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TECHNOLOGY AND POLICY DRIVERS OF THE FUEL ECONOMY OF NEW LIGHT-DUTY VEHICLES

Comparative analysis across selected automotive markets

Working Paper 12

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Executive summary

This report investigates the development of fuel consumption and other light-duty vehicle (LDV) characteristics (vehicle dimensions, weight, and technical parameters such as fuel type, engine power and displacement) for new vehicle registrations from 2005 to 2013 for more than 20 countries. This analysis provides insights on the drivers that influenced this evolution, accounting in particular for the influence of the policy context (e.g. the presence of fuel economy regulations, vehicle and fuel taxation schemes) and average national income level.

Key findings

The combined adoption of regulatory instruments, such as fuel economy standards, and fiscal incentives, such as vehicle taxes differentiated on the basis of the emissions of CO_2 per km, led to the highest energy savings from LDVs.

Fuel economy standards guaranteed effective improvements of fuel economy. Stringent targets led to the prioritisation of fuel economy improvements over other vehicle characteristics (such as weight and size) by original equipment manufacturers (OEMs) and consumers.

Differentiated vehicle taxation was effective even when not coupled with fuel economy standards, especially in markets with lower purchasing power due to low average income levels (the case of South Africa is especially interesting in this respect).

Fuel economy improvements are variable across countries: This reflects an uneven diffusion of fuel economy regulations

The visualisation of new vehicle fuel economy (using units of fuel consumption, litres of gasoline equivalent per 100 kilometres, or Lge/100 km) by segment, as a function of vehicle weight and footprint provides a good summary of these effects. Two main patterns can be identified:

- In some countries (such as France, Figure 1), the average fuel economy of LDVs improved significantly (in the range of 15% to more than 25%) between the years 2005 and 2013.

  Fuel consumption by segment as a function of vehicle empty weight and footprint also showed strong improvement over time, with little change in these attributes (vehicles got only slightly heavier and slightly larger).

  This pattern was typical in developed country markets with relatively high per capita income which:

  A. have stringent fuel economy regulations in place
  B. provide monetary incentives to buy fuel-efficient vehicles in the form of feebate schemes or vehicle taxation based on CO_2 emissions per km
  C. impose high taxes on automotive fuels.

  The combination of these measures has effectively resulted in consumers choosing more fuel-efficient vehicles in a given size class.

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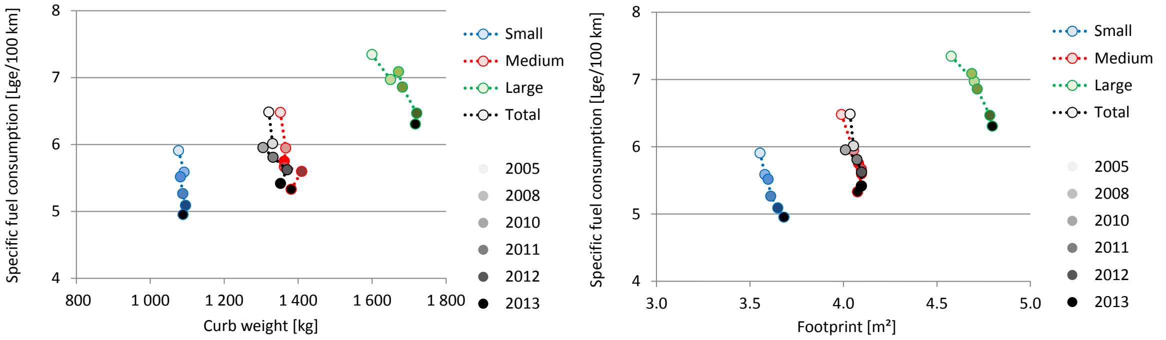
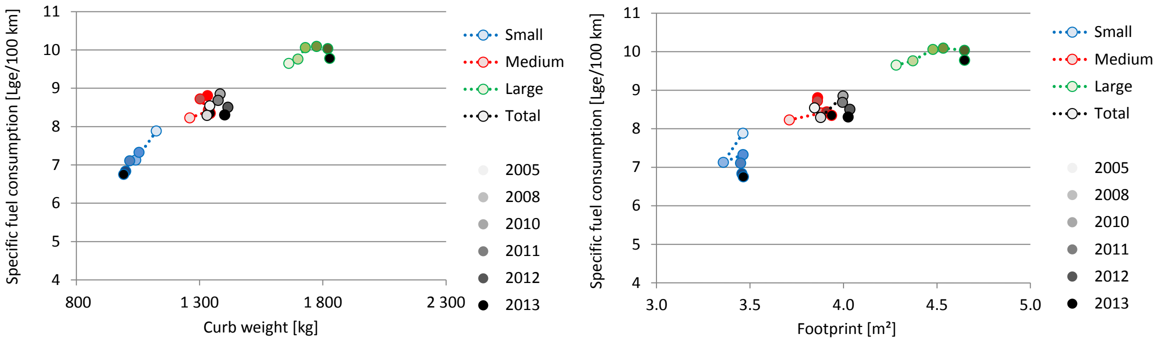
Figure 1 • General patterns of new LDV fuel economy by segment as a function of vehicle empty weight and footprint: France, Chile and Indonesia, 2005-13

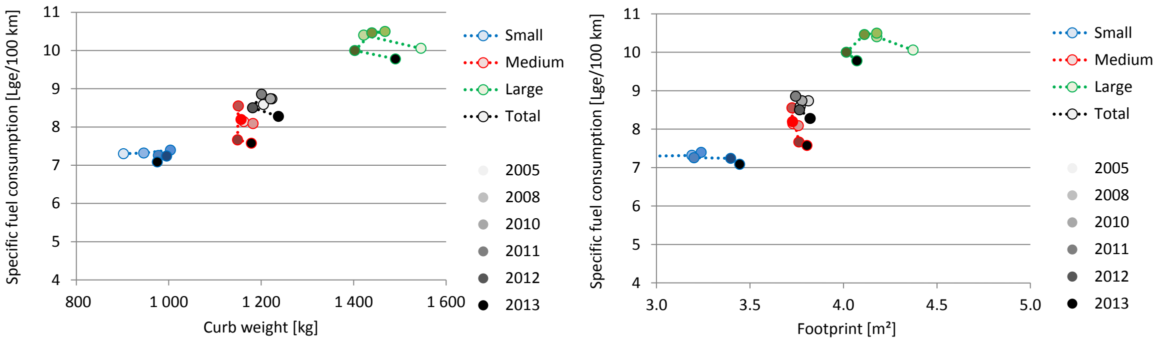
France



Chile



Indonesia



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

- At the other extreme (Chile[1] and Indonesia are shown in Figure 1 to illustrate this), fuel economy remained almost constant between 2005 and 2013.

  Vehicle empty weight and footprint also stagnated or increased slightly in the same time period (in Chile, increases in weight and footprint for large LDVs were compensated by reductions in these same attributes in the small segment).

  Fuel consumption by segment as a function of vehicle empty weight and footprint did not follow a clear trend and moved mainly horizontally, rather than vertically as in the case of France.

  This pattern can be observed especially in countries which:

  A. had no dedicated fuel economy regulations in place

[1] Chile introduced in 2015 a differentiated taxation scheme for new vehicle registrations. The trends identified in the example used here pre-date this policy change. As discussed in the report, differentiated vehicle taxation is expected to be effective to stimulate fuel economy improvements in the Chilean LDV market.

B. provided only small incentives to buy more fuel-efficient vehicles

C. imposed only moderate taxes on petroleum fuels.

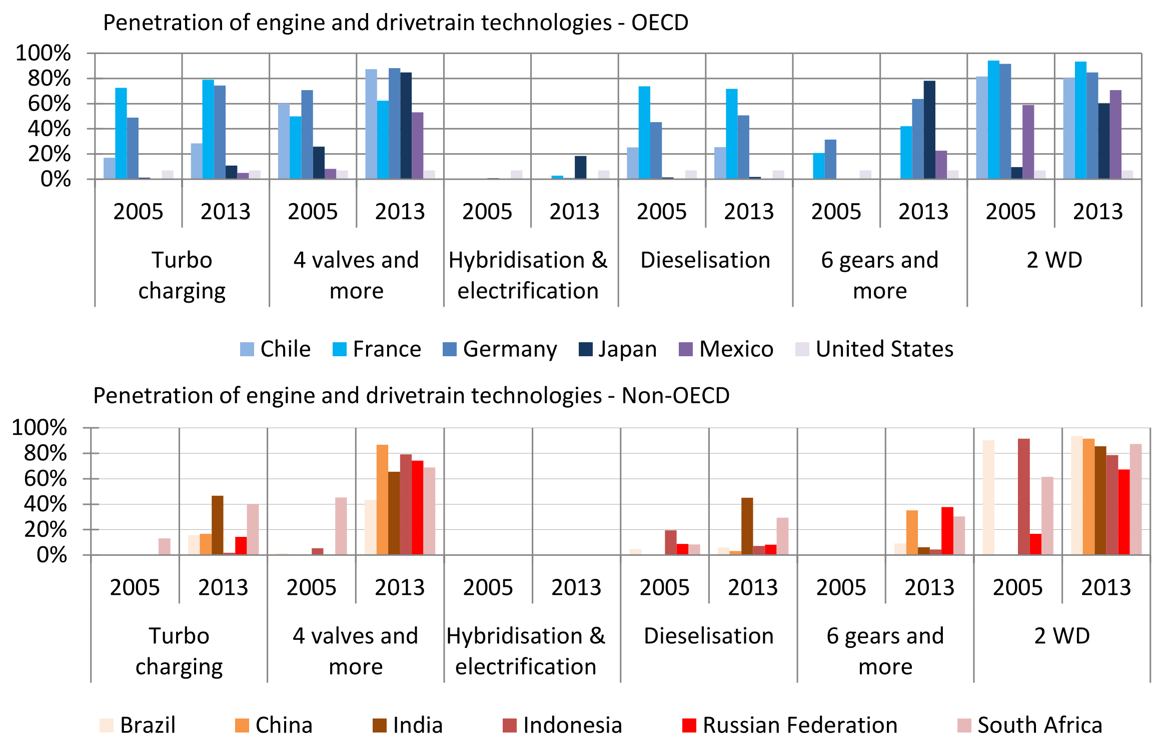
This pattern also tends to be more prevalent in economies with per capita incomes below the Organisation of Economic Co-operation and Development (OECD) average (regulatory pressure tended to be lower in these countries).

Most of the fuel economy patterns of new vehicle registrations in the countries analysed here lie between those represented in Figure 1 by France on the one hand, and by Chile/Indonesia on the other. The evolution of vehicle characteristics, as well as the adoption of efficient vehicle technologies, determines the trends in fuel economy, weight and footprint shown in these plots.

Technology deployment is also unevenly distributed

The adoption of vehicle efficiency technologies such as hybrid powertrains, turbocharged engines and transmission systems with more than five gears is significantly higher in OECD countries (Figure 2) that have established fuel economy standards and where such technologies were feasible due to high consumer purchasing power.

Figure 2 • Penetration of efficient engine and drivetrain technologies of new LDV registrations for selected OECD and non-OECD countries, 2013



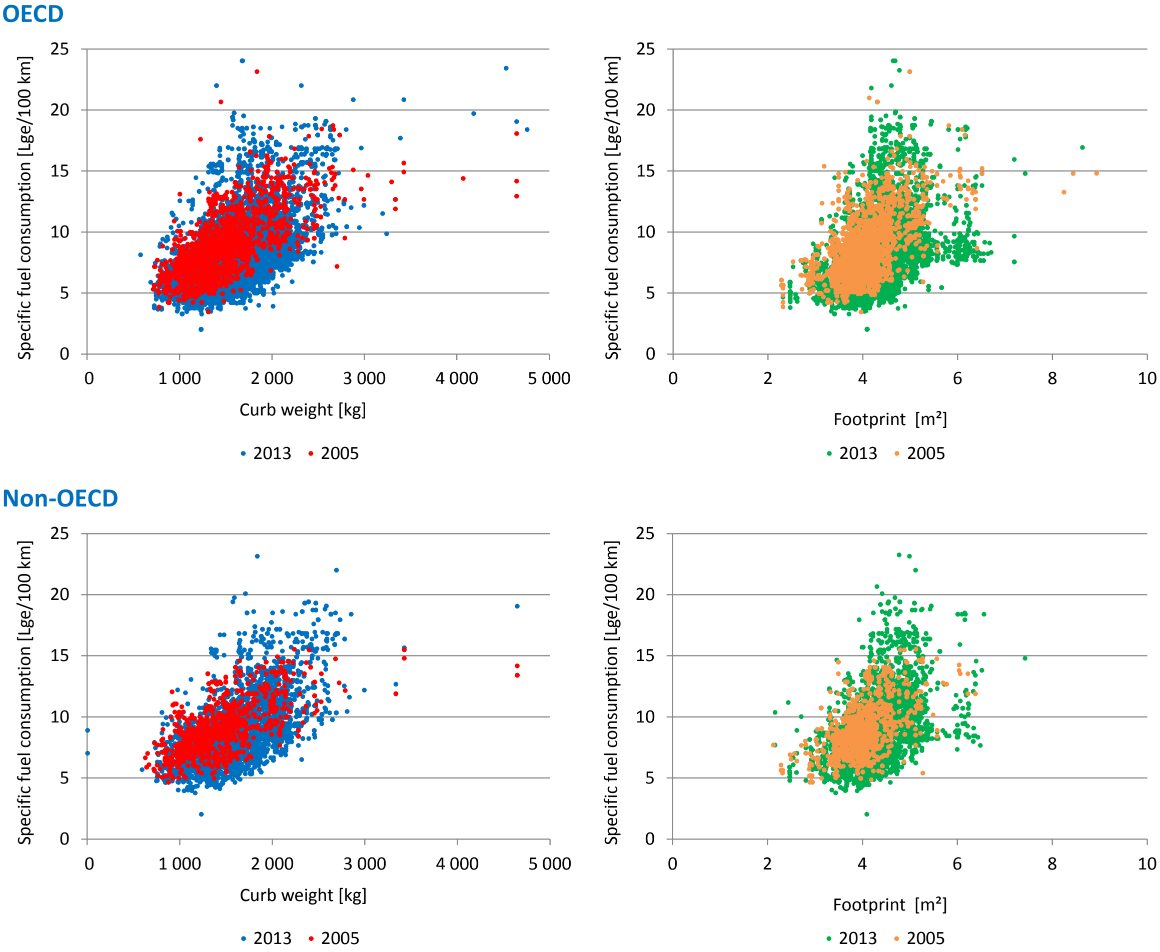
Note: Chinese data for 2005 are not available.

Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market trends in developing economies are towards larger, heavier LDVs

Although most new LDVs in non-OECD countries are still substantially smaller and weaker compared to those sold in the OECD, the trend over time towards acquisition of larger and more powerful cars is more pronounced than in OECD countries. This is confirmed by the marked increase in the market diversification of non-OECD countries, as suggested by the introduction, by 2013, of a variety of models that had larger weight and footprint compared to 2005 (Figure 3). One component of a policy for achieving improved fuel economies across the vehicle fleet is the use of measures that discourage shifts to larger, heavier vehicle market segments. Differentiated vehicle taxation and regulatory measures requiring stronger fuel economy improvements for large segments have the capacity to restrict the impact on fuel economy of shifts across market segments. They will be especially relevant in the non-OECD.

Figure 3 • New LDV fuel economy over vehicle weight and footprint, OECD, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Methodological insights

The refinement of the methodology had notable impacts on the calculated average fuel economy results, compared with earlier GFEI reports.

The methodological revision includes two main components: A) normalisation of the results to the World Light-duty vehicle Test Cycle (WLTC), taking into account improvements in the way vehicles are tested and reducing the gap between tested and real-world fuel economy; and B) improved consistency in accounting for all light commercial vehicles, pick-up trucks and Sport Utility Vehicles (SUVs) across all regions.

Normalising all fuel consumption values to the WLTC takes into account improvements in the way vehicles are tested and thus results in a better alignment of the estimates presented in this report with real-world fuel consumption. The revision establishes a basis that can be consistently applied on future reports analysing the development of global fuel economies.

The uniform inclusion of light commercial vehicles, pick-ups and SUVs achieves more consistent comparability of results among countries, leaving less scope for different interpretations of vehicle definitions.

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The combined effect of the inclusion of light commercial vehicles and the normalisation to the new WLTC increased specific fuel consumption of global new registrations by 13% on average across all years.

The methodological revisions yield historical improvement rates (at the global scale) that are lower than what has been found in earlier GFEI reports. This implies that reaching the GFEI target is more challenging. While the former analysis showed a global annual fuel economy improvement rate of 2.0% between 2005 and 2013, the new methodology suggests an annual improvement rate of only 1.6%. This is significantly lower than the 3% improvement rate necessary to achieve the GFEI target of reducing new LDV fuel consumption by 50% by 2030. This partly reflects the aim of the WLTC to reduce the gap between tested and on-road fuel economy, improving the accuracy of future estimates of the CO_2 mitigation potential of petroleum-fuelled cars.

Introduction

Beginning in 2011, the IEA has released an annual series of GFEI working papers investigating the global fuel economy of newly registered LDVs over time: the *International Comparison of Light-Duty Vehicle Fuel Economy* (IEA, 2011; IEA, 2012; IEA, 2014). In its last edition, the report included time-series of sales-weighted average fuel economies for the years 2005 to 2013 for about twenty-six countries, including 14 non-OECD economies, and representing more than 80% of the global LDV market.

The unique value of these analyses lies in their country coverage, as they do not only cover OECD countries like the United States, the main Member States of the European Union, Mexico, Japan and Korea (where sales-weighted average fuel economy is already tracked in other assessments, such as US EPA, 2016a and EEA, 2015), but also analyses trends in non-OECD countries including Brazil, Russia, India, People's Republic of China ("China") and South Africa (the "BRICS") and other growing markets such as Indonesia, Malaysia, Thailand and the Philippines, among others.

The latest update of global fuel economy trends concludes that, while global average fuel economy is improving, more needs to be done to meet the ambitious, yet realistic GFEI target of halving the specific fuel consumption of new passenger LDVs (measured in Lge/100 km) by 2030, compared to a 2005 baseline. Effective measures include adoption or extension of ambitious fuel economy and CO_2 emission standards, differentiated taxation of vehicles either at registration – as for instance in the French feebate system (MEEM, 2016) – or on an annual basis, as well as taxation of transport fuels.

Monitoring fuel economy over time is essential for gauging the effectiveness of fuel economy policies (such as fuel economy standards, differentiated vehicle taxation and mandatory fuel economy labelling), but it is insufficient for illustrating which strategies are best suited to deliver the required changes. This new report aims to identify these strategies. It does so by:

- Gathering information on economic and demographic characteristics of each country under consideration (i.e. average income, geographic situation), as well as information on the fuel economy policies in place (fuel and vehicle taxation levels and structures, the presence or absence of fuel economy regulations).
- Monitoring changes in the average fuel economy with respect to country-specific LDV market structures, focusing in particular at vehicle specifications such as segmentation, weight, footprint, as well as engine and drivetrain technologies.

This report is structured as follows:

- The following section describes important methodological revisions that aim to improve the representation of fuel economies of LDVs across countries by virtue of uniform inclusion of light commercial vehicles (LCVs) and though evaluating fuel economies according to the newly developed Worldwide harmonised Light vehicles Test Procedures (WLTP).
- A comparative assessment of new LDV markets, providing insights for selected OECD and non-OECD countries, looking at vehicle segmentation, powertrain, weight and footprint.
- A section analysing the penetration of advanced vehicle technologies in the main markets, providing insights on the penetration of fuel-saving technologies and how they relate with fuel economy policies, engine power and other drivers, such as average income and vehicle prices.
- Detailed country sheets provide information on the LDV market characteristics, technology penetration, average new LDV fuel economy as well as today's policy landscape in a wide selection of representative national markets.

Methodology

This analysis has been undertaken using different releases of IHS Polk databases, combined with additional information on fuel economy at the model level extracted from technical sources (see IEA, 2014 for details on the methodological approach). Results shown here build on the database enhancements already developed for earlier GFEI assessments (IEA, 2011; IEA, 2013; IEA, 2014), on additional information that was already available in the IHS Polk datasets (vehicle weight, power, footprint and drivetrain technologies) and on the inclusion of data from additional technical sources.

Revisions with respect to earlier assessments

This new report also incorporates two major methodological changes:

- **Improved consistency with regard to vehicle segmentation**: different classifications of LDVs exist across countries and regions. In Europe and in the United Nations, light vehicles are differentiated on the basis of the usage, between passenger (M1) and freight (N1), as well as according to load capacity and mass (UNECE, 2016b), with a grey area for some vehicle categories that are actually defined as passenger cars or LCVs depending on their main usage definition at purchase. Vehicles are primarily classified by weight in other regions (e.g. in the United States and some Latin American countries) (US EPA, 2016b). In order to maximise comparability between regions, this report consistently presents results including all LDVs such as passenger cars, passenger light trucks (comprising SUVs, pick-ups and other large cars), as well as LCVs.
- **Normalisation to the WLTC**: three different test cycles are applied worldwide to measure specific fuel consumption (Lge/100 km) or fuel economy (MPG or km/Lge): the European NEDC, the US Corporate Average Fuel Economy (CAFE) and the Japanese JC08. The WLTP and its related test cycle (WLTC) have been developed (and are being refined) to replace region-specific approaches with a harmonised testing scheme (UNECE, 2014). The conversion of the results (published according to region-specific test results) was performed using conversion equations recently developed by the ICCT (2014a).[2]

The inclusion of all LDVs combined with the normalisation to WLTC alters national fuel economy values. While the normalisation to WLTC generally increases specific fuel consumption, its impact varies among different test cycles and powertrain configurations.

Box 1 • Spotlight on the WLTP and WLTC

A Global Technical Regulation harmonising the test procedure used for testing LDVs (especially relevant for the measurement of per kilometre local pollutant emissions, fuel consumption and CO_2 emissions) has been recently endorsed by the World Forum for the Harmonisation of Vehicle Regulations (WP.29) of the United Nations (UNECE, 2014).

This new test procedure (WLTP) comprises a newly developed test cycle (Worldwide harmonised Light vehicle Test Cycle, WLTC) and will progressively replace region-specific test cycles, such as the New European Driving Cycle (NEDC) in Europe and the JC08 in Japan.

The WLTC has been developed using driving data from various countries from all over the world and provides an assessment of fuel economy and pollutant emissions that better reflects real-world vehicle operation. In order to reduce the gap between tested and real-world on-road fuel economy,

[2] The conversion was performed using the zero-intercept conversion factors. The decision to use these conversion factors is based on the observation that linear, non-zero-intercept conversion schemes with constants cause highly variable results depending on the magnitude of the original fuel consumption value.

the new WLTC also covers a much greater range of charge states within the engine map compared with earlier test cycles.

The WLTP will become the global reference for LDV testing in the near future thanks to: *i*) its joint development in the United Nations framework, ensuring its progressive adoption in international regulatory texts;[3] and *ii*) the benefits derived from global harmonisation, which guarantee support from industrial players in the automotive sector.

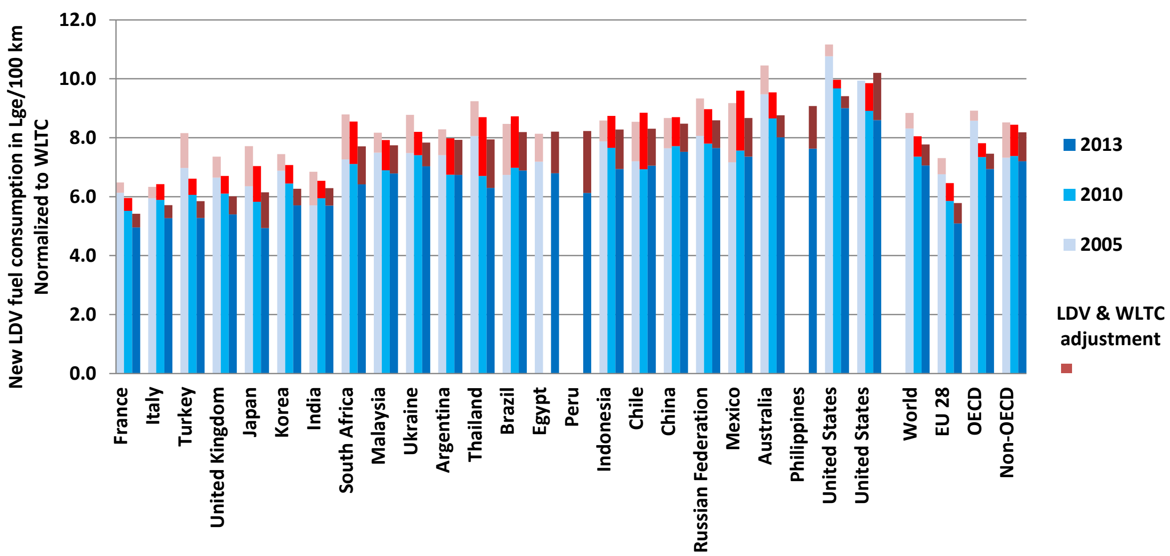
Due to its capacity to reduce the gap between real-world driving conditions and laboratory tests, the WLTP will provide more accurate and representative information to consumers, and enable better estimates on expected CO_2 emission reductions from road transport. However, the process of developing the new WLTP is not yet finished. Recent developments have addressed issues that were primarily associated with electric and hybrid-electric vehicles (UNECE, 2016a). On-going efforts to complete the development of the WLTP target the use of air conditioners and on-board diagnostic requirements, among other aspects (UNECE, 2015).

This report relies on preliminary conversion factors, developed by the International Council for Clean Transportation (ICCT, 2012), to normalise NEDC, CAFE and JC08 to WLTC.

Impacts on fuel economy developments

Figure 4 shows average new LDV fuel economy values by country, normalised to the WLTC, for the years 2005 to 2013.

Figure 4 • Average new LDV fuel economy by country normalised to the WLTC, 2005-13



Note: Historic data are not available for Macedonia, Peru and the Philippines (2005 and 2010), nor for Egypt (2010).
Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Blue bars show the fuel consumption values previously published in the 2014 GFEI report (IEA, 2014). Red bars indicate changes due to the adjustment of the methodology. Globally, the changes in methodology result in an increase in average specific fuel consumption of 13%. In some of the countries (e.g. Mexico, Peru and Thailand), the increase can exceed 20%. There are several reasons for these variations: the uniform inclusion of LCVs, pick-up trucks and SUVs in all countries drives up average fuel economy in countries with a high share of these vehicles

[3] Switching to the WLTP will take place progressively as new regulatory texts are developed. In Europe, changes in the methods used to evaluate per kilometre pollutant emissions (Euro 6) and fuel consumption/CO_2 emissions are expected to be adopted between 2017 and 2020 (Delphi, 2015).

(e.g. Mexico, Peru and Thailand). The impact of normalising to WLTC is stronger in countries with a high share of vehicles tested under the US CAFE cycle than for regions using on the European NEDC test cycle. This is due to larger discrepancies between US CAFE test and WLTC results. In addition, gasoline-fuelled cars are more strongly affected by the normalisation to WLTC than diesel-fuelled cars. This means that countries with a higher diesel penetration are less affected by the conversion than countries with a high share of gasoline-fuelled LDVs in new sales. It also means that changing shares of powertrain configurations over time affect the discrepancy between average fuel economy normalised to NEDC and average fuel economy normalised to WLTC.

The key message stemming from this revision is less optimistic than messages based upon earlier assessments: reaching the GFEI target of halving the fuel consumption per km of new LDVs by 2030 (compared with 2005) will be more challenging than has been previously assessed. This is because historic improvement rates evaluated by the new methodology are lower than the values estimated in earlier GFEI reports. Table 1 provides an overview of the impacts of the methodological changes on global fuel economy developments between 2005 and 2013.

Table 1 • Impacts of methodological changes on global fuel economy developments, 2005-13

			2005	2008	2011	2013	2030
Values published in IEA, 2014 with no LCVs, based on NEDC	OECD average	average fuel economy (Lge/100 km)	8.6	7.9	7.3	6.9	
		annual improvement rate (% per year)		-2.7%	-2.6%	-2.6%	
					-2.6%		
	Non-OECD average	average fuel economy (Lge/100 km)	7.3	7.4	7.3	7.2	
		annual improvement rate (% per year)		0.5%	-0.4%	-0.9%	
					-0.2%		
	Global average	average fuel economy (Lge/100 km)	8.3	7.7	7.3	7.1	
		annual improvement rate (% per year)		-2.3%	-1.9%	-1.8%	
					-2.0%		
	GFEI target	average fuel economy (Lge/100 km)	**8.3**				**4.2**
		required annual improvement rate (% per year) 2005 base year			**-2.7%**		
		required annual improvement rate (% per year) 2014 base year			**-3.1%**		
Values published in this report including all LCVs, based on WLTC	OECD average	average fuel economy (Lge/100 km)	8.9	8.4	7.8	7.5	
		annual improvement rate (% per year)		-2.1%	-2.5%	-1.9%	
					-2.2%		
	Non-OECD average	average fuel economy (Lge/100 km)	8.5	8.5	8.4	8.2	
		annual improvement rate (% per year)		-0.1%	-0.4%	-1.2%	
					-0.5%		
	Global average	average fuel economy (Lge/100 km)	8.8	8.4	8.0	7.8	
		annual improvement rate(% per year)		-1.7%	-1.6%	-1.4%	
					-1.6%		
	GFEI target	average fuel economy (Lge/100 km)	**8.8**				**4.4**
		required annual improvement rate (% per year) 2005 base year			**-2.7%**		
		required annual improvement rate (% per year) 2014 base year			**-3.3%**		

Note: Results in the upper table are taken directly from the report, "International comparison of light-duty vehicle fuel economy" (IEA, 2014), in which LCVs and pick-up trucks were not consistently included for all countries. They are hence not directly comparable to the numbers shown in Table 2 below.

While the former global annual fuel economy improvement rate from 2005 to 2013 was estimated at 2.0%, the new methodology suggests an annual improvement rate of only 1.6%, well below the 3% necessary required to achieve the 2030 GFEI target.

The inclusion of LCVs had a greater impact on average new LDV fuel economy in the non-OECD economies than in the OECD member countries. This is mainly due to a higher share of pick-up trucks used for commercial purposes in the non-OECD, but also due to the fact that pick-up trucks have already been included in former assessments in the United States, Canada and Australia. Since fuel economy regulation for LCVs has been adopted in only a few countries, the fuel economy of LCVs improved at a lower rate, which subsequently affects not only absolute specific fuel consumption values but also calculated improvement rates.

The switch from NEDC to WLTC also resulted in a greater increase of calculated specific fuel consumption in the non-OECD compared with the OECD. This is partially explained by the lower penetration of diesel vehicles in the non-OECD. Since the discrepancy in calculated fuel economy resulting from the switch to WLTC is lower for diesel-fuelled vehicles, and since the OECD Europe is one of the global regions with the highest diesel sales shares globally, the calculated increase fuel consumption is more moderate in the OECD region.

One rationale for developing the WLTC was to reduce the gap between tested and on-road fuel consumption. Adopting measurements using the WLTC, and thereby better reflecting real-world conditions, leads to the conclusion that the GFEI target will be more difficult to achieve than it was previously estimated.

