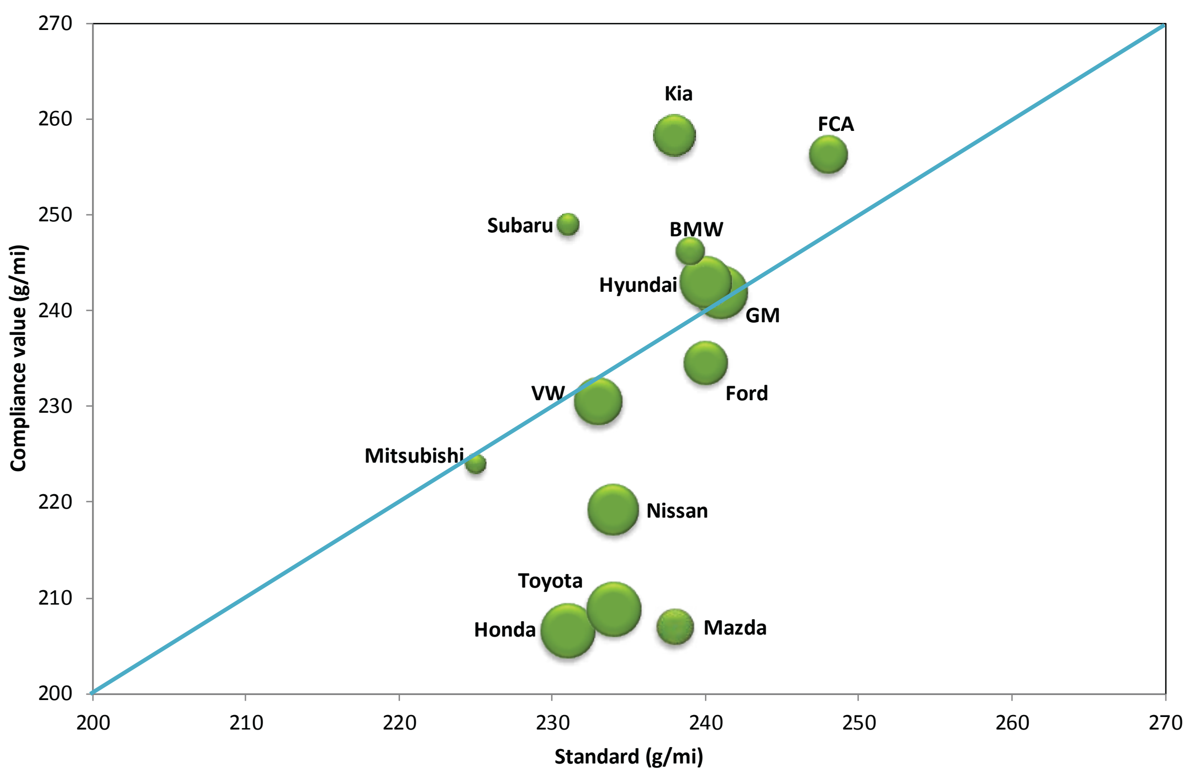
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-11 2014 Compliance Status of Passenger Automobile Fleet with Company Size



