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SOUTH AFRICA'S NEW PASSENGER VEHICLE CO_2 EMISSION STANDARDS:

BASELINE DETERMINATION AND BENEFITS ASSESSMENT

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EXECUTIVE SUMMARY

This report provides a transparent assessment of the new passenger vehicle market in South Africa in terms of carbon dioxide (CO_2) emissions, as well as an evaluation of the benefits of adopting standards for fuel economy and CO_2 emissions for those vehicles. This briefing report is intended to inform South African policymakers and domestic stakeholders, as well as an interested international audience, on the potential CO_2 reductions and fuel savings that could be achieved with the adoption of said standards.

The South African new passenger vehicle (PV) fleet is the largest on the African continent and the 18th largest globally. South African manufacturers sold more than 412,000 new vehicles in 2015, and exported more than 333,000 units in that year. The top two manufacturers are Volkswagen and Toyota. Like most global markets, the South African market contains large shares of small vehicles, medium vehicles, and sport utility vehicles (SUVs).

The average CO_2 emissions of new passenger cars in South Africa, tested under the New European Driving Cycle (NEDC), was 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. A comparison of the South African (SA) passenger car fleet with that of Europe shows that the SA fleet emits, on average, 22% more CO_2 than the EU fleet, which is rated at 121 gCO_2/km. This large difference is exacerbated by the fact that the SA fleet is 5% lighter than the EU fleet, indicating lower average efficiency of vehicles in South Africa. The lower efficiency of the average SA vehicle is also evident when comparing the fleets by segment, and is more pronounced for SUVs. Comparing CO_2 emissions performance by manufacturer shows a significant gap between EU and SA models. Toyota presents the highest CO_2 gap between regional fleets, 43%, which is partially explained by a SUV preference in South Africa and also by reduced access to highly efficient vehicle technologies. Renault has the smallest gap between fleets, at 15%.

Adopting a CO_2 emission standard or its fuel economy (FE) equivalent for passenger vehicles in South Africa would result in significant CO_2 emissions reductions, reducing the impact of a projected future increase in PV fleet size. Three scenarios were studied: a) the baseline case where no emission standards are adopted; b) a short-term policy adoption scenario where the standard requires a 19% improvement by 2024; and c) a long-term scenario where the rate of improvement is maintained until 2030, resulting in a fleet improvement of 36%. The short-term and long-term scenarios are designed under the same annual rate of improvement in fuel efficiency of 4.1%. A model was developed to assess the impact of each scenario in terms of total CO_2. The model shows that adopting CO_2 standards would offer significant benefits, even in the face of a larger fleet: A short-term policy adoption scenario of 120 gCO_2/km standard by 2024 would result in an annual reduction of 4.5 million tons (Mt) of CO_2 by 2050; adopting the long-term target of 95 gCO_2/km by 2030 would result in an annual reduction of 11.1 Mt CO_2 by 2050. These represent a 12% and 28% reduction with respect to the baseline scenario. The results show the large potential of FE/CO_2 emission standards to decarbonize the PV market.

INTRODUCTION

South Africa leads the continent's automotive industry not just in terms of vehicle stock and new vehicle sales, but also as the main automotive manufacturing hub in the region and one of the largest globally. According to the Organization of Motor Vehicle Manufacturers (OICA), the total South African passenger vehicle population was 6.4 million units in 2015 (OICA, 2017). This is by far the largest fleet in Africa, accounting for 22.6% of vehicles on the continent. New passenger vehicle sales were more than 412,000 units in 2015, about 37% of the African market and 60% more than Egypt, the second largest new vehicle market in Africa.

The transportation sector is the second-highest contributor to the country's greenhouse gas emissions, just after the energy generation sector. Transport emitted 61 Mt CO_2 in 2013 and accounts for about 13% of total emissions, which is primarily due to South Africa's heavy dependence on fossil fuels. The energy sector, due to its reliance on coal, is responsible for around 66% of all emissions (Department of Environmental Affairs, 2014; World Bank, 2016).

Given South Africa's relatively young population and the country's continued growth in gross domestic product (World Bank, 2017), the transport sector's carbon footprint is poised to expand unless this growth is met with policy tools to curb that impact. The SA government has begun to incentivize consumers to purchase fuel-efficient vehicles through vehicle taxation policies that are based on emissions. The next logical step is to find ways to incentivize manufacturers to offer the most fuel-efficient vehicles.

The objective of this report is to begin to analyze potential regulatory tools that can help reduce the carbon footprint of passenger vehicles in South Africa. This report contains a baseline analysis of the passenger vehicle fleet for calendar year 2015, looking at characteristics and performance of the fleet and drawing comparisons with global markets, especially the European market. It also presents the future CO_2 emissions contribution from the passenger vehicle fleet and an assessment of the CO_2 emissions and fuel consumption benefits achieved under two different scenarios.

The results of this report can become the main input for studying potential policy tools and their impact on projected carbon contributions for the SA passenger vehicle fleet.

This briefing report is structured as follows: The first section presents a description of the South African passenger vehicle market; the second section provides the CO_2 emission values for the entire fleet by segment and by manufacturer as well as a comparison with the European vehicle market and a discussion of the differences; the third section introduces the CO_2 emission standards evaluation model methods and assumptions; and the fourth section presents the potential results of adopting future standards.

DATA SOURCES

The data on vehicle sales and characteristics, including CO_2 emission values, were obtained from the National Association of Automobile Manufacturers of South Africa (NAAMSA). The data cover more than 2,100 different models sold in calendar year 2015. The relevant data needed to calculate fleet average CO_2 emissions were available for more than 98% of all new vehicles sales for that year, making the analysis and conclusions representative of the market for that calendar year.

1. VEHICLE MARKET OVERVIEW

South Africa is the largest new passenger vehicle (PV) market on the African continent and is the 18th largest market globally (Figure 1-1). In calendar year 2015, a total of 412,670 new passenger vehicles were sold in the country. Between 2010 and 2015, new vehicle sales grew by 22%, with an average annual rate of 4% [1] (NAAMSA, 2016).

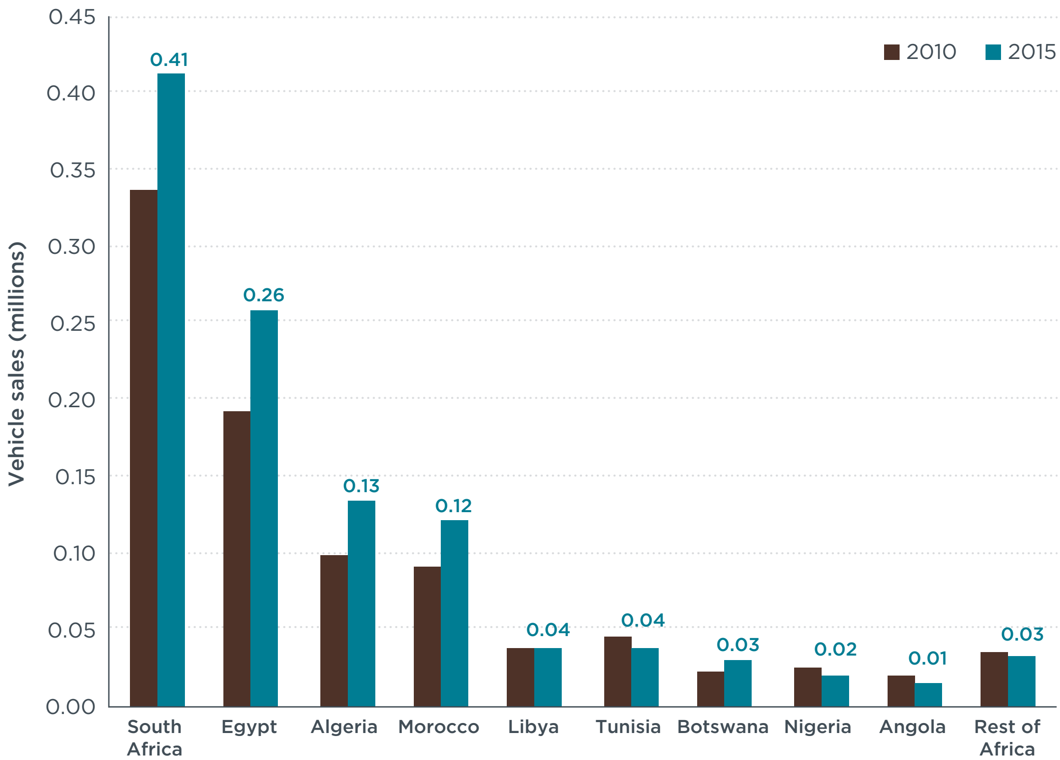

Figure 1-1. Top 10 passenger vehicle markets in Africa.
Source: OICA (2016)

