THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

SOUTH AFRICA'S NEW PASSENGER VEHICLE CO_2 EMISSIONS BASELINE ANALYSIS

Final Report

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Prepared for:
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Executive Summary

This report provides a transparent assessment of the current new passenger vehicle market in South Africa in terms of CO_2 emissions and technical characteristics to domestic policymakers and stakeholders as well as to an interested international audience.

The South African new passenger vehicle fleet is the largest in the African continent and the 18th largest globally. South African manufacturers sold more than 412 thousand new vehicles in 2015, and exported more than 333 thousand units in that year. The two top manufacturers are Volkswagen and Toyota.

The South African market aligns in terms of market composition with most global markets: a contrasting combination of large shares of small vehicles and SUVs. Most vehicles sold in South Africa in 2015 are small and lower medium sized vehicles, such as VW Polo and Toyota Corolla; the SUV market is about 21%.

With respect to fuel use, about 17% of all passenger vehicles in SA are sold with a diesel engine. Sales of diesel vehicles are heavily focused on the SUV segment. VW and Toyota are the highest sellers of diesel vehicles in absolute terms; Daimler and BMW have the highest share of diesel vehicles sales compared to all other manufacturers.

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC test cycle, was 148 gCO_2/km in 2015 (Figure ES-1). The equivalent metric in terms of fuel consumption is 6.3 L/100 km. Disaggregating the data by fuel 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, on average, Renault is the best performer and Toyota the least efficient.

South Africa's passenger car fleet average CO_2 emissions are about 21% higher than EU's fleet average emissions, 121 g/km. This large difference is highlighted by the fact that SA's fleet is 5% lighter than the European fleet. The lower efficiency of the average SA vehicles is also evident when comparing the fleets by segment, being more pronounced for SUVs (Figure ES-2). 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 regional fleets, 43%, which is partially explained by a SUV preference in South Africa and also by reduced access to highly efficient vehicle technologies.

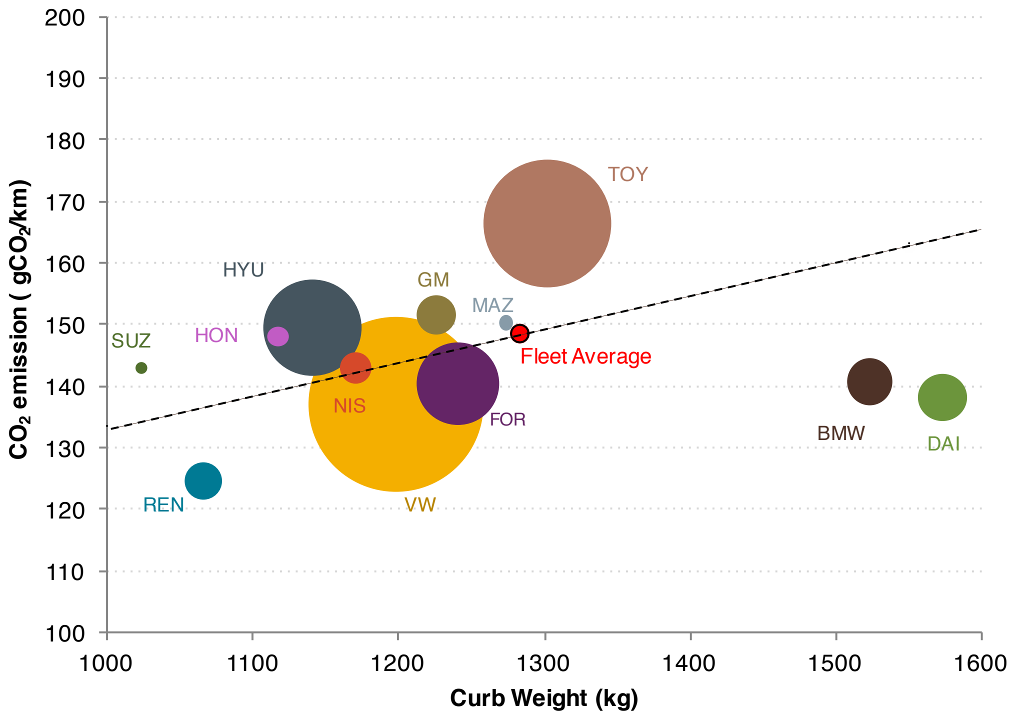

Figure ES-1 Average new vehicle sales-weighted CO_2 emissions by manufacturer (2015). Circle diameter represents sales numbers. Dotted lines correspond to linearization of sales weighted data

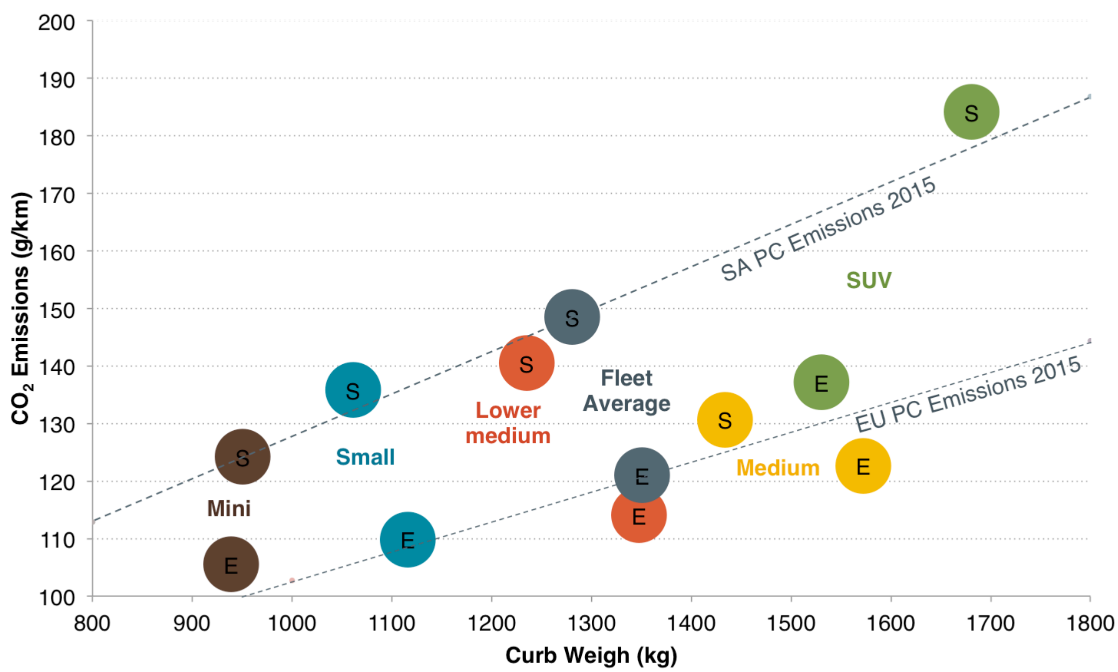

Figure ES-2 Average new vehicle sales-weighted CO_2 emissions as a function of curb weight, by segment - all fuels (2015). Segments are differentiated by color. Internal circle label **S** correspond to South Africa and **E** to Europe**.** Dotted lines correspond to linearization of sales weighted data for each market.

Introduction

South Africa leads the continent's automotive industry not just in terms of vehicle stock, new vehicle sales, but also as main auto-manufacturing hub in the region and one of the largest globally. It also plays a strategic role in the future fleet of vehicles in the African continent as the main exporter of automobiles to neighboring countries.

According to the Organization of Motor Vehicle Manufacturers (OICA), the total South African vehicle population was 9.6 million units in 2014 (OICA, 2016). This is by far the largest fleet in Africa, accounting for 22.6% of the vehicles in the continent. New passenger vehicle sales were more than 0.41 million units in 2015, about 37% of the African market and 60% more than the second largest vehicle market in Africa, Egypt.

South Africa's automotive industry is a very important sector for the national economy. The automotive industry contributes 7.5% to the country's GDP in 2015, for a total of $ZAR399 billion (AIEC, 2016). Vehicle and component production add up to 33.5% of total manufacturing output in 2015. With respect to exports, the automotive industry is responsible for 10.1%, totaling USD$9.5 billion out of the USD$93.7 billions generated in 2015 (MIT 2016). Within the automotive industry, passenger vehicle exports represented 63% of export revenue.

In addition to its contribution to economic growth, the transportation sector is the second-highest contributor to the country's greenhouse gas emissions, just after the energy sector. Transport emitted 61976 ktCO_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 (DEA 2014, World Bank 2016).

Given its relatively young population and its continued growth in gross domestic product (GDP) the transport sector's carbon footprint is poised to continue growing unless this growth is met with policy tools to curb that impact. The South African government has already taken steps to incentivize consumers to purchase fuel-efficient vehicles. The measures adopted are vehicle fuel economy label programs and vehicle taxation policies that are based on vehicle CO_2 emissions. The next logic step would be to adopt policies that incentivize manufacturers to offer into the SA market the most fuel-efficient vehicles.

The objective of this report is to provide the basis for further analysis of potential regulatory tools that can be adopted aiming to reduce the carbon footprint of passenger vehicles in South Africa. This new vehicle CO_2 emissions baseline analysis provides a snapshot of the passenger vehicle fleet for calendar year 2015, looking at characteristics and performance of the fleet and drawing comparison with global markets, especially the European market. The data was purchased from NAAMSA's data manager company, LighStone Auto.[1] The results of this report can become the main input for studying potential policy tools and project their impact on SA's passenger vehicle fleet carbon contributions.

The market baseline analysis report is structured as follows: the first section presents a description of the South African passenger vehicle market; the second section describes

[1] LightStone Auto : http://www.lightstoneauto.co.za/

the South African passenger vehicle fleet characteristics; the third section provides an overview of vehicle technologies and the fourth section provides the CO_2 values for the entire fleet, by segment and by manufacturer; this section also presents a comparison with the European vehicle market and a discussion into potential reasons for the large lag that South African vehicle show compared to European vehicles in terms of CO_2 emissions.

1. Vehicle Market Overview

South Africa has the largest new passenger vehicle market in the African continent and is the 18th largest market on a global scale (Figures 1-1). In calendar year 2015, a total of 412670 new passenger vehicles were sold in the country. Between 2010 and 2015 new vehicle sales grew by 22%, with an average annual rate growth of 4.1%. However, between 2014 and 2015 the new passenger vehicle market suffered a 6% reduction, which according to the National Association of Automobile Manufacturers of SA (NAAMSA), was due to a slowdown in the domestic economy propelled principally by an increase in interest rate that also affected financing costs.

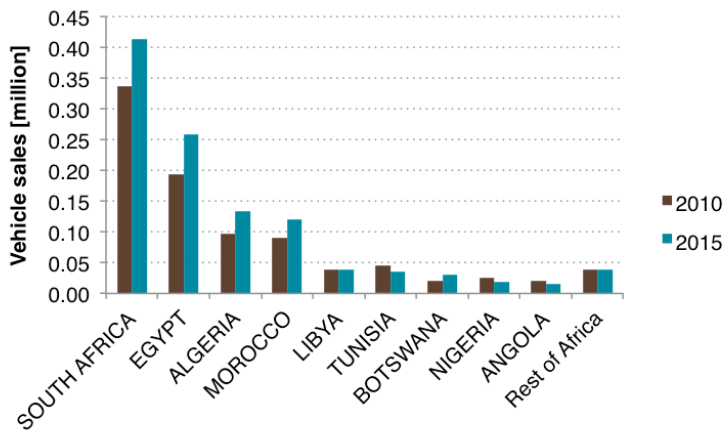

Figure 1-1 Top 10 passenger vehicle markets in Africa. ***Source: OICA (2016)***

The top ten manufacturers – Volkswagen (VW), Toyota, Hyundai/Kia, Ford, Daimler, BMW, General Motors (GM), Renault, Nissan and Honda – commanded a vast majority (~90%) of the entire market in 2015, with the remaining manufacturers accounting for less than 2% of market sales each (Figure 1-3). One remarkable characteristic of the vehicle market in South Africa is that luxury automakers, Daimler and BMW hold around 6% of the market, and are the 5th and 6th largest sellers, very similar to their position in Europe, but far from the positions held in other BRIC countries such as Brazil (less than 1%) or China.

The best-selling car in 2015, consistent with 2014 trends, was the Volkswagen Polo, accounting for 13.56% of the passenger vehicle market with 55957 sales. Next was the Toyota Corolla, with a 5.7% share in passenger vehicles for a total of 23542 sales in 2015. Next came the Toyota Etios (16270), Mercedes C class (12480), and the Hyundai grand (i10) and Hyundai i10 (11861).

The market distribution by segment shows that small- and lower medium-sized vehicles dominate the market with 54% of all sales. The SUV market is similar is size to the lower medium market share, with 21% of the market. This combination of large shares of small vehicles and SUVs shows that the South African passenger vehicle market is aligned with global tendencies in that low income consumers are driven to smaller vehicles, while consumers with disposable income prefer SUVs over large sedans at similar prices.