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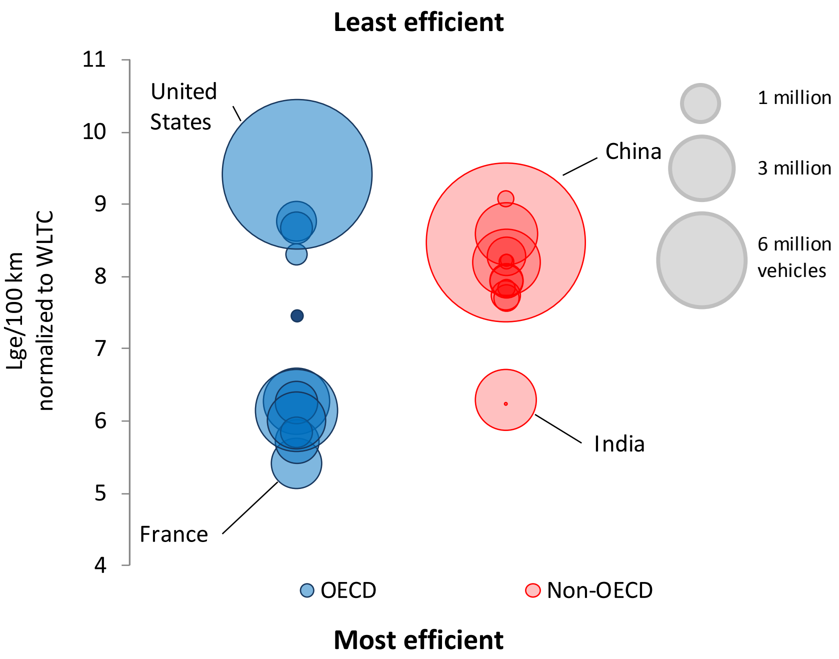
Comparative assessment of vehicle characteristics

In 2013, 78 million LDVs were sold globally, with the majority (54%) being registered in non-OECD countries (IEA, 2016a).

The average national fuel economy [normalised to WLTC] of 2013 new vehicle sales covered in this analysis (representing more than 80% of the global market) ranges from 5.4 to 10.2 Lge/100 km (132 to 237 g CO_2/km), with a discrepancy of a factor of two between the most efficient and least efficient national market.

Figure 5 • Fuel economy distribution across national new LDV markets in the OECD and non-OECD, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The range of average fuel economy values is much wider in OECD countries than in non-OECD countries (Figure 5). The OECD includes both the most and the least efficient markets and contains two main clusters, one well below (Europe, Japan), and the other well above (North America, Australia) the regional average.

While the non-OECD region started in 2005 from a much lower average fuel consumption value than the OECD, non-OECD improvement rates over time were much lower than those in the OECD. By 2011, the OECD average new sales fuel economy had become better than in the non-OECD region. In 2013, the average OECD new LDV fuel consumption (7.4 Lge/100 km) was about 10% lower than in the non-OECD (8.4 Lge/100 km).

Characteristics of LDVs such as vehicle segment, powertrain technology, vehicle weight and footprint differ significantly among regions. These variations are based on differences in income levels, fuel prices, vehicle taxation, geographic preconditions and policies targeting vehicle specifications such as fuel economy, CO_2 and pollutant emissions. Historic and country-specific elements such as technology mix also have substantial impact on new LDV fleet specifications.

Table 2 • Summary of country-specific LDV market characteristics and fuel economy trends

	Average fuel economy 2013 (Lge/100 km, NEDC)	Average fuel economy 2013 (Lge/100 km, WLTC)	Average power 2013 (kW)	Average displacment 2013 (cm³)	Average empty weight 2013 (kg)	Average footprint 2013 (m²)
Argentina	7.1	7.9		1 689	1 285	3.9
Australia	8.0	8.8	128	2 344	1 570	4.2
Brazil	7.3	8.2	80	1 508	1 168	3.8
Canada	9.0	10.2	129	2 164	1 715	4.8
Chile	7.6	8.3	94	1 845	1 402	4.0
China	7.5	8.5	94	1 709	1 440	4.0
Egypt	7.4	8.2	62	1 639	1 337	4.1
France	5.1	5.4	80	1 592	1 352	4.1
Germany	5.8	6.3	100	1 754	1 453	4.2
India	5.8	6.3	57	1 355	1 110	3.5
Indonesia	7.4	8.3	78	1 568	1 237	3.8
Italy	5.3	5.7	76	1 507	1 281	3.9
Japan	5.5	6.1	73	1 311	1 167	3.5
Korea	5.7	6.3	120	1 936	1 517	4.2
Malaysia	6.9	7.7		1 606	1 228	3.9
Mexico	7.7	8.7	95	1 796	1 402	4.0
Peru	7.3	8.2			1 417	4.0
Philippines	8.0	9.1			1 527	4.1
Russian Federation	7.7	8.6	94	1 865	1 384	4.0
South Africa	7.0	7.7	96	1 899	1 491	4.1
Thailand	7.4	7.9	88	2 004	1 529	4.3
Turkey	5.5	5.8	79	1 546	1 356	4.1
Ukraine	7.1	7.8		1 796	1 411	4.0
United Kingdom	5.6	6.0	92	1 683	1 401	4.1
United States	8.4	9.4	173	3 069	1 812	4.5
OECD	**6.7**	**7.5**	**128**	**2 283**	**1 559**	**4.2**
Non-OECD	**7.3**	**8.2**	**89**	**1 680**	**1 362**	**3.9**
World	**7.0**	**7.8**	**110**	**1 993**	**1 470**	**4.1**

Note: Results in Table 2 reflect the consistent inclusion of LCVs and pick-up trucks in all countries and are hence not directly comparable to the data shown in the upper part of Table 1. Revised conversion factors to normalise CAFE test values to NEDC test values (based on ICCT, 2012) also lead to lower NEDC based average fuel economies for the OECD countries and the world when compared to the results of Table 1.

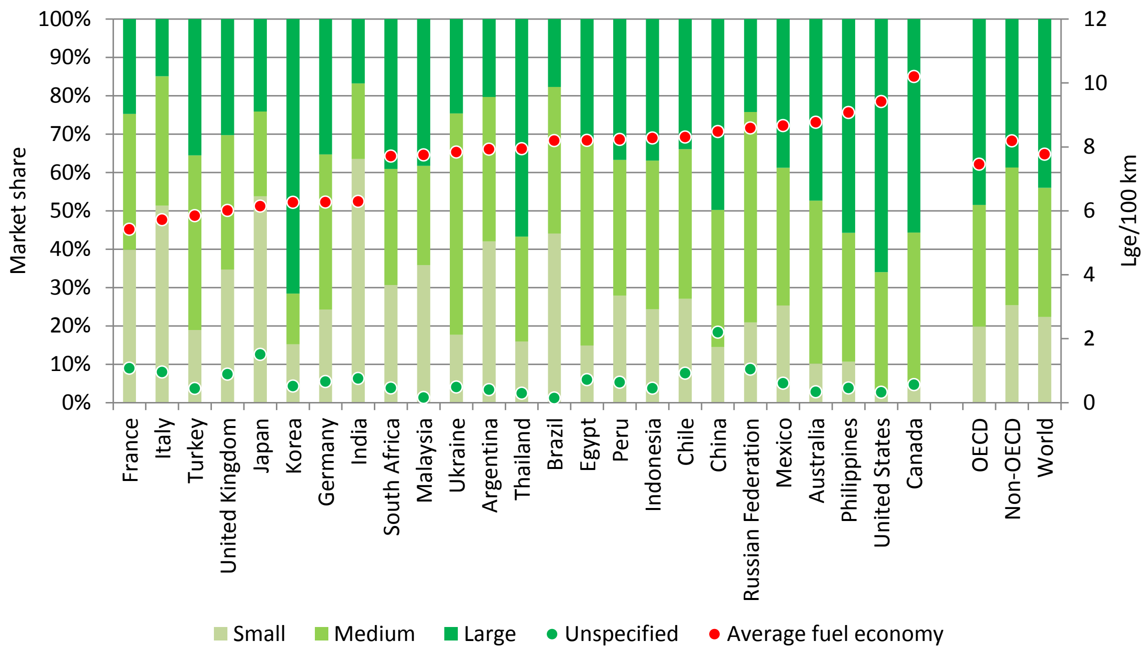
Table 2 provides an overview of the main characteristics of the LDV markets for 26 countries.

- Globally, the average engine power of new LDVs sold in 2013 was 110 kW. Regional differences in engine power are substantial. India had the lowest average vehicle power rating (57 kW), while the average new LDV in the United States was almost three times as powerful (173 kW).
- A similar observation can be made for engine displacement. While the global average in 2013 was almost 2 litres (L), the average Japanese car had an engine size slightly above 1.3 L. At the same time, engine displacement averaged more than 3 L in the United States.
- Regional average engine power and displacement are markedly different between the OECD and non-OECD: in the non-OECD, the average new LDV is about 30% less powerful and the engine capacity is about 26% smaller than in the OECD.
- Differences in vehicle weight and footprint are less pronounced. Compared to the OECD, vehicles sold in the non-OECD were about 12% lighter and 6% smaller. Weight and size characteristics also tend to be highly correlated. In 2013, the average weight and size of new LDVs sold in India were on average lighter and smaller than those sold in all other regions,

while the national average of cars sold in the United States were the world's heaviest and cars sold in Canada had the largest national average vehicle footprint.

Vehicle segmentation

Figure 6 • New LDV market by vehicle segment by country, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Vehicle segmentation varies greatly among countries (Figure 6). While in Japan more than 50% of newly registered cars belong to the small segment[4], more than 65% of cars entering the market in the United States belong to the large vehicle segment.

Figure 6 suggests that markets with large shares of small LDVs are characterised by better fuel economies than markets with bigger shares of large LDVs. In France and Italy, where the small segment accounted for roughly half of the 2013 sales, average fuel economy was close to 5.4 Lge/100 km; in the United States and Canada, where large LDVs accounted for more than half of the total amount of vehicles registered in the same year, it was much higher: 10 Lge/100 km.

Vehicle segmentation is not the only criterion affecting fuel economy: in India 65% of cars sold in 2013 belonged to the small segment, while small cars accounted for just under 30% of the German vehicle market in 2013. Nevertheless, average fuel economy in both these markets was almost identical in that year. Another exception is Brazil, where fuel consumption was well above the global average, despite the fact that the share of small vehicles on the Brazilian market was among the largest in the world in 2013. This is likely to be due to the powertrain profile of new car sales in Brazil, with a dominant share of flex-fuel vehicles and a marginal portion of diesels.

Figure 6 also shows that cars in non-OECD markets were slightly larger than in the OECD. This further contributed to the fact that weighted average specific fuel consumption in the OECD was lower than in the non-OECD: 7.4 Lge/100 km against 8.2 Lge/100 km.

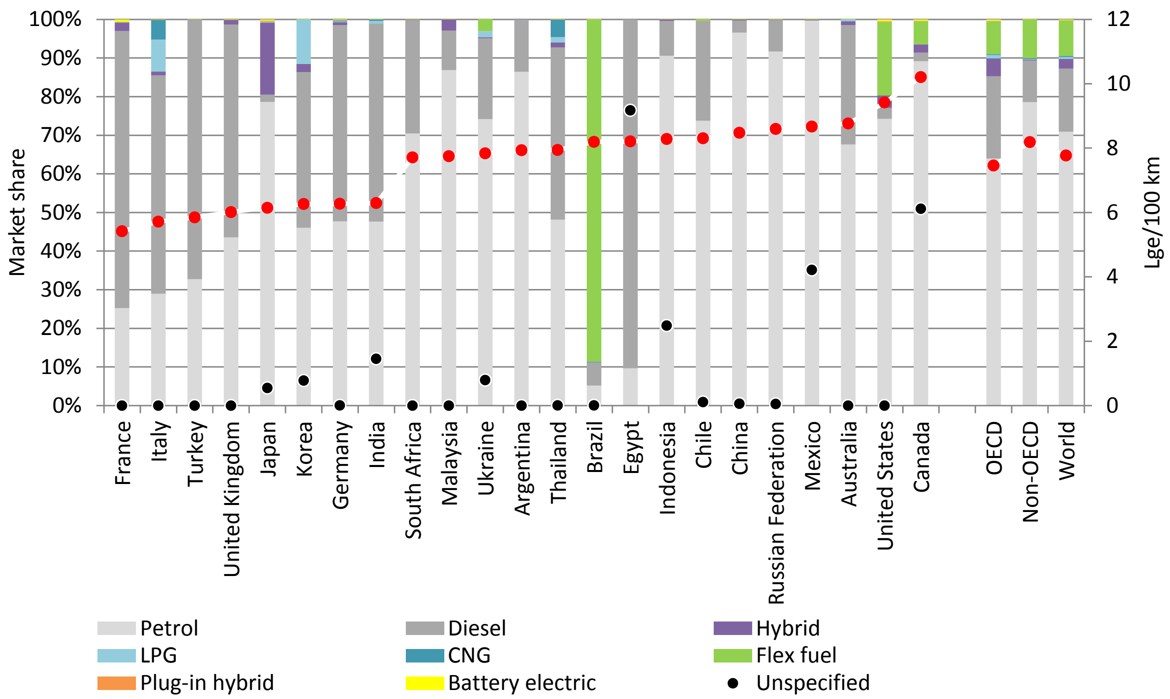
[4] *Kei*-cars – the Japanese small cars – are also exceptionally small compared with the average size of vehicles sold in Europe or the United States.

Vehicle powertrain technology

Vehicle powertrain technology also has a strong impact on average fuel economy. Figure 7 shows that a strong penetration of diesel engines tended to be associated with better fuel economy (diesel vehicles are more efficient than gasoline vehicles offering the same performance). European markets such as France, Italy, Turkey and Germany had shares of diesel-powered cars around 50% or more. The same economies were characterised by average fuel economies below 6 Lge/100 km.

The opposite is true for markets such as the United States and Canada, but also for Russia and China. Shares of spark-ignition engines exceeded 90% in these countries, with 2013 new sales average fuel economies ranging from 8.5 Lge/100 km (China) to above 10 Lge/100 km (Canada).

Figure 7 • New LDV market by vehicle powertrain by country, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

In Japan, the high share of hybrids (above 20%) contributed to the efficiency of the LDV fleet, despite spark-ignition engines accounting for almost 100% of the market. Hybrid cars, which are still more expensive than comparable conventional models, sold almost exclusively in OECD markets. In these markets, the share of diesel-fuelled cars was still twice as high as the share in non-OECD markets in 2013.

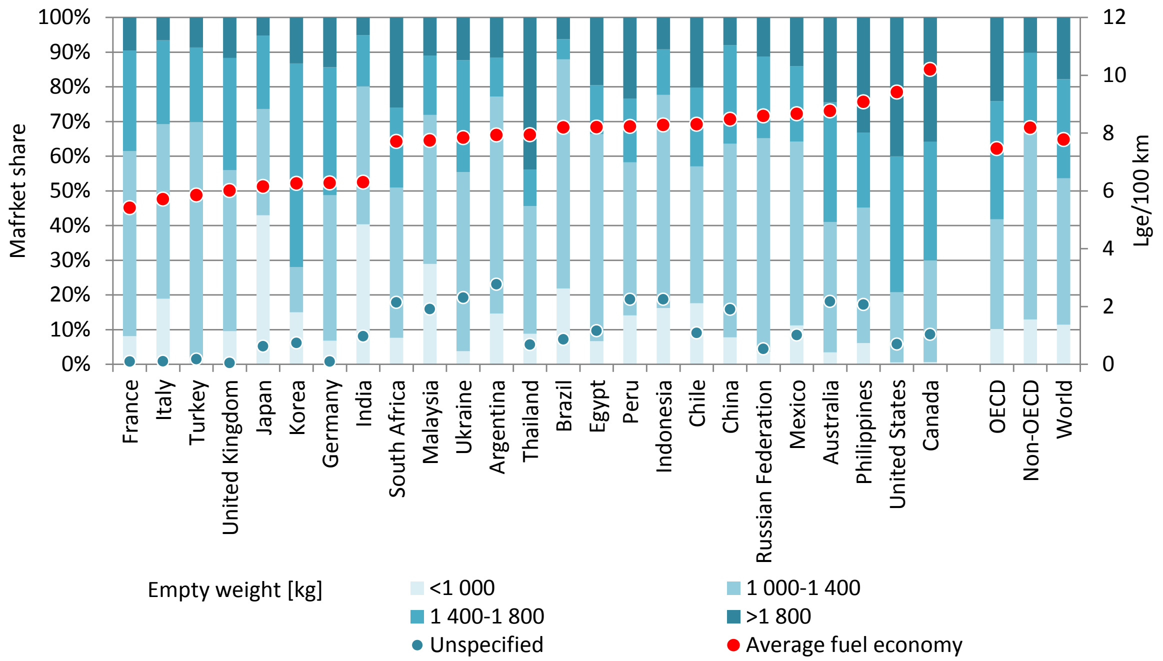
Flex-fuel cars were the primary technology choice in Brazil, where sugarcane ethanol competes with conventional gasoline to supply fuel. Besides Brazil, vehicles using ethanol, liquefied petroleum gas (LPG) or compressed natural gas (CNG) only reached sizeable sales shares in markets with supportive policies for the deployment of fuel distribution infrastructure (e.g. Italy) or with a significant uptake in captive fleets (e.g. taxis in Thailand). These markets also tended to apply preferential tax rates to alternative fuels.

Flex-fuel vehicles, as well as vehicles powered by CNG and LPG, tend to have fuel economy performance on par with gasoline-powered engines (as they all rely on spark-ignition technologies) and hence inferior to diesel powertrains (all else being equal). The limited market uptake of powertrains using alternative fuels limits savings that could be achieved by optimising engines for alternative fuels (for instance, compression ratios for CNG engines could be higher than for gasoline ones, favouring energy efficiency). Innovations in spark-ignition engines, such as direct injection, are primarily conceived for gasoline fuel, due to its importance in terms of market size. Technologies in use in engines using multiple fuels are more likely to be based on mature solutions and embedding fewer innovations. Variable valve timing is a potential enabler of fuel efficiency improvements in multi-fuel engines, as it could influence the compression ratio in a way that is optimised for the fuel used.

Vehicle weight

As in the case of vehicle segmentation, vehicle weight varies widely among countries (Figure 8). Countries such as France, Turkey, Japan and India were among the national car markets with the most efficient new vehicles in 2013. In these countries, more than two-thirds of new LDVs have empty weights below 1 400 kg. At the opposite end of the spectrum, the United States and Canada are the markets with the heaviest cars (almost 80% of new LDVs weighed more than 1 400 kg in the United States, with almost 40% of LDVs being heavier than 1 800 kg). These markets also have the highest specific fuel consumption.

Figure 8 • New LDV market by vehicle empty weight by country, 2013



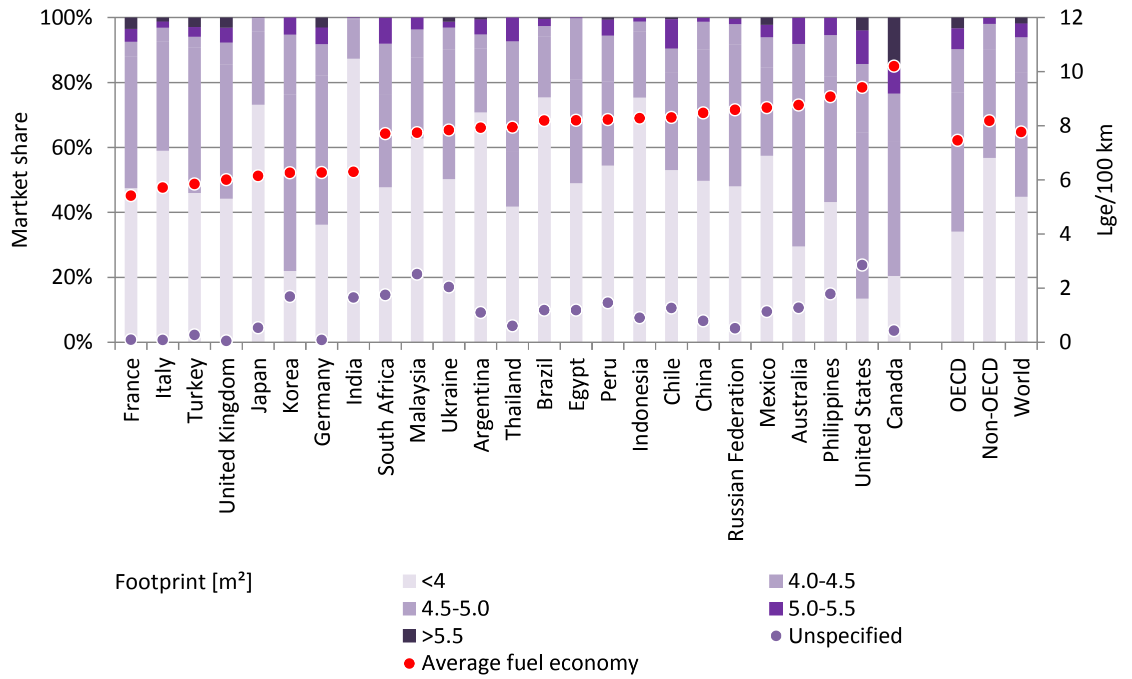
Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Vehicle weight directly affects inertial forces and rolling resistance, two of the major forces adversely impacting the fuel consumption of cars (the third being aerodynamic drag). This explains why lighter vehicles tend to have better fuel economy. As in the case of vehicle segments, the relationship between fuel economy and weight is mitigated by the fact that heavier fleets can offset the weight effect on fuel economy by using better vehicle technology. Comparing Germany and India provides a good example in this respect. On average, cars are significantly heavier in Germany, diesel shares are very similar, but new vehicle average fuel economy is almost identical, suggesting that the deployment of fuel-saving technologies is more widespread in the German market than it is in India. Similar considerations hold in other non-OECD markets: the 2013 average fuel economy was above the global average in Brazil, Indonesia and Argentina, even if these markets had relatively light vehicle fleets. This reveals a limited penetration of fuel-saving technologies in these global areas.

Vehicle footprint

Vehicle footprint denotes the area formed by wheelbase and axle width and is generally used as a proxy for vehicle size. A larger vehicle footprint often implies a larger frontal area, which in turn negatively affects fuel economy due to higher aerodynamic drag. Figure 9 shows average fuel economies together with the share of vehicle footprint classes in the markets shown in previous figures. Markets with similar specific fuel consumption can have very different vehicle footprint distributions, as it is the case for the aforementioned example of Germany and India. Markets can also have similar market segmentation of vehicle footprint, but very different average fuel economy (this is the case for Germany and Canada, for instance).

Figure 9 • New LDV market by vehicle footprint by country, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Engine and drivetrain technology deployment

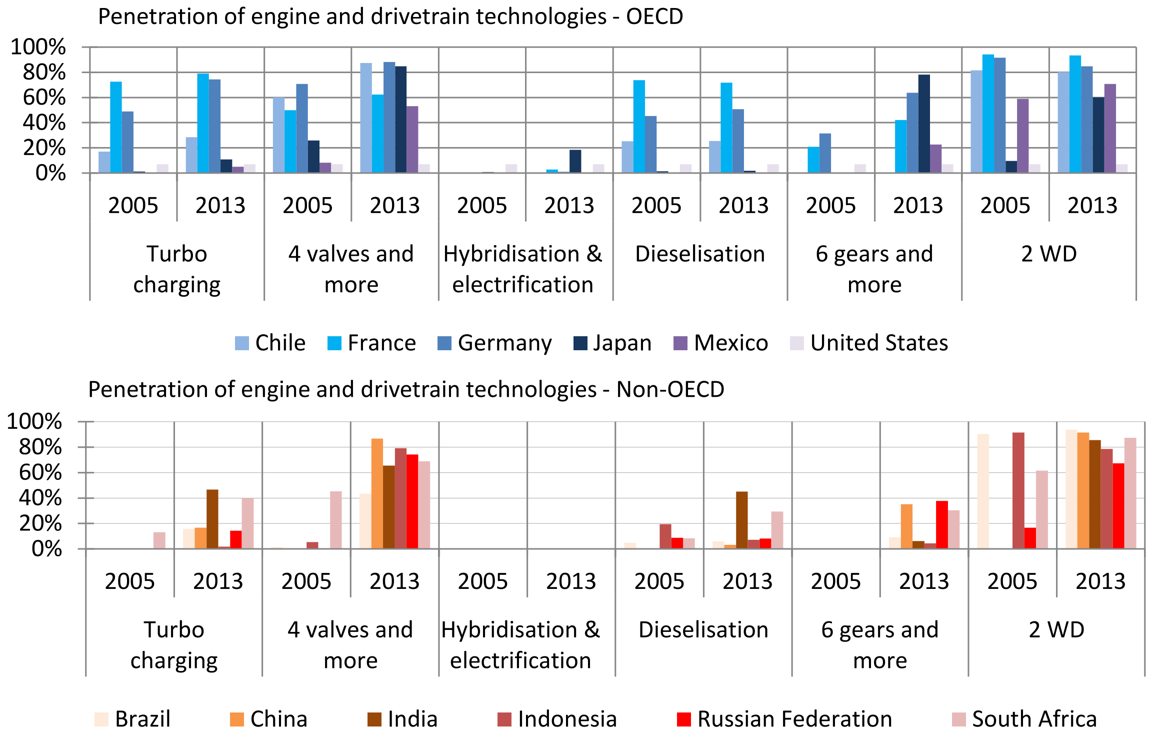
Engine and drivetrain technologies enabling improved fuel efficiency consist of (1) solutions that allow engine downsizing (i.e. providing the same power output with less engine displacement and fewer engine cylinders), namely the use of turbocharging and hybridisation, and (2) changes in drivetrain characteristics, such as an increased number of gears (either in manual or automatic transmission).[5] Engine technologies that reduce energy losses or improve combustion (e.g. an increased number of cylinder valves) and other drivetrain characteristics (such as the use of all-wheel-drive) also influence vehicle fuel efficiency.

Figure 10 provides an overview of the percentage share of a range of vehicle engine and drivetrain efficiency technologies in selected OECD and non-OECD countries for the years 2005 and 2013. The adoption of compression ignition engines is highest in Europe, with Germany and

[5] Vehicle weight reduction through the use of light-weighting materials (e.g. high-strength steel, aluminium and magnesium alloys, as well as carbon fibre reinforced plastics) is also an effective option for delivering fuel economy improvements and moreover enables further engine downsizing. This is not discussed in detail in this section due to the nature of the indicators available from the IHS Polk dataset and other sources consulted for this analysis, as they focus on engine and drivetrain technologies and do not include details on the uptake of light-weighting materials in vehicles.

France leading among the countries shown, with more than 50% and up to 70% of all newly registered LDVs being diesel-fuelled, respectively. The rate of diesel penetration in the LDV segment is almost zero in Japan and below 5% in the United States. Other developing non-OECD markets show increased dieselisation over time – between 2005 and 2013, the market share of compression ignition vehicles doubled in India, reaching almost 50% of all new sales in 2013. A similar development can be observed in South Africa, where nearly a third of the new vehicles registered in 2013 were powered by diesel engines. Diesel shares have stabilised and decreased in the recent past, especially in Europe, in the wake of the tightened pollutant regulations, of lower confidence following the recent debate on the gap between emission values under test and real word driving conditions, and because of the improvement of competing (and cheaper) technologies such as direct injection gasoline engines.

Figure 10 • Penetration of efficient engine and drivetrain technologies for selected OECD and non-OECD countries, 2013



Note: Chinese data is not available for 2005.

Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The penetration of advanced drivetrains such as hybrids, plug-in hybrids and battery electric vehicles is generally much higher in OECD regions, where well-established fuel economy standards stimulated the penetration of fuel-saving technologies and higher purchasing power eased their deployment, especially in vehicle classes that yield larger margins for manufacturers. Japan represents an exceptional case within the OECD: there the penetration of hybrids (which reached almost 20% market share in 2013) occurred in a framework characterised by a low average vehicle size (and price) in comparison with other OECD markets.

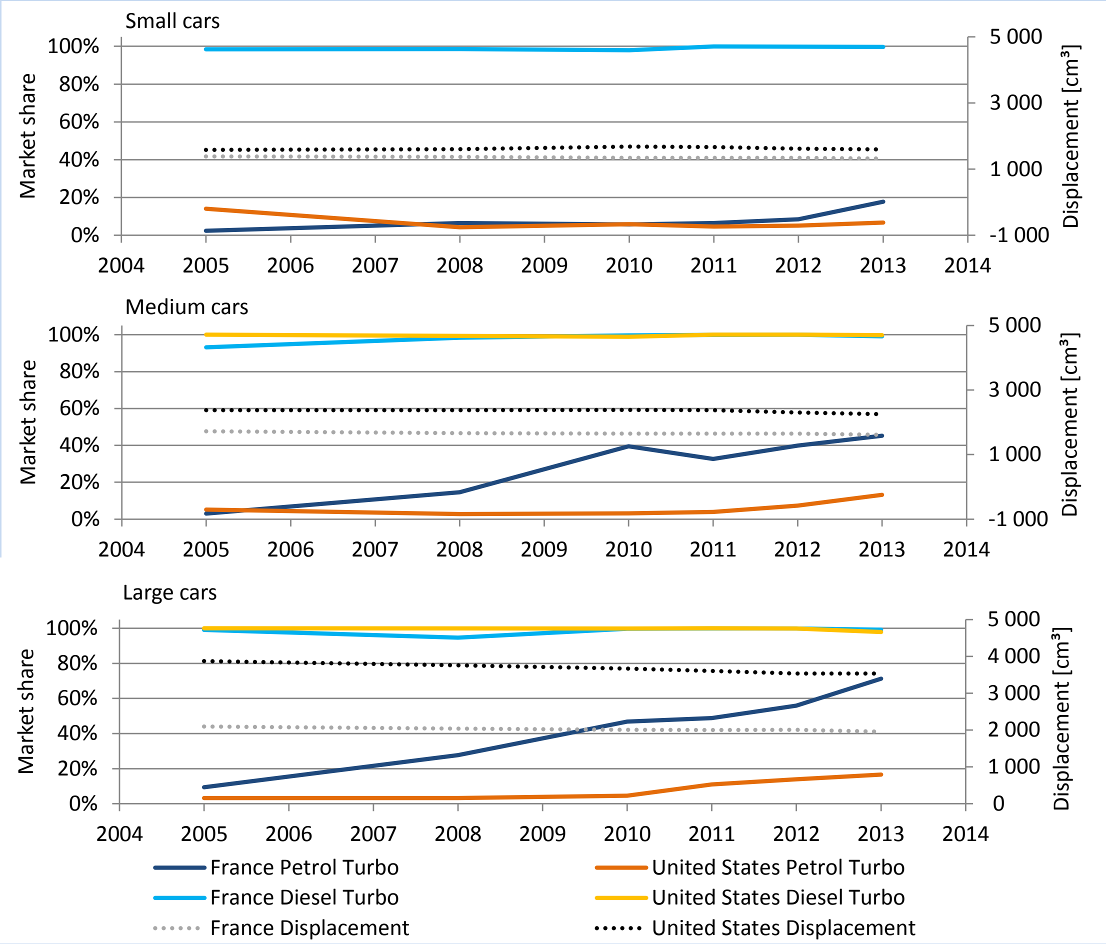
The use of turbocharging is highest in countries with a large diesel fleet, as turbocharged diesel engines using direct injection have been standard since the mid-1990s. Turbocharging is also a key requisite for engine downsizing, as a means of compensating for the loss of power that takes place when reducing the size of naturally aspirated engines.