The South African market is covered by 27 manufacturers that offer a total of 45 brands; as an example, Volkswagen (VW) as a manufacturer offers vehicles in South Africa under two brands, VW and Audi. The top 10 manufacturers—VW, Toyota, Hyundai/Kia, Ford, Daimler, BMW, General Motors (GM), Renault, Nissan, Honda—command more than 93% of the market (Figure 1-2). One remarkable characteristic of the vehicle market in South Africa is that luxury automakers Daimler and BMW hold around 12% of the market, and are the 5th and 6th largest sellers. This trend is very similar to the automakers' position in Europe, but is far from the positions held in other BRICS countries such as Brazil (less than 1%) or China.[2]

The best-selling car in 2015, consistent with 2014 trends, was the Volkswagen Polo, which accounted for 13.6% of the passenger vehicle market with 55,957 sales. Next was the Toyota Corolla, with a 5.7% share in passenger vehicles for a total of 23,542 sales in 2015.

The market distribution by segment shows that small- and lower-medium size vehicles dominate the market with 54% of all sales. The SUV market is similar in size to the lower-

1 Between 2014 and 2015 the new passenger vehicle market suffered a 6% reduction.

2 BRICS is an acronym that refers to the countries of Brazil, Russia, India, China and South Africa.

medium market share, with 21% of the market. This combination of large shares of both small vehicles and SUVs shows that the South African (SA) passenger vehicle market is aligned with global tendencies: Low-income consumers are driven to smaller vehicles, while consumers with enough disposable income prefer SUVs over large sedans at similar prices.

It is important to note that, according to SA vehicle type definitions, bakkies, known in international markets as pickup trucks, are not considered passenger cars but light commercial vehicles, which are outside the scope of this analysis.

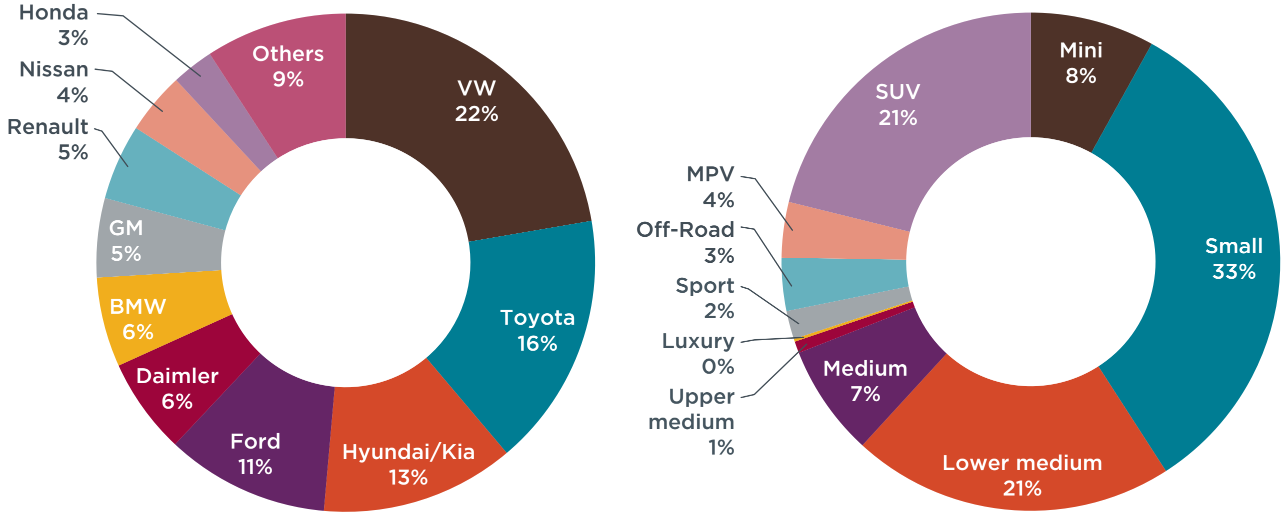

Figure 1-2. South African market share by manufacturer (left) and by segment (right)

Figure 1-3 provides an overview of the distribution of vehicle segmentation by manufacturer. VW, Hyundai and GM have very similar market structures, focusing on small vehicles. Toyota, the second largest manufacturer, focuses more on medium vehicles and SUVs. Ford's offering is almost binary, as it focuses on smaller sedans and SUVs. Daimler and BMW's segment share structures are similar, but BMW leans toward smaller sedans and more SUVs, while Daimler offers a larger share of multipurpose vehicles (MPVs). Both manufacturers sell a significant share of sports models.

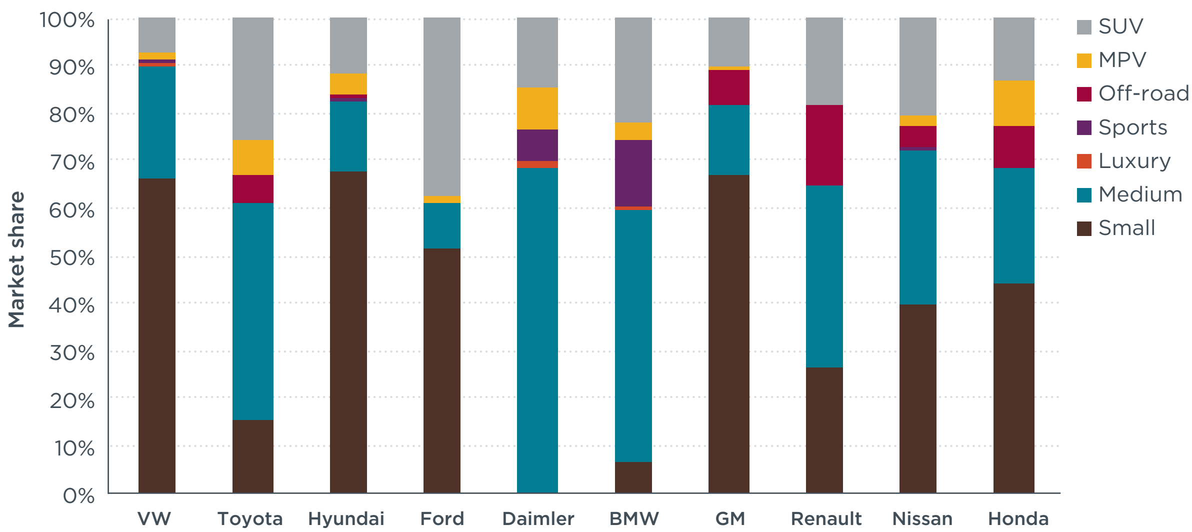

Figure 1-3. Manufacturer vehicle segmentation, by sales ranking from left to right

2. VEHICLE CHARACTERISTICS

This section provides an overview of average vehicle characteristics. These include number of cylinders, engine displacement, curb weight, engine power and power-to-weight ratio (PTWR), which are relevant indicators to characterize a vehicle fleet and understand fleet average fuel consumption and CO_2 emissions. Vehicle characteristics are presented for the entire fleet, by segment, by manufacturer, and by fuel type (gasoline vs. diesel), and are compared against a set of global vehicle markets. Average characteristics are calculated on a sales-weighted basis.

VEHICLE CHARACTERISTICS BY SEGMENT

Figure 2-1 illustrates key vehicle fleet characteristics by vehicle segment. As expected, most parameters grow in magnitude for heavier and larger vehicle segments. Luxury vehicles are the most powerful and heavy cars. All other parameters also follow this trend. SUVs have similar characteristics as cars in the upper-medium segment, which helps explain why the upper-medium segment is dwarfed in terms of sales by SUVs, as these provide a wider range of uses given similar vehicle characteristics. SUVs tend to have powerful engines and lower mass, thereby making their PTWR the highest of the group.