The reader should notice that according to South African vehicle types definitions, bakkies, known in international markets as pick-up trucks, are not considered passenger cars but light commercial vehicles. Light commercial vehicles (LCVs) are out of the scope of this analysis but are mentioned here for sake of completeness. For light commercial vehicles in the 2015 market, the Toyota Hilux was the top-selling car, with a 20% market share and 35,684 sales out of the total market of 174,746 car sales. A close second was the Ford Ranger, accounting for 19% of market share with 33,916 sales; the Nissan NP200, Toyota Quantum, and Chevrolet Utility were the next three top-selling LCVs.

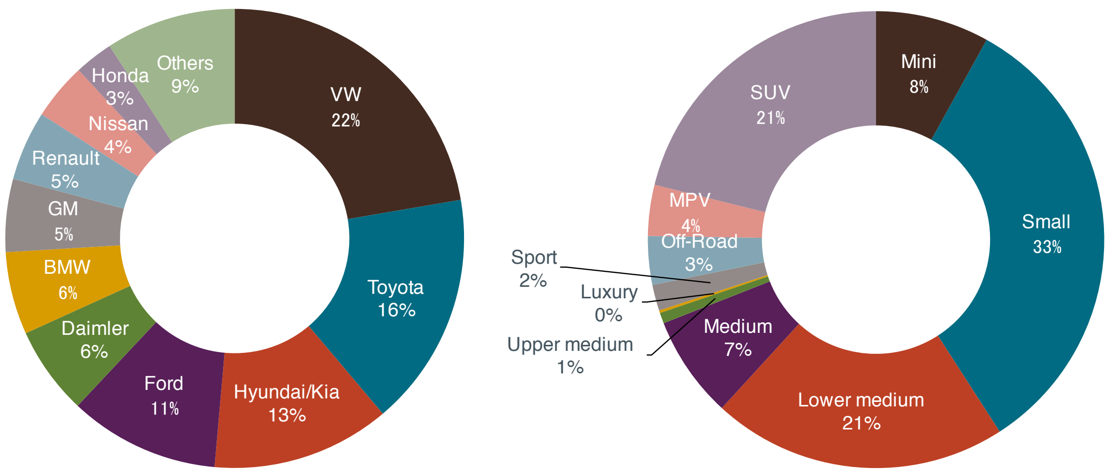

Figure 1-2 South African market share by manufacturer and by segment

Figure 1-4 provides an overview of the distribution of vehicle segmentation by manufacturer. VW, Hyundai and GM have very similar market structures, focusing on small sized vehicles. Toyota, the second largest manufacturer, focuses more on medium size vehicles and SUVs, similar to the segmentation of Mazda. Ford offering is almost binary, as it focuses on the smaller sedans and SUVs. Daimler and BMW's segment share structures are similar, but BMW leans towards smaller sedans and more SUVs, while Daimler offers a larger share of MPVs; both manufacturers sell a significant share of sports models. Chrysler focuses it sales on the larger segments, SUVs (83%) and off-road vehicles.

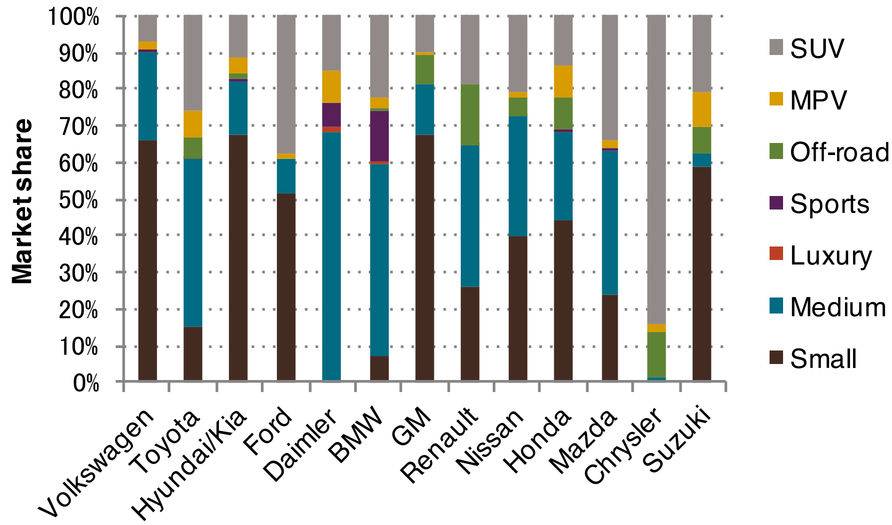

Figure 1-3 Manufacturer vehicle segmentation – listed by sales ranking from left to right

South African Vehicle Exports

Despite an overall decrease in domestic sales in 2015, vehicle exports hit a record high of 333748 units compared to 276936 vehicles in 2014, placing South Africa 25th in the global vehicle production ranking, with 0.63% of the global market share (AIEC 2016). Since 2010, exports have jumped by 41%. Despite stalls in domestic sales, overall industry production levels—backed by the growth in vehicle exports—should still trend upwards in upcoming years (Carmag 2016).

Its top export locations include the US, Germany, Japan, Belgium-Luxembourg, and neighboring African countries (Figure 1-5a) (AIEC 2016). As shown, exports within Africa amount to almost 7% of South Africa's total vehicle exports. However, exports within Africa have been stalled by lack of infrastructure, primarily due to road transport and a diverse set of tariffs. According to the Industrial Development Corporation of South Africa, two out of every three African countries have experienced more difficulty in trading with their neighbors than they have in trading with the rest of the world, largely due to tariff and non-tariff barriers (IDC 2014). Non-tariff barriers include insufficiencies in infrastructure, weak implementation of regional integration agreements, and a lacking in economic diversity. As a result, exporting goods within Africa tends to be more costly than exporting goods between Africa and other parts of the world. Figure 1-5b is a representation of top value export countries within Africa (AIEC 2016).

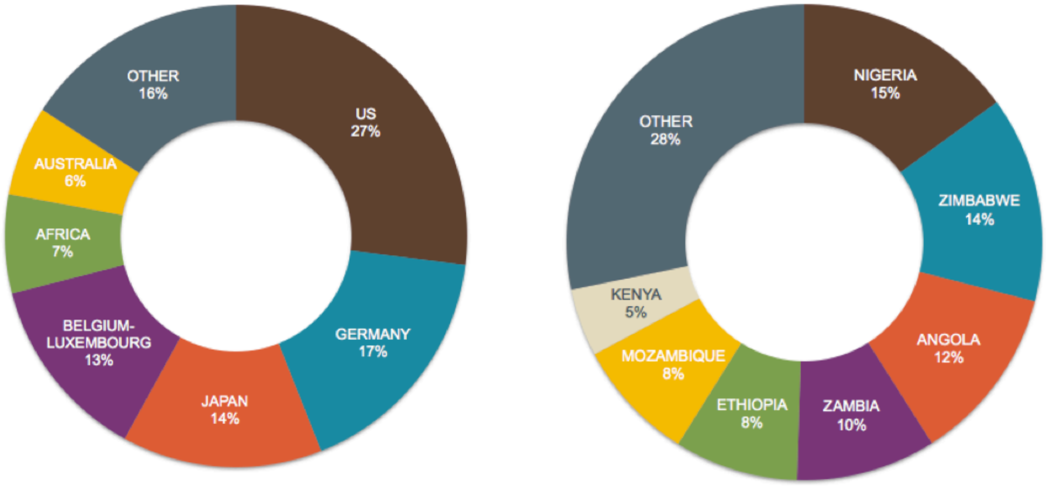

Figure 1-4 Share of passenger car value exports from South Africa to: a) Global markets, b) African markets. ***Source: AIEC (2016).***

New vehicle imports

South Africa's imports of vehicles and equipment components tend to remain in line with domestic market demand. Germany, India, and Japan, are the top three importing countries, in descending order, followed by Turkey, South Korea, and the U.S. Imports of light vehicles declined from 377,994 units in 2014 to 353,338 units in 2015, which accompanied the slowdown of domestic vehicle sales. In 2014, new vehicle imports came from 31 different countries around the world (AIEC 2016). In 2014, South Africa's transportation sector imported $13.5 billion worth of goods, accounting for 13% of $103 billion as the total import value (USD) (MIT 2016). Passenger vehicles accounted for 36% of the share, worth $4.85 billion (MIT 2016). Figure 1-6 shows import value shares for 2014 for PVs. Used vehicle imports are not allowed in South Africa.

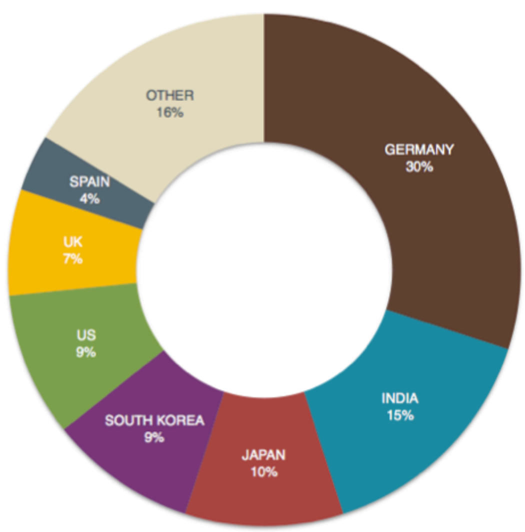

Figure 1-5 Sources of value vehicle imports. ***Source: AIEC (2016)***

2. Vehicle Characteristics

This section provides an overview of key average vehicle characteristics in SA and provides a comparison with other global vehicle markets. Number of cylinders, engine displacement, curb weight, engine power and power-to-weight ratio (PTWR) 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, by fuel type (gasoline vs. diesel), and compared against a set of global vehicle markets. Segment definition is described in Appendix A.

Vehicle characteristics by segment

Figure 2-1 illustrates key vehicle fleet characteristics by vehicle segment. As can be expected, most parameters grow in magnitude as for heavier and larger vehicle segments. Luxury vehicles are the most powerful and heavy cars. All other parameters also follow this trend. Sport Utility vehicles (SUV) have similar characteristics as the 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 under similar characteristics. Sports vehicles tend to have powerful engines and lower mass, thereby making their power to weight the highest of the group.

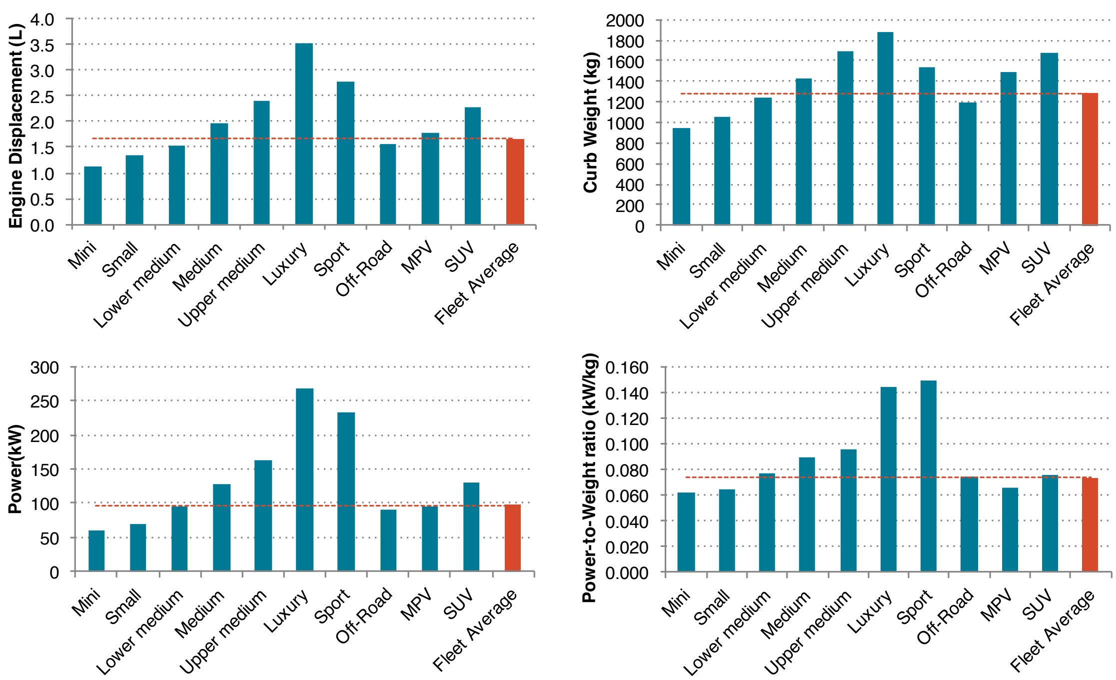

Figure 2-1 Fleet characteristics of new South African passenger vehicles by segment (2015).

Vehicle characteristics by manufacturer

There are a total of twenty-seven manufactures, which sell approximately forty-three different brands of vehicles in South Africa. The top thirteen manufacturers account for about 95% of all vehicles sold in South Africa, both gasoline and diesel. Among the top four manufacturers, Volkswagen, Hyundai/Kia and Ford, produce on average smaller vehicles that are lighter and with less powerful engines. Toyota, the second largest manufacturer sells vehicles that on average have larger engines (1.8 L) than the average SA car (1.7 L); this is driven by numerous sales of SUVs with large engines such as the *Toyota Fortuner* and *Land Cruiser*. Luxury manufacturers, BMW and Daimler, as well as Chrysler, offer vehicles with much more powerful engines than the average South African car with 97 kW or 130 hp. PTWR is evenly distributed across manufacturers except for those three manufacturers. Renault and Suzuki sale vehicles that have, on average, the smaller engines, are lighter and have the least powerful engines across the set of studied manufacturers; interestingly, power to weight ratio values for these remain close to others, making those vehicles exhibit the same drivability characteristics as heavier and more powerful ones.