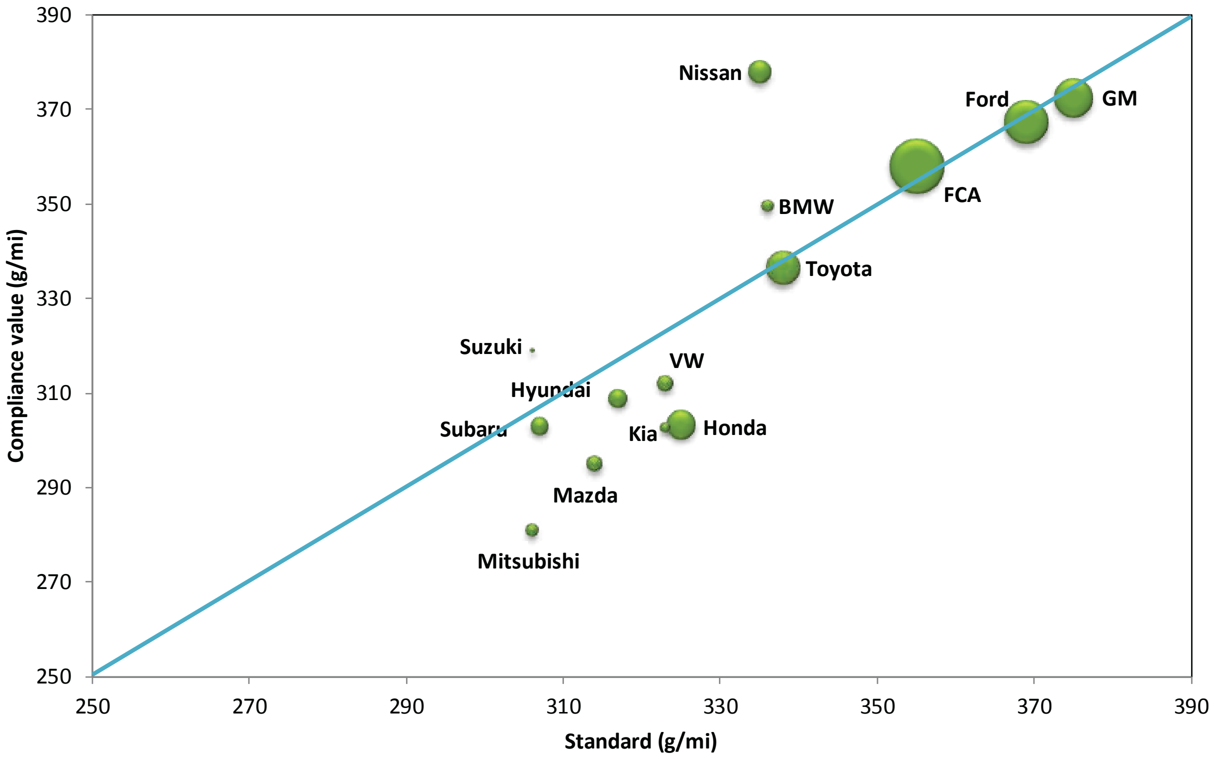
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-12 2015 Compliance Status of Passenger Automobile Fleet with Company Size



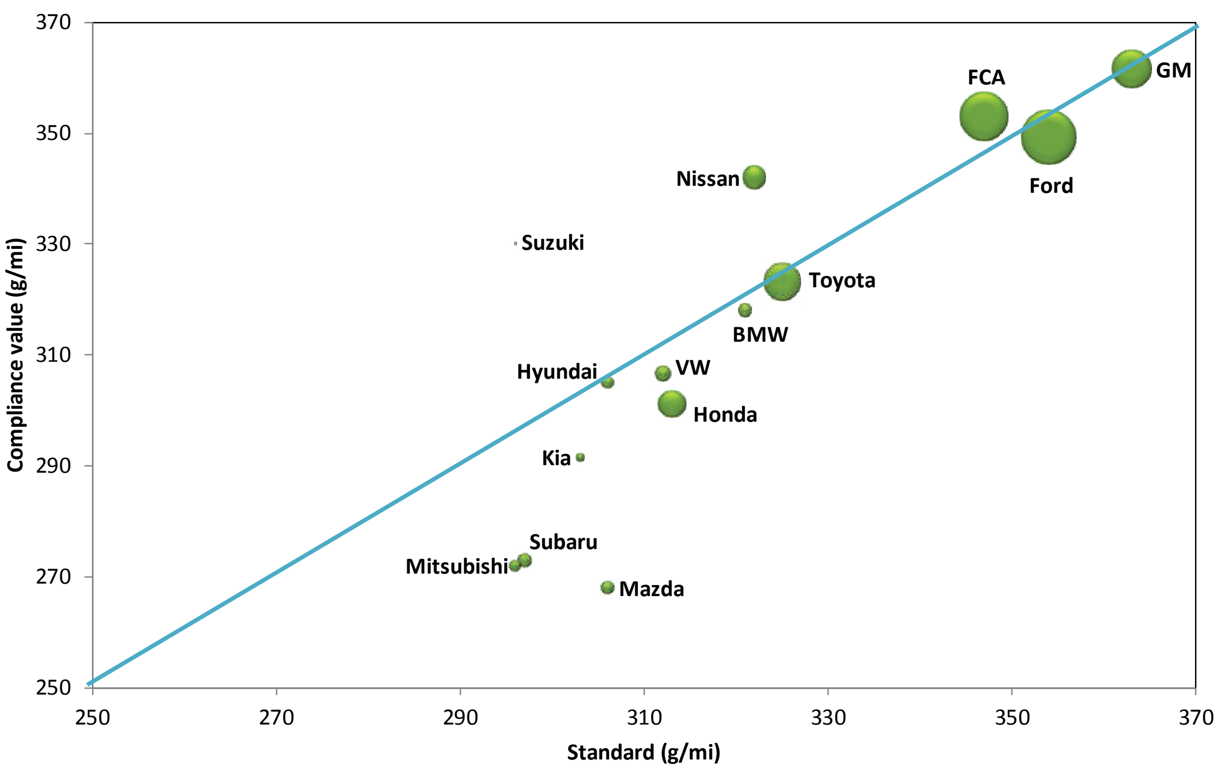
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-13 2012 Compliance Status of Light Truck Fleet with Company Size