Box 2 • Spotlight on turbocharging

A comparison of the French with the US auto market (figure below) reveals that turbocharging is much more widespread among all vehicle segments in France. While turbocharging of diesel engines among different car sizes shows high levels (almost 100%) in both countries, turbocharged spark-ignition engines are far more widespread in France, and even start to spill over to the small vehicle segment. By 2013, almost 50% of medium-sized gasoline cars and more than 70% of large gasoline cars were turbocharged, while in the United States more than 80% of gasoline-powered LDVs, both in the medium and in the large car segment, were still naturally aspirated.

One obvious reason is the much higher engine power and engine displacement characterising vehicles registered in the United States (average engine power is almost twice as high in the United States as in France). The increased use of turbocharging in regions with low technology adoption rates currently could result in engine downsizing without power losses. The effect would be especially evident in the United States, where engine sizes are close to 2.4 L for medium-sized cars and 3.5 L for large cars.

Penetration of turbocharging by segment for diesel and petrol engines in France and the United States, 2013



Note: As there are very few small diesel cars in the United States, the share of turbocharged diesel engines is not representative (and therefore not shown in the figure).

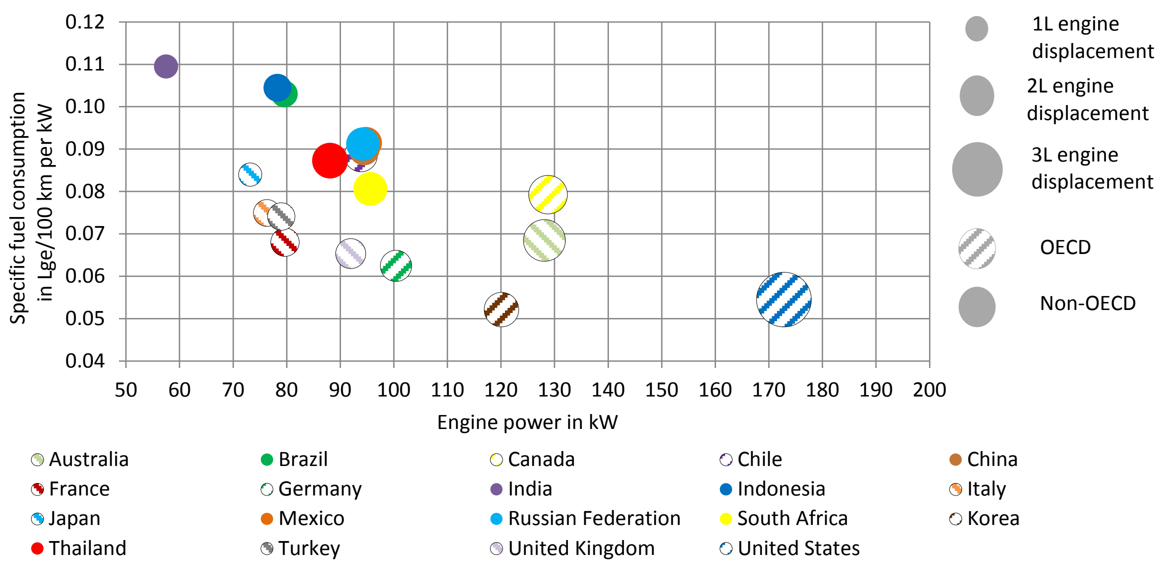
Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

While gaps still exist between the OECD and the non-OECD markets in the rate of dieselisation, hybridisation and turbocharging, the share of vehicles with at least 4 valves per cylinder is broadly aligned, at close or above 80%.

In the past, transmission efficiency had a notable impact on vehicle efficiency. Automatic transmissions were once coupled with diminished fuel economy in the past, mainly due to losses within the torque converter as well as to the limited number of gears. Today's automatic transmission boxes have nearly overcome this hurdle and have performances that are generally on par with manual transmission (and potentially even better, due to optimised shifting algorithms). A higher number of gears tends to result in better fuel economy. The share of cars (both manual and automatic) with six gears or more tends to be high in the OECD. It is highest in Japan, where continuously variable transmissions (CVTs) are widespread, as well as in the United States, where the share of automatic transmissions is also quite high (far higher than in Europe). China, Russia and South Africa are the leading non-OECD markets in terms of adoption of efficient transmission technologies, but there is a significant lag compared to OECD economies.

Most cars in Europe and in non-OECD markets have two-wheel drive. The North American and the Latin American markets show a higher penetration of four-wheel drive cars, mainly due to higher shares of SUVs and pick-up trucks. In the past, the share of four-wheel drive cars was exceptionally high in Japan, and even many small cars had been equipped with all-wheel drive. The trend reversed in the recent past, and nowadays the share of four-wheel drive vehicles in Japan is closer to the values seen in the United States.

Figure 11 • Specific fuel consumption per unit of engine power related with engine power ratings for selected OECD and non-OECD countries, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Figure 11 shows the specific fuel consumption per unit power (in Lge/100 km per kW) as a function of engine power, both for OECD and non-OECD markets, for the year 2013. Non-OECD markets tend to have lower engine power and higher fuel consumption per kW than most OECD markets, suggesting that vehicles in the non-OECD tend to have lower performance than new sales in the OECD, but also that technology is less up-to-date than in OECD markets. This is corroborated by the low shares of newly registered vehicles having advanced powertrains (Figure 7), and is also consistent with:

- a policy environment that did not mandate continued improvements in the recent past (fuel economy policies have only been enforced very recently in Brazil, India and Saudi Arabia; China is the main exception in this respect)
- lower interest in and awareness of fuel-saving technologies in countries with poorer consumer information (e.g. due to the lack of fuel economy labelling)
- higher pressure to cut costs in markets characterised by low average per capita incomes, as this generates stronger consumer interest for lower investment costs
- lower average margins available for OEMs on small market segments

- greater relevance for the build-up of innovation capacities and the subsequent deployment of innovative technologies in developed economies
- interest among OEMs to increase the market life of technologies that have been deployed initially on premium markets.

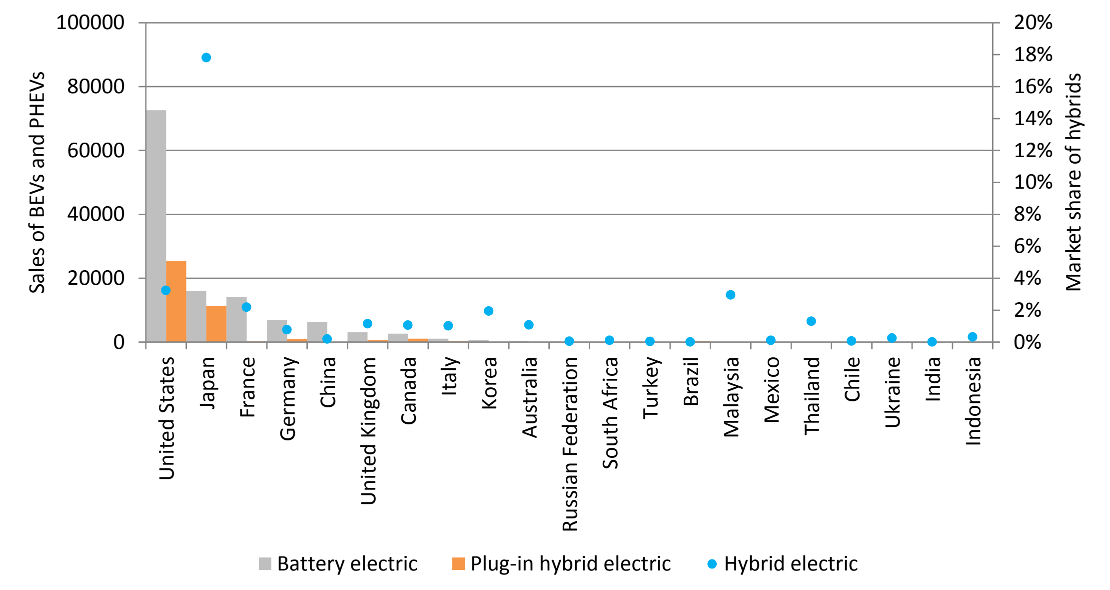
Brazil, India and Indonesia are some notable outliers among the countries shown in Figure 11, with high fuel consumption per unit power in all three countries. India's new vehicle sales had a low average specific fuel consumption (6.3 Lge/100 km), thanks to a very low power rating. Brazil and Indonesia, with average power levels comparable to some of the OECD markets, had much higher average specific fuel consumption than India (8.5 Lge/100 km).

Another clear outlier is the United States. Although average per kW fuel consumption is on the lower end, vehicles sold had much more power on average compared to any other market in the world: with 175 kW on average, US cars were more than twice as powerful as French, Italian or Turkish cars.

Box 3 • Spotlight on electrification

An overview of sales of plug-in hybrids and battery electric vehicles, as well as the market share of hybrid vehicles, is shown in the figure below. In 2013, the United States was by far the country with the highest sales of battery electric vehicles and plug-in hybrids in the sample of countries selected[6] (China became global leader in battery-electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) sales in 2015 [IEA, 2016b]). Japan has the highest market share of hybrid vehicles (almost 20%, as shown in the figure).

Sales of hybrids, plug-in hybrids and battery electric vehicles by country for the year 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

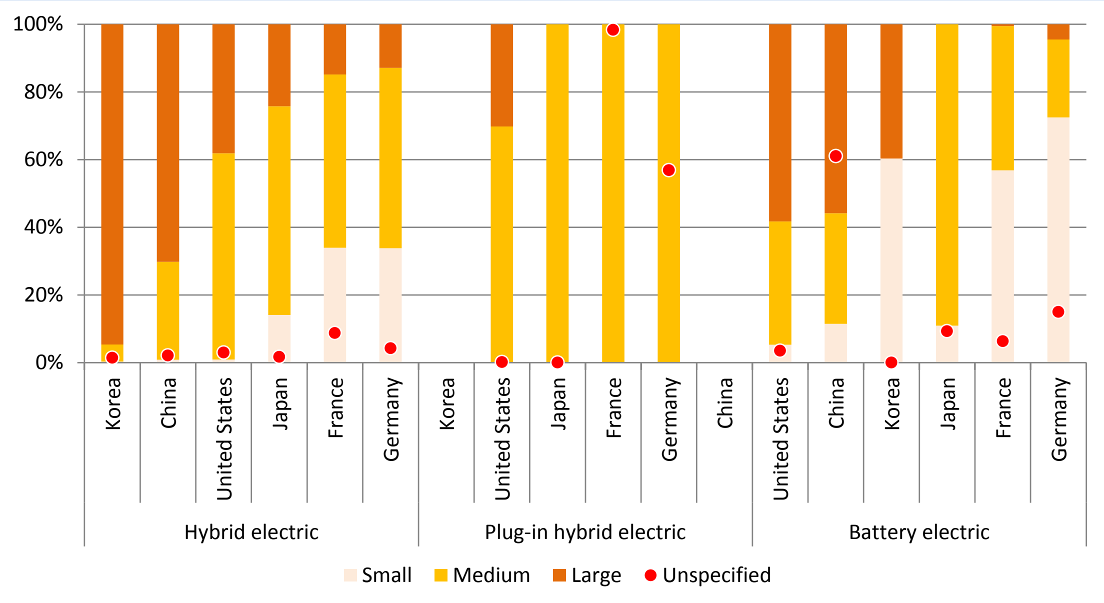
The selection of countries considered for this analysis confirms that, up to 2013, the market for electric vehicles has been largely driven by policies such as fiscal incentives, waivers on fees applied to conventional cars (e.g. parking, congestion charging) and access restrictions (e.g. access to bus lanes or high-occupancy vehicle [HOV] lanes). New EV registrations are much higher in the presence of significant financial support. In the United States, for instance, the purchase of an electric car has been subsidised using a tax credit mechanism totalling up to USD 7 500 per car (IRS, 2009). In Japan, direct subsidies to electric vehicle (including plug-ins) buyers were as high as USD 8 500 throughout

[6] Globally, Norway and the Netherlands had the largest EV market shares in 2014 and 2015 (IEA, 2015a and IEA, 2016b), but neither Norway nor the Netherlands were included in the selection of countries discussed in this analysis.

the year 2014 (APEC, 2014). In France, consumers enjoyed a rebate of up to EUR 6 000 on an EV purchase (MEEM, 2016). IEA (2016b) provides more detailed information on the evolution of the electric vehicle market, including an update to 2015.

In addition, the possibility of charging EVs either at publicly available or private charging points plays a substantial role in consumer acceptance and the decision of whether to purchase an EV.

Sales shares of electric vehicles by vehicle segment by country for the year 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The figure above provides an overview of the shares of hybrid and plug-in electric vehicles registration by vehicle segment in 2013.

Large hybrids such as the Hyundai Sonata Hybrid, the Kia K5 Hybrid or the Toyota Camry Hybrid were most common in South Korea and the United States, while in other markets medium-sized hybrids such as the Toyota Prius were more common. In France and Germany, small and relatively expensive hybrids such as the Toyota Yaris Hybrid have a high market share – over 20% of hybrids sold were small-sized.

Plug-in electric cars are the higher-end of medium and large vehicle segments in all countries. With a high sales share commanded by the Tesla Model S, battery electric vehicles have a high sales share in the large vehicle segment in the US, while small cars such as the Renault Zoe or the BMW I3 have a higher market share in France and Germany. In order to achieve higher total market shares, battery electric vehicles will need to expand into the medium-size vehicle segment, where they would compete with models with higher average prices than those of small vehicles.

Country reports

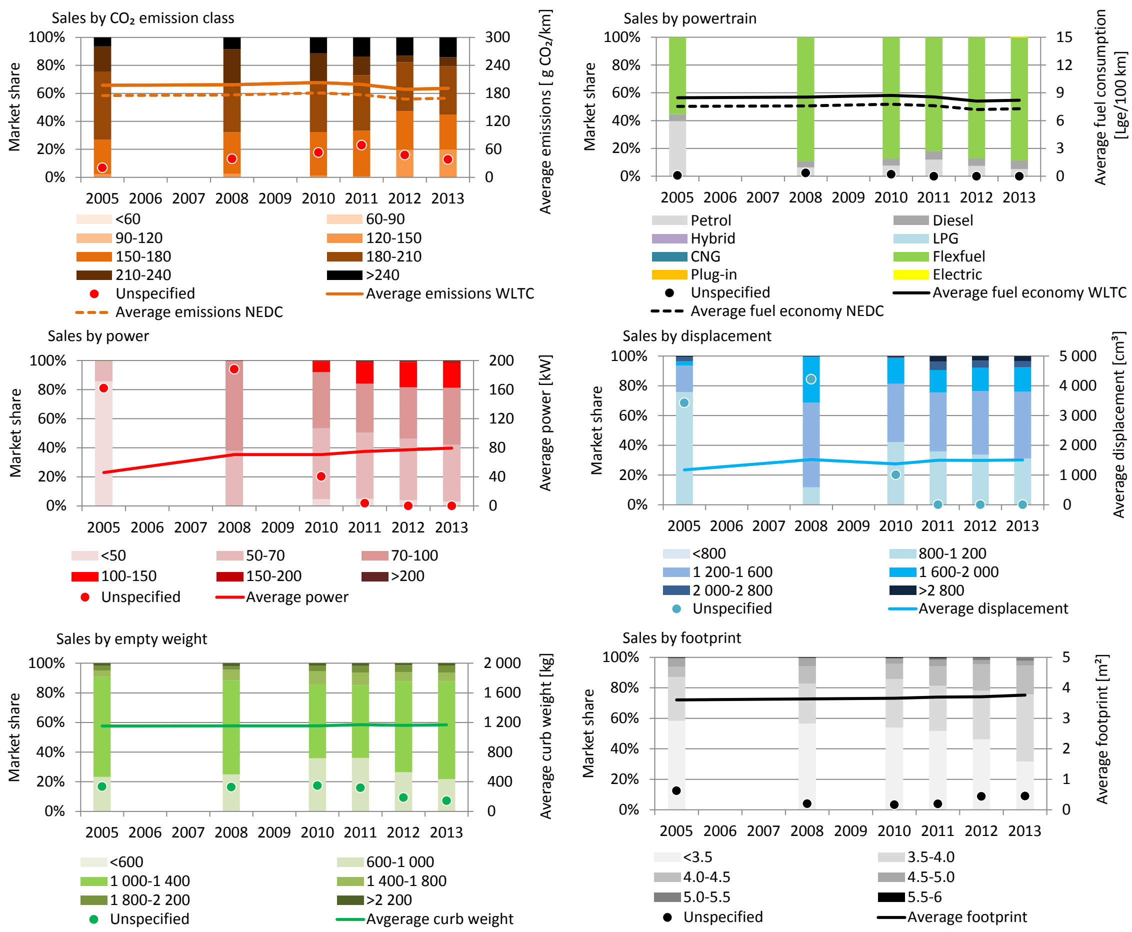
Brazil

Country spotlight

Population (million) (World Bank, 2016a):	206.1
Share of urban population (World Bank, 2016b):	86%
GDP per capita (2014 USD/year) (World Bank, 2016c):	11 400
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	127
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	102
Fuel tax class (2014) (GIZ, 2015):	Taxed petroleum fuels

In 2013, about 3.6 million LDVs were sold in Brazil (IHS Polk, 2014), making it the biggest Latin American car market. The LDV stock totalled 34 million registered vehicles (IEA, 2016a) and car ownership was roughly 0.17 vehicles per capita. In 2012, the government approved a program to foster the adoption of more efficient vehicles. Manufacturers and importers meeting a CAFE target benefit from a tax reduction on industrial products of up to 30%. When fuel economy targets are met, this tax reduction effectively offsets the 30% rate that was established before the introduction of the fuel economy regulation (TransportPolicy, 2016). Due to the success of a government program promoting biofuels that began in 1975, bioethanol accounted for 18% the total road transport fuel use in 2013 (IEA, 2015b). A voluntary label informing consumers about vehicle fuel economy performance of vehicle models was introduced in 2007 (ICCT, 2014b).

Figure 12 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

With 3.6 million new LDVs registered (IHS Polk, 2014) and a domestic production of almost 3.8 million cars (OICA, 2016), Brazil was the fourth biggest single country market and the seventh biggest car producer worldwide in 2013. The local car market is dominated by foreign OEMs, which have large production capacities in the country. The four market leaders (Fiat, GM, Volkswagen and Ford) accounted for 66% of the market in 2014.

CO_2 emissions per unit LDV travel (Figure 12, top left) averaged 190 g CO_2 per km in 2013 (without accounting for the mitigation effect of biofuels). Between 2005 and 2013, average emissions remained roughly constant. The increased market share of vehicles emitting up to 150 g CO_2 per km was offset by a similar increase in the share of cars with emissions greater than 240 g CO_2 per km. With an average new LDV fuel consumption of 8.2 Lge/100 km (Figure 12, top right), the fuel consumption of Brazilian cars was on average about 6% higher than the world average.

Due to the National Alcohol Program (Proàlcool, created in 1975 and enabling the production of ethanol as transport fuel from sugarcane), gasoline blended with anhydrous ethanol (with shares between 18% and 25%) is widely available in Brazil, allowing for blending of hydrous ethanol (also available as transport fuel) in any ratio. Flex-fuel vehicles (i.e. vehicles which are able to use variable shares of gasoline and ethanol) reached market shares of more than 50% already in 2005 (Figure 12, top right). By 2013, their share increased to almost 90%, thanks to almost universal availability across vehicle models. New registrations of hybrids, CNG and LPG vehicles were marginal compared with other technologies.

Over time, average engine power and engine displacement increased (Figure 12, centre). From 2010 to 2013, new registrations of cars with an engine power of more than 100 kW almost doubled, and the sales share of vehicles with an engine displacement of less than 1.2 L declined markedly. Compared to other developed markets, Brazilian new car sales are less powerful and have smaller engines.

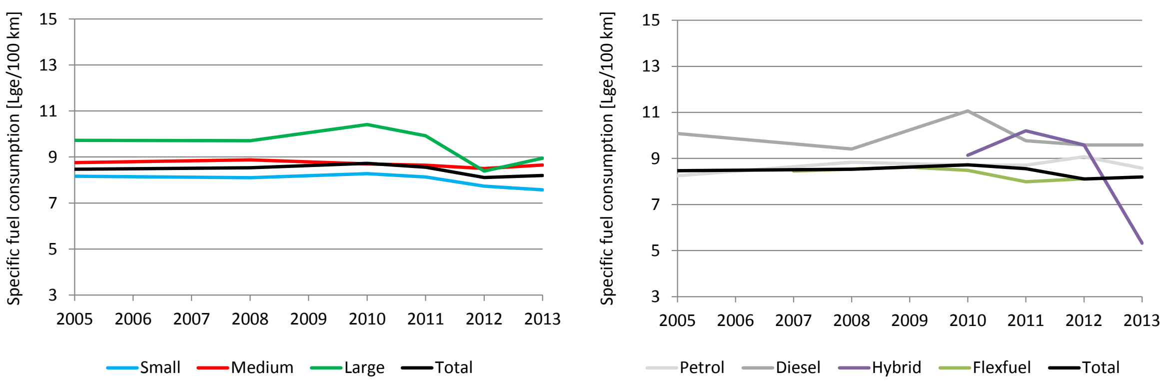
Between 2005 and 2013, the average empty vehicle weight and footprint remained roughly constant (Figure 12, bottom). The share of vehicles with an empty weight up to 1 000 kg and a footprint of below 3.5 m² significantly decreased, but the average vehicle weight remained close to 1 200, and the average footprint increased only slightly to 3.8 m² in 2013. This makes the Brazilian new LDV fleet one of the smallest and lightest within the subset of countries analysed in this report.

Analysis of fuel economy trends

The average specific LDV fuel consumption decreased by only 4% between 2005 and 2013, from 8.5 Lge/100 km to 8.2 Lge/100 km (Figure 13 right). Fuel consumption by vehicle segment showed only slight variations in Brazil (Figure 13, left). Diesel engines had a minor market share, which was confined primarily to large segments: this explains why the average fuel consumption of diesel cars is significantly higher than it was for petrol and flex-fuel vehicles (Figure 13, right). As in many other countries, fuel economy improvements from 2005-13 were greatest in the large vehicle segment. This is consistent with fuel economy savings coming at lower marginal costs for large vehicles, as well as larger margins generally available for OEMs on large cars.

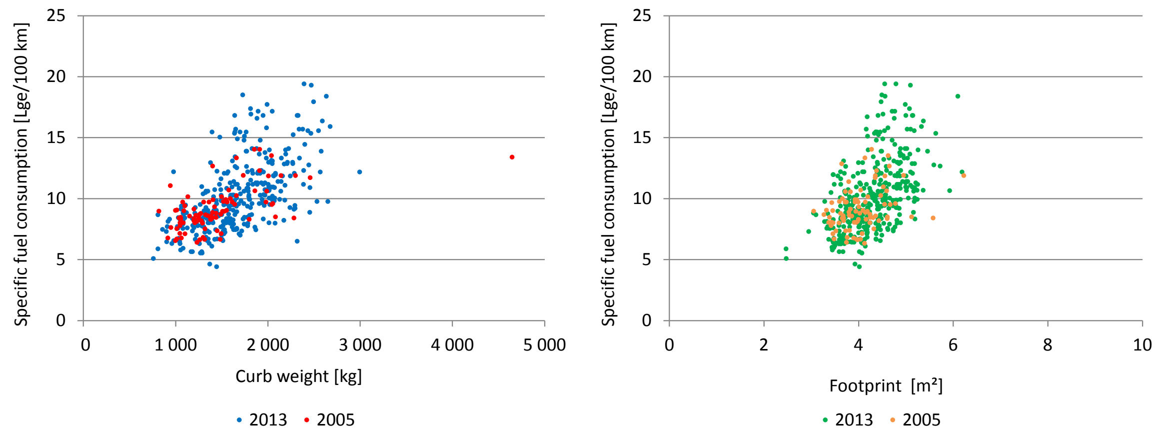
The stability of average fuel economy, empty weight and footprint between 2005 and 2013 does not imply that Brazilian LDV market structure did not evolve. Plotting the specific fuel consumption against vehicle empty weight and footprint (Figure 14) shows no clear pattern towards improved fuel economy, but does clearly show that the spread between cars with fuel efficiencies well below and well above the national average widened over time.

Figure 13 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

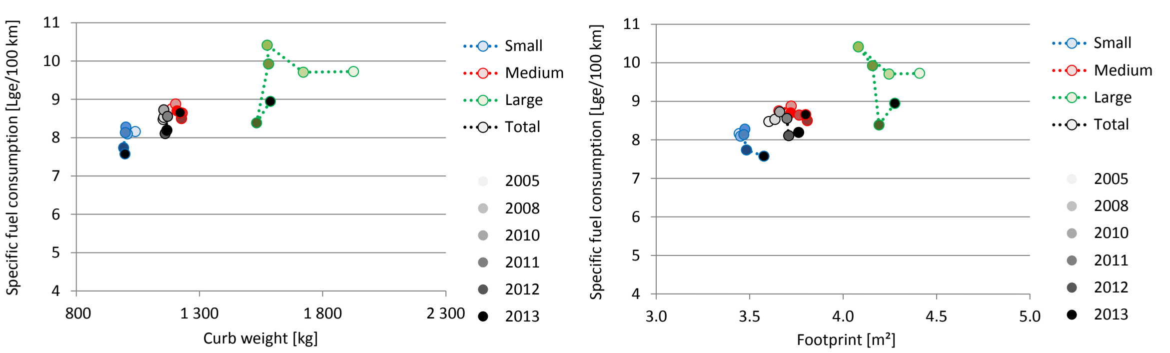
Figure 14 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Figure 15 shows no clear trend towards light-weighting or size reductions: larger vehicles were the only segment that became notably lighter and slightly more efficient from 2005 to 2011, though this trend slowed down and even reversed somewhat in 2012 and 2013. Generally, Brazilian cars were less fuel efficient than cars sold in many other developed markets, despite being much lighter, smaller and less powerful. This suggests that comparatively large potential exists in the Brazilian LDV new sales fleet for improving fuel economy (by adopting more efficient vehicle technologies) compared with OECD economies. The next edition of this report will show the degree to which the measures adopted in 2012 with the aim of reducing average fleet fuel consumption have attained this goal.

Figure 15 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

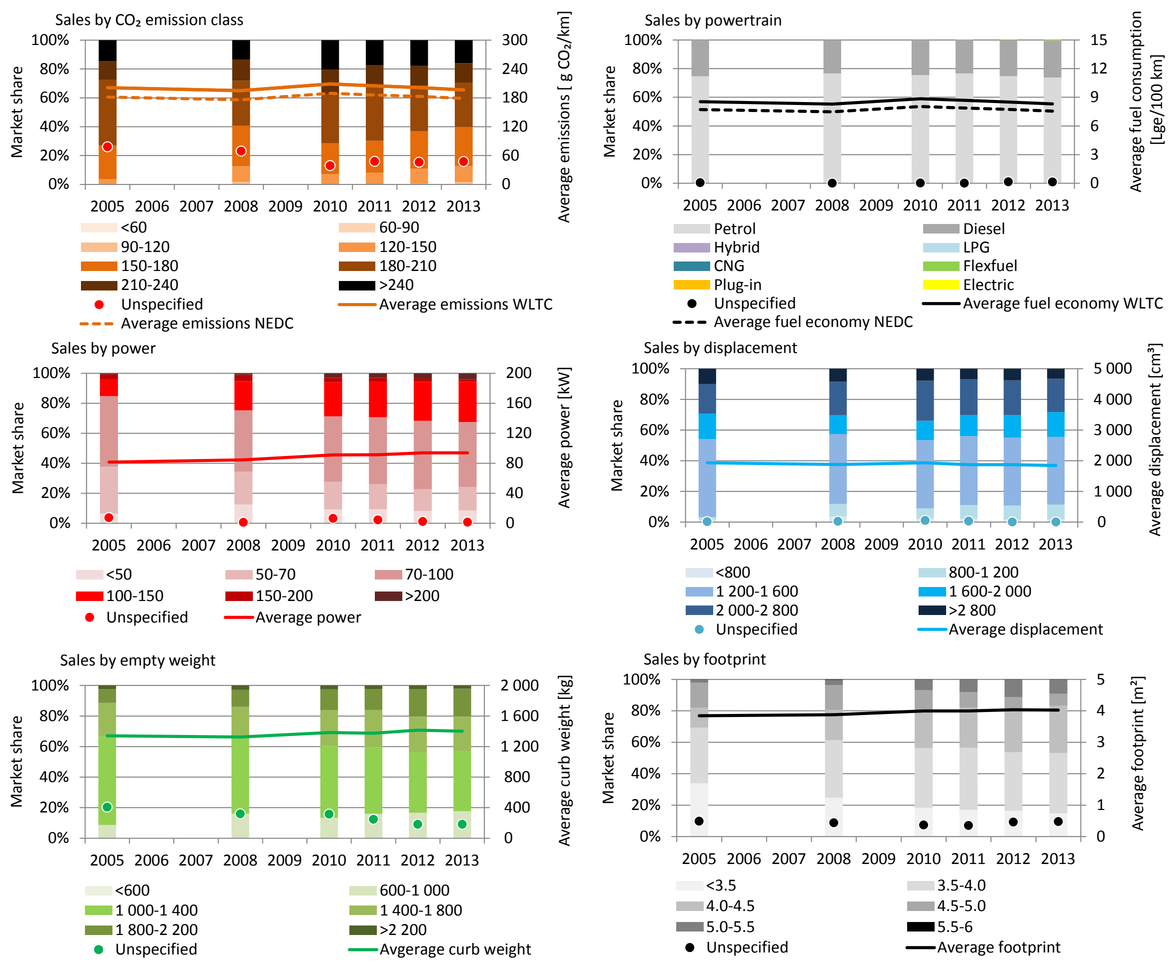
Chile

Country spotlight

Population (million) (World Bank, 2016a):	17.8
Share of urban population (World Bank, 2016b):	89%
GDP per capita (2014 USD/year) (World Bank, 2016c):	14 500
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	152
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	109
Fuel tax class (2014) (GIZ, 2015):	Highly taxed petroleum fuels (gasoline)

In 2013, about 380,000 LDVs were sold in Chile (IHS Polk, 2014), while around 3 million LDVs had been registered (IEA, 2016a). Car ownership was slightly less than 0.17 cars per capita. Since 2012, vehicle labels providing information on fuel economy and pollutant emissions to consumers have been obligatory (Lopez, 2014). In 2014 the Chilean Congress also approved a tax reform introducing progressive fees (GFEI, 2015a; Lopez, 2014) on vehicles for which specific fuel consumption and pollutant emissions surpass a certain threshold. As a result, diesel vehicles with high NO_X emissions are strongly taxed.

Figure 16 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

From 2008, Chile has no domestic car production and domestic industry is limited to the supply of automotive parts (KPMG, 2014). The Chilean car market is dominated by Korean, Japanese and American OEMs.

Similar to Brazil, the Chilean new vehicle market showed almost no emission improvement over the 2005-13 timeframe. The average CO_2 emissions per kilometre were almost 200 g CO_2 per km (Figure 16, top left) in 2013. From 2010 to 2013, the average carbon emissions per km decreased by 6%. This is primarily due to the recent uptake in sales of cars with specific CO_2 emissions of less than 150 g CO_2 per km. Contrary to Brazil, the share of sales in the vehicle segment with emissions above 240 g CO_2 per km decreased from 2010 to 2013. In 2013, the average LDV fuel consumption in Chile was about 8.3 Lge/100 km, 7% higher than the world average (Figure 16, top right).