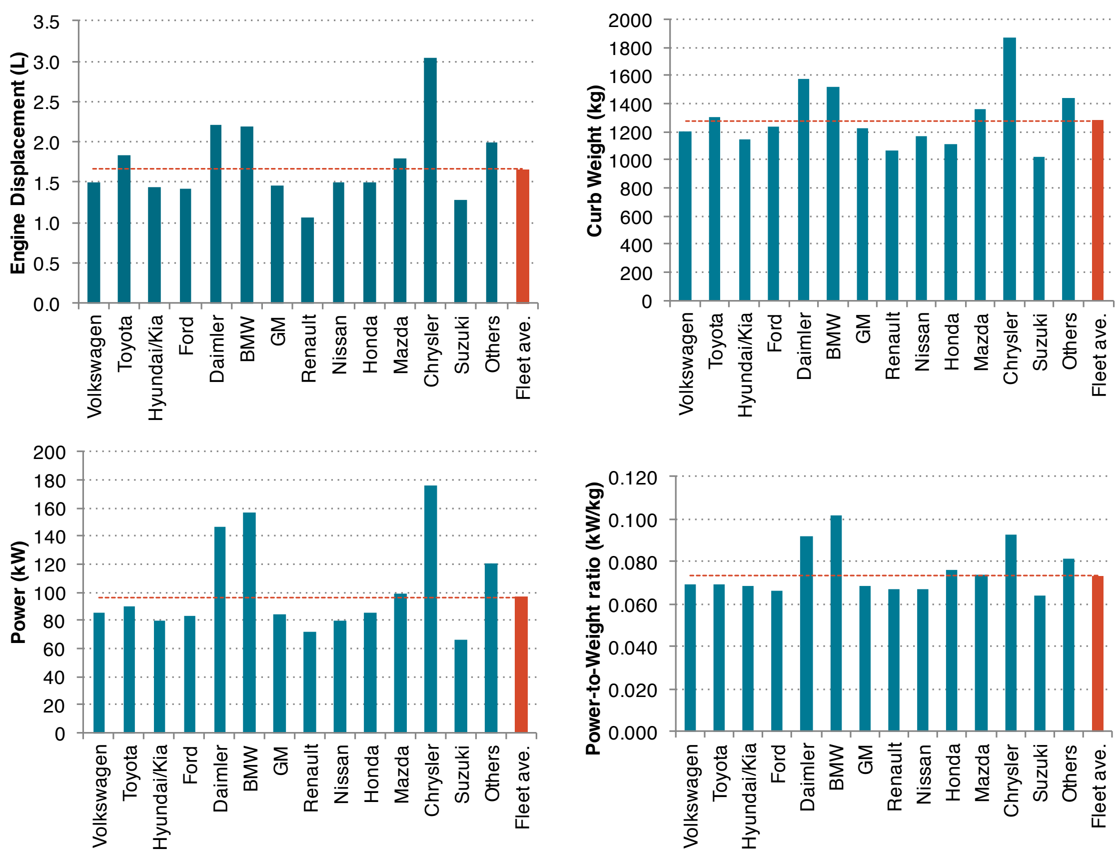

Figure 2-2 Fleet characteristics of new South African vehicles by Manufacturer – listed by sales ranking from left to right

Vehicle characteristics by fuel type: diesel vs. gasoline

About 17% of all passenger vehicles in SA are sold with a Diesel engine. This section looks at the vehicle characteristics introduced before but for each fuel type. The most remarkable market characteristic is that although gasoline sales outstrip the number of diesel vehicles by a factor of 5, within the SUV segment absolute sales numbers are one to one, around 43,000 units sold in 2015 for each type of fuel. In market share terms, this makes SUV the dominant segment among diesel powered vehicles, 2 out of 3 diesel vehicles are SUVs, followed by the medium size segment (Figure 2-3).

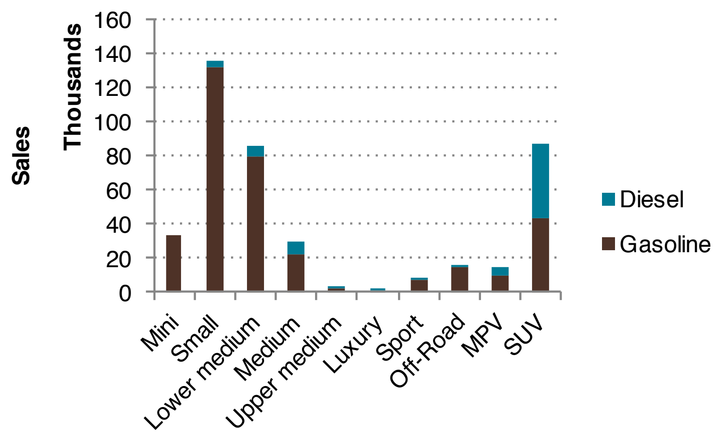

Figure 2-3 Fuel type sales of new South African passenger vehicles by segment

Figure 2-4 shows that gasoline engines are smaller in average than the diesel engines fitted in the South African vehicles; 1.5 L compared to 2.3 L, respectively. Diesel engines are not used in the mini segment. The most popular segments, small, lower-medium, medium, and SUV, are fitted with gasoline engines that are on average smaller than the diesel engines being offered. High-end segments and sport cars are featuring gasoline engines that are larger on average than those sold in diesel models.

The average gasoline passenger car is about 500 kilograms lighter than the average diesel model. A diesel market that is focused on SUV causes this large difference in average values. The gasoline market on the other hand is focused on smaller cars; more than 70% of gasoline cars belong to the mini, small or lower medium segments. While comparing within segments, gasoline vehicles are 4-10% lighter than diesel ones for sedans, and around 15% for SUVs.

Within the largest share segments, small and medium, gasoline vehicles are about 10% more powerful than diesel ones. Luxury and sports cars are sold with 60% higher rated power than diesel models. It is remarkable that the average power of SUV in gasoline and diesel vehicles is almost equivalent. This number is also backed by the sales number of these two categories, which is almost identical, both at 43,000 units.

PTW ratio values tend to favor gasoline models as the trend is enhanced by the fact that gasoline vehicles are lighter when comparing within the same segment. The difference is remarkably large in the sports and luxury car market, where the PTW ratios favor gasoline by about 65% compared to diesels within the same segment.

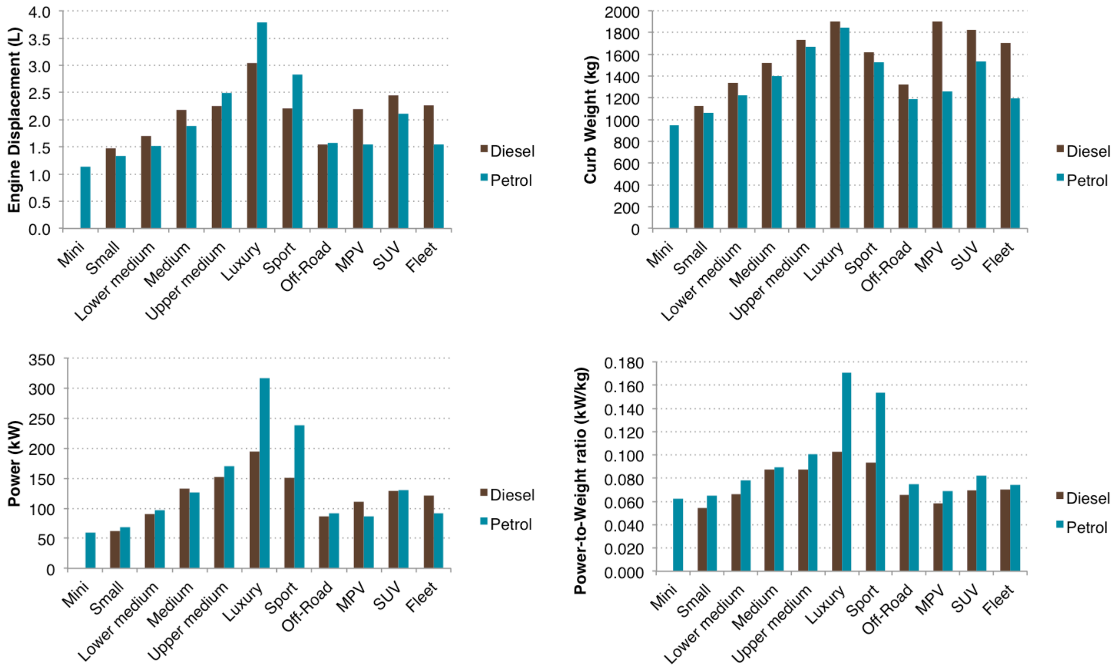

Figure 2-4 Fleet characteristics by fuel type of new South African passenger vehicles, by segment

Figure 2-5 shows the manufacturer average fleet characteristics for vehicles sold in 2015 in South Africa. This data analysis approach provides a better idea into the individual OEM sales strategies regarding fuel adoption. The largest manufacturers VW, Toyota and Hyundai/Kia are offering a range of vehicles where the diesel models have significant larger engines, are heavier and have larger rated power. Ford vehicles on the other hand are, one average, very similar when comparing diesel and gasoline models; this results in gasoline models that are, on average, more powerful and with higher PTW ratio values than the average diesels models offered. Luxury manufacturers MB and BMW also offer vehicles that are on average very similar in terms of displacement and weight. Chrysler is unique in that it offers heavier diesel vehicles with smaller average diesel engines, resulting in less powerful with lower PTWR diesel vehicles .

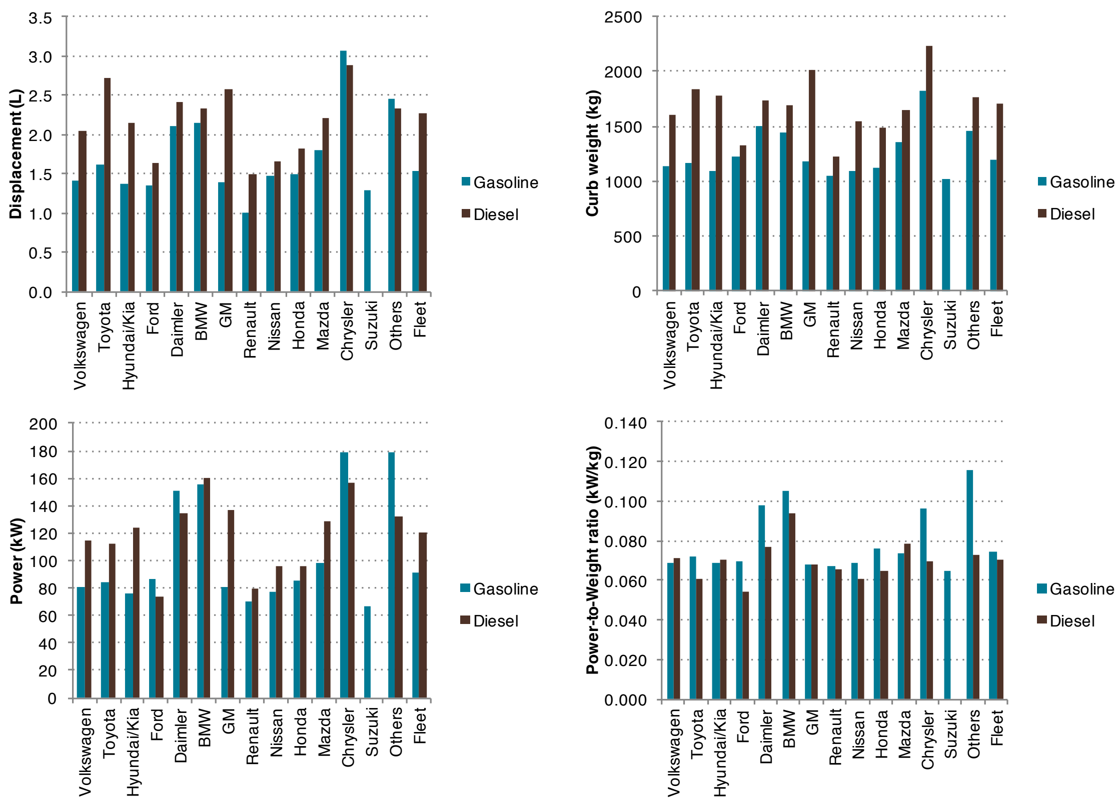

Figure 2-5 Fleet characteristics by fuel type of new South African passenger vehicles – Manufacturers listed by sales ranking from left to right

3. Vehicle Technologies

This section provides an overview of current technology adoption, including fuel type, transmission, and engine technologies that influence vehicle energy consumption.

Fuel Type

Gasoline vehicles are the main consumer choice among South African consumers, with 82.9% of the new vehicle market. Diesel is the second largest fuel option, taking 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 SA in the period studied.