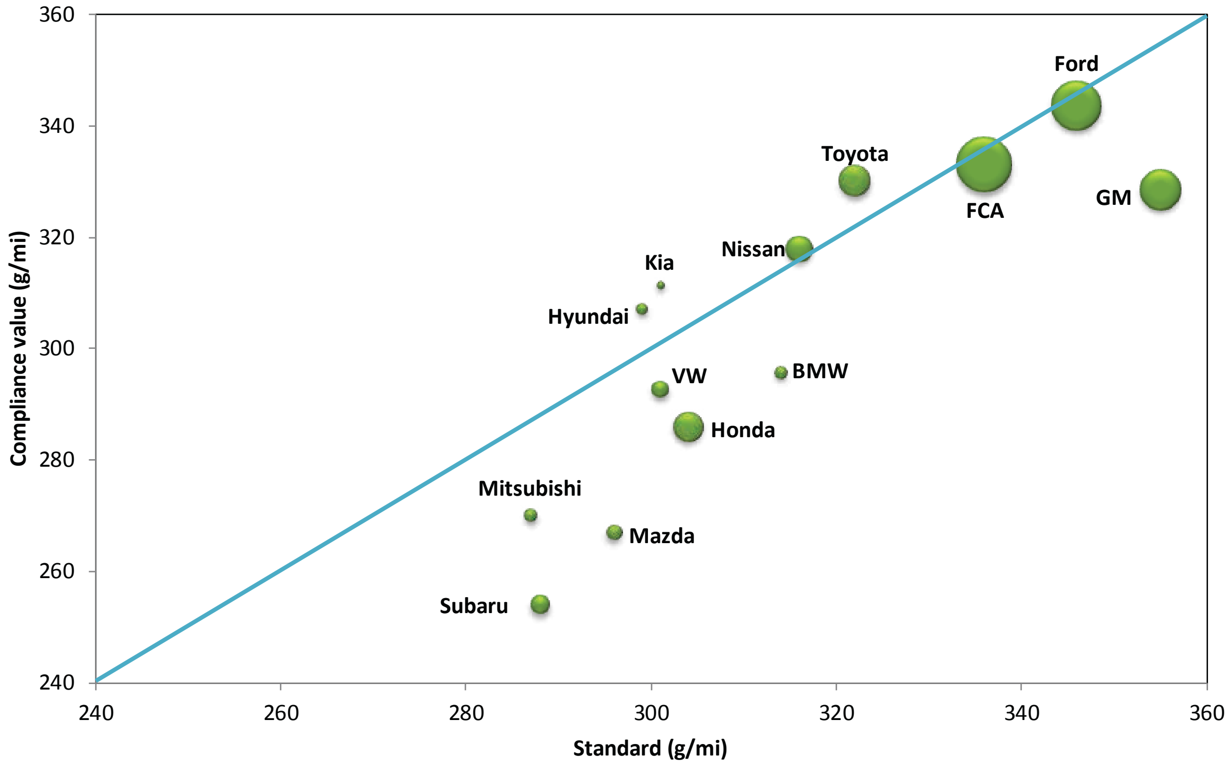
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-14 2013 Compliance Status of Light Truck Fleet with Company Size