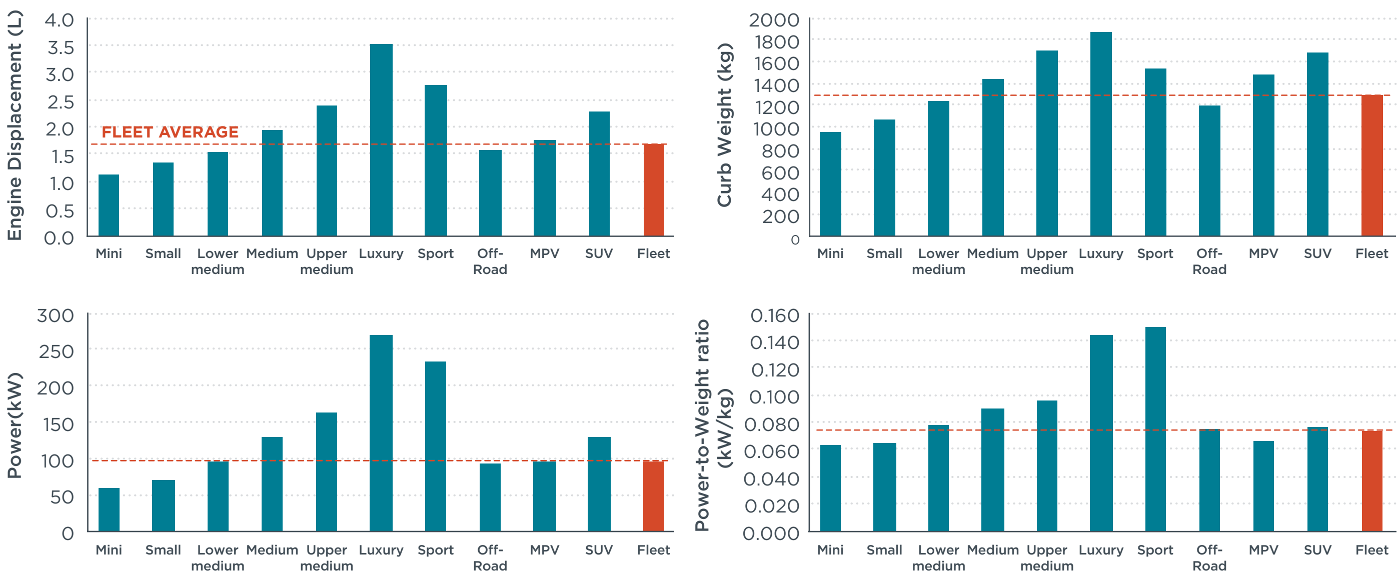

Figure 2-1. Fleet characteristics of new SA passenger vehicles by segment, 2015.
Dashed line shows fleet average.

VEHICLE CHARACTERISTICS BY MANUFACTURER

There are 27 manufacturers in South Africa, selling vehicles under 43 brands. The top 13 manufacturers account for about 95% of all gasoline and diesel vehicles sold in South Africa. Among the top four manufacturers, Volkswagen, Hyundai/Kia and Ford on average produce smaller, lighter vehicles with less powerful engines. Toyota, the second largest manufacturer, sells vehicles that have larger engines (1.8 L) than the average South African car (1.7 L); this is driven by sales of SUVs with large engines, such as the Fortuner and Land Cruiser. Luxury manufacturers BMW and Daimler offer vehicles with much more powerful engines than that of the average SA car, which is 97 kW, or 130 hp.

PTWR is evenly distributed across manufacturers except for luxury manufacturers. Renault sells vehicles that on average have the lowest curb weight and the smallest and least powerful engines. Interestingly, PTWR values for Renault remains close to those of heavier and more powerful vehicles from other manufacturers.

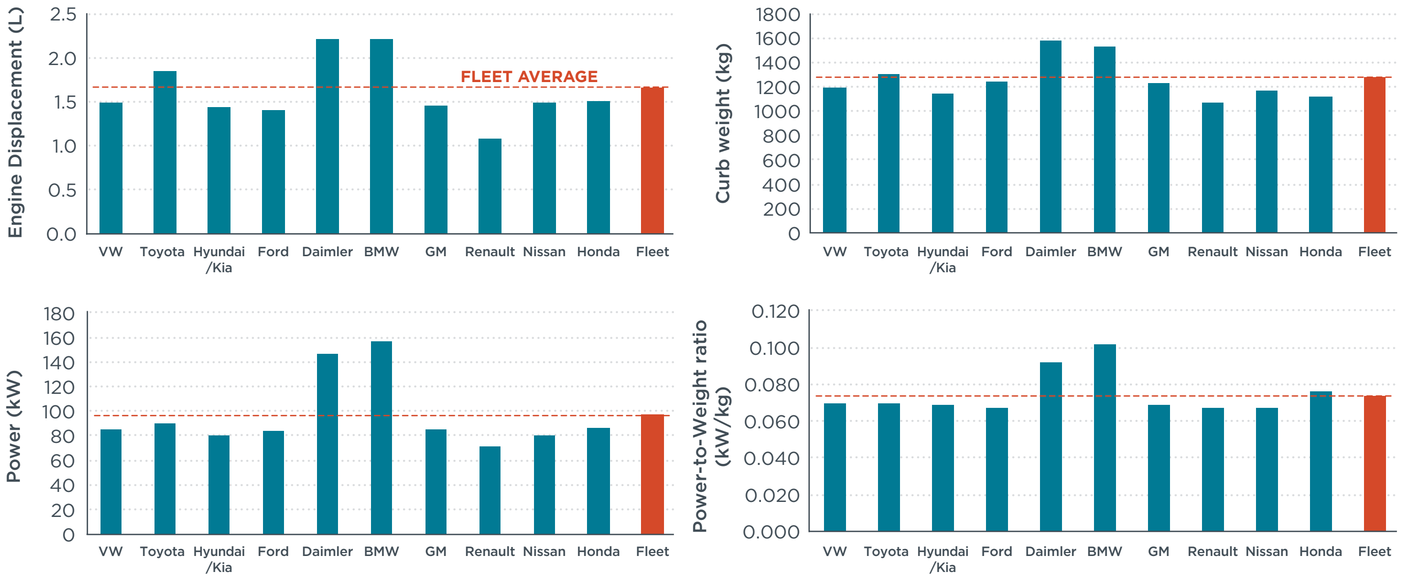

Figure 2-2. Fleet characteristics of new SA vehicles by manufacturer, listed by sales ranking from left to right

MARKET COMPOSITION BY FUEL TYPE

Gasoline vehicles are the main consumer choice among SA consumers, with 82.9% of the new vehicle market. Diesel is the second largest fuel option, with 16.9% of sales. Sales of advanced fuel-efficient vehicles, such as hybrids, had a very small market share in 2015, with 0.1% or 512 units. Only 79 electric vehicles were sold in the period studied. Figure 2-3 shows the fuel type distribution across vehicle segments and for the PV fleet as a whole. Gasoline is the dominant technology across all vehicle segments. All top 13 manufacturers produce primarily gasoline engines (Figure 2-4).

Sales of diesel vehicles are strong among SUVs and MPVs, and among the largest sedan segments including luxury vehicles. Toyota sells the most diesel passenger vehicles, almost 14,000 units, followed by Volkswagen and Ford. German luxury manufacturers Daimler and BMW place 4^{th} and 5^{th} in absolute sales, with more than 30% of their vehicles powered by diesel fuel. Among manufacturers with diesel models available, Honda sold the fewest at just 1% of its models.

Hybrid sales in South Africa for 2015 are concentrated in three segments: upper-medium, luxury, and sport. Only five manufacturers sold hybrids: Toyota, BMW, Daimler, Nissan, and Honda. Interestingly, almost 60% of those were luxury hybrids. The Toyota Prius is the most popular hybrid.

Electric vehicles (EVs) are also referred to as battery-only electric vehicles (BEVs). EVs have no engine and are propelled by electricity that comes from one or several onboard high-energy batteries. Modern models use a regenerative braking system to save energy, similar to hybrids. In South Africa, EVs were sold only in the small and lower-medium segments. BMW and Nissan were the only manufacturers offering the technology. The BMW i3 and Nissan Leaf were the only two models sold in 2015.