Figure 3-1 shows the fuel type distribution across vehicle segments and for the passenger vehicle fleet as a whole. Gasoline is the dominant technology across all vehicle segments. All top 14 manufacturers produce primarily gasoline engines (Figure 3-2).

Diesel engines offer 20% to 25% reduction in fuel consumption over traditional gasoline multi-point fuel injection (MPFI) engines due to higher compression ratios, reduced pumping losses, and 12% higher energy content per liter of fuel. The challenge for further commercialization is twofold: the complexity and additional cost of advanced exhaust after-treatment technologies that reduce emissions of particulate matter and oxides of nitrogen to levels comparable to those of gasoline engines.

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 4th and 5th in absolute sales, with more than 30% of their vehicles powered by diesel fuel. Among the group of manufacturers studied, Honda sold the least 1% of models as diesel, and Suzuki does not offer diesel vehicles.

Hybrid-gasoline vehicles achieve reduced fuel consumption by incorporating in the drivetrain a battery and an electric motor in addition to an internal combustion (IC) engine. This technology permits the IC engine to shut down when the vehicle is decelerating and is stopped, to recover energy during braking, and to downsize the IC and operate it more efficiently. Depending on the level of complexity, hybrid systems can achieve 15% to 35% reductions in fuel consumption with respect to similar-sized vehicles.

Hybrid sales in South Africa for 2015 are concentrated in three segments, upper medium, luxury and sport. Only 5 manufacturers sold Hybrids in SA: Toyota, BMW, Daimler, Nissan and Honda. Interestingly, almost 60% of those were luxury hybrids. The Toyota Prius is the most popular hybrid in SA.

Electric vehicles (EVs) are also referred to as battery-only electric vehicles (BOEVs). 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. BMW i3 and Nissan Leaf were the only two models sold in 2015.

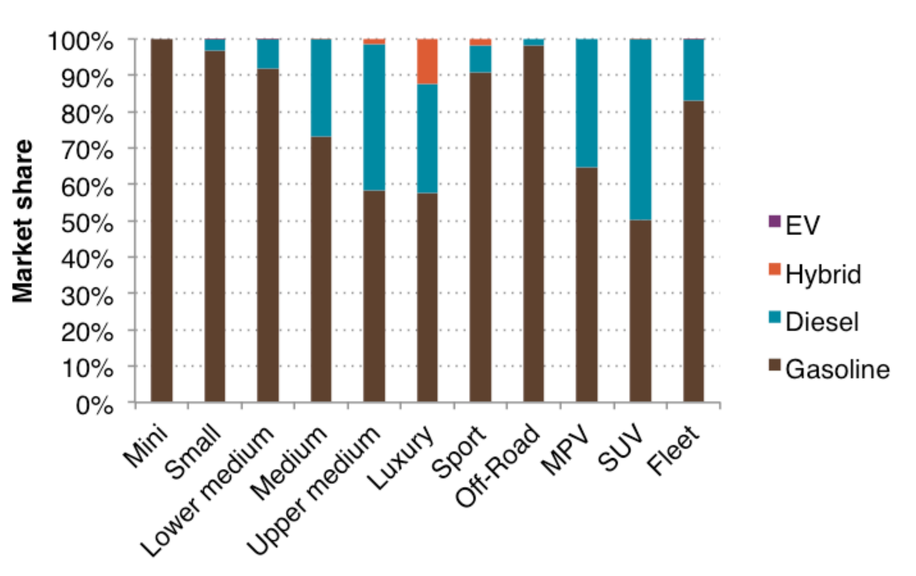

Figure 3-1 Fuel type by segment

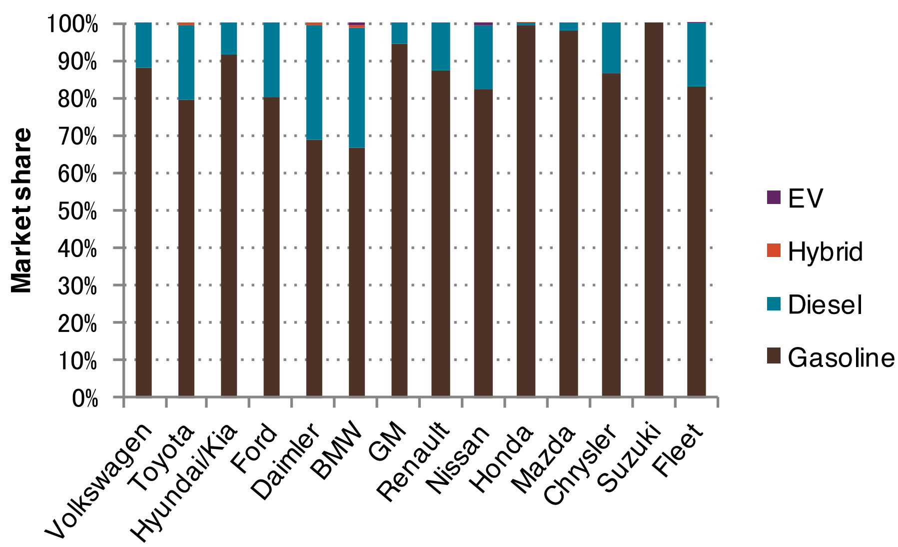

Figure 3-2 Fuel type by manufacturer – listed by sales ranking from left to right

Transmission

Transmission technologies can reduce vehicle fuel consumption and CO_2 emissions in two ways: first, by allowing engine operation on a more efficient region of the engine map and, second, by reducing the mechanical losses within transmissions. Traditionally, manual transmissions have offered better fuel consumption than traditional automatic transmissions (with 4 or 5 speeds) due to lower friction losses. However, new generation of automatic transmissions with higher number of gears, lower friction, better materials and computer-controlled shift points have exceed manual transmission's performance.

New technologies such as dual-clutch transmissions (DCTs) and continually variable transmissions (CVTs) are gaining market share due to the need for lower vehicle energy consumption. DCTs can be defined as manual transmissions with electro-hydraulically operated dual-clutch systems, allowing for faster shifting times and selective automatic or "manual" operation. As opposed to manual, automatic and DCT transmissions, which have a discrete number of gear ratios, CVTs have a theoretically infinite choice of ratios between fixed limits, which allows engines to be further optimized for minimizing energy consumption. CVT technology has been used in lower-horsepower vehicles because of maximum-torque limitations with the most common metal-belt design (NAS 2011). These advanced transmission technologies offer significant benefits in energy consumption compared to traditional manual or automatic technologies. According to the U.S National Academy of Sciences, a 6-speed DCT provides 6% to 9% lower energy consumption than a 4-speed automatic transmission. Note that a traditional 6-speed automatic transmission provides an estimated 3% to 5% benefit. The energy consumption benefit of CVT depends on the application, and is estimated to be 1% to 7% (NAS 2011).

Although sales of vehicles with manual transmissions predominate in South Africa (67%), nearly one-fourth of vehicles use advanced transmissions, DCT & CVT (Fig). Manual transmissions are predominant in the smaller size segments and the off-road and MPV segment. The top four largest manufacturers sell most of their vehicles with manual transmissions (Fig X). GM, Renault, Nissan and Suzuki are also heavy users of such technology.

Advanced DCT and CVT technologies are predominant in the upper medium, luxury and sport segments. German manufacturers Volkswagen and BMW sell the largest numbers of vehicles with DCT technology; for BMW, DCT comprises almost all of their transmission technologies in their vehicles.

Automatic transmissions represent less than 10% of total, and are predominantly sold in the SUV, MPV and off-road segments. Among manufacturers, Toyota and Hyundai/Kia sell are the leaders in automatic transmissions, in absolute numbers. Chrysler and Mazda sold in 2015 the largest share of their models with automatic transmissions.

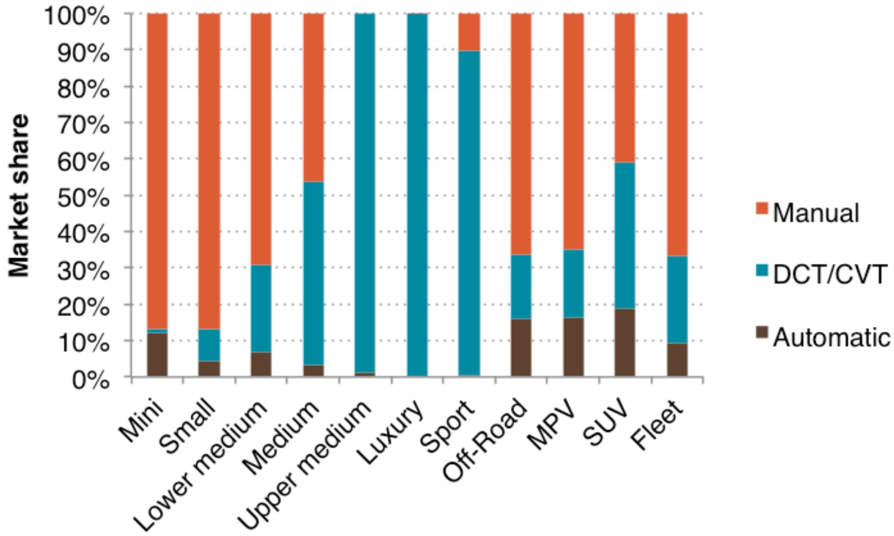

Figure 3-3 Transmission type by segment

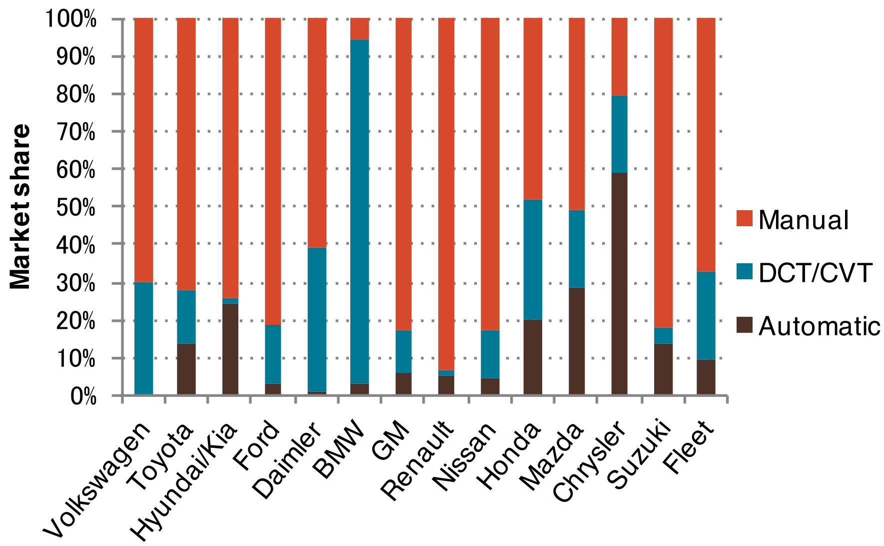

Figure 3-4 Transmission type by manufacturer

Number of Cylinders

Across all vehicle markets, 4-cylinder engines are the most common design in automobile engines with displacements below 2.5 liters. This engine configuration presents the right balance between complexity and performance for the target vehicle segments (small to mid-size sedans, SUVs, and some off-road vehicles). Engines with six and more cylinders are designed to provide a smoother vehicle driving experience, with lower vibration and noise than 4-cylinder engines can provide, and with higher power output. This better overall performance comes at a higher cost, driving their widespread use in large and luxury vehicles, and heavier SUVs and off-road vehicles.

The need to attain better energy consumption has resulted in a recent wave of 3-cylinder engines from a handful of manufacturers in vehicles that typically used 4-cylinder engines, achieving similar or better performance. This practice is known as engine downsizing. Downsizing can also be applied to larger engines, from V-8s to V-6s, and from V-6s to I-4s. In most cases engine downsizing is accompanied with turbocharging and changes to the fuel delivery system.

In South Africa, the biggest market share is of the 4-cyclinder engines with nearly 82% of total market. This is in line with trends across the world where the market is dominated by 4 cylinder engines. 4-cyclinder engines are the dominant technology in all segments, except for luxury. Out of the 13 manufacturers studied in this section, only Renault and Chrysler use other type of engines; Renault focuses on 3-cylinders, and Chrysler is invested in 6 and more cylinder engines.

The second most popular type of engine, with 11% of the market, is the 3-cylinder engine, which have also gained global popularity in the past few years. Due to their light weight, relatively low power output (without turbocharging), 3-yclinder engines are being deployed in mini and smaller sedans, as well as some off-roads and SUVs, although these segments may be paired with turbochargers. Renault and Nissan are the clear market leaders for 3-cylinder vehicle sales; the most popular model is the Renault Clio (0.9 L engine) and the Nissan Datsun Go (1.2 L engine).

6 cylinder engines have 4% of the market, and are mostly placed in luxury vehicles and sports vehicles – vehicles that have a high rated power outputs and are expected to provide a smooth riding experience. BMW and Chrysler sell about the same number of 6-cylider vehicles in South Africa, about 4300 units in 2015.