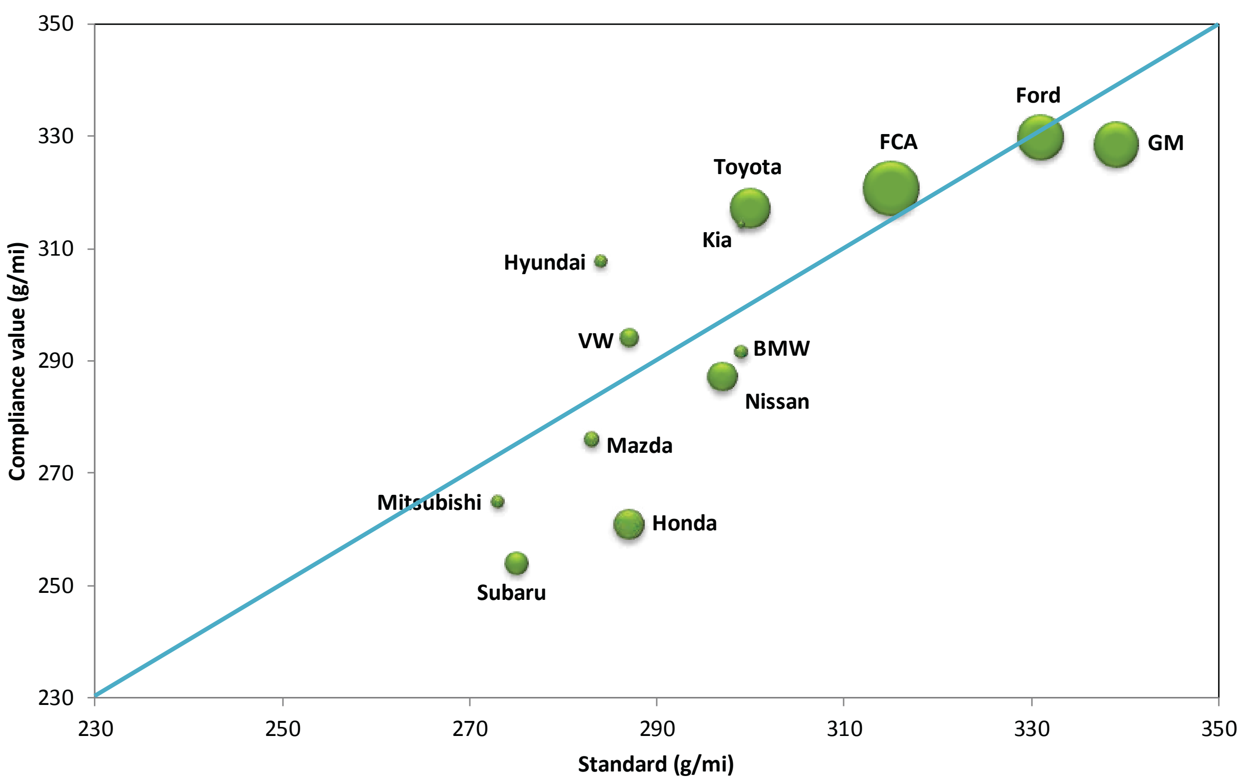
Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-15 2014 Compliance Status of Light Truck Fleet with Company Size



Notes: Companies that used the temporary optional fleet provisions are not shown in this graph

Figure A-16 2015 Compliance Status of Light Truck Fleet with Company Size



Notes: Companies that used the temporary optional fleet provisions are not shown in 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 (e.g. 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 (e.g. 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 (e.g. pulse width modulated power controller).	0.9
Internal heat exchanger (e.g. 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 Volume of Vehicles with Turbocharging and Engine Downsizing