The share of diesel cars remained almost constant at 25% of the total market (Figure 16, top right). New registrations of hybrids, CNG and LPG vehicles remained negligible between 2005 and 2013. Due to the recent introduction of a vehicle registration tax (GFEI, 2015A; Lopez, 2014), affecting primarily diesel vehicles, the sales share of diesel cars is likely to decrease in the coming years.

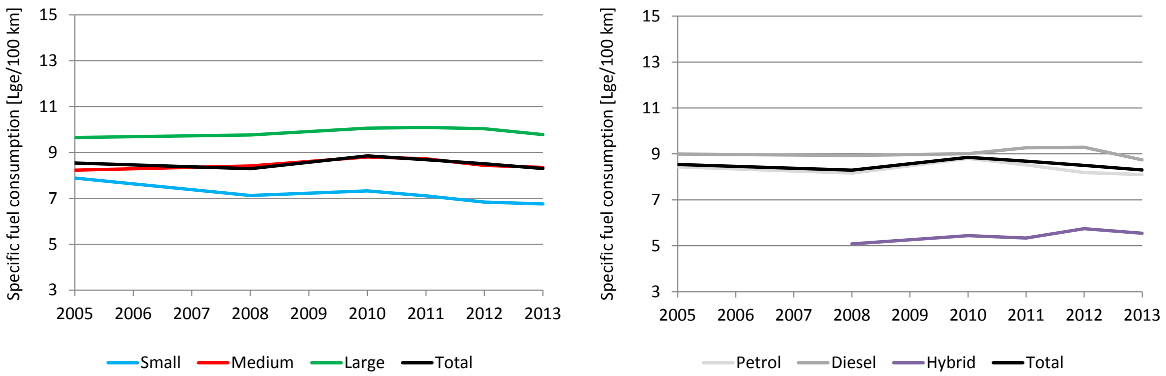
The average power of new LDVs increased by 15% between 2005 and 2013, while engine displacement remained constant (Figure 16, centre). This is attributable to an increased uptake of more advanced engine technologies, which however were not adopted with the goal of delivering fuel savings. Increasing average vehicle empty weight and footprint between 2005 to 2013 (Figure 16, bottom) implies that technologies delivering (though not necessarily targeting) fuel economy improvements have been instrumental in accommodating structural changes in the market (the market segment of cars weighting between 1 800 to 2 200 kg almost doubled, reflecting the increased popularity of SUVs and pick-up trucks) without augmenting average fuel consumption.

With an average power of about 94 kW, Chilean cars are similarly powerful to vehicles sold in the European Union. The average fuel consumption of Chilean vehicles (8.3 Lge per 100 km), however, is significantly higher than the EU average (about 5.5 Lge per 100 km). This large difference (almost 50%) suggests that there a large potential for increased deployment of fuel-saving technologies.

Analysis of fuel economy trends

In Chile, the biggest fuel economy improvement occurred in the small vehicle segment, which was dominated by Korean and Japanese models (Figure 17, left). Diesel engines mainly equipped large passenger cars, pick-up trucks and LCVs. The larger weight and footprint of these market segments offset the better technical efficiency of diesel engines, resulting in a slightly higher specific fuel consumption of diesels compared with gasoline LDVs (Figure 17, right).

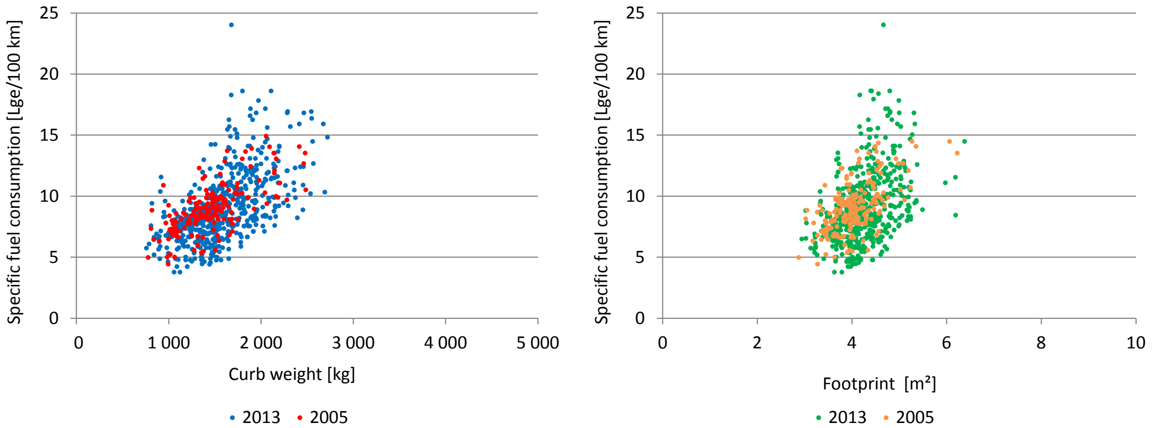
Figure 17 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The cloud of specific vehicle fuel consumption plotted against empty weight and footprint (Figure 18) reveals a slight improvement of fuel economy at a given weight and footprint level, as the 2005 cloud shifted vertically and downwards yields the 2013 cloud. Figure 18 also shows a general trend towards heavier and larger cars, demonstrated by a higher density of points representing 2013 models on the right side of the figures. As in the case of Brazil, the wider vertical distribution of points on both plots shows that the vehicle market became more diverse between 2005 and 2013.

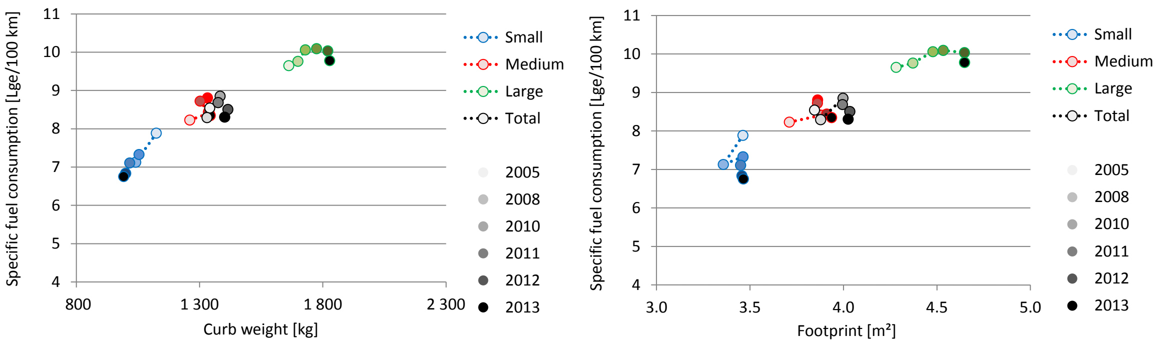
Figure 18 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

While average weight and footprint of the new LDV fleet as a whole increased, Figure 19 suggests that there was a clear tendency towards smaller and lighter in the large and small vehicle segments. Buyers of smaller and larger vehicles seem to have paid more attention to the fuel economy label than those of medium-sized and large cars, possibly due to higher sensitivity to fuel costs (e.g. stricter budget constraints in the case of buyers of small cars, and a higher relevance in the total cost of ownership in the case large car buyers).

Figure 19 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

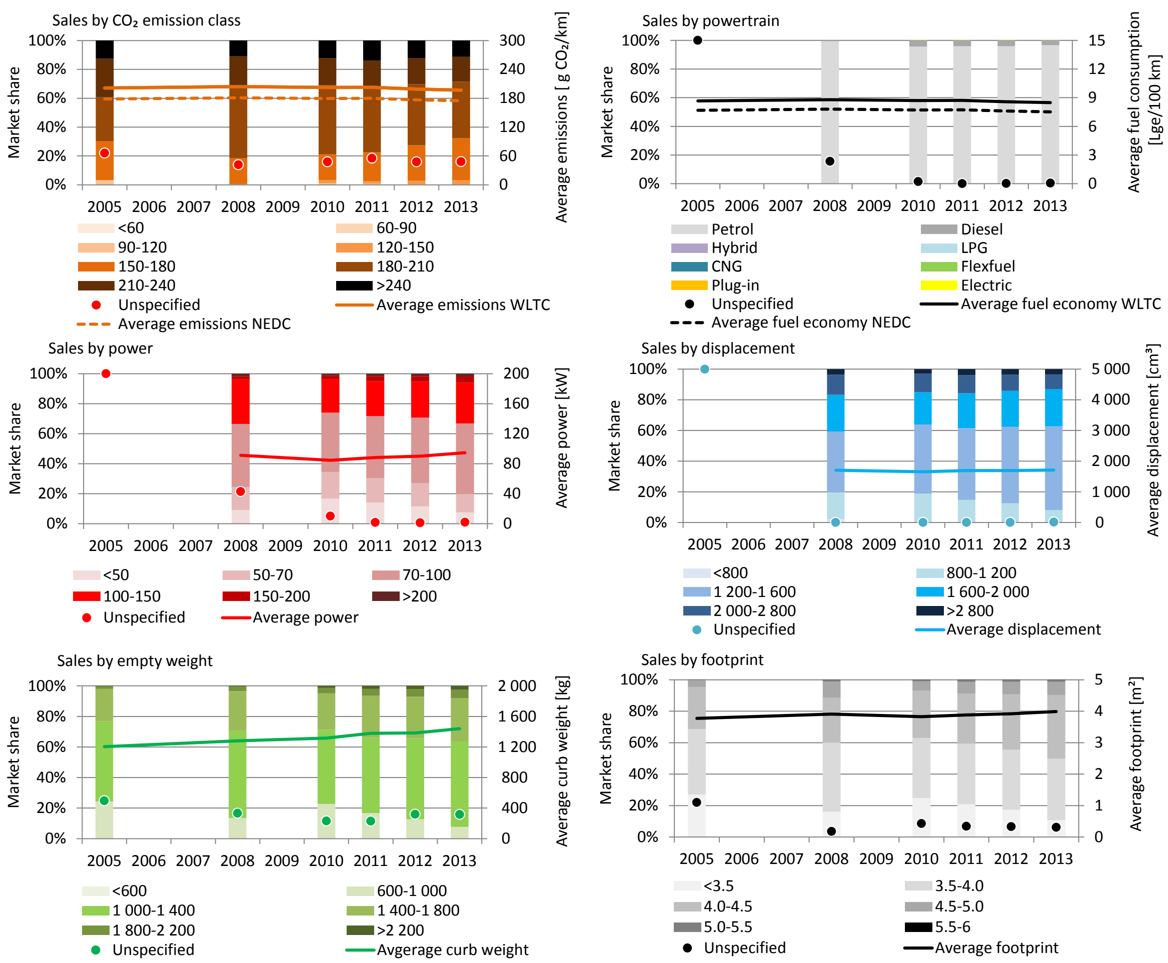
China

Country spotlight

Population (million) (World Bank, 2016a):	1,364
Share of urban population (World Bank, 2016b):	55%
GDP per capita (2014 USD/year) (World Bank, 2016c):	7 600
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	117
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	109
Fuel tax class (2014) (GIZ, 2015):	Taxed petroleum fuels

In 2013, more than 18 million LDVs were sold in China (IHS Polk, 2014), making it the world's largest car market. The Chinese on-road LDV stock reached about 92 million cars in the same year (IEA, 2016a). Car ownership is still very low compared with OECD economies at about 0.07 cars per capita. Fuel economy regulations for passenger cars were first introduced in 2005. During Phase I and Phase II, individual models were required to meet specific thresholds, which were differentiated on the basis of vehicle weight. Corporate average fuel consumption targets were established with the introduction of Phase III (2012-15). Phase IV, which took effect on January 1st 2016, target a new sales fleet average specific fuel consumption of 5 L/100 km by 2020 (based on the NEDC) (TransportPolicy, 2016). LCVs are subject to standards that differ both in terms of target value and compliance structure: individual LCV models are still subject to fuel consumption targets (TransportPolicy, 2016). Labels showing fuel economy, fuel type, rated power and empty weight, among other information, were made mandatory for passenger cars in 2009 (ICCT, 2014b).

Figure 20 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2009 China became the single largest car market in the world (OICA, 2016). In 2010, Chinese LDV sales overtook those of the entire European Union. In 2013, more than 60% of LDVs sold in China were produced in China based on joint ventures between foreign brands and Chinese companies. Very few foreign manufactured cars are directly imported.

Between 2005 and 2013, average CO_2 emissions per km of new LDVs declined by only 2%, from 201 g CO_2 per km to 197 g CO_2 per km (Figure 20, top left). At the same time, the volume of China's new car market grew fourfold, from 3.7 million to 18.3 million LDVs. The average fuel consumption of newly registered Chinese LDVs in 2013 was 8.5 Lge/100 km, 9% above the world average (Figure 20, top right).

Chinese LDVs use mainly gasoline engines: diesels represented less than 5% of new registrations in 2013. Sales shares of hybrids and vehicles using alternative fuels are negligible (Figure 20, top right).

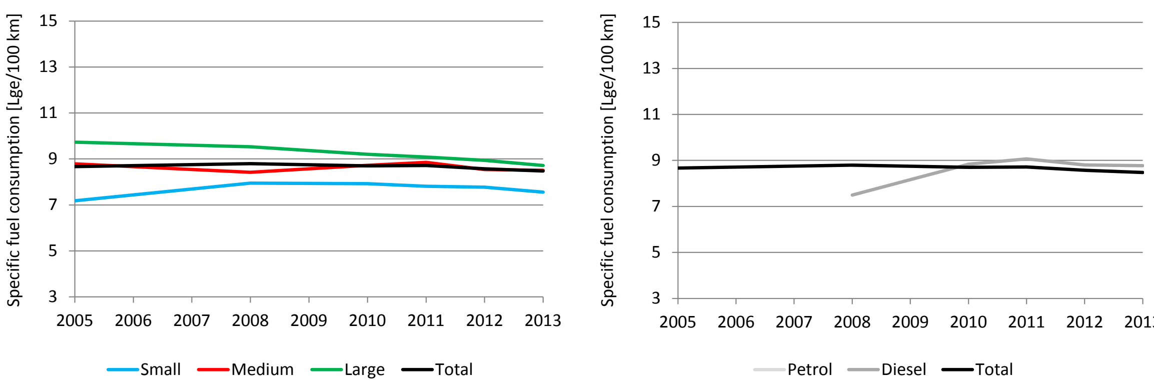
From 2010 to 2013, the average power and displacement of Chinese new car sales has increased (Figure 20, centre). Prior to 2010, when market growth rates were highest, many smaller and less powerful cars entered the market. In recent years, market segments with engine power above 100 kW saw the greatest growth in market share. The share of new registrations of small LDVs, having less than 50 kW engine power or less than 1.2 L engine displacement (often small multi-purpose vehicles), more than halved since 2010.

The average vehicle size increased slightly from 2005 to 2013, driven by the expansion of the segment of cars with a footprint of 4 to 4.5 m² (upper middle class cars, e.g. Audi A4). The growth of the average vehicle weight was remarkable. Weight went up by 20% from 2005, reaching 1 400 kg in 2013 (Figure 20, bottom).

Analysis of fuel economy trends

Figure 21 (left) shows that the majority of the fuel economy improvements occurred in the large vehicle segment. The fuel consumption of medium-sized cars stayed almost constant, while specific fuel consumption of small cars increased due to an upward size shift within the segment. The market share of SUVs declined in the past decade, leading to a smaller spread, in 2013, between fuel consumption of large and medium-sized cars. As in the case of Brazil, the small share of diesel vehicles and the high focus on the large market segment (mostly LCVs or SUVs) explain the higher specific fuel consumption of diesel vehicles compared with gasoline-fuelled cars (Figure 21, right).

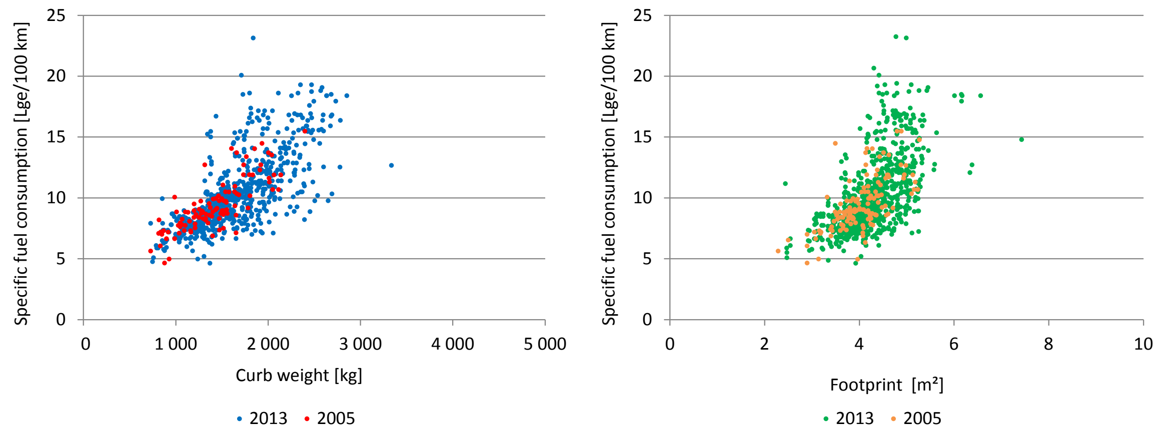
Figure 21 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting vehicle fuel consumption against empty weight reveals no overall fleet improvement between 2005 and 2008 (Figure 22). The distribution of fuel consumption by vehicle weight is narrower than in other countries. This reflects the characteristics of weight-based fuel consumption regulation effective under the Phase I and Phase II fuel economy standard (2005 – 2009), which excluded vehicles with performance exceeding a certain threshold from the market.

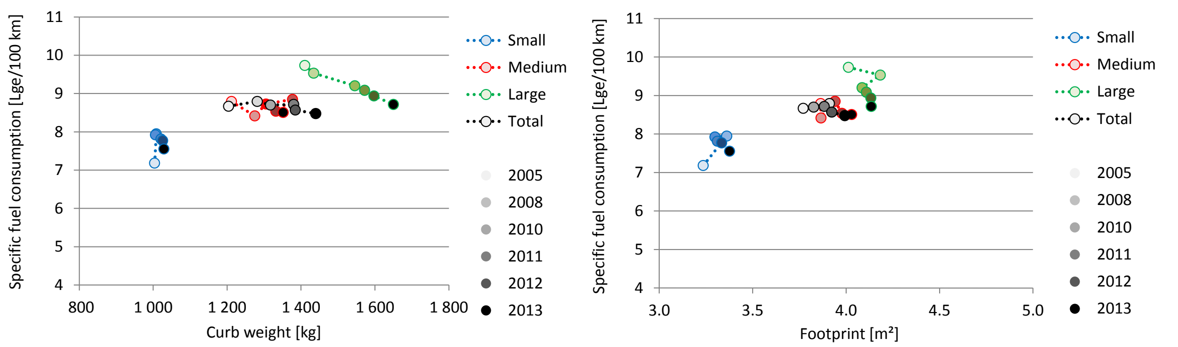
Figure 22 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting specific fuel consumption against weight and footprint for the main vehicle segments (Figure 23) shows that both weight and footprint increased across the whole market while fuel consumption slightly decreased between 2005 and 2013. This suggests that technology deployment has not been primarily targeted towards fuel economy improvements. More stringent fuel economy standards specifically targeting medium and large vehicle segments have the capacity to mitigate these trends in the future.

Figure 23 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

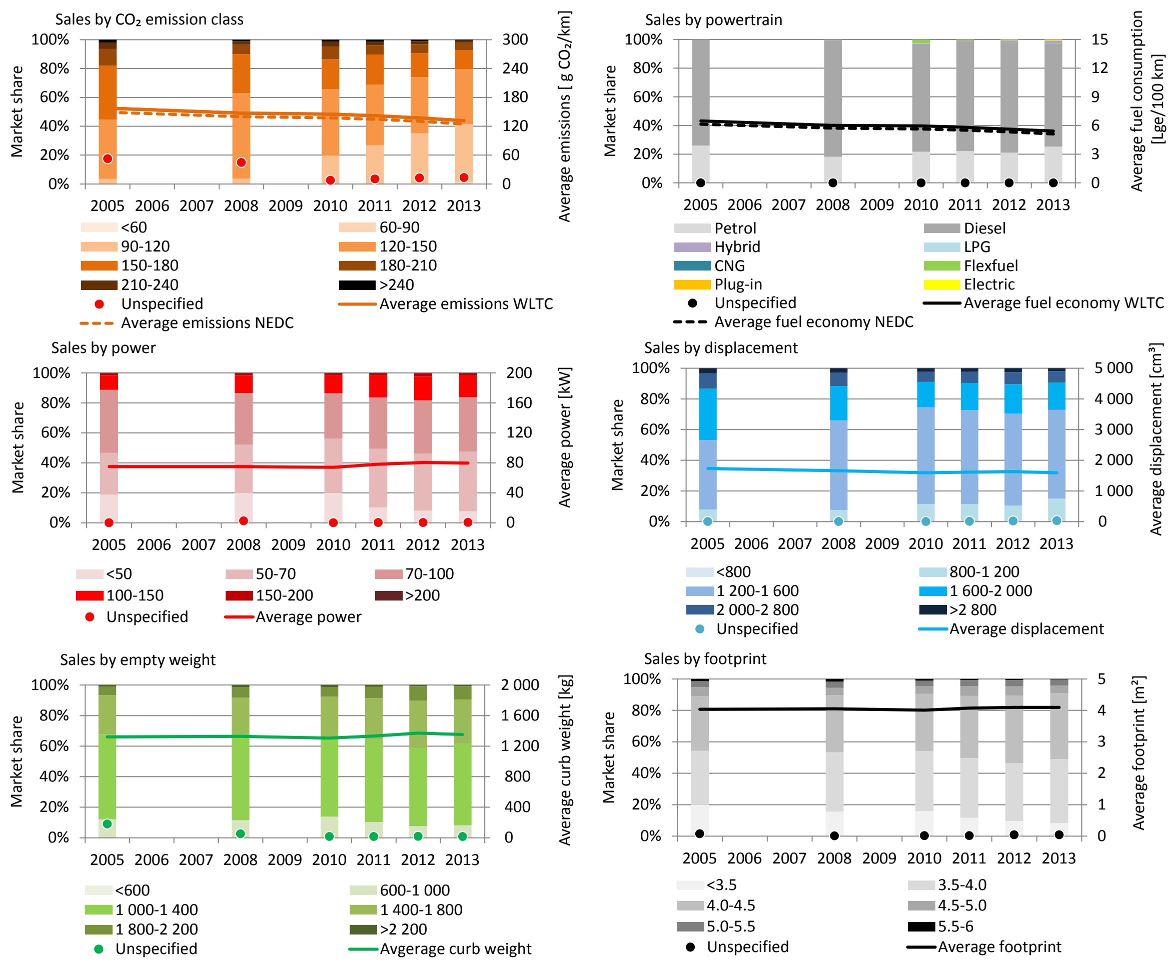
France

Country spotlight

Population (million) (World Bank, 2016a):	66.2
Share of urban population (World Bank, 2016b):	77%
GDP per capita (2014 USD/year) (World Bank, 2016c):	42 700
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	179
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	163
Fuel tax class (2014) (GIZ, 2015):	Highly taxed petroleum fuels

In 2013, more than 2.1 million LDVs were sold in France (IHS Polk, 2014). The on-road vehicle stock accounted for about 32 million cars (IEA, 2016a), and car ownership averaged approximately 0.48 cars per capita. Voluntary CO_2 emission standards were first introduced in the European Union in 1998, and they became mandatory in 2009. The 2015 target of 130 g CO_2/km for passenger cars was met in advance in the case of France (EEA, 2015). By 2021, CO_2 emissions of passenger cars should reach 95 g CO_2/km (based on NEDC), and those of LCVs are required to attain 147 g CO_2/km (based on NEDC) (TransportPolicy, 2016). In addition to the EU emission standards, France introduced in 2008 (and revised on a regular basis in following years) a feebate scheme that redistributes revenues from taxation on vehicles with poor fuel economies to vehicles with superior performance. In its latest update, fees can reach up to EUR 8 000, while rebates can be as high as EUR 6 000 per vehicle (MEEM, 2016). A label that displays specific fuel consumption, CO_2 emissions and efficiency class was made mandatory in France in 2002 (Ricardo AEA, 2011).

Figure 24 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

France is the second largest vehicle market and vehicle producer, after Germany, in the European Union. It is home to the car manufacturers PSA (Peugeot Citroën) and Renault-Nissan. In 2013, about 55% of new LDVs sold in France were produced by these OEMs.

In 2013, France was the country with the lowest weighted average LDV emissions among those countries covered in this report, with 132 g CO_2/km (NEDC: 125g CO_2/km) (Figure 24, top left). The average fuel consumption of all LDVs was 5.5 Lge/100 km, more than 30% below the world average of 7.8 Lge/100 km (Figure 24, top right). Between 2005 and 2013, CO_2 emissions decreased by 16%. In 2013, more than 40% of all newly registered LDVs had specific emissions of less than 120g CO_2/km. The high market share of low-emission vehicles is the result of the combination of stringent EU emission targets, the success of the French feebate scheme, and the historic preference of French consumers for relatively small and less powerful cars.

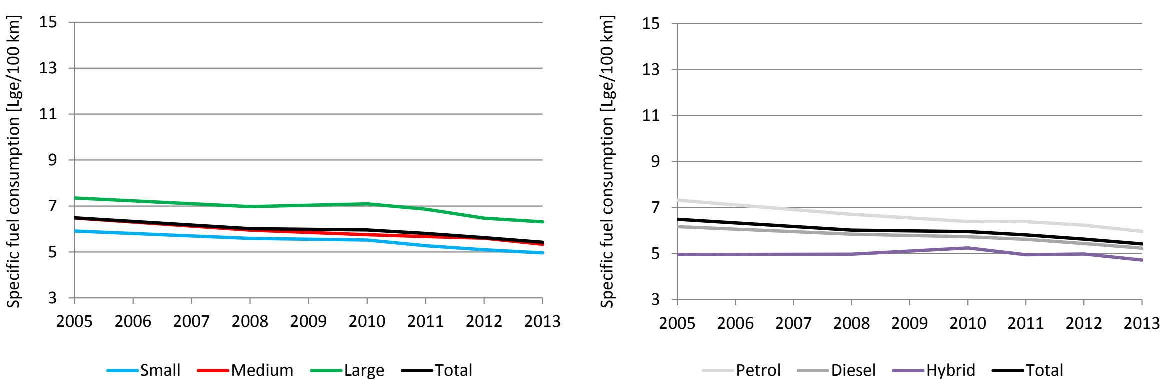
The market share of diesel cars was very high in France, and reached its all-time-high in 2008, when diesels accounted for more than 80% of all newly registered cars (Figure 24, top left). Since then, the share of diesels has declined, but at a market share of about 75% in 2013, France was still is the country with the highest diesel share worldwide. The preference of French consumers for diesel cars is based on the long history of diesel engine development, the differentiated taxation of gasoline and diesel and the incentives for lower-emission vehicles provided through the feebate scheme. In 2013, hybrids (mainly the Toyota Prius) accounted for a market share of about 2%. Government incentives contributed to the registration of about 15 000 battery electric and plug-in hybrid cars in 2013.

Between 2005 and 2013 average power increased by 6%, while average displacement decreased by 8% (Figure 24, centre right). At an average power of 80 kW in 2013, France was among the countries with the least powerful new vehicle fleet. In 2013, more than 75% of all new LDVs entering the French market had an engine displacement below 1.6 L.

The empty weight and footprint of new LDVs remained almost constant from 2005 to 2013, despite the fact that market shares of vehicles weighing less than 1 000 kg and with a footprint less than 3.5 m² dropped by almost 50% (Figure 24 bottom right).

Analysis of fuel economy trends

Figure 25 • Average new LDV fuel economy by vehicle segment and powertrain, 2013

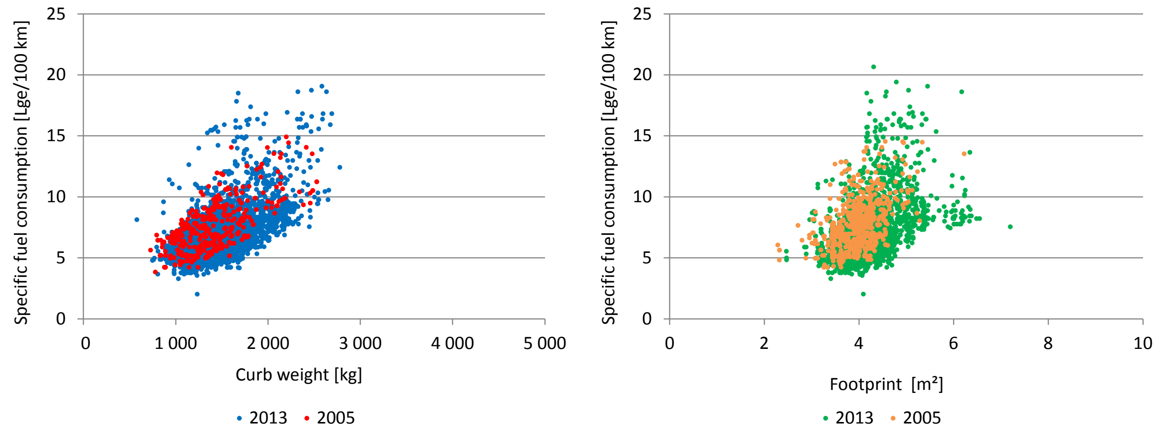


Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Figure 25 (left) shows that all vehicle segments contributed to fuel economy improvements. Gasoline and diesel vehicles also achieved roughly equivalent fuel consumption reductions between 2005 and 2013. The average fuel consumption of diesel cars is well below that of gasoline-fuelled vehicles (Figure 25, right). This is consistent with high diesel shares, even in small market segments. The specific fuel consumption of hybrids is lower than that of gasoline and diesel vehicles. Its evolution over time is influenced by the small market share of hybrid and is therefore not representative of established trends.

The clouds plotting specific fuel consumption as a function of empty weight and footprint in 2005 and 2013 (Figure 26) reveal a clear trend towards reduced fuel consumption at similar weight and footprint levels and do not show a shift towards lighter or smaller cars.

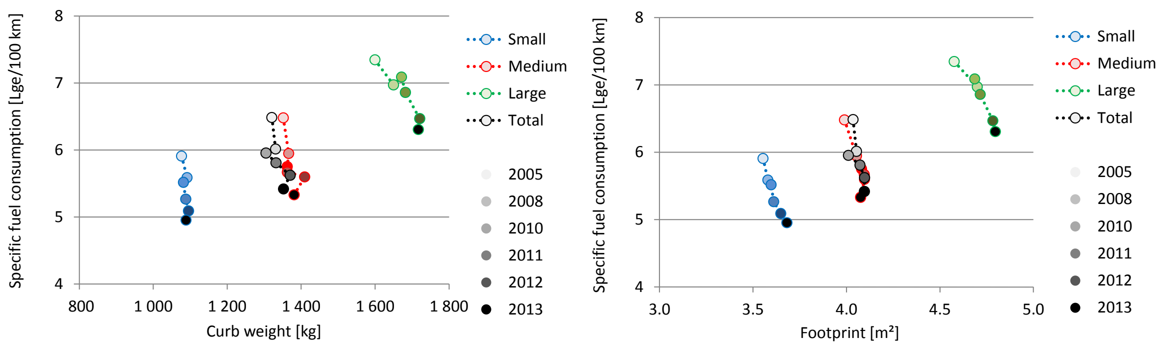
Figure 26 • New LDV fuel economy over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting average specific fuel consumption against empty weight and footprint by segment (Figure 27) clearly shows the impact of fuel economy policies. Fuel economy improved significantly over time, even in the absence of a shift to smaller vehicles. The average size of cars in the small vehicle segment increased while maintaining roughly the same average weight, revealing some reliance on light-weighting technologies. In the larger vehicle segments, vehicle weight and size grew approximately proportionately.