There is a small percentage of vehicles which have 8 and more cylinders. These vehicles are the high performing luxury, sports cars, and high-end SUVs. Daimler and Chrysler appears to sell a larger fraction of 8-cylinder vehicles than any other manufacturer, but in absolute sales numbers, Toyota is the leader, selling about 1200 units compared to 1030 from MB and 360 from Chrysler.

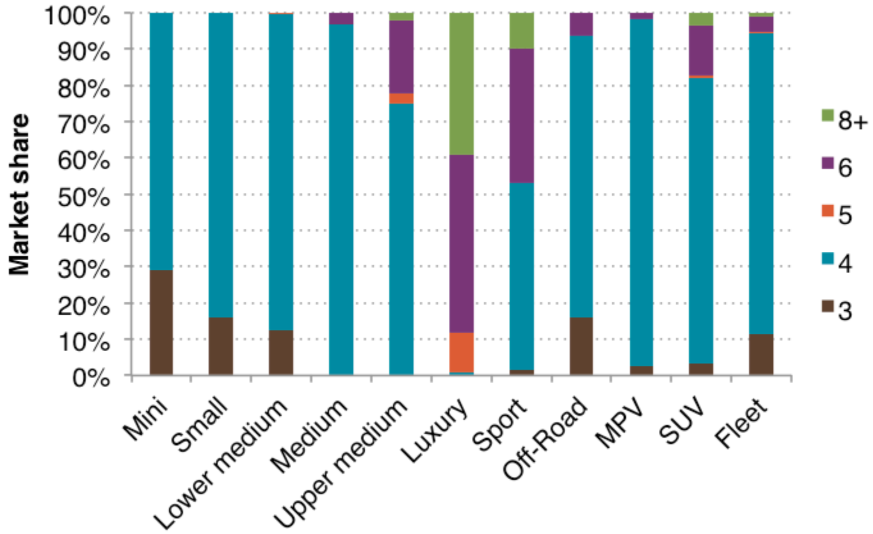

Figure 3-5 Number of cylinders by segment

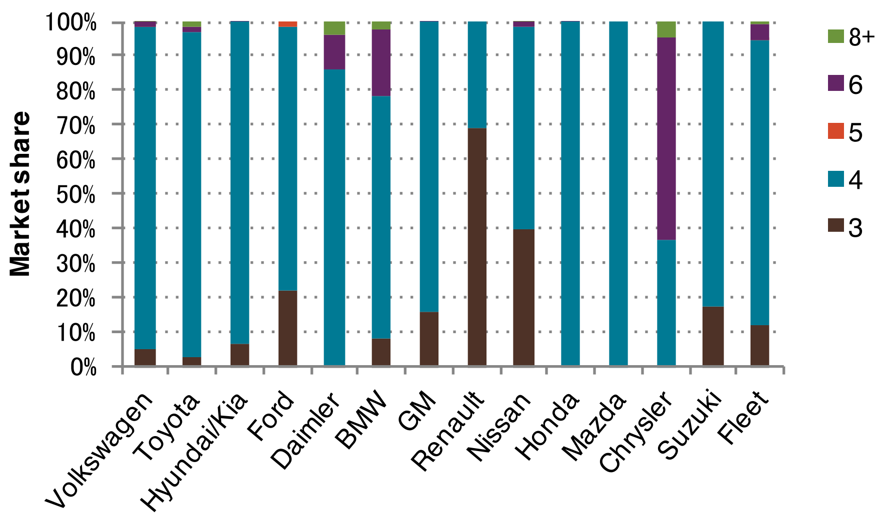

Figure 3-6 Number of cylinders by manufacturer

4. CO_2 Emissions

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC test cycle, was 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. Per vehicle CO2 emission values used in this report was obtained from the National Association of Automobile Manufacturers of South Africa (NAAMSA). The CO_2 data provided by NAAMSA is obtained under chassis testing protocols defined by South African national standard SANS 20101:2006 (SABS, 2009). The methodology used in the estimation of the emission baseline remains the same as previously presented in earlier cases in the report – on a sales-weighted average methodology.

Figure 4-1 presents the average by segment compared to the fleet overall. The smaller vehicle segments are counterweighting the impact of the large sales of SUVs, sports and luxury vehicles. Disaggregating CO_2 emissions by fuel type, gasoline and diesel, for each segment shows that for most segments, diesel emit less CO_2 than the gasoline counterpart; in the SUV segment however, it is the diesel option the one that emits more. Overall the average diesel vehicle in South Africa emits more CO_2, 166 gCO_2/km, than the average gasoline one, 145 gCO_2/km. This can be explained by the fact that most diesels vehicles are sold as SUVs (62%), and these are the heavier and least efficient models of the fleet. Gasoline luxury and sport vehicles are the most inefficient ones, along with MPV and SUV diesel models. Medium size diesel vehicles are among the most efficient models.

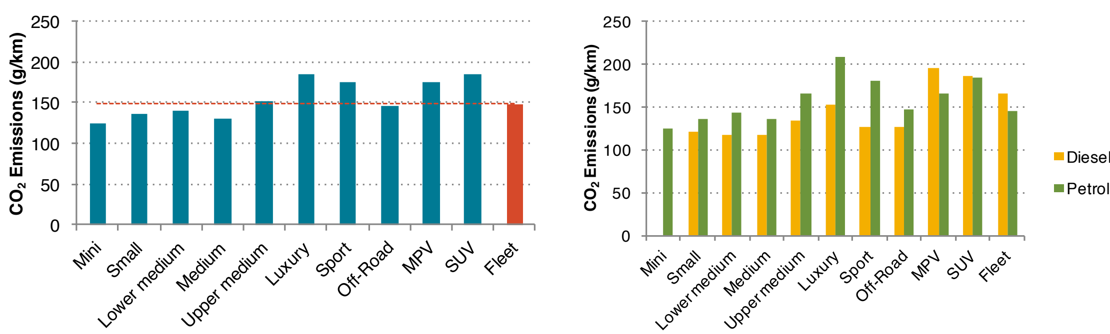

Figure 4-1 Fleet average CO_2 emissions by segment (a) and disaggregated by fuel type (b)

Figure 4-2 presents the manufacturer average CO_2 emissions. 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. Luxury manufacturers Daimler and BMW are 4th an 5th in terms of lowest CO_2 emissions. Chrysler exhibits the highest CO_2 emission values due to their focus on sales of SUVs and MPVs.

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

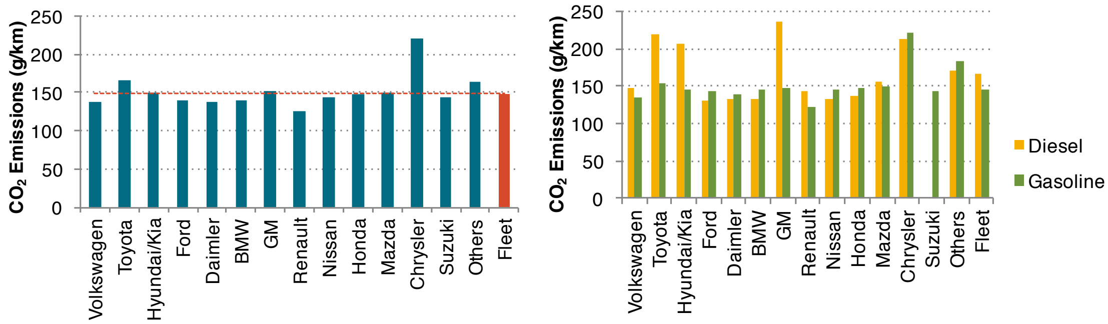

Figure 4-2 Fleet average CO_2 emissions by manufacturer (a) and disaggregated by fuel type (b)

Figure 4-3 illustrates sales weighted average for 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 their market capture. Manufacturers in the lower-left quadrant produce the lightest and most efficient vehicles, with Renault presenting the best overall average fuel consumption. Hyundai, in the upper-left quadrant, produces vehicles that are equivalent in weight, but on average with higher CO_2 emissions. 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 heavier and least efficient vehicles, with Toyota producing least efficient cars on average, while paradoxically close to 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 Suzuki).

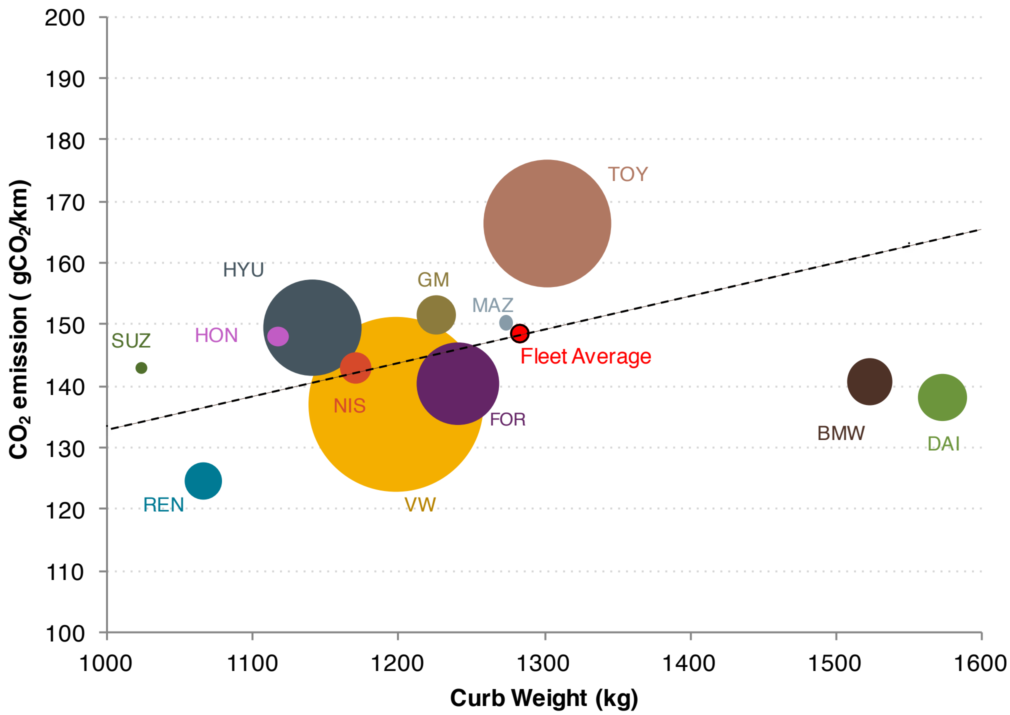

Figure 4-3 Average new vehicle sales-weighted CO_2 emissions by manufacturer (2015). Circle diameter is proportional to sales numbers. Dotted lines correspond to linearization of sales-weighted data

Comparison with international Markets

Table **4-1** puts the South African new passenger car market in comparison with some other key automotive markets worldwide. South Africa is among the top 20 largest vehicle markets in the world, with 0.4 million passenger car sales per year. In relation, the number of new cars sold every year in China is 20.7 million, in the United States 16.7 million, in the European Union 13.7 million, in Japan 3.5 million, and in South Korea 1.3 million.

In terms of average engine displacement (1.7 L) and engine power (97 kW), the market in South Africa is most similar to those in the EU and China. In comparison, average displacement and engine power tends to be significantly higher in the United States, and South Korea. In terms of average vehicle weight (1.3 metric tons), new cars in South Africa are most similar to those sold in the EU and in China. In the United States and South Korea, new cars tend to be heavier. The power-to-weight-ratio for S.A (0.073 kW/kg) is within 10% of the average value in the China, Brazil and the EU.

The average CO_2 emissions of new cars, normalized to the New European Driving Cycle (NEDC) for the South African fleet (148 gCO_2/km) is close to the Brazilian and South Korean average.[2] Only vehicles in China and the United States present higher average

[2] The normalization methodology for comparing average vehicle efficiency and CO_2 emissions across markets and testing methodologies is described at length in the study by Kühlwein, German, and Bandivadekar (2014) on Global CO_2 emission Standards comparison and normalization.

emissions than the South African vehicles. European and Japanese vehicles are the most efficient vehicles principally due to high market adoption of fuel efficient technologies: Japan has the largest hybrid vehicle market in the globe (13%), and Europe presents high adoption rates of conventional technologies such as Start-Stop, gasoline direct injection (GDI), and advanced transmissions. A detailed discussion of fuel efficient technology penetration in Europe can be found in the European vehicle market statistics 2016/17 (ICCT, 2016).

Table 4-1 International market comparison of new passenger car fleet characteristics.[3] Data sources: Posada and Façanha (2015), ICCT (2016), Yang et al. (2017).