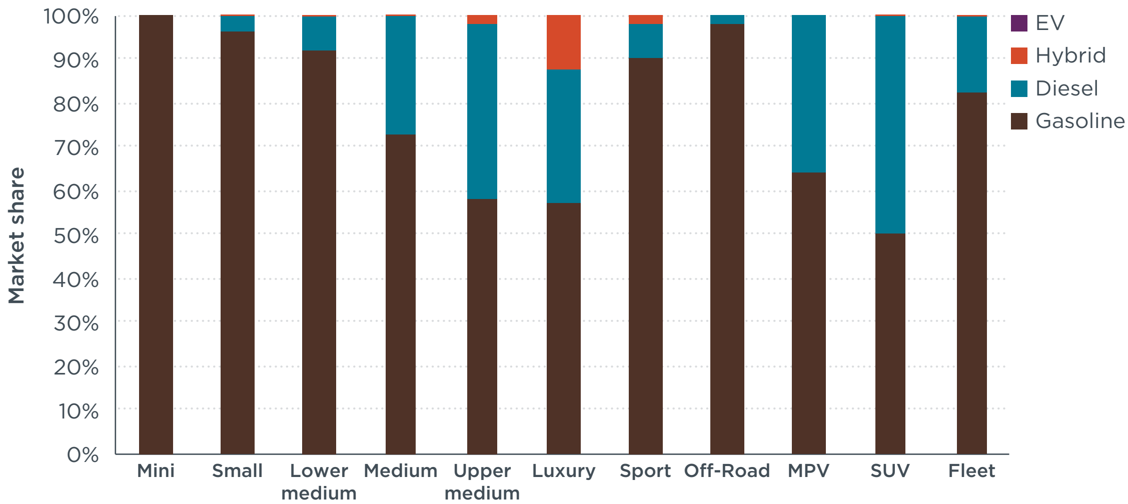

Figure 2-3. Fuel type by segment

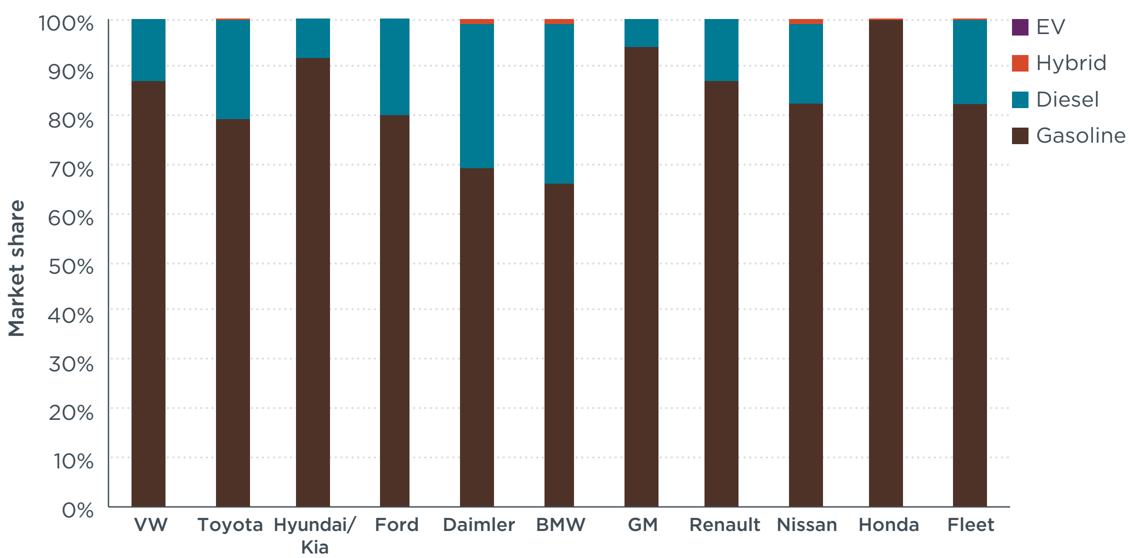

Figure 2-4. Fuel type by manufacturer, listed by sales ranking from left to right

3. CO_2 EMISSIONS

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC, were 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. Per vehicle CO_2 emission values used in this report were obtained from NAAMSA. The CO_2 data provided by NAAMSA were obtained under chassis testing protocols defined under the South African national standard SANS 20101:2006, developed by the South African Bureau of Standards (SABS) (SABS, 2009). The emission baseline was estimated using sales-weighted average methodology.

Figure 3-1 presents the average emissions by segment compared with the fleet overall. The lower emissions of the smaller vehicle segments counteract the impact of the large number of sales of SUVs and sport and luxury vehicles. For each segment, disaggregating CO_2 emissions by fuel type—gasoline and diesel—shows that, for most segments, diesel vehicles emit less CO_2 than their gasoline counterparts. In the SUV segment, however, it is the diesel option that emits more. The average diesel vehicle in South Africa emits 166 gCO_2/km, which is more than the average gasoline vehicle, at 145 gCO_2/km. This can be explained by the fact that most diesel vehicles are SUVs (62%), and these are the heavier and least efficient models of the fleet. Gasoline luxury and sport vehicles, along with diesel MPVs and SUVs, are the most inefficient segments. Medium diesel vehicles are among the most efficient models.

Figure 3-2 presents manufacturer average CO_2 emissions, listed by sales ranking. Renault is by far the most efficient among the listed manufacturers. Out of the four largest manufacturers, only Toyota emits significantly more than the fleet average value and has the highest emissions among the studied group of manufacturers. Luxury manufacturers Daimler and BMW are 3rd and 5th in terms of lowest CO_2 emissions.

For Toyota, Hyundai, and GM, diesel models are driving up their manufacturer CO_2 emission averages. Luxury manufacturers Daimler and BMW present higher CO_2 emissions from their average gasoline models than from their average diesel ones, about 5% to 9%. Renault, the most efficient manufacturer, derives CO_2 gains from smaller and lighter gasoline models, for which CO_2 emissions are about 14% lower than diesel models.

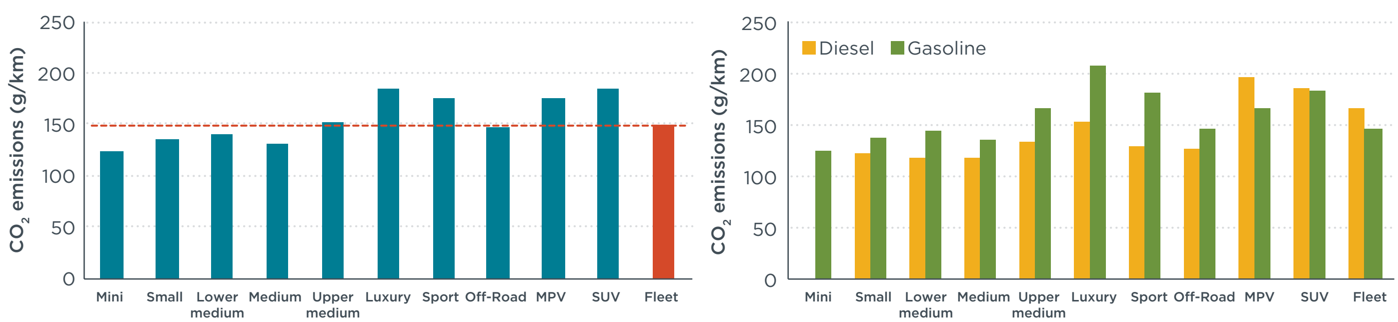

Figure 3-1. Fleet average CO_2 emissions by segment (left) and disaggregated by fuel type (right)

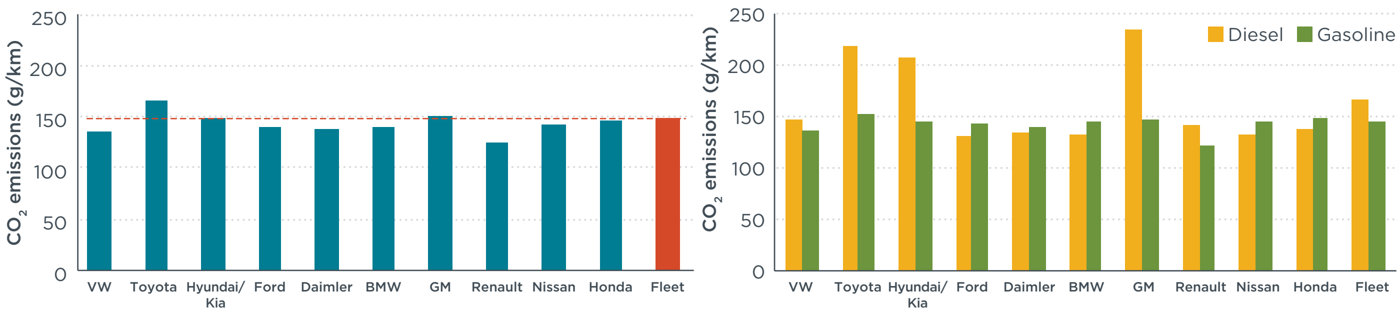

Figure 3-2. Fleet average CO_2 emissions by manufacturer (left) and disaggregated by fuel type (right). Listed by sales ranking from left to right.