Figure 27 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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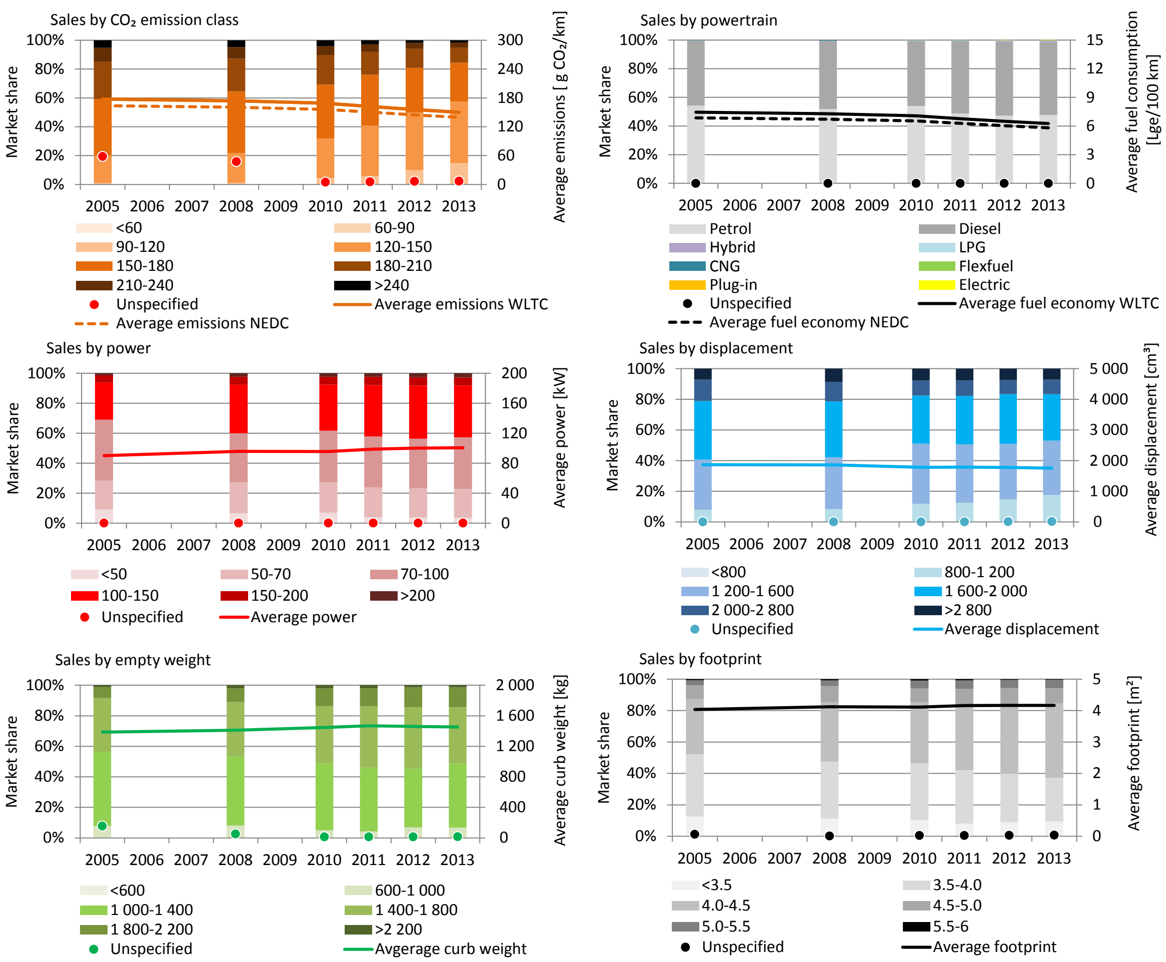
Germany

Country spotlight

Population (million) (World Bank, 2016a):	80.9
Share of urban population (World Bank, 2016b):	75%
GDP per capita (2014 USD/year) (World Bank, 2016c):	47 800
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	180
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	158
Fuel tax class (2014) (GIZ, 2015):	Highly taxed petroleum fuels

In 2013, about 3.2 million LDVs were sold in Germany (IHS Polk, 2014). The German LDV stock accounted for about 44 million cars in the same year (IEA, 2016a), implying car ownership of around 0.55 cars per capita. Voluntary CO_2 emission standards were first introduced in the European Union in 1998 and became mandatory in 2009. By 2021, CO_2 emissions of passenger cars must attain 95 g CO_2/km (based on NEDC), and those of LCVs are required to reach 147 g CO_2/km (based on NEDC, TransportPolicy, 2016). In Germany cars are subject to an annual vehicle circulation taxes based on engine displacement, CO_2 emissions and pollutant emission class (e.g. Euro 5 or Euro 6). Furthermore, gasoline and diesel fuels are taxed differently, with diesel being on average 12% cheaper per litre at the station. New vehicles have been required to have a label showing specific fuel consumption, CO_2 emissions and efficiency class since 2004 (Ricardo AEA, 2011).

Figure 28 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2013, Germany was the biggest European car market and the fifth largest car market worldwide (IHS Polk, 2014). With 5.4 million cars produced (OICA, 2016), Germany ranked third among car producing countries, following China and Japan and preceding the United States. Germany is home of major automotive OEMs, including BMW, Daimler and Volkswagen.

The weighted average of LDV emissions per kilometre declined 15% from 2005 to 2013, reaching 150 g CO_2/km in 2013 (Figure 28, top left). The average specific fuel consumption of new vehicles registered in Germany was 6.3 Lge/100 km in 2013, a value significantly below the world average of 7.8 Lge/100 km, but well above the EU average of 5.5 Lge/100 km (Figure 28, top right). In Germany, emission reductions and fuel economy improvements accelerated markedly following the introduction of mandatory EU standards, in 2009. Between 2010 and 2013, the sales share of vehicles emitting more than 180 g CO_2/km decreased by almost 50%. At the same time, the share of new registrations of cars with emissions below 120 g CO_2/km more than doubled.

The shares of vehicles using gasoline and diesel engines were almost equal in 2013 (Figure 28, top right). Compared with other OECD economies, the share of hybrid vehicles is low – only 0.8% of all new LDVs registrations were hybrids in 2013. No government incentives existed for battery electric and plug-in vehicles in 2013. As a result, sales of electric cars reached only 7 900 vehicles in 2013: this was about half the volume of the French electric vehicle market. Although CNG models are available from various manufacturers, the CNG refuelling network totals about 1 000 stations in Germany, and despite the fact that tax incentives for CNG vehicles are in place, only 8 800 CNG cars were sold in 2013.

Average engine power increased by 12% between 2005 (90 kW) and 2013 (100 kW) (Figure 28, centre), making German vehicles more powerful than the world average. Engine displacement decreased by 6%, from almost 1.9 L to 1.8 L in the same time period. The opposing trends of for power and displacement have been made possible by engine downsizing technologies. This is also demonstrated by the significant growth of new registrations of vehicles with an engine capacity of below 1.2 L (for which the market share more than doubled between 2005 and 2013, when it reached almost 20% of the entire LDV market).

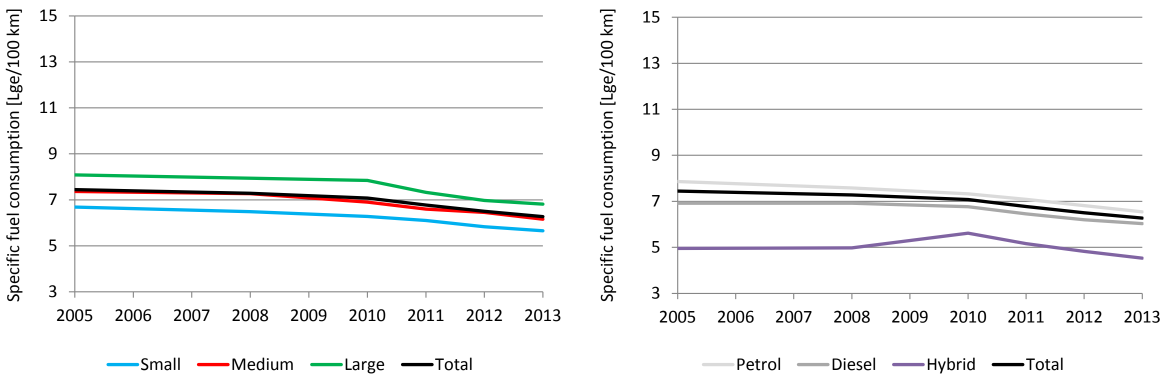
Both the average vehicle weight and footprint increased between 2005 and 2013 (Figure 28, bottom), primarily because of a shift from the smallest and lightest vehicle categories towards medium and large weight and footprint segments. In the case of weight, 2013 was marked by a trend reversal.

Analysis of fuel economy trends

As in the case of France, all vehicle segments contributed to fuel economy improvements in Germany (Figure 29, left). The introduction of mandatory emission standards across Europe in 2009 is especially visible in the large car segment: from 2010 onwards, fuel economy improved at a much faster rate in this segment. Average fuel consumption of gasoline cars is only slightly higher than that of diesel cars (Figure 29, right). This is consistent with a higher diesel penetration in large market segments, which partially offsets the fuel savings provided by the better technical efficiency of diesel engines.

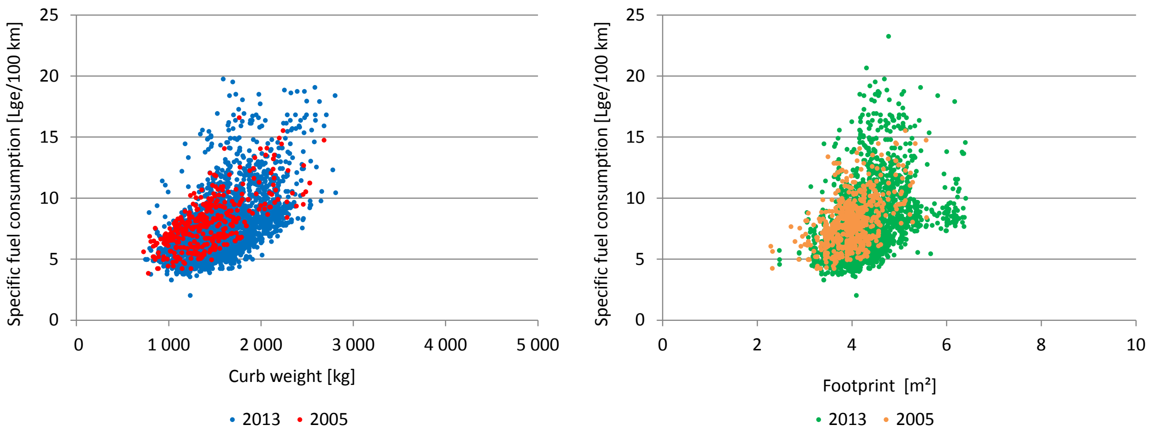
The cloud of points representing vehicle fuel consumption as a function of empty weight and footprint for individual models (Figure 30) reveals a clear improvement of fuel economy at a given weight or footprint. By 2013, the data points are subject to a sizeable vertical shift. Contrary to the case of France, there is no global trend towards lighter and smaller cars in Germany.

Figure 29 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

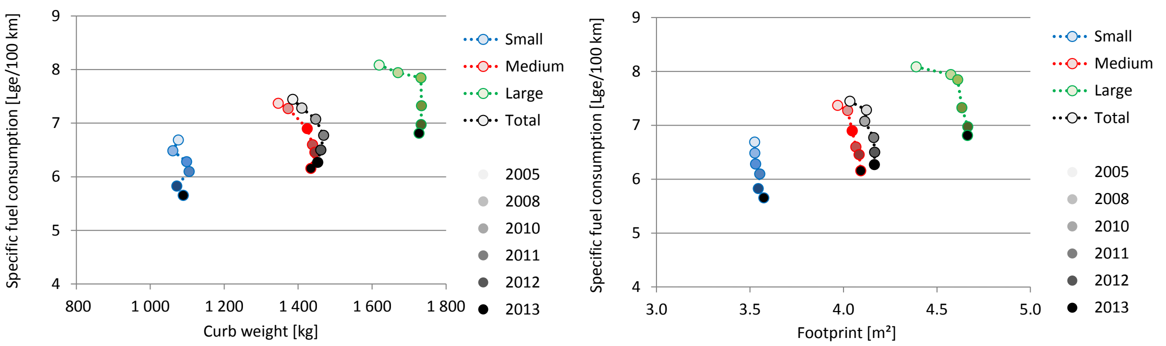
Figure 30 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting average fuel consumption as a function of weight and footprint by vehicle class (Figure 31) shows that the EU emission regulation led to a significant improvement in average fuel consumption across all weight and size classes. The large car segment is especially interesting. In the years after 2010, fuel economy improvement not only accelerated – the introduction of mandatory emission regulations also seems to have halted or even reversed the prior trend towards heavier and larger cars, refocusing technology deployment considerably towards fuel savings.

Figure 31 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

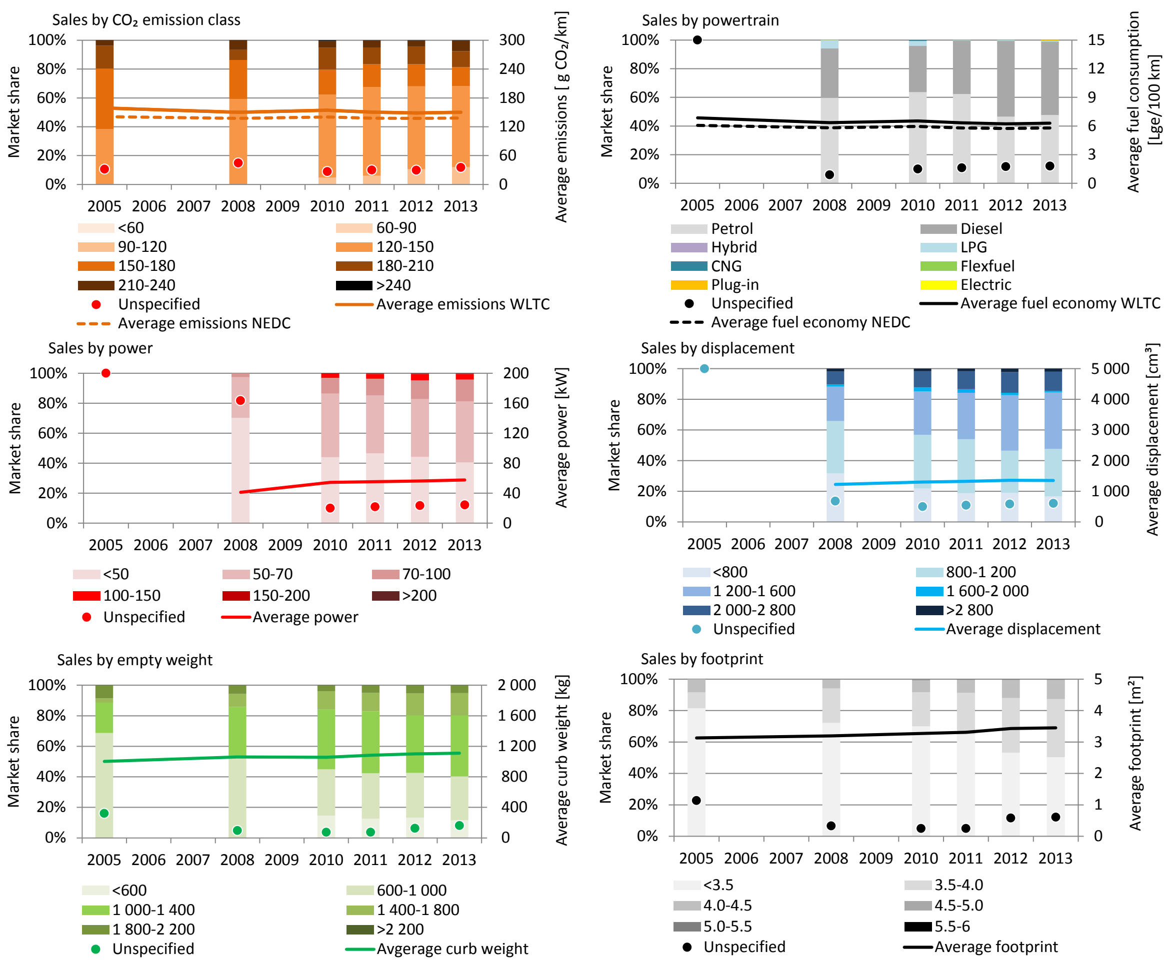
India

Country spotlight

Population (million) (World Bank, 2016a):	1,295
Share of urban population (World Bank, 2016b):	32%
GDP per capita (2014 USD/year) (World Bank, 2016c):	1 600
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	110
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	91
Fuel tax class (2014) (GIZ, 2015):	Taxed fuel price for gasoline, subsidised fuel price for diesel

In 2013, about 2.8 million LDVs were sold in India (IHS Polk, 2014). The LDV stock accounted for slightly less than 25 million cars (IEA, 2016a), implying car ownership of only 18 cars per thousand people. This is by far the lowest car ownership level among the group of countries discussed in this report. India is the economy with the strongest growth prospects for future LDV sales, with remarkable growth rates in vehicle ownership likely to take place once personal income approaches and exceeds 5 000 USD/year. In January 2014, the Indian government finally adopted CO_2 emission regulation, which will take effect from April 2016 (TransportPolicy, 2016). The standard sets a fleet target of about 130 g CO_2/km for 2016, which will go down to 113 g CO_2/km in 2021 (based on NEDC) (TransportPolicy, 2016).

Figure 32 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

The Indian car market is dominated by locally produced cars: in 2013, the three Indian OEMs Maruti, Tata and Mahindra alone accounted for more than 60% market share. Foreign brands make up slightly more than 20% of the total new LDV registrations in India.

In 2013, average CO_2 emissions per kilometre were at 150g CO_2/km (Figure 32, top left). Between 2005 and 2013, new LDV emissions dropped by 6%, and the market shares of both relatively low-emission (<120 g CO_2/km) and high-emission LDV segments (210 to 240 g CO_2/km) increased. This is illustrative of the increased diversification of the Indian vehicle market that took place over the past decade. With an average fuel consumption of 6.3 Lge/100 km, India's average new sales fuel economy was about 19% below the world average (Figure 32, top right).

Diesel-fuelled vehicles gained market share in recent years (Figure 32, top right). From 2008 to 2013, the diesel share grew from 40% to more than 50%. At the same time, the share of cars running on alternative fuels dropped: in 2008 more than 6% of new LDVs were LPG vehicles. In 2013, LPG-fuelled cars accounted for only 1% of the market. Hybrid vehicles had negligible market shares.

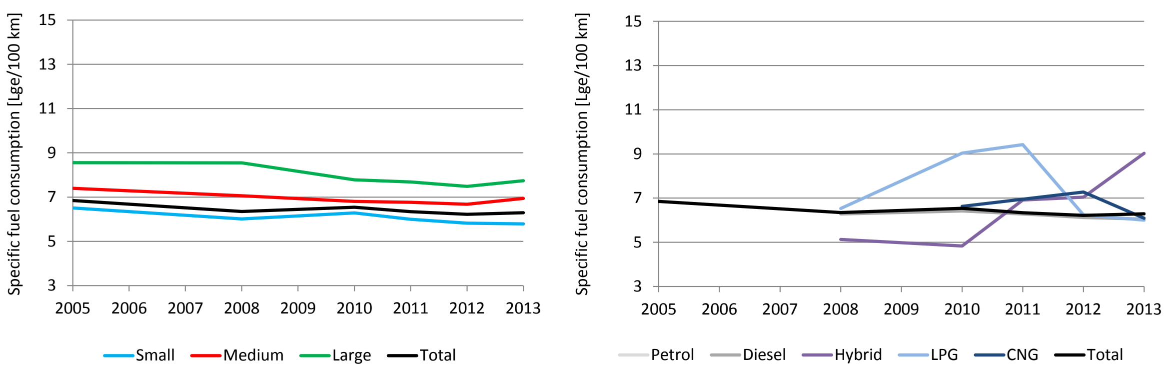
Increased diversification of the vehicle market is also reflected by major changes in average LDV power and displacement. The Indian market has been and still is dominated by small (and often cheap) cars. In 2008, more than 75% of new Indian cars had less than 50 kW of engine power. In 2013, this share dropped to roughly 40% (Figure 32, centre). Between 2008 and 2013, average power increased by 40%, from 41 kW to 58 kW. Over the same period, average displacement increased by only 11%. This is a clear indication that the diversification of the Indian vehicle market was accompanied by the modernisation of engine technologies.

Data on empty weight and vehicle footprint also suggest a clear shift towards larger cars. While empty weight in 2005 was around 1 000 kg, it increased to 1 100 kg by 2013 (Figure 32, bottom left). Footprint by class shifted even more: in 2005, 80% of new cars had a footprint below 3.5 m². By 2013, almost 90% of vehicles had a footprint of at least 3.5 m², with almost 40% being larger than 4 m² (Figure 32, bottom right).

Analysis of fuel economy trends

The plot of fuel economy by segment over time (Figure 33, left) shows that all vehicle classes contributed evenly to fuel economy improvements that took place between 2005 and 2013. Medium and large car segments are primarily responsible for the overall stabilisation of fuel economy seen in 2013. Average fuel economies of gasoline- and diesel-fuelled cars are very similar (Figure 33, right), while trends for LPG- and CNG-fuelled cars are affected by low market shares and are therefore not very representative.

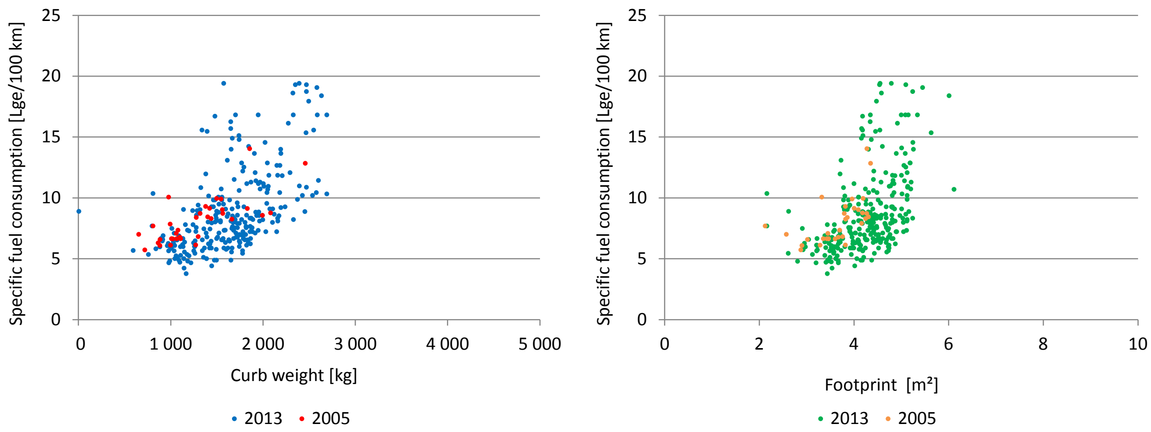
Figure 33 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Detailed representation of fuel consumption as a function of vehicle weight and footprint at the model level (Figure 34) clearly reveals the marked diversification of models that took place between 2005 and 2013. The same plot shows the modernisation of vehicle technologies: vehicles having comparable weight and size became more fuel-efficient over time. Figure 34 illustrates also the shift towards larger cars, since both clouds shift right between 2005 and 2013.

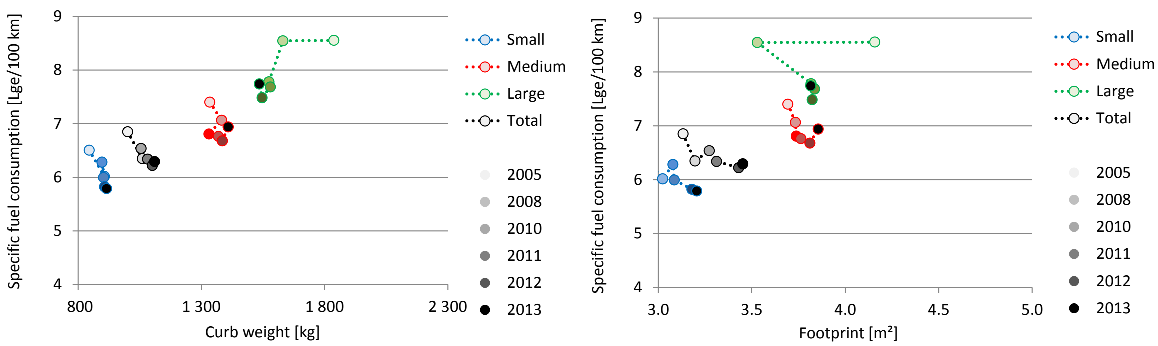
Figure 34 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Figure 35 shows the average new vehicle fuel consumption by segment, drawn as a function of both weight and footprint. This figure illustrates once more that fuel economy improved among all vehicle segments in India, although there was a trend reversal in medium and large vehicles in 2013. While empty weight and footprint of medium-sized and small cars increased over time, large vehicles became on average a little lighter. Despite encouraging signs within each vehicle segment, the fuel economy improvements delivered within each class may be offset by structural shifts across classes. In particular, continued shifts towards heavier and larger LDVs may exacerbate the increase of specific fuel consumption that began to emerge in medium and large segments in the very recent past beyond 2013.

Figure 35 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

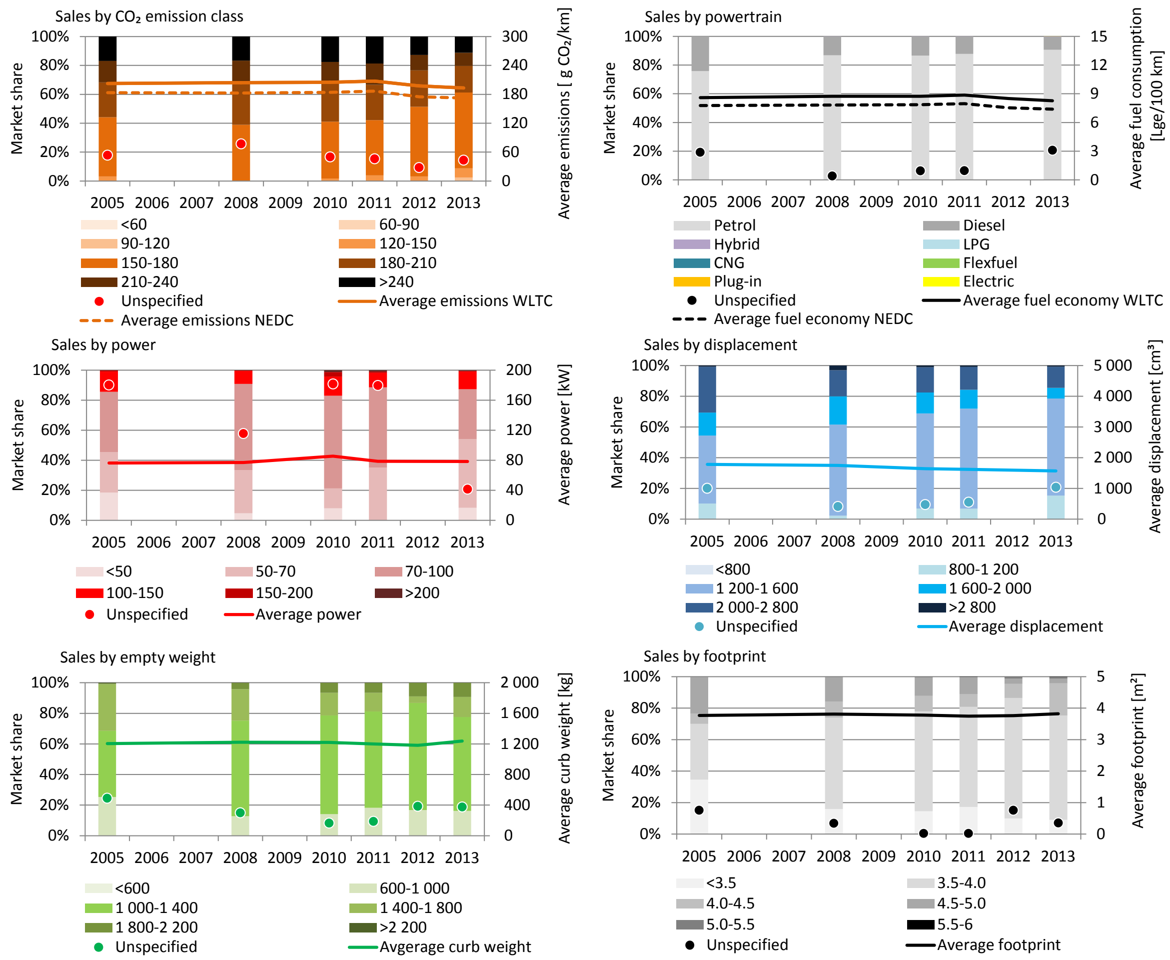
Indonesia

Country spotlight

Population (million) (World Bank, 2016a):	255
Share of urban population (World Bank, 2016b):	53%
GDP per capita (2014 USD/year) (World Bank, 2016c):	3 500
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	93
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	80
Fuel tax class (2014) (GIZ, 2015):	Taxed fuel price for petroleum fuels

In 2013, about 1.2 million LDVs were sold in Indonesia (IHS Polk, 2014). The on-road LDV stock accounted for more than 9 million cars. (IEA, 2016a), and car ownership was 0.036 cars per capita. This is more than twice as high as India's car ownership levels, but still more than ten times lower than the average European ownership level. In 2015, fuel price subsidies were abolished in Indonesia (Economist, 2015). The low crude oil price masked the impact on fuel prices at the station. As a result, prices for diesel in 2015 were even lower than the year before, when diesel was still subsidised.

Figure 36 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2013, 1.2 million LDVs were sold in Indonesia. In the same year Indonesian car production totalled 1.2 million passenger cars and commercial vehicles (OICA, 2016). Seven Japanese brands

(Toyota, Suzuki, Daihatsu, Honda, Mitsubishi, Nissan and Isuzu) cover 95% of the Indonesian LDV market. Ford was the number one non-Japanese brand, with a market share of 1.4% in 2013.

Between 2005 and 2013, average new LDV emissions per unit travel dropped by 5% from 201 g CO_2/km to 191 g CO_2/km (Figure 36, top left). The average CO_2 emissions per km peaked in 2011. Since then, the market share of vehicles emitting less than 180 g CO_2/km grew by 50%, with most of the growth occurring in cars with an emission rating below 150 g CO_2/km. At 8.2 Lge/100 km, the average fuel consumption in Indonesia was about 5% higher than the world average and on par with the non-OECD average.