Region	South Africa	EU-28	U.S.	China	Japan	Brazil	India	South Korea
Data year	2015	2015	2015	2014	2013	2013	2015	2014
Sales (million)	0.4	13.7	16.7	20.7	3.5	3.0	2.8	1.4
Number of cylinders	3.9	3.9	4.6	---	3.8	4.0	3.6	4.3
Engine displacement (l)	1.7	1.6	2.5	1.7	1.4	1.4	1.3	2.0
Engine power (kW)	97	93	171	93	78	76	59	120
Curb weight (metric tons)	1.3	1.4	1.8	1.4	1.2	1.1	1.1	1.5
Footprint (m^2)	---	4.0	4.6	4.0	3.7	3.7	3.5	4.2
Power-to-weight-ratio (kW/kg)	0.073	0.067	0.093	0.066	0.065	0.067	0.052	0.084
CO_2 emissions - NEDC (g/km)	148	121	185	171	119	151	123	148
Gasoline	83%	43%	96%	98%	86%	6%	47%	51%
Diesel	17%	52%	1%	2%	0%	0%	50%	39%
Hybrid-electric	0.1%	3%	3%	0%	13%	0%	0%	0%
Others (Ethanol, CNG, LPG)	0%	2%	0%	0%	1%	94%	3%	10%
Manual transmission	67%	75%	5%	49%	1%	83%	98%	9%
Automatic transmission	33%	25%	95%	51%	99%	17%	2%	91%

In comparison to other key automotive markets worldwide, the market share of diesel cars in South Africa (17%) is moderate. Only EU, India and South Korea have a significant diesel market share among passenger cars. With respect to hybrid-electric vehicles, Japan is the leader while the United States and Europe stand at only 3% of the new passenger vehicles; as of 2015, the number of hybrid-electric vehicles in South Africa is very small.

In SA, two out of three new passenger cars are equipped with manual transmission, the reminder using automatic and advanced transmissions. The share of automatic or advanced transmission vehicles is therefore higher than the EU average, where manuals are dominant. In the United States, Japan, and South Korea, nearly all new passenger cars are equipped with an automatic or advanced transmission system.

[3] Sales / registration weighted averages; energy consumption data was converted using the methodology described in (Yang 2015).

Comparison with the European Market

The similarities between the South African and the European vehicle markets in terms of vehicle characteristics and technology were presented in the previous sections of this report. This section takes a closer look at South Africa's PC fleet CO_2 emissions compared to Europe's. CO_2 emissions from the overall fleet, by segment and by manufacturer are discussed in this section.

Figure 4-4 shows that South Africa's passenger car fleet average CO_2 emissions stand at 148 g/km, about 21% more than EU's fleet average emissions, 121 g/km. This large difference is highlighted by the fact that SA's fleet is 5% lighter than the European 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 km driven. A comparison between the segments of each market and within the markets show interesting trends.

The segments analyzed here cover only those with more than 5% market share. The most remarkable feature is that regardless of segment, South African vehicles consume significantly more fuel per distance driven than the European models. The comparison for small and medium segments, show that these types of vehicles in South Africa are lighter, between 4% to 8%, but less fuel efficient. For the mini segment the difference in weight is about 1% but the South African mini vehicles are 18% less efficient on average than the European mini models. SUVs are markedly heavier than the EU counterparts, by 10%, and significantly less efficient than European SUVs, by 34%.

The graph also shows that the CO_2 regulatory environment in the EU is generating a market that is more even in terms of CO_2 emissions across a wide variety of 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 corresponding South African minis.

A similar comparison for gasoline only vehicles is shown in figure 4-5. Note that comparing gasoline only vehicles removes the impact of CO_2 emission differences between the fleets due to diesel market uptake. The net effect is small in South Africa, from 148gCO_2/km for the entire fleet to 145gCO_2/km for gasoline vehicles; for Europe, where the diesel penetration stands at 53%, the impact is an increase of 1.7% in fleet average CO_2 emissions. Except for the medium size segment, all other segments of gasoline South African vehicles emit more CO_2 per distance traveled than the corresponding European segments. The largest segments, small and medium, show that these gasoline vehicles in South Africa are lighter, between 3% to 5%, but significantly less fuel efficient than the EU models. For the mini segment the difference in weight is around 2% but the South African mini vehicles are 18% less efficient than the European mini models. SUVs are 14% heavier on average than the EU counterparts, and significantly less efficient than European SUVs, by 29%. The performance of medium sized vehicles, which cover about 7% of the SA market departs from the trend and shows a 6% benefit with respect to the EU segment.

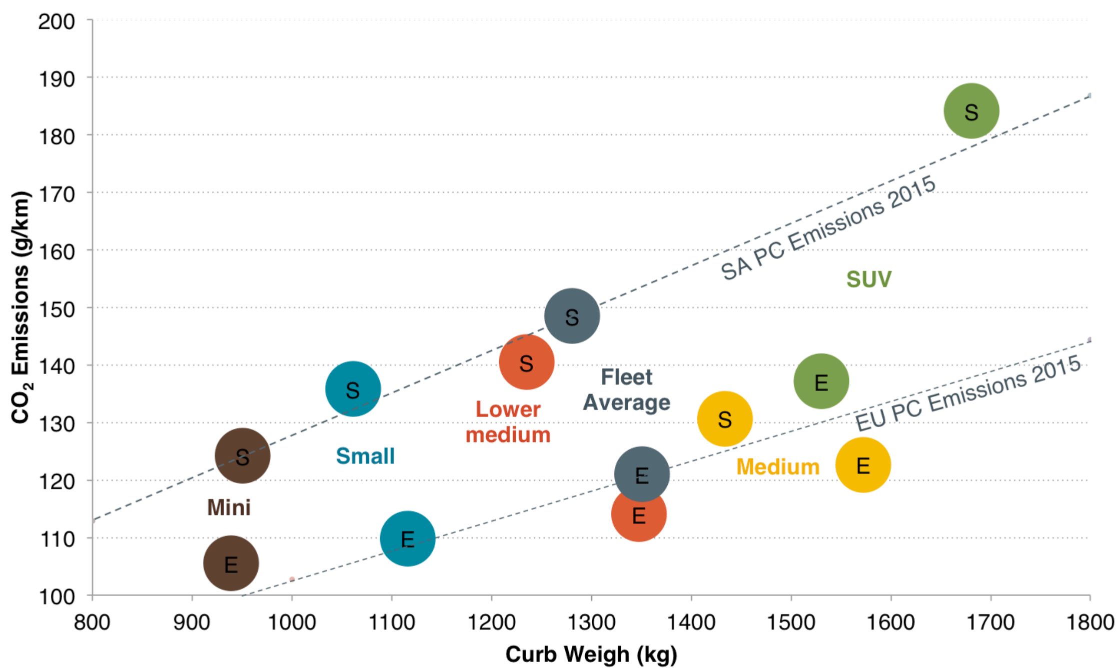

Figure 4-4 Average new vehicle sales-weighted CO_2 emissions as a function of curb weight, by segment - all fuels (2015). Segments are differentiated by color. Internal circle label **S** correspond to South Africa and **E** to Europe**.** Dotted lines correspond to linearization of sales weighted data for each market.

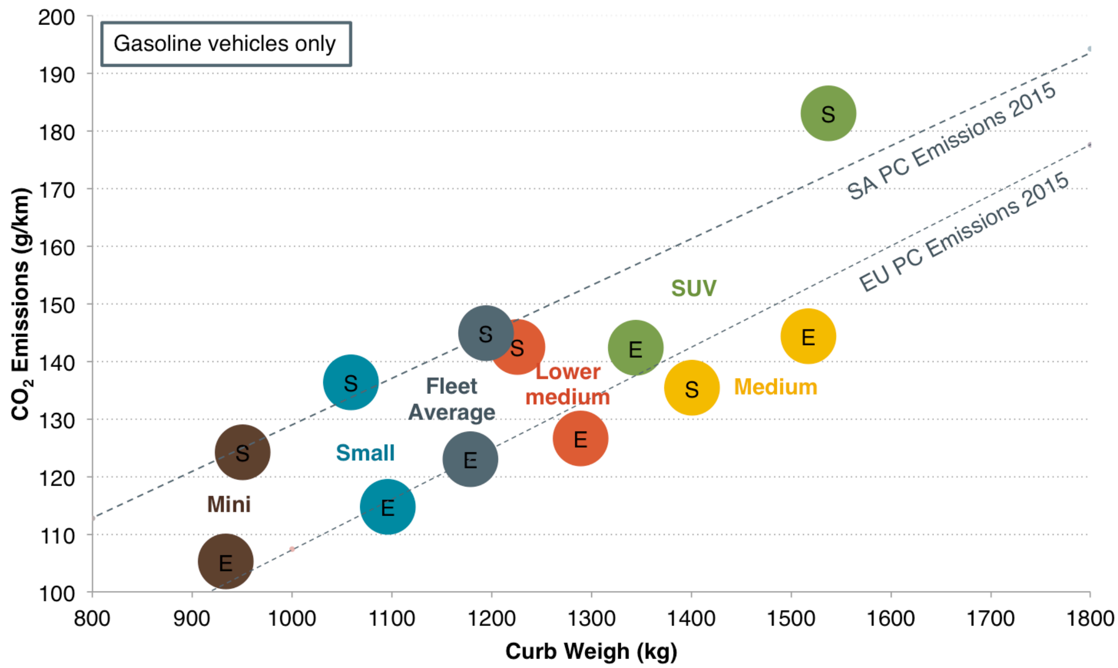

Figure 4-5 Average new vehicle sales-weighted CO_2 emissions as a function of curb weight, by segment - gasoline vehicles only (2015). Segments are differentiated by color. Internal circle label S correspond to South Africa and E to Europe. Dotted lines correspond to linearization of sales weighted data for each market, gasoline vehicles only.

The manufacturer average CO_2 performance and average weight is presented in Figure 4-6 for a selected set of manufacturers that offer models in both markets. The most salient feature is that for every manufacturer shown, the European models emit less CO_2 than the South African models. By contrast South African models are lighter on average than European ones, except for Toyota, which is significantly heavier. The best performer in SA, Renault, is 12% lighter but emits 15% more CO_2 than their European average models. South African market leader VW presents similar behavior, being 13% lighter but emitting 14% more CO_2 on average than the European models. The manufacturer that presents the biggest contrast in terms of average CO_2 emissions is Toyota with 43% more than the European average values, 166 gCO_2/km in SA vs. 117 gCO_2/km in the EU; the average weight in Toyota-SA is higher than in Europe by 8%. Attention should be drawn to the fact that luxury manufacturers BMW and Daimler exhibit the smallest average CO_2 difference between markets, with 8% for BMW and 9% for Daimler.

Figure 4-7 presents a comparison between each manufacturer's fleet for gasoline vehicles. This comparison removes the distortion caused by different diesel market shares. Renault is on average 4% lighter but shows 5% higher CO_2 emissions on average. Volkswagen presents a similar weight difference, 5% lighter in SA, but follows the trend of higher CO_2 emissions in South Africa, 15% more than in EU. For gasoline vehicles, Toyota is heavier on average in SA than in EU, and the CO_2 emissions gap is slightly reduced to 35%, by far the largest among all South African manufacturers. It is also remarkable that luxury manufacturers BMW and Daimler are the only gasoline vehicle manufacturers that present lower CO_2 emissions in SA than in the EU counterparts, while exhibiting the smallest average CO_2 difference between gasoline vehicle markets, with 1% for BMW and 3% for MB.

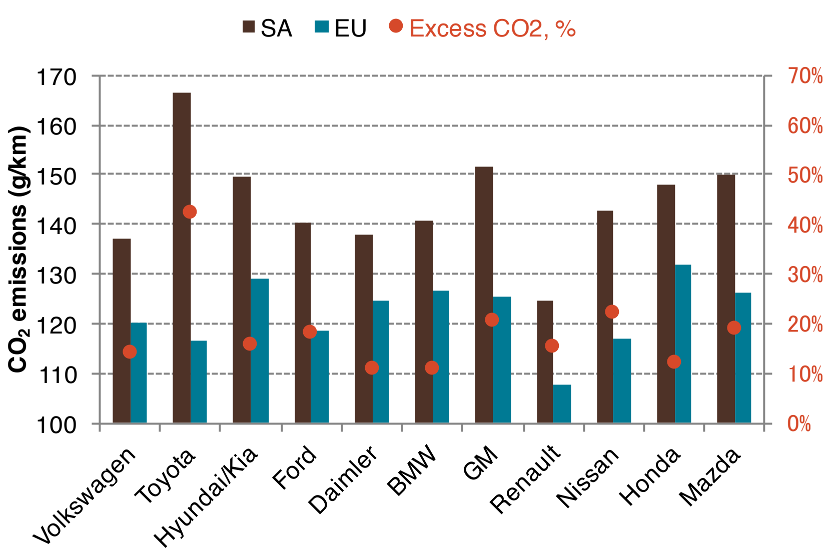

Figure 4-6 Comparison of average new vehicle sales-weighted CO_2 emissions by selected manufacturers in South Africa and Europe (2015). Orange dot markers show the excess CO_2 emissions of South African fleets compared to European fleets.