Figure 3-3 shows sales-weighted average new vehicle CO_2 emissions by mass for the top manufacturers in South Africa in 2015. The size of the bubble represents the total relative size of a manufacturer's market capture. Manufacturers in the lower-left quadrant produce the lightest and most efficient vehicles, with Renault representing the best overall average fuel consumption, and VW alongside. Hyundai, in the upper-left quadrant, produces vehicles that are lighter than VW, but with higher than average CO_2 emissions given their weight class. In the lower-right quadrant are manufacturers that produce relatively heavier vehicles, but with lower fuel consumption in their weight class. Despite producing heavier vehicles on average than many manufacturers, BMW and Daimler achieve lower CO_2 emissions on average than many of the lighter car manufacturers. In the upper-right quadrant are manufacturers that produce on average the heaviest and least efficient vehicles. Toyota produces the least efficient cars on average, but sits close to the average fleet weight. A regression line correlating vehicle CO_2 emissions and mass highlights the best performers by weight rating (Renault, VW, Ford, BMW and Daimler), average performers (Nissan), and those performing worse than average (Toyota, GM, Honda, and Hyundai).

Figure 3-3. New vehicle sales-weighted CO_2 emissions by manufacturer, 2015.

Circle diameter is proportional to sales numbers. Dotted line corresponds to linearization of sales-weighted data.

COMPARISON WITH THE EUROPEAN MARKET

This section takes a closer look at the SA fleet CO_2 emissions compared with those of Europe. CO_2 emissions from the overall fleet, by segment and by manufacturer, are discussed in this section.

Figure 3-4 shows that SA passenger car fleet average CO_2 emissions stand at 148 g/km, about 22% more than EU fleet average emissions of 121 g/km. This large difference is even more significant given that the SA fleet is 5% lighter than the EU fleet. The trends presented for each fleet in 2015 follow the basic principle that heavier vehicles within each market emit larger amounts of CO_2 per kilometer driven. A comparison among the segments of each market and within the markets shows interesting trends.

This analysis covers only those segments that have at least a 5% market share of new car sales. Regardless of segment, SA vehicles consume significantly more fuel per distance driven than their EU counterparts. The comparisons for small and medium segments show that these types of vehicles in South Africa are lighter by 4% to 8%, but are less fuel efficient. For the mini segment, the difference in weight is about 1%, but the SA mini vehicles are 18% less efficient on average than the EU mini models. SUVs in South Africa are markedly heavier than those in Europe, by 10%, and are significantly less efficient, by 34%.

Figure 3-4 shows that the CO_2 regulatory environment in Europe is resulting in more consistent CO_2 emissions across vehicle segments. Comparing the most and least efficient segments, mini and SUV, European SUVs emit 30% more CO_2 than European minis, while South African SUVs emit 50% more CO_2 than the SA minis.

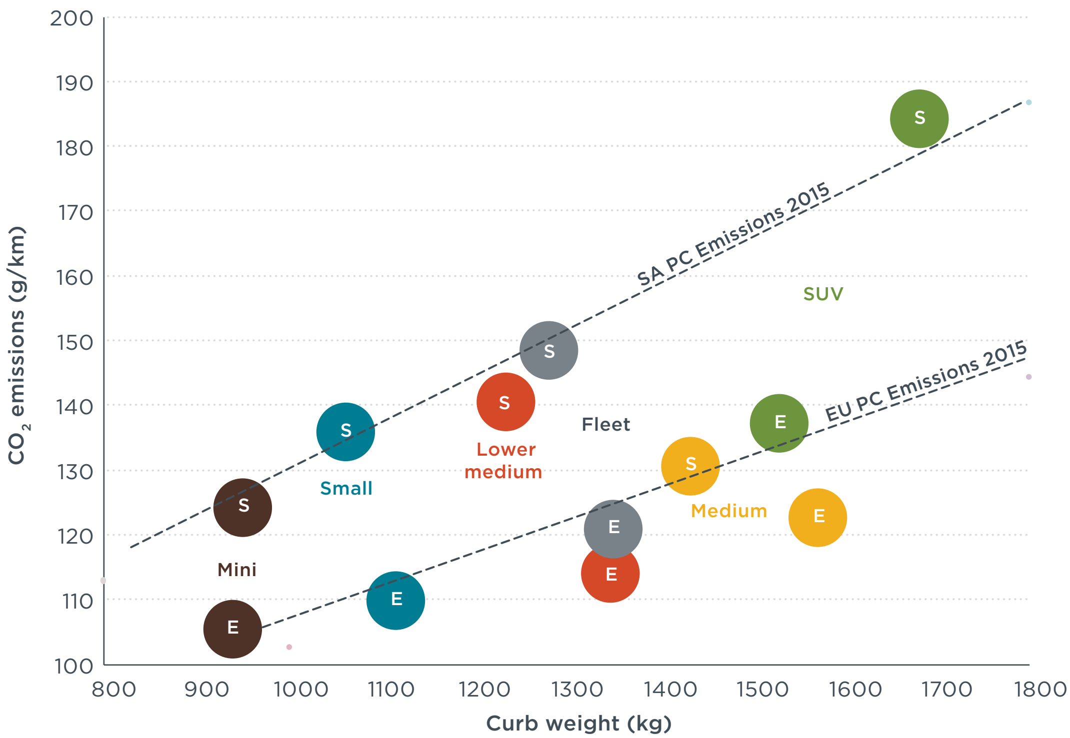

Figure 3-4. New vehicle sales-weighted CO_2 emissions as a function of curb weight, by segment, all fuels (2015).

*Segments are differentiated by color. Internal circle label **S** corresponds to South Africa and **E** to Europe**.** Dotted lines correspond to linearization of sales-weighted data for each market.*

Figure 3-5 presents a comparison between each manufacturer's fleet for gasoline vehicles. Only the top 10 manufacturers of South Africa are compared. This comparison removes the distortion caused by different diesel market shares. The most salient feature is that, for every manufacturer shown, the EU models emit less CO_2 than the SA models. Renault is on average 4% lighter in South Africa but has 5% higher CO_2 emissions on average. Volkswagen is 5% lighter in South Africa but has 15% higher CO_2 emissions than in Europe. Toyota is heavier on average in South Africa, and its CO_2 emissions gap is 35%, by far the largest among all SA manufacturers. Gasoline vehicles produced by Honda, Renault and BMW for the SA market present a CO_2 gap below 10% with respect to their European counterparts.

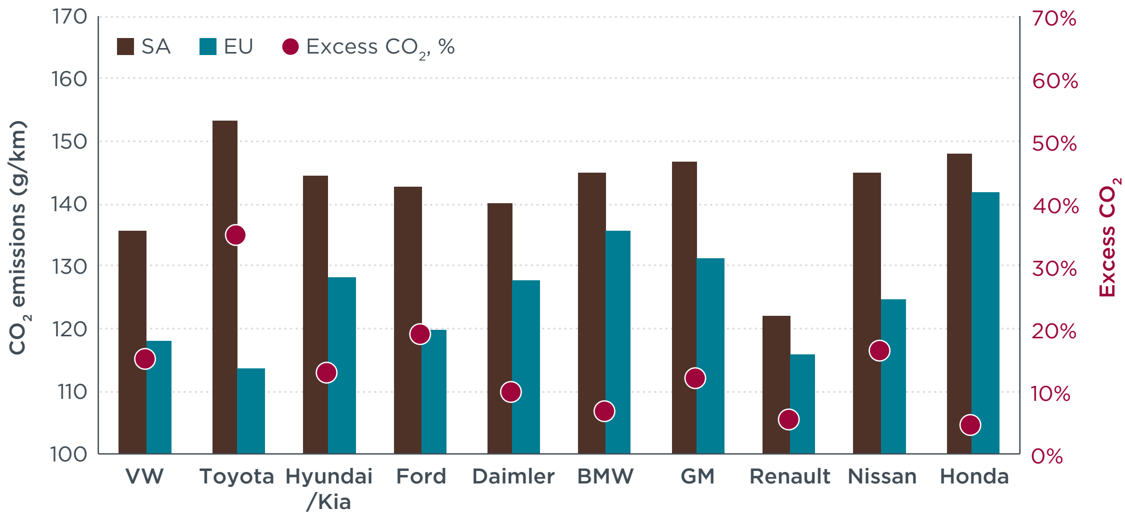

Figure 3-5. Comparison of average new vehicle sales-weighted CO_2 emissions by selected manufacturers in South Africa and Europe, gasoline vehicles only (2015).
Orange dot markers show the excess CO_2 emissions of South African vehicles compared with European vehicles (right axis).