Technology	2012	2013	2014	2015	2016
BMW	13,836	21,986	23,772	25,828	29,406
FCA	373	6,069	4,991	2,938	853
Ford	1,023	69,638	72,505	55,845	43,338
GM	28,010	30,549	56,752	47,464	50,509
Honda	0	0	0	0	18,150
Hyundai	2,624	23,283	14,487	10,130	18,148
JLR	1,492	2,743	1,718	2,857	4,461
Kia	636	3,203	3,009	1,724	8,422
Mercedes	991	7,080	8,338	17,803	18,329
Mitsubishi	621	347	773	850	0
Subaru	0	0	3,027	5,361	4,195
Toyota	0	0	0	5,793	5,617
Volkswagen	0	45,748	46,997	0	79,468
Volvo	0	0	0	1,051	100
Total	49,606	210,646	236,369	177,644	280,996

Table A-4 Volume of Vehicles Sold with VVT

Technology	2012	2013	2014	2015	2016
BMW	32,059	40,103	34,699	37,387	42,953
FCA	218,969	210,464	269,016	260,401	258,715
Ford	197,973	290,656	276,852	178,400	185,730
GM	195,270	175,849	224,242	245,384	193,764
Honda	171,975	143,816	156,408	178,785	201,420
Hyundai	116,849	195,951	105,683	108,528	128,167
JLR	4,620	6,230	7,362	7,695	10,398
Kia	64,991	77,800	71,165	67,761	73,392
Mazda	66,368	62,157	68,163	64,927	61,706
Mercedes	23,896	34,085	35,490	42,931	36,968
Mitsubishi	14,064	15,155	20,633	23,173	13,109
Nissan	0	81,703	108,943	152,399	121,017
Porsche	2,344	3,579	4,617	4,889	6,666
Subaru	22,246	22,166	38,079	53,328	46,682
Suzuki	4,155	1,260	--	--	--
Toyota	169,881	193,020	193,628	226,272	207,045
Volkswagen	48,838	48,363	40,617	72,443	86,451
Volvo	7,490	4,779	2,269	6,411	5,776
Total	1,361,988	1,607,136	1,657,866	1,731,114	1,679,959

Table A-5 Volume of Vehicles Sold with VVL

Technology	2012	2013	2014	2015	2016
BMW	27,178	37,902	34,409	36,846	42,192
FCA	12,904	13,614	35,488	35,022	32,956
GM	0	0	5,478	12,265	7,294
Honda	171,975	143,816	156,408	178,785	201,420
JLR	3,128	3,487	1,179	1,507	10,398
Mitsubishi	3,580	1,876	7,325	3,876	8,819
Nissan	0	4,545	84,844	8,378	5,284
Porsche	2,344	3,579	4,617	4,889	6,666
Subaru	9,095	0	0	0	0
Toyota	0	0	2,354	865	3,877
Volkswagen	23,914	17,317	15,573	14,711	24,551
Volvo	1,618	1,305	786	103	0
Total	255,736	227,441	348,461	297,247	343,457

Table A-6 Volume of Vehicles Sold with Higher Geared Transmissions

Technology	2012	2013	2014	2015	2016
BMW	18,900	29,944	32,031	32,846	38,414
FCA	5,117	16,528	111,746	134,568	143,185
GM	0	0	713	9,085	25,666
Honda	41	1,832	7,059	18,144	42,156
Hyundai	1,450	2,419	740	3,165	9,627
JLR	0	1,382	6,776	7,477	12,814
Kia	0	0	0	79	374
Mercedes	29,976	30,426	34,960	41,293	34,967
Nissan	6,971	4,227	7,268	28,302	30,340
Porsche	2,057	3,345	4,298	4,708	6,205
Subaru	0	0	0	3,479	2,434
Toyota	189	1,499	16,368	16,596	25,860
Volkswagen	13,379	19,158	20,978	20,849	18,034
Volvo	0	0	0	1,142	3,037
Total	78,080	110,760	242,937	321,733	393,113