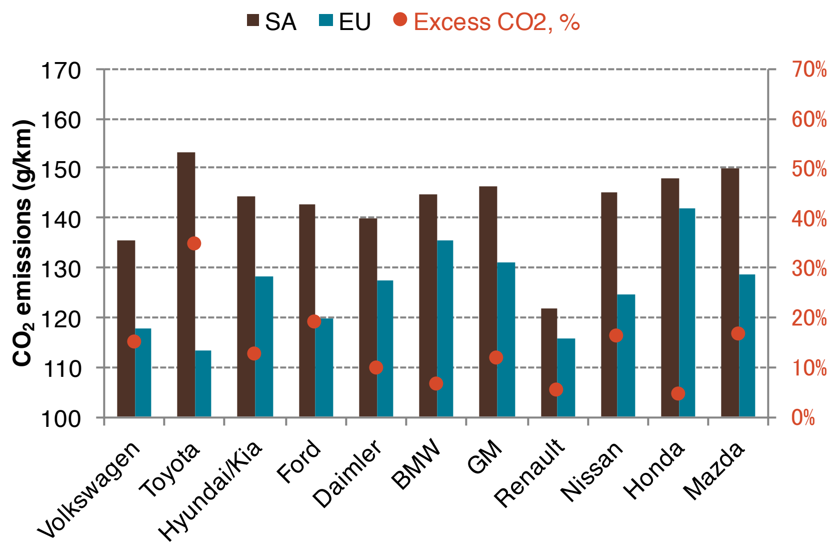

Figure 4-7 Comparison of average new vehicle sales-weighted CO_2 emissions by selected manufacturers in South Africa and Europe, gasoline vehicles only (2015). Orange dot markers show the excess CO_2 emissions of South African fleets compared to European fleets (right axis).

Discussion on CO_2 performance

What is the reason behind such large differences in CO_2 performance between South African and European vehicles? To answer this question, the study looks at vehicle characteristic distributions for each market and selected manufacturers aiming to understand relative differences in terms of engine size, weight, rated power and power to weight ratios. The second part looks at specific models with the largest sales values that are common to both SA and EU markets, and compares in detail de level of technologies present in those vehicles, including engine, transmission and other technologies that directly affect fuel efficiency and CO_2 emissions.

Vehicle characteristic distributions

This section compares vehicle characteristics between both markets and looks at individual manufacturers trying shed some light into the CO_2 gap between markets. The review focuses on 3 manufacturers, Renault (best performer common to both markets), Toyota (worst performer in South Africa), and Ford (average performer in both markets).

Figure 4-8 shows the CO_2 market distribution for South Africa and Europe. SA passenger vehicle market tends to be biased towards higher CO_2 emitting models. The European market exhibits a significant presence of vehicles with emissions below 95 g/km (the 2020/2021 target), which is almost inexistent in South Africa. Highly efficient vehicles, mainly hybrids, are also notoriously underrepresented in SA. There is also a constant market difference of about 15% between EU and SA for the market sector covering 90-120 g/km.

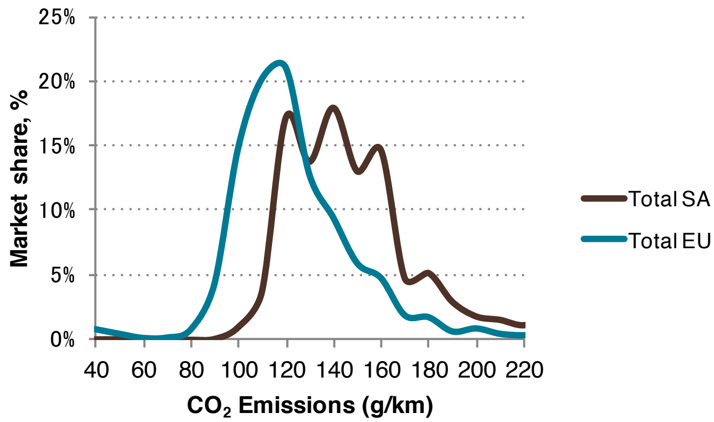

Figure 4-8 CO_2 emission distribution for South African and European passenger vehicles. Area under each curve adds up to 100%**.**

Fig 4-7 presents a closer look at vehicle characteristics distributions for both markets. Engine size (in liters) is almost identical and tri-modal for both markets, with strong sales of engine models 1.6, 2.0 and 3.0 liters. Curb weight on the other hand shows a strong differential bias for lighter models in South Africa. More than 50% of new vehicles have weights below 1200 kg in South Africa, while that share is reached around 1300 kg in Europe. Rated power numbers are similarly distributed, with a tendency for higher market share of models with 70 kW engines in SA. Power to weight ratio numbers follow a very similar trend but with a small bias towards higher PTWR vehicles in South Africa.

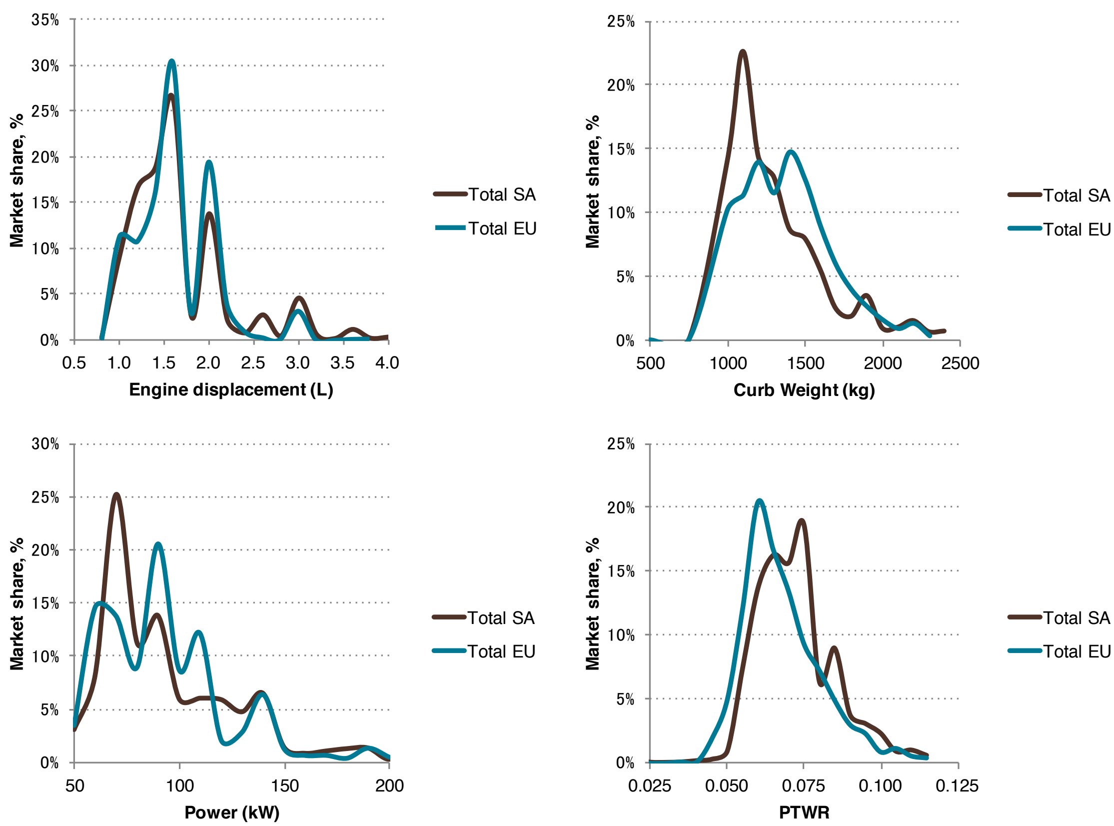

Figure 4-9 Market characteristics of new passenger vehicles in South Africa and Europe. Area under each curve adds up to 100%**.**

The South African new passenger vehicle market is on average 5% lighter and has 7% higher engine rated power. The differences in weight and power are not fully reflected in terms of CO_2 emission reductions or fuel economy, which is 21% worst in SA than in the EU. Literature written on the effect of vehicle mass and power on fuel consumption, shows that a 20% reduction in mass alone would bring about 7% reduction in fuel consumption under the same powertrain technology and testing conditions; a combined 20% reduction in both mass and power brings about 12-14% fuel consumption reductions (US NRC, 2011). Based on these rules of thumb, a 5% weight benefit for SA vehicles would roughly imply a 1.7% benefit in CO_2 emissions; 7% higher power for SA vehicles would imply a 1.7-2.4 % increase in CO_2 emissions; this will result in a combined CO_2 penalty derived from mass and power differences of around one to two percent. This means that 1-2% out of the 21% CO_2 emissions difference can be attributed to vehicle characteristics, mainly heavier vehicles in South Africa. The primary potential reason for a 20% plus 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.

Individual manufacturer's performance

A closer look at three individual manufacturers comparing their CO_2 emission profiles in both markets is presented in Figure 4-10. Renault, which is the best performer in both markets, has similar CO_2 emission distributions, but with a small bias for higher emissions in South Africa; its market below 100 gCO_2/km is almost null in South Africa. Toyota presents the largest divergence between markets: 75% of their models are sold below 120 gCO_2/km in Europe, while that same emission rate is only present in 7% of their best performing models in South Africa. Ford exhibits a more evenly distributed market share between 90-150 gCO_2/km models, but the SA market shows a strong peak at 160 gCO_2/km, which is inexistent in EU.

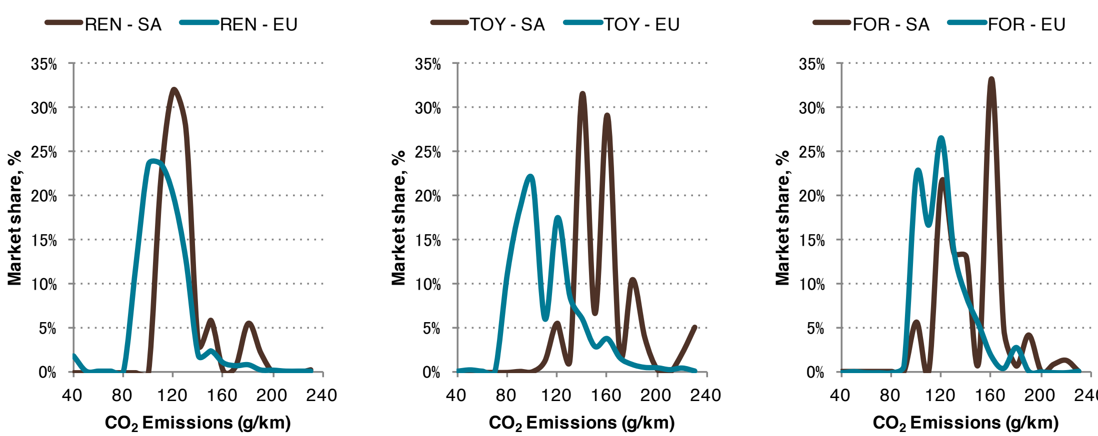

Figure 4-10 CO_2 emission distributions for Renault (REN), Toyota (TOY) and Ford (FOR) in South Africa (SA) and European Union (EU)

The engine size distribution shows various levels of market differences for both regions (Fig 4-11). For Renault, the engine size distribution of SA models shows a bimodal distribution with a maximum for smaller engines, 1.0 L followed by 1.6 L engines; the EU models also show a bimodal distribution but in the opposite direction, with maximum market shares for engine sizes around 1.6 L. This contrasts with CO_2 profiles (Fig 4-10) that suggest that Renault's smaller engines in SA are emitting at a rate similar to their much larger EU engines. For Toyota, the most remarkable market characteristic in terms of engine size is that the market is more evenly distributed in EU, while the SA market is heavily focused on 1.6 L engines and 3.0 L engines; the 3.0 L engines are deployed mainly in popular SUVs such as the Toyota Fortuner and Prado which have average CO_2 emissions around 235 g/km, which coincides with their spike on the far right side of the CO_2 distribution for TOY-SA in Figure 4-10. Ford vehicles share similar engine sizes as well as market shares for each size; the most remarkable difference comes from the 2.0 L size, which shows an important share in Europe and very small share in SA. However, those large engines are not responsible for the CO_2 spike located at the 160g/km bin in Figure 4-10. A look at the underlying data shows that that comes mainly from vehicles with engine sizes 1.4-1.6 L.

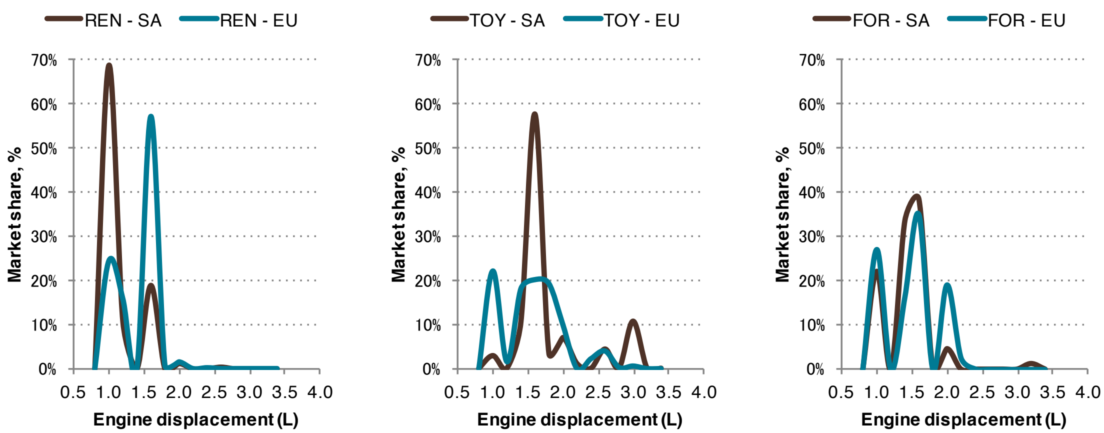

Figure 4-11 Engine displacement distributions for Renault (REN), Toyota (TOY) and Ford (FOR) in South Africa (SA) and European Union (EU)

Figure 4-12 shows the differences between EU and SA market distribution by vehicle curb weight for the three selected manufacturers. For Renault, both markets are focused on lighter vehicle offerings, although the South African is markedly biased towards lighter models, and the European market is more evenly distributed. Toyota's market shows different vehicle weight distributions, expressed in SA's high sales of mid-weight vehicles around 1400 kg and the second spike around 1900 kg, both of which are completely absent in Europe. Ford's market is very similar, with 50% of cumulative sales located at 1200 kg for SA models and 1300 kg for EU models. Renault's 12% and Ford's 7% average lighter models do not explain South African fleets that show 15% and 8%, respectively, higher CO_2 than their European fleets. Toyota's 8% higher average weight in SA would only explain around 3% of the 43% excess CO_2 emissions differential with their European fleet.