DISCUSSION OF CO_2 PERFORMANCE

In an effort to understand why there are such large differences in CO_2 performance between SA and EU vehicles, we will compare vehicle characteristics in these markets.

Figure 3-6 shows the CO_2 market distribution for South Africa and Europe. The SA passenger vehicle market tends to be biased toward higher CO_2 emitting models. The European market exhibits a significant presence of vehicles with emissions below 95 g/km, which is the European new vehicle CO_2 emissions target for 2020/2021, while those vehicles are almost nonexistent in South Africa. Highly efficient vehicles, mainly hybrids, are also notoriously underrepresented in South Africa.

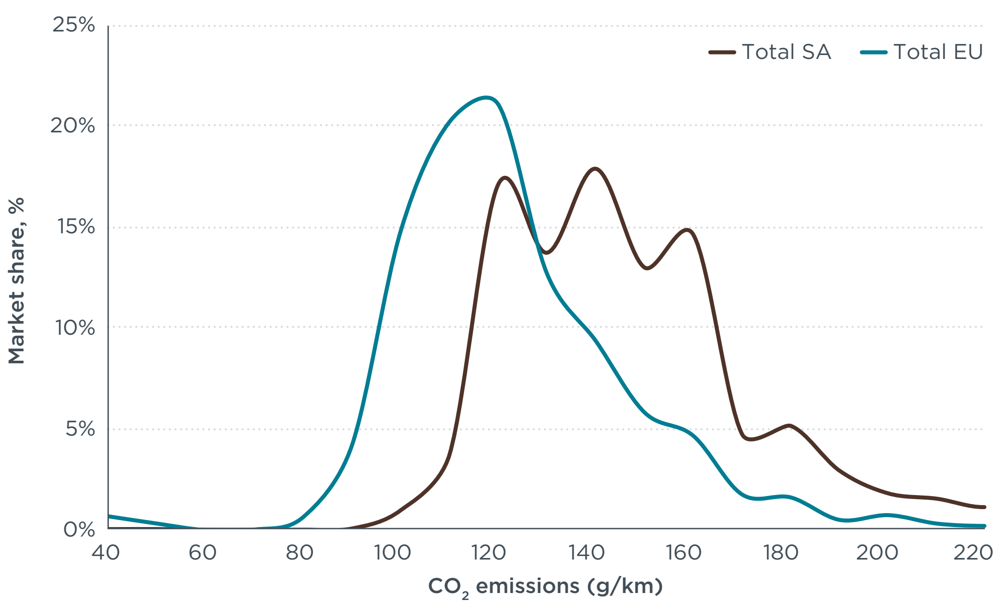

Figure 3-6. CO_2 emissions distribution for SA and EU passenger vehicles.
Area under each curve adds up to 100%.

Fig 3-7 presents a closer look at distributions of vehicle characteristics for the two markets. Engine size (in liters) is almost identical and tri-modal for both markets, with strong sales of engine sizes 1.6, 2.0, and 3.0 liters. On the other hand, curb weight shows a strong differential bias for lighter models in South Africa. More than 50% of new vehicles have weights below 1,200 kg in South Africa, while in Europe 50% of vehicles are under 1,300 kg. Rated power numbers are similarly distributed in the two countries, with a tendency for higher market share of models with 70 kW engines in South Africa. PTWR numbers follow a very similar trend between the two markets but with a small bias toward higher PTWR vehicles in South Africa.

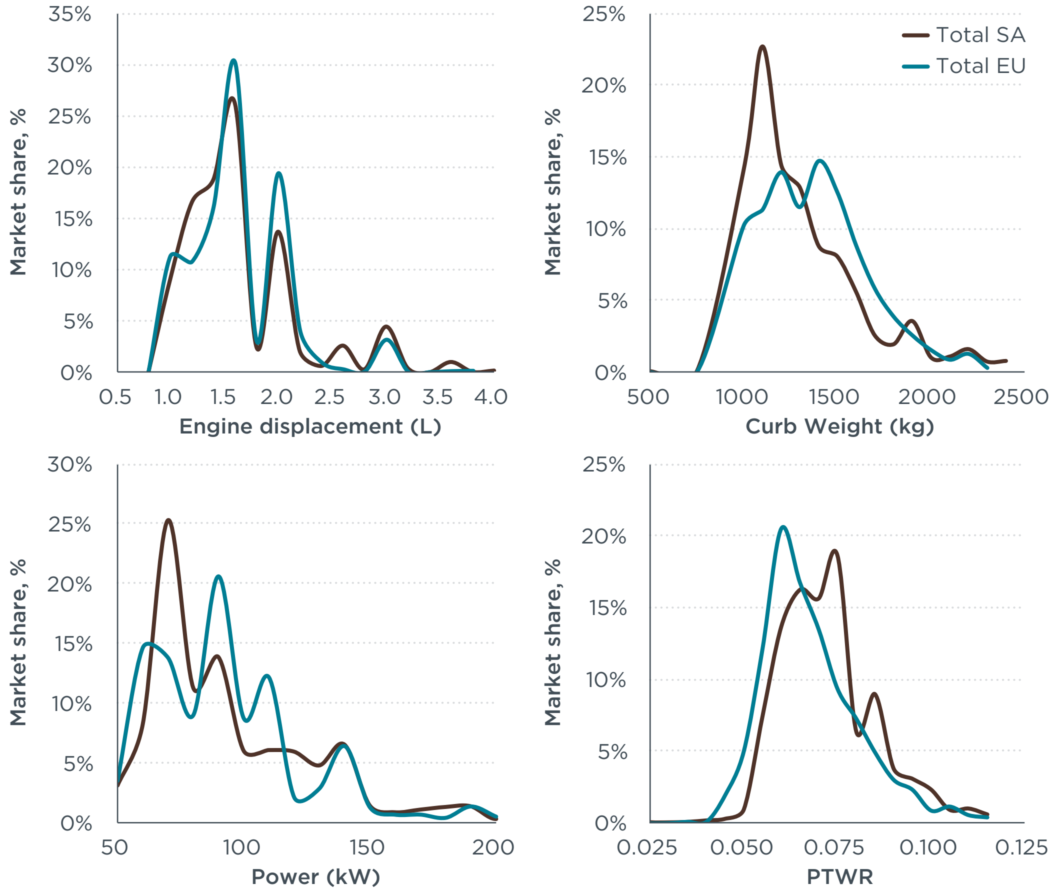

Figure 3-7. Market characteristics of new passenger vehicles in South Africa and Europe.
Area under each curve adds up to 100%.

The SA new passenger vehicle market is on average 5% lighter and has 7% higher engine-rated power. These differences do not adequately explain the gap in CO_2 emissions between the two countries, which is 22% worse in South Africa than in Europe. Research written on the effect of vehicle mass and power on fuel consumption shows that a 20% reduction in mass would bring about a 7% reduction in fuel consumption under the same powertrain technology and testing conditions; a combined 20% reduction in both mass and power brings about 12% to 14% fuel consumption reductions (National Research Council [NRC], 2011). Based on this, the 5% lower mass for SA vehicles would roughly imply a 1.7% benefit in CO_2 emissions and the 7% higher power for SA vehicles would imply a 1.7% to 2.4% increase in CO_2 emissions. These two factors would mean a CO_2 difference of around 1% to 2%. This means that no more than 2% of the 22% CO_2 emissions difference can be attributed to vehicle characteristics, mainly more powerful vehicles in South Africa. A potential reason for the emissions misalignment between fleets could be differences in vehicle technology (i.e., the average new vehicle in South Africa today lags behind fuel-efficient technologies available to new vehicles in the European market). A detailed technology analysis, looking more closely at other fuel-efficient technology penetration (e.g., gasoline direct injection, turbocharging, electric accessories, and dual clutch transmissions) would be required to better explore the difference.