The share of diesel-powered cars accounted for more than 20% in 2005 and dropped below 10% in 2013 (Figure 36, top right). This is a trend that is unique to the Indonesian market: between 2005 and 2013, diesel shares tended to either grow or, in markets where diesel was marginal, to remain marginal. Hybrid cars accounted for 0.4% of new LDV registrations in 2013. This is remarkable and could possibly be driven by an uptake of hybrids in the taxi fleet, given the country's low per capita income of only USD 3 500 per capita.

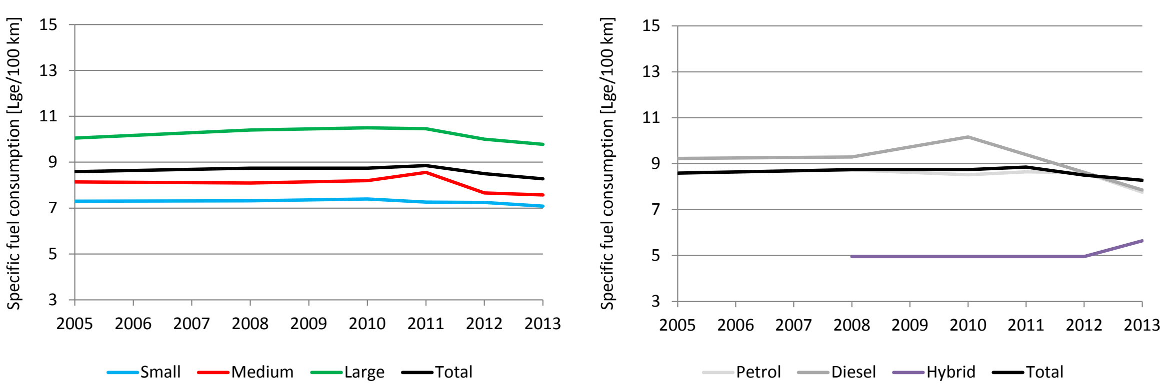
Notwithstanding limited data availability on the average power of new LDV registrations, Figure 36 (centre left) shows an increasing share of vehicles with a power rating below 70 kW. Growing shares of engines belonging to low displacement classes, accompanied by a decline in average cylinder capacity, can also be observed. This is consistent with the decline in diesel shares shown in the top right part of Figure 36, as diesel engines tend to have larger volumes than gasoline engines.

The plots showing market shares by weight and footprint (Figure 36, bottom) indicate that the Indonesian vehicle market is largely dominated by medium cars weighing between 1 000 kg and 1 400 kg and having a footprint between 3.5 and 4.0 m².

Analysis of fuel economy trends

Specific fuel consumption by vehicle segment shows a wide spread between large cars and other segments (Figure 37, left). Large cars in Indonesia consume about 40% more fuel per kilometre than small cars. The fuel economy of gasoline- and diesel-fuelled cars was rather similar (especially in 2013), while hybrids consumed much less fuel per km (Figure 37, right).

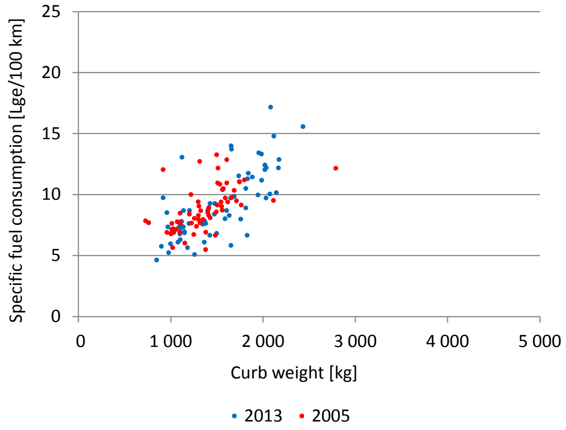
Figure 37 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The representation of the fuel economy as a function of vehicle weight and footprint at the model level (Figure 38) does not reveal significant changes in fuel economy between 2005 and 2013 and confirms that most of the models sold belong to the medium vehicle segment.

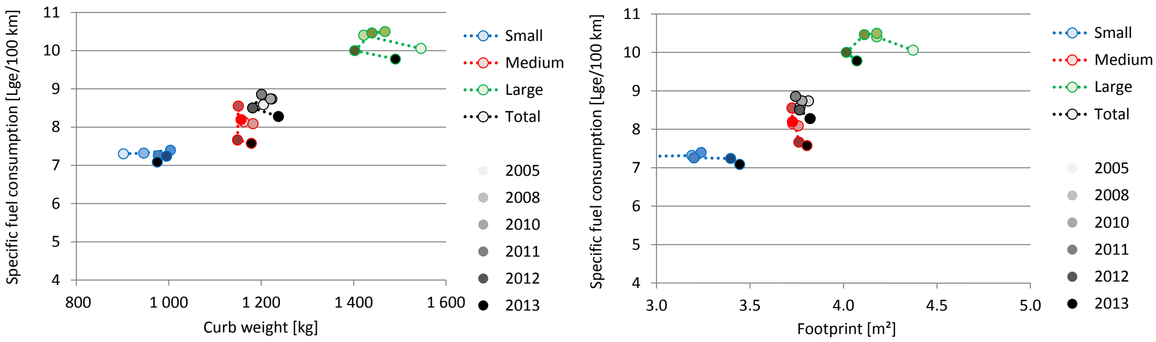
Figure 38 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Fuel economy as a function of weight and footprint by vehicle segment (Figure 39) confirms earlier observations: characteristics of both the small and the large vehicle segments tended to converge towards those of medium-sized cars. The very modest improvements in the average fuel economy between 2005 and 2013 are consistent with the limited pressure placed on energy saving technologies in the absence of fuel economy policies and in a context of subsidised transport fuel prices.

Figure 39 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

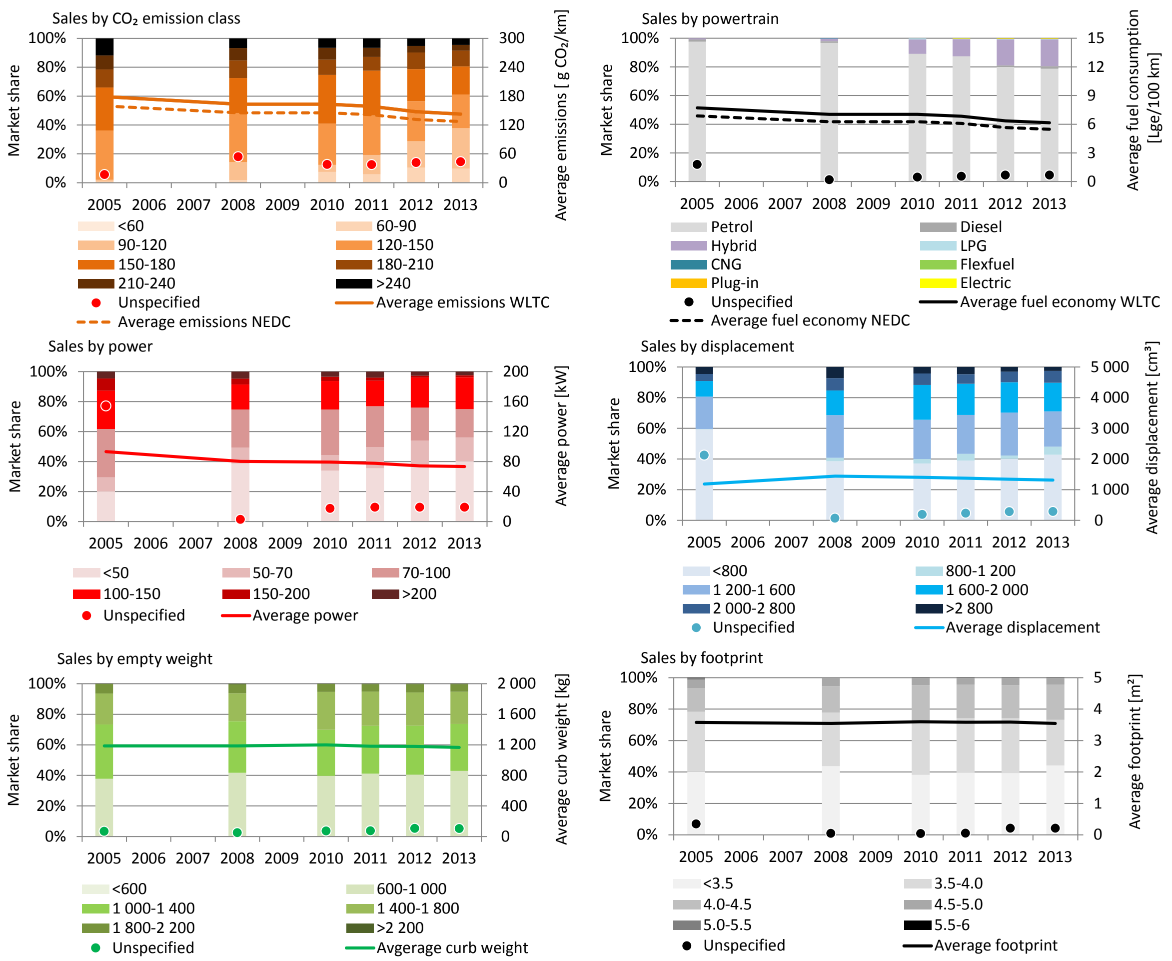
Japan

Country spotlight

Population (million) (World Bank, 2016a):	127
Share of urban population (World Bank, 2016b):	94%
GDP per capita (2014 USD/year) (World Bank, 2016c):	36 200
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	138
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	110
Fuel tax class (2014) (GIZ, 2015):	Taxed fuel price for petroleum fuels

In 2013 5.2 million LDVs entered the Japanese vehicle fleet (IHS Polk, 2014), bringing its on-road LDV stock to 61 million vehicles (IEA, 2016a). Car ownership was slightly below 0.48 vehicles per capita. Fuel economy standards have a long history in Japan. The first regulation was put in place in 1979, and applied first to 1985 vehicles. The Top Runner Program, introduced in 1999, required all vehicles in a given weight class to exceed the fuel economy of the best performing model within three to ten years (TransportPolicy, 2016). Fuel economy labelling has also been mandatory since the year 2000 (ICCT, 2014b). Japanese fuel economy standards have resulted in ambitious improvement targets in the past. Recent regulatory targets (for 2020) are less aggressive than in Europe, despite the fact that average national new sales fuel economies in Europe and Japan in 2013 were similar in magnitude. In addition to fuel economy standards, tax incentives encourage consumers to buy lighter vehicles. Vehicles that perform significantly better than the target values are also eligible for tax reductions (TransportPolicy, 2016). This helps explain why Japanese vehicles met fuel consumption targets ahead of time.

Figure 40 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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Market profile and vehicle characteristics

In 2013 Japan was the second biggest car producing country after China. With more than 9.6 million cars and commercial vehicles (OICA, 2015), Japan produced almost twice the volume of vehicles sold on the domestic market. Japan is the largest car exporter, with Japanese brands accounting for large market shares in all car markets around the globe. The domestic market is dominated by Japanese brands: nearly 95% of the cars entering the Japanese vehicle stock each year are produced in Japan.

In 2013, new LDVs emitted 143 g CO_2/km (Figure 40, top left). Passenger cars only emitted 137g CO_2. Until 2012, Japan had the most efficient new vehicle fleet worldwide, but in 2013 France, Italy, Turkey and United Kingdom had an even more efficient new car fleet.

Hybrid cars had the highest market share in Japan of all national markets considered here, and accounted for almost 20% of all new LDV registrations in 2013. Plug-in hybrids and battery electric vehicles accounted for almost 1% of all new registrations in 2013. Other powertrain technologies, including as diesel, CNG or LPG had very low market shares in Japan (Figure 40, top left).

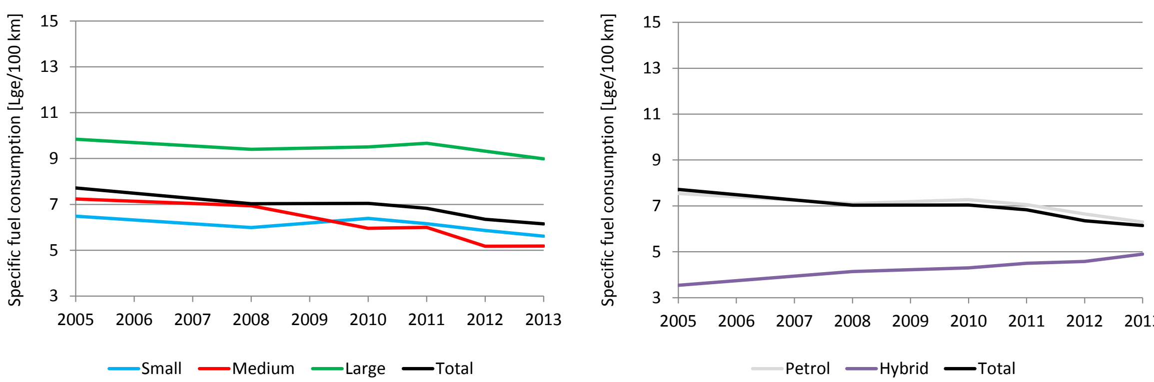
Japanese cars have been less powerful than LDVs sold in other developed markets for several years. Figure 40 (centre left) shows that the average power of new LDVs in Japan dropped by 9% (from 93 kW to 73 kW) from 2005 to 2013, driven by a doubling of the market share of vehicles with less than 50 kW of power (from 20% to 40%). The average engine capacity and vehicle weight of new sales were also among the lowest globally. These parameters remained consistently low from 2005 to 2013: 40% of all new LDVs entering the Japanese market during these years used engines with a displacement below 0.8 L.

In 2013, 40% of all new LDV sales had a vehicle weight between 600 kg and 1 000 kg (Figure 40 bottom). The sales distribution by footprint reveals that, in Japan, medium-sized cars were progressively replaced by either very small “kei cars” or larger vehicles. The share of vehicles with a footprint between 3.5 m² and 4.0 m² contracted by almost 50% between 2005 and 2013. This trend cannot be observed in any other of the economies considered in this report.

Analysis of fuel economy trends

The fuel economy distribution by vehicle segment provides very interesting insights in the case of Japan. Due to the high level of hybridisation of medium-sized cars (e.g. the Toyota Prius), the medium car segment actually consumed less fuel per km than vehicles in the small segment (Figure 41, left). The fuel economy of large cars was significantly worse than the average. In 2013, large cars consumed almost twice the fuel needed by small vehicles to cover the same distance.

Figure 41 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13

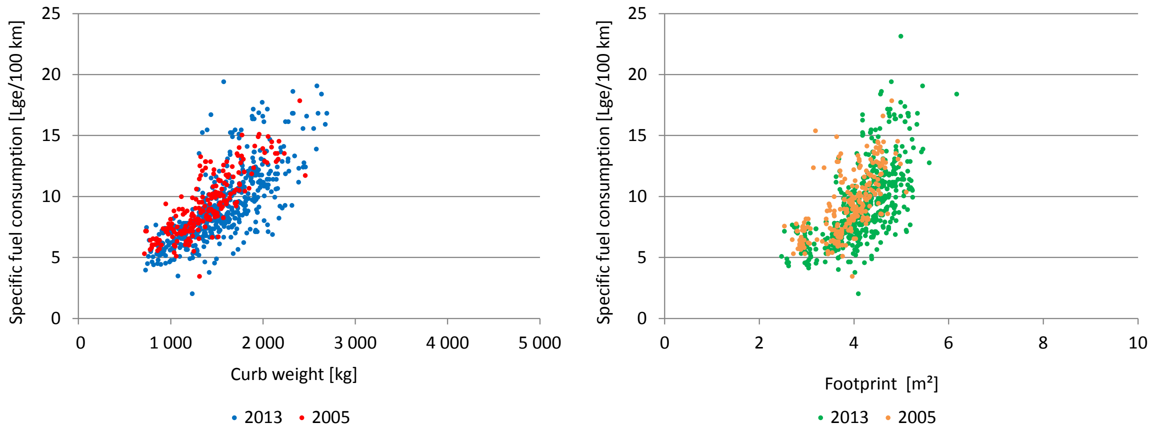


Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Figure 41 (right) shows that the fuel economy of hybrids got worse over time. This effect is imputable to the increasing diversification of the available models, occurring jointly with the growth of the penetration of hybrid technologies on relatively large vehicle models such as the Toyota Camry, the Nissan Serena or the Honda Accord, all having an engine power much higher than the Toyota Prius.

The clouds plotting model-level fuel consumption by vehicle empty weight and footprint clearly indicate a reduction in specific consumption (Figure 42). It also shows that the Japanese car market got more diverse over time.

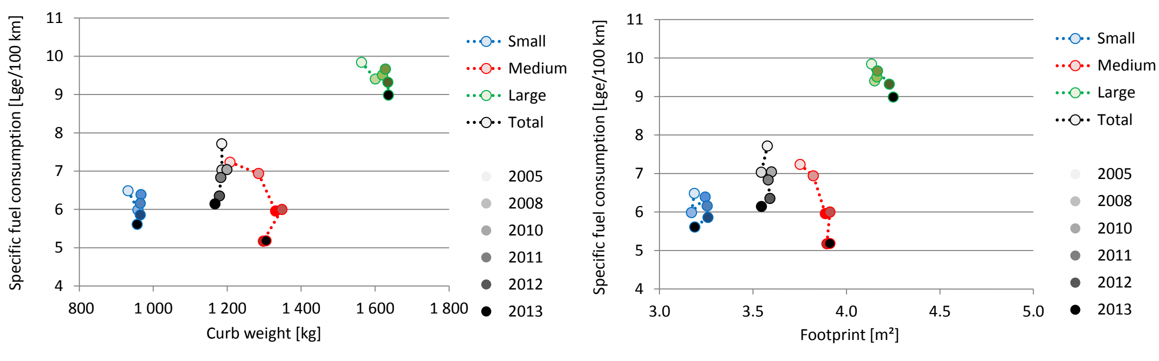
Figure 42 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plots of fuel consumption against weight and footprint by vehicle segment (Figure 43) confirm that fuel economy policies led to a reduction in specific fuel consumption over time in all segments, with limited changes in weight and footprint within each segment.

Figure 43 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

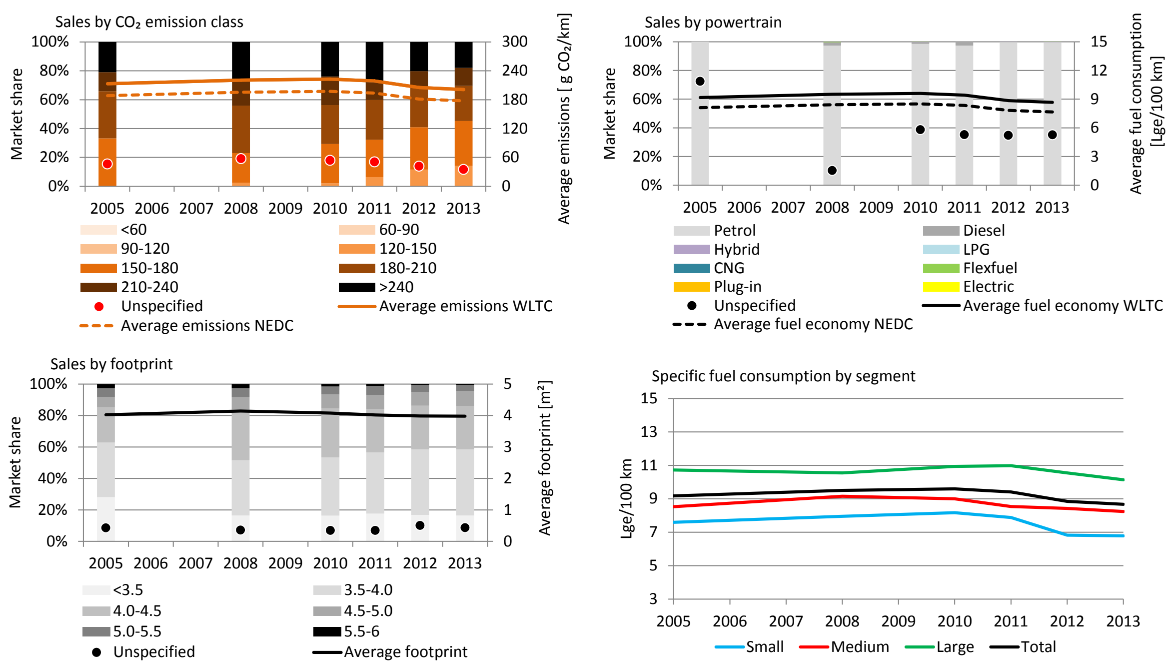
Mexico

Country spotlight

Population (million) (World Bank, 2016a):	125
Share of urban population (World Bank, 2016b):	79%
GDP per capita (2014 USD/year) (World Bank, 2016c):	10 300
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	103
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	102
Fuel tax class (2014) (GIZ, 2015):	Taxed fuel price for petroleum fuels

In 2013, about 1.1 million LDVs were sold in Mexico (IHS Polk, 2014). The rolling stock of LDVs attained 23 million (IEA, 2016a). The car ownership rate was 0.185 cars per capita, a higher than other Latin American countries with comparable per capita income, including Brazil. In 2013, the Mexican government adopted fuel economy regulation similar to the US CAFE standards, although with less ambitious targets and more flexibility for car manufacturers and importers (SEGOB, 2013). Similar to the United States and Canada, Mexican fuel economy targets are footprint-based. In contrast to the United States and Canada, Mexican manufacturers are permitted to pool for compliance (TransportPolicy, 2016).

Figure 44 • LDV market by CO_2 emission class, powertrain technology, vehicle empty weight and vehicle footprint, 2005 to 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2013, Mexico was the second largest Latin American market after Brazil. With a little more than 3 million vehicles produced (including trucks and buses) (OICA, 2015), Mexico was also the eighth largest car manufacturing country. The three main OEMs selling vehicles in Mexico are Nissan, Chevrolet and Volkswagen, which collectively account for almost 60% of the market.

The average emissions of new LDVs registered in Mexico was 201 g CO_2/km (Figure 44, top left) in 2013. Between 2005 and 2013, the average CO_2 emissions per km of LDVs dropped by 6%. They peaked around 2010, when they averaged 223 g CO_2/km. From 2010 to 2013, emissions dropped by 10%. New LDV fuel consumption was about 8.7 Lge/100 km in 2013 (Figure 44, top right), 12% higher than the world average.

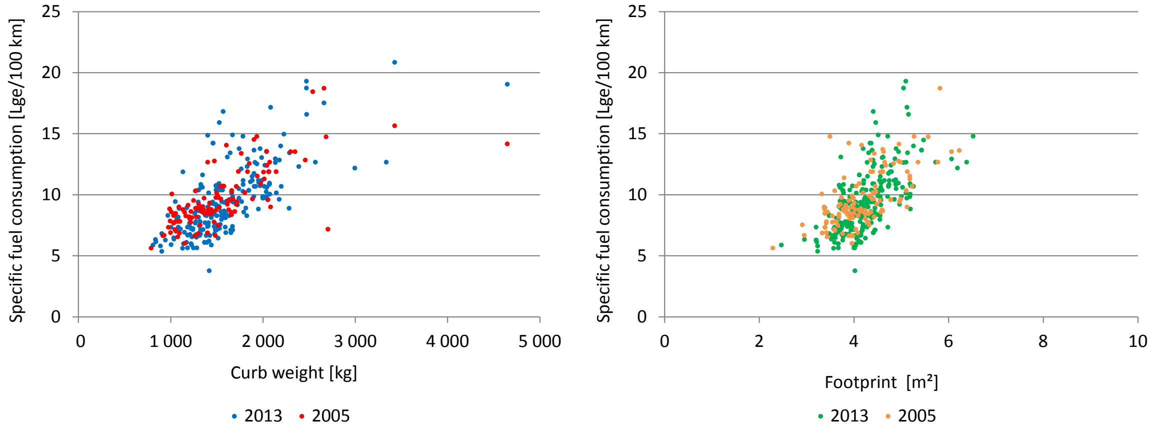
The Mexican vehicle market comprises almost exclusively gasoline-fuelled cars. Figure 44 does not include full details on powertrain shares, vehicle power and engine displacement due to the limited availability of detailed information. The weight and footprint distribution across different vehicle classes changed only marginally between 2005 and 2013. As a result, average weight remained close to 1 400 kg and average footprint was about 4 m². This indicates that the Mexican new LDV fleet is comparable to the Chilean one and significantly larger than Brazil's.

Vehicle fuel consumption by segment (Figure 44, bottom right) illustrates that fuel economy improvement resulted from changes affecting all vehicle segments. The average LDV fuel economy is close to the values characterising medium-sized cars.

Analysis of fuel economy trends

The clouds plotting model-level vehicle fuel consumption against vehicle weight and footprint (Figure 45) indicate a slight reduction in fuel consumption since 2005 and do not show a tendency towards weight or size reduction.

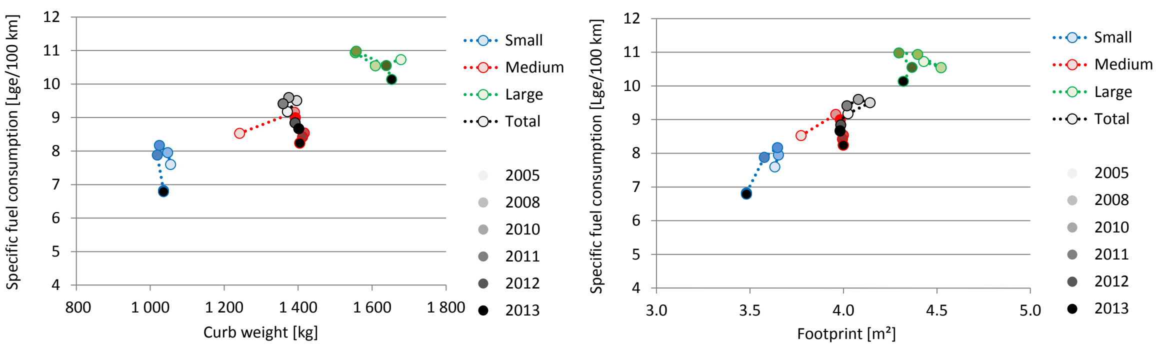
Figure 45 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting fuel economy against weight and footprint in the main vehicle segments (Figure 46) confirms that fuel economy improved in recent years, after stagnating before 2010. These changes were not accompanied by major shifts in weight. Footprint reductions are mainly visible for the medium and small segments, and only in 2013.

Figure 46 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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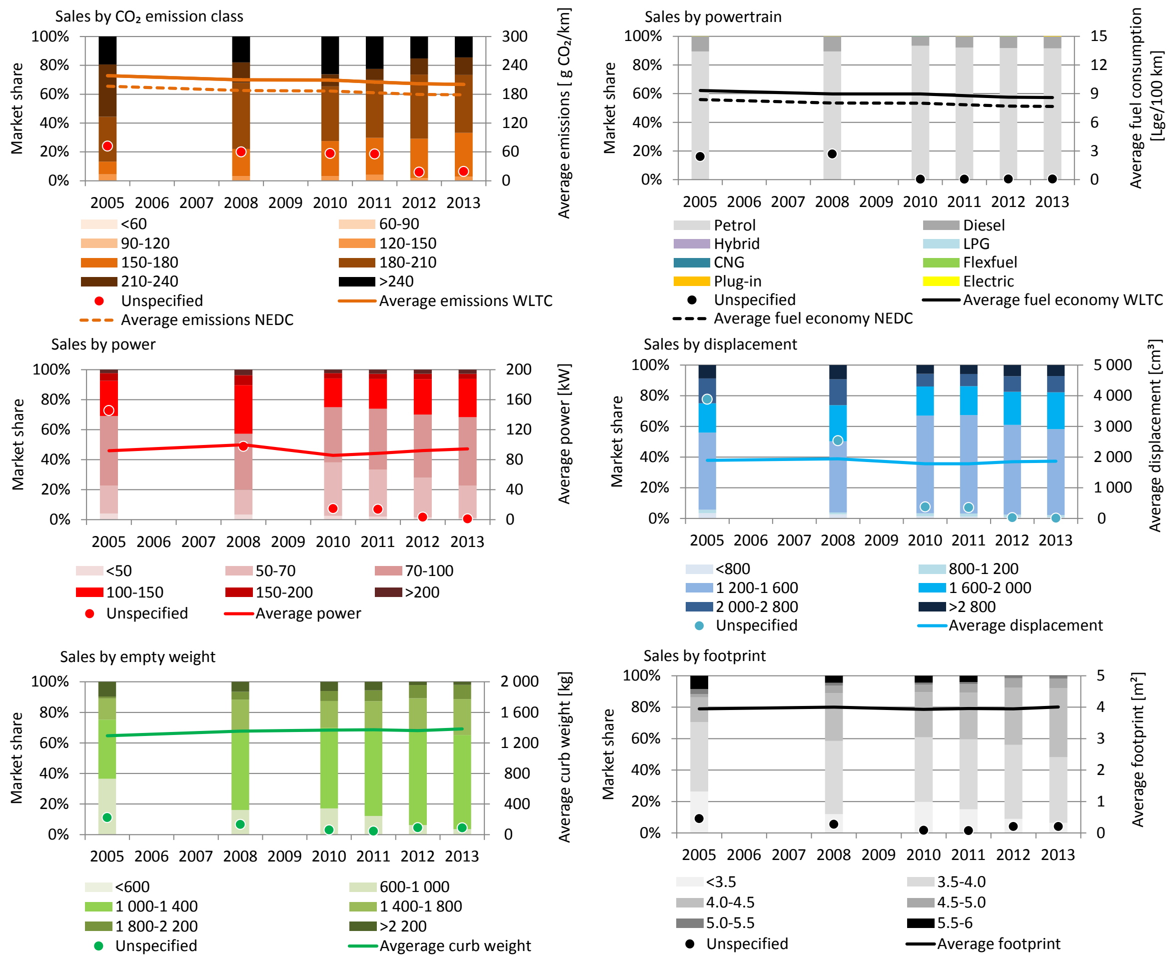
Russian Federation

Country spotlight

Population (million) (World Bank, 2016a):	144
Share of urban population (World Bank, 2016b):	74%
GDP per capita (2014 USD/year) (World Bank, 2016c):	12 700
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	75
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	81
Fuel tax class (2014) (GIZ, 2015):	Subsidised fuel price for petroleum fuels

In 2013, new LDV registrations in the Russian Federation totalled about 2.8 million (IHS Polk, 2014). The on-road stock of LDVs reached about 43 million in the same year (IEA. 2016). Car ownership attained nearly 0.3 cars per capita, a value that is twice as high as the average for other countries with comparable levels of personal income. Fuel economy is not regulated in the Russian Federation. On the other hand, the Russian Federation levies an annual circulation tax from vehicle owners, which increases progressively with vehicle power (Ernst&Young, 2010).

Figure 47 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2013, the Russian Federation was the sixth largest passenger car market in the world (OICA, 2015). The Russian brand Lada was the best-selling brand in 2013, with a market share of almost

17% (IHS Polk, 2014). It was followed by Renault, Kia and Hyundai, all having sales shares around 7%.

The sales-weighted CO_2 emissions per km of Russian cars averaged 201 g CO_2/km in 2013 (Figure 47, top left). Notwithstanding a decline of about 6% since 2005, Russia's new car sales in 2013 had a rather high fuel consumption. The average fuel economy of new vehicles registered in 2013 was 8.6 Lge/100 km (Figure 47, top right), about 11% higher than the world average.