Table A-7 Volume of Vehicles Sold with CVT

Technology	2012	2013	2014	2015	2016
FCA	11,846	5,287	862	417	519
Ford	563	3,274	2,946	2,145	1,801
GM	175	347	2,550	4,681	3,158
Honda	525	10,860	49,929	112,020	120,129
Mitsubishi	0	0	3,203	3,178	0
Nissan	63,537	68,863	89,546	88,952	76,305
Subaru	9,648	13,157	31,054	0	0
Suzuki	2,290	280	--	--	--
Toyota	19,547	11,991	39,025	36,854	34,849
Volkswagen	33	29	0	0	0
Total	108,164	114,088	219,115	248,247	236,761

Table A-8 Volume of Vehicles Sold with Cylinder Deactivation

Technology	2012	2013	2014	2015	2016
FCA	53,390	44,091	71,658	50,332	56,549
GM	35,298	44,136	84,095	97,824	77,537
Honda	16,080	24,894	34,570	35,595	42,630
Mercedes	72	0	38	27	0
Volkswagen	7	567	573	536	1,260
Total	104,847	113,688	190,934	184,314	177,967

Table A-9 Volume of Diesel Vehicles Sold

Technology	2012	2013	2014	2015	2016
BMW	1,911	1,033	2,418	3,893	3,060
FCA	0	0	9,395	14,521	15,077
GM	0	0	1,836	1,258	1,200
Mercedes	6,768	5,770	11,309	12,569	7,191
Porsche	0	520	701	522	527
Volkswagen	20,093	21,963	20,364	22,695	1,756
Total	28,772	29,286	46,023	55,458	31,259

Table A-10 Volume of Vehicles Sold with GDI

Technology	2012	2013	2014	2015	2016
BMW	22,773	33,608	33,982	37,085	42,953
FCA	0	0	1	3,408	13,294
Ford	43,681	0	0	0	0
GM	80,019	66,342	152,896	191,703	166,895
Honda	0	13,740	21,106	79,935	157,680
Hyundai	42,780	88,576	85,049	84,446	100,695
JLR	716	6,230	7,362	7,695	10,398
Kia	20,488	40,454	60,213	60,983	67,140
Mazda	27,840	32,840	60,755	59,411	60,819
Mercedes	23,903	28,315	24,181	30,362	29,777
Nissan	4,138	5,130	4,296	222	7,440
Porsche	2,268	3,059	3,916	0	0
Subaru	0	0	3,027	5,361	4,195
Toyota	1,394	697	3,033	2,568	1,829
Volvo	0	0	0	1,142	3,037
Total	270,000	318,991	459,817	564,321	666,152

Table A-11 CO_2e Standard Over the 2008 - 2010 Model Years (g/mi)

Manufacturer	2008		2009		2010	
	PA	LT	PA	LT	PA	LT
BMW	323	439	323	439	301	420
FCA	323	439	323	439	301	420
Ford	323	439	323	439	301	420
GM	323	439	323	439	301	420
Honda	323	395	323	385	323	378
Hyundai	323	439	323	439	301	420
Kia	323	395	323	385	323	378
Lotus	323	--	323	--	323	--
Mazda	323	395	323	385	323	378
Mercedes	323	439	323	439	301	420
Mitsubishi	323	439	323	439	301	420
Nissan	323	439	323	439	301	420
Suzuki	323	439	323	439	301	420
Tesla	323	--	323	--	323	--
Toyota	323	395	323	385	323	378
Volkswagen	323	439	323	439	301	420
Volvo	323	439	323	439	301	420

Table A-12 Compliance Values Over the 2008-2010 Model Years (g/mi)

Manufacturer	2008		2009		2010	
	PA	LT	PA	LT	PA	LT
BMW	310	375	302	376	288	361
FCA	303	402	300	380	306	374
Ford	325	395	276	375	268	382
GM	277	376	254	380	270	360
Honda	243	346	239	348	237	325
Hyundai	256	359	249	354	245	303
Kia	274	362	270	351	251	341
Lotus	302	--	298	--	336	--
Mazda	266	336	272	314	255	302
Mercedes	298	396	309	400	322	386
Mitsubishi	297	350	284	334	275	321
Nissan	265	343	254	339	258	349
Suzuki	269	380	269	350	258	341
Tesla	--	--	--	--	-3	--
Toyota	225	360	228	328	229	337
Volkswagen	291	439	273	349	266	347
Volvo	309	408	310	406	308	383