4. ASSESSMENT OF BENEFITS OF NEW VEHICLE FE/CO_2 EMISSION STANDARDS

Adopting a fuel economy or CO_2 emission standard for new passenger vehicles in South Africa would result in significant sectorial CO_2 emissions reductions, which would mitigate the impact of a projected increase in PV fleet size. This assessment required the development of a model to better understand the impact of potential standard adoption scenarios. Three scenarios were studied: a) the baseline case where no emission standards are adopted; b) a short-term policy adoption scenario where the standard requires a 19% improvement by 2024; and c) a long-term scenario where the rate of improvement is maintained until 2030, resulting in a fleet improvement of 36%. The short- and long-term scenarios are designed under the same annual rate of improvement in fuel efficiency of 4.1%.

This section summarizes the methods used for model development, including inputs, and the results for the three scenarios studied.

FUEL ECONOMY/CO_2 EMISSION STANDARD IMPACT ASSESSMENT MODEL

A fuel economy and CO_2 emission standard implementation assessment model was developed for this project. The model is built upon the methodology developed for the fuel economy standards evaluation tool (FESET). The FESET model is publicly available, and a detailed description of it can be found online (Gesellschaft für Internationale Zusammenarbeit [GIZ], 2017). The model calculates the annual rate of CO_2 emissions from the passenger vehicle fleet for a given year. In general terms, it is the product of sales-weighted average CO_2 emission values (g/km), vehicle activity (km/year), and the number of vehicles in the fleet.

The model that was developed for SA passenger vehicles includes specific scenarios and inputs that apply solely to this market. A model validation exercise was run to make sure the model reflected the total vehicle parc (also known as vehicle stock) and total fuel consumption. A detailed description of the inputs, scenarios, and model validation is presented below. The model validation is described in Appendix A.

MODEL INPUTS

The model inputs can be grouped by vehicle activity, vehicle numbers, and CO_2 emission values. Table 4-1 summarizes the key input data used for modeling the South African PV fleet. Data on vehicle activity and some vehicle number parameters were obtained from a 2012 report by the South African National Energy Development Institute (SANEDI) on the energy needs from the transport sector (Merven et al., 2012). Historical stock vehicle numbers where obtained from OICA (2017). Historical new vehicle sales, covering years 2005 to 2015, were obtained from NAAMSA (2017). CO_2 values for new vehicles in calendar year 2015 come from this analysis, and are presented in section 3.

Table 4-1. Key input parameters used for modeling South Africa's PV fleet

Input parameter	Description	Value for South Africa	Source
Vehicle activity in vehicle kilometers traveled (VKT)	VKT when new. VKT is reduced over time, by 50% after 20 years of operation	21,000 km	Merven et al. (2012) and FESET
	Rebound effect	10% per percentage of efficiency improvement	ICCT estimate
Passenger vehicle numbers	2015 Sales	412,670 units	NAAMSA (2017)
	2015 Stock (parc)	6,4 million	OICA (2017)
CO_2 emission values	2015 new vehicle average emission level (gCO_2/km)	148 gCO_2/km	Section 3 of this report
	Real world emission adjustment factor	+20%	ICCT estimate

As the objective of the model is to estimate the future impact of potential new vehicle CO_2 emission standards, the model inputs also include projections to 2050 on vehicle fleet growth and future new vehicle CO_2 emission levels. Fleet growth is introduced here, and the projected CO_2 values are presented in the scenarios section. Projections to year 2050 on new vehicle sales were obtained from fleet growth projections available in the SANEDI report, as well as from the International Energy Agency Mobility Model (MoMo), which contains detailed projections for South Africa (IEA, 2017). According to MoMo's projections for South Africa, new vehicle sales are expected to grow to 600 thousand units by 2030 and to 800 thousand units by 2050. Merven and his team from the University of Cape Town projects sales of 640 thousand units by 2030 and 950 thousand units by 2050 (Merven et al., 2012). Based on those two projections, the model assumes fleet growth of 4% in the early 2020s, and assumed to slow to about 1.9% by 2050, as shown in Figure 4-1.

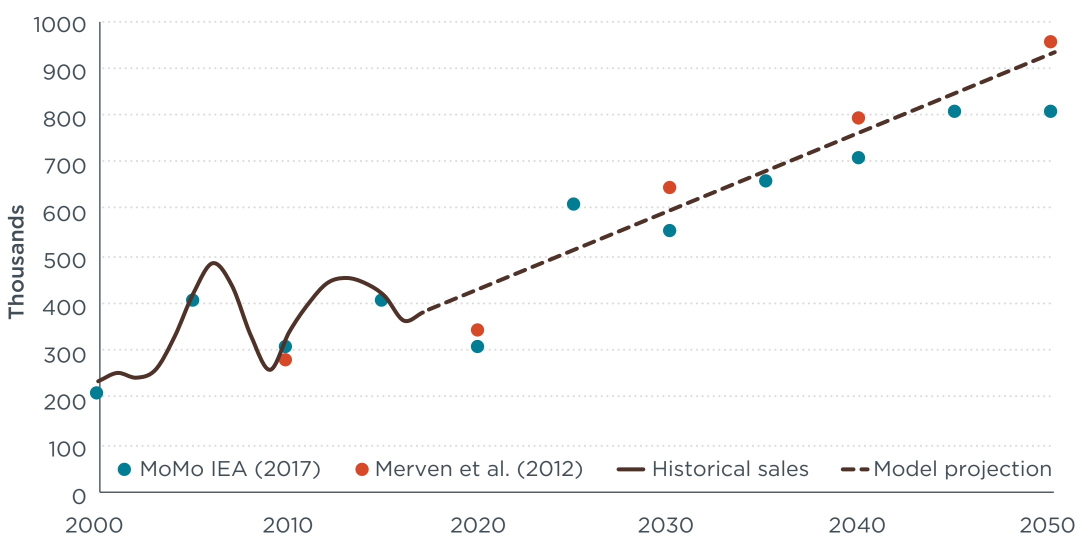

Figure 4-1. ICCT model passenger vehicle fleet growth projections

SCENARIOS

Three scenarios projecting the South African passenger vehicle CO_2 emission trends were studied. In the baseline case, no emission standards are adopted. The two other scenarios assume an adoption of new vehicle CO_2 emission standards, or its fuel economy standard equivalent, starting in 2020 and under effect until two different dates, 2024 and 2030. Both scenarios share the same rate of improvement in terms of annual PV fleet average CO_2 emission reduction: 4.1%. This number is similar to the rate of improvement experienced under the European Union CO_2 emission standards program for passenger vehicles. Table 4-2 shows the passenger vehicle fleet target evolution under the two policy adoption scenarios. The short-term scenario would require new vehicle manufacturers and importers to sell a fleet of vehicles that meet a 120 gCO_2/km level by 2024. The long-term scenario would require a 95 gCO_2/km by 2030, matching the European 2020 target.

Table 4-2. Modeled scenarios for South Africa's passenger vehicles

Scenario	Label	Annual rate	Regulation period	CO_2 level at end of period	Comments
Business as usual	BAU	0.5%	—	—	Assumes a technology improvement driven by international markets
Short-term	120 g/km by 2024	4.1%	2024	120 gCO_2/km	The average vehicle would consume 19% less fuel than current market vehicles.
Long-term	95 g/km by 2030	4.1%	2030	95 gCO_2/km	The average vehicle would consume 36% less fuel than current market vehicles.

MODELING RESULTS

The model predicts that the size of the passenger vehicle fleet in circulation would increase from 6.4 million vehicles in 2015 to 14.7 million vehicles by 2050. Under the business-as-usual case, this fleet size increase would double the fuel consumption for the PV sector in South Africa, from 8.6 billion liters of fuel per year in 2015 to 17 billion liters of fuel per year in 2050.

BENEFITS OF ADOPTING THE STANDARDS

Adoption of new vehicle CO_2 emission standards would result in significant improvements in fleet average fuel efficiency with significant benefits in CO_2 emission reductions. Figure 4-2 shows the projected benefits in terms of CO_2 emissions under the two studied scenarios.

Under the short-term scenario, reaching 120 gCO2/km by 2024, the annual contribution of CO_2 emissions would reduce the impact of the growth in fleet size. The reductions are about 2 Mt per year by 2030 and increase to 4.5 Mt per year by 2050, once the older fleet has been retired from the rolling fleet. Although this scenario presents some benefits, it would not stabilize or reduce the overall CO_2 contribution from PVs. A longer period of regulatory compliance would be required to reach a plateau, especially under the pressure of a doubling fleet size.