The Russian market is dominated by gasoline cars, which had a market share around 90% (Figure 47, top right). Diesels accounted for most of the residual share: new registrations of LDVs using natural gas or LPG are rare, and hybrids are almost non-existent (in 2013 their market share was 0.2%).

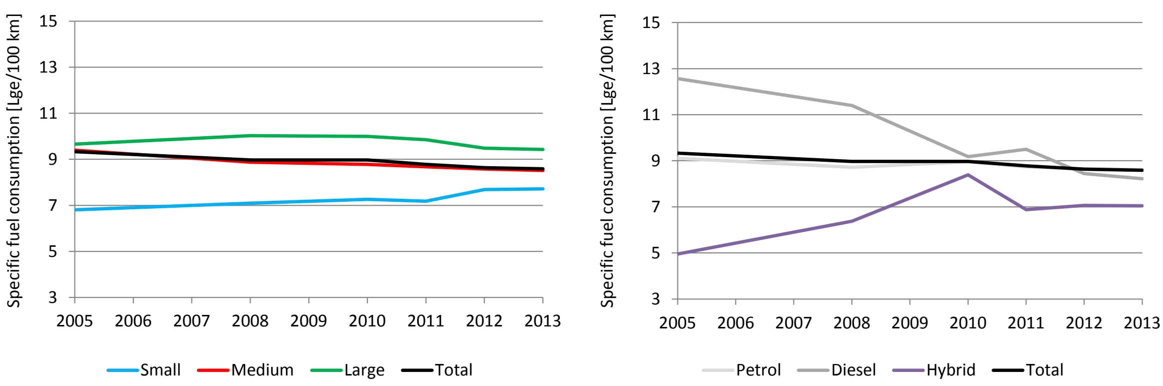
Since 2010, the average power and displacement of new LDVs increased: the share of cars with a power rating below 70 kW declined by more than 40% between 2010 and 2013, when cars with engine power above 100 kW saw a 25% increase (Figure 47, centre). Changes in market segmentation with respect to engine capacity are less pronounced. The limited data coverage on power and displacement before 2010 does not allow for a robust assessment of market trends prior to 2010.

Data on vehicle size and weight (Figure 47, bottom), however, suggest notable changes in the fleet structure before 2010. Cars weighing less than 1 000 kg, which exceeded a third of new registrations in 2005, almost disappeared in 2013, when cars with a mass between 1 000 kg and 1 400 kg represented 60% of the market. Very heavy cars (above 2 200 kg), still relevant in 2005, had a negligible market share in 2013. Vehicle footprint shows a similar picture. Both very small and very big cars lost market share. In 2013 more than 85% of the market had a footprint ranging between 3.5 m² and 4.5 m².

Analysis of fuel economy trends

In the Russian Federation, the major importance of medium-sized cars is reflected in the improvement of fuel economy by segment (Figure 48, left). Figure 48 also shows that the fuel economy of small and large segments converged towards the value of medium LDVs, following the pattern discussed earlier for weight and footprint parameters. The reduction in overall fuel consumption is also a consequence of the improvement of gasoline vehicles, which account for 90% of the sales (Figure 48, right). Trends for diesels show that substantial improvement took place in between 2005, when most diesel cars were LCVs, and 2013, when SUVs accounted for the largest part of diesel LDV registrations.

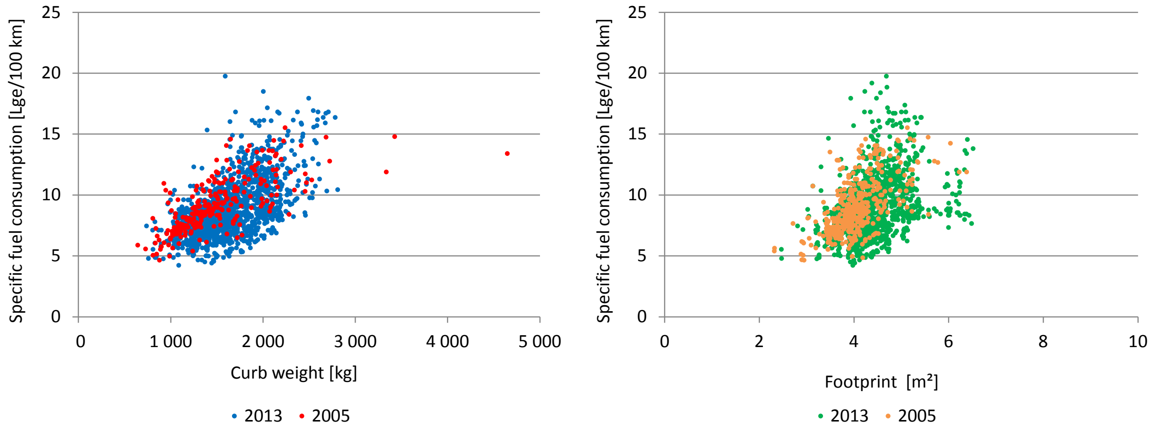
Figure 48 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plots of vehicle fuel consumption as a function of vehicle weight and footprint at the model level (Figure 49) show two main shifts from 2005 to 2013: first, vehicles with similar weight and footprint tended to become more efficient; second, the diversification of sales led to a larger share of models with higher weight and footprint in 2013.

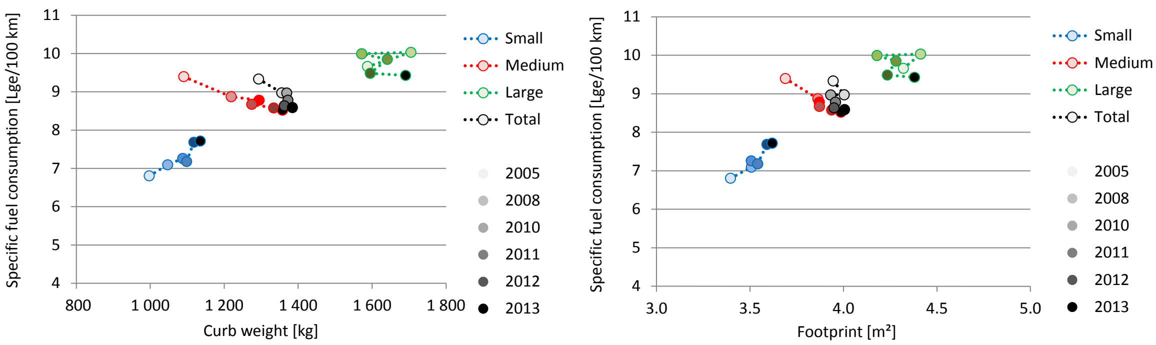
Figure 49 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plotting the evolution of fuel economy by vehicle segment against weight and footprint (Figure 50) reveals that different trends across segments: small cars tended to become heavier and larger, with negative impacts on fuel economy; medium cars also grew in size and weight, but the modernisation of the fleet counterbalanced the negative consequences on the fuel economy; changes for large vehicles were less uniform over time. The differing trends observed across vehicle segments in Russia reflect changes due to rapid market developments and the diversification of the offer. They also suggest that fuel economy has a secondary importance in the absence of a regulatory framework requiring its improvement.

Figure 50 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

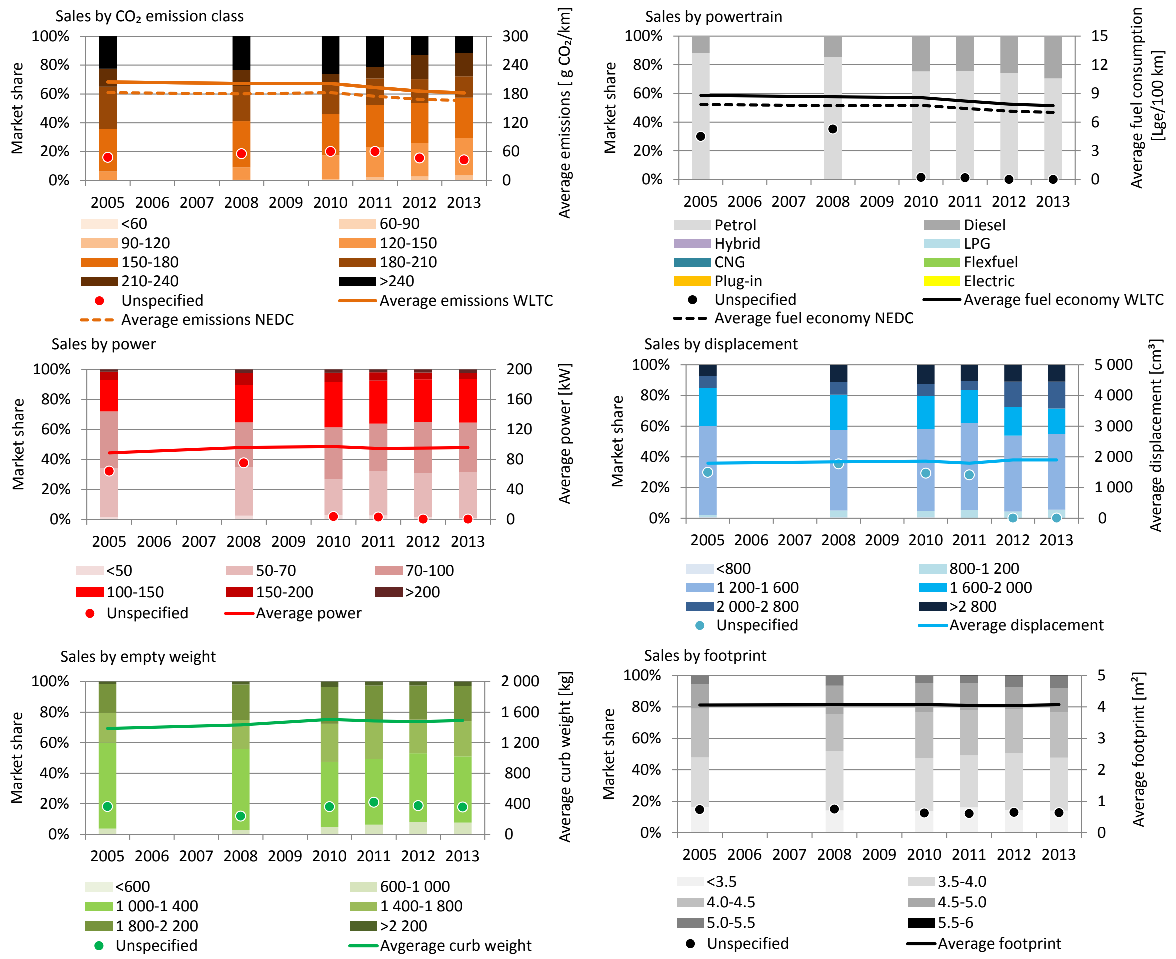
South Africa

Country spotlight

Population (million) (World Bank, 2016a):	54
Share of urban population (World Bank, 2016b):	65%
GDP per capita (2014 USD/year) (World Bank, 2016c):	6 500
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	119
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	117
Fuel tax class (2014) (GIZ, 2015):	Taxed fuel price for petroleum fuels

About 620 000 LDVs were sold in South Africa in 2013 (IHS Polk, 2014), when the LDV stock reached 6.5 million vehicles (IEA, 2016a). The car ownership rate was 0.12 cars per capita. There are no fuel economy regulations in South Africa. Since 2008, car dealerships have been obliged to inform clients about the specific fuel consumption of the car through a labelling scheme (UNEP, 2012). Differentiated vehicle registration taxes, including a component that varies according to the CO_2 emissions per km of the vehicles, were introduced in 2010 (OECD, 2013).

Figure 51 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

In 2013, South Africa produced nearly 300 000 cars, about half the volume of its own market (OICA 2015). South Africa is also home to a number of car industry suppliers: the National

Association of Automotive Component and Allied Manufacturers (NACAAM), which represents about 140 companies, released sales revenues of about 50 billion Rand (~USD 3.1 billon) for the year 2014 (NCAAM, 2016). Four OEMs cover more than half of the South African vehicle market: Toyota, Volkswagen, Ford and Nissan.

New LDV registrations in 2013 emitted, on average, 182 g CO_2/km (Figure 51, top left). The introduction of differentiated vehicle taxation, in 2010, marks a change in the direction of the evolution of CO_2 emissions per km of new LDVs. Between 2010 and 2013, average CO_2 emissions per km decreased by 10%. Average LDV fuel consumption was 7.9 Lge/100 km in 2013 (Figure 51, top right), on par with the world average.

Diesel engines accounted for about a quarter of the new LDV registrations in South Africa in 2013 (Figure 51, top right), up from 15% in 2005. Most diesel cars are pick-ups and SUVs. Besides diesel, there were no significant alternatives to gasoline engines in South African LDVs.

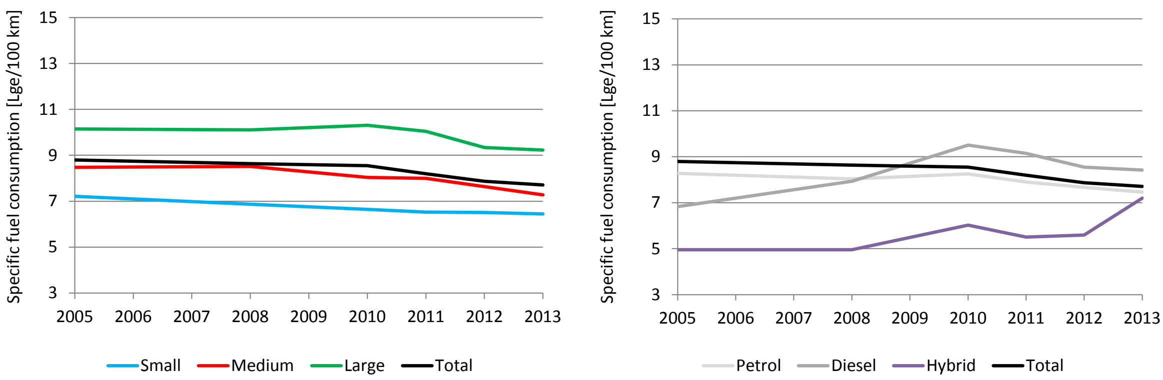
Between 2005 and 2013, South African cars became, on average, 8% more powerful. Their displacement increased by 3% in the same timeframe (Figure 51, centre). About two-thirds of the cars that entered in the South African market in 2013 had an engine power lower than 100 kW and an engine displacement below 1.6 L.

South Africa has a relatively high share of heavy cars with an empty weight above 1 800 kg (Figure 51 bottom), most of these are pick-up trucks and SUVs. Only minor changes occurred in vehicle empty weight and footprint between 2005 and 2013.

Analysis of fuel economy trends

Tracking average fuel consumption by vehicle segment (Figure 52, left) shows that most of the fuel economy improvements were achieved in the large and medium market segments. Both gasoline and diesel technologies contributed to lower fuel consumption after 2010 (Figure 52, right). Prior to 2010, poor data quality permits less robust statements. The evolution of diesel fuel consumption, in particular, might be biased by lower data coverage.

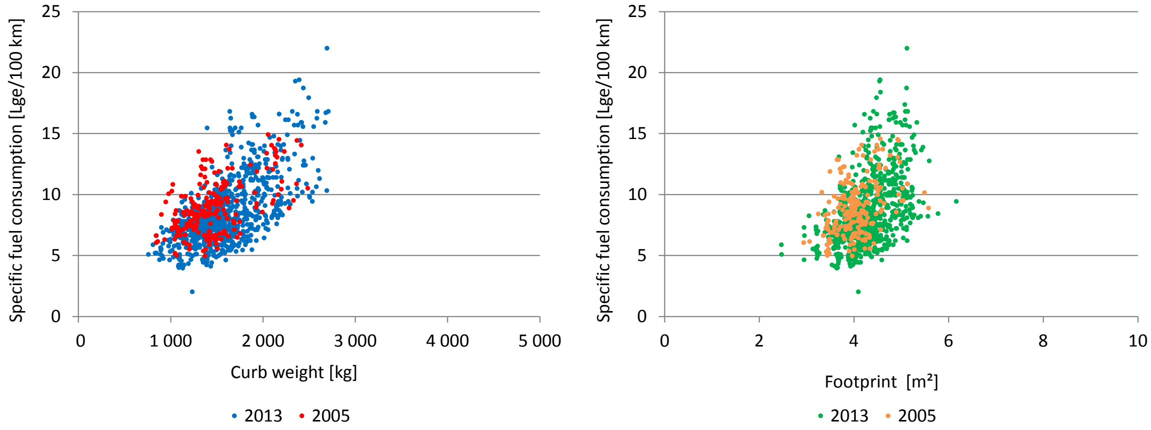
Figure 52 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The clouds showing fuel consumption data at the model level, plotted as a function of vehicle weight and footprint, show a slight vertical shift indicating lower fuel consumption at comparable empty weight and footprint (Figure 53). This is consistent with the fuel economy improvements observed after 2010. The plots in Figure 53 also illustrate a diversification of the market towards heavier and larger cars.

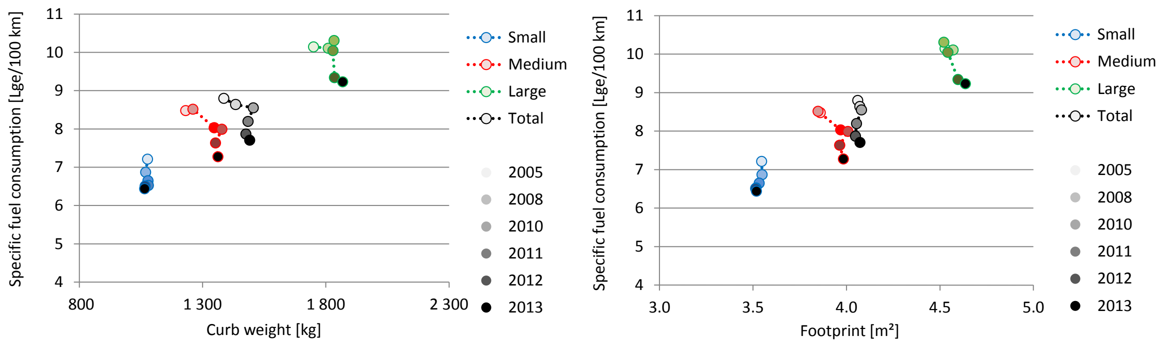
Figure 53 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Plots of fuel consumption by vehicle segment as function of empty weight and footprint (Figure 54) show that the introduction of the differentiated taxation of newly registered vehicles in 2010 had a visible impact on the way vehicles were marketed in South Africa. Prior to 2010, South Africa followed a pattern characteristic of unregulated and developing car markets: vehicle weight and footprint increased, while fuel economy improvement was of secondary importance for most consumers. After 2010, the line graphs are almost vertical: fuel economy improvement accelerated, and the shift towards heavier and larger cars slowed down in all segments.

Figure 54 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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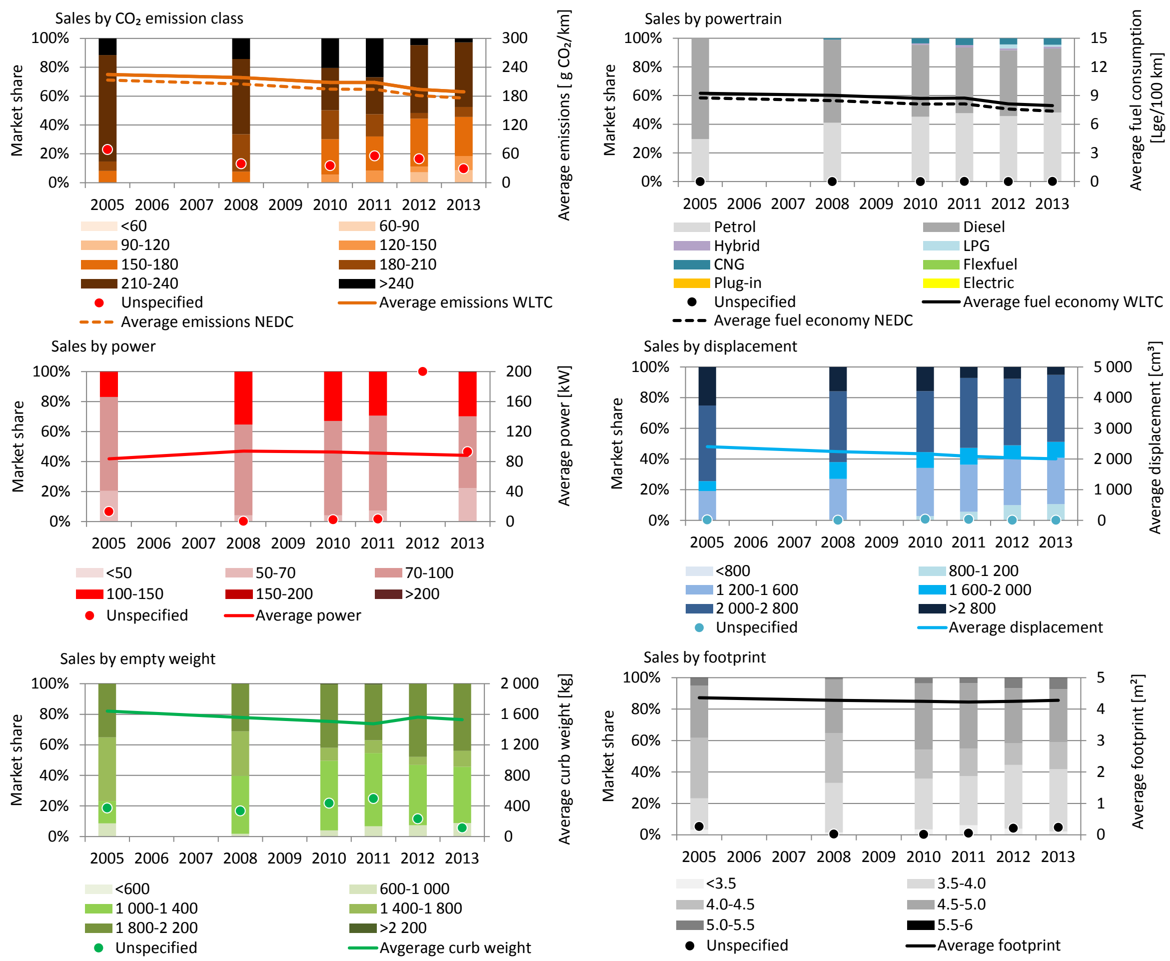
Thailand

Country spotlight

Population (million) (World Bank, 2016a):	68
Share of urban population (World Bank, 2016b):	65%
GDP per capita (2014 USD/year) (World Bank, 2016c):	6 000
Average price gasoline (USD cent per L, 2014) (GIZ, 2015):	150
Average price diesel (USD cent per L, 2014) (GIZ, 2015):	100
Fuel tax class (2014) (GIZ, 2015):	-

In 2013 the Thai LDV market size was nearly 1.2 million vehicles (IHS Polk, 2014). The rolling LDV stock reached 14 million in the same year (IEA, 2016a). Car ownership was 0.2 vehicles per capita, a value that is extremely high, given the country's rather low average income. Thailand has almost three times more cars per capita than China, despite the fact that Chinese per capita income is about USD 1 600 higher. Car ownership in Thailand is even higher than in Brazil or Chile, although per capita income is more than twice as high in these countries. Thailand has no fuel economy standards in place, but is currently developing them. Since October 2015, car dealerships have been obliged to inform clients about the specific fuel consumption of vehicles for sale (in addition to information such as the pollutant emission class of the vehicle) through a labelling scheme (GFEI, 2015b). A tax incentive for the production of "eco-vehicles" was established in 2009, offering reduced excise taxes (17% instead of 30%) for cars complying with specific requirements (UNESCAP, 2011).

Figure 55 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

About 1.2 million LDVs were sold in Thailand in 2013 (IHS Polk, 2014). This makes Thailand one of the biggest Asian LDV markets, after Korea and before Indonesia. The five best-selling brands on the Thai LDV market are all Japanese. Taken together, they account for more than 80% of new LDV registrations. Toyota alone covers almost one-third of the entire market.

New LDV registrations in 2013 emitted, on average, 189 g CO_2/km (Figure 55, top left). Between 2005 and 2013, the average CO_2 emissions per km dropped by 9%. Most of the improvement was achieved between 2011 and 2013. This was partly due to the rapid fall in market share of vehicles emitting more than 240 g CO_2/km, as well at significant growth in market share of cars emitting less than 120 g CO_2/km. Average new LDV fuel consumption in Thailand was 7.7 Lge/100 km in 2013 (Figure 55, top right), slightly below the world average.

Thailand has a very high diesel share. In 2005, about 70% of all newly registered LDVs were diesel cars. By 2013, this share dropped to about 45% (Figure 55, top right). In 2013, the two best-selling models were both pick-ups, (Toyota Vigo Hilux and Isuszu D-Max) and together accounted for almost 30% of the total market share. Both cars are almost entirely sold in the diesel version. The Thai car market also showed a high penetration of CNG and LPG-fuelled vehicles. By 2013, CNG cars accounted for almost 5% of the new registrations and LPG for 1.5%.

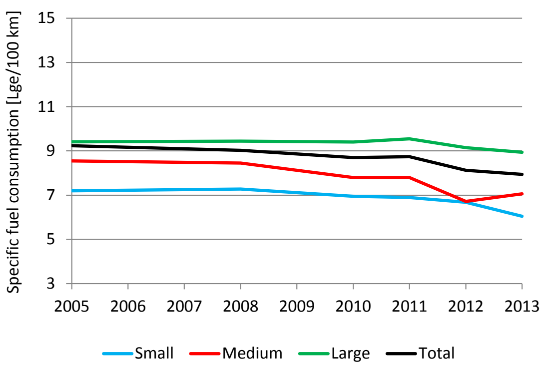
On average, the distribution of new sales by power shows no apparent development between 2005 and 2013 (Figure 55, centre). The limited data availability for 2013 does not allow strong conclusions to be drawn from the apparent increase in the share of vehicles with a power rating below 70 kW. The data available suggest that an upward evolution compared to 2012 is likely. Between 2005 and 2013, the average engine capacity decreased substantially. While the average new LDV had an engine with more than 2.4 L in 2005, engine capacity dropped by 17% to 2 L in 2013. This, combined with the stability of the average power, suggests an increasing penetration of technologies allowing for engine downsizing, such as turbochargers.

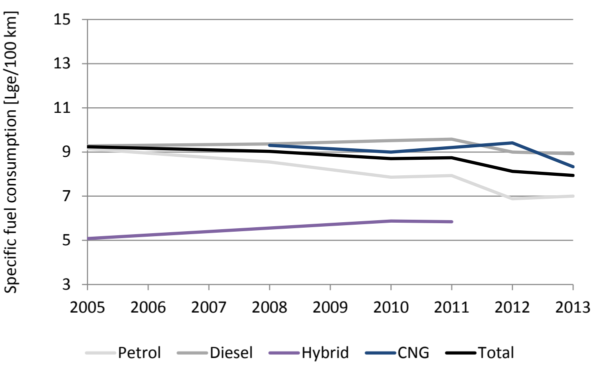
The plots of sales by empty weight and footprint show that cars in Thailand were rather heavy and large (Figure 55, bottom). By 2013, the average LDV weighed more than 1 500 kg, which was almost 30% more than the average weight of new vehicles sold in Indonesia. In the recent past, the sales share of vehicles above 1 800 kg increased. Footprint was also on the high end of ranges observed in Asian economies, and remained almost constant over time.

Analysis of fuel economy trends

The graph of average specific fuel consumption of new LDVs by segment shows that all vehicle classes contributed to the recent drop in fuel consumption (Figure 56, left).

Figure 56 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13





Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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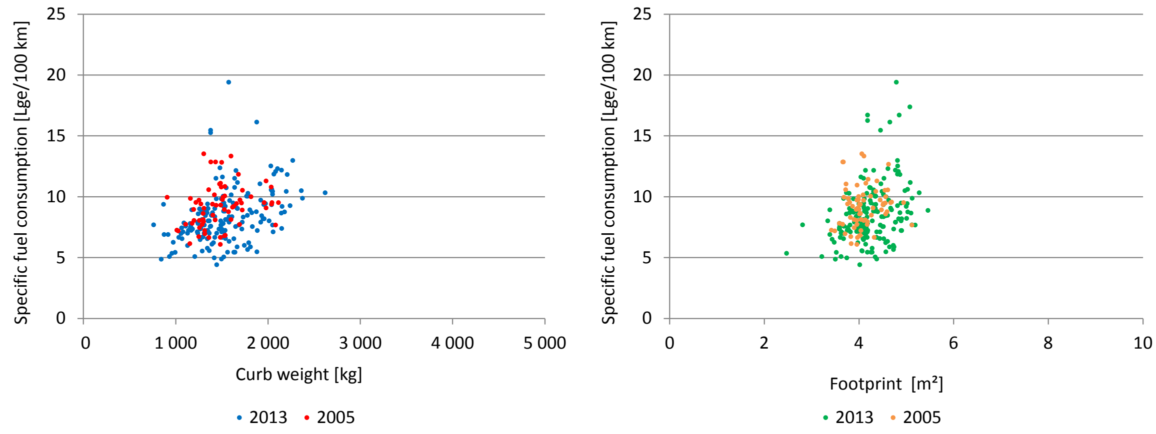
The main reasons for the improvement are the successful market introduction of new efficient models such as the Honda City and the Nissan Almera (these two models alone accounted for almost 40% of the medium size car sales in Thailand in 2012). The plot of fuel consumption by fuel type suggests that large cars (e.g. pick-ups and SUVs) are most likely to be offered with diesel engines. This also explains why the average fuel consumption of diesel cars is much higher than that of vehicles fuelled with gasoline.

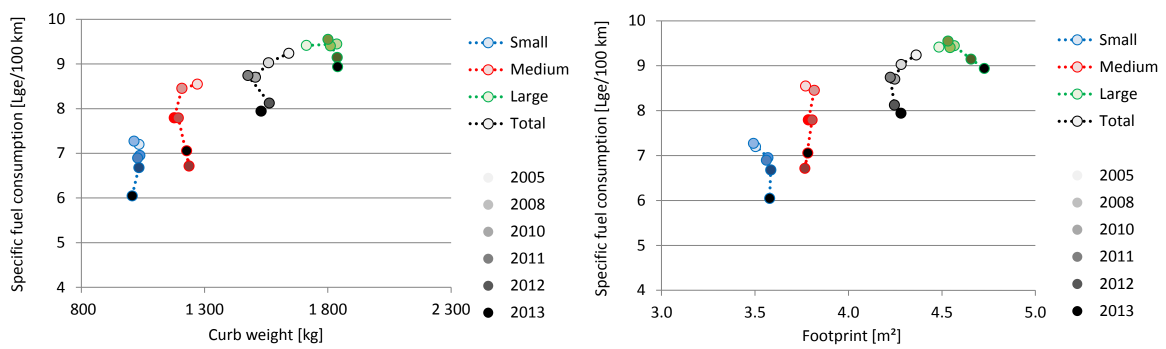
Figure 57 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The cloud showing model-level LDV fuel economy as a function of vehicle empty weight and footprint (Figure 57) confirms the findings highlighted earlier: fuel economies of models having comparable weight and size improved over time. At the same time, the horizontal spread of the clouds representing all models widened: indicating that the distribution of vehicle weight and footprint in 2013 was less homogeneous than in 2005. The weight and footprint of models located at the high end of the respective ranges also increased more than those in the centre of the clouds.