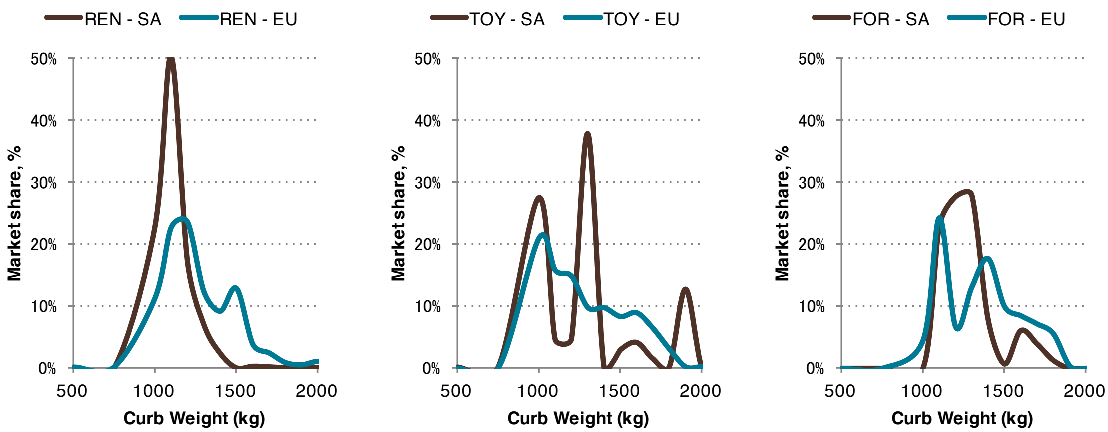

Figure 4-12 Curb weight distributions for Renault (REN), Toyota (TOY) and Ford (FOR) in South Africa (SA) and European Union (EU)

Vehicle rated power market distributions among the three selected manufacturers show some level of similarity as observed for the overall fleets (Figure 4-13). Renault shares very similar average power values between both markets, around 73 hp, and shows similar uptakes of low power vehicles for the 70-80 kW bracket, but in the EU, there is a prominent spike around 90 kW that is not present in SA. Toyota's market distribution in South Africa is shifted by 10 kW higher with respect to their European market; in general Toyota SA shows a profile leaning towards higher rated power values. For Toyota, these market differences are also evident while looking at the average value, which is significantly higher in South Africa, 90 kW, compared to the lower rated power of Europe, 75 kW. Ford's markets appear more evenly distributed compared to the other two manufacturers, and presents average rated power of 84 kW in SA and 86 kW in Europe. The underlying data shows that there is a wider product offering in EU than in SA for vehicles below 130 kW; the share of higher powered vehicles is very similar in both markets for Ford. Thus, very low average power differences between SA and EU vehicles sold by Renault and Ford can't explain the large CO_2 differences between their SA and EU fleets. Toyota's large share of powerful SUVs in SA drive rated power up by 20%, which helps explain about 6% of the 43% excess CO_2 emissions difference with the EU fleet.

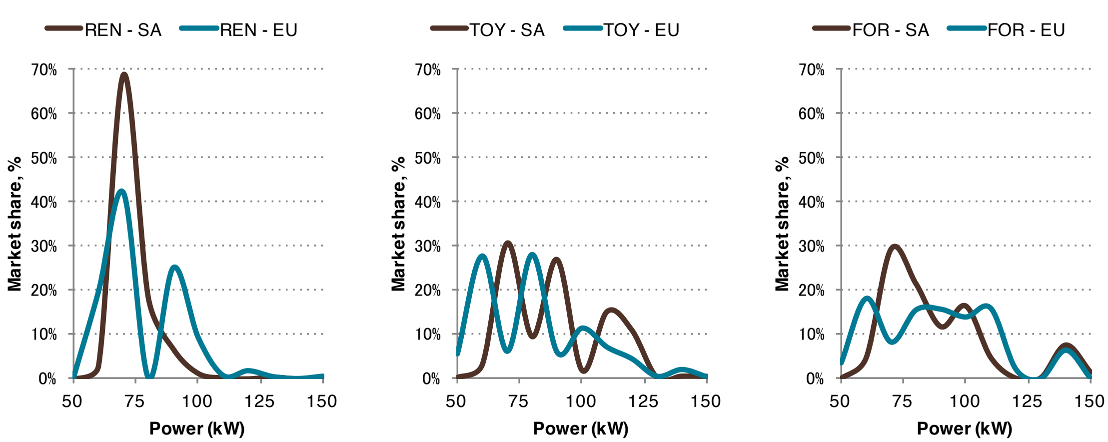

Figure 4-13 Rated power distributions for Renault (REN), Toyota (TOY) and Ford (FOR) in South Africa (SA) and European Union (EU)

Figure 4-14 shows power to weight ratio distributions for Renault, Toyota, and Ford in South African and European markets. There is a striking contrast between the relative markets distributions for Renault and Toyota when compared against Ford. Renault's and Toyota's markets lean towards vehicles with higher PTWR values in South Africa, while Ford's market distribution is very similar for both regions. Renault's PTWR average value in SA, 0.067 kW/kg, contrasts with the EU value, 0.060 kW/kg. For Toyota, the average PTWR value in SA is 0.070 kW/kg, higher than the 0.062 kW/kg average in Europe. Ford's average PTWR values are very similar, 0.067 kW/kg in Europe and 0.064 kW/kg in SA.

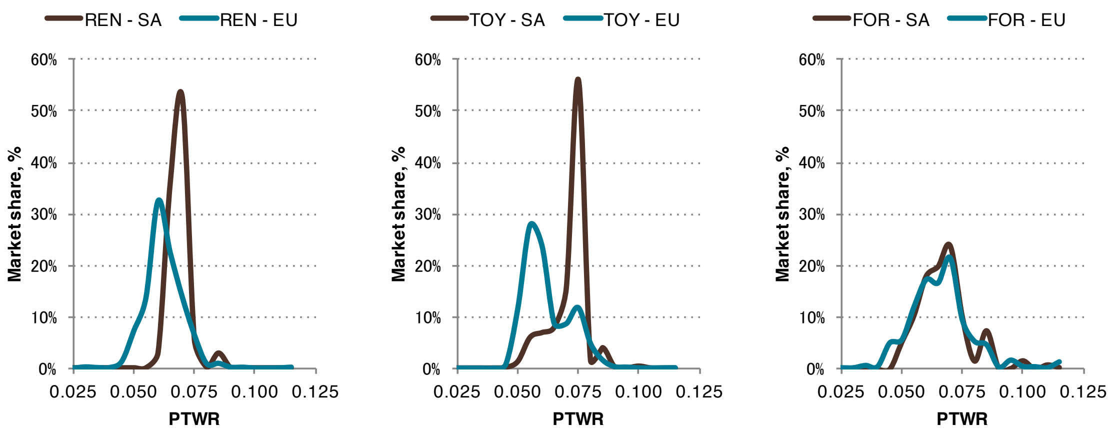

Figure 4-14 Power to Weight ratio distributions for Renault (REN), Toyota (TOY) and Ford (FOR) in South Africa (SA) and European Union (EU)

Vehicle comparisons

As vehicle fleet characteristics analysis is limited to properly explain the large efficiency difference between South African and European fleets for each manufacturer, a closer look by model is carried out in this section. Figure 4-13 shows selected passenger vehicle models sold in both, South African and European markets. Six vehicle models were selected as representative of the most popular segments, lower-medium and SUV.

For the lower-medium vehicle segment, the Renault Sandero 0.9 L 3-cylinder manual transmission was chosen for the comparison, as it is the top-selling model for Renault in South Africa (36% of Renault's sales) and the top selling version for Renault Sandero in the EU (the second most popular is the Sandero Diesel 1.5 L). In Europe, the Renault Sandero 0.9 L is not among their top selling cars but is available and fairly popular (about 57,000 units sold per year). Both models share some vehicle characteristics in terms of engine size and rated power (66 kW), and very similar curb weight (4.6% heavier in Europe), but CO_2 emissions are higher in SA, 119 gCO_2/km compared to 112 gCO_2/km for the EU model, a 6% difference. The most popular lower-medium segment vehicle, the Toyota Corolla, shows a similar pattern of higher CO_2 emissions for the SA model, 13% more than the European one, with similar vehicle characteristics. A review of available technology on this basic model does not reveal a reason for the difference in performance.

A review of two SUVs, the RAV4, which is the most sold Toyota SUV in South Africa and available in Europe, and the EcoSport, the most popular small SUV in South Africa, shows the same behavior: higher CO_2 emissions from South African models, 7.8% and 3.3% respectively, and very similar vehicle characteristics. However, only the European Ford EcoSport presents a technology differential that helps explaining the benefit in efficiency: a manual transmission with 6-gear ratios vs. 5-gear ratios on the South African, which would provide an estimated benefit around one percent.[4]

Table 4-2 Comparison of vehicle models sold in South African and European markets

Vehicle characteristic	Units	Renault Sandero		Toyota Corolla		Toyota RAV4		Ford EcoSport	
Segment		Lower-medium		Lower-medium		SUV		SUV	
Region		**SA**	**EU**	**SA**	**EU**	**SA**	**EU**	**SA**	**EU**
Emissions	gCO_2/km	119	112	157	139	179	166	154	149
Engine size	L	0.9	0.9	1.6	1.6	2.0	2.0	1.5	1.5
No Cylinders	-	3	3	4	4	4	4	4	4
Weight	Kg	1023	1075	1255	1280	1485	1565	1228	1270
Rated power	kW	66	66	90	97	107	111	82	82
Transmission	-	M-5	M -5	M -6	M -6	M-6	M-6	M-5	M-6
Turbo	-	Yes	Yes	No	No	No	No	No	No
VVT	-	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Notes: M-5 and M-6 mean manual transmission with 5 or 6 gear ratios, respectively. VVT means variable valve timing. Data for EU models from ICCT's European Vehicle database (2016)

This sample of high sales models from Renault, Toyota and Ford in the largest market segments show that the SA models emit more CO_2 than the European models, by 3% to 13%. Vehicle curb weight is similar but typically higher in European models.

In conclusion, differences at market preferences higher power and PTWR vehicles in South Africa and individual model level performance differences partially explain the large differences in fleet average CO_2 emissions between the two markets. A detailed technology analysis, looking more closely at other fuel-efficient technology penetration (e.g., gasoline direct injection, turbocharging, electric accessories, dual clutch transmissions, and others) would be required to explain the 20% higher emissions from the South African fleet of 2015 compared to the European passenger vehicle fleet.

[4] These benefit applies under U.S. testing conditions and are presented here as an indication of the benefits of 6-speed transmissions compared to 5-speed transmissions. Some differences are expected when vehicles are tested under the European protocol, which is followed by the South African regulatory framework. National Research Council. 2015. *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*. Washington, DC: The National Academies Press. doi:https://doi.org/10.17226/21744.

5. Conclusions and Outlook

The South African new passenger vehicle fleet is the largest in the African continent and the 18th largest globally. South African manufacturers sold more than 412 thousand new vehicles in 2015, and exported more than 333 thousand units in that year. The two top manufacturers are Volkswagen and Toyota.

The South African market aligns in terms of market composition with most global markets: a contrasting combination of large shares of small vehicles and SUVs. Most vehicles sold in South Africa in 2015 are small and lower medium sized vehicles, such as VW Polo and Toyota Corolla; the SUV market size is about 21%.

With respect to fuel use, about 17% of all passenger vehicles in SA are sold with a diesel engine. Sales of diesel vehicles are heavily focused on the SUV segment. VW and Toyota are the highest sellers of diesel vehicles in absolute terms; Daimler and BMW have the highest share of diesel vehicles sales compared to all other manufacturers.

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC test cycle, was 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 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 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 21% more than EU's fleet average emissions, 121 g/km. This large difference is highlighted by the fact that SA's fleet is 5% lighter than the European fleet. The lower efficiency of the average SA vehicles is also evident when comparing the fleets by segment, 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.

In a next step, specific potential policy measures will then be assessed and discussed in more detail, with the aim of summarizing the results of this policy assessment in a follow-up publication. Potential national policy measures include new vehicle CO_2 emission standards, updating current fiscal measures linked to vehicle CO_2 emissions, and updating the current fuel economy and CO_2 label program.

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