The long-term scenario that requires new vehicle CO_2 emission compliance from 2020 to 2030, resulting in a fleet average value of 95 gCO_2/km by 2030, would increase the annual rate of emission reduction by 3.3 Mt in 2030 and by 11.1 Mt in 2050. The benefits jump from 12.6% in 2030 to 28.4% in 2050, once fleet renewal has occurred.

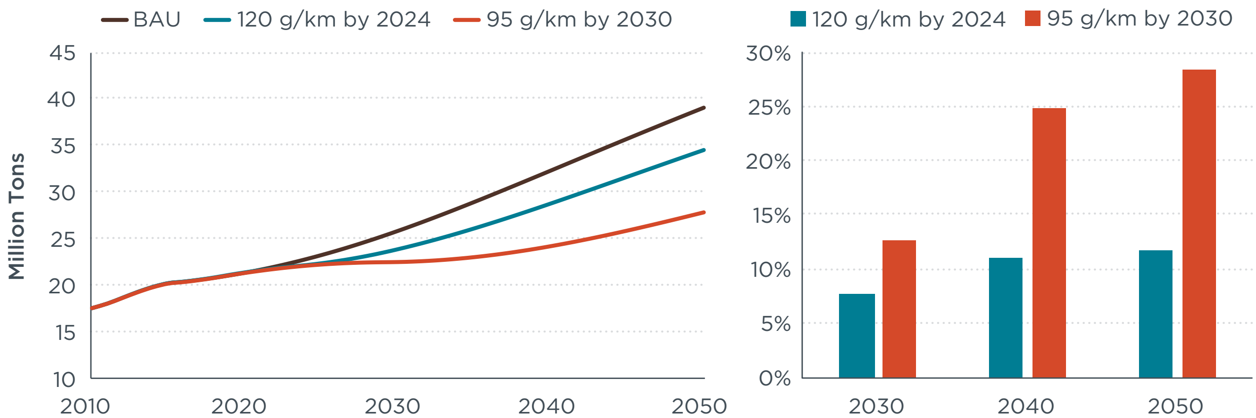

Figure 4-2 Model results: CO_2 emissions under different scenarios.
Graph on right shows the benefits with respect to the BAU scenario.

Fuel consumption benefits are proportional to the CO_2 benefits under the two policy scenarios. The short-term scenario would reduce fuel consumption from 17 billion liters by 2050 to 15 billion liters, a 12% reduction. At current fuel price at the pump, 13.5 rand per liter, that would imply a national fuel cost saving of 26 billion rand. The long-term scenario would reduce the projected fuel consumption by 4.7 billion liters, resulting in monetary savings of 64 billion rand. Table 4-3 provides a results summary for the studied scenarios.

This reduction in fuel use would result in societal savings, as more South Africans would have access to efficient vehicles that cost much less to operate per distance traveled.

Given that South Africa is a net importer of crude oil and refined products (U.S. Energy Information Agency, 2017), the standards would also result in significant reductions in national oil trade deficits and would reduce currency outflows, making it less vulnerable to oil price shocks (Council on Foreign Relations, 2017)

Table 4-3 Summary of modeling results for key years

Scenario Summary	Annual CO_2 emissions (million tons)			Annual fuel consumption (billion liters)		
	2030	2040	2050	2030	2040	2050
BAU	25.8	32.2	39.0	11.02	13.79	16.68
120 g/km by 2024	23.8	28.7	34.5	10.19	12.29	14.75
95 g/km by 2030	22.5	24.2	27.9	9.63	10.37	11.95
Reductions with respect to BAU						
120 g/km by 2024	2.0	3.5	4.5	0.84	1.50	1.93
95 g/km by 2030	3.3	8.0	11.1	1.39	3.42	4.73
% improvement with respect to BAU						
120 g/km by 2024	7.6%	10.9%	11.6%	7.6%	10.9%	11.6%
95 g/km by 2030	12.6%	24.8%	28.4%	12.6%	24.8%	28.4%

5. CONCLUSIONS AND OUTLOOK

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC, were 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. Disaggregating the data by fuel type shows that diesel passenger vehicles emit about 14.4% more CO_2 per km than the average gasoline vehicle; this is explained by a much wider use of diesel engines in SUVs, which are on average the heaviest and highest rated power vehicles in the fleet. Manufacturer analysis shows that, among market leaders, Renault is the best performer and Toyota is the worst performer in terms of fleet average CO_2 emissions.

South Africa's passenger car fleet average CO_2 emissions are 22% higher than the EU's fleet average emissions of 121 g/km. This large difference is worsened by the fact that the SA fleet is 5% lighter than the EU fleet. The lower efficiency of the average SA vehicles is also evident when comparing the fleets by segment, with the difference being more pronounced for SUVs. Comparing CO_2 emissions performance by manufacturer shows a significant gap between the European and South African models. Toyota presents the highest CO_2 gap between markets, 43%, which is partially explained by a SUV preference in South Africa and also by reduced access to highly efficient vehicle technologies. When diesel vehicles are removed from the analysis, Toyota's efficiency gap with European models improves to 35%, still the highest among the market leaders.

The adoption of CO_2 emission standards for new vehicles, or an equivalent metric for fuel economy, would produce significant CO_2 emission reductions and fuel savings, ranging from 11.6% for a short-term policy design to 28.4% for a long-term policy case; both cases evaluated to 2050. This evaluation takes into account that the South African fleet is expected to double in size by 2050. The economic benefits of adopting the standards were estimated between 26 and 64 billion rand, and proportional to the level of ambition of the standards.

Further research is required to understand the technology requirements to reach the targets under each of the policy scenarios. That analysis would also yield the cost of technology associated with compliance. Thus, the next step should focus on predicting the technology and cost associated with meeting the CO_2 standards. This would also provide a clear idea of the payback period, or how much time would be required for drivers to recoup the investment in fuel-efficient technology with savings from reduced fuel consumption.

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ANNEX A—MODEL VALIDATION

The model developed for estimating the CO_2 emissions from South African passenger vehicles was validated against historical data. The validation covers two elements: number of vehicles in the fleet and total fuel consumed.

The first one, number of passenger vehicles in circulation or passenger vehicle stock, looks at the total parc of vehicles registered in South Africa between 2005 and 2014. It integrates historical new sales data and the outflow of vehicles as they age and are removed from the fleet in circulation. The reader should note that South Africa does not allow for the import of used vehicles. Table A-1 provides an impression on the ability of the model to account for the vehicle parc in circulation; the average difference for the years covered is 0.4%.

The second validation targeted the ability of the model to predict total fuel consumed by the passenger vehicle feet, compared to historical fuel consumption data from the South African Department of Energy (DOE, 2017). Historical fuel consumption data combined all forms of transportation. An estimate of the fraction of fuel consumed by the passenger fleet was required. The PV fuel consumption fraction, ranging from 60% to 76% of all fuel consumed between 2005 and 2015, was obtained from Merven's conclusions on PV fleet greenhouse gas contribution to the total on-road transport sector in 2010 and 2020, at 37% of the overall fleet. Table A-2 shows the fuel consumption (gasoline equivalent) attributed to the PV fleet and the model estimates; the average difference is less than 1%.

Table A-1. Model validation: Number of vehicles in circulation

Million vehicles in operation	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Model	4.64	4.91	5.14	5.26	5.30	5.41	5.58	5.79	6.01	6.20	6.37
OICA	4.58	4.89	5.16	5.28	5.41	5.32	5.51	5.73	5.97	6.19	6.38
% difference w/r to OICA	1.4%	0.5%	-0.4%	-0.4%	-2.1%	1.8%	1.4%	1.0%	0.7%	0.3%	-0.3%

Table A-2. Model validation: National fuel consumption for passenger vehicles

Total fuel consumed, billion liters	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Model - Test cycle	5.4	5.8	6.0	6.1	6.1	6.2	6.4	6.6	6.9	7.0	7.2
Model- CO_2 gap corrected	6.5	6.9	7.2	7.4	7.4	7.5	7.7	8.0	8.2	8.5	8.6
DOE gasoline consumption, Liters	11.2	11.3	11.6	11.1	11.3	11.5	11.9	11.7	11.4	10.9	11.5
% Fuel consumed by PV fleet	0.59	0.61	0.65	0.67	0.63	0.65	0.67	0.68	0.72	0.76	0.76
DOE PV fleet, Billion Liters	6.6	6.9	7.5	7.5	7.2	7.5	8.1	8.0	8.2	8.2	8.7
% difference	-2%	0%	-4%	-1%	2%	0%	-5%	0%	0%	3%	-1%