Figure 58 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The representation of vehicle fuel economy by segment as a function of weight and footprint reveals that the Thai market has undergone a remarkable development (Figure 58). Even in the absence of regulatory fuel economy legislation (fuel economy policies in place are limited to labelling and fiscal incentives for the production of environmentally friendly vehicles), the Thai market has been subject to a clear shift towards vehicles consuming less fuel. In addition to the fuel economy polices in place, this downward shift may be a consequence of higher sensitivity to fuel costs of Thai vehicle owners (who tend to have lower average incomes compared with other countries having similar vehicle ownership rates), despite the fact that gasoline and diesel prices in Thailand do not fall in the high end of international fuel price ranges.

Turkey

Country spotlight

Population (million) (World Bank, 2016a): 76

Share of urban population (World Bank, 2016b): 73%

GDP per capita (2014 USD/year) (World Bank, 2016c): 10 500

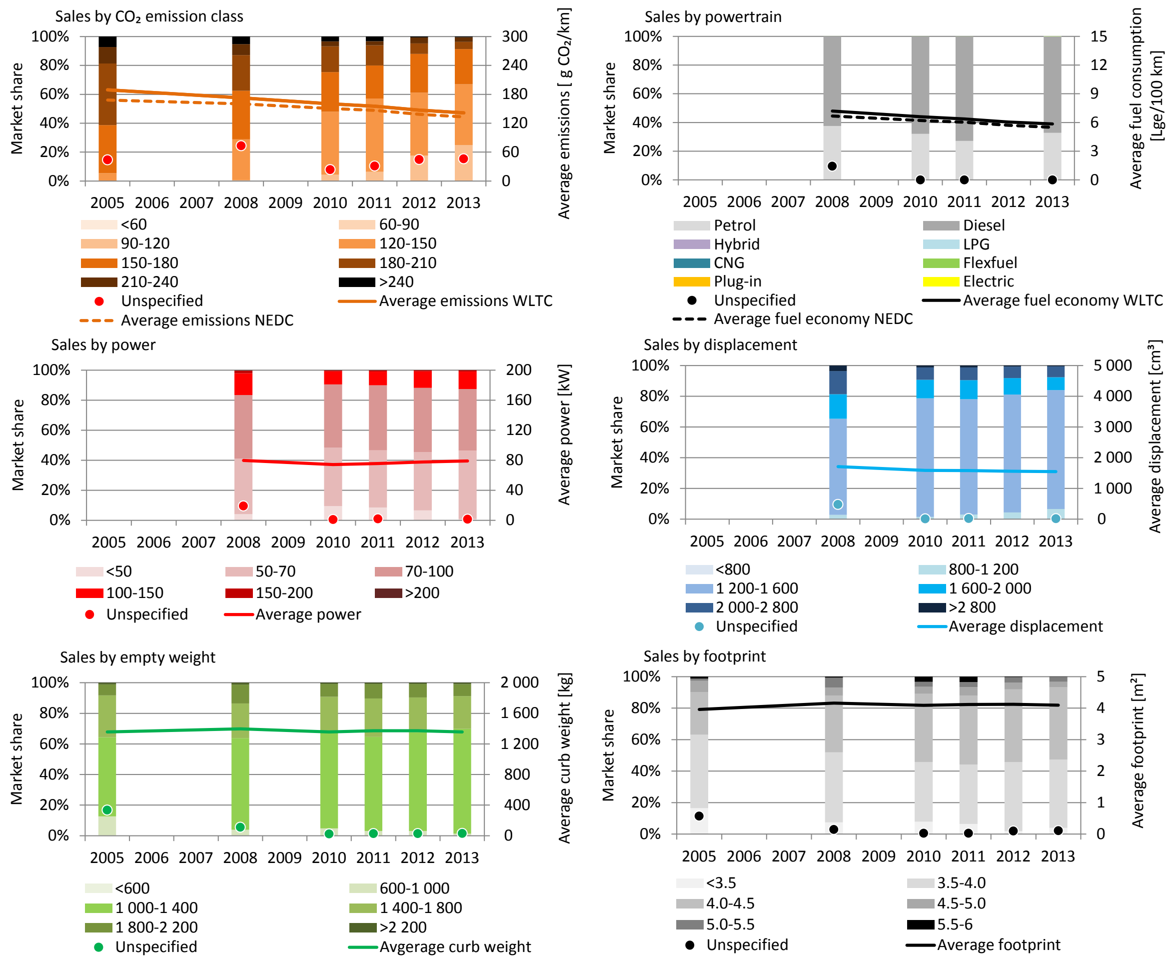
Average price gasoline (USD cent per L, 2014) (GIZ, 2015): 206

Average price diesel (USD cent per L, 2014) (GIZ, 2015): 190

Fuel tax class (2014) (GIZ, 2015): Highly taxed petroleum fuels

In 2013, about 840 000 LDVs were sold in Turkey (IHS Polk, 2014). The LDV stock reached 10.5 million in the same year (IEA, 2016a), and car ownership attained 0.14 cars per capita, lower than in countries with a comparable income level (e.g. Brazil). Turkey does not have dedicated fuel economy policies in place, but it imposes gasoline and diesel taxes that are among the world's highest (GIZ, 2015). Turkey also imposes an annual vehicle circulation tax that is a function of engine size (with progressive increases above 1.6 L) and vehicle age (the circulation tax decreases with vehicle age) (IA-HEV, 2016).

Figure 59 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

Turkey is among the world's largest vehicle markets. Neverthess, with low levels of current car ownership, and projections for sustained economic and population growth, Turkey is one of the candidates for signifcant vehicle market growth. Turkey also has considerable production capacities. It ranked among the top 20 car manufacturing countries in 2013 (OICA, 2015). The five best-selling brands on the Turkish market (covering almost 60% of it) are all European.

In 2013, Turkey was the third most efficient LDV market, ranking just after France and Italy and before the United Kingdom and Japan (IEA, 2014). The average level of CO_2 emissions per km of new LDVs registrations in Turkey in 2013 was 142 g CO_2/km (Figure 59, top left). Between 2005 and 2013, emissions per km dropped by 25%, one of the largest fuel economy improvement rates observed among the countries monitored by the GFEI. Cars with emissions exceeding 180 g CO_2/km were nearly completely phased out: in 2013, their market share went below 10%. With an average fuel consumption of 5.8 Lge/100 km (Figure 59, top right), new LDVs in Turkey are almost 25% more efficient than the world average.

The new LDV market had a very high share of diesel-fuelled vehicles (almost 70% in 2013) (Figure 59, top right). Fuel prices are high, and fuel taxation is differentiated, with diesel being about 10% cheaper than gasoline. This is very similar to the characteristics of the EU vehicle market, with high diesel shares in all market segments, and would be consistent with a higher sensitivity to fuel prices than in the OECD because of the comparatively low average income level.

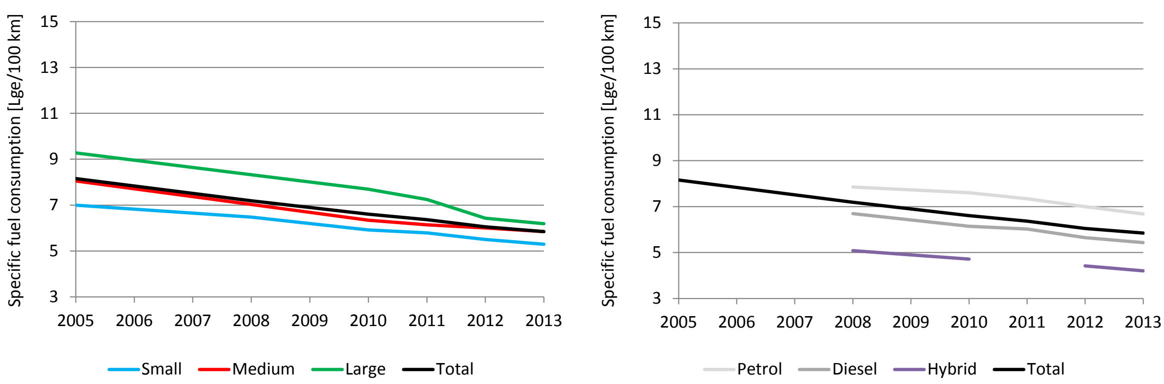
Average new LDV engine power and displacement are both relatively low in Turkey (Figure 59, centre). In 2013, the average power of new LDVs registered in Turkey was 79 kW. This was on the same order magnitude as countries with the lowest fuel consumption globally, such as France, Italy and Japan.

Vehicle weight did not change much over time. Historically, the Turkish fleet has been relatively light (Figure 59, bottom): vehicles weighing less than 1 400 kg accounted for 70% of all vehicle sales. Vehicle footprint increased slightly over time. Cars with a footprint below 3.5 m², which accounted for more than 10% of the market in 2005, almost disappeared in 2013.

Analysis of fuel economy trends

The figure with average new LDV fuel consumption by vehicle segment (Figure 60, left) shows that fuel consumption of the different vehicle classes converged over time. All vehicle segments were subject to substantial fuel economy improvements. The high shares of diesels in all segments shows that diesel motors were not only being offered for heavy and large vehicles. This, combined with the better technical efficiency of diesel engines, explains why the average fuel economy of gasoline cars is markedly worse than the fleet average (Figure 60, right).

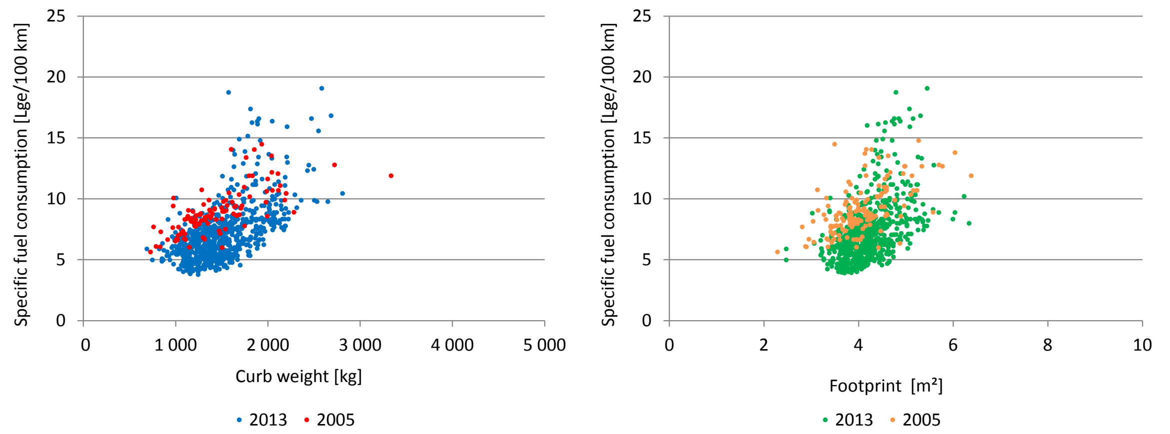
Figure 60 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The model-level representation fuel economy against vehicle weight and footprint (Figure 61) shows a clear vertical shift towards lower specific fuel consumptions between 2005 and 2013. This was not accompanied by any apparent shifts towards lighter and smaller vehicles.

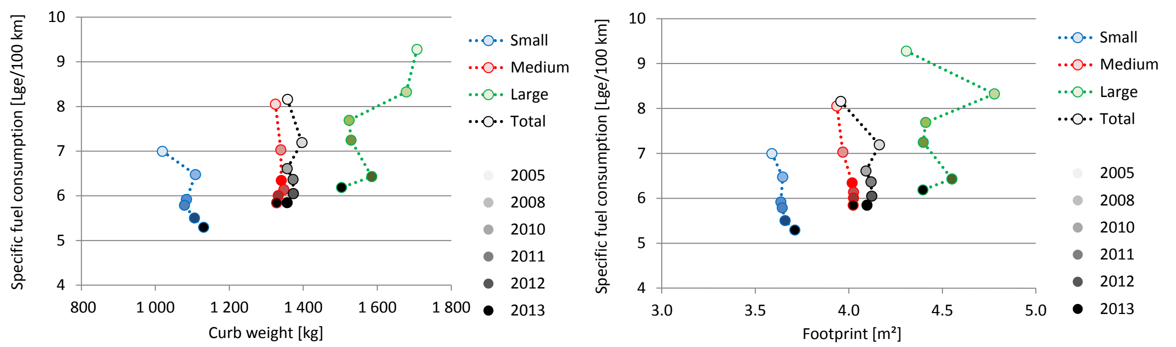
Figure 61 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The visualisation of fuel consumption by vehicle segment as a function of empty weight and footprint (Figure 62) illustrates that all LDV segments underwent marked fuel economy improvement between 2005 and 2013. This is a remarkable development, since Turkey has not to date introduced dedicated fuel economy policies. Turkey provides evidence that monetary incentives through high fuel prices and progressive taxation of large and powerful cars alone can lead to an efficient fleet – under the precondition that consumers are sufficiently sensitive to the price signals. Given its proximity with the European Union and the similarities between the Turkish fleet structure and the European one, the fuel economy development seen in Turkey also suggest that fuel economy polices in major markets could have significant spillover effects in neighbouring markets, provided that complementary signals are in place.

Figure 62 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

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United States

Country spotlight

Population (million) (World Bank, 2016a): 319

Share of urban population (World Bank, 2016b): 82%

GDP per capita (2014 USD/year) (World Bank, 2016c): 54 600

Average price gasoline (USD cent per L, 2014) (GIZ, 2015): 86

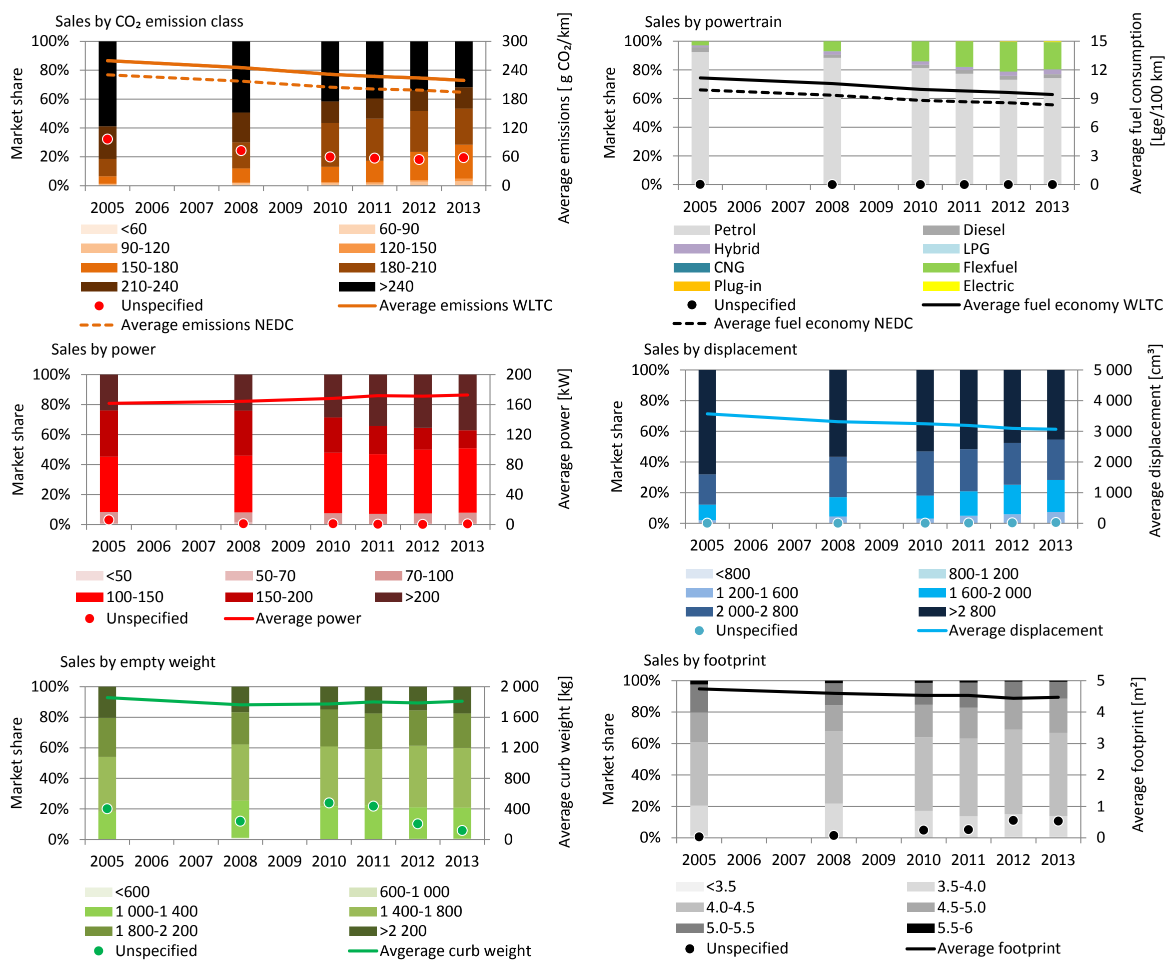
Average price diesel (USD cent per L, 2014) (GIZ, 2015): 97

Fuel tax class (2014) (GIZ, 2015): Taxed petroleum fuels

In 2013, about 14.3 million LDVs were sold in the United States (IHS Polk, 2014). The LDV stock totalled 218 million cars (IEA, 2016a). Car ownership exceeded slightly 0.7 cars per capita, the highest globally. Each household in the United States owned on average 1.9 cars (US Census, 2016).

Fuel economy regulations were first established in the 1970s. The CAFE standards were introduced in 1975. Fuel economy labelling of new cars was introduced as early as 1978 (ICCT, 2014b). Even if the United States pioneered their introduction, the historical evolution of regulatory limits underwent distinct phases, including decades (late 1980s, 1990s and early 2000s) of stagnation. This resulted in deteriorating fuel economy due to a market shift towards larger vehicles. In 2009, the stringency of fuel economy improvements for models entering the market between 2012 and 2016 was strengthened considerably. Compared to 2009, by 2016 average CO_2 emissions per km must be reduced by 26% (of about 4.2% per year). Targets were extended to 2025 and will require a 35% reduction of the average fuel use per km from 2016 (TransportPolicy, 2016).

Figure 63 • LDV market by g CO_2/km, powertrain, power, displacement, weight and footprint, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

Market profile and vehicle characteristics

The United States was the largest car market for decades, until China took the global lead in 2009 (OICA, 2015). In 2013, the United States was the fourth largest producer of passenger cars after China, Japan and Germany. Including commercial vehicles such as trucks and buses, the US auto-industry is the second largest after China (OICA, 2015). The US market is very diverse, with OEMs from all the main car producing countries (except China) among the 15 best-selling brands.

New LDVs registrations in 2013 in the United States had the second highest average CO_2 emissions per km globally: 219 g CO_2/km (Figure 63, top left). Specific emissions declined significantly since 2005, when 60% of the cars registered emitted more than 240 g CO_2/km. By 2013, this share declined about 30%, and was accompanied by a growing share of cars emitting less than 180 g CO_2/km. The latter accounted for 30% of the total market in 2013, up from 10% in 2005. At an average new LDV fuel consumption of 9.4 Lge/100km (Figure 63, top right), the United States has the second highest average fuel consumption after Canada. It is about 21% higher than the world average of 7.8 Lge/100km.

The share of fuel types in US new cars sales also underwent an interesting evolution. Historically, the diesel share among LDVs has been consistently very low in the United States: in 2013, it accounted for less than 3% and mainly comprised very large pick-up trucks (the average displacement of diesel engines used on LDVs was more than 5 L in 2013). Flex-fuel vehicles reached a high market share in the US. In 2013, they accounted for about one-fifth of the entire market (Figure 63, top right). The main reason for this has been the provision of credits easing compliance with CAFE standards for manufacturers that produce flex-fuel vehicles. Since the additional costs of converting a gasoline car into a flex-fuel vehicle are in the range of USD 100 to USD 200 per car, the credit system allows car manufacturers to match their fuel economy standards without further changes and at low costs. Hybrids also experienced a significant growth in market share: by 2013, they accounted for a little more than 3%, exceeding the share of diesel cars.

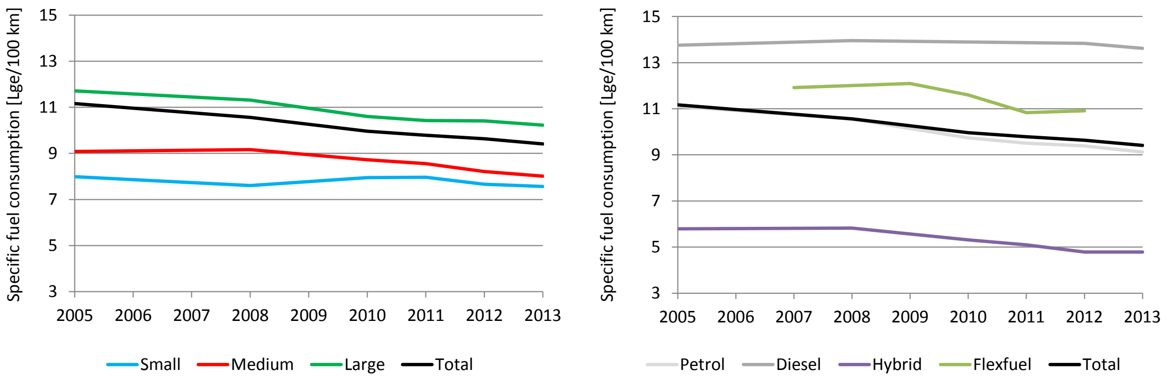
Vehicle sales by power and displacement show that the US market has both the most powerful LDV fleet and the highest engine capacity worldwide. In 2013, the average power exceeded 170 kW, and the average engine capacity was almost 3.1 L (Figure 63, centre). This compares with a global average power close to 110 kW and an average displacement that of just under 2 L. Between 2005 and 2013, the average power increased by 7% in the United States, and the segment of cars with more than 200 kW saw an increase in sales share of almost 50%. At the same time, the average engine capacity decreased by about 14%, suggesting that the US car market was increasing its deployment of engine downsizing technologies, partly to accommodate increased vehicle performance.

Sales by empty weight and footprint provide a similar picture: the US new LDV fleet is well above global averages. Average new LDV empty weight was more than 1 800 kg in 2013, footprint averaged about 4.5 m². Over time, both empty weight and footprint slightly decreased.

Analysis of fuel economy trends

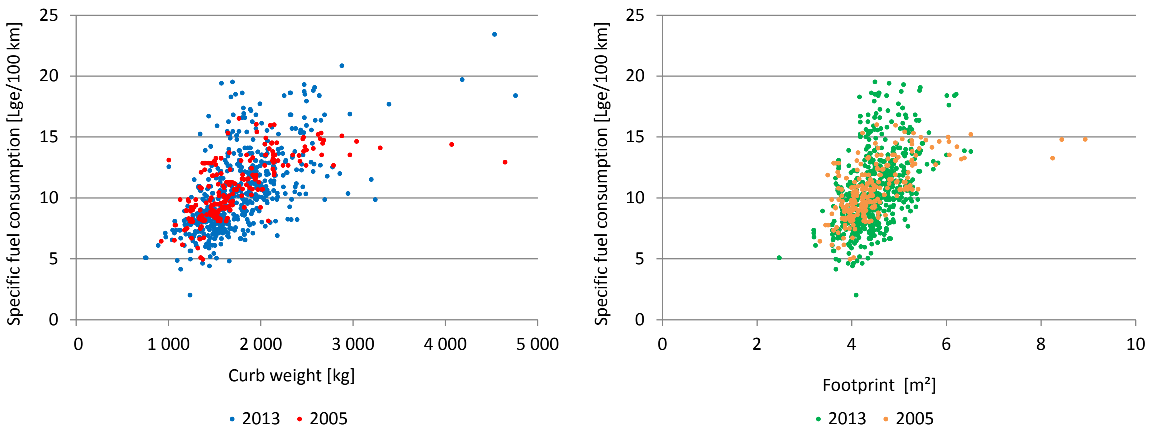
Examination of the evolution of fuel consumption by segment shows that average fuel consumption of the entire fleet is heavily influenced by the share of and fuel economy trends within the large and medium vehicle segments (Figure 64, left). The fuel consumption of small cars – the vehicle segment with the lowest share of new registrations – remained almost constant from 2005 to 2013. Plotting fuel consumption by powertrain confirms that diesel engines are primarily used in very large pick-up trucks. This explains why the average fuel consumption of diesel cars is almost 50% above the average value (Figure 64, right). Flex-fuel vehicles were also more frequently used in large vehicle segments. Their fuel economy (in gasoline mode) is therefore higher than the new sales average. Hybrid cars in the United States have a fuel consumption level well below the fleet average. This can be attributed partly to the better fuel economy of hybrid powertrains, and partly to the much larger share (70%) of hybrids belonging to the small and medium segments.

Figure 64 • Average new LDV fuel economy by vehicle segment and powertrain, 2005-13



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

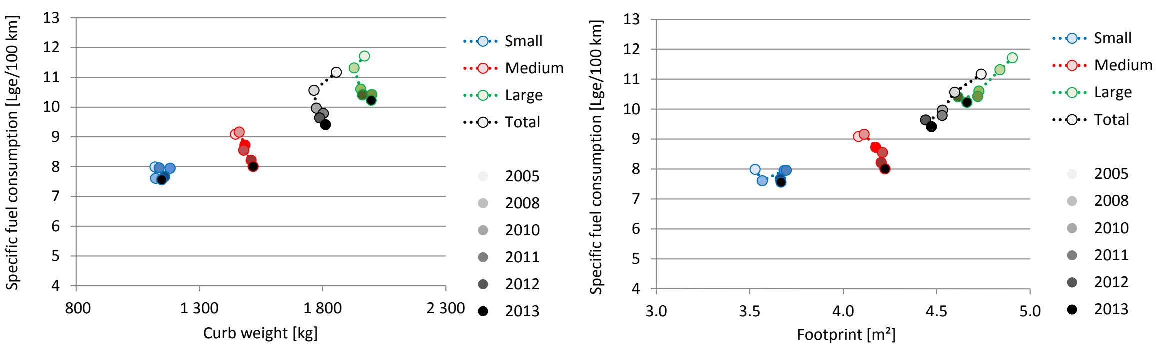
Figure 65 • Fuel economy of new LDVs over vehicle weight and footprint, 2005 and 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The cloud plotting model-level specific fuel consumption against vehicle weight and footprint shows a downward shift in average fuel consumption of new models between 2005 and 2013, as well as a higher variability among modes having similar weight and size (Figure 65).

Figure 66 • Average new LDV fuel economy by segment over vehicle weight and footprint, 2013



Source: IEA elaboration and enhancement for broader coverage of IHS Polk database.

The graphs showing fuel consumption by segment confirm that the evolution of the average fuel consumption of new LDVs against weight and footprint was strongly influenced by the changes taking place in the large vehicle segment (Figure 66). The CAFE standards are set in a way that assigns different targets to vehicles of different sizes, except for vehicles exceeding a maximum and minimum threshold. These vehicles are subject to an upper and lower limit that, in a given year, is independent on their size. This makes it more difficult to meet the target values for very large vehicles, and makes compliance easier for smaller ones. Figure 66 suggests that this resulted in a tendency to reduce the average vehicle footprint in the large market segment, and in an increase in the small segment. Changes in the average size were not accompanied by major variations of vehicle weight in any of the market segments.

Conclusions and recommendations

Conclusions

The refinement of the methodology used to calculate country-specific average LDV economy had a substantial impact on the resulting average fuel economy values in all regions. Normalising all fuel economy/fuel consumption values (based on region-specific test cycles) to the WLTC allowed a reassessment of earlier estimates of fuel economy performance, taking into account improvements in the way vehicles are tested that should better align the estimates presented in GFEI reports with real-world values. This revision also establishes a basis that can be consistently applied in future reports analysing the development of national and global fuel economy trends. The inclusion of LCVs, also included in the methodological revisions, led to a better comparability of results among countries by reducing scope for different interpretations of vehicle definitions. The combined effect of the inclusion of LCVs and the normalisation to the new WLTC increased the global specific fuel consumption of new vehicle sales by 13%.

Based on the more stringent test cycle, reaching the GFEI target will be more challenging, and historic improvement rates are lower than stated in former GFEI reports. While the former global annual fuel economy improvement rate was estimated at 2.0% between 2005 and 2013, the new methodology suggests an annual improvement rate of only 1.6%, which is significantly lower than the 3% need to achieve the GFEI target of reducing new LDV fuel consumption by 50% by 2030.

Countries with ambitious fuel economy regulations in place experienced a marked decrease in average specific fuel consumption. The presence of ambitious fuel economy/fuel consumption/CO_2 emission standards clearly led to an uptake of fuel efficiency technologies and a resulting decline in fuel consumption across all vehicle segments. On the other hand, in most cases fuel economy regulations did not induce significant light-weighting or vehicle size reductions.

Differentiated vehicle taxation has a measurable impact on consumer choices and market developments. The example of France shows that differentiated vehicle taxation, reducing costs of best performers while increasing costs of vehicles with poor fuel economy, can augment the impact of regulatory measures by driving consumer choices towards more efficient vehicles. In France, the combination of monetary advantages and regulatory measures enabled the 2015 target of 130 g CO_2/km for passenger cars to be met well in advance. The example of South Africa, where the introduction of differentiated taxation in 2010 altered technology deployment so as to prioritise fuel savings over size and weight increases, also demonstrates the efficacy of differentiated vehicle taxation.

Fuel taxation is an important determinant of average vehicle fuel consumption. All countries with high fuel prices at the pump show a market structure oriented towards vehicle segments with low specific fuel consumption. The case of Turkey shows that high fuel prices, combined with differentiated vehicle taxes, provide a strong incentive to sell efficient vehicles in markets characterised by a per capita income well below the OECD average, even in the absence of regulatory measures.

The absence of fuel economy polices tends to be associated with the prioritisation of technology deployment that favours weight and size increases over fuel economy improvements. The comparison of specific new LDV fuel consumption by segment, both as a function of empty weight and footprint, clearly show an increase of vehicle weight and footprint and only moderate efficiency improvements (horizontal trends in the figures reporting the average new LDV fuel economy by segment over weight and vehicle footprint in the country profiles) in countries with no fuel economy policies.

Recommendations

The most effective results in terms of fuel savings were achieved in countries, like France, that combined ambitious regulatory frameworks, requiring significant improvements in corporate average fuel efficiencies, with monetary incentives, both on the vehicle (differentiated taxation) and fuel side (fuel taxation). Consumer information schemes (labelling) were pre-requisites for the development of the combined policy actions. **The adoption of combined and complementary regulatory and fiscal measures appears to be the best path to follow in order to achieve energy savings from LDVs**.

The stringency and ambition of regulatory targets and monetary incentives had a major impact on the way consumers valued fuel savings and OEMs prioritised the use of technologies, favouring fuel economy improvements over other changes in the vehicle characteristics (such and weight and size).

Fuel economy standards tend to guarantee progress towards lower average fuel consumption in new vehicle sales. Differentiated vehicle taxation seems to be effective even when not coupled with fuel economy standards, especially in markets with lower purchasing power due to low average income levels (the case of South Africa is especially interesting in this respect). **Differentiated vehicle taxation is also generally easier to set up than fuel economy regulations: it should be prioritised, especially in developing regions**.

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What is the Global Fuel Economy Initiative?

The Global Fuel Economy Initiative believes that large gains could be made in fuel economy which would help every country to address the pressing issues of climate change, energy security and sustainable mobility. We will continue to raise awareness, present evidence, and offer support to enable countries to adopt effective fuel economy standards and policies that work in their circumstances and with their vehicle fleet